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Brief Summary of TVA's Research and Development on Improving Fertilizers for Developing Countries

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Brief Summary of TVA's Research and Development on Improving Fertilizers for Developing Countries*

For more than six years, TVA through its international fertilizer program has been intensively developing and testing various fertilizer materials under tropical and subtropical conditions (some 30 countries). Efforts have been directed primarily at two materials--sulfur-coated urea (SCU) and ground phosphate rock. Other materials are being considered but are still in the infancy stages of development.

SCU--What is it?

SCU is granular or prilled urea coated with (1) molten sulfur and impregnated with a wax sealant or with (2) sulfur only. The first method is the oldest process and consists of preheating the urea to about 150° to 160°F and then spraying with atomized molten sulfur to form a uniform sulfur base coat on each particle. Depending upon the urea particle size, the sulfur content is about 16% of the product. Following the sulfur application, a thin film of microcrystalline wax, or other sealant such as a mixture of petroleum oil and low molecular weight polyethylene, is applied by spraying the molten sealant onto the sulfur-coated substrate in a second rotary drum, the product contains about 2% sealant. The product is then cooled in a rotary or fluid-bed cooler. In the last unit, a rotary drum, about 2% powdered conditioner is added to offset the tacky nature of the sealant.

Recent improvements in the engineering phase of producing this product (mainly the falling curtain technique) has resulted in a vast improvement in the sulfur coating process. This has led to a more

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uniform coating of either the urea prill or granule, eliminated the need for a wax sealant, increased production rates, and thereby shows promise to reduce production costs. Recent engineering estimates incorporating these new improvements indicate SCU should cost no more than 15%-20% more per unit of N than regular urea.

Although extensive agronomic field testing is now under way with the new sulfur only SCU, almost all results reported thus far have dealt with the old process where urea is coated with molten sulfur and the wax sealant.

Research Results with SCU

Most of these agronomic tests have been conducted on rice. Results obtained in more than 30 countries have revealed that SCU performs best as a basal dressing for rice grown under water management regimes where water control is poor such as intermittent flooding, alternate wetting and drying, or extremely heavy flooding. Nearly 75% of all the rice now produced in Asia is grown under such conditions.

Under water management practices described above, SCU has consistently produced anywhere from 15%-30% more rice than cases where urea and/or ammonium sulfate are applied as a basal dressing. SCU holds a 10%-15% advantage even when SCU is compared with the more favorable split applications of urea.

The results shown in table 1 are averages of 41 experiments in 7 countries where high-yielding varieties of rice were grown under the types of poor water management described above.

Table 1

Average Yields of Rough Rice Grown Under Poor Water Management.

Results from 41 Experiments in 7 Countries,
All with High-Yielding Varieties

Source of Nitrogen[a]	Yield of Rough Rice	Increased Yield due to Nitrogen	Kg Rice per Kg N
No N	kg/ha	kg/ha	
No N	3234	-	-
Urea	4911	1677	15.5
SCU	5572	2338	21.9

[a]All nitrogen applied as basal treatments at or before transplanting. Equal amounts of N were applied on SCU and urea, rates vary from 80 to 250 kg N per hectare.

When SCU was applied, an average of 6.4 kg more rice was obtained per kg of N than when regular urea was applied. Depending upon the type of urea being sulfur coated and upon the differences in the cost of nitrogen fertilizer and the price of rice in different countries, an increase of from 1 to 2 kg rice per kg of applied N is needed to pay for the cost of sulfur coating urea. The frequency distributions of yield increases per kg of N applied as SCU as compared to N applied as urea for the 41 experiments summarized in table 1 are given in table 2.

Table 2

Frequency Distribution of Rice Yield Increases for 41 Experiments in 7 Countries Using High-Yielding Varieties

Yield Increase due to SCU as compared to Urea (Kg rice/kg N)	Percentage of Experiments
Less than 1	12
1-2	10
2-4	22
4-6	10
Greater than 6	46

These results show that in 12% of the experiments there was no yield advantage so that the use of SCU would have lost the farmer money. In 10% of the experiments, the yield increase was about enough to pay for the additional cost of SCU, and in 78% of the experiments the use of SCU was profitable.

The results cited above confirm those given in previous reports and indicate that SCU is a superior source of nitrogen for rice under conditions of inadequate water management. Further work with SCU on rice will be conducted (1) to more precisely define the situations where SCU should be used and (2) to acquaint agronomists (research, extension, and industry) in the various countries with this material. As research data accumulate, the second objective will become increasingly important.

Additional studies need to be initiated with other crops grown under conditions where SCU might be a superior N source. Some

preliminary results from Hawaii and Florida suggest the use of SCU in sugarcane production may be advantageous.

The exact area of rice grown in developing countries under conditions where both leaching and denitrification can occur is difficult to ascertain, but Engelstad, et al. ("Tailoring of Fertilizers for Rice," TVA Bulletin Y-52) state that the staff of IRRI has estimated that over 75% of the rice in Southeast Asia is grown under this type of water management. Preliminary observations suggest that at least 50% (and possibly more) of the rice in West Africa is grown under delayed or intermittent flooding.

According to FAO reports, approximately 131 million hectares of rice were grown in the world in 1972. Assuming that one-half of this rice was grown under conditions where SCU would be advantageous at locations where N fertilizer should be applied at a rate of at least 60 kg N/ha, then approximately 4 million mt of N could profitably be used as SCU. In 1972, 33 million mt of N was used in the world, and these figures suggest that as much as 12% of the world consumption could potentially be expected to be applied as SCU on rice.

On a smaller scale, approximately 114,000 ha of rice are grown in Peru, nearly all of which is grown under conditions where SCU would be the most desirable source of N. Average rice yields in Peru are about 4,000 kg/ha, but research results indicate that with ample N yields of 9,000 kg/ha can be attained. To obtain these yields, 25,500 mt of N as SCU would be needed, compared to 42,000 mt of N as regular urea to obtain the same yield. Thus, SCU would save 16,500 mt of N, or roughly 40% of the N needs.

Results from India indicate that when equal amounts of N were applied, an average of about 400 kg/ha more grain was produced when SCU was used than when regular urea was used. In 1972, 36.5 million ha of rice were grown in India, with an average yield of 1,616 kg/ha. The use of SCU would have resulted in an increase of 18.3 million mt of rice, an increase of 31% over the 1972 production of 59 million mt.

Phosphate Rock--Research Under Way

Phosphate rocks vary greatly in their agronomic effectiveness as sources of phosphorus when applied directly to the soil. This relative effectiveness has been related to the specific properties of the apatite minerals which are easily identifiable and can be readily measured in laboratories which have X-ray and/or electron microscope equipment.

These procedures which have been developed at TVA allow for an evaluation of the agronomic effectiveness of a specific phosphate rock without going through extensive and expensive agronomic field trials. The relative effectiveness of the phosphate rocks can be related to the ratio of the solubility of the phosphorus in citric acid to the theoretical phosphorus content of the particular apatite species as determined by X-ray analyses.

These developments provide a valuable tool to fertilizer scientists and country leaders alike in determining the merits for development of new and/or small indigenous deposits of phosphate rock found in many of the developing countries. Recent shortages of supply and price increases by major producers of phosphate rock have spurred interest in utilizing more indigenous sources of phosphate rock.

The results of a number of experiments for Southeast Asia indicate that certain phosphate rocks can represent alternatives to the more costly acidulated phosphates. As a rather crude estimation, it appears that the price per unit of P in the acidulated phosphates should be near twice that in the phosphate rock before the latter should be considered seriously as an alternative. The phosphate rock chosen should contain "some" citrate soluble P in order to be effective. The evidence on what the minimum level should be is quite meager; however, it would appear that the content of citrate soluble P should be no lower than 15% of the total P contained in the phosphate rock.

It should also be pointed out that only rarely have the phosphate rocks equalled TSP in maximum yield. Generally, the more reactive rocks are slightly less effective than CSP.

An attempt has been made to estimate the portion of the rice-growing area in selected countries in Southeast Asia that is sufficiently acid to be suitable for phosphate rock application. After omitting the very acid soils of less than pH 4.0, there still appears to be substantial areas suitable for phosphate rock application. The estimate is 62% of the rice-growing area of Malaysia, 78% of the rice-growing area of Thailand, and 32% of the rice-growing area of South Vietnam.

There is some interest in granulating urea and phosphate rock for convenience in handling and application. The evidence is conflicting at this point as to the agronomic effectiveness of these products.

Considerable exploratory work has been done at TVA studying possible low-cost methods of altering phosphate rocks to increase the availability of the phosphorus, such as heating a mixture of phosphate rock and a neutral salt or limestone to 500°C or 1,000°C to break down

the apatite structure. This procedure offers a method of developing small deposits, or deposits not suitable for present soluble phosphate production methods, to produce a material at a relatively low cost for local use. Further exploratory projects in this area appear warranted. Apparently, the effectiveness of these alteration methods can be determined by measuring their effect on the relative phosphorus solubility in citric acid. This form of phosphorus does appear to be relatively available to plants even though it would be characterized as largely "unavailable" according to the results of the standard "neutral ammonium citrate" solubility test.

Emphasis is being placed upon obtaining samples of phosphate rock from deposits in developing countries and testing and improving procedures for increasing their citrate solubility and thus availability of the phosphorus. From this laboratory screening process, several sources will be selected from which small amounts (50 to 100 pounds) will be prepared for greenhouse and field experiments on various soils.

From these results, one or two locations (or countries) will be selected for development of a pilot program to utilize local sources of phosphate rock. This program will involve production of the altered phosphate rock and its agronomic evaluation and then educational programs with government and commercial representatives to introduce its use to the farmers.

Future Directions in Searching for More Efficient Fertilizers

This past August, a consultative group convened at TVA to review the status of TVA's research and development in the search for more efficient fertilizers. The following recommendations were adopted as areas needing consideration for future research efforts.

1. Broaden the base of low cost materials that could prove effective coating agents and give that fertilizer a slow or controlled release property. (The group supported the work already done on sulfur as a coating agent for urea but stressed the importance of developing alternate coating agents because not all countries have indigenous sources of sulfur. Additional efforts in this area should include materials likely to occur in a number of developing countries.)
2. Expand the work where additives are added to elemental sulfur as a means of improving its properties as a coating agent. This work is particularly needed since the sulfur only process of coating urea offers significant cost savings but (at present) results in a more fragile coat than is the case where a wax sealant is also used.
3. Confirm the seriousness of the problem volatilization of N from urea and ammonia fertilizers applied to tropical soils and develop techniques to minimize these losses. It was suggested that the present type of SCU might very well prove to be an extremely effective product in reducing such losses.
4. Establish more clearly the factors which affect the rate and patterns of N release from the present family of SCU fertilizers and how these release rates may be synchronized to best meet the crop needs. The group felt this was an extremely important area where additional research was needed now. Items needing specific attention were: (a) effect of pH, temperature and moisture of soil on the release of N from SCU, (b) the release patterns of nitrogen from key tropical crops as rice and sugarcane. It was suggested that much of this work should be quantified through the use of such labeling techniques as N^{15} and S^{31}. Furthermore, this work should also reflect the importance of plant genotype in determining nutrient utilization.

5. Reexamine the possibility of using more slowly soluble nitrogen compounds as possible sources of nitrogen fertilizer. The group suggested TVA reexamine the potential of using slowly soluble N compounds such as SCU, IBDU, and expand to ligno-protein nitrogen materials and others as possible nitrogen fertilizers. Production of controlled release fertilizers from coal, garbage, and various organic wastes was also suggested.

6. Additional testing of SCU on rice should be conducted under farmer field conditions. The group felt sufficient was known about the conditions under which SCU is effective that further tests should be shifted from experiment stations to actual farmer fields. This shift in testing was considered extremely important. India is an example where experiment station conditions represent less than 5% of the situations under which farmers must grow rice.

7. SCU should also be more intensively and extensively evaluated on major tropical crops other than rice. While the original focus on rice was justified, more field evaluation work is needed on crops such as sugarcane, pineapple, maize, and cassava before the full potential of the present SCU can be assessed.

8. SCU should be evaluated as a nitrogen source within an entire cropping (multiple) system. Such evaluations appear to be particularly important in areas where food production schemes intensify and multiple cropping techniques (such as those used in Taiwan) become prominent. In this case the N release pattern and plant needs should be considered over several crops.

9. Investigate further the value of increasing the granule size of urea (or SCU) to several centimeters and use this property through proper placement to improve the nitrogen recovery by the rice plant. The feasibility should be considered for producing super urea granules that could be hand placed in zones that would insure greatest recovery by the crops.

10. Move ahead to familiarize farmers, government workers, and the fertilizer industry with the present properties and merits of SCU. There was a general feeling that the current engineering process and economic and agronomic data base (particularly for rice) was sufficiently sound to warrant moving ahead and consider ways to bring SCU into commercial production.

There are several areas where further research or exploration is needed with rock phosphates.

1. Even under optimal conditions, within short periods of time, phosphate rock seldom, if ever, equals ortho or polyphosphates as a phosphorus source for crops.
2. There are only a limited number of long-time experiments (more than five years) comparing the effectiveness of direct applications of phosphate rock with more conventional concentrated phosphates.
3. Very few of phosphate deposits in developing countries have been adequately characterized as to their suitability for either direct application or for processing into conventional phosphate fertilizers.

In general, a vast amount of research and product introduction of high analysis fertilizers remains untapped by most tropical regions. For example, such fertilizers as diammonium phosphate (18-46-0), ammonium polyphosphate (15-62-0, 11-37-0, and 10-39-0), urea ammonium

polyphosphate (28-28-0) routinely produced at TVA and/or in much of the United States are only marginally used and/or produced in the developing countries of the world. In many respects, it appears that the potential savings in freight rates either with current products or new high analysis fertilizers TVA has under immediate development may be economically feasible for immediate use in such distant areas as Chad and Niger of Central Africa, Laos or Afghanistan of Asia, and Bolivia or Peru of South America.

Recommendations for Work in Other Areas

Discussions in these peripheral areas resulted in the group suggesting additional activities as follows:

1. In view of new increases in both raw material costs and high freight rates, reassess the potential of high analysis fertilizers in the more remote areas of the developing world.
2. Work should continue toward developing economical means to produce even high analysis or slowly soluble fertilizers. Examples of these are SCK, potassium phosphates, nitrogen ring compounds.
3. Look at ways to get the rice plant to fix nitrogen directly from the air. It was stressed that present supplies of hydrocarbons (ingredient now used to fix N from the air) are exhaustible and that a program should be developed to get rice, corn, and wheat plants to fix nitrogen directly from the air much as is now the case for legumes.
4. Identify the conditions and crops under which N, P, and K fertilizer might be foliar applied economically in the tropics. This technique may be of considerable importance in areas wherelimited supplies of fertilizer are available and maximum response per unit of nutrient desired.

5. Develop analytical methods that will be accepted worldwide and which clearly reflect the nutritive value of a particular fertilizer. There appears to be considerable confusion in developing an internationa acceptable procedure that will clearly and fairly reflect the true fertilizer value of such products as various phosphate rocks, fused magnesium phosphate, polyphosphates, various slowly soluble N sources, and the like. The group proposed a move should be made to eliminate some of this confusion.

November 6-8, 1974, TVA and cooperators from 12 countries will meet at TVA to (1) review research progress, (2) evaluate research needs, and (3) develop future work plans.

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