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Getting nutrients to flooded rice

An international consortium of scientists searches for better ways

By O.P. Englestad, agronomist, and J. H. Parker, editor, Tennessee Valley Authority (U.S.A.)

■Growing rice under flooded conditions must be guided by some principles that are different from those used with non-flooded (upland) rice.

One area of difference is in fertilization. For example, nitrogen in the nitrate form, while suitable for upland crops, is quite unsatisfactory for flooded rice.

Severe losses of nitrate-nitrogen can occur as a result of leaching in soils where downward movement of flood water is rapid. In other soils, where percolation is slow, the nitrate can be reduced quite readily to volatile gases (N_2 and N_2O), which escape promptly to the atmosphere. In either case, the nitrogen is lost as far as the crop is concerned.

The ammonium form of nitrogen is, therefore, preferred for lowland, or flooded, rice. The ammonium ion is held fairly tightly in the soil complex and losses are generally much less than with the nitrate form. Urea also is suitable since it converts to the ammonium form after application to the soil.

It's not easy

Thus, the farmer's job appears simple: Choose a non-nitrate nitrogen. True, this is the first step. But there is more. The objective must be not only to apply nitrogen in the ammonium form, but also to keep it in this form and prevent conversion to nitrate.

There is no problem where flooding is continuous. As long as the ammonium nitrogen is incorporated with the soil and the field is kept under water at all times, most of the nitrogen will stay in the ammonium form. Some will nitrify if placed on the soil surface.

However, lowland rice grown in many countries is not flooded continuously. The flooding is either delayed for a time after planting or done intermittently during the growing season. (Upland rice, of course, is never flooded.)

During the periods when the field is not flooded, ammonium nitrogen tends to convert to nitrate nitrogen. Upon reflooding, the nitrate is subject to the leaching and volatilization losses described earlier.

Under these conditions, the solution is not so simple.

Search for answers

In 1968 the U.S. Agency for International Development (USAID) requested that the Tennessee Valley Authority (TVA) in the U.S. undertake research to improve the effectiveness of fertilizers for rice grown in countries where farmers cannot maintain continuous flooding.

To make sure that the research would be on the right track, the first act was to set up an international advisory committee. This committee, numbering eight in all, was composed of rice fertilization experts from Thailand, Japan, The International Rice Research Institute (Philippines), India, Colombia, Peru, and the U.S. The committee has met annually to review progress in the field and to recommend areas of study. Members also took it upon themselves to help evaluate several experimental fertilizers supplied by TVA.

Emphasis has been on increasing the effectiveness of nitrogen under systems of intermittent or delayed flooding.

Slow release of nitrogen

The main emphasis has centered around fertilizers that release their nitrogen slowly after application to the soil. The idea is that nitrogen kept in the fertilizer granule until flooding will not be converted to nitrate, and thus subject to heavy losses.

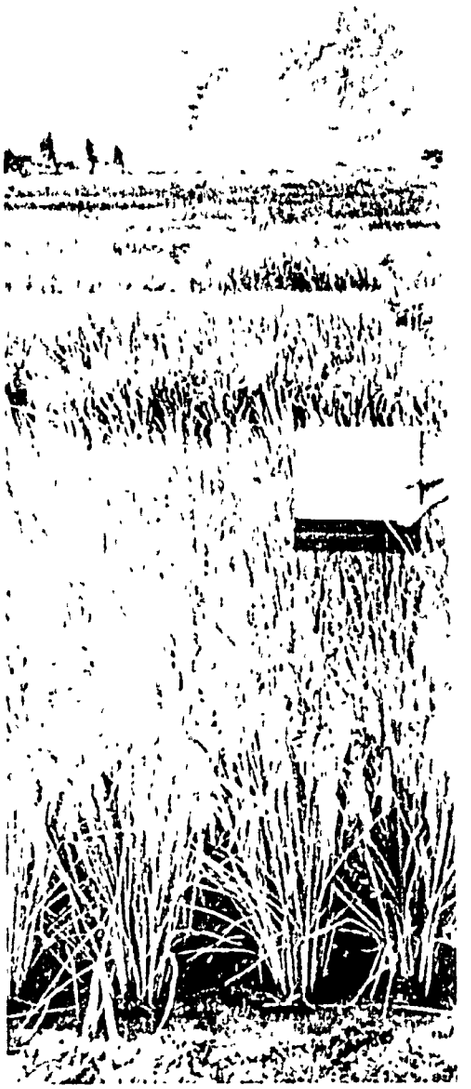
Such products as isobutylidene (IBDU) and oxamide were included in some tests, but they are not considered "frontrunners" because of their high cost. They did, however, show agronomic promise.

Most of the testing has involved TVA's sulfur-coated urea (SCU). This is a new product which TVA is as yet producing in a pilot plant. It is made by coating granules of urea with molten sulfur and sealing the coat with a wax-microbicide mixture. Depending on the thickness of the coating, from 15% to 30% of the nitrogen in SCU will dissolve in water in seven days. Under field conditions, SCU can supply nitrogen to a crop over a period of several months.

Tests to compare SCU with uncoated urea were conducted in TVA greenhouses and in field experiments in India, Thailand, Philippines, Peru, and Brazil. SCU looked extremely promising in most of these tests. Losses of nitrogen were reduced and rice yields were generally higher with SCU as the source of nitrogen.

Out of a total of 56 comparisons, 46 showed SCU superior to uncoated urea when both were applied at transplant-

Micrograph of bisected SCU granules shows relative thickness of sulfur coating used to retard breakdown of urea in the soil. *Tennessee Valley Authority*



At Jequetepeque, Peru: Above left, IR-8 rice which received 320 kg. N/ha. via SCU in a single application. It yielded 10.3 metric tons/ha. Right, adjacent plot which received same amount of N via conventional fertilizer in two equal applications. Rice yielded 7.3 metric tons/ha. Pictured is Ruillerma Ramirez, soils specialist, Ministry of Agriculture, Lambayeque.

ing time. In 19 of the comparisons, the nitrogen was applied as split applications, i.e., part applied at transplanting and the remainder at a later topdressing. SCU was superior in 12 of the 19 comparisons.

Five experiments in Peru included treatments in which all the uncoated urea was added as topdressing. SCU applied at transplanting was superior to topdressed urea in 19 of 26 comparisons.

This pattern showing general superiority of SCU over urea under conditions of intermittent flooding agrees quite well with data obtained in the U.S. where flooding was delayed after application in connection with direct seeding.

Extra cost appears justified

SCU produced commercially is estimated to cost 25-30% more than uncoated urea per unit of nitrogen. However, calculations indicated that the higher yields obtained with SCU would more than pay for its higher cost.

Researchers and the fertilizer industry have followed closely the development of SCU. Among countries indicating interest in building commercial production facilities are Mexico, Taiwan and India. One British plant already is producing small quantities for domestic use.

SCU may be a good fertilizer for other crops, also, such as long-season upland crops in the tropics where leaching losses are severe.

Work with phosphates

The research program also has included work with phosphate fertilizers on flooded rice. The object here was to find out if there are some situations where certain forms of phosphate, particularly those with little or no chemical processing, might be about as good as conventionally manufactured phosphate fertilizers.

Products tested include finely ground rock phosphates, granular urea-rock phosphate mixtures, partially acidulated granular rock phosphates, basic slag, fused magnesium phosphate, triple superphosphate, etc. Tests were made at the TVA National Fertilizer Development Center and in

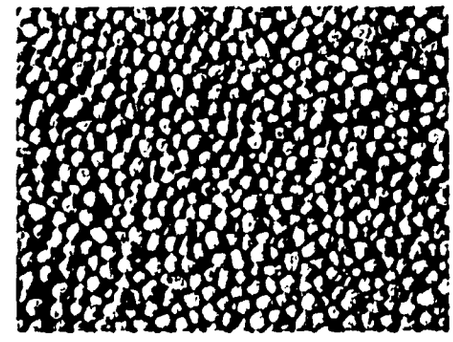
India, Thailand, Ceylon, the Philippines, and Colombia.

The greatest effort went into evaluating a series of rock phosphates from different world deposits that represented a wide range of citrate solubility. In general, the phosphates highest in citrate-soluble phosphorus were almost as good as triple superphosphate for rice on acid soils of Thailand. Response was about equal in eastern Colombia.

Thus, in areas of highly acid soils, the most reactive (soluble) rock phosphates may offer alternatives to the more expensive acidulated phosphates, i.e., triple superphosphate. However, the rock phosphates are low in nutrient content. For this reason, they probably would not be competitive when long hauls are required.

Another potential handicap is that

Why they have high hopes for SCU



Sulfur-coated urea (SCU), which is looking good in tests with rice (see related article these pages), was born in the laboratories of the Tennessee Valley Authority (U.S.A). By slowly releasing its nitrogen over a period of months, it achieves the scientists' objectives of a nitrogenous fertilizer that is used more efficiently by plants with less losses due to leaching, runoff etc. It also doesn't have to be applied as frequently, permitting additional economies.

After screening many materials, TVA scientists found that a sulfur coating held the most promise. It, however, was susceptible to moisture penetration. The final breakthrough came when this problem was solved by coating the sulfur with a wax compound containing about 10 per cent oil plus a small amount of coal tar, which protects the wax coating from action by soil microbes

Sulfur-coated urea has been manufactured in limited quantities in a pilot plant by the TVA. Large, well-rounded urea granules (1.7 to 3.3 mm.) are best for coating. The smaller particle size of prilled urea results in too little urea in relation to the amount of sulfur coating.

Higher production costs would make SCU a more expensive form of nitrogen. However, TVA scientists believe this could be more than absorbed by its agronomic advantages. Also, SCU has excellent storage and handling characteristics, giving it an advantage over other types of dry fertilizers in humid climates. Several countries have indicated interest in building commercial production facilities for SCU.

In addition to its promising performance in rice trials, Travis P. Hignett Director of Chemical Development with TVA summarizes other agronomic work with SCU as follows:

A single application of SCU on coastal bermuda grass in the spring gave as good or better results than four (split) applications of ammonium nitrate.

SCU prevented excessive (luxury) consumption and excessive growth of grass forage shortly after a single application.

SCU produced better distribution of protein throughout the forage growth period.

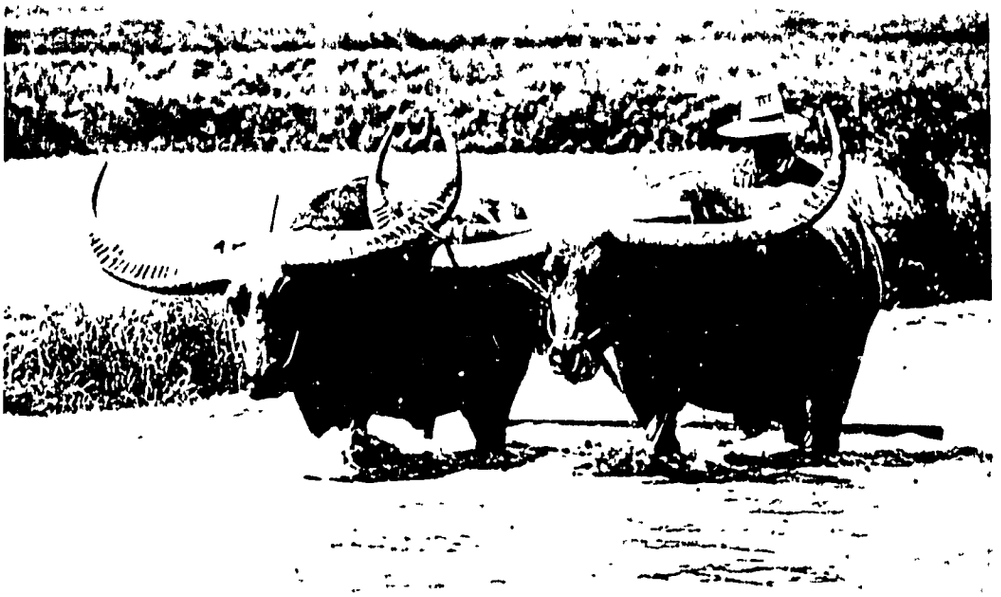
The sulfur residues oxidize slowly to plant-available sulfate.

Heavy application to grasses did not cause burning or N (decomposition) losses as with uncoated urea.

SCU resisted leaching and denitrification under heavy rainfall and gave higher yields under this condition.

Hignett says that SCU is being tested in 23 countries. It has given good results in sugarcane, pineapple and other long season crops where conditions favor high leaching or decomposition losses.

If you have specific questions: Travis P. Hignett, Director of Chemical Development, Tennessee Valley Authority, Muscle Shoals, Alabama 35660, U.S.A.



It's hard to do a good job of fertilizing lowland flooded rice when the farmer doesn't have complete control over his water supply. *Tennessee Valley Authority*

rock phosphates must be applied in finely ground form. Most farmers now prefer to apply granular materials.

Some "in-between" alternatives may be worth consideration. One is partial acidulation of the rock phosphate. This increases the content of soluble phosphorus and makes it possible to produce a granular product. Another is a mixture of urea and rock phosphate produced in granular form. The idea is that when the urea dissolves, the remaining granule would be porous and therefore act more or less as the finely ground phosphate. Early results, however, have not been especially promising. More field work is needed before conclusions can be drawn.

Powdered fused magnesium phosphate and basic slag, which are citrate-soluble but water-insoluble, were effective sources of phosphorus in Thailand experiments. They need to be tested more widely on acid soils of the tropics.

It is of interest to note that phosphorus sources behave similarly for lowland rice and upland crops. That is, the water-soluble sources are important for akaline soils, whereas citrate solubility seems to be a suitable criterion of effectiveness on acid soils. This relationship exists in spite of the fact that acid soils become less acid, and alkaline soils become less alkaline in reaction after flooding. In terms of soil pH, both acid and alkaline soils tend to approach 6.5 after a period of flooding.

Micronutrient work

Micronutrient deficiencies are becoming more serious for rice. This is especially true for zinc. More attention will need to be devoted to preventing zinc deficiencies as management of rice intensifies.

Studies at TVA show that the chemical form of zinc is not as critical for correcting deficiencies in paddy rice as for upland crops. There is evidence, for example, that organic carriers of zinc (chelated) have an agronomic advantage for rice over less expensive inorganic carriers; in some tests at TVA, chelated zinc has been less effective than inorganic sources.

Agronomists at the International Rice Research Institute in the Philippines have found that dipping the roots of rice seedlings into a suspension of ZnO supplies sufficient zinc to avoid deficiencies.

Various macronutrient fertilizers have been granulated with sources of zinc at TVA. Most formulations are ef-

Members of the international committee which guides fertility research in rice: front row, left to right: Y. Ishizuka, ASPAC, Taiwan; D. S. Mikkelsen, University of California, U.S.A.; W. H. Patrick, Louisiana State University, U.S.A.; Sombhot Suwonwaong, Rice Department, Thailand; P. J. Stangel, TVA; O. P. Engelstad, TVA. Back row: S. K. DeDatta, International Rice Research Institute, Philippines; J. M. Spain, CIAT, Colombia; Aroon Jugsujinda, Rice Department, Thailand; P. A. Sanchez, North Carolina State University, U.S.A.; A. Tanaka, Hokkaido University, Japan.

fective. The potential use of this approach for supplying zinc will depend upon prevailing cultural practices. For example, if zinc is to be applied with a nitrogen fertilizer, it should be applied preplant or at least shortly after seeding or transplanting, since the main requirement for added zinc appears to be early in the growth cycle. However, this may not always correspond to the optimum time for nitrogen application.

Since the main requirement for zinc is during the early growth stage, placement of the zinc may be an important consideration. Greenhouse data show that zinc applied to seed, floodwater, or to the soil (shallow mixing) is equally effective for early growth. However, deep placement is less effective.

Marked varietal differences in response to zinc have been noted in greenhouse experiments. Studies should be initiated in the tropics to determine those varieties more tolerant to low levels of soil zinc. □

If you have specific questions: O. P. Engelstad, Soils and Fertilizer Research Branch, Tennessee Valley Authority, Muscle Shoals, Alabama 35660, U.S.A.

The science of rice fertilization with materials now on the market

By H. N. Shahi, Agronomist,
Punjab Agricultural University (India)

■ Applying nitrogen in rice presents very complex problems. Not only is the quantity applied of significance, but the form of nitrogen, method of application and other management practices have great bearing on how rice responds to nitrogen.

Varieties differ

Different varieties of rice differ in their response to nitrogen application. Tall varieties which are more susceptible to lodging respond only up to 50 kg. N/ha. The short duration dwarf varieties of rice show conspicuous increase in grain yield up to 100 kg. N/ha and thereafter there is no significant increase in yield due to increased nitrogen application. The medium or long duration dwarf varieties of rice, however, respond very well up to 150 kg. N/ha.

Forms of nitrogen

Rice plants can use both ammonium (NH_4^+) and nitrate (NO_3^-) forms of nitrogen. The ammonium form is preferred, especially at early stages of growth. Application of the ammonium form is preferred under flooded anaerobic conditions because the nitrate form is readily lost through either deep percolation or denitrification. Under water-logged conditions, therefore, ammonium fertilizers are much superior to nitrate carrying fertilizers. The ammonical fertilizers are also beneficial in that they are less susceptible to leaching. After incorporation into the soil, the NH_4^+ ions are fixed with the soil particles and they become available to the crop plants through exchange phenomena, whereas, nitrate nitrogen does not get fixed and hence is highly susceptible to losses.

Out of the several nitrogenous fertilizers available in the market, ammonium sulphate is the best choice for rice as it provides nitrogen exclusively in ammonical form. Urea also supplies nitrogen in the form of ammonium ions after going through some changes in the soil. However, urea as such is highly susceptible to leaching losses. Any application of nitrate fertilizers should be made during the latter half of the crop lifecycle. Efficiencies of different nitrogenous fertilizers with respect to rice production as observed at the Central Rice Research Institute, Cuttack, India, are illustrated in Fig. 1.

Green manure crops

Apart from inorganic fertilizers, green manuring with some quick growing legumes is very beneficial. *Sesbania aculeata* is a very suitable green manure for rice. It thrives very well in standing water. It becomes ready for burying after 8 to 9 weeks of sowing and it rots into the soil in 10 to 15 days time. It gives on an average 40 to 60 kg. N/ha. If the *Sesbania* green manure crop is to be raised prior to rice cultivation, then it is desirable to

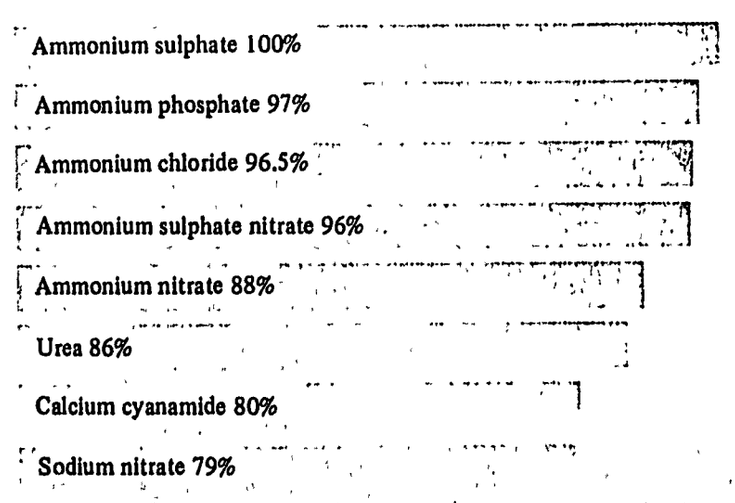


Fig. 1 Relative efficiency of nitrogenous fertilizers in rice production