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—a 'time pill' for plants

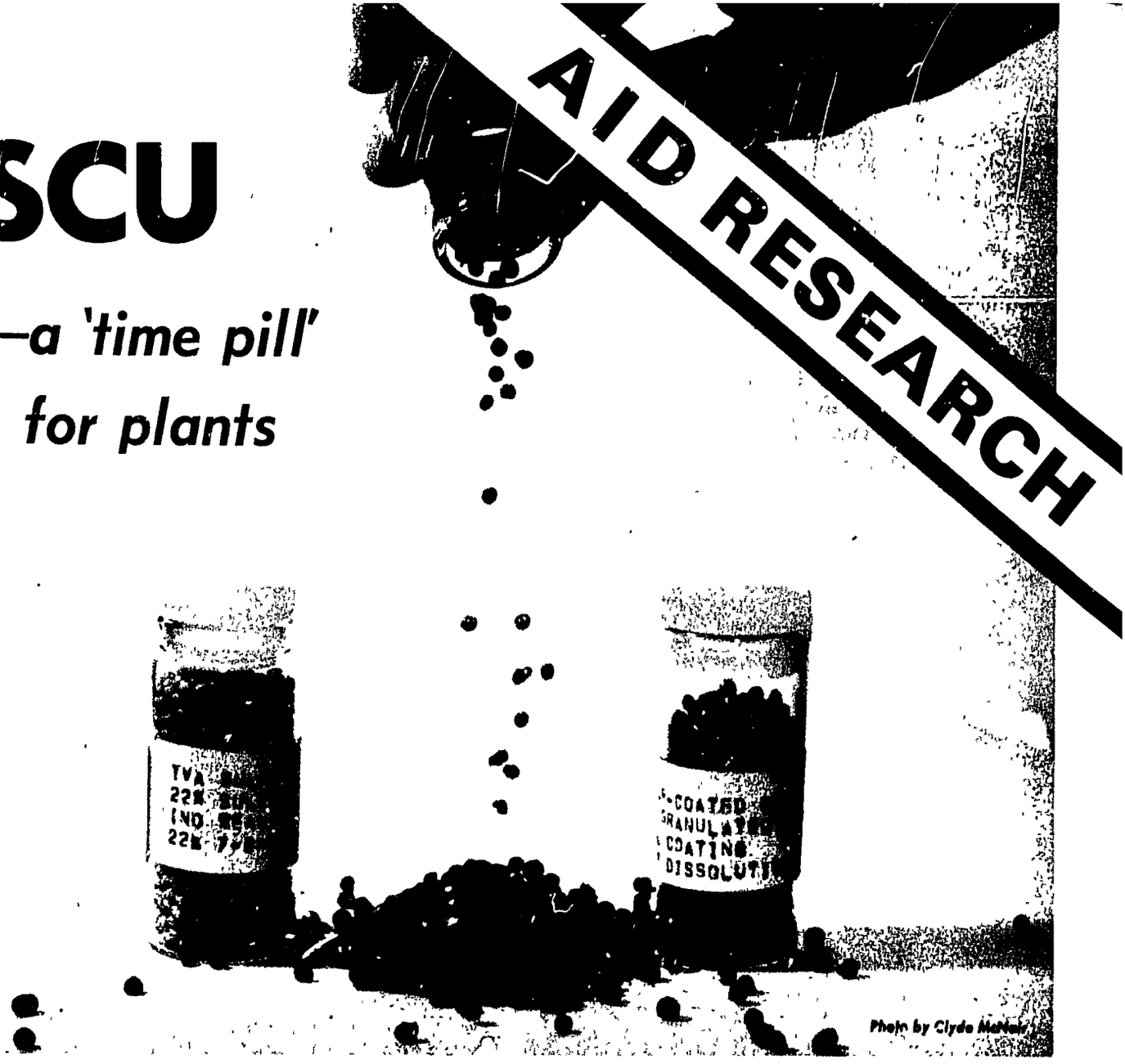


Photo by Clyde Mahaffey

What could be mistaken for pills are actually wax and sulfur coated pellets of urea which release nitrogen gradually to crops.

By Jerry E. Rosenthal

A dramatic development in fertilizers, recently disclosed by the Tennessee Valley Authority, may supply another potent weapon in the battle to feed the world's hungry millions.

Sulfur-coated urea—SCU—has been tested both in the United States and 29 foreign countries with the help of the Agency for International Development. The results, according to TVA and AID specialists, warrant optimism that this improved fertilizer can be commercially produced and made economically available throughout the world.

"This could mean a most welcome addition to the efforts to spur economic and social development in Asia, Africa and Latin America," AID Administrator John A. Hannah commented. "Continuing increases in food production are vital in the developing countries where expanding populations must be fed. The improvement, availability and use of fertilizers are necessary to achieve these increases.

"By 1980 the fertilizer requirements of the developing countries are expected to multiply six times what they were in 1965. To meet this need it is imperative that technological progress continue. SCU would seem to be another example of the way in which we are trying to meet this challenge."

SCU basically is a granule of urea—a widely-used nitrogen—supplying chemical compound—coated with a thin layer of sulfur, and wax for sealing.

The general objective of SCU, as with all fertilizers, is to provide a nutrient—in this case nitrogen—to a crop at a feasible cost. Specifically, SCU is designed to release nitrogen at a slow even rate—something like a "time pill"—nourishing the plant when it needs it most. The coating also makes SCU more durable than uncoated urea. SCU handles better, cakes less and resists humidity. It is less harmful to the environment. The sulfur adds an important nutrient to the soil.

Reprinted from the January 1973 issue of War on Hunger, Agency for International Development.

Field tests carried out in India, the Philippines, Thailand, Brazil and Peru, under an AID-sponsored project called "Tailoring of Fertilizers for Rice" reveal that SCU is particularly effective with rice in areas where flooding is intermittent. This is a condition that exists in about 75 percent of the rice acreage in Southeast Asia and in most of the other rice growing areas of the developing world. Rice is the world's most important food—the basic diet of nearly two-thirds of the three and a half billion people who inhabit the globe. Obviously, anything that can increase rice production efficiently and economically can be of enormous benefit.

A Specialized Fertilizer

SCU, however, is not an all-purpose fertilizer. In those areas where rice paddies are continuously flooded, SCU shows no advantage over conventional nitrogen sources. Where flooding is delayed, intermittent or where water management is poor, the results are impressive.

Dr. Orvis P. Engelstad, agronomist with TVA's Soils and Fertilizer Research Branch, who managed the AID rice "tailoring" project, cites tests in Garikapadu, India, where he said the experiment showed "a consistent superiority of SCU over uncoated urea." And in Hyderabad, India, the tests showed "a marked increase in yield for the SCU materials over that from straight urea."

In Peru, SCU increased rice yields while lowering the nitrogen rate needed for maximum yield. The report on the Peru tests also stated that in spite of 48 percent higher unit cost, the overall effect of SCU was to increase net returns by 17 percent.

A TVA summary of rice studies reports on 24 tests conducted under delayed flooding conditions, using SCU versus conventional urea, both of which were applied before planting. Seventeen resulted in superior yields for SCU, in five there was no difference, and in two cases the conventional urea produced a greater yield. Where the comparisons were made under intermittent flooding conditions, SCU exceeded the conventional urea treatment in all. In tests using SCU as preplant, and conventional urea as topdressing, under delayed flooding conditions, yields from SCU exceeded the conventional fertilizers in 11 of 14 cases. Under intermittent flooding conditions, SCU, applied preplant, exceeded the conventional top-dressed urea in three of five cases and was equal to the conventional form in the other two.

The TVA-AID "tailoring" project was begun in 1968 and ended December 31, 1972, at a cost of about $400,000. Much of the work was conducted under the guidance of an advisory committee, considered unique for this type of project.*

Don L. McCune, Director of TVA's International Fertilizer Development Staff, believes the committee's work and the results of the tests indicate that SCU can be a significant aid to farmers growing high-yield

A cross-section of SCU viewed through a microscope shows the outer layer of wax and sulfur which helps to retard dissolution.

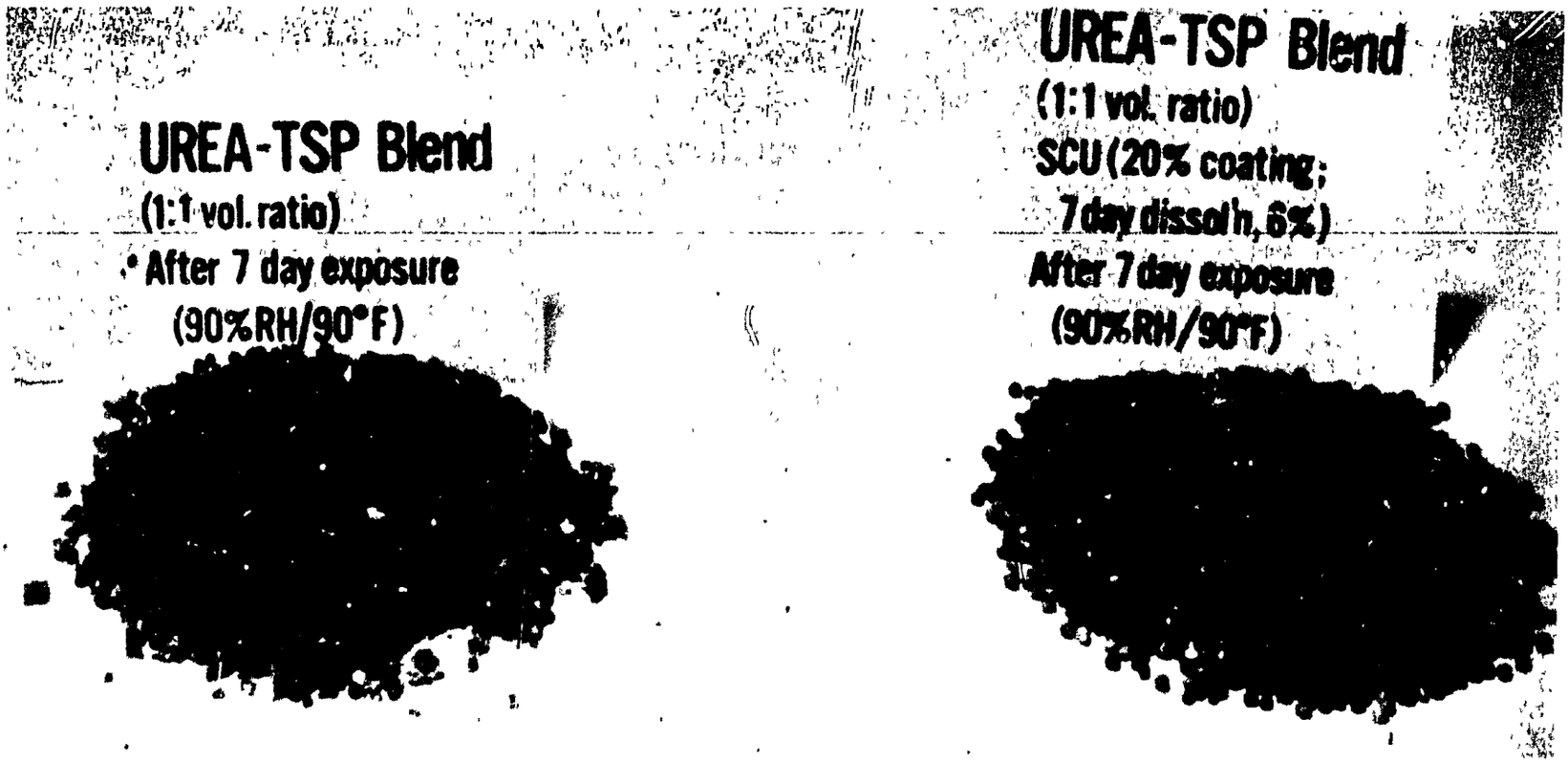
varieties of rice. These varieties, hailed when they came to world attention in 1967 as "miracle" rice, require more inputs—fertilizers, pesticides, cultivating techniques and water management—than the ordinary types. SCU, he says, could save the farmer some of the extra effort required in using these inputs.

"It compensates to some degree for poor management," he says. "But it should not be an excuse for poor practices."

Dr. McCune also says that SCU is less wasteful. This is an important factor in developing countries where farmers emerging from a subsistence economy must borrow money to pay for the inputs necessary to increase their yields and cannot afford to suffer excessive losses.

"Say a farmer buys a bag of nitrogen fertilizer—the usual type," he says. "The farmer uses half of

* The committee consisted of Dr. S. K. DeDatta, head agronomist at the International Rice Research Institute, Philippines, Dr. Duane S. Mikkelsen, Department of Agronomy and Range Sciences, University of California at Davis, Dr. W. H. Patrick, Jr., Department of Agronomy, Louisiana State University, Dr. Pedro A. Sanchez, Department of Soil Science, North Carolina State University, Dr. J. M. Spain, soil scientist at the Centro Internacional de Agricultural Tropical in Columbia, Sombhot Suwanawaong, Chief of the Technical Division in the Rice Department, Thailand, Dr. Akira Tanaka, professor of plant nutrition at Hokkaido University, Sapporo, Japan, and Dr. H. ten Have, formerly agronomist at the All India Cooperative Rice Improvement Program, Hyderabad, India (now at Wageningen, the Netherlands).



The differing rates of dissolution between conventional urea granules (left) and SCU are apparent after a one week period.

the bag, and lets the other half sit, expecting to use it later. Under tropical or sub-tropical conditions, that other half deteriorates. The farmer is not getting his money's worth.

"SCU, with its good keeping quality, would still be in good condition when he wanted to use it."

TVA, at its Ninth Biennial Demonstration of Fertilizer Technology last October, exhibited samples of SCU and conventional urea to compare stability and compatibility. Conventional urea, mixed with concentrated superphosphates, showed deterioration after one day. SCU, on the other hand, was still free-flowing after one month.

In addition to rice, SCU has been tried on other crops and in some cases, especially long-seasoned crops, has achieved results similar to or surpassing those for rice. In Hawaii, the sulfur coated urea was tested on sugarcane, a crop grown in many developing countries.

Sugarcane requires nitrogen over an 18 month period. Up to six applications of conventional nitrogen fertilizers are needed in this period. Aerial application must be used after the crop is a few months old. Field tests showed, however, that two applications of SCU produced more sugar than five applications of the same amounts of uncoated urea.

Tests using SCU on pineapples in the Philippines, watermelons in Florida, and tomatoes in North Carolina also resulted in increases over uncoated urea. It has also proved more efficient for forage grasses and lawn turfs. On the other hand, SCU has shown no advantage over conventional nitrogen sources in experiments with such row crops as corn, grain sorghum and small grains. This is because these crops take up a majority of their nitrogen over a relatively short period of time. Thus, a slow-release fertilizer normally would not be beneficial.

There is an additional advantage to SCU, other than its slow-release characteristics, resistance to moisture, caking and compatibility. This is the sulfur provided in the coating.

Many soils are becoming increasingly deficient in sulfur, an essential plant nutrient. For example, an AID-financed study of soils in Latin America, undertaken by North Carolina State University, has revealed, among other findings, that soils in the central plateau of Brazil are very poor in sulfur content due in large part to repeated burning of fields.

Potential in Brazil

A similar situation also is reported in Northeast Brazil, a depressed area. John P. Lloyd, an official of a fertilizer manufacturing firm in Recife, and one of those attending the recent TVA fertilizer demonstration, said he thought SCU could be useful in this respect in Northeast Brazil. "It could go a long way in improving food production," he said.

Adolfo Sisto Velasco of Mexico, an official of the government-owned fertilizer corporation, Guanos y Fertilizantes de Mexico, S.A., said he was "very interested" too in what SCU could do in his country. Mr. Sisto, who was trained by TVA under a Rockefeller Foundation grant, said he personally would like

to see "Mexico become the first to produce SCU commercially."

"Mexico has the sulfur," he says, "and we are manufacturing urea now. The sulfur source is only 25 miles from the plant."

Mr. Sisto said that because some of Mexico's soils are deficient in sulfur, SCU would be of great use. He noted also that Central America would be a possible market for export.

Since much of the field testing of SCU was carried on in India, that country also may produce SCU. Taiwan has expressed interest as well.

Broad Development Policy

The interest of foreign as well as U.S. fertilizer manufacturers in SCU is the latest evidence of a broad development policy that extends back to the establishment of TVA in 1933. The TVA was created to develop and conserve the resources of the Tennessee Valley—an area of some 41,000 square miles in seven states.

Fertilizer research and education was one of the responsibilities included. Unlike TVA's other activities which are confined to the Tennessee Valley itself, however, Congress specified that the fertilizer program should be a nationwide effort.

At the time TVA came into being, chemical fertilizers were relatively primitive and not widely used. Until after World War II, nitrogen fertilizers were mostly by-products of steel manufacture and food processing. The establishment of the National Fertilizer Development Center (NFDC) within TVA at Muscle Shoals, Alabama, however, provided a facility exclusively devoted to research and development of fertilizers. Seventy-five percent of the fertilizers used in the United States today are based on processes developed by the NFDC.

Leading Source of Expertise

Through its association with state universities, the growing fertilizer industry and other agencies, the NFDC became recognized as the leading source of expertise in the field. This reputation spread abroad. European nations, Japan and other more developed countries began to utilize the facility and its competence. Information on all new developments, such as SCU, research findings, advice, and technical assistance, are available to U.S. and foreign processors, either without cost or at nominal charge. This sometimes is not fully understood at first, according to Owen W. Livingston, chemical engineer with the NFDC's International Fertilizer Development Staff.

Mr. Livingston, who was born and raised and has lived his entire 39 years near Muscle Shoals, recalls a recent trip to Brazil where a team from TVA was assisting in setting up a fertilizer plant.

"The people couldn't understand why we were doing this," he said. "They thought at first that there must be some hidden motive.

"We tried to convince them that we were there to be helpful, that the United States was interested in their welfare and this was one of the ways of showing it."

With this type of spirit, it was inevitable that TVA and AID should become associated. As food production became an increasingly vital problem in the developing countries, AID's interest in fertilizers became more intense. The financing of fertilizer exports to developing countries has been one of AID's important programs. AID also has participated in studies and financing of fertilizer plants abroad.

In the early 1960s AID requested TVA to assist it in fertilizer-related problems and in 1965 the two agencies signed a general agreement under which AID funds have financed the collection and cataloging of worldwide information on fertilizers; computerization of information on fertilizer production facilities around the world; studies by about 50 teams in specific countries, and the training of nearly 300 participants from 25 countries.

These activities are administered by TVA's International Fertilizer Development Staff, formed within the NFDC.

Work in Korea

The international staff, headed by Dr. McCune, carries the responsibilities of training and technical assistance. It functions under the Office of Agricultural and Chemical Development. An official of this office, J. Harold Parker, recalls the work TVA did in Korea under AID's impetus in the early 1960s.

"The Koreans were seeking advice in what direction to go. They had planned to build a number of small plants, but our TVA team recommended a large plant. The report of the team pointed out that Korean fertilizer use had reached a stage where large-scale manufacturing facilities could be justified on an economic and foreign exchange basis."

The team also found that urea and diammonium phosphate fit the Korean needs, from agronomic and economic standpoints, better than the low-analysis single superphosphate which was being considered for processing in the numerous small-scale plants.

As a result, Dr. Parker said, Korea built a plant to produce 500,000 tons a year, and its success resulted in other plants being considered. Two—one at Chinhae and another at Ulsan—were partially financed by AID loans. Korea now exports nitrogen fertilizers.

A recent example of successful AID and TVA collaboration was a feasibility study of bulk shipment of urea that led to a commercial sale of urea to India, mutually beneficial to the fertilizer-hungry Asian nation and the United States. As noted, urea is hygroscopic—it absorbs moisture from the air when the relative humidity is fairly high, and can lose moisture when the relative humidity is lower.

Thus, shipping urea in bulk form has posed a problem, especially to the humid tropics where most

of the AID-financed urea shipments are destined. The urea would deteriorate under normal bulk shipping conditions. Bulk shipping, of course, is considerably cheaper than transporting in bags. AID asked TVA to make a study.

The study was carried out in 1970 under the direction of John T. Shields of TVA's International Fertilizer Development Staff. About 16,500 metric tons of urea were shipped from Kenai, Alaska, to Singapore.

Mr. Shields reported that such bulk shipments were technically and economically feasible. As a result, in the fall of 1972 India purchased 18,750 metric tons from an American firm for more than $800,000, a savings of $200,000 from the cost of a bagged shipment.

'A Good Deal All Around'

According to John Malcolm, AID fertilizer specialist, "this was a good deal all around."

"The cost of the feasibility study was $10,000, but the cash sale was nearly 80 times that," he said. "When the urea arrived in India, the bagging operation provided much needed jobs, an additional spin-off. The United States benefitted, India benefitted, and we have learned a lot."

The lessons learned, however, pointed up the need for the proper facilities, care in preparation, handling and storage in the ship's hold. These are not always available.

It is significant that in Mr. Shields' report on the study he recommended "new coating and conditioning materials should be developed and tested. . ." The report was published before conclusions had been reached on SCU.

Such AID-assisted studies along with technical assistance efforts and training programs have gone hand-in-hand with TVA's research activities.

Rice grown in greenhouses for experiments testing the value of SCU is hand-harvested at Muscle Shoals.

Owen Livingston, who directs the chemical engineering activities of the international staff, recalls how it began. He started full-time work with TVA—"my ambition ever since I was a kid growing up in the Valley"—in 1960, coming from Auburn University with a B.S. in chemical engineering. As a youth he had worked part-time for TVA.

In the applied research branch of the center, Mr. Livingston recalled, "our job was to find new and improved fertilizers and processes. We would try anything. We even tried to develop a fertilizer from coal, and did come up with a slow-release nitrogen material.

"It was slow all right—too slow. After a year, the fertilizer had only released 25 percent of its nitrogen."

This was the early 1960s and TVA had recognized earlier the need for a low-cost improved nitrogen fertilizer. Studies had shown that only about half of the nitrogen applied in conventional fertilizers is used by the crop. The rest is lost—largely through volatilization into the atmosphere and by leaching out. From an economic standpoint, this is costly. TVA estimated that American farmers invest annually about $1.2 billion for nitrogen, of which $600 million brings no return. The loss to farmers in developing countries would probably be proportionately greater.

As with coal, TVA researchers worked with scores of compounds. Many were completely unsuitable; others like oxamide, which had nearly ideal characteristics, were too expensive.

Urea at the time was coming into wide use as a nitrogen source. It contained more nitrogen (45 percent) than ammonium nitrate (33.5 percent) or ammonium sulfate (20 percent), the other two most popular nitrogen sources. Ammonium nitrate, however, is an explosive if misused and releases poisonous fumes when ignited. Because ammonium sulfate has a lower nitrogen content, more of it is needed to do

A pilot plant for producing SCU has replaced the hand-held laboratory equipment used initially in developing the fertilizer.

the job, thus its handling and transportation costs are higher.

It was decided that urea—made by reacting ammonia and carbon dioxide under pressure—held the most promise as a cheap and concentrated form of nitrogen. The objective was to find a way of slowing down the rapid release of nitrogen, protect the urea from its tendency to degrade under moist conditions, and to make it compatible with other fertilizer materials in mixed and bulk blends.

"I'm not sure where the idea of coating urea to achieve these goals came from," Mr. Livingston said, "but I believe the idea of coating granules of urea with sulfur originated with the man I worked for, A. V. Slack, then head of the Applied Reserach Branch."

Mr. Slack, who is now involved with the enormously complicated task of seeking ways to depollute smokestack emissions, claims he doesn't remember who had the original idea.

"There were several of us working on it," he says.

In any case, Mr. Livingston recalls the first laboratory work on coating urea pellets.

First Work by Hand

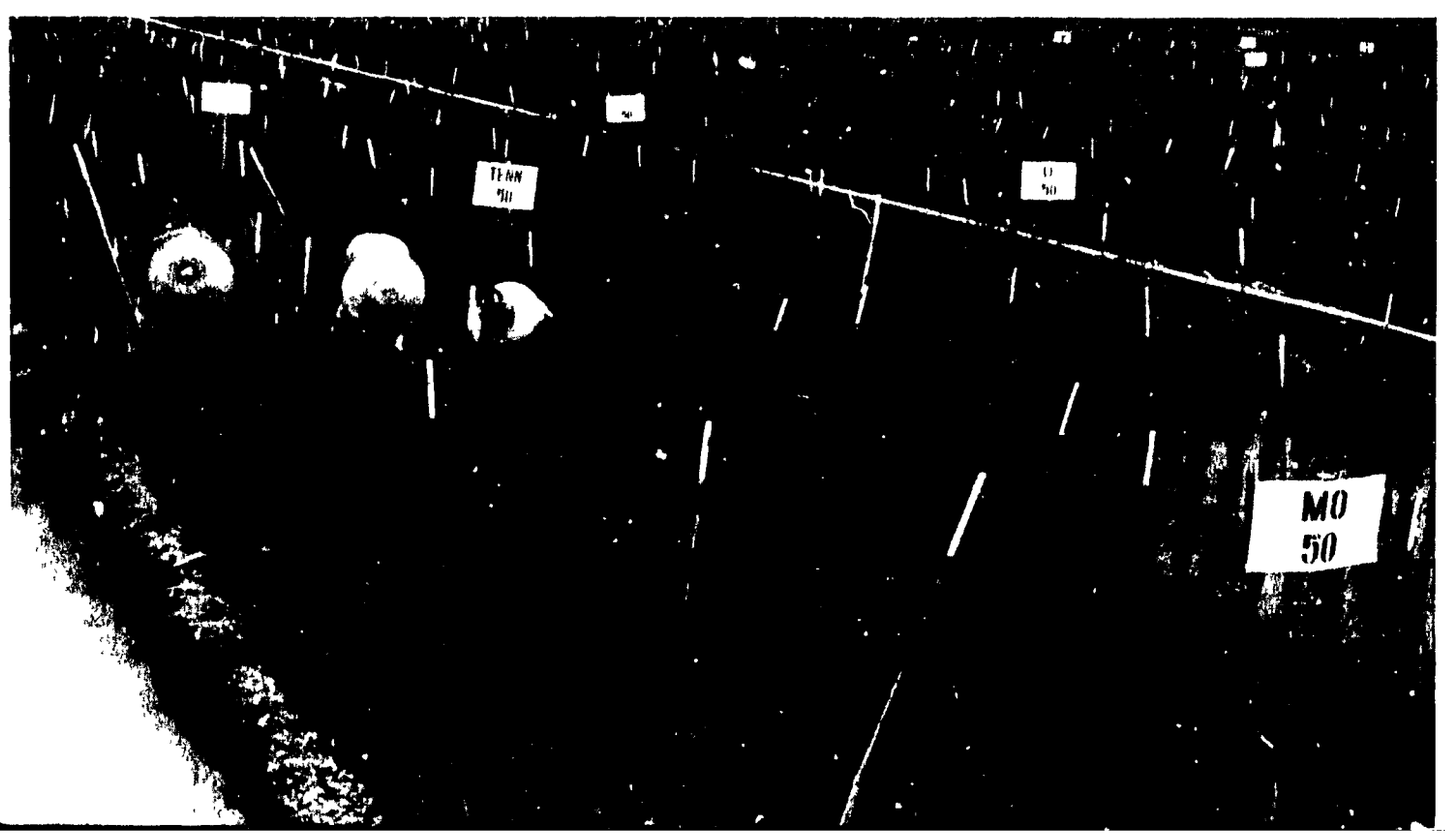
"We did it by hand in the laboratory," he said. "We would melt the sulfur and dip a particle of urea into it and try to get a uniform coating.

"We made our first agronomic studies and the lab scale work looked good."

From the laboratory, the work with SCU progressed to the greenhouse where agronomist Seward E. Allen has observed the effects of the fertilizer on a variety of plants.

"The efficiency of SCU rests in the slow rate of solubility," Dr. Allen said. "When the urea has re-

At test plots like these in Thailand and in other countries SCU helped increase rice yields where flooding was intermittent.



leased its nitrogen, the sulfur remaining is in elemental form. Soil micro-organisms oxidize the sulfur and it eventually becomes available to crops.

"The wax which seals the coating," he said, "has no use as a nutrient, eventually turning into carbon-dioxide and water through the action of soil micro-organisms."

Dr. Allen, 52, who grew up in upstate New York and took his degrees at Cornell and the University of Wisconsin, has been with TVA for the past 10 years. Prior to his service with TVA he was with private research foundations. He doesn't consider his work with SCU finished.

"We want to learn more about how nitrogen is released from SCU. Also, the more uses we can find, the cheaper the product will be. What we're also aiming for is an even better environmental fertilizer, one that does a better job of feeding the crop and pollutes less."

Advantage in Reducing Pollution

Conventional nitrogen fertilizers release nitrogen to the soil faster than the crop can use it. Excess nitrogen not used by the crop may find its way into ground and surface waters, causing pollution.

SCU's developers believe that the improved fertilizer can reduce this potential problem. Dr. Allen says:

"We're pretty sure fertilizers contribute little to pollution if correctly used. We have evidence that with SCU less nitrogen is lost to drainage water and more is used by the crops."

Both greenhouse and field tests indicate that SCU will reduce leaching of fertilizer nitrogen without penalizing crop yields. Dr. Allen cited an experiment with grass in which SCU was tested against uncoated urea. As much as one-third of the nitrogen in uncoated urea was lost over a six-month period. Only 5 percent of the nitrogen in SCU was lost during the same period. In addition, the SCU produced one-third greater yield than the uncoated urea.

Dr. McCune says that if restrictions were to be placed on the use of conventional soluble nitrogen fertilizers as an antipollution measure, "SCU is the only known low-cost, slow-release product that could be substituted."

The imposition of such restrictions could seriously affect American farmers, according to Dr. L. B. Nelson, TVA Manager of Agricultural and Chemical Development. For example, reducing nitrogen use 10 percent might cut total farm income by as much as $290 million. Use of SCU, however, would enable farmers to reduce this loss by 90 percent. Similar estimates have not been made for developing countries, but they illustrate potential economic implications.

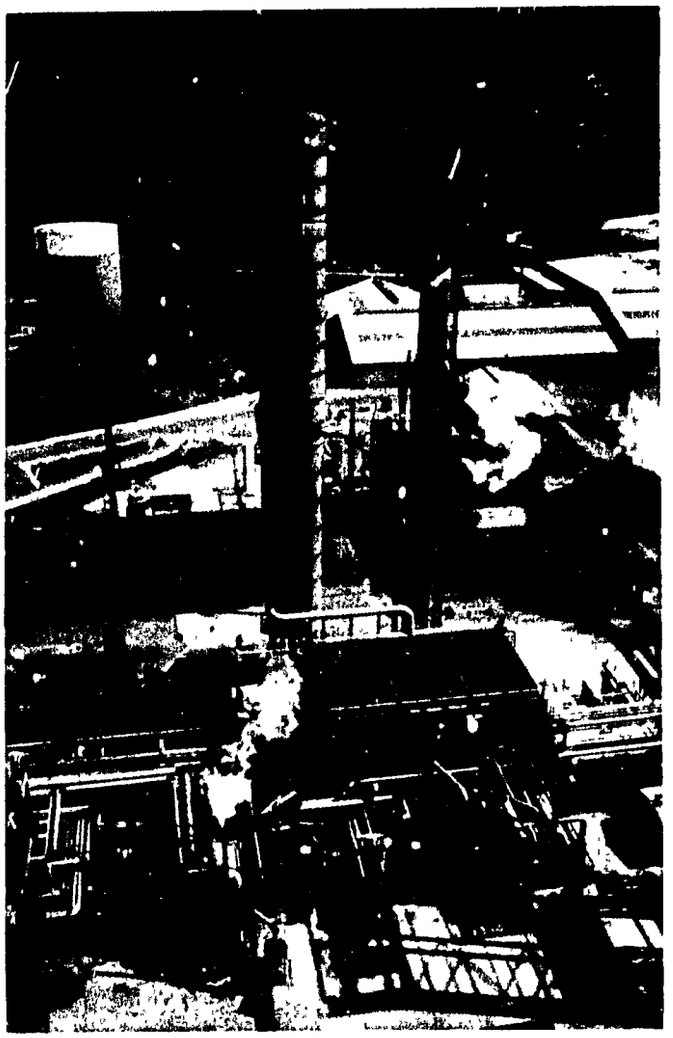
Although laboratory research, greenhouse experiments and field testing have indicated the potential of SCU as an efficient and environmentally feasible fertilizer, commercial production has not yet begun. TVA does not produce fertilizer commercially. It does, however, produce SCU in a pilot plant at the rate of one ton per hour.

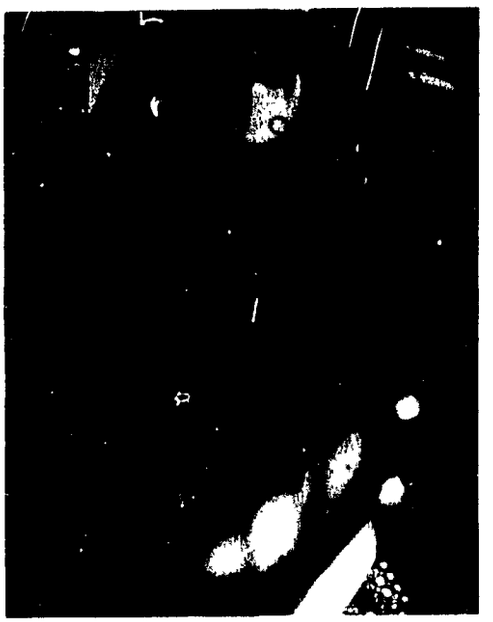
One of the essential steps found necessary to produce SCU efficiently is to use a granule large enough to take an effective coating. Urea now is produced commercially in "prill" form—droplets of liquid urea sprayed from the top of a tower which solidify as they fall and cool. Besides having other disadvantages, the tiny prill form requires more sulfur for coating. To surmount this, TVA devised a method of making larger size granules. Most of the SCU made by the pilot plant is about one-eighth inch in diameter.

A plant to make SCU would not be complicated, engineers say. The Muscle Shoals pilot plant consists of a urea storage hopper, urea feeder and preheater, sulfur-coating drum, fluidized-bed cooler, conditioning drum and some auxiliary process equipment.

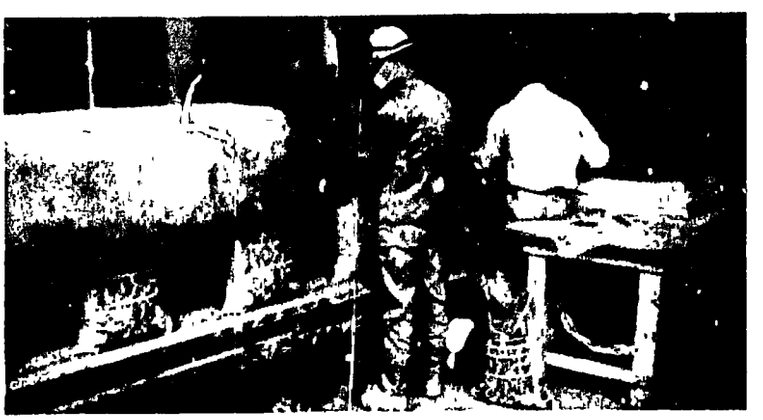
The heated urea enters a revolving drum containing nozzles which spray molten sulfur. From there the coated urea is conveyed by an elevator to the wax coating drum, where preheated wax is pumped into a mix with coal tar or other inert material. This mix-

Dr. Allen (left) discusses greenhouse evaluations of new fertilizers with members of a multinational training group at TVA's National Fertilizer Development Center in Muscle Shoals, Alabama. AID has helped finance the studies of nearly 300 training participants from 25 countries at the center, which also collects and catalogues information on fertilizers from around the world.





The Chinhae fertilizer plant in Korea was built with AID assistance after TVA specialists studied the country's fertilizer needs and manufacturing capabilities. Photographs taken at the plant in the late 1960s show the prilling tower (far left), fertilizer bags being sealed as they come off the production line (below), and Mr. P.S. Song (left), the Korean manager of the plant who received his training with the TVA in the United States.



ture is distributed onto the sulfur-coated urea through a "drip-tube" distributor. The material then feeds by gravity into the cooler, conditioning drum, scalping screen and finally into bags.

The experience with the pilot plant has been successful, TVA officials say. The cost of producing SCU commercially, however, would appear to be higher than conventional urea, but cheaper than any controlled-release fertilizer now commercially available. For the farmer, a bag of SCU would cost more, but, as field tests have shown, increased yields result in a greater net return.

Costs Variable

Costs, moreover, can be varied according to the size of the urea granule and the thickness of the sulfur coating. Also, Dr. McCune hopes, a way will be found to eliminate the wax, which would further reduce production costs.

The advantages of SCU over conventional urea are also expected to lead to further development, which, if past experience holds true, would decrease production costs, and thus lower expense to the farmer.

Further studies also are contemplated by AID and TVA to expand knowledge of areas where SCU can best be used. International research centers and other institutions are expected to participate.

Both TVA and AID estimate that SCU can fill a great need. The world consumption of fertilizers is expected to climb from the 1971 level of 68 million metric tons to more than 105 million tons by 1980. India, for example, recently announced plans to build five new fertilizer plants to meet her growing needs. TVA believes that much of the increase in nitrogen consumption will be supplied by facilities—largely for urea production—in the developing countries, such as India. SCU could be a likely product.

Because of expanding populations in the developing countries, SCU and other improvements that can help boost food production are bound to draw considerable attention among researchers.

"Products under development and products and processes yet to be conceived hold as much promise for tomorrow as today's fertilizers held over those of a generation ago," says Dr. Nelson.

"There are whole new frontiers yet to be conquered as science opens up new avenues . . . Furthermore, the need was never greater. Earth's multiplying millions call forth the best we have. Fertilizer is one of the essentials to prevent mass starvation."