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AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

Interview with the Director

Minnesota Science asked the Director of the University of Minnesota Agricultural Experiment Station, Dr. William F. Hueg, Jr. about the future of the world food situation:

Q. *Dr. Hueg, what do you see ahead as major issues of food production?*

A. Some issues that will be before us will be:
– domestic and world-wide food reserves
– incentives for family planning
– development of land-use planning and control policies
– relation of food production systems to other types of developments

We need to develop alternative technologies before we use up present fuel resources. This means the development of atomic power, solar energy, geo-thermal energy and combinations of energy sources.

Q. *Can food production be doubled?*

A. Food production can be increased 2 to 3 times but at what cost? How many more inputs will be needed? What stresses do these demands place on other parts of the economy and on already scarce resources? Corn yields greater than 300 bushels have been obtained, and higher yields are reported with other crops. These are test and research yields however, and many of them will be difficult to reproduce even under the most ideal field conditions.

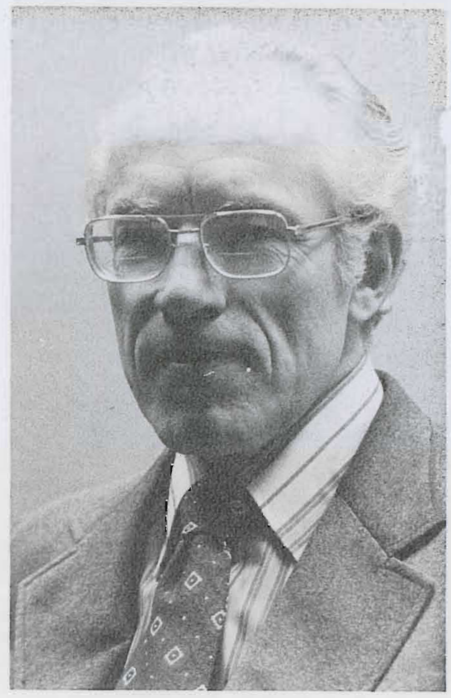
Q. *Do you forsee a change in environmental demands placed upon the farmer?*

A. Climate will replace pollution as the major environmental issue. We may be coming into cycles of more drought than excessive moisture conditions. If you were farming in the Red River Valley, southern or northern Iowa and through the corn belt this year this speculation would be hard to believe. We are talking about long-run situations however. Yet, droughts are already causing mass-hunger.

Q. *How does the energy-efficiency of agriculture compare with the efficiency of other industries?*

A. Agriculture is the nation's only major industry where energy output is greater than input, at least for crop production. Products from agriculture, forestry, fisheries, wildlife, and rangeland are renewable resources.

One major goal of our nation's agricultural and home economics colleges is to insure that these renewable resources continue to serve humankind. To meet this goal we must have outstanding research, teaching, and extension programs.



Q. *With the increasing demand for food, will agriculture fare better in the world competition for fuel?*

A. Fertilizers and other agriculture chemicals will be competing more and more with respect to the marginal return to the alternative uses of fuels. The manufacture of nitrogen fertilizer requires oil and natural gas. But alternative uses for oil and gas have become increasingly attractive. With respect to agricultural chemicals, we must take a very critical look at environmental regulations already part of state and federal laws. What type of restraints do environmental demands place on food production? Do they prevent the industry from meeting world food demands? Again we must consider the trade-off of having a pure and completely safe environment in which we cannot live because we have starved to death!

For example, just one delay in fuel delivery has already reduced the estimated production of wheat in India by 1 million metric tons. The reason for the reduction was a five-day delay in obtaining gasoline for pumps to provide water to newly-seeded wheat fields. This occurred close to the time we were seeing on television and in our newspapers, and hearing commentary on radios about the long lines of automobiles waiting for gasoline.

One must ask the question of priority and commitment with respect to the use of fuel supplies to feed hungry people where starvation is a stark reality, or to provide fuel so that we can have the convenience of our automobiles for pleasure and business.□

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COVER: Minnesota wheat field in Yellow Medicine County near Canby.

MINNESOTA SCIENCE is published by the University of Minnesota Agricultural Experiment Station, Institute of Agriculture, St. Paul, Minnesota 55108. **Director:** William F. Hueg, Jr. **Editor:** Phillip E. Miller **Design:** Dianne Swanson **Photography:** Don Breneman for cover and pages 2, 7, 8, 9, and 16; American Forest Products Industries, Inc. for page 4; and Alvin A. Alm for page 6.

A note about the new editor: After teaching biology for two years at Western Kentucky University, Phillip E. Miller went to the University of Wisconsin where he completed science writing training. In 1968, he went to Michigan State University where he wrote on science research, and taught science writing and technical writing. Miller became science editor of the University News Bureau there, in 1970. He held that post until this summer when he came to the University of Minnesota's Department of Information and Agricultural Journalism.

Great Forests from Little Containers

ALVIN A. ALM

Assistant Professor
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Cloquet Forestry Center

For many years foresters and tree farmers, as here, faced the decisions of tree removal and possible tree replacement.

Foresters have two main choices in their plans for artificial reforestation—seeding or planting. Both alternatives are necessary because Mother Nature can not always be relied on.

Planting is usually the more reliable, though more costly method. But ways of growing planting stock and getting trees into the ground really have not changed a great deal through the years. The quality of planting stock has been improved because of increased knowledge in use of fertilizers and water. Yet, the procedure of growing millions of trees in large nurseries, lifting them out of the ground after a specified number of years, and then sorting and bundling them for shipment has remained much the same except for equipment modifications designed to do the job easier. Field planting is essentially the same except for modifications of planting machines. However, this could rapidly change if recently introduced containerization techniques prove feasible.

Containerization refers to the growing of trees in small containers in greenhouses with carefully controlled environmental conditions. Containerized stock can be produced in about 4 to 6 months. In comparison, the normal nursery cultural period for conventional forest tree planting stock in Minnesota is from 2 to 4 years.

Conventional bare-root planting must be done during a short period in the spring when the seedlings are still dormant. If the planting is not completed, then it is necessary to wait until the following spring (except when the weather conditions may allow some fall planting). Planting during the summer months is not ordinarily done because of low soil moisture conditions and because it would be too great a shock to the new root and shoot growth and development of the seedlings.

Containerization avoids many problems inherent in the bare-root method. Containerization systems were developed not to replace conventional bare-root nursery stock but rather to supplement it. With containerization the planting season is extended into the summer months. This is possible through elimination of most of the planting shock.

To avoid planting shock the container stock is set out in the field in the same soil mass in which it was cultured. When planted, the roots are at the bottom of the container and ready to emerge. They are not disturbed as is the case when bare-root stock is lifted from the nursery. The soil in the container also provides moisture for the tree during its initial adjustment to field conditions.

Field survival and growth under a variety of conditions are being determined in a research project headquartered at the Cloquet Forestry Center in northeastern Minnesota. Work with container-grown trees at the Forestry Center, which is an integral part of the University of Minnesota College of Forestry, began in 1967 on a cooperative basis with Potlatch Corporation, Northwest Paper Division. More than 20,000 test trees have been planted in Saint Louis, Carlton, Aitkin and Itasca counties in northern Minnesota.

The test plantings in Minnesota have been primarily with jack pine and red (Norway) pine. Assortments of planting sites have been used along with different site preparation methods such as prescribed burning, spraying, discing, and mechanical scarification. Jack pine, a species with very rapid growth in the early stages, has done quite well in some of the plantings. Average survival on well-prepared sites after six years was 90 percent for jack pine planted during the summer months of June, July, and August. This survival compares very favorably with spring-planted jack pine nursery stock in many areas. The red pine plantings have been less successful. Nevertheless, in one of the summer plantings of red pine, the survival averaged about 80 percent—very good for summer plantings.

Most of the plantings in Minnesota have been with an Ontario containerization system referred to as the tubeling system. Tubelings are simply small trees grown in plastic tubes, about 3 inches long and 9/16 inch in diameter. The tubes are split along one side to permit expansion and root egress as the tree grows. The tubes are placed in plastic trays (200 per tray), loaded with soil, seeded, and then placed in a greenhouse for germination and growth. Very little space is required for the 200 trees as the trays are only about 7 x 13 inches in size. After a short growing period of from 12 to 16 weeks, the trees are placed outside several weeks for conditioning and then planted in the field.

Bare-root planting used to be about the only alternative to reforestation by seeding. Now there is another way.

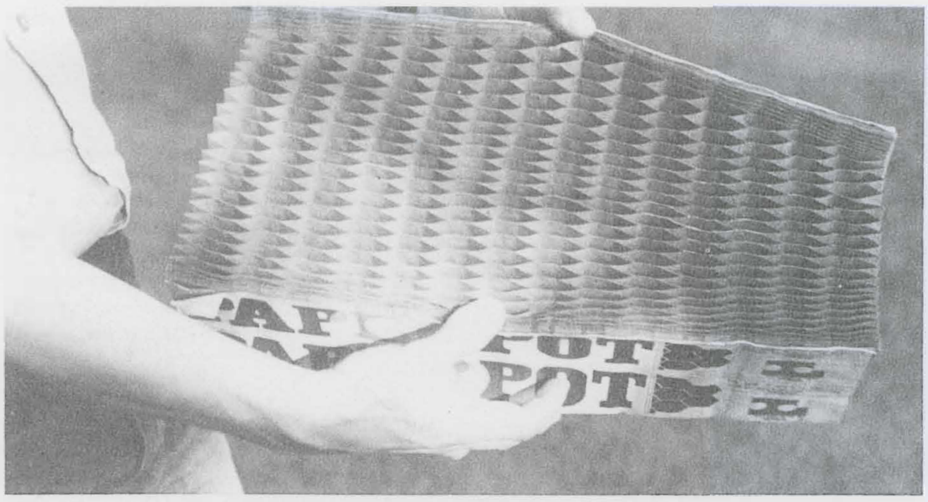
The tubeling system has some problems: In some cases, the rigidity of the plastic tube prevents normal root development. Also, the small plastic tube has very little rooting volume. It limits the size of tree that can be grown. Small trees are very susceptible to mortality from competing vegetation and especially from leaf smother resulting from overhead shrubs and trees.

Another container system which arrived on the scene about the same time as tubelings is the bullet method. Bullet containers were designed in British Columbia and are being used in the Pacific Northwest, both in Canada and the US. The plastic bullets are larger than tubelings. They come in a range of bullet-shaped sizes with the most common being about 4.5 inches long with a top diameter of .75 inch. The system, including holding trays, is similar to the tubeling system. To overcome the root restriction problem of a rigid container, the bullets are currently being redesigned to take advantage of the development of a biodegradable plastic. In the way of innovations, it is interesting to note that a researcher recently tried small scale aerial test plantings from a helicopter using the plastic bullets with an attached fin, much like a small bomb.

Since the introduction of tubelings and plastic bullets, a host of new systems have been developed. For example, the BC/CFS (British Columbia/Canadian Forest Service) styrofoam blocks and the Spencer-Lemaire System of book planters are really containerless techniques: A soil plug with a seedling in it is extracted from the container before placement in a planting hole.

In the BC/CFS system, the trees are grown in 4.75 inch long bullet-shaped cavities in a rectangular block of styrofoam, 20 by 14 inches. The styrofoam blocks, which have 192 cavities, are filled with soil, seeded, and placed in a greenhouse where the trees are cultured. At time of planting, the soil mass—referred to as a styroplug—is removed from the cavity and placed in the planting hole.

The book planter system works much in the same manner except that the trees are grown in rectangularly-shaped cavities in hinged plastic books which fit into a holding tray. At time of planting, the



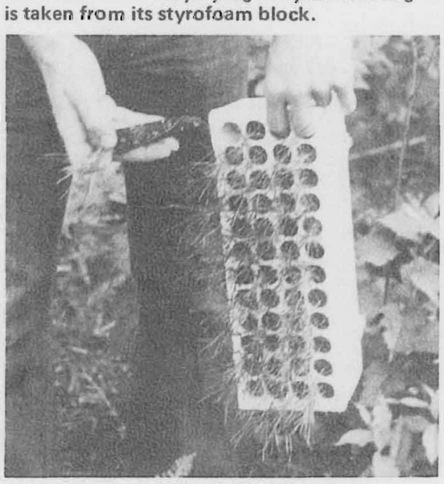
A pull of the paper pot opens hundreds of containers ready for soil and seed.

books are unfolded and the soil plugs with seedlings are extracted.

A recently-introduced technique that looks very promising is the paperpot system developed in Finland. This system offers a compromise between the rigid plastic tube and the containerless seedling. The paperpots come in sets consisting of a flat package which opens in accordion fashion. When opened up, the set is stretched on a frame and placed in a box or tray where it is loaded with soil and seeded. The individual pots vary in size, with the most common being about 5 inches long and 1 inch in diameter. The pots are held together in a set with water-soluble glue. After a period of watering, which is required in the greenhouse culturing process, the glue dissolves and each individual container can be separated at time of planting. The specially-treated paper has a life of about six months and breaks down shortly after being planted in the field. This system has the advantages of the tubeling concept but also has a larger rooting volume and a disintegrating container.

The method of growing container seedlings is about the same regardless of the type of system. A greenhouse where the environment can be controlled is used until the seedlings are big enough to be set outside for the hardening-off process. Intensive watering, lighting, and fertilizing schedules have been established to give best results. The actual time period from germination to field planting varies with the size of container and species of tree. The time period of from 10 to 12 weeks, when tubelings were first introduced, has now been extended to about 16 weeks. The extended growing period results in larger, better-developed trees. In some cases the trees have been over-wintered before planting.

A five-month old styroplug red pine seedling is taken from its styrofoam block.



Hand planting has been employed with containers. A simple dibble, sometimes attached to a hoe blade for scarifying a small spot, is usually used to make the planting hole. With some tools, a person can remove a plug of soil from the designated planting hole and plant while standing. However, it is generally agreed that if a particular system proves biologically feasible, a machine to plant containers will soon follow.

Most of the advantages of using container-grown stock are oriented toward efficiency and flexibility of production. The possibility exists of replacing the large tracts of land currently used for production of nursery stock with small greenhouses for container production. The advantage of being able to grow trees in relatively short time periods to meet short lead time demands is also very real. The potential of mechanized production of containerized stock is tremendous. Packaged seedlings could have built-in fertilizer and moisture. These advantages and others, such as possible cost reduction, depend largely on satisfactory performance of the containerized seedlings in the field.

It may well be that no specific container system will prove workable for all areas. There will likely be different systems adopted for different areas depending on climate and site requirements. There may also have to be some trade-off in what foresters now think of as acceptable survival in order to attain some of the other advantages that containerization offers. □

Not Enough Food for All

WILLIAM F. HUEG, JR.
Director
University of Minnesota
Agricultural Experiment Station

World demand for food makes its impact at the Minneapolis Grain Exchange.

In the Spring of 1974 there was not enough food for all. Many people of the world starved as numerous farmers and ranchers went broke. The reason: lack of purchasing power by a major share of the world's growing population, high grain prices brought about by high world demand, and the strongest price squeeze on the livestock producer ever known in agriculture's history.

In 1972, a similar crisis resulted because of a 3 percent difference in world food and feed grain production. In 1971, 903 million metric tons of food and feed grains had been produced, but in 1972 only 878 million metric tons.

Why a crisis with a difference of 3 percent?

It was because of the demand brought about by increased purchasing power, rising population and erratic weather conditions.

The sale does not always bring profit to the farmer.

How did the world get into a series of food crises?

Up to 1830, world population growth was essentially horizontal. There were peaks, and valleys of famine and pestilence, but the general trend was stable. But from 1830 to World War II a moderate growth increase turned the horizontal line into a population growth curve. Now there are nearly 3.5-4 billion people on earth. From 1974 to the year 2000 the growth rate may be essentially vertical. By the year 2000, it is predicted, there will be 6 billion people.

The world adds 200,000 mouths per day. This is like adding one-half of the people of Saint Paul, every day, to the world population. Yet, also daily, 10,000 people die of starvation. At such rates 4 billion people of 1974 would increase to 8 billion in a 40-year period. By 2055, there would be 16 billion people. Today, half a billion people, mostly women and children, are starving in a very slow and painful way. Another half billion are undernourished and another 1 billion are malnourished. Even a malnourished life is a horrible fate: Many of these victims will never have a chance to contribute to the world. Malnutrition has already caused brain damage and other health defects which will cause them to become a burden not only to themselves but to others. The remaining 1.5-2 billion people are in the category of fairly-well to excessively nourished.

Imagine a world-representative town with a population of 1,000. What would that population breakdown be?

Five hundred of the 1,000 would be hungry, 250 would be malnourished, 250 would be fair to good as far as diet is concerned. Of 90 North Americans, 60 would be from the US and they would control half of the income of the total group. This represents the world as it now exists.

Why not equally divide all the food?

If all food supplies were to be divided equally around the world, then the world supply of food grains would last between about 20 and 30 days at present rates of consumption. Then we would all be hungry.

What is to be done?

One, we must commit ourselves to education on birth control and family planning and we must provide the appropriate incentives in those societies where population runs rampant.

Two, we must devise programs to upgrade agricultural production in the developing nations, improve storage and marketing systems, and develop those industries so essential for a productive agriculture.

These are the first steps, the essential steps, to control world population and the future destiny of the world.

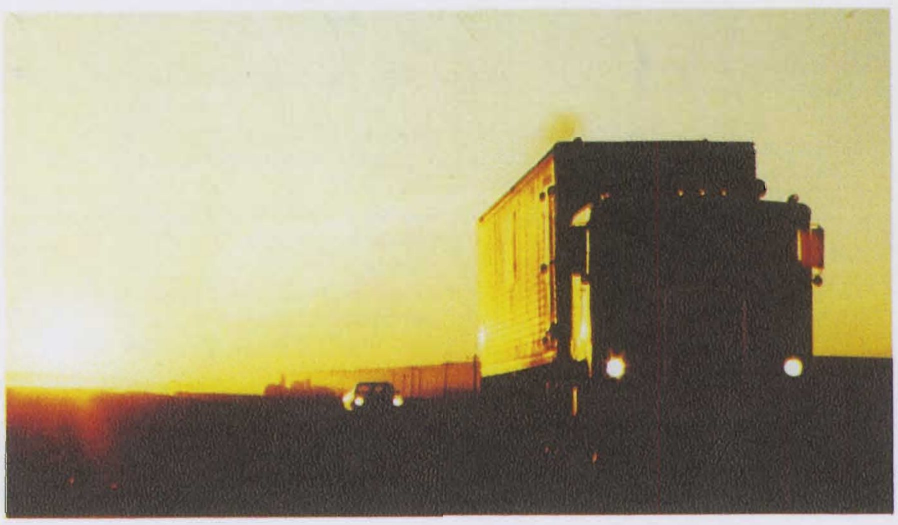
World Challenge to Agriculture

Developing nations want to improve their diets. What pressure do they place on the existing food production system?

Recent world trading has opened up two large population areas, and the second greatest economy in the world. The USSR and China have been opened up for world trade and part of the currency is food. The USSR has three hundred million people, China has eight hundred million people. The combination is one-third of the world's population.

Storage systems remain one of the most vital of technologies for agribusiness.

Transportation keeps getting more expensive. Fuel costs hit hard at food prices.



A truckload of

Probably this would be a continuing market, one difficult to deal with, but nonetheless a very real factor in the agricultural explosion which is yet to come.

At no time in recent American history has agriculture played a more vital role, captured more headlines, been placed under greater contraints, been asked to go for maximum production, moved so quickly from surplus to scarcity, or seen so many anxious about their food supply. Agriculture is called upon now, as never before, to produce for world explosions of: population, technology, education, disposable income, and general affluence.

Agriculture has had to function under shortages of machinery, fuel, fertilizers and pesticides. Although many of the regulations from the hysteria days of ecology and the environment in the late 1960's and 1970's appear not to be workable, the restraint is there. Burden of proof of compliance is placed on the farmer, the agricultural supply industry, or the process industry. The government concept of cheap and abundant food is now being challenged; for if we are to have abundant food it will not necessarily be cheap.

The future currency of world trade will be food. It may also be fuel but it will also be food.

We hear a great deal about farmers' productivity and the number of people fed from their labor. In 1970 each farmer was able to provide food for himself and his family and only one-twentieth of the food for another person. By 1910 the farm family, with 22 billion hours of labor, could provide for 7 other people. By 1960 the support figure increased to 26 people; by 1970 6.5 billion hours of labor could provide for 54 other people. By the year 2000 each farmer may feed 200 additional people at a labor expenditure of 2.3 to 4 billion hours. The range in figures comes from some of the restraints that face agriculture and how these will be reconciled in this next 25 year period. Furthermore, the hours of labor expended are dependent upon the availability of energy and its related products.

World food production must double in the next 18-20 years, some say. But is it possible? A doubling of world food production would require a greater use of land resources, and better use of inputs such as water, fertilizers, machinery, labor, storage, and processing. There is the potential to increase production as much as 2 to 3 times in practical terms. (Table 1. shows 1973 average, top, and record crop yields, in the US.)

Whether or not world food production will reach desired goals depends upon how well the world faces such issues and

arrives at port.

Barge transportation remains one of the cheapest ways to move grain.

As winter sets in the farmer has time to check the books and consider next year's demands.

challenges as climate; control and use of land; population growth; domestic and world food reserves; adequate supplies and delivery of fuels, fertilizers and agricultural chemicals; and the coordination of food production systems with modern technologies.

Table 1. Top and Record Crop Yields

	Bushels per Acre		
Crop	1973 Average	Top	Record
Corn	94	230	360
Wheat	32	135	216
Soybeans	28	80	110
Sorghum	63	200	320
Rice	28	130	350
Potatoes	385	1000	1400
Sweet Potatoes	180	600	900
Barley	41	150	212
Oats	49	150	296
Sugar Beets (tons)	20	40	54

MINNESOTA AGRIBUSINESS

Today's American agriculture is capitalized at about 460 billion dollars a year. It is the single largest industry in the US. The term agriculture has many definitions but as discussed here it is the industry which includes farms from the time the land is prepared and the seed planted until the finished product is moved to the consumer. This is the vast agribusiness complex. We would not have the agricultural productivity as known in this country if we did not have the important input and output industries which provide the supplies for production, storage, processing, and transportation of the raw products to the consumer. Nevertheless, of course, the farm is vital to agribusiness.

Many corporation farms are family operations, family managed, but established for estate management. Such farm families operate the business and make the management decisions. Their farm operation may be any size or income. Less than 2 percent of this country's farmlands are controlled by corporations. About 800,000 farms out of a total 2.5 million US farms produce about 85 percent of the US food supply.

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High Fertilizer Prices:

DAVID A. ZARKIN
Assistant Professor
Department of Information and Agricultural Journalism

As the world faces a food crisis, many observers ask what the United States and Canada will do about it.

"North America now controls a larger share of the world's exportable supplies of food grains than the Middle East does of oil," *New York Times* columnist and news analyst James Reston recently noted.

Prices of wheat, soybeans and corn have more than doubled in the last two years and the nations that need food the most are precisely those least able to pay for it, he pointed out.

Although enormous progress has been made in increasing food production, agricultural scientists are not satisfied either. More could be done with more funding for research and education, they emphasize.

To further complicate the picture, commercial fertilizer has come into relatively short supply. Fertilizer costs have increased to the extent that it is difficult for farmers to produce the quantities of food needed to feed a hungry world. Some farmers cannot afford the inflating prices.

Fertilizer has become a tool of international policy—a power tool without equal, according to Raymond Ewell, chemical economics expert, in a recent article in *Farm Chemicals* magazine. Fertilizer distribution and management are pivotal points on which turn the progress of nations and the survival of populations. Developed and less-developed countries will be tested in the caldron of the coming food crisis. According to Ewell, the fertilizer input-yield ratio climbs a sharply ascending curve. To obtain twice as much production in developed countries requires four times as much fertilizer as presently used. Ewell predicts that the current world fertilizer shortage will continue indefinitely, but he adds that he does not think the world will have widespread famine.

Will fertilizer manufacturers meet the demand, fail to meet demand, or over-produce and cause a fertilizer glut that will reverse continuing prosperity trends for the industry?

"The ability of world fertilizer-producers to respond to increased fertilizer prices with increases in fertilizer output is limited in the next year or two," says Dale C. Dahl, University of Minnesota agricultural economist.

In the 1960s prospects for a green revolution in developing countries signaled major production capacity expansion in fertilizer plants throughout the world. Each manufacturer expanded without apparent regard for the similar long range plans being made by its competitors. The result was over-expansion, particularly for nitrogen, in the '60s, resulting in reduced profits and losses for many companies.

"This experience made many manufacturers 'gun shy,' and a reduction in the rate of industry capacity expansion has been the result," Dahl adds.

Also, the levels of economic growth in developing countries in the late '60s were such that they could construct their own fertilizer plants, especially for nitrogen materials. Tennessee Valley Authority (TVA) estimates of nitrogen capacity in 1960 showed slightly more than 10 percent of the capacity in developing nations in 1965, but the 1975 announced capacity increases show that almost 20 percent of the nitrogen production capacity will be in the less-developed countries. Planned capacity expansion and corresponding production capacity for nitrogen will be such that production in 1975 will only slightly exceed the consumption trend in 1975.

Dahl says the TVA did not anticipate near shortages of phosphorus and potassium in the early '70s. Such shortages have not yet become evident. Part of the reason is the storability of phosphorus and potassium as compared to nitrogen. Many nitrogen fertilizers must be consumed within a few months after they are produced; but the shelf life of phosphates and potash products usually exceeds a year. Inventories of phosphorous and potassium apparently increased in the late '60s and only now are they being reduced, the economist adds.

A World Burden

In addition to the supply, the price of fertilizer is another ingredient affecting the ability of many farmers throughout the world to obtain this much-needed material. Fertilizer prices started to rise in 1972. Prices were held from going higher in the US by price controls. And in many other major countries where fertilizer prices were controlled by government, Dahl says, efforts were made to hold farm level prices down by increasing subsidies. Such moves resulted in an apparent dramatic decrease in the real fertilizer prices. Clamor for increased quantities, especially for nitrogen was overwhelming. Canada, a former net exporter of nitrogen, withheld its nitrogen from international trade in order to meet internal needs. Korea, enjoying a net balance of nitrogen for export in 1970 and 1971, was forced to impose a rationing system for the first time since 1965.

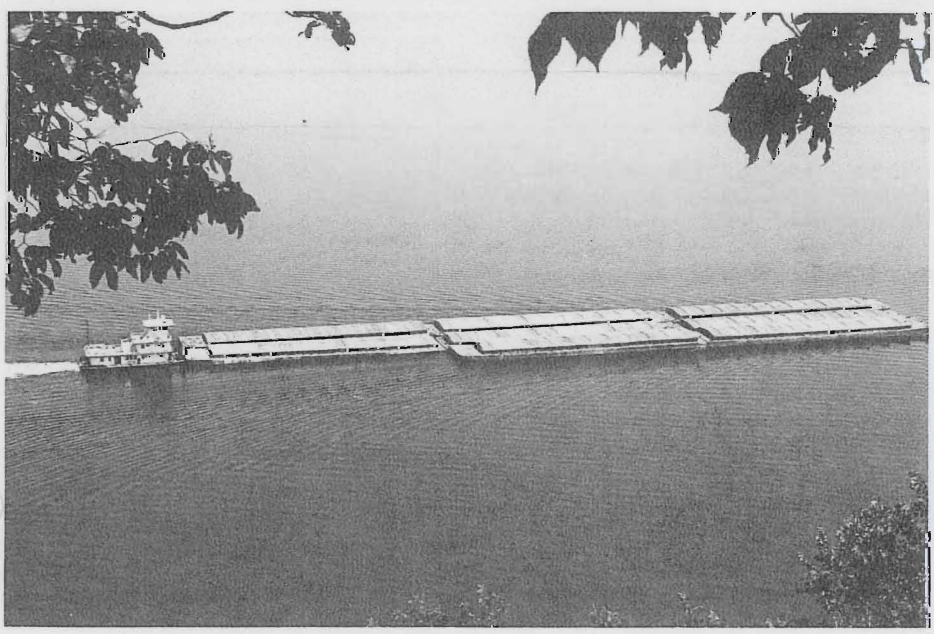
With price controls in domestic markets, US fertilizer producers actively sold abroad. The Soviet Union seemed to hold on to its fertilizer. Europe and Japan enjoyed brisk trade at high prices. As world food prices continued to explode into 1973, the US lifted its price controls on fertilizer. Domestic prices soared. Then came the energy crisis when doubling and redoubling crude oil prices caused an increased demand for natural gas, the gas needed to make nitrogen fertilizer. In the face of huge demand the supply of nitrogen fertilizer became inelastic.

Increases in feedstock prices, probable continued increases in world food prices and inelastic fertilizer supply signal continued fertilizer price increases. The real price of fertilizer appears to be increasing for the first time in two decades.

Nitrogen supplies will last indefinitely, but hydrogen must be combined with nitrogen to form ammonia before it is useful to plants, says Curtis J. Overdahl, University of Minnesota extension soils specialist. The catch is that natural gas, the low-cost source for hydrogen, is in short supply. Hydrogen can be obtained from other sources, but for a higher price. US phosphorus reserves will last at least 250 years, but eventually phosphorus will be more difficult to mine. There is little fear of running out of potassium, where the largest reserves are in the Soviet Union, Canada, East Germany, West Germany and the US.

The world fertilizer situation is expected to have a marked impact on the economic fate and political stability of many less-developed countries, foreign aid questions, and the pattern of agricultural trade, says the Minnesota soils scientist. Less-developed countries probably will have to reevaluate many of their economic and political goals. Agricultural self-sufficiency, where it is possible, will become more important than industrial development for some countries. Agricultural research will need to direct its energies to developing fertilizer-saving technologies. □

Along the St. Lawrence seaway the maritime industry—world shippers of food and fertilizer—has suffered unexpectedly. Ship wrecks and ship pilot strikes affect world prices. Already the dock price of fertilizer is much more than fertilizer manufactured and transported within this country.



Minnesota Outlook

The fertilizer outlook for next year will be bad news for some Minnesota farmers, according to University of Minnesota agricultural economist Dale C. Dahl.

Last year was bad enough. Many Minnesota farmers were not able to get enough nitrogen fertilizer to meet their needs, points out Dahl. Some farmers did not even get enough phosphate fertilizer to meet their needs.

It will be 1977 or '78 before all of the Minnesota farmers will be able to buy all of the fertilizer they need, says Dahl. But there is no telling at what prices the fertilizer will be available.

The problems which are being encountered by Minnesota farmers are very similar to those for US farmers in general. Minnesota is not a producer of primary plant nutrients; therefore, the most serious problems will be high prices and imperfections in the distribution system. Probably the number of small

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Sludge and Excess Manure:

Farm and city wastes for crops can ease the fertilizer bill; but precautions are in order:

"Some wastes, because of unfavorable physical conditions and toxic chemicals, are not suitable for use on land," says University of Minnesota soil scientist William E. Larson.

Transportation and handling costs also limit the uses of many wastes on land, says Larson of UM and the US Department of Agriculture's Agricultural Research Service.

Wastes useful to the farmer include livestock wastes, food-processing wastes, sewage sludges, and sewage effluents.

Excess Manure Harmful

Farm manures contain the major nutrients for plants. But some nitrogen may be lost as gaseous nitrogen products such as nitrogen and ammonia, says Larson. In addition, for the first year after application, only about half of the organic nitrogen of many manures gets mineralized into available forms which can get into the plants.

In spite of such lack of availability of some chemicals, other chemicals tend to accumulate:

Larson cautions that if excessive amounts of manure are put on land, then "sodium chloride, copper, boron, zinc, arsenic, manganese, various pesticides, and other chemicals may accumulate from some animal wastes and present serious contamination of soils and waters. For example, exceptionally high rates of manure application may slow plant growth. But such dangers are reduced if manure is applied at crop-utilization rates."

For maximum production, he says, many non-leguminous crops take about 200 pounds of nitrogen per acre per year in farm manures.

Some researchers say that 100 acres of soil cropped to continuous corn would efficiently use the nitrogen in manure from 200 feeder cattle for a year, 1,000 hogs for 175 days, 100 dairy cattle for a year, 100,000 broilers for 70 days, or from 10,000 layers for a year.

Other benefits of manure include its effectiveness in protecting and rebuilding problem soils such as scalped or badly-eroded areas.

Sewage-Fertilizers Abundant

Substitutes for manure and manufactured fertilizers include urban

In the past, digested sewage sludge was merely d ed to get rid of it, as shown here. Now, gr possibilities for recycling include irrigation with liquid wastes, spreading solid sludge with conventional spreaders, or spraying liquid wastes—sewage or manure—with special spraying equipment. But precautions are advised (see story below).

Be Careful

wastes such as sewage effluents and sewage sludges.

The average US production-equivalent of sewage sludge is about 40 pounds per person, he says. This is roughly a national production of 200,000 tons of nitrogen, 120,000 tons of phosphorus, and 150,000 tons of potassium. This amount of sludge contains approximately 2.5 percent of the nitrogen, 6 percent of the phosphorus, and less than 1 percent of the potassium of the amount contained in commercial fertilizers used in the US per year.

"Of course, it is unrealistic to think that we can, in the near future, recycle all of the wastes back to the land for agricultural and forest production," says the UM researcher.

Transportation cost is one limiting factor to such recycling, he says. But such costs could become acceptable in the face of severe fertilizer shortages.

Sludges Can Be Harmful

As with manures, sludges also contain chemicals which can accumulate and become a hazard. Removing such chemicals is, so far, too costly to be practical, says the Minnesota scientist.

Sludges contain metals that can damage the long-term productivity of soils, says Larson. In addition, uptake of large amounts of toxic metals could be harmful to animals and humans.

"Sewage effluents contain significant quantities of nutrients but in low concentrations; so large amounts of water are required to obtain enough nutrients for good growth of many non-leguminous plants," says the UM scientist.

"Because of the large amounts of water required, application of sewage effluent as a crop fertilizer is most feasible where both the water and nutrients are needed."

Only digested sludges should be used on land because of possible disease and odor problems from raw sludges.

Special equipment is needed for spraying liquid waste; but solid sludges can be spread like manure.

Scientists figure that no more than 2 inches (about 7 dry tons per acre or 700 pounds of nitrogen) of an anaerobically-digested sewage sludge should be applied each year for a non-leguminous crop.

Benefits of Sludge

Sewage sludge has increased corn yields up to 160 bushels per acre and increased potato yields up to 595 hundred weights per acre when applied to Hubbard sandy loam, says the Minnesota soil scientist.

Sewage sludges also have been highly effective in reclaiming non-productive land such as mine-spoil banks, wastes from glass factories, dune and dredged sands, covered-over garbage dumps, and sanitary land fills.

With proper selection, control of soil acidity or alkalinity, crop residue management, selection of crop, and wise use of the crop, many sludges can be used safely, he says. However, sludges with high metal contents should not be put on land.

Farmers should contact their county agents and environmental officials before using sludge, says the UM scientist.

"With proper precautions concerning heavy metals and toxic chemical composition, nitrate leaching, erosion losses, and undesirable odors, organic wastes can be used safely and effectively to increase the productivity of our soils," says Larson.

Most organic wastes, when applied at crop-utilization rates and with proper soil management, present no serious environmental hazards, concludes the University of Minnesota agricultural researcher. □

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independent farm-input supplies will decrease. A decrease has already been seen in 1973 in the number of dry-blending plants in Minnesota.

In a recent issue (no. 559) of the *Minnesota Agricultural Economist*, economists Dahl and Winston W. Grant point out some alternatives for easing the fertilizer situation:

(1) modify energy allocations in favor of fertilizer production
(2) embargo exports
(3) allocate fertilizer
(4) encourage imports
(5) establish an improved information system
(6) work to improve scheduling in the transportation system

"In the long run the most feasible alternatives to improve the situation are increased availability of feedstocks, increases in production capacity, and improved use of effective capacity, especially in less-developed countries," point out the Minnesota agricultural economists.

High prices will prevail for some time, they say. Countries and regions that can pay the highest prices will have the advantage, while some of the poorer countries, especially the less-developed countries, could face serious shortages.

United States demand for nitrogen fertilizers is expected to be 9.3 million for the 1973-74 fertilizer year, 12 percent above the previous year's demand, say the University of Minnesota agricultural economists.

They expect that phosphate demand was up 9 percent.

"The nitrogen supply probably fell short of demand by as much as 5 percent and the phosphate deficit likely reached 15 percent," say the Minnesota scientists. "The potash situation was relatively good. The most serious problem for potash was transportation bottlenecks during crop shipping peaks."

Even though we are experiencing fertilizer shortages in nitrogen and phosphates, 1974 use of both was greater than 1973 use, they report. In addition, application in recent years has been well above maintenance levels. Therefore, reductions in planned applications are not expected to significantly reduce crop yields.

"Even though nitrogen and phosphate production will increase substantially by 1980 in the US and throughout the world," say the UM researchers, "shortages or tight markets can be expected for several years due to the 2 to 4 year lag times required to build new plants." □

Science Notes

ENERGY CUTS CAN CRIPPLE NATION'S FOOD PRODUCTION

Agricultural energy needs—about two and one-half of the nation's total energy input—needs to be fully understood by policy makers, say L. F. Nelson and W. C. Burrows in a recent report to the American Society of Agricultural Engineers.

"However, if any measure adopted can lead to a reduction in food production, a potentially dangerous situation will exist," they warn.

Corn has the highest energy input per acre, of the major US crops, because of the high energy inputs for drying and fertilizer, they point out. Energy for wheat production varies, in part, because of the need for fallow in some areas.

"The total energy requirement per acre for soybeans is the lowest," when compared to corn, cotton and wheat, they say. "This is because soybeans do not require nitrogen fertilizer, nor is drying usually used."

From a gallon of diesel fuel equivalent can be produced about two bushels of corn (diesel fuel they describe as more efficient than gasoline). The energy content of the grain harvested is about 6 times as great as the fossil fuel energy input required to grow the crop. On a whole plant basis, the energy return is about 12 times the investment.

Nelson and Burrows, are formerly of the University of Minnesota.

LEGUME USE UP*

Legume production has increased from 17 percent of the total crop acreage in 1930 to 32 percent in 1970. Approximately one-half the 8.8 million tons of nitrogen harvested from US farmlands in 1970 was symbiotically fixed by legumes. Minnesota, a corn-soybean state, has about 37 percent of its total crop acreage in legumes. (It is too early to say what affect the current legume seed shortage will have upon future production.)

Interseeding of legumes is not practical in row crops, such as corn, without great sacrifice in crop production. But establishment of legumes by interseeding in cereal crops is quite successful, say University of Minnesota scientists.

FARMERS RECHARGE SOIL'S FOSSIL FUEL*

Cultivation of prairie grasses usually results in a new humus level lower than the original. Cultivation of very sandy soils or subhumid soils under irrigation usually results in a humus level higher than the original.

One of the best examples of the effects of tillage upon soil humus is that of cultivated summer fallow. Researchers have found that after 37 years of cropping, cultivated fallow soils contained 33 percent less humus than soils under continuous cropping. Our forefathers traditionally overtilled the soil. The tillage increased decay of humus and the mineralization of organic nitrogen, phosphorus and other nutrients into forms available to plants. In some of the older cropping systems humus can be regarded as a fossil fuel that will be lost from the soil unless replaced by fertilization.

THREAT OF SOIL COMPACTION*

Demand for earlier spring tillage and planting has brought some farmers to a collision point with regard to soil compaction, says UM soil scientist George R. Blake. Culprits are greater tractor weights, careless fertilizer application practices, and tillage when soils are too wet. Soil bearing properties, tractor tire design effects, alternative methods of performing tillage and other operations needed to care for the crop, possibilities for concentrating machine traffic, and rethinking the whole of machine-use in crop production are in serious need of investigation, cautions Rouse S. Farnham, U of M soil scientist, who has been examining Minnesota soils for some 20 years.

"During this summer's drought Farnham observed a field of new ground next to compacted ground, both in corn:

"The plants in the new ground were doing well," he says, "but the plants in the compacted ground, low in humus, were wilting and dying.

"I have seen more soil compaction problems this year than in any previous year. This was the year that bad tillage practices were evident.

"Even when it rained the compacted soils did not take up water well because they had sealed over."

SURFACE CROP RESIDUES SHORTEN GROWING SEASON*

While surface residues will help protect against erosion of sloping soils, Minnesota research results indicate that surface residues on poorly-drained soils reduce soil temperatures and may further shorten Minnesota's minimum growing season. Wet seasons further complicate the problems of poor drainage because root systems of the plants can suffer in such situations.

Additional research on poorly-drained to somewhat-poorly-drained soils, at Waseca and elsewhere, has shown that no-till corn will frequently have a higher moisture content at harvest (requiring more fuel for drying) than corn which is conventionally tilled. The additional moisture increases the amount of energy required to grow and dry a no-till corn crop in Minnesota, but is not as serious a problem in states with longer growing seasons.

SOIL IMPROVED WITH CORN*

As farmers know, heavy applications of manure can help to maintain or increase soil humus. Yet it takes 20 tons or more of wet manure per acre to adequately maintain soil humus content. Some scientists contend that early crop rotations and fertilizer practices were exploitive of soil humus because the soils were under-fertilized. Recent work by UM soil scientists shows that soil humus can be successfully maintained or increased with well-fertilized continuous corn when the abundant crop residues are returned to the soil. For example, 4 tons or more of dry corn stalks per acre has been shown to maintain soil humus.

NITROGEN LOSS PLAGUES MANURE RECYCLING*

With the exception of some poultry enterprizes, virtually all animal manure wastes currently produced in Minnesota are being returned to the land as fertilizers.

According to many studies of manure and nitrogen, the maximum availability of organic nitrogen to crops is 50 percent and inorganic nitrogen 70 percent. These same studies estimated an average farm utilization by crops of 35 percent of the organic nitrogen and 50 percent of the inorganic nitrogen applied to the soil. Numerous studies in North America confirm these observations. As much as 70 percent of the nitrogen and potassium and 25 percent of the phosphorus in manures may be lost before it is hauled to the fields.

*Most of this information was excerpted from a research overview on agriculture and the food and energy dilemma. The overview—based upon results by many researchers, both in and out of state—was received by the editor from Professor Russell S. Adams, Jr. of the Department of Soil Science of the University of Minnesota.

Research in manure, legume and fertilizer management could pay great dividends in the form of improved timing of application, storage and handling, treatment of residues, incorporation methods, and machinery. For example, 20-30 percent higher yields from anhydrous ammonia (knifed in) than from an equal amount of ammonium nitrate applied on the surface in no-till corn, have been reported. Benefits of the deep placement of anhydrous ammonia included decreased leaching of nitrate nitrogen over the winter and a greater flexibility in timing of application so that soil compaction could be avoided.

ECONOMICS OF CROP ROTATION VERSUS CONTINUOUS CORN*

Complete reliance upon legumes as a nitrogen source comes at considerable expense to the farmer and at a considerable loss in energy production, say University of Minnesota agricultural scientists.

Various calculations, depending upon climate, location, and cropping system, have shown legume nitrogen to cost from 50 cents to $1.00 per pound to produce. A continuous corn rotation could produce 6 million kilocalories. Whereas, a 3 year wheat-alfalfa-corn rotation, with alfalfa as the only source of nitrogen, could produce 3.2 million kilocalories, a 47 percent reduction in energy production if the alfalfa is used only for nitrogen production and not fed to livestock.

Long term rotations supplemented with nitrogen seem the most acceptable compromise. At the current price situation a five-year rotation of wheat-alfalfa-corn-corn-soybeans would return about the same benefits to the farmer as continuous corn at only a 28 percent reduction in energy output. If most of the feedstuff were passed through livestock, and the manure returned to the land, then the synthetic nitrogen needs in the five-year rotation could be essentially eliminated. (See table at right.) However, in adopting such rotations other problems must be overcome: →

— Unless technology provides better means of utilizing alfalfa as a human feed, the five-year rotation calls for an expansion of the livestock industry. (The latter may be incompatible with the following:)

— Five-year rotation calls for a major redistribution of livestock enterprizes at a considerable loss in efficiency, with attendant increases in meat prices, to remain economically feasible.

— Legumes make much greater demands on soil phosphorus, potassium, and calcium (lime), where these elements are limiting, and require greater fertilization than cereals.

GOOD BEAN HARVEST

Nearly 100,000 acres of dry edible beans were harvested this year, according to University of Minnesota plant pathologist Howard L. Bissonnette.

The beans—mostly pinto and navy—were grown from south-central Minnesota to the Canadian border. Some beans were grown in the north-central regions of the state where dry sandy soil ordinarily would not support a crop, says the UM scientist.

"With the advent of irrigation, the north-central area has turned out a good crop," he says.

Most of the beans are exported.

Plant pathologist Bissonnette points out that disease is not yet an important limiting factor for bean crops in Minnesota.

Diseases have been limiting for beans in other states. As a result, some bean processors come to Minnesota from states where disease has seriously cut bean yields.

"When a bean processor decides to move to a new area he makes quite a commitment in bringing his equipment and putting up new plants," says the UM scientist.

The best protection from disease is to buy high-quality disease-free seed, says Bissonnette.

Harvesting involves cutting or pulling, and then combining. Best moisture content at harvest for navy beans is around 18 percent and for pinto beans around 16 percent. Moisture tends to protect the edible beans from damage.

FARMERS REBUILD SOIL*

Decline in humus content of Minnesota soils is believed to have essentially ceased and, in some cases, reversed by less-exploitive modern agriculture. Improved practices in the past 20 years include:

— Minimum tillage practices and combined tillage operations systems.

— Increased crop residues returned to the soil.

— Higher fertilizer rates which gave great increases in plant vigor and great return of crop residues.

— Application of soil conservation measures such as contouring, ridging, terracing, and grassing waterways.

Research aimed at increasing crop yields of usable carbohydrates and proteins should evidently take into account the stored energy within organic matter of the soil. (Crude estimates place the energy value of organic matter in fertile soil at the energy contained in a thousand bushels of corn. Ignoring this storage mechanism could lead to unrealistic estimates of energy relationships in the husbandry process.) Organic levels in Minnesota soil are 50 percent or more of their original value.

GREEN PEA PRODUCTION NEARS 100,000 TONS

Minnesota's 1973 pea production is estimated to have been 10,000 tons for freezing and 90,000 tons for canning (5 and 30 percent, respectively, of total US output), says research assistant Kenneth M. Menz, formerly of the University of Minnesota's Department of Agricultural and Applied Economics. A recent UM study suggests that, under prevailing industry conditions, Minnesota's increased production of peas for freezing would lower the total industry cost of satisfying consumer demand (at the expense of frozen pea production in the West).

Menz points out that, "Recent price increases of commodities competing with peas for cropland have forced processors to raise the price of peas paid to growers.

Comparison of a Five-year Rotation Versus Continuous Corn

Years	Crop	Ave. crop yield/acre	Best yield/acre	N. need: lbs/acre	Net energy yield: kcal/acre (for ruminants)	Unit price (1973)	Gross return/ acre	Cost/ acre**	Net return/ acre
1	Wheat	40 bu	70 bu	100	3,557,440	$ 4.35	$304	$125	$179
2	Alfalfa	2 tons	5 tons	0	4,150,000	40.00	240	126	114
3	Corn	94 bu	130 bu	50	5,991,440	2.28	296	158	138
4	Corn	94 bu	130 bu	150	5,991,440	2.28	296	170	126
5	Soybeans	29 bu	40 bu	0	2,032,800	5.22	209	131	78
	Total	-----	-----	300	21,723,080	-----	$1345	$667	$635
5	Continuous Corn	94 bu	130 bu	850	29,957,200	2.28	1480	875	605

*See footnote, page 14.

**Cost per acre—All crops are charged $75 per acre land cost and cultural costs for seed, fertilizer, land preparation and harvest: wheat $50 per acre plus nitrogen fertilizer, alfalfa $51 per acre plus nitrogen fertilizer, alfalfa $51 per acre, corn $75 per acre plus nitrogen fertilizer and soybeans $56 per acre. Nitrogen fertilizer costs estimated at 15 cents per pound. Unit prices would have to be adjusted to fit current market situations.

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Minnesota agricultural industry generated about 35 percent of our state's wealth for a total of $5 billion in 1973. It may be higher in 1974, but there are some soft spots in the livestock economy; and livestock is important to our total agricultural production and income. Drought conditions in southwest counties may also have an impact on total income. There are approximately 107,000 farms in our state. The southern third of Minnesota is in the corn belt and has the same levels of production and potential as found in Iowa and other parts of the corn belt. Our agricultural industry provides 28 percent of the state's employment, and 23 percent of personal income.

There are 25 million acres of prime agricultural land in Minnesota (about 43 percent of our total land area). Corn and soybeans are grown on 10 million acres of this land with wheat, oats, barley, alfalfa, sugar beets, sunflowers, and potatoes being other major crop enterprises. Our horticulture industry is relatively small, but important. New agricultural development through irrigation on sand lands may add 1.5 to 2 million acres for increased food production, if the cost-return relationships are adequate.

Minnesota ranks third in the nation's milk production, with more than a million cows which produce nearly 10 billion pounds of milk per year. We are first in turkey production. Over 6 million pigs are fed annually. Our beef industry is increasing although that may not be true for long if prices stay as they are at the farm.

Minnesota agriculture is very diverse: there are relatively small farms in the southeast and north central areas to the extremely large grain farms of the Red River Valley in the northwest and the large corn and soybean farms in the southwest portion of the state.

A Soviet ship with US goods at the Port of Duluth prepares for her trip home.

Research Benefits

Research programs have made significant contributions to Minnesota agriculture, US, and world agriculture: By the early 1920s, research on hybrid corn set the stage for a tremendous production explosion. Wheat stem and leaf rust research proved without a doubt that rust organisms hybridize in nature. (One solution for the rust problem is to develop plant resistance that lasts 5 to 10 years.) Early work on artificial insemination, freezing of semen, and ova transplantion made great strides possible in the livestock and turkey industry. (This basic work also led to improved methods in organ transplantation.)

A new hard red spring semi-dwarf wheat variety, Era, was grown on nearly 900,000 acres in 1973. It yielded about 6 bushels more per acre than standard varieties. This resulted in $26 million of additional income to farmers, plus an additional $12-$15 million income for transportation, milling, baking, and sales. Nearly 27 million more loaves of bread were produced from this added production.

New soybean varieties released this year, Hodgson and Evans, will be planted on about 2 million acres by 1976. The extra yield of these varieties will produce enough protein to meet the needs of over 1 million people for a year.

Minnesota can be proud of its agricultural heritage as well as its modern food-production capabilities. □

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