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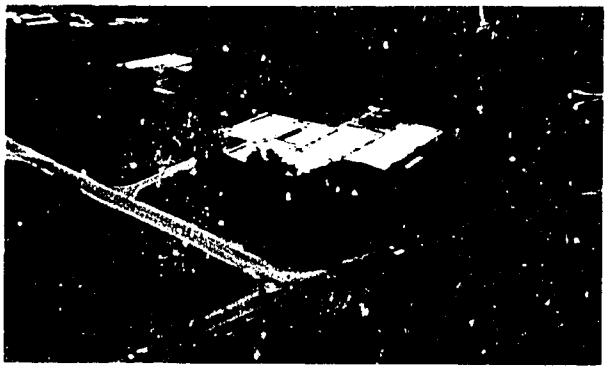
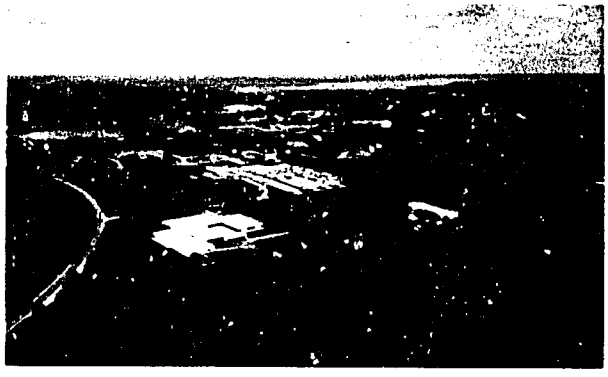
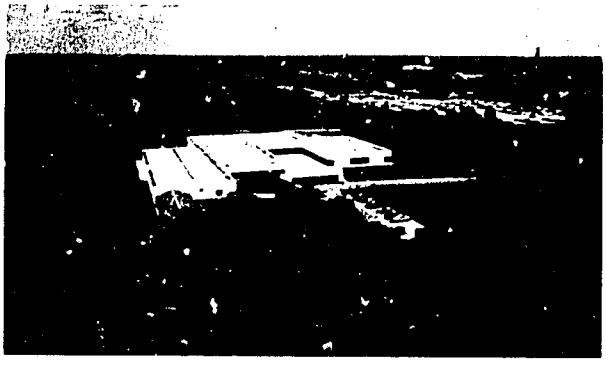
IFDC

Reaching







People of the World

1979 Annual Report

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Managing Director's Report

The events of 1979 may provide a preview of what to expect in the coming decade. By the end of 1979, the world price of urea had escalated 50% in slightly more than 14 months; triple superphosphate prices had risen 94%; and prices for diammonium phosphate and muriate of potash were approximately 75% above 1978 levels. These price increases were partly caused by shortages of natural gas and sulfur in the U.S.S.R. and western Europe—results of the cold winter and the disturbances in Iran; however, the primary cause for these inflationary prices was the near doubling of oil prices.

Rising energy costs will continue to have telling effects on the cost of nitrogen and phosphate fertilizer and on the basic structure of these two industries. Japan, once the world's leading exporter of nitrogen fertilizer, has closed nearly 2 million metric tons of ammonia capacity. Western Europe, also a traditional exporter of nitrogen, finds its industry going through a major realignment. Rising energy costs have also raised doubt as to the future capability of the U.S.S.R. and the United States, the world-leading producers of nitrogen, to meet their needs and production targets. Thus, the nitrogen industry, which 12 months ago seemed to have surplus capacity through 1985, appears to be entering the 1980s with uncertainty.

The high cost of energy is having similar effects on the phosphate industry. Moreover, sulfur, a major raw material in the production of phosphoric acid and finished phosphates, doubled in price during 1979 and has thus been a major factor in the recent price increase in phosphate fertilizers. This rise in sulfur costs is favoring a major shift toward production of finished phosphates in a few countries that are basic in sulfur and phosphate rock. As a result, some of the export facilities in western Europe and Japan have closed or will soon cease operation.

These events and their economic ramifications for the 1980s have amplified even more the importance for developing countries to use their own resources wherever possible to produce fertilizer and to intensify their efforts to increase the efficiency of fertilizer.

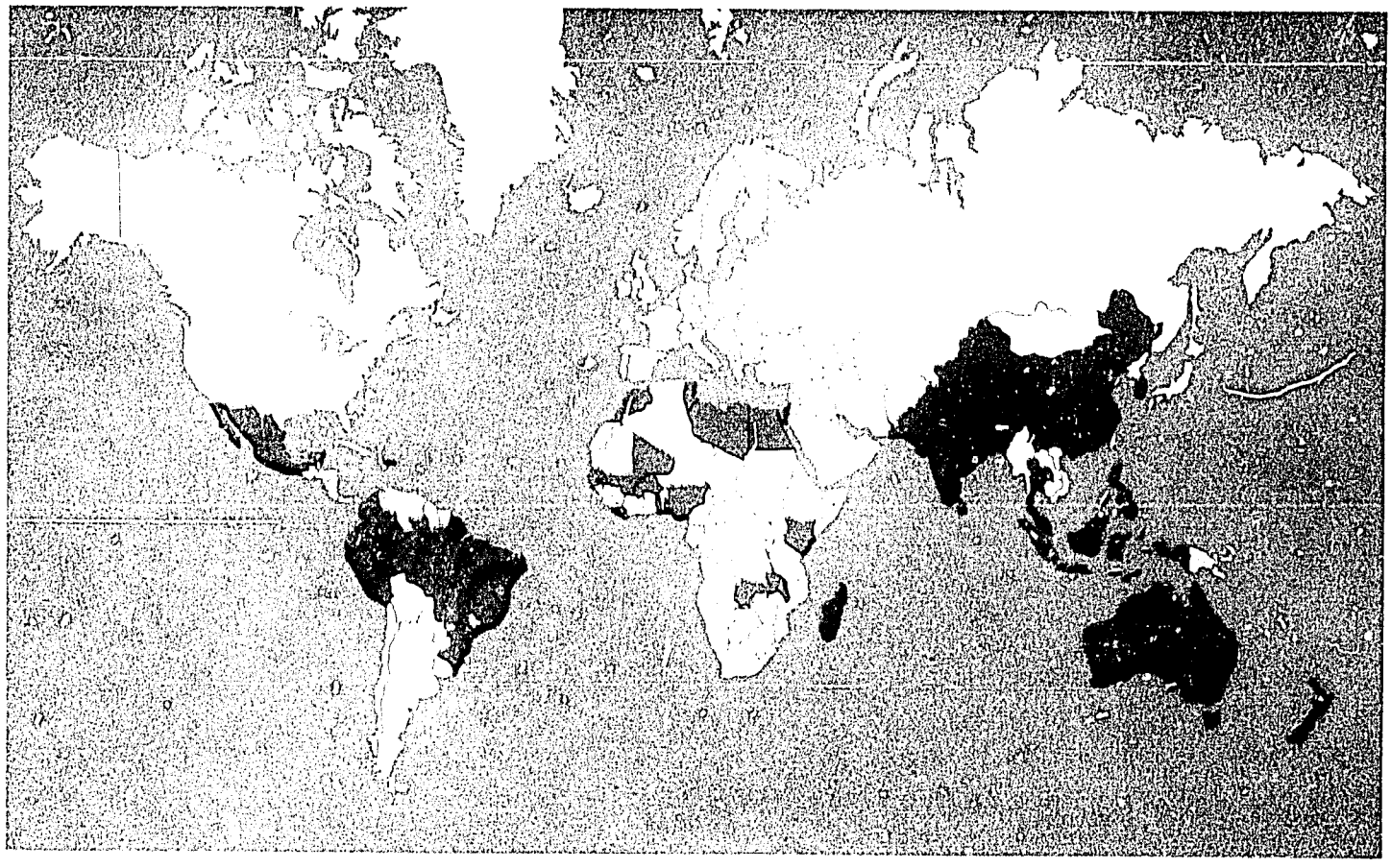
IFDC is dedicated to helping developing countries in this effort. During 1979, IFDC continued and expanded its nitrogen, phosphate, and sulfur programs. Efforts to increase nitrogen efficiency, particularly for lowland rice, were intensified and an upland nitrogen program started. The phosphate program continued to be directed toward finding ways to utilize local phosphate resources in making effective phosphate fertilizers. Special emphasis was placed on alternate technology to permit the development of indigenous deposits in specific countries. Work on sulfur continued, and attention for the first time was directed to potassium, calcium, and magnesium. Particular focus was given toward identifying constraints to fertilizer use and the development of policies that would lead to their removal and to increased use so that all will benefit.

We at IFDC look to the 1980s with optimism knowing that several fertilizers and fertilizer practices developed by IFDC in the 1970s can markedly reduce the burden that rising costs of energy are placing on developing countries.

IFDC remains dedicated to developing new and/or improved fertilizer know-how that can be used effectively in food production in the tropics and subtropics.

Donald L. McCune

IFDC



IN-COUNTRY INVOLVEMENT

Australia
Bangladesh
Brazil
Colombia
Dominican Republic
Ecuador
Egypt
Guyana
India
Indonesia
Israel
Kenya
Liberia
Libya
Madagascar
Malawi
Malaysia
Mali
Mexico
Morocco
Nepal
New Zealand
Nigeria
Pakistan
People's Republic of China
Peru
Philippines
Senegal
Sierra Leone
Singapore
South Korea
Sri Lanka
Thailand
Togo
Trinidad
Tunisia
Upper Volta
Zambia

Mission

The International Fertilizer Development Center (IFDC) is dedicated to the development of appropriate fertilizer technology and related know-how needed to sustain and increase food production in the developing countries. More specifically, IFDC's goal is to develop technology that will keep fertilizer costs down through improvements in fertilizer nutrient efficiency, adaptation of capital and energy-saving technology, and, wherever possible, use of indigenous raw materials and local manpower. Equally important are efforts aimed at the identification of constraints to fertilizer use and the development of policies that will lead to their removal or relaxation. In this regard, attention is directed toward the development of policies and technologies to ensure that fertilizers will play an important role in providing real growth in rural incomes and in the alleviation of absolute poverty, particularly for the small farmer and the rural landless.

Framework

IFDC has assembled a team of scientists and engineers covering a wide range of disciplines needed to carry out its overall mission. Currently the staff numbers 140–60 of whom are engineers and scientists including geologists, chemical engineers, chemists, agronomists, soil scientists, economists, and sociologists. Modern physical facilities have been provided including laboratories, growth chambers, electronic instruments (such as X-ray and atomic absorption machines and mass spectrographs), as well as pilot plants needed for studying beneficiation, acidulation, and granulation of fertilizers.

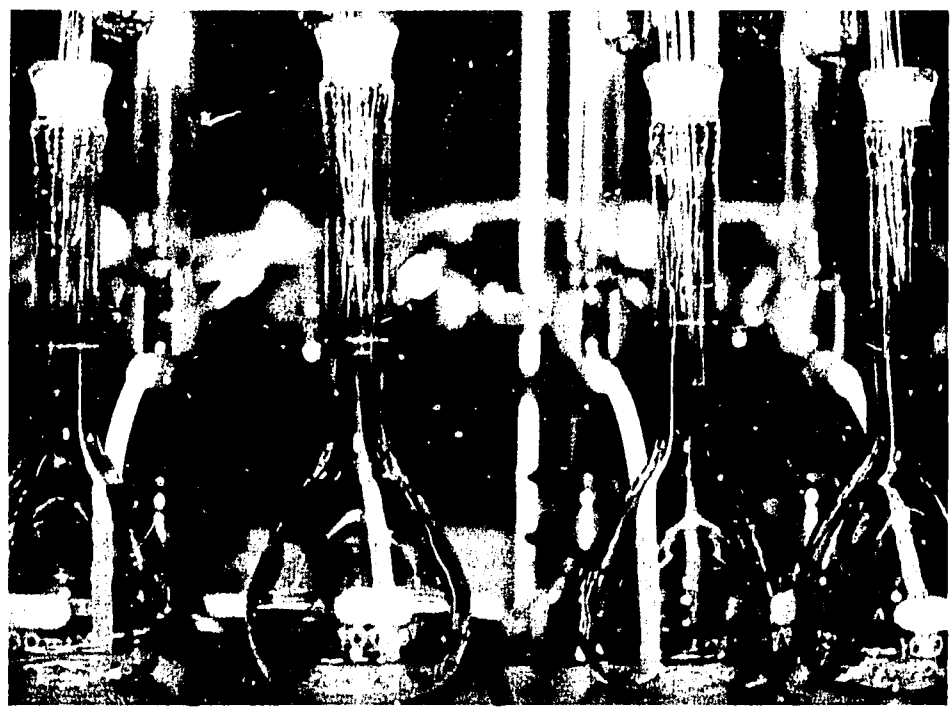
These capabilities have been organized into three divisions. The Outreach Division has the responsibility of identifying problems requiring research and development, training of needed manpower, and transfer of appropriate technology. The two research divisions—Agro-Economic Division and Fertilizer Technology Division—focus on the development of products and practices to solve immediate problems identified by the Outreach Division as well as long-range problems for which solutions are likely to be needed in the years ahead. The talents of these scientists and engineers as well as the capabilities of the modern facilities are focused on specific problems through the use of multidisciplinary task teams. These multidisciplinary task teams, backed by appropriate equipment and facilities for research and development, give IFDC its uniqueness in the fertilizer world. To date, task teams have been established to work on problems related to nitrogen, phosphate, and constraints to fertilizer use.

Linkages

IFDC recognizes that it cannot carry out its mission alone but that it requires considerable assistance and must cooperate with many international, regional, and national institutions. Technology developed by IFDC scientists and engineers must be tested under a wide range of conditions before its applicability can be established for a given area and the technology eventually transferred to specific producers, distributors, and users. IFDC works with existing institutions either at the international or at the national level to ensure that relevant fertilizer problems are identified, technology developed, manpower trained, and technology transferred to meet the needs of developing countries.

Program Focus

IFDC programs are based on the assumption that new and/or improved fertilizer materials and practices are needed by developing countries and that these can be developed and transferred through a combination of problem-oriented research, selective technical assistance, and appropriate manpower development.



Research efforts focus on developing appropriate fertilizer technology for increasing food production in developing countries.

Research

IFDC's research programs are aimed at solving problems that have broad applicability—generally to more than one country or region. Major focus has been on developing solutions to problems related to phosphate, nitrogen, and constraints to fertilizer use. Additional efforts are underway to identify problems related to sulfur, potassium, calcium, and magnesium.

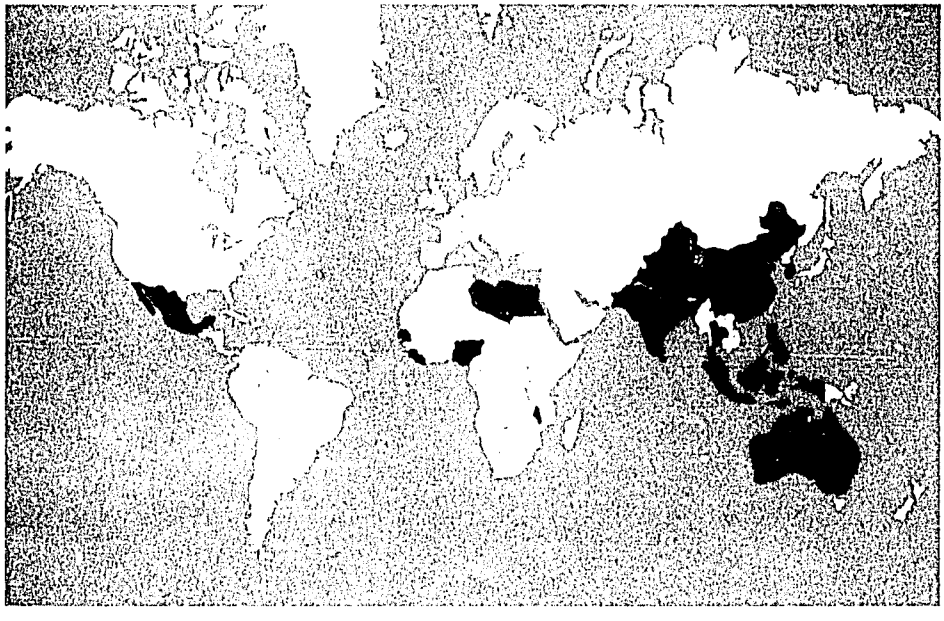
NITROGEN RESEARCH
COUNTRY INVOLVEMENT

Australia
Bangladesh
Egypt
India
Indonesia
Liberia
Libya
Malawi
Mexico
Nepal
Nigeria
Pakistan
People's Republic of China
Philippines
Senegal
Sierra Leone
South Korea
Sri Lanka
Thailand

Nitrogen

Nitrogen research is aimed at increased recovery of applied nitrogen fertilizer by the crop. Ever increasing costs of energy and capital required to construct or operate modern nitrogen complexes coupled with the poor nitrogen recovery by crops at the farm level make it imperative that improvements in recovery by the crop be achieved. Initial research has focused on reducing losses for rice systems grown under flooded conditions where recovery rates of less than 30% of nitrogen fertilizer applied are common.

A three-phase program to correct this problem has been developed. The program includes: identification of causes and magnitude of losses, development of practices and/or products that reduce these losses, and applicability of this technology to given geographic areas. These efforts are being expanded to study problems of nitrogen efficiency on upland crops. Improvements in nitrogen efficiency have widespread applicability and are likely to be beneficial to farmers throughout the developing world.



DEVELOPMENT OF PRODUCTS TO REDUCE LOSSES

No known commercial or experimental nitrogen products that result in maximum yields can be 100% recovered during a single crop year. Present nitrogen fertilizers need to be improved and new compounds identified that have the potential for serving as fertilizer. IFDC's Nitrogen Research Program is committed to filling these needs.

During 1979, IFDC scientists concentrated their efforts on finding new ways to (1) coat soluble nitrogen fertilizers with a physical barrier and (2) identify nitrogen compounds of limited water solubility. In either case, the improved or new fertilizer hopefully will lead to a cheaper, more efficient source of nitrogen for key agricultural crops grown in the tropics.

Coatings

IFDC continued tests using sulfur as a coating for granules ranging from conventional (2-3 millimeters [mm]) to supergranules (11-17 mm = 1-3 grams [g]) of urea. Release rates of nitrogen were erratic, but the addition of sealants, a mixture of bright stock oil (70%) and low molecular weight (<2,000) polyethylene (30%), improved the uniformity of release patterns and provided greater resistance to damage to the coating from impact. This was particularly true for large supergranules.

Exploratory tests were made with other coating materials including: masonry cement and acrylic latex and monoammonium phosphate with magnesium oxide, magnesium hydroxide, calcium oxide, calcium hydroxide, calcium carbonate, and zinc oxide. More than 30 combinations of coating and modified urea were prepared for greenhouse testing. Most of the materials tested failed to provide the desired controlled-release characteristics. The one exception was magnesium ammonium phosphate coating applied to urea supergranules (USG) where nitrogen recoveries as high as 75% were recorded for rice grown in the greenhouse.

Nitrogen Compounds of Limited Solubility

There are literally thousands of nitrogen compounds of limited solubility in water and/or soil solution. A literature survey completed in 1978 identified some of those showing potential as fertilizer. In 1979, IFDC scientists selected three (triuret, glycoluril, and oxalyl diureide) for more careful study. Their chemical formulas are shown in Figure 1. These materials were custom synthesized in IFDC laboratories to obtain some background in the synthetic methods available and to provide the experience necessary for scale-up to produce larger quantities for further study.

Triuret, prepared from urea and dry hydrogen chloride, was chosen because the raw materials are readily available, the process gives a relatively high yield, and the end product (a mixture of triuret and ammonium chloride) could be either separated or used as a mixture containing a slow as well as readily available nitrogen fertilizer.

Glycoluril is a condensation product of glyoxal and urea. It is a possible candidate for an effective slow-release fertilizer because it combines very low water solubility (~0.1% at 17°C) with a higher than

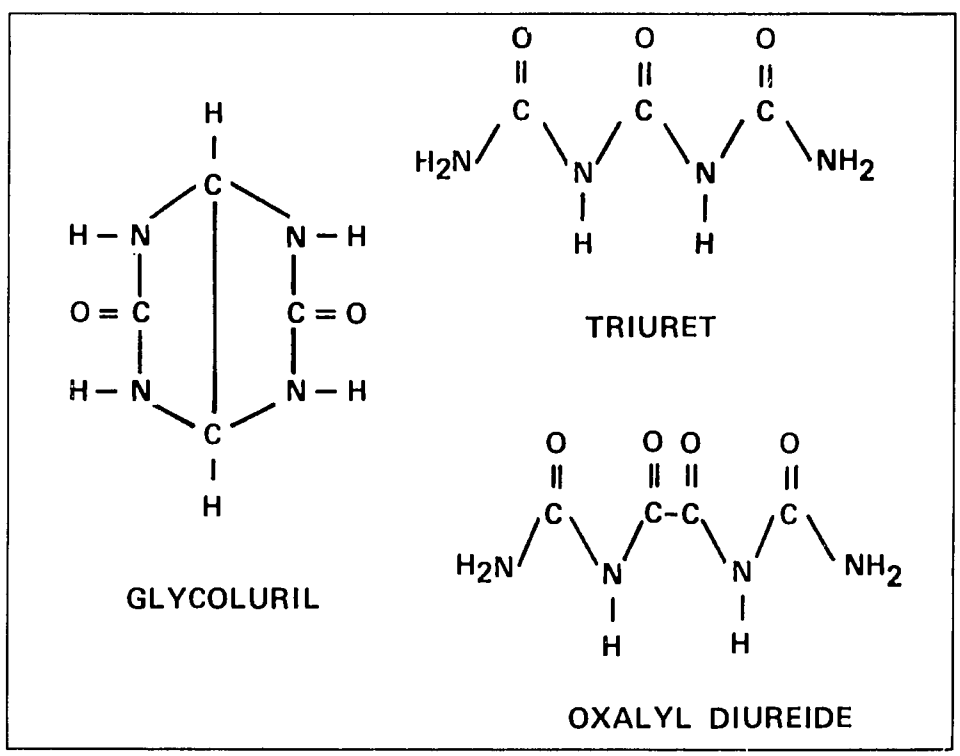


Figure 1. Chemical Formulas for Nitrogen Compounds Being Studied by IFDC Scientists.

average nitrogen content (39.4% nitrogen).

Oxalyl diureide is the diureide of oxalic acid. It is essentially insoluble in water and contains 32.18% nitrogen. The current methods of synthesis are complex, and specific reactions are difficult to identify and quantify.

Quantities were prepared for evaluation in the IFDC greenhouse. Results are shown on page 15.

Future Work

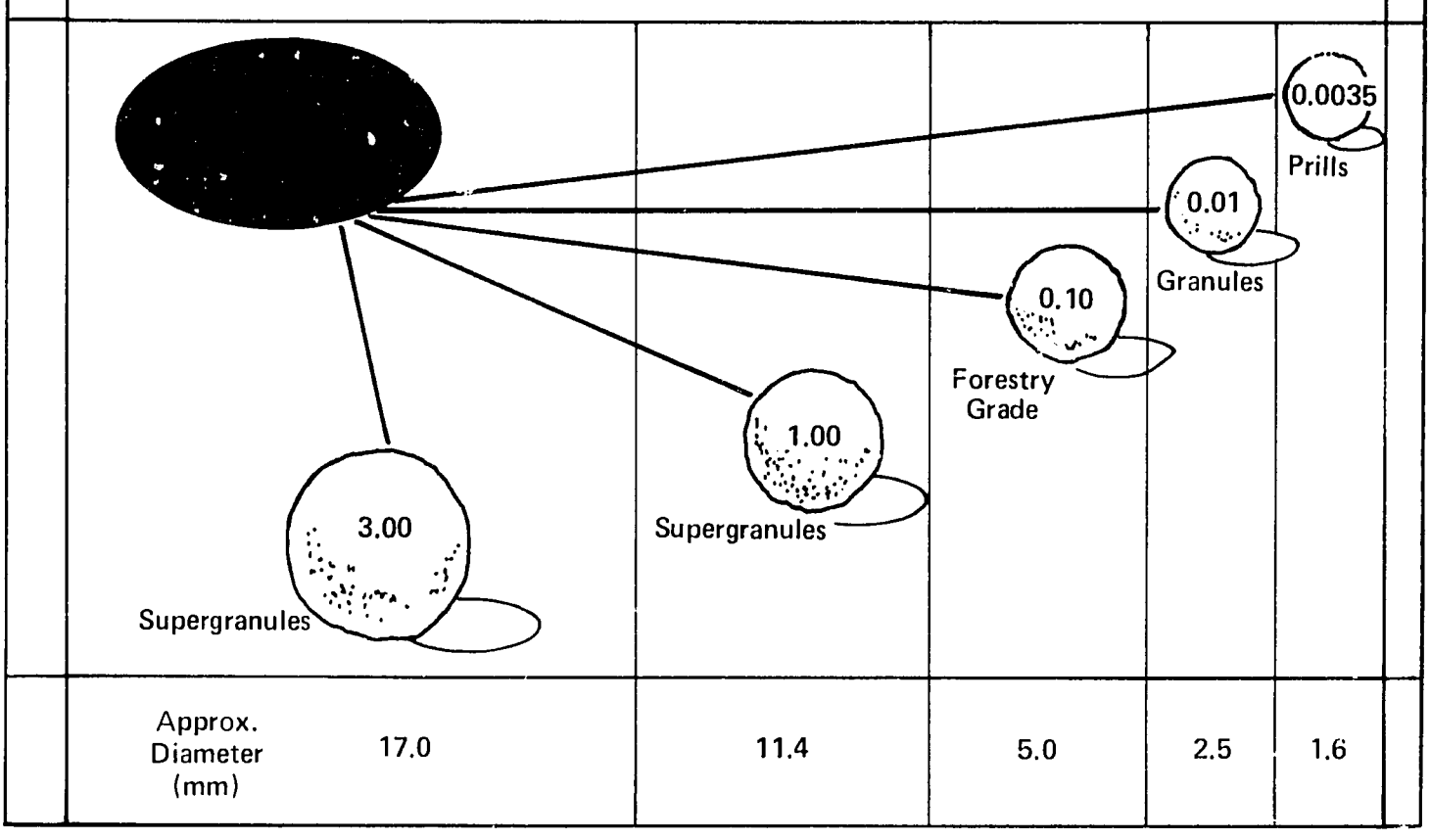
Sulfur-coated urea (SCU), particularly larger particles, will continue to be furnished to IFDC researchers and others as requested. Other coatings to be evaluated as a controlled-release mechanism for rice fertilizers will be chosen from such materials as organic polymers, metal ammonium phosphates, natural and synthetic rubber, and rice bran wax. A program designed to evaluate coated materials in soil is to be implemented soon. The incorporation of neem cake into the coating to serve as a combination nitrification inhibitor/controlled-release mechanism is being considered.

Urea Pan-Granulation Studies (Regular and Supergranules)

It is widely known that deep placement of nitrogen fertilizer increases nitrogen efficiency and can increase the yield of rice grown under wetland conditions. Although deep placement of nitrogen is relatively easy to accomplish with current materials on large landholdings through conventional mechanical means, these techniques are not readily applicable to small landholders in developing countries. Furthermore, prilled urea, the form of nitrogen fertilizer most commonly available in developing countries, absorbs moisture readily under the hot humid conditions of the tropics and, therefore, is not well adapted for use in small, simple fertilizer applicators.

IFDC and the International Rice Research Institute (IRRI) field research has shown that either granular urea (2-3 mm) or supergranules (11-17 mm) can be deep placed with equipment currently available. It is possible to produce a wide range of urea particle sizes. The product, weight, and size range appear in Figure 2.

Figure 2. Size and Weight Range of Conventional and Modified Urea Fertilizers



One way to produce granular urea is through pan granulation. During 1979, two series of tests were made at IFDC in the granulation pilot plant using a pan with a 1.36-meter (m) diameter to granulate urea. The first series of 15 tests was done as part of a training program for 11 P.T. PUSRI engineers and supervisors from Indonesia to provide hands-on training in urea granulation (see page 48).

The second series of 9 tests was designed to determine the technical feasibility of producing USG with a conventional pan. No problems were encountered in making urea granules in the size range of 3-5 mm; however, considerable difficulty was experienced in making supergranules larger than 5-10 mm (0.25 g). This was considerably below the 1- to 3-g sizes (11.4-17.0 mm) used in agronomic testing.

Other conclusions drawn from the 1979 tests are as follows:

1. Pan granulation can be used to make several sizes of urea granules.
2. The geometry and configuration of each pan establish the maximum urea granule size that can be produced.
3. The key variables used to control granulation were external recycle feed rate, pan temperature, pan rotational speed, cooler discharge temperature, and pan inclination.
4. The control of the aforementioned variables is crucial, and continuous, strict monitoring is required for good operation. Failure to recognize this can lead to a rapid major breakdown in the entire granulation process.

Additional tests planned for 1980 will seek to obtain more information on energy consumption, overall efficiency of the process, and better identification of factors affecting production of supergranules.

Pan-granulation tests are made to determine the technical feasibility of producing USG and provided training to PUSRI engineers in 1979.

IFDC/KIST Collaboration

Losses of fertilizer nitrogen applied to the surface of paddy can be reduced by either a reduction in the solubility or a delay in the release of the nitrogen fertilizer. This can be accomplished by coating the fertilizer with either a semipermeable membrane, an insoluble material, or both. Considerable research has been done by the Tennessee Valley Authority (TVA) on coating urea with sulfur. However, the resultant product, SCU, has a release rate that is less than ideal for many crops and costs approximately 50% more per unit of nitrogen than for regular urea. Furthermore, because many countries lack a local supply of sulfur, they must use significant quantities of foreign exchange if they are to produce SCU.

The Korea Institute of Science and Technology (KIST), working in collaboration with the IFDC Fertilizer Technology Division, has been experimenting with indigenous nonsulfur raw materials as potential agents for coating urea. For these materials to be effective, they should be less costly and have a release property that can be varied, thus resulting in greater use efficiency to the rice crop than is currently possible with SCU. Initial screening of a large number of locally available coating materials began in late 1978 and revealed that polymer-coated urea (PCU) possessed several of the properties desired in a controlled-release fertilizer. This PCU consisted of large granular urea (0.1-1.0 g) covered with a thin coating of sodium silicate which in turn was coated with a layer of acrylic latex. Zinc or other divalent metal is used to decrease the solubility of the silicate coating. This product is made in the laboratory using a fluidized bed process. It possesses the unusual property of increasing in size when immersed in water and may swell to 2 to 3 times its original diameter in 8-10 days. The sodium silicate, which reduces the solubility of the urea, provides a smooth surface for the latex to form an excellent, almost pinhole-free bond. The latex film acts as a semipermeable, flexible membrane, allowing water to pass through and accommodating volume increases by stretching.

It is assumed that the process of urea dissolution is one of mass transport through the polymer coating which acts as a semi-permeable membrane. Urea diffuses out due to concentration difference, and water permeates through the membrane due to osmotic pressure. The rate of release of nitrogen via this mechanism is influenced by the thickness of the latex and sodium silicate coatings, amount and type of zinc added, temperature, and drying time.

Agronomically, PCU consisting of 7% silicate and 3% acrylic latex was found to be equal to SCU as a source of nitrogen for rice grown at IRRI. There were some indications that it may be a more efficient source of nitrogen than SCU.

Tests revealed that release rates of PCU increase with storage time, temperature, and pressure; hence, the present product cannot be stored for extended periods under normal conditions. Preliminary cost estimates suggest PCU is about 30% more expensive than SCU and 95% more costly than regular urea. Further evaluation of PCU will continue in 1980.

PCU is shown before being emersed in water (right) and after being emersed in water (left).

HEADQUARTERS RESEARCH FOR WETLAND RICE

Nitrogen agronomic research activities at IFDC Headquarters this year comprised four major experiments: (1) field study of ammonia volatilization, (2) assessment of denitrification losses under various water management schemes, (3) study of the effect of solar radiation on the need and utilization of fertilizer nitrogen by rice, and (4) testing of experimental fertilizers. All of these experiments were aimed at providing a better understanding of the causes for the generally poor nitrogen efficiencies reported from the field and at designing fertilizers or fertilizer management techniques for improved nitrogen efficiency.

Ammonia Volatilization

Following the findings of previous greenhouse and growth chamber experiments that pointed to the susceptability of urea nitrogen to ammonia volatilization following application, a program was initiated to study ammonia volatilization under field conditions without plants. Ammonia was trapped from air flushing the headspace of an enclosure permanently installed in the field following the application of urea according to practices commonly recommended in Asian rice-growing areas. The airflow was maintained at a level preventing a temperature differential of the air and floodwater inside and outside the enclosure. Daily analysis of the chemical composition inside and outside the enclosure served to spot any difference in ammonia loss rate between the open and enclosed systems.

Data collected during the summer of 1979 at the TVA experimental farm show that more than 25% of the urea applied could be lost within the first week following application. As is seen in Figure 3, the ammoniacal nitrogen level inside and outside the enclosure fluctuated in a similar manner, indicating that the rate of ammonia loss inside the enclosure adequately simulated that of the bulk paddy. Additional experiments using the ^{15}N isotope are planned for the next season to corroborate these findings.

Denitrification

Past ^{15}N balance studies conducted at IFDC do not support the widely held view that nitrification-denitrification is a significant loss mechanism in flooded and intermittently flooded soils. Intermittent flooding is thought to promote losses by encouraging nitrification during the drained or aerobic phase and denitrification during subsequent waterlogging. The failure to demonstrate appreciable denitrification losses

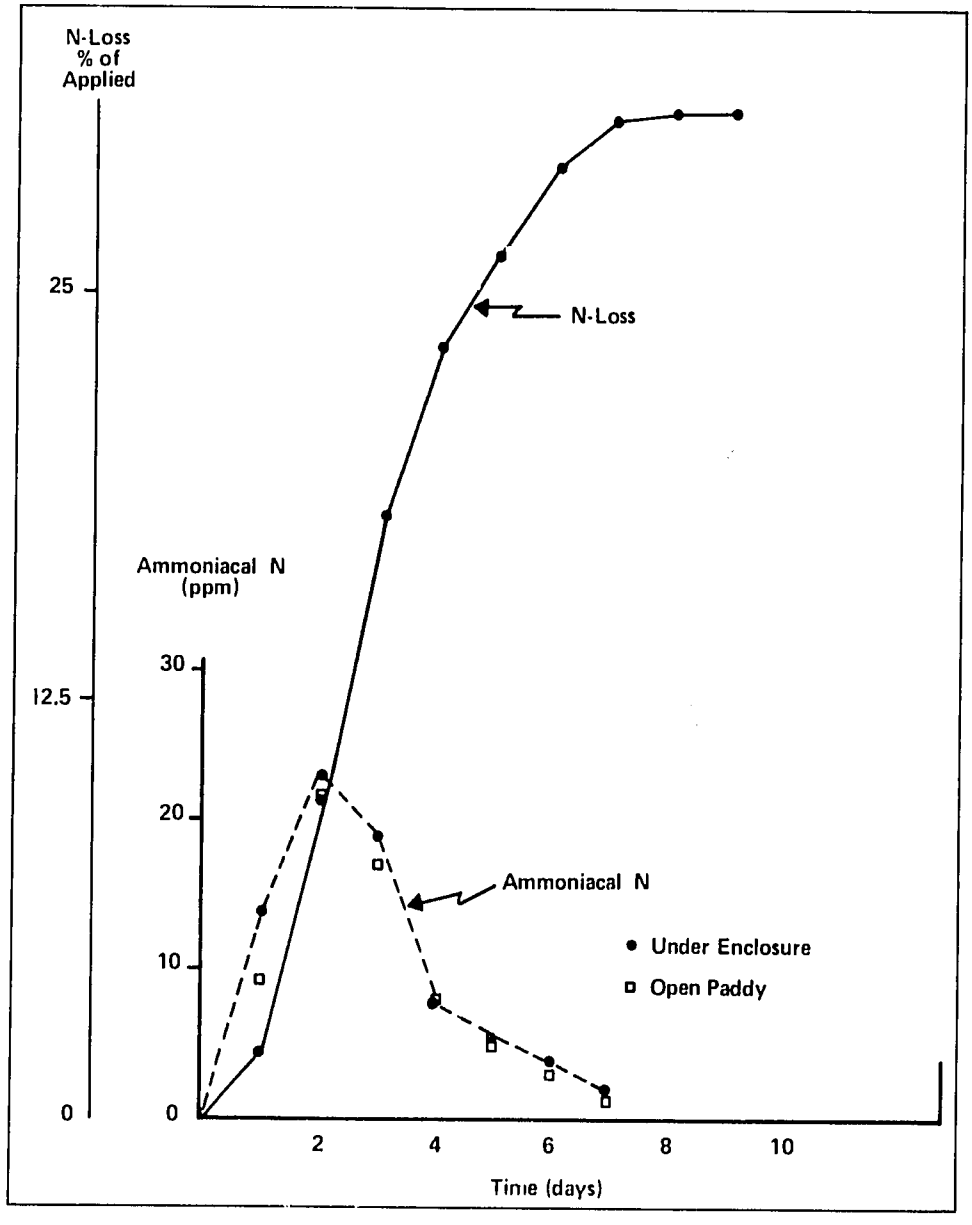


Figure 3. Ammoniacal Nitrogen (N) in Floodwater and Loss of N As Ammonia (NH_3) in Field Experiment.

from soils planted to rice under both flooded and intermittently flooded conditions may attest to the competitiveness of the plant for soil mineral nitrogen. Most researchers working in this field, have focused their past attention on the soil system alone. An analysis of the role of the plant in the loss of nitrogen from flooded and intermittently or nonflooded soils would provide a better understanding as to the importance of this loss mechanism.

Two ^{15}N experiments were conducted in the IFDC greenhouse facilities in an attempt to elucidate the importance of denitrification and to determine the time period and duration when fertilizer nitrogen is most likely to be lost by denitrification.

Preliminary analysis of the data point to the following: (1) the soils used in these studies (Crowley silt loam and Sharkey clay) have an adequate and active nitrifier population, (2) when urea was applied and harrowed in and the system was not flooded, losses were negligible whether applied all at preplanting or in two splits, (3) invariably, split urea caused less loss of nitrogen than all urea applied at transplanting, (4) losses of nitrogen from the lighter textured soil (Crowley) were higher than from the Sharkey clay, (5) loss of nitrogen from flooded soil was not affected greatly by the occurrence, timing, or duration of the dry spell. Experimental data are given in Table 1.

The losses observed in this experiment are most likely due to ammonia volatilization from the floodwater. In the absence of floodwater (upland conditions), the soil and water infiltration provide protection against this loss. The magnitude of loss is lower than observed in earlier experiments due to a more thorough incorporation of the fertilizer into the soil. Independent measurements of ammonia loss from similarly treated soils were in agreement with the losses found in this experiment. Data from the second experiment will provide more detailed information concerning the effect of plant root interception on the denitrification process.

TABLE 1. RECOVERY OF UREA NITROGEN APPLIED TO RICE GROWN UNDER VARIOUS WATER REGIMES

	% ^{15}N Recovered in Soil + Plant			
	Crowley		Sharkey	
	Basal	Split	Basal	Split
Upland[a]	95.4	98.3	98.3	98.8
Continously flooded	79.8	96.9	86.5	90.8
10 wet/5 dry	72.0	88.9	85.6	93.1
10 wet/10 dry	80.4	95.0	90.0	94.7
10 wet/15 dry	73.2	92.7	87.3	92.3
10 dry/5 wet	81.5	93.6	88.5	92.8
10 dry/10 wet	82.2	93.4	84.4	93.8
10 dry/15 wet	82.5	90.5	82.6	94.6
10 dry/20 wet	84.1	91.9	90.1	94.0
Average	81.2	93.5	88.1	93.9

a. With the exception of the upland treatment, all soils were maintained flooded for 5 days following transplanting and cycles imposed subsequently.

Nitrogen Utilization and Solar Radiation

The amount of fertilizer that the crop can absorb and efficiently utilize to produce grain varies with the plant age and the climatic conditions under which it is grown. One of the most important differences in rice productivity between the wet and dry seasons in the tropics is the amount of solar radiation (SR) received by the crop to carry on photosynthesis. A greenhouse experiment simulating wet and dry season SR levels was conducted to determine how plant growth and fertilizer utilization are affected by seasonal difference.

Rice (IR 36) was grown in Crowley soil and fertilized with ^{15}N-labeled urea at transplanting or as a delayed application at 43 days after transplanting (DAT). A split application, one-half at transplanting and one-half at 43 DAT was a third treatment. Crop growth was divided into three periods, vegetative growth (0-42 DAT), reproductive growth (43-69 DAT), and grain filling (70-93 DAT). Plants were shaded to simulate wet season SR conditions during one, two, or all three of the growth stages.

The data collected on nitrogen uptake and yield component development indicate that (1) the grain yield is most severely reduced by shading during the reproduction stage due to a reduction in all four

yield components, (2) the reduced yield of the plants receiving continuous low SR during all three growth stages was primarily due to a reduction in the number of panicles produced per hill, (3) the rate of nitrogen uptake and fertilizer recovery were reduced by shading during the vegetative period but not during the reproductive or grain-filling periods. Figure 4 shows total nitrogen and fertilizer uptake at 21 and 42 DAT. Although the total amounts of soil and fertilizer nitrogen in the plants at 42 DAT and afterward were nearly the same under high and low SR, the totals at 21 DAT were quite different. The wet season SR level resulted in a delay in the time and level of fertilizer demand by the crop. This information, along with growth chamber experiments and field experiments in the tropics planned for 1980, will help in the design of fertilizer materials and management strategies to reduce losses and to meet the fertilizer needs of a crop under specific agro-climatic conditions.

Fertilizer Testing

The basic research carried out in the wetland program has as its primary goal to set criteria for the design and proper use of nitrogen fertilizer on rice. It is the technological aspect that is unique to the IFDC mission. Experimental products are continuously being produced in quantities suitable for greenhouse testing.

As in previous years, the Fertilizer Technology Division provided a variety of fertilizer materials that

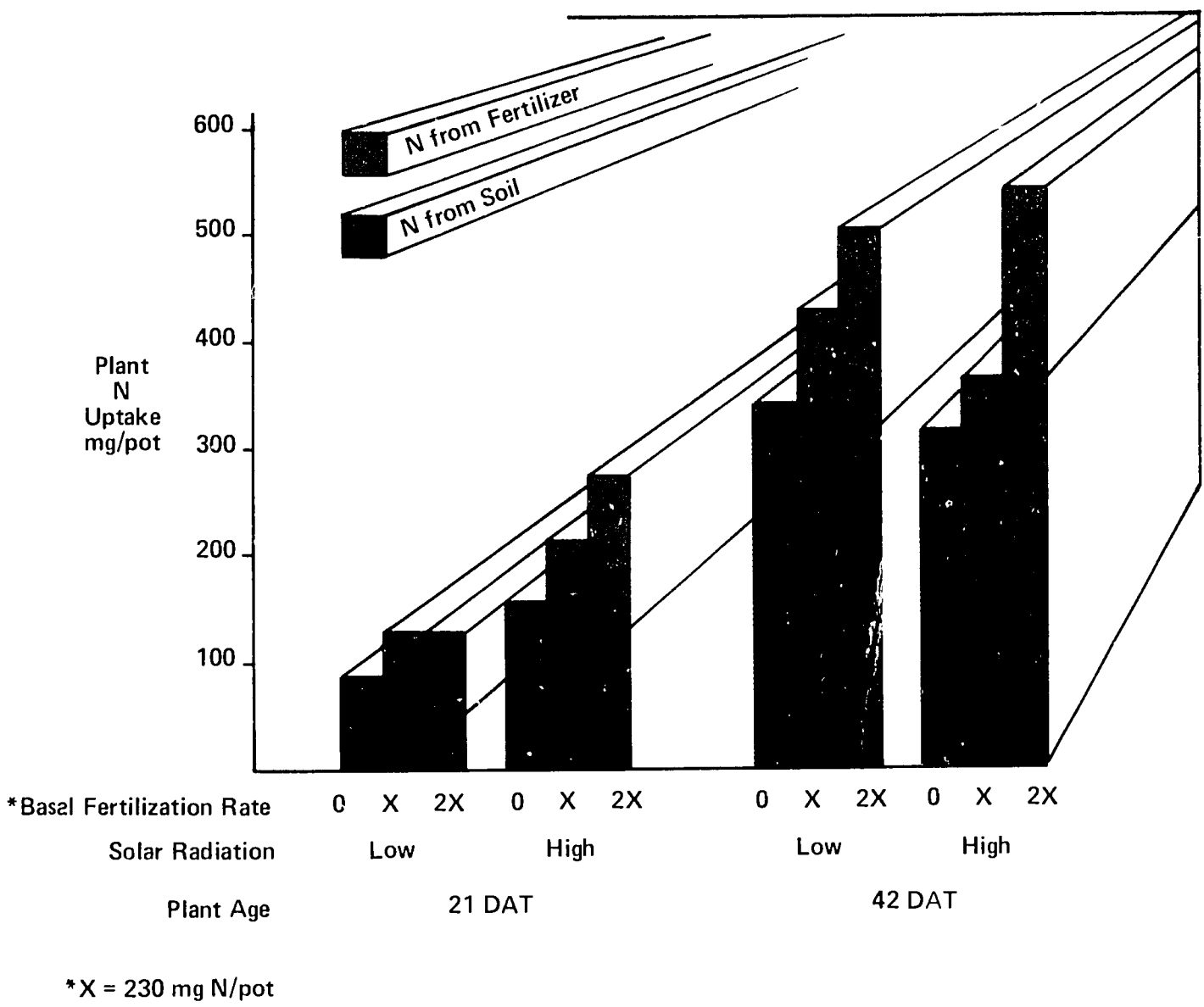


Figure 4. Soil and Fertilizer Uptake from Basal Application of Urea Under High and Low Radiation Levels.

were subjected to an initial screening on flooded rice. The materials belonged to one of four categories (Figure 5)—(1) traditional products and control, (2) chemical modifications or inhibitors, (3) coated forestry-grade materials, and (4) supergranules with various coatings. These products were tested in the greenhouse under continuously flooded conditions on the Crowley soil with rice (IR 28) as the test crop. With the exception of ordinary urea, all products were applied at transplanting. Supergranules were placed at an 8-centimeter (cm) depth, 10 cm from the plant (1 hill per pot of 8 kilograms [kg] of soil). Other products were applied and harrowed into the top 5 cm of soil.

Results obtained to date are given in Figure 5. Although an excellent nitrogen response was found, few products other than supergranules outperformed the split urea treatment. Coated supergranules performed less or only equally as well as noncoated supergranules. Sulfur-coated products performed best with the lighter coating. A single application of urea with urease inhibitors matched the yield from the split urea treatment. Additional experiments are being planned to further evaluate some of the promising products as well as new products being developed by IFDC scientists and engineers.

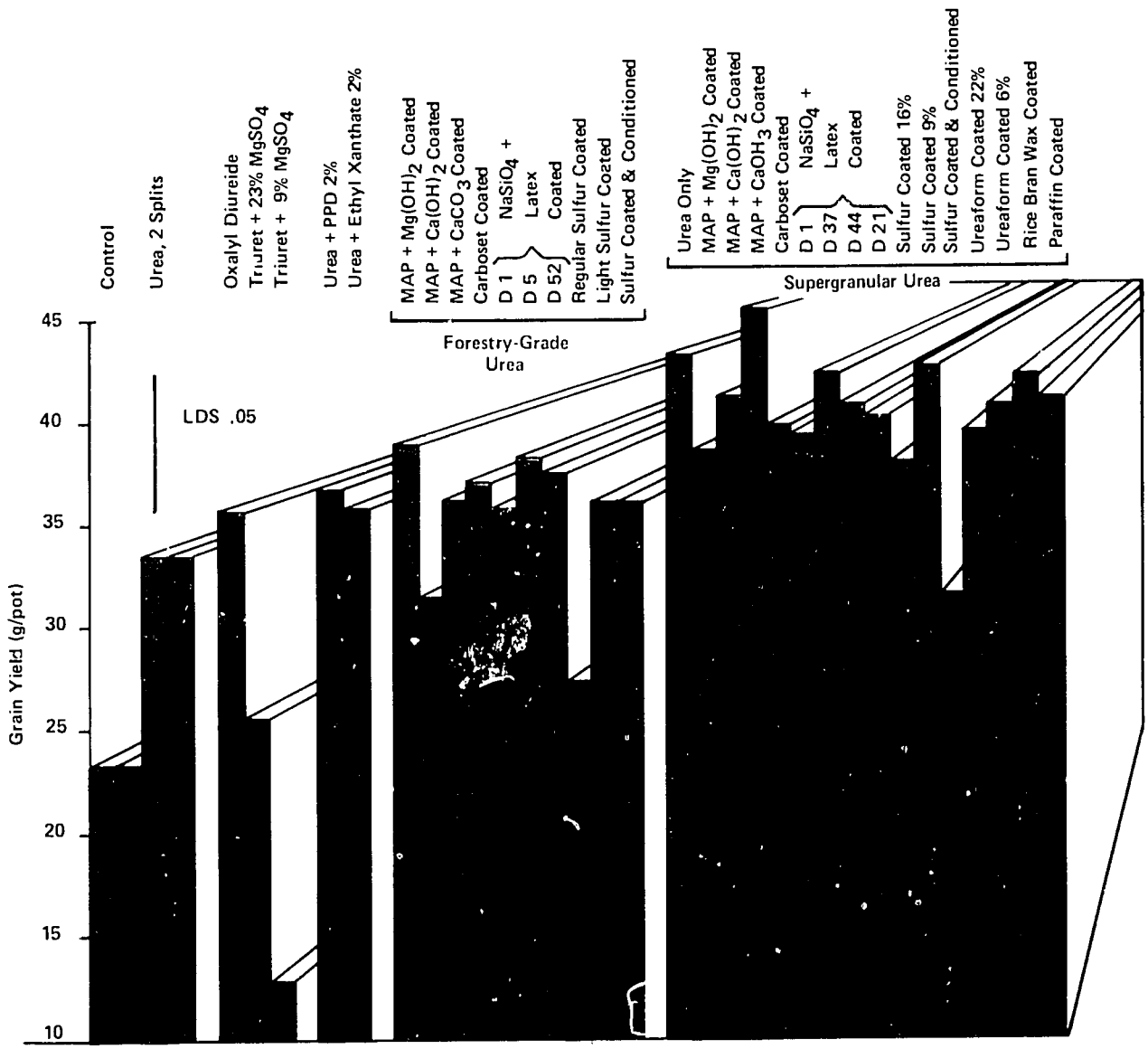


Figure 5. Results of Fertilizer Materials Tested in the IFDC Greenhouse During 1979.

IFDC/IRRI COLLABORATION

Nitrogen fertilizers are being tested at IRRI Headquarters to determine their efficiency and the role of nitrogen losses in influencing this efficiency.

This project is designed to determine the efficiency of different nitrogen fertilizers for tropical rice and the role of nitrogen losses in determining fertilizer efficiency. The program is a joint project between IFDC and IRRI where an IFDC soil scientist has been assigned since 1978.

Field experiments were conducted to study the effect of the time and mode of nitrogen application on fertilizer response in the wet and dry season. The best technique currently available to farmers—the "best" split application—was compared with the farmer's split (Table 2). Experimental fertilizers developed by IFDC, supergranules for point placement and forestry-grade SCU for slow release, were also included.

The effectiveness of different times and ways of applying nitrogen varied widely between the wet- and dry-season crops. In the dry season, the farmer's split gave the poorest results followed by the best split, SCU, and supergranules. The order was the same in the wet season, but the difference between the best split and either SCU or the supergranules increased. Compared with the farmer's split, root-zone placement of supergranules more than doubled apparent nitrogen recovery and increased grain yield by 15% to 35%. In the wet season, the delayed application in the farmer's split did not reduce fertilizer efficiency. Furthermore, the use of SCU improved both yield and nitrogen recovery, compared with the best split, in the wet season. In both seasons, deep placement of USG in the root zone

TABLE 2. THE 1979 YIELD OF RICE AND APPARENT RECOVERY OF NITROGEN SHOW THE DIFFERENTIAL RESPONSE OF RICE TO BASAL AND DELAYED SPLIT APPLICATIONS OF PRILLED UREA COMPARED WITH SLOW-RELEASE AND ROOT-ZONE PLACEMENT FERTILIZERS

Treatment	Fertilizer Timing[a]			Dry Season (87 kg N/ha)[b]		Wet Season (54 kg N/ha)[b]	
	ODT	21DT	PI	Grain Yield (t/ha)	Apparent N Recovery (%)	Grain Yield (t/ha)	Apparent N Recovery (%)
No nitrogen	0	0	0	4.1d		3.1c	
Best split urea	2/3	0	1/3	5.7b	44b	4.0b	35c
Farmers split urea	0	2/3	1/3	5.4c	23c	3.8b	36c
SCU[c]	All	0	0	5.8b	46b	4.9a	78a
Supergranule	All	0	0	6.2a	75a	5.1a	85a

a. DT = Days after transplanting; PI = panicle initiation. All basal (ODT) fertilizers were broadcast and incorporated except for the supergranules which were placed 10-cm deep, 1 for every 4 hills. All 21DT and PI applications were broadcast directly into the floodwater.
b. In a column, means followed by the same letter are not significantly different at 5% level.
c. Sulfur-coated urea, forestry grade.

of the crop was the most effective method of nitrogen application.

In these experiments, the ammonium and urea concentration and pH in the floodwater of plots from the different fertilizer treatments were measured. The results showed that broadcast applications of urea produced high (as much as 230 parts per million) nitrogen concentrations in the floodwater. These concentrations fell to zero within 4-6 days. The high concentrations were accompanied by pH values as high as 9.3 in midafternoon. Thus, the potential for ammonia volatilization was very high. Deep-placement and slow-release fertilizers produced relatively low nitrogen concentrations in the floodwater, which corresponds with high yield and apparent nitrogen recovery in the crop.

Nitrous oxide evolution from the floodwater surface was measured to provide an indication of the effect of fertilizer management on the other major nitrogen loss mechanism, nitrification-denitrification. Only relatively small fluxes (<100 nanograms of nitrogen per m^2 per second) were measured; however, nitrous oxide is only a minor product of the denitrification process. The data show that the process does occur in tropical wetland soils and that broadcast application of urea, particularly, encourages nitrous oxide evolution.

This research shows that any fertilizer material or fertilizer practice that produces high concentration of urea or ammonium in the floodwater will be inefficiently utilized by the rice crop. Additional field research is needed to determine what is the major mechanism of nitrogen loss.

Other field research at IRRI shows that the deep placement of USG, by reducing the concentration of fertilizer nitrogen in the floodwater, permits blue-green algae on the soil surface to continue to fix nitrogen biologically. Thus, deep placement of supergranules provides a bonus of nitrogen to the soil system. Broadcast application of urea, the traditional practice, reduced nitrogen fixation by blue-green algae to zero.

INSFFER ACTIVITIES

International Network on Soil Fertility and Fertilizer Efficiency Research (INSFFER) is a collaborative effort among IFDC, IRRI, and rice researchers from national institutions in Asia with the objective of improving fertilizer efficiency for rice under various growing conditions.

Nitrogen Source Efficiency

Since 1975, more than 155 nitrogen source trials have been conducted in 13 countries through INSFFER. Approximately one-third of these trials were conducted in the dry season and two-thirds in the wet season. Principal compari-

sons of nitrogen sources and placement have been deep point placement (supergranules and briquettes), broadcast basally incorporated SCU, and split application of prilled urea.

Surface incorporated SCU and point deep placement of USG gave significant yield increases over best split urea in about 50% of the trials. Significant negative responses (compared to best split) were recorded in only 2% of the cases for SCU or point deep placement of USG. Average yield responses to 56 kg of nitrogen per hectare (ha) were about 250 and 390 kg per ha greater to point deep placement and SCU, respectively, than to urea best split.

Nitrogen Source Efficiencies Related to Site Characteristics

Data from 114 INSFFER experiments conducted in 11 countries to compare best split urea, liquid-banded urea, mudball placement, supergranule urea placement, and SCU as nitrogen sources for rice were analyzed. The purpose of the analysis was to determine possible relationships between the efficiency of the different fertilizers and characteristics of the sites where the experiments were conducted.

Efficiency was defined as the increment in rice yield per unit of fertilizer nitrogen applied in the range of 0-56 kg of nitrogen per ha and was determined by linearly regressing rice yield on applied nitrogen within the indicated nitrogen range. The overall average efficiency for mudballs, supergranules, and SCU was in the range of 21-24 kg of rice per kg of nitrogen; whereas the efficiency of split and liquid banded urea was only 16-17 kg of rice per kg of nitrogen.

Efficiency varied widely, however, between different seasons and in different countries (1.0-41.0 kg of rice per kg of nitrogen). Countries were grouped into those where large (Bangladesh, Sri Lanka, and Indonesia), medium (India, Korea, Nepal, Thailand, and Philippines), and small (Sierra Leone, Egypt, and Malaysia) differences between split urea and the improved urea fertilizers were observed.

The relationship between the efficiency of individual nitrogen fertilizers and various site factors was then explored using correlation analysis after grouping the data according to season and elevation. For wet-season experiments conducted at elevations below 300 m, the efficiency of liquid-applied urea, mudballs, and supergranules was strongly correlated with the cation-exchange capacity of the soil. The correlation coefficients for split urea and SCU were lower and at a lower level of statistical significance. Dry-season data did not show the same relationship with cation-exchange capacity but did suggest that liquid-applied urea, mudballs, and USG were less effective in light-textured soils than split urea and SCU. Nitrogen efficiency was also correlated with pH (positively), transplanting date (negatively), and organic matter (negatively), among others.

The results obtained so far are encouraging, and further studies will be conducted to identify environmental and management characteristics associated with the efficiency of urea and urea-derived fertilizers applied to rice. Future experiments will include more nitrogen rates for each fertilizer to better define the respective yield response curves. In addition, a more detailed and complete description of relevant soil, climatic, and management properties will be recorded at each experimental site in the future.

Training Program for Cooperators

The first INSFFER training program was held in February-May 1979 at IRRI. The INSFFER program is sponsored by IRRI and IFDC, and the training course was designed to strengthen the theoretical and practical capacity of cooperating scientists to conduct the network experiments. The training course was attended by 22 scientists from 9 different countries.

Workshop on ^{15}N Experiments With Rice

A workshop was held at IFDC Headquarters in September to train research workers to sample and analyze plant material and soils for nitrogen and to prepare nitrogen samples to be sent for analysis on the IFDC and IRRI mass spectrometers.

Attending the workshop were scientists from India, Korea, and Thailand who will conduct a ^{15}N balance experiment with rice in the field during 1980. This network of isotope experiments, which is being sponsored by IFDC and IRRI, is designed to determine the losses, immobilization, and crop recovery of fertilizer nitrogen. The data obtained will provide valuable support information for the agronomic experiments of INSFFER to determine the effects of fertilizer source and management on the efficiency of fertilizer nitrogen in some of the different soils

A participant in the workshop on ^{15}N experiments prepares nitrogen samples for mass spectrometer analysis.

and environments in which rice is grown.

A senior scientist from the Commonwealth Scientific and Industrial Research Organization in Australia provided experienced support to the workshop and was involved in the original planning of the ^{15}N experiment at IRRI in April 1979.

IFDC/THE EAST-WEST CENTER COLLABORATION

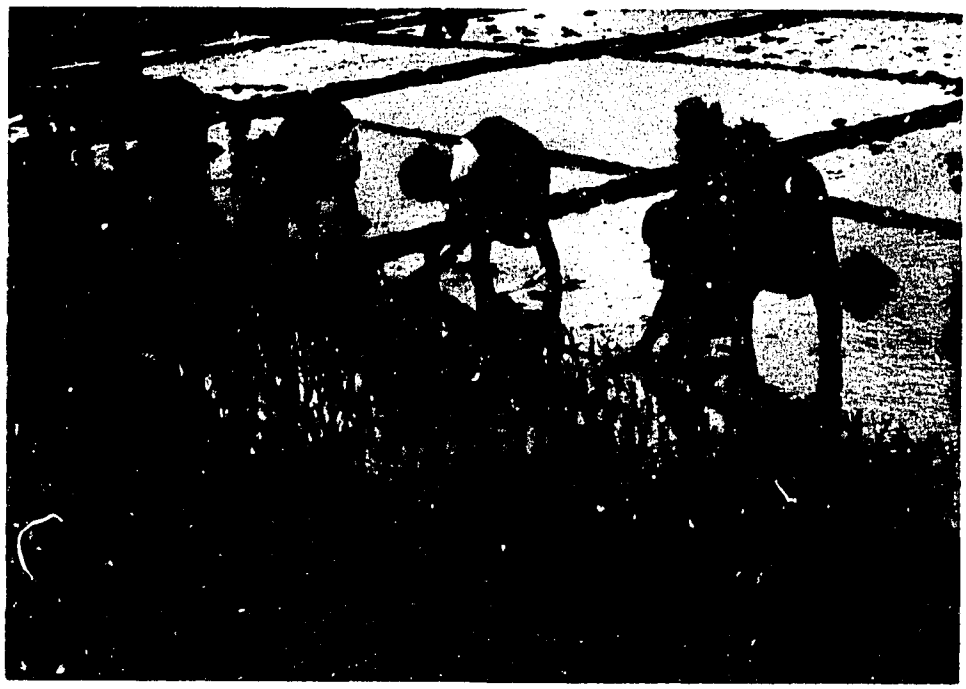
Increasing Nitrogen Productivity Under Tight Supplies (INPUTS network), which has been a collaborative effort among IFDC, The East-West Center, and rice researchers from national institutions, became an IFDC-coordinated network in 1979. Since 1974, more than 80 trials have been conducted in 9 countries to evaluate different means of increasing rice yields and improving nitrogen efficiency. Principal comparisons in the trials have been point deep placement (mudball and USG), broadcast basally incorporated SCU, and split applications of prilled urea.

Point deep placement of USG was superior to other sources of nitrogen. The superiority of USG was mainly in those areas where soil cation-exchange capacity exceeded 10 milliequivalent per 100 g when medium- to short-season varieties were grown. On the average, one-third less urea was required with USG to achieve yields similar to those attained through best split urea. SCU was superior to best split urea in one-third of the trials, never superior to point deep placement of USG, and in some cases inferior to best split urea. Isobutilidene diurea and peatballs were used in some of the experiments. Neither was statistically superior to best split urea, and both were usually inferior to either SCU or USG. The response to spatial variation in the placement of USG varied with locality and must be investigated in greater detail. Hand-placed USG was an economical choice in all countries where local labor costs were low. It was not economical in Japan, Korea, or Taiwan.

PHILIPPINES

In collaboration with IFDC, the Food and Agricultural Organization (FAO) of the United Nations and the National Food and Agriculture Council Fertilizer Program conducted about 100 nitrogen source trials for rice in the wet season of 1979. The multiple rate trials were conducted in farmers' fields in 13 provinces. SCU (forestry-grade) and prilled urea were compared at 3 and 4 nonzero rates at each location. The average yield responses in the first 69 trials showed that SCU was superior to urea. At 60 kg of nitrogen per ha, SCU produced 350 kg more rice than urea, or yields were equal with 60 kg per ha of SCU or 98 kg of nitrogen per ha of urea. The economically optimum rates of nitrogen were 82 and 120 kg of nitrogen per ha from SCU and urea, respectively (assuming that nitrogen as SCU cost 50% more than nitrogen as urea).

At the optimum rates of nitrogen, yield responses were similar at 1,414 kg of rice per ha from urea



Initial emphasis of IFDC's Nitrogen Research Program has been placed on increasing fertilizer efficiency in wetland rice cultivation.

and 1,499 kg of rice per ha from SCU. The estimated net profit was $12 per ha more from SCU than from urea. Maximum yields and maximum profits were similar for both the nitrogen sources.

This work has highlighted the need for integrated national rice fertilization programs to move the findings of the various networks to the farm-level adaptive stage. Continuing work with institutions in the Philippines and elsewhere will emphasize other sources of nitrogen, methods of placement, and incorporation and correlation of differences in responses to source and nitrogen management to soil, climate, and crop factors.

INDIA

Through a collaborative agreement between IFDC and the Hindustan Fertilizer Corporation Ltd (HFC), nitrogen source trials were conducted in farmers' fields in eastern India by the staff of HFC. Point deep placement of USG, broadcast surface incorporation of SCU, and split applications of prilled urea were compared at 120 locations in 7 states (1977-79). Responses to the indicated applications of the modified urea products were significantly greater than from split applications of prilled urea in one-third to one-half of the trials. At 36 kg of nitrogen per ha, average yield responses each to point deep placement of USG and of SCU were 8.0 kg of rice per kg of nitrogen higher than when standard split urea application was used. At 72 kg of nitrogen per ha, the response advantages were 5.6 and 3.9 kg of rice per kg of nitrogen for USG and SCU, respectively.

UPLAND NITROGEN RESEARCH

Starting in August 1979, IFDC entered into a cooperative agreement with the United Nations Development Program (UNDP) aimed at improving food production in developing countries. The agreement enabled IFDC to expand its Nitrogen Program to upland crops. The Upland Nitrogen Program will deal with nitrogen-use efficiency problems for many different crops grown under a broad range of agro-climatic conditions.

The specific objectives of the project were delineated in detail by a workshop of concerned specialists held at IFDC in December 1979. Specific recommendations pointed to five major areas of research including:

1. Acquisition of baseline data on the nitrogen balance in tropical upland agriculture, thus enabling a proper assessment of fertilizer nitrogen losses as affected by soil moisture, soil type, nitrogen source, and crop.
2. Conducting a survey on the efficiency of fertilizer nitrogen recovery by the crop as affected by soil type, agro-climatic environment, cropping system and farming input level, nitrogen source, and management.
3. Studying the mechanisms of nitrogen loss in arid and semi-arid environments and assessing their relative importance and means of prevention.
4. Development of improved fertilizers and fertilizer management techniques that will increase crop uptake efficiency through improved availability or reduced loss of fertilizer nitrogen.

The workshop recommended that wherever possible these studies should be conducted in close collaboration with other international centers where UNDP-supported global agricultural research projects are being implemented. To that end, companion programs are being developed with the International Institute of Tropical Agriculture (IITA) for the humid tropics of Africa, with the International Centre for Agricultural Research in the Dry Areas (ICARDA) for the semi-arid and arid regions of Africa and western Asia, and with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in the semi-arid regions of the Indian subcontinent.

The project will utilize the collective expertise available from the collaborating institutions to obtain improved fertilizer nitrogen efficiency by the introduction of improved fertilizer use and management practices, improved crop, soil, and water management practices, and inexpensive fertilizer modifications that reduce nitrogen losses through volatilization and leaching and improve nitrogen utilization by the crop. Preference will be given to the fertilizer or management practices that do not depress biological nitrogen fixation by (intercropped) legumes. Where appropriate, ^{15}N-labeled materials will be used to help assess the fate of nitrogen.

Nitrogen research is being expanded to solve nitrogen-use efficiency problems for different crops grown under a broad range of agro-climatic conditions.

Phosphate

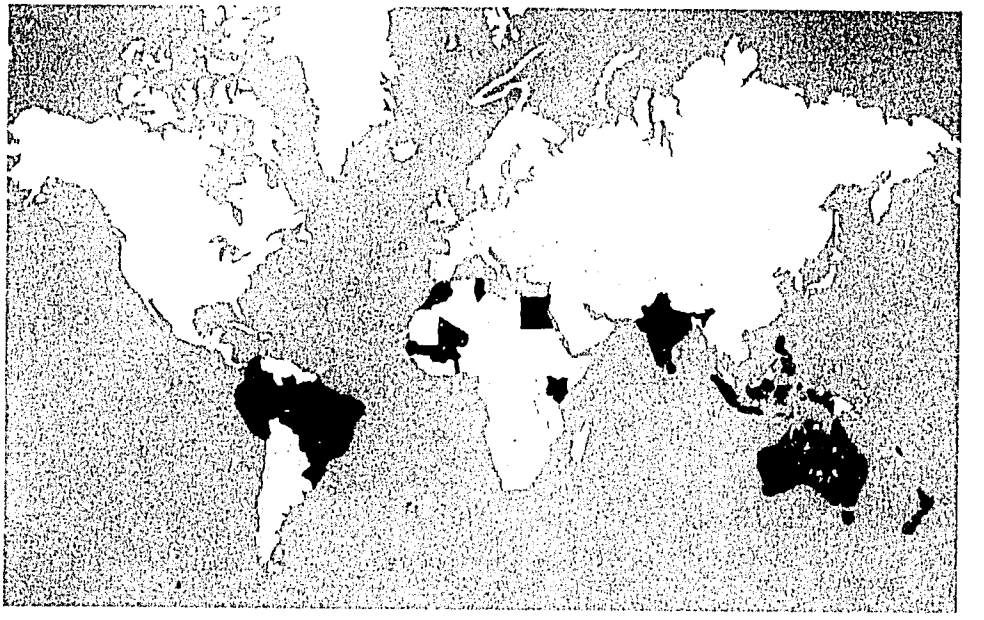
Phosphate rock deposits are widely distributed throughout the world. Although total phosphate reserves appear to be ample to meet global needs for the foreseeable future, present mining, beneficiation, and processing technology is effective on only 15%-20% of the known reserves. Furthermore, recovery of phosphate is poor and often results in losses of 50% or more of the original phosphate value in the ore before it is processed into finished phosphates. Many of the conventional phosphate fertilizers now in use in the tropics and subtropics either are inefficient sources of phosphate or they cannot be produced economically in many of the developing countries.

The objectives of IFDC's Phosphate Research Program are to develop more efficient methods for processing phosphate ores and to identify fertilizer products that can serve as efficient sources of phosphate to crops grown in tropical and subtropical soils. Special emphasis is placed on the development of technology that requires minimal capital and energy input, is suitable for satisfying limited markets, and utilizes, wherever possible, indigenous raw materials. Particular emphasis is directed toward those phosphate deposits located in landlocked countries or more remote areas where transportation costs have made imported phosphates extremely expensive. IFDC researchers attempt to meet these objectives by developing new, or identifying existing, technologies and products that are effective on a number of phosphate ores, soils, and crop management schemes. Each new material being studied is put through a series of systematic steps involving characterization of the raw material and identification or development of technology (including beneficiation, partial or full acidulation, or thermal treatments) that will be effective in improving the physical and chemical properties of the ores. The resultant products are evaluated agronomically and economically as to their suitability in specific geographic areas.

PHOSPHATE RESEARCH

COUNTRY INVOLVEMENT

Australia	Morocco
Brazil	New Zealand
Colombia	Peru
Ecuador	Philippines
Egypt	Senegal
India	Sri Lanka
Indonesia	Togo
Israel	Trinidad
Kenya	Tunisia
Mali	Upper Volta



CHARACTERIZATION

Characterization of phosphate ores is a critical first step in determining their effective use as phosphate fertilizers. Phosphate ores fall into two broad categories: (1) easily processed ores (no technical problems preventing their development or further processing) and (2) "problem ores" (ores having physical or chemical properties that prevent their economic development). These so-called problem ores are usually classified as being high in one or more of the following impurities: silica, organic matter, iron/aluminum oxides, iron/aluminum phosphates, carbonates, or chlorides.

Each phosphate ore examined by IFDC, with assistance from TVA, is characterized as to its potential for use as a fertilizer, including potential routes for development that will require minimal inputs of capital, energy, and other developmental costs. As a result, phosphate ores usually fall into two potential use categories: (1) suitable for direct application and (2) require some modification through granulation, acidulation (partial or full), or thermal treatment. Each step represents an increase in capital costs, complexity, and depending on the choice of process and economies of scale, higher energy requirements and production costs.

Efforts are being made to classify information on phosphate ores throughout the world in accordance with size and quality of deposits, economic and technical potential for development, and identification of further work required for a deposit's exploitation. In 1979, IFDC received 177 samples from six countries.

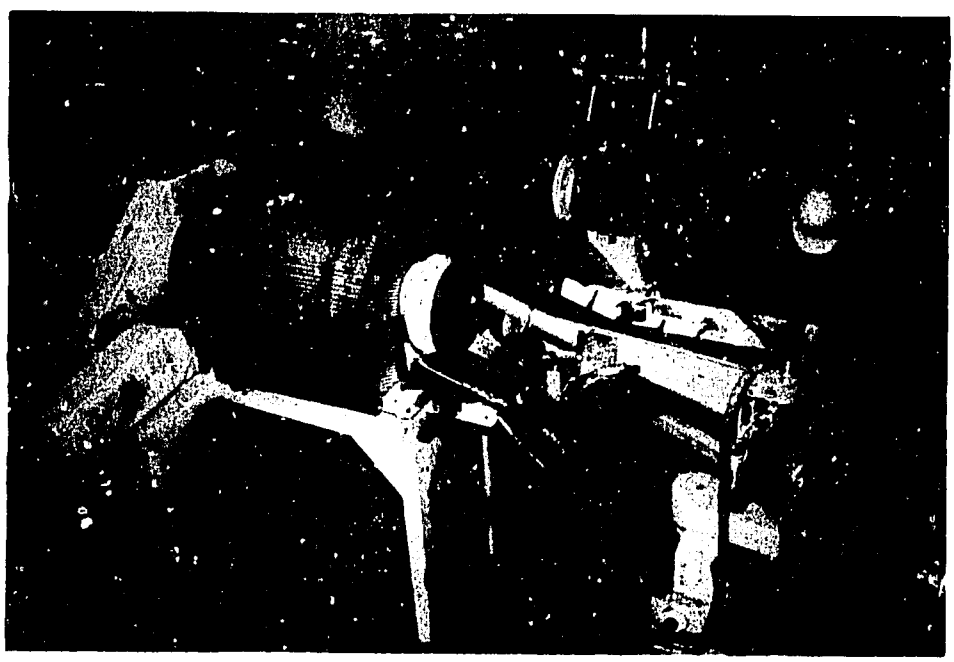
IFDC also serves as a reference source where scientists can send samples or request information on samples that have been analyzed by IFDC. Activities in this area in 1979 included exchanges from India, Australia, and Brazil. Characterization work in 1980 will focus on Africa and will include a cataloging of phosphate reserves with particular emphasis on landlocked countries.

BENEFICIATION STUDIES

Most phosphate ores go through a concentration step called beneficiation before they are shipped commercially as concentrates or processed into finished phosphates. Losses of phosphate commonly reach 40% in this beneficiation step even for easily processed phosphate ores and can exceed 60% for problem ores.

In 1979, IFDC commissioned a pilot plant to work on beneficiation of problem phosphate ores. IFDC engineers selected Utah phosphate rock as a study ore to be used in the commissioning process because its mineralogy and texture are similar to many ores that are high in silica and carbonates and are found in developing countries.

IFDC engineers were able to make significant improvements in a conventional fatty-acid flotation method used to beneficiate the high-silica, sedimentary, Utah phosphate rock. Laboratory bench-scale flotation tests produced a phosphate concentrate assaying 31%-32% phosphate with total recoveries of as much as 60% of the phosphate found in the original ore. Similar results were obtained in continuous pilot-plant runs. These findings are applicable to other problem ores that are high in silica, such as Pesca of Colombia, Hazara of Pakistan, and Kodjari of Upper Volta.



Pilot-plant research enables IFDC to work on problems associated with the beneficiation of phosphate ores.

DEVELOPMENT OF APPROPRIATE PHOSPHATE FERTILIZERS

The current rise in costs of energy and capital has emphasized the need for the development of phosphate fertilizers that require minimal amounts of each and still serve effectively. IFDC's Fertilizer Technology and Agro-Economic Divisions are actively engaged in achieving this goal. IFDC engineers, chemists, soil scientists, and agronomists have produced and evaluated a number of phosphate fertilizers in the laboratory, greenhouse, and field. The following is a description of the materials receiving major research attention and a review of the research program in 1979.

Phosphate Rock for Direct Application

Direct application of finely divided phosphate rock may be one of the cheapest ways to supply phosphate to crops grown in large areas of the tropics and subtropics. This approach has certain advantages, particularly for development of deposits containing highly reactive rocks that are located in landlocked regions and/or are close to important agricultural areas. Under such circumstances, direct application may offer an attractive alternative to conventional phosphates because: (1) the technology is relatively simple and can employ local expertise for operation; (2) capital costs are low, and energy requirements are about one-third that of conventional phosphates; (3) production costs are near scale neutral; and (4) it represents the quickest and perhaps cheapest way to start the development of a basic phosphate industry in a developing country. However, this approach has certain distinct disadvantages which cannot be ignored. The most notable of these are.

1. The phosphate content in phosphate rock often is considerably less than that found in high-analysis conventional phosphates, thereby limiting its competitiveness for markets at increasing distances from the mine site.
2. Phosphate rocks have a limited scope of use, and in addition to differences in reactivity, their agronomic effectiveness is strongly influenced by soil, crop, and climatic conditions.
3. The handling properties of finely divided rock are often objectionable.

Use of phosphate rock for direct application is inhibited by the lack of an accepted chemical test for evaluating the agronomic suitability of various rocks. In addition, current agronomic and economic methods take into account only its immediate benefits and not its residual effectiveness.

The current IFDC program on phosphate rock for direct application takes into account these advantages and problems. Through detailed laboratory, greenhouse, and field studies, IFDC is attempting to identify the factors that determine the potential of rock phosphate as a fertilizer and the soil and management factors that determine how and under what conditions this potential is likely to be reached.

During 1979, IFDC prepared a large number of phosphate rock products from several different deposits. These samples ranged in particle size from finely ground (<200-mesh), minigranulated (-48 +200-mesh) to conventional (1-4 mm) product. The majority of these materials were used for agronomic testing at Headquarters and at selected locations in the developing world.

Partially Acidulated Rock

The phosphate in some rocks may not be available to plants in short-term agronomic tests. For certain crops, it may be desirable to convert some of the phosphate to an available form. This may be achieved by reaction with only a portion of the phosphoric or sulfuric acid required for the manufacture of superphosphates. Partial acidulation also may be done in conjunction with granulation. Partially acidulated (10%-40%) products are being evaluated agronomically in a number of cooperative projects. During 1979, partial acidulation tests were carried out on Eppawala, Kodjari, Pesca, and Togo phosphate rocks.

An alternate method for achieving some water-soluble phosphate is to use mixtures of ground rock and superphosphate (single superphosphate [SSP] or triple superphosphate [TSP]). The mixtures also may be granulated.

Specialty Phosphates

Specialty phosphates often may be prepared directly from unbeneficiated phosphate ore. They contain almost no water-soluble phosphate but usually contain citrate-soluble phosphate (neutral ammonium citrate). They may offer advantages on soils that have high phosphate-retention capacities. These fertilizers also contain some

secondary nutrients and micronutrients. Unfortunately, the processes for preparing specialty phosphates are energy intensive, although some of these products are available commercially. Some specialty phosphates are Rhenania phosphate, fused calcium-magnesium phosphate, and chlorospodiosite. IFDC's main interest is to determine the suitability of certain indigenous ores to these products. During 1979, several specialty phosphates were produced from ores found in Sri Lanka (Eppawala), Upper Volta (Kodjari), and Colombia (Pesca).

HEADQUARTERS RESEARCH ON GROUND AND MODIFIED PHOSPHATE ROCKS

Laboratory and greenhouse research at IFDC Headquarters this year focused on the following major topics: (1) the dissolution of phosphate rock in relation to soil properties, (2) the relative efficiency of an expanded range of finely ground phosphate rocks, (3) the effect of granulation and placement of finely ground rocks, and (4) the efficiency of partial acidulation and ways to increase the initial responsiveness to phosphate rocks. The research conducted in these areas was designed to identify the most promising approaches in preparation for field-level evaluation and/or to determine the most effective methods of product preparation.

Specialty phosphates are being studied to determine the suitability of certain indigenous ores for commercial processing.

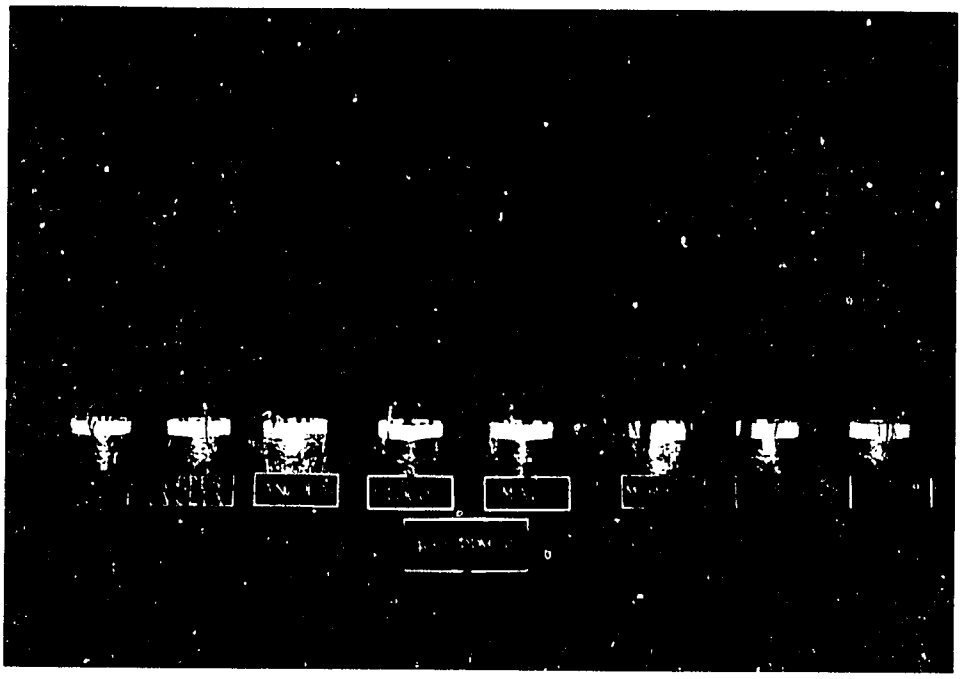
Soil Factors Affecting Dissolution of Phosphate Rock

During 1979, a study was conducted to investigate the relationships between the dissolution rate of phosphate rock in 16 acid Colombian soils and their soil properties. A kinetic model was developed from these relationships to describe the dissolution rate as a function of rock sources and soil types. It is possible to predict the dissolution rate of a phosphate rock in a given soil from a single measurement of reactive aluminum content of the soil. Tests with two other soils from Colombia confirmed this model.

Agronomic Effectiveness of African Phosphate Rock

In IFDC's initial research projects on direct application of phosphate rock, the major emphasis was placed on correlations between the chemical solubility (or potential) of the apatite and relative crop response. The correlations in turn led to the ability to categorize the rocks evaluated into groups of high, medium, or low potential with respect to short-term phosphate availability. The objective was to predict the suitability of finely ground rock for use as a direct application phosphate source. In these studies, the majority of the rocks used were from sites in Latin America. Due to IFDC's increasing involvement in west Africa, a series of phosphate rocks from deposits potentially available in the region were screened in a greenhouse test to rank their agronomic effectiveness and to test the reliability of the chemical tests previously developed.

The results of the greenhouse trial indicated that (1) the relative



Greenhouse tests are conducted to rank the agronomic effectiveness of African phosphate rocks.

crop response was well related to the chemical solubility measurements and (2) samples from Tunisia and Morocco could be ranked with the high reactivity rocks; the sample from Mali was in the medium range; and the materials from Upper Volta and Togo showed low effectiveness. Previously, rankings such as this were made more difficult because crop response curves to phosphate from phosphate rock do not conform to the requirements of classical efficiency models in that each source may possess a characteristic maximum yield regardless of increased rate of application rather than approaching a common maximum. Data from this evaluation also were used to determine the most appropriate comparative model to describe the relative source efficiency over the entire crop response curve. It was found that a semi-log model with a common intercept was best suited and was highly effective in ranking overall source effectiveness.

Granulation of Finely Ground Phosphate Rock

Research conducted both previously and in 1979 clearly indicated that granulation of phosphate rock to improve handling characteristics greatly reduced the effectiveness of the rock when it was granulated to conventional sizes and incorporated into the soil. It also was shown that mini-granulated phosphate rock (-48 by +200-mesh) was effective in improving handling characteristics without reduction in crop response when incorporated into the soil.

However, because a major potential area of use for phosphate rock is in pasture systems that require surface application of phosphate fertilizers for maintaining fertility, a preliminary study was conducted to determine the suitability of both ground and granulated rocks without incorporation. The results from this study indicated that when granulated rock is surface applied to grass, it only has a slight reduction in effectiveness when compared to the incorporated rock. However, with corn, granulated rock is not effective. Additionally, it was shown that rock granules which disintegrate on the soil surface perform almost as effectively as the powdered rock.

Partial Acidulation of Phosphate Rock

Some situations require a phosphate fertilizer that is an intermediate between direct application of finely ground phosphate rock and conventional fully acidulated fertilizers. This need is apparent where reactivity of available phosphate rock is too low to give acceptable short-term yields and where the phosphate-sorption capacity of the soil is high enough to make readily available soluble phosphate fertilizers rapidly unavailable to the plant. Partially acidulated phosphate rock (PAPR) is an alternative that may fill this need and can be especially important to developing countries that have rock deposits but only limited availability of acids (sulfuric acid or phosphoric acid) for production of conventional fertilizers.

In 1979, studies were conducted to determine the effect of partial acidulation of low reactivity phosphate rock in improving initial levels of plant available phosphate. A number of production variables were considered—(1) type of acidulant, (2) degree of acidulation, (3) granule size, and (4) product drying temperature.

With respect to these variables, it was observed that phosphoric acid was highly effective in increasing the initial phosphate availability of the phosphate rocks from Colombia and Togo. With sulfuric acid, 40%-50% of the sulfuric acid required to make SSP may be required to be equally as effective as the phosphoric acid. Additionally, the product produced with sulfuric acid required lowered drying temperatures. Drying at 110°C drastically reduced the water solubility and agronomic effectiveness, but this reduction was not observed at 66°C. No consistent advantage was observed for any of the granule sizes evaluated.

It is anticipated that the PAPR should be most effective in soils with high phosphate-sorption capacity where a portion of the phosphate will be immediately available to promote early plant development, while the rest remains as unreacted rock that is less susceptible to immediate reaction with the soil. These studies showed that product effectiveness was related directly to the water-soluble phosphate level and that the materials tested fell short of the immediate effectiveness of superphosphate. The soil on which the materials were tested, however, was not as high in phosphate-sorption capacity as many found in the tropics.

Laboratory studies on the reaction of a partially acidulated North Carolina phosphate rock (20% of the phosphoric acid required for TSP) showed that (1) the presence of unreacted rock in PAPR or in the mixture of TSP and phosphate rock slowed down the immobilization of water-soluble phosphate by reducing the acidity produced during monocalcium phosphate hydrolysis, thus decreasing the amount of acid available to solubilize soil aluminum and iron; (2) the reaction of acid with phosphate rock could release additional phosphate to the water-soluble pool; and (3) the relative effectiveness of PAPR was highest in the Oxisol that had the highest capacity to sorb phosphate.

Future evaluations are planned on soils with varying phosphate-retention capacities to identify optimum conditions for use of PAPR. Results show that PAPR has a higher phosphate availability in short-term cropping than that of finely ground rock but less than that of TSP. PAPR made from Pesca rock resulted in a crop response 79%-90% as effective as TSP; the non-acidulated rock was only 10% as effective as the TSP. Togo PAPR was 55%-74% as effective as superphosphate.

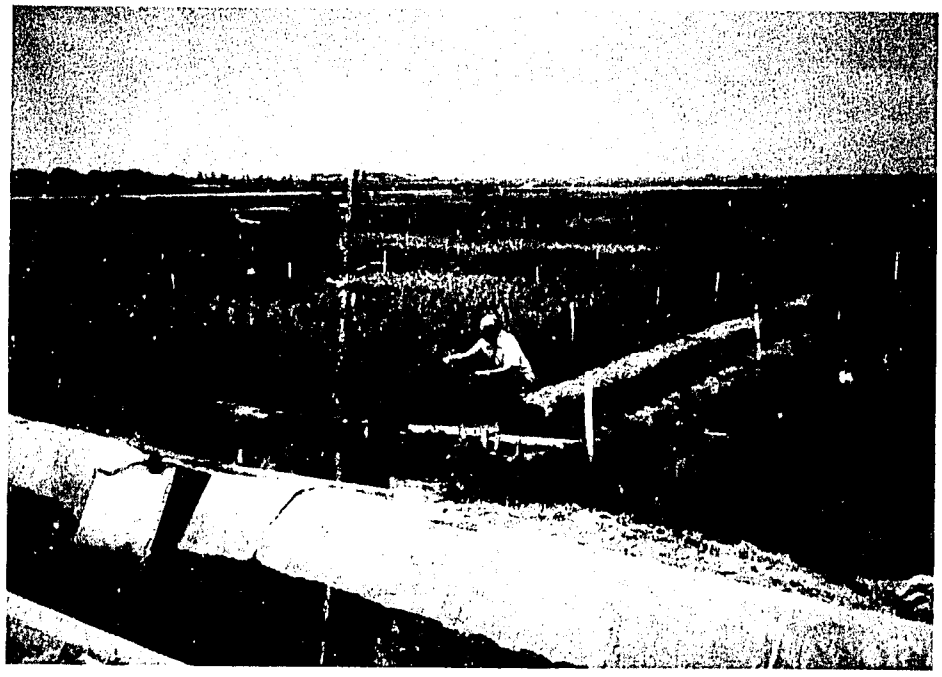
IFDC/BSP field research is being conducted in the Philippines to test the effectiveness of phosphate sources and methods of phosphate application.

Phosphate fertilizers are being tested at CIAT Headquarters to determine their effectiveness in the acid infertile soils of Latin America.

COLLABORATIVE PROJECTS

IFDC worked with a number of institutions in 1979 to expand the effectiveness of its Phosphate Program. Projects were continued or established with the following:

1. **International Center of Tropical Agriculture (CIAT)**, Colombia—Greenhouse and field research aimed at developing and/or identifying more effective phosphate fertilizers for the acid soils of subtropical and tropical Latin America.
2. **Israel Institute of Technology (TECHNION)**, Haifa, Israel—Laboratory and greenhouse research aimed at identifying the factors affecting dissolution of phosphate rock, both chemical and physical.
3. **Midwest Universities Consortium for International Activities (MUCIA)**—(a) Laboratory research at Michigan State University to determine the role of calcium activity and surface area on the dissolution of phosphate rock and (b) laboratory and growth-chamber research at Ohio State University to develop soil test methodology appropriate for determining phosphate requirements when using nonconventional phosphate fertilizers.
4. **Benchmark Soils Project (BSP)**, through the University of Hawaii—Field research in the Philippines and Indonesia to determine the effectiveness of phosphate sources and methods of phosphate application on selected Benchmark soils.
5. **Caroni, Ltd.**, Trinidad—Field research to evaluate residual value of phosphate carriers in long-term sugarcane experiments.



IFDC/CIAT PHOSPHATE PROJECT

The research that has been and is being conducted in the IFDC/CIAT project has considered primarily: (1) the characteristics of the acid infertile soils of Latin America as the target area and (2) the agronomic effectiveness of experimental phosphate carriers in relation to these soils, using a wide variety of indicator crops. This research is being conducted through funding made available by the International Development Research Centre, Canada. Two IFDC scientists have been stationed at CIAT since 1977. Production of the experimental phosphate fertilizers and the chemical characterization studies on these materials have been carried out primarily at IFDC Headquarters.

The Problem

The acid soils of Latin America (pH <5.5) present management problems that have been a factor in inhibiting the development of agriculture in Latin America. Although phosphate is the most limiting plant nutrient, once phosphate fertilizers are added, nitrogen, potassium, sulfur, boron, and calcium may very rapidly become factors most limiting crop growth. In addition, widespread aluminum and manganese toxicities also limit crop growth, especially with row crops. The addition of lime to these soils may create zinc deficiencies. Because the mandate of the project is to study phosphate, "blanket" applications of all other potentially limiting nutrients and amendments are applied in amounts needed to overcome any nutrient deficiencies or toxicities in experiments being conducted.

The solution to the soil phosphate problem is multifaceted; no "quick" answers will remedy this situation. These acid soils are low in both available phosphate (<5 parts per million [ppm] phosphate) and in total amounts (100-400 ppm phosphate). Therefore, breeding a plant that is highly phosphate efficient to low phosphate soils will only be a short-term solution. The capacity factor for supplying phosphate over any extended period of time is inadequate. It appears that the only effective way to overcome this problem is by adding phosphate as economically as possible. Then, phosphate efficient plants can be selected to better utilize the applied phosphate.

Phosphate fixation also is considered a major problem on these soils. When soluble forms of phosphate are added, large doses are generally necessary to provide enough phosphate in the soil solution for effective plant growth. The acid soils under consideration are high in reactive iron and aluminum oxides which are generally associated with high phosphate fixation. Studies with 23 Colombian soils indicate that the phosphate fixation is mainly due to reactive aluminum. In another incubation study, it was shown that the exchangeable aluminum was not a causative factor in phosphate fixation.

Because the soils under consideration are very acidic in nature, phosphate rock was given a high priority for research as a potential source of phosphate. In

addition, because many of the soils were believed to be high phosphate fixers, it seemed logical to use a source of phosphate that became available with time rather than highly available sources such as TSP or SSP, which in theory at least, could be very rapidly fixed and become unavailable to plants. Two other factors also contributed to the major research thrust being focused on the use of phosphate rock. These were: (1) many significant phosphate rock deposits are in South America (Figure 6) and (2) phosphate rock is potentially the cheapest source of phosphate in the agricultural areas near these deposits.

Phosphate Rock for Direct Application

A greenhouse experiment was conducted on a Las Gaviotas Oxisol (Colombia) to compare the agronomic effectiveness of 18 different phosphate rocks in comparison with TSP. *Panicum maximum* was the test crop, and yield results are given in Figure 7. The phosphate rocks that are known to be highly reactive such as North Carolina, Bayovar, and Gafsa performed nearly as well as TSP.

Many of the other phosphate rocks also appear to hold promise for direct application. The overall results of this experiment are even more encouraging when one considers the short-term nature of the study (5-6 months). In general, it is assumed that phosphate rocks would be more effective in longer term situations.

On these highly acid soils, even the low reactivity phosphate rocks are effective with time. This is shown in a field experiment conducted on a Carimagua Oxisol with *Brachiaria decumbens* where six phosphate rocks with varying agronomic effectiveness ratings were compared to TSP. This long-term study that was established in 1976 has application rates ranging from 0 to 400 kg of phosphate per ha, all broadcast and incorporated. After almost 4 years, the yields of forage from the phosphate rock treatments compare favorably with those for TSP. In many instances, the yields where phosphate rocks were used are considerably higher. For the period of time this experiment has been conducted, an application rate of 50 kg of phosphate per ha appears to be adequate. Similar results have been recorded from a field experiment conducted in Peru on a Pucallpa Ultisol.

Placement in the soil of soluble phosphate in conjunction with varying levels of phosphate rock applied as basal treatments was another factor studied. In a

Figure 6. Major Known Phosphate Deposits of Latin America.

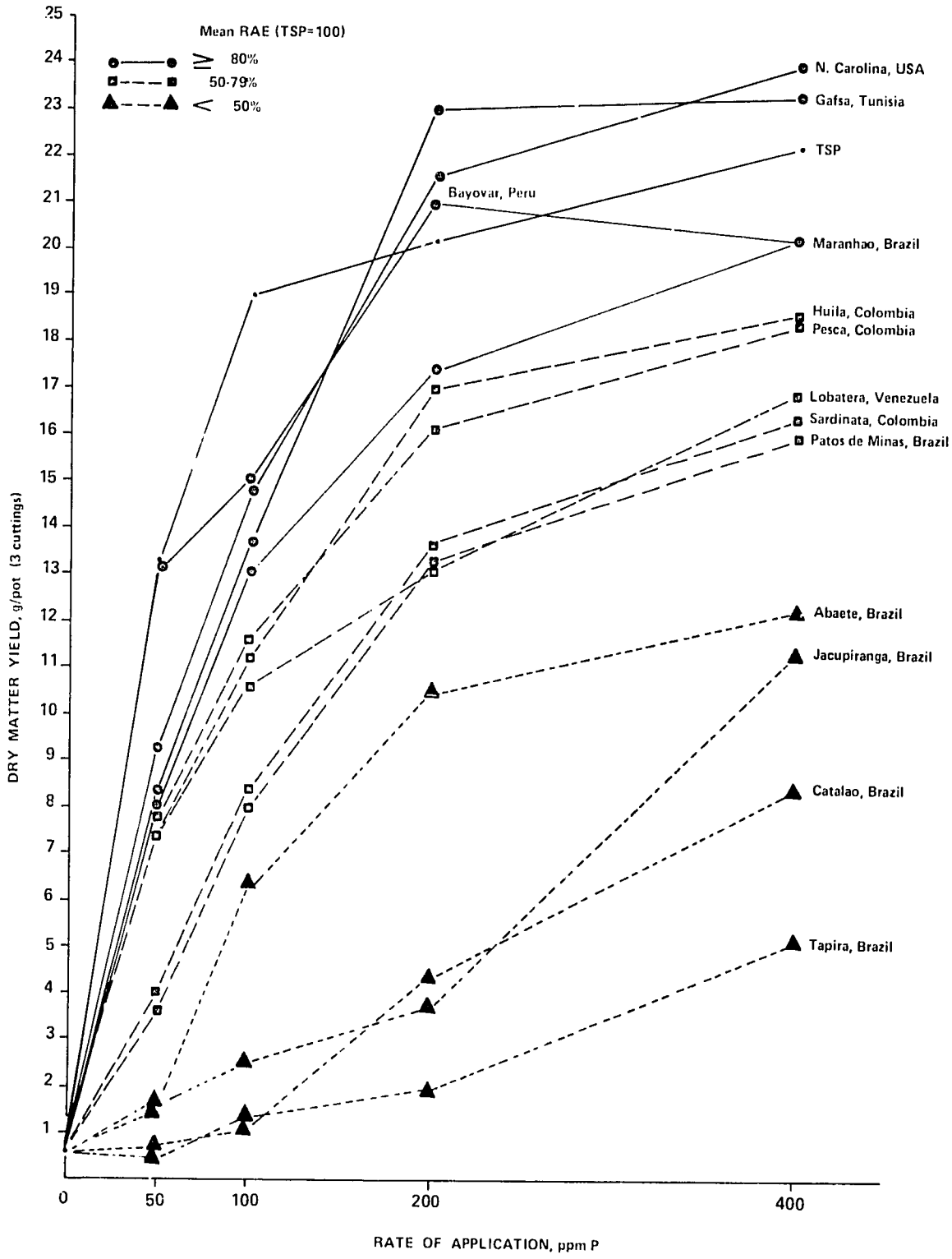


Figure 7. Results of a Greenhouse Experiment to Compare the Agronomic Effectiveness of Phosphate Rocks and TSP.

field experiment established in May 1978, on a Quilichao Ultisol, the results to date show Pesca phosphate rock applied alone compares favorably with both TSP and combinations of TSP with phosphate rock. Topdressed Pesca phosphate rock gave similar yields obtained by other treatments. This suggests that many of the phosphate rocks could be used not only as a source of phosphate in establishing pastures but perhaps also as a topdress application on established pastures.

Granulated Phosphate Rock

The previously described experiments with phosphate rock were all conducted using finely ground materials. From a research standpoint, these materials can be handled and spread evenly and accurately if patience is exercised. However, when one considers the practical aspects of handling and spreading these powdery, dusty materials on a larger farm scale, it is doubtful that either the farmer or the fertilizer dealer in Colombia and perhaps much of Latin America could be convinced to make widespread use of them.

In an effort to overcome these handling problems, researchers at IFDC Headquarters initiated a study to determine if finely ground phosphate rocks could in some way be granulated and still retain their agronomic effectiveness. It was found that stable granules of varying sizes could be made using a potassium chloride solution as a binder. Two separate greenhouse experiments with *Panicum maximum* and corn were conducted to test these materials. The small granules (-48 +200-mesh) proved to be as agronomically effective as the finely ground phosphate rocks. Apparently when these minigranules come in contact with the soil and the potassium chloride binder dissolves, the effective surface area is not markedly different than when finely ground materials are applied. Although the larger sized granules (-6 +16-mesh) were not as effective initially, they did release increased amounts of phosphate with time.

Co-Granulation

Although the use of phosphate rocks looks promising for the acid infertile soils, the initial release of phosphate is still a problem, especially with the medium and low reactivity phosphate rocks. In a greenhouse experiment with corn grown on a Carimagua Oxisol where varying ratios of phosphate rock to TSP or SSP were used, the initial growth response was in proportion to the amount of soluble phosphate in the mixtures. When a comparison of powdered materials was made with co-minigranulated phosphate rocks and TSP, the granulated materials were superior in every instance. This would indicate that the acid produced from the soluble phosphate in the granule is reacting with the phosphate rock, thus releasing additional phosphate for the plants.

Partial Acidulation

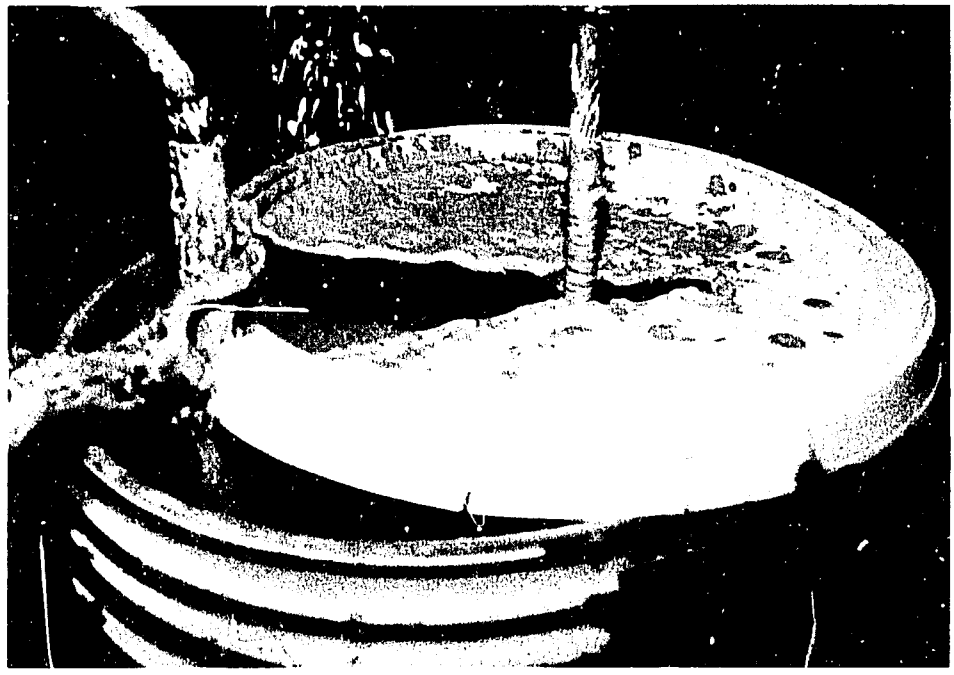
In another series of experiments, PAPR was tried in an attempt to overcome the problem of initial release of phosphate. In a field experiment conducted at Carimagua with upland rice and using 20% acidulated (sulfuric acid) North Carolina and Florida phosphate rocks, the highly reactive North Carolina showed no benefit, but the yield results with Florida were considerably higher. With both phosphate rocks, the minigranulated materials were superior to the powdered materials. In all cases, the phosphate rocks gave comparable yields to those of TSP.

Similar results were obtained with *Panicum maximum* in Carimagua where Florida phosphate rock was partially acidulated (20%) with phosphoric acid. Results are extremely encouraging because both the mini- and regular-sized granules gave yields comparable to TSP even in the initial harvest.

The results that have been reported on in this section are only meant to highlight some of the research findings and do not represent the total scope of the research project. Additional research in Peru, Ecuador, and other Latin American countries is being made possible through the support of UNDP. The major aim of the expanded research is to verify research station results and identify the areas of greatest potential impact.

SPECIAL STUDIES—PROBLEM ORES

IFDC is receiving an increasing number of requests from individual countries or firms requesting help in solving technical problems in the processing of a specific phosphate ore. In 1979, these requests focused on Senegal, Sri Lanka, Upper Volta, Egypt, and Colombia. A brief description of the problems, organization involved, and accomplishments to date follow.



Results of the Senegal slimes project may be applicable to problems associated with the processing of other phosphate deposits.

Technical Evaluation for Senegal Phosphate Slimes Utilization as Fertilizer

An estimated 10 million tons of phosphate as 30%-35% solids slimes analyzing about 25% phosphate on a dry basis have been accumulated as the waste byproduct of a phosphate mining and beneficiation operation in Taiba, Senegal. About 0.8 million tons of phosphate continue to be disposed of per year as a 12% solids slurry. Some characteristics of the slimes are: (1) it is very finely divided, more than 50% by weight of the solids are smaller than 2 microns and (2) it is mostly apatite, about 63%, with iron and aluminum-bearing clays as the bulk of the impurities. No technology was known for the processing of that material. PHOSVALOR, a company based in Dakar, Senegal, asked IFDC to solve this problem.

During 1979, a process was developed in which byproduct slimes containing 15%-30% solids are acidulated directly with sulfuric acid, producing a phosphoric acid solution of concentration about 4%-9% phosphate. The phosphate is recovered as an ammonium salt. In the process, extraction of iron and aluminum compounds is depressed in favor of apatite decomposition.

It is critical to reject the iron and aluminum compounds in the acidulation step and attack the apatite selectively. Rejection was as high as 80% under proper conditions of temperature, residence time, and acidulation ratios.

Using a bench-scale pilot plant, IFDC has demonstrated that this is technically possible. The economic feasibility appears favorable if no value or a low value is assigned to the slimes.

The capital investment for a 1,000-tons-per-day phosphate complex producing monoammonium phosphate (MAP) was estimated to be $250-$300 million. The product cost from such a plant compared favorably with the same product from a conventional MAP/diammonium phosphate (DAP) plant operating with a commercial phosphate concentrate.

The technological route of producing merchant-grade, wet-process acid from the slimes is being investigated in order to compare with the route outlined above.

Pilot-plant work is needed to define the full process in engineering detail. Considerable effort was made to prepare a 1-ton-per-hour phosphate pilot-plant proposal for evaluation by the sponsors.

Although the results of this study are directed toward a specific problem in Senegal, they can also be used in the processing of other phosphate ores which are high in iron and aluminum, where selective extraction is important, and in the recovery of mineral values from the wastes of ore processing. The conservation of nonrenewable resources is especially important for the fertilizer minerals.

Use of Local Resources for Phosphate Fertilizer Production in Upper Volta

Upper Volta, being a landlocked country, is at a disadvantage to participate on an equal basis with other countries in world fertilizer trade. The importation of fertilizers is costly and complicated. Upper Volta does have local deposits of phosphate ore; however, the demand is too low to allow construction and economic operation using conventional technology. One of these ores, the Kodjari deposit, offers potential as a fertilizer source for Upper Voltan farmers if a suitable means can be found for its processing as a fertilizer.

The German Agency for Technical Cooperation (GTZ) and IFDC initiated a research project to produce phosphate fertilizer that is agronomically effective and lower in cost than imported phosphates in Upper Volta. The first phase of the GTZ/IFDC project began in October and is to be completed within 9 months from the date of initiation. The project consists of research to determine the best method or methods for using Kodjari phosphate rock for fertilizer production in Upper Volta. Experimental products of different types are being made by IFDC researchers. These materials will be tested in laboratories and greenhouses at IFDC Headquarters and in West Germany. Preliminary production economics of the processes considered will also be made.

As part of this project, a counterpart scientist from Upper Volta arrived at IFDC Headquarters in October for a period of 3 months to participate in the preparation and evaluation of experimental products.

A scientist from Upper Volta prepares experimental products made from Kodjari phosphate rock.

Sri Lanka-Eppawala Phosphate Rock Study

Most countries of Asia lack sufficient deposits of easily minable phosphate ore to meet domestic demand. Many deposits that are present have specific problems. The Eppawala phosphate deposit of Sri Lanka, estimated to contain 25 million tons, is sufficient to provide the needs of Sri Lanka for many years and is an example of such an ore. In November 1976, an appraisal mission sponsored by the Government of the Netherlands (Stamicarbon of Dutch State Mines and the Netherlands Economic Institute) recommended that domestic phosphate production be considered. The problem was to determine the most feasible method or methods to utilize the Eppawala phosphate. Earlier studies had suggested that use of the ore in thermal phosphates be considered. Such processes might be simple and not influenced by impurities or the lack of raw materials which are locally available. Favorable agronomic response had been obtained in these preliminary trials.

The Dienst Internationale Technische Hulp (DITH) requested a project proposal from IFDC to study alternatives for using the ore and to carry out agronomic tests with experimental products. A proposal was subsequently approved by DITH and Sri Lanka. The project was initiated in January 1979 to be completed within 12 months from receipt of the samples.

An IFDC geologist traveled to Sri Lanka to obtain representative samples of Eppawala phosphate and serpentine to be used for the study. A shipment of the raw materials arrived in Muscle Shoals in April. The phosphate ore was crushed, blended, and sampled for mineralogical and chemical analysis.

The chemical and mineralogical data revealed that the Eppawala phosphate is a high-grade ore (36.4% phosphate) consisting of two distinct apatite minerals, namely, a coarsely crystalline chlorapatite of variable chlorine: fluorine ratio and a cryptocrystalline carbonate apatite of the francolite variety as the interstitial cementing phase. The main impurities are chloride (1.1%) or iron and aluminum oxides (6.7%).

Initial phosphoric acid and corrosion tests using uncalcined Eppawala phosphate began in June and ran through August. The acid produced was used for making TSP, MAP, and DAP. Eppawala

A soil scientist (left photo) and a chemical engineer (right photo, on the right) from Sri Lanka evaluate and test experimental fertilizer made from Eppawala phosphate rock.

phosphate also was used for producing SSP, Rhenania phosphate, and fused magnesium phosphate (FMP). TSP, SSP, FMP, and Rhenania phosphate are being tested in laboratories and greenhouses at IFDC Headquarters and in the Netherlands to evaluate the agronomic effectiveness of these experimental products. Preliminary cost estimates of these experimental products also will be made.

As a part of this project, a chemical engineer from the State Mining and Mineral Development Corporation, Sri Lanka, arrived at IFDC Headquarters in June for a period of 4 months to participate in the technical evaluation program. A soil scientist from the Central Agricultural Research Institute, Sri Lanka, arrived in August for a period of 5 months to help test the experimental fertilizers in IFDC laboratories and greenhouses.

Evaluation of Abu Tartur Phosphate Deposit

The Abu Tartur phosphate deposit, located in western Egypt, is an example of an undeveloped phosphate that may help the economy of Egypt. However, because this ore contains certain impurities (matrix), it is difficult to process into finished phosphates using present technology. The matrix of this ore is high in iron sulfides, organic matter, carbonates, and magnesium. These properties can cause excessive foaming, corrosion, or poor recovery if attempts are made to produce phosphoric acid from the matrix using conventional technology. Beneficiation eliminates some but not all of these problems.

In 1979, the Egyptian General Executive Organization for the Industrial and Mining Complexes contracted IFDC to (1) evaluate the Abu Tartur matrix and concentrate for conversion to phosphoric acid and (2) determine through greenhouse evaluation the suitability of Abu Tartur matrix and concentrate for direct application to acid and alkaline soils. A 500-kg sample of the matrix was received in August 1979, and a similar quantity of concentrate was received in November 1979. Representative samples of both matrix and concentrate were subjected to mineralogical characterization studies. Assistance in the characterization was provided by TVA.

Acidulation tests were started in October 1979 and will be completed in early 1980. The greenhouse experiment to study materials for direct application will begin in early 1980.

Sardinata Deposit—Colombia

The Monomeros Colombo-Venezolanos S.A. (MONOMEROS), a public-held fertilizer company in Colombia, has a nitric phosphate plant that consumes about 50,000 tons of phosphate rock per year. At the present time, the phosphate rock used is a blend of 95% Florida rock and 5% Sardinata rock, a phosphate from the northeastern part of Colombia close to the Venezuelan border. In-plant experience by MONOMEROS has shown that increased quantities of Sardinata rock in the blend caused difficulties in the gypsum filtration step. The Colombian government has asked MONOMEROS to use Sardinata rock to substitute for a greater part of or to replace imported rock.

In August 1979, MONOMEROS contracted IFDC to conduct bench-scale tests to study the production of nitric phosphate using Sardinata rock simulating the MONOMEROS nitric phosphate process. During 1979, IFDC conducted bench-scale tests that included process-control analyses and filtration tests which will be completed in early 1980.

Sulfur

Sulfur deficiencies are becoming increasingly more common in tropical and subtropical areas of the world. Reductions in crop yield occur if these deficiencies are not corrected. Fertilizers commonly supplied to the tropics are either low in sulfur or lack sulfur. IFDC has initiated a program to identify areas where it can contribute to solving the problem.

The general proposal for the IFDC Sulfur Research Program identified priority areas for sulfur research and indicated techniques and methodologies needed to study sulfur problems in the tropics. Laboratory, greenhouse, and field research on sulfur was initiated in 1979. The main areas of concentration were (1) research on agronomic effectiveness of rock-phosphate-elemental sulfur fertilizer materials and (2) development of analytical techniques to study deficiencies and responses in the tropics.

AGRONOMIC EFFECTIVENESS OF ROCK PHOSPHATE-ELEMENTAL SULFUR FERTILIZER MATERIALS

Published studies have indicated that the addition of elemental sulfur to rock phosphate increases the availability of rock phosphate to plants as well as provides the needed sulfur. Several countries in the tropics, in particular Nigeria and Brazil, have expressed interest in the use of the phosphate-sulfur mixtures as a possible substitute for the increasingly expensive SSP.

A field study was conducted in Kenya to assess the agronomic effectiveness of rock phosphate elemental sulfur mixtures on maize and peanut. The study was conducted in collaboration with the Kenya Agricultural Research Institute as a part of the sulfur project under the auspices of the U. K. Ministry of Overseas' Development. The study was carried out on the coastal region of Kenya in the 1979 rainy season (March-August). The materials used were Gafsa rock phosphate (obtained from Tunisia) mixed with elemental sulfur at various phosphate:sulfur ratios (1:0.5, 1:1.0, 1:1.6), SSP, and TSP. The phosphate-sulfur materials were applied as a powdered mixture and in minigranulated form.

The addition of elemental sulfur to rock phosphate significantly increased the crop yields. There was a strong response to the addition of 15 kg of sulfur per ha but no significantly increased response above this level. The maximum relative agronomic efficiency of the phosphate-sulfur mixtures were 67% and 87% of SSP for maize and peanut, respectively. Contrary to previous reports, cogranulation of rock phosphate with elemental sulfur did not increase the efficiency of phosphate-sulfur fertilizers. This discrepancy, as well as a relatively poor performance of rock phosphate alone, was attributed to the effect of applying the fertilizer in a band instead of broadcasting. The agronomic data indicate that the phosphate-sulfur materials may serve as an efficient source of phosphate for maize and peanut.

The field study in Kenya was conducted under the conditions most favorable to rapid solubilization of rock phosphate, in particular low soil pH (4.3) with a highly reactive rock (Gafsa). However, in many phosphate-sulfur deficient areas in Africa, e.g., Nigeria and Upper Volta, the soils are less acid and the available rock phosphate sources are very unreactive. A growth chamber experiment was conducted to assess the effect of phosphate-sulfur materials on a higher pH soil.

The rock used was a medium reactivity central Florida rock, and the soil was a phosphate- and sulfur-deficient Josephine fine sandy loam soil (pH of 6.0). Powdered mixtures of the rock and elemental sulfur with various phosphate: sulfur ratios were used. The test crop was maize. Two crops (initial and residual) were harvested.

Poor yields were obtained regardless of rate of phosphate application and phosphate:sulfur ratio. The efficiency of the phosphate-sulfur mixtures was not greater than 30% of SSP. Plant tissue analysis indicated a severe phosphate deficiency in all treatments and a sulfur deficiency in all treatments that had not received sulfur. The addition of sulfur increased the level of soil sulfate but did not affect the level of available phosphate, indicating that sulfur oxidation in soil did not increase the solubilization of rock phosphate.

It appears that the main benefit of adding elemental sulfur to rock

phosphate in the phosphate-rock materials is in supplying the available sulfur to sulfur-deficient soils. However, the addition of sulfur is not likely to result in a higher efficiency of the rock unless the source is highly reactive.

Turbidimetric methods for available soil sulfate and total sulfur in plant materials were modified. Work is continuing to improve the precision and reproducibility of the methods and to develop methods for total soil sulfur and elemental sulfur analysis.

DEVELOPMENT OF SULFUR ANALYTICAL TECHNIQUES

A collaborative project with the Royal Tropical Institute (RTI), Amsterdam, The Netherlands was initiated to study sulfur analytical techniques. The purpose of the project is to develop methods of soil and plant sulfur analysis applicable to the less developed countries in the tropics and to correlate soil sulfur levels with plant sulfur levels in an effort to develop diagnostic tests for sulfur deficiency. Soil samples for the laboratory and greenhouse study were shipped to the RTI from sulfur-deficient regions in Nigeria and Malawi. The greenhouse study on sulfur responses will be initiated in March 1980.

A greenhouse study was conducted in order to assess the effect of plant type, soil volume, and planting density on soil sulfur supplying capacity. Two pot sizes (2 kg and 4 kg) and two indicator plants (corn and cotton) were used. The decrease in yields and plant sulfur content due to sulfur deficiency was more pronounced in cotton than in corn. The soil volume and plant:soil ratio did not appear to affect the response to sulfur fertilizer.

Potassium, Calcium, and Magnesium

Potassium, calcium, and magnesium are major plant nutrients essential to crop productivity. Information from the tropics, however, on their availability, their interactions with soils and other nutrients, their losses, and crop requirements is scarce. A need for a review of the current status of potassium, calcium, and magnesium research in the tropics was recognized, and a consultant from the Potash & Phosphate Institute prepared a report for IFDC entitled "Potassium, Calcium, and Magnesium in Tropical Agriculture." The report defines the roles these nutrients play in crops, soils, and fertilizers to affect tropical food production with special emphasis on Latin America. It also defines some future research needs and how they relate to IFDC's research, development, and outreach programs.

Large land areas in the tropics, especially in Latin America and Africa, have soil low in exchangeable potassium, calcium, and magnesium. Because more of this land is coming under cultivation and because of the desire for higher yield levels, the consumption of calcium and magnesium containing materials, potassium fertilizers, and lime is expected to increase. Some areas which need coordinated research efforts are (1) mechanisms and magnitudes of nutrient losses, (2) soil interactions of these nutrients with other minerals such as aluminum and manganese, (3) requirements and responses of tropical crop species and varieties, and (4) development and evaluation of new sources of these nutrients for areas where traditional sources either are not readily available or do not perform well. IFDC's future role in the research and development of materials containing these elements is now under evaluation.

Adoption/Demand

Increasing food production and agricultural productivity are important objectives in any agricultural policy. Fertilizer is recognized as a crucial input to meet these objectives; however, constraints on demand must be removed. A clear understanding of the nature, magnitude, and relative importance of farm-level constraints is essential to formulate effective and efficient policy measures to increase food production by increasing fertilizer usage on small farms. There must be extensive knowledge of the demand prospects and the required policy measures for demand expansion to avoid imbalances between supply and demand for fertilizer. A fertilizer adoption/demand study, therefore, provides for large potential payoffs.

In broad terms, the objectives of IFDC adoption/demand research are (1) to expand the knowledge and understanding of how rapid rates of adoption of economically sound fertilizer usage among low income farmers in the lesser developing countries can be achieved through appropriate policy action, (2) to identify principal constraints for rapid expansion of economically sound fertilizer usage, and (3) to demonstrate the use of improved methodologies for fertilizer demand forecasting and public policy.

Adoption/demand research was initiated in Bangladesh and India. The present status of this research project is as follows:

1. Progress of Bangladesh Agricultural Research Council (BARC)/IFDC Bangladesh Field Survey—covering 480 farms the survey work was extended to include the 1979 Aman crop and will be completed by January 1980. Coding and preliminary analysis of the data are being carried out in Dacca. More detailed analysis and writing of the report will be done at IFDC Headquarters.
2. Progress of HFC/IFDC Indian Field Survey—HFC placed field investigators in field locations and survey work started with the summer (Kharif) season, 1979. Again, after the data are coded in India, it will be transferred to IFDC for analysis and report preparation.
3. Progress at IFDC— Formats and codes to process farm survey data from Bangladesh and India have been prepared for use in computer processing/analysis. At present, work continues with the development of methodologies for analysis of the farm survey data.

The results of this project will be useful to (1) public as well as private institutions and agencies within the study country which are involved in establishing effective and efficient policies and strategies for expanding food production through increased fertilizer use, (2) international institutions with agricultural development programs, including IFDC, and (3) national agricultural development institutions in countries other than the study country. The potential benefit to institutions outside the study country is expected to be realized through the overall IFDC research effort in the area of adoption and demand.

Policy

Government intervention in different aspects of the fertilizer sector is common practice in most of the developing countries. The purpose of fertilizer policy research is to generate appropriate information which will assist national planners and policymakers as well as decisionmakers in international institutions in making decisions which have direct bearing on the national fertilizer sectors in developing countries.

Fertilizer policy research includes (1) evaluating fertilizer policies with respect to their relative cost effectiveness, distribution of social benefits and costs, and administrative feasibility; (2) estimating the contribution of fertilizer to food production and economic development in general; (3) analyzing the policy implications of modified fertilizer technology; (4) identifying information gaps and data needs for fertilizer sector planning; and (5) developing guidelines for designing fertilizer policies and monitoring their performance.

The fertilizer policy research-related activities conducted during 1979 are summarized under three subheadings. These are (1) general fertilizer policy studies, (2) rice policy studies, and (3) global fertilizer study.

GENERAL STUDIES

In 1979, IFDC's general fertilizer policy studies consisted primarily of an analysis of the policy implications of new fertilizer technology (nitrogen efficiency) and the evolution and implications of fertilizer price policy.

One of the major research efforts at IFDC involves chemical and physical modifications of urea in order to make it less expensive and/or more efficient. Urea is the major source of nitrogen fertilizer for rice in Asia which has 82% of the world's rice area. An effort was made to quantify for 13 rice-growing Asian countries the relationship between fertilizer use and rice production at the national level and the policy implications of increased fertilizer efficiency for rice production in Asia. In Asia from 1965 to 1975, fertilizer contributed approximately 37% to incremental rice production and 62% to incremental rice yields.

It was estimated that doubling nitrogen efficiency for rice would have permitted a savings of fertilizer equivalent to approximately US $450 million or would have generated additional rice output valued at approximately US $4 billion during 1965-75. This clearly demonstrates that improving nitrogen use efficiency through research can result in substantial economic returns with implications for food supply and foreign exchange savings.

Another project dealing with the issues in the evolution of fertilizer price policy was completed, and the results were presented at the 17th International Conference of Agricultural Economists, Banff, Canada, September 3-12, 1979. The paper discusses the role of fertilizer prices in expanding fertil-

izer use and prospects for fertilizer price stability. It was emphasized that there exist large inefficiencies in fertilizer production, marketing, and use in developing countries. This provides significant opportunities and large potential for lowering fertilizer prices through improvements in fertilizer production efficiency, fertilizer marketing efficiency, and fertilizer use efficiency. Consequently, fertilizer policies need to be designed to reduce these inefficiencies rather than manipulating prices through fertilizer subsidies alone.

Two presentations were made at FAO's invitation at conferences organized by FAO. First, the implications of fertilizer subsidies for the small farmer were discussed at the "FAO Workshop on Price and Income Supports and Their Impact on the Small Farmer," held in Bangkok, Thailand, January 22-27, 1979. Second, principal fertilizer policy issues facing the fertilizer sector in Africa were discussed at "FAO/Fertilizer Industry Advisory Committee Seminar on Fertilizer Pricing Policies and Subsidies," held in Dakar, Senegal, October 8-13, 1979. The participation in various conferences provides opportunities not only to report on the results of various ongoing IFDC research studies but also to interact with experts from different international organizations and national policymakers dealing specifically with fertilizer.

RICE POLICY STUDIES

Fertilizer policy is one of the five sub-projects of the International Food Policy Research Institute (IFPRI)/IFDC/IRRI collaborative project on Rice Policies in Southeast Asia. The project is coordinated by IFPRI. The main objective is to analyze the role of fertilizer policies with respect to rice production and rice price stability. The completed project proposal was divided into two phases. Phase I of the project was initiated in collaboration with researchers and advisors in the national institutions in each participating country. This phase of the fertilizer component of the project involves personnel from the Ministry of Agriculture in Indonesia; faculty from the University Pertanian Malaysia, Serdang; personnel from the Bureau of Agricultural Economics in the Philippines; and faculty from the Chulalongkorn University in Bangkok, Thailand.

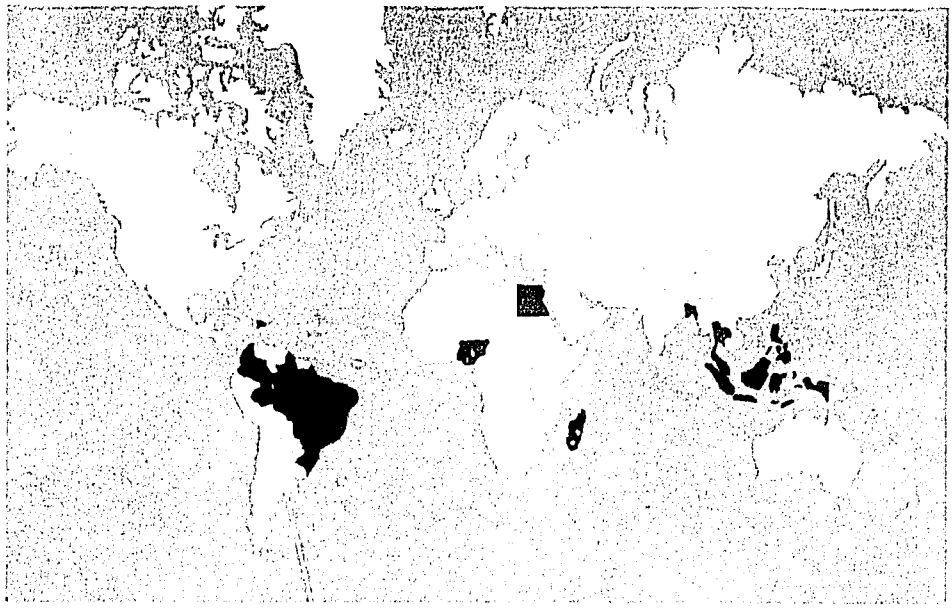
Preliminary country-specific Phase I reports were discussed at a UNDP financed workshop held at IRRI in May 1979. These reports will be published during 1980, and Phase II research dealing with more in-depth analysis of specific policy issues will be initiated. This project is probably the first of its type that involves researchers from three international institutions and four countries with a particular focus on the public policies that influence supply, demand, and trade aspects of rice. The results will provide economic implications for alternative policy scenarios and thus are expected to be extremely useful to policymakers in each of these countries.

GLOBAL FERTILIZER STUDY

In addition to these studies with a national focus, a new project dealing with the economic analysis of the fertilizer sector at the global level was conceived during 1979. The purpose of the project is to develop information with respect to (1) the performance of the fertilizer sector from 1955 to 1980, (2) the demand and supply prospects of fertilizers from 1980 to 2000, (3) needed fertilizer policies at the national level, and (4) the role of international institutions dealing with fertilizer research, financing, technical assistance, and market intelligence. The project proposal was completed. The project, a joint undertaking between IFDC and the Institute for Agricultural Market Research of the Agricultural Research Center, Braunschweig-Voelkenrode, West Germany, will be implemented in two phases. Phase I deals with nitrogen, and Phase II deals with phosphate, potash, and sulfur.

Technical assistance provides developing countries with solutions to fertilizer-related problems that are unique to their situation.

Technical Assistance



TECHNICAL ASSISTANCE COUNTRY INVOLVEMENT

Bangladesh
Brazil
Colombia
Dominican Republic
Egypt
Guyana
Indonesia
Madagascar
Malaysia
Nigeria
Philippines
Singapore
Thailand

Technical assistance plays an important role in IFDC programs. Through selective response to requests from developing countries to help solve fertilizer problems, IFDC staff are better able to identify problems that are of concern to institutions in developing countries and are within the capabilities of IFDC and consistent with its overall mission. By responding to these requests, IFDC is able to develop programs that reflect the immediate as well as the long-term needs of the developing country. Of equal importance, these programs establish a developing country's confidence in IFDC to work on problems relevant to their needs and to facilitate the transfer of new and/or improved technology relevant to their long-term development.

Global

MINI-NITROGEN PLANT

Some developing countries have hydroelectric potential but are not industrially advanced enough to construct fertilizer plants to use it. Small nitrogen fertilizer plants operated from run-of-stream hydroelectric plants could have application in the hills of Nepal, the eastern slope of the Andes in South America, and parts of central Africa. Nitrogen fertilizer could be produced and used in areas where imported fertilizers are so expensive that they are not currently used at all.

Under sponsorship of the National Science Foundation, a U.S. firm designed a fertilizer plant of 1,000 tons per year, based on hydrogen from the electrolysis of water and nitrogen from air liquefaction. The plant would operate on wind-generated electric power. It appears that this design could be modified to use the continuous electric supply available from hydroelectric generation. IFDC has proposed that this design be used for fertilizer manufacture in Nepal. Calculations indicated that the fertilizer produced would be competitive in cost with imported urea. Work on this concept is continuing.

WORLD FERTILIZER STUDY

At the request of United States Agency for International Development (USAID), IFDC, with the cooperation of TVA, made a world fertilizer study that was completed and a report published in March 1979. The goal of the study was to provide high-level governmental planners and decisionmakers with current information on world fertilizer production, consumption, and trade. Demand projections were included.

Some findings of the study are as follows:

1. Potential world fertilizer production (as nutrients) will increase from 98 million tons in 1977 to 141 million tons by 1985.
2. Developing countries will produce almost one-fourth of the world's fertilizer by 1985 as compared with their producing one-tenth of the world's fertilizer in 1969.
3. World fertilizer consumption will increase from 95 million tons of nutrients in 1977 to more than 135 million tons in 1985.
4. Fertilizer consumption will increase 4.6% during the next 8 years as compared with a 6.0% growth rate during the past 8 years.

Africa

AFRICAN FERTILIZER CENTER PROPOSAL

Africa has ample identified natural resources, with the possible exception of sulfur, to be self-sufficient in the production of fertilizers. A rationalized fertilizer industry is needed if each country is to fully develop its potential for food crop production.

The Scientific Technical and Research Commission of the Organization of African Unity (OAU) requested IFDC to prepare a project proposal for the establishment of an African Fertilizer Center. The proposal was submitted to the Executive Secretary of OAU during the third quarter of 1979. A series of discussions has been conducted with OAU, member states, and potential funding agencies regarding the center's concepts, organizational structure, function, and location.

The long-range goal of the proposed center is to help make African countries self-sufficient in the production of food through the improved use of fertilizer.

The five broad functions of the proposed African Fertilizer Development Center are:

1. To identify and propose solutions to the constraints that restrict fertilizer consumption in the African context;
2. To make the governments of the respective countries aware of the constraints and proposed solutions;
3. To improve the training capability for developing personnel with specialized expertise to assist the fertilizer industry in member countries;
4. To develop professional cooperation among fertilizer-related organizations to aid in developing the fertilizer industry in each country; and
5. To seek financial assistance for fulfilling the center's objectives and developing the fertilizer industry in member countries.

The proposal stipulates that the fertilizer center is to be an autonomous organization with a director and co-director responsible to the founding organizations. A technical advisory committee will be selected to guide and monitor the center's activities. A site selec-

tion committee was proposed for screening possible locations. Discussions are continuing.

EGYPT

Study Program for Engineers

As part of IFDC's continuing effort to help solve problems that are of immediate concern to institutions in developing countries, four engineers from the Egyptian National Research Center (ENRC) spent 1 to 2 months at IFDC. ENRC is studying selected phosphate deposits in Egypt, currently in laboratory scale, with plans to continue the studies in pilot scale. Funding for the study program was provided by USAID with coordination through the National Academy of Sciences. The program consisted of on-the-job training and visits to beneficiation plants and laboratories at IFDC and other locations in the United States.

Laboratory-scale equipment is being provided to the project to strengthen the research capability of ENRC. Assistance was provided in equipment selection for phosphate beneficiation and chemical processing. Additional help is expected to be provided next year.

NIGERIA

Fertilizer Marketing Study

In late 1979, the Federal Republic of Nigeria commissioned IFDC to undertake a fertilizer marketing study in Nigeria that would assess the present distribution system, identify constraints to the supply and consumption of fertilizers, and recommend a marketing system designed to consume and deliver in the domestic market the full production of a proposed new nitrogen plant at Port Harcourt.

The proposed nitrogen plant is scheduled to produce 1,000 tons per day of ammonia that will be used to provide 590,000 tons of urea per year. The 75,000 tons of SSP produced by the Kaduna superphosphate plant is also to be marketed by the new marketing system.

In 1979, Nigeria had one of the lowest consumption rates of nutrients per ha of crop land in the world, consuming only 3.1 kg per ha compared to a world average of 68 kg per ha. In 1979, fertilizer consumption in Nigeria was 85,000 metric ton (mt) of nutrients, 46,000 tons of nitrogen, 28,000 tons of phosphate, and 11,000 tons of potash, or 263,964 tons of fertilizer product. The development of a marketing system that could successfully market the entire production of the proposed plant was a challenge to IFDC.

For the study, IFDC assembled an international team whose selection was based on past experience in developing successful marketing systems in other tropical countries; the team members had a combined total of more than 35 years' experience in Nigeria alone.

Points implied in the terms of reference and included in the study were an assessment of (1) the role that the Federal Superphosphate Fertilizer Plant at Kaduna can play in supplying superphosphate, (2) the agronomic research required to support the recommended system, (3) the requirements for essential crop production inputs other than nitrogen, phosphate, potassium, and sulfur, (4) the roles of government agencies in support of the recommended marketing system, and (5) the economic and social environment of the farmer.

Data for the study were obtained by the team in Nigeria during the period November 4 through December 12, 1979. To obtain these data, the team visited the Ministry of Agriculture in each of the 19 states, the Federal Fertilizer Procurement and Distribution Unit of the Federal Ministry of Agriculture and Rural Development, The Federal Department of Agriculture, Federal Department of Rural Development, and twenty-seven other organizations that are concerned with the production, marketing, and research of fertilizers.

The study team scheduled 4.5 months for the field survey, analysis of data, and formulating the final recommended marketing system. The team found the following constraints to fertilizer consumption in Nigeria that the new system is to overcome.

1. A timely supply of fertilizers at the farmer level is unavailable.
2. Fertilizer marketing system is poorly structured and inadequate.
3. Farmer educational and promotional programs on fertilizer use are inadequate.
4. Research studies to produce precise fertilizer recommendations for optimum crop yields in each farming area based on soil and climatic conditions are lacking.
5. The present fertilizer transporta-

tion system is expensive and inadequate.

6. The communication system for managing a marketing system is inadequate and must be restructured.
7. The purchasing power of the farmer is low and needs to be improved.

The principal food grain production area lies within the savanna area that covers the northern two-thirds of the country. This area is favorable for the production of sorghum, millet, groundnuts, cotton, sugarcane, maize, cowpeas, beniseed, and wheat. Soil fertility research has been carried out with relatively low levels of inputs; however, nitrogen and phosphate have been found to be profitable, and responses to potassium have occurred in the southern part of Nigeria. Crop production research indicates that yields can be increased by 100% or more for most food crops with the adoption of improved agronomic practices and fertilizer use.

The recommended marketing system, when implemented, will be able to meet its target of marketing 1,057,000 tons of fertilizers per year in Nigeria by 1992. The farmers and consumers of Nigeria will greatly benefit from the new marketing system. The final report will be completed in early 1980.

MADAGASCAR

Economic Study of Ammonia/Urea Project

At the request of the Overseas Private Investment Corporation (OPIC), U.S. Department of State, the economic viability of a proposed ammonia/urea plant in Madagascar as an alternative nitrogen fertilizer supply source to current imports was studied. The plant, with an annual rated capacity of 90,000 mt of urea and with 1981 as the targeted first year of operation, was to be sited at Tamatave and would utilize naphtha and fuel oil from a nearby local refinery as feedstock and process/utility fuel, respectively. The objective of the study was to aid OPIC in its decision of providing investment insurance for the U.S. portion of the project loan. The project was to be financed through long-term borrowings from banks in the United States, Canada, Austria, and Belgium and by equity contributions from the Government of Madagascar (GOM) and a U.S. firm.

The total domestic consumption and export potential of Madagascar-produced urea for fiscal years 1981-85 were projected, and the costs of imported urea and domestically produced urea (in 1981 constant U.S. dollars) were estimated. Additionally, potential benefits of the proposed project in terms of foreign exchange savings and employment of production facilities for Madagascar were estimated. To evaluate comparative economics of domestically produced and imported urea, average delivered costs to in-country fertilizer-using areas for 1981-85 were used as a basis.

The study concluded that it would appear more economical for the GOM to continue to import fertilizer urea rather than to produce urea at the proposed plant.

Asia

ASEAN REGIONAL FERTILIZER ECONOMY PLANNING STUDY

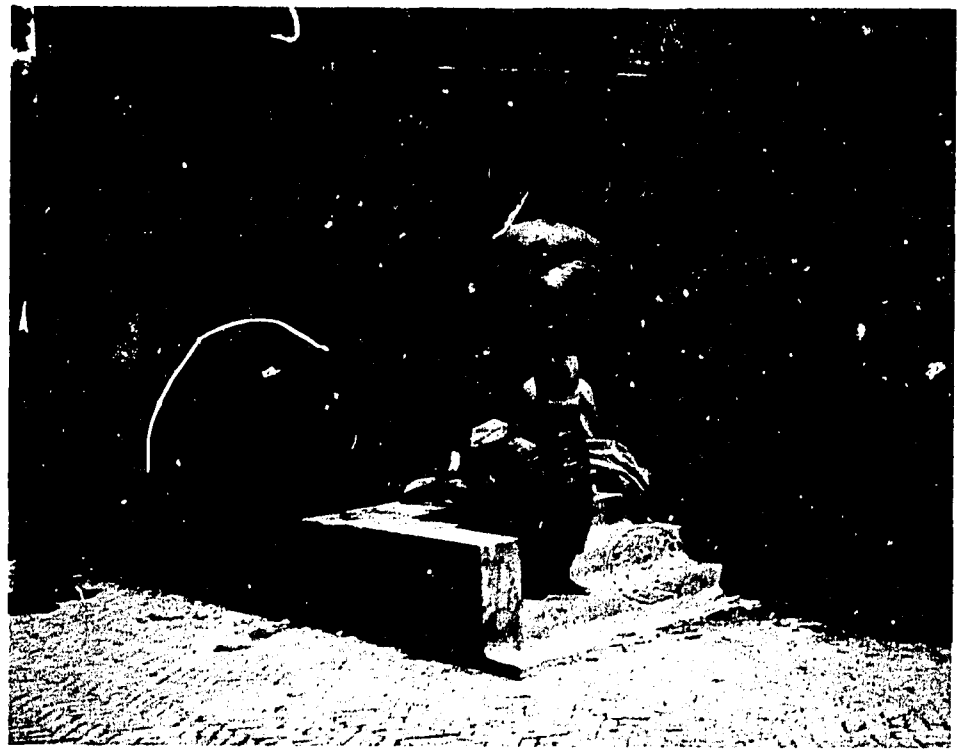
Often, cooperative production and trade agreements among countries can result in monetary savings to each partner. But there generally exists a strong desire within individual countries to develop at least some degree of self-sufficiency, particularly with a strategic material like fertilizer. This study investigated the economic implications of alternative fertilizer supply strategies for the ASEAN countries—Indonesia, Philippines, Malaysia, and Thailand.

An initial study of the ASEAN regional fertilizer economy was conducted jointly by The World Bank and IFDC in 1975. A new dynamic model of the regional fertilizer economy was developed using linear programming technique. Input was generated in 1977-78. Data were collected in collaboration with country representatives; program solutions were obtained; a report was prepared; and discussions were held in each country. Input data were revised, and in 1979 work was initiated to update the study based upon mid-1979 input data.

The study considers economic aspects at the regional and country level of some alternative supply strategies that range from complete cooperation within the region to a degree of self-sufficiency for each country. The model is used to calculate the least-cost solutions to supply the projected fertilizer needs of the ASEAN region under different supply strategies. Current and planned expansion of production facilities, consumption of

nitrogen, phosphate, and potassium products in 17 separate market regions, and transportation relationships (intercountry, intracountry, and world markets) are considered in the model.

The study will offer some insight about the effects of different supply strategies upon the fertilizer economy of the countries and provide a basis for decisionmaking in the future development of fertilizer supply sources for the region.



Technical assistance to Bangladesh includes recommendations for improving the fertilizer transportation system.

BANGLADESH

Marketing and Distribution Assistance

In early January 1979, IFDC entered into a contract with the Bangladesh Agricultural Development Corporation (BADC) to provide fertilizer distribution and marketing consultancy services. The contract, financed by USAID, was originally for 15 months but was extended to an 18-month contract. Plans are currently underway to again extend the contract through June 1981.

The IFDC-BADC consultancy contract is part of USAID/ Bangladesh Fertilizer Distribution Improvement Project that has the goal of increasing food grain production, especially among small farmers, through the increased use of fertilizer on an equitable basis to be achieved by removal of fertilizer supply limitations and relaxation of fertilizer distribution and marketing related constraints. To this end, a New Marketing System was introduced to relieve distribution and marketing constraints by improving the effectiveness of private wholesalers and retailers. Early in 1979, IFDC outposted two of its resident consultants in Dacca to assist BADC; they were supported by short-term specialists from IFDC Headquarters.

The IFDC consultants assisted BADC with preparation of the monthly newsletter, the principal document used in programming fertilizer imports and reporting monthly sales, inventory, and the warehousing status. Technical advice was given on import prices and alternatives. A review of the incidental costs of the fertilizer scheme was performed. The New Marketing System for fertilizer distribution was monitored and studied, and changes were suggested to BADC. The need for fertilizer training in light of the increasing wholesale activities of fertilizer dealers was stressed.

Assistance was provided to improve fertilizer movement contracts and shipping agent contracts. National projections of fertilizer use, imports, and warehousing were made and discussed and the need for a central fertilizer inventory control system stressed. A national fertilizer transport movement plan was drawn up for domestic production and imports. Participant training was provided in the United States and India.

BADC's sales to dealers have increased yearly since 1975-76. Actual sales are shown in Figure 8 through 1978-79. Sales for 1979-80 are estimated to be approximately 854,000 product long tons. Sales for 1980-81 are currently projected by IFDC consultants at close to 1 million long tons of product.

The agronomic fertilizer use potential for Bangladesh has been developed by IFDC consultants. The total agronomic potential of fertilizer use is currently placed at 3,985,254 product long tons. Sales for 1979-80 show that BADC's sales to dealers in 1979-80 will be approximately 21% of the national agronomic potential. IFDC is confident that dealers, with BADC assistance and with appropriate changes in government policy, can meet the challenge of increasing sales to farmers and of removing the gap between actual sales and the fertilizer agronomic potential.

Fertilizer Equity Study

In September 1979, IFDC signed an agreement with the BARC to jointly conduct a field investigation for equity of fertilizer use in Bangladesh. The funding for this study is provided through the IFDC-BADC contract.

The Fertilizer Equity Study (FES) was designed to assess the degree to which chemical fertilizer has been distributed to and used by selected farmer groups targeted as beneficiaries of the USAID/ Bangladesh Fertilizer Distribution Improvement Project. The objective of the FES is to measure the impact of the Fertilizer Distribution Improvement Project on (1) owner-cultivators of various farm sizes, (2) tenant-cultivators including landless sharecroppers, and (3) hired agricultural labor. This measurement of impact will be made using farm survey data on numerous variables including (1) numbers of those using fertilizer and intensity of use, (2) prices paid for fertilizer, (3) use of credit, water, High-Yielding Variety (HYV) seed, and other inputs complementary to fertilizer use, (4) changes in output and employment arising from fertilizer use, and (5) changes in income and returns to labor from crop production arising from fertilizer use.

The field work of this study started during September with the recruitment and training of a field staff. A questionnaire based on the previous fertilizer adoption/demand questionnaire was developed jointly by BARC and IFDC personnel and approved by the Coordination Committee for the FES.

The study is based on a sample survey of approximately 1,200 randomly selected cultivators within and outside the area of the distribution project. Presently, field surveys are going on at 10 locations in 10 districts (one in each district). The work will be extended in the early spring of 1980 to cover another 5 or 6 locations in the remaining 10 districts of Bangladesh.

The first equity report on the T. Aman crop will be submitted by April 30, 1980. A second brief report covering the complete crop cycle will be due by December 31, 1980. A third report covering a full crop cycle ending with the 1980 T. Aman crop will be due by April 30, 1981. An additional benefit of this study should be a continuation of the increasing capacity within Bangladesh to conduct similar studies on a continuing basis.

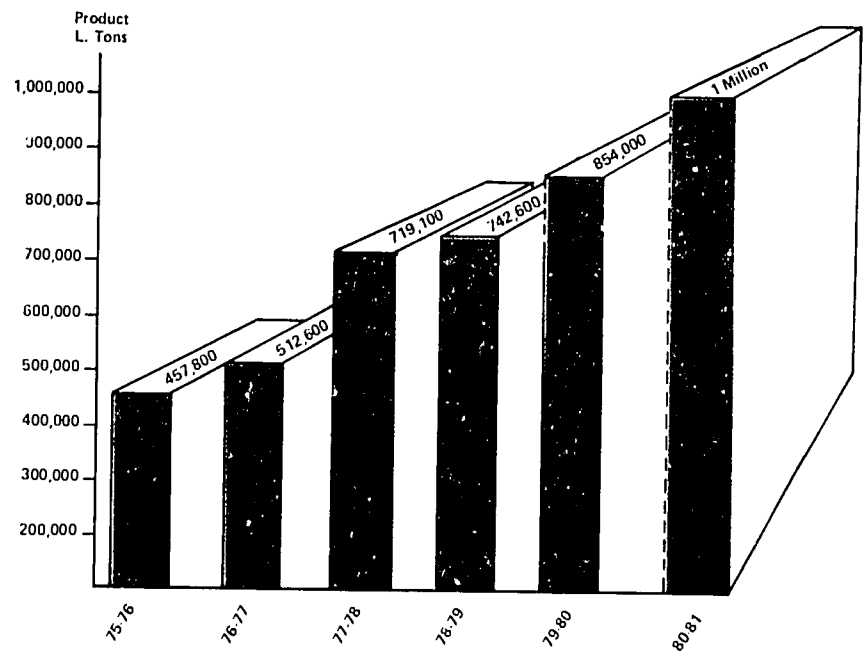


Figure 8. BADC Actual Fertilizer Sales to Dealers 1975-76 Through 1978-79 and Projections For 1980-81.

Fertilizer Sector Study

The Government of Bangladesh requested the International Fund for Agricultural Development to finance a Fertilizer Sector Study. IFDC staff members took part in a preparation/appraisal mission that visited Bangladesh from July 23 to August 9, 1979. The findings of the mission were discussed with the government, USAID, and Asian Development Bank officials.

The project, as identified, was aimed principally at increasing the access of the poor, small farmer to fertilizer and related inputs by, among other things, (1) increasing total fertilizer supply and removing supply constraints and (2) increasing local availability of fertilizer in the project area of Kushtia, Faridpur, and Jessore.

The IFDC consultants prepared fertilizer demand projections for the project area and identified the wheat crop as being the major source of agricultural growth and therefore of fertilizer demand in the project area. The fertilizer and imported wheat seed needs for 1980 and 1981 were estimated and costed, and the value of these inputs was included in the sector credit.

A lack of fertilizer storage facilities was identified as a constraint on the efficient supply of fertilizers. The IFDC consultants quantified the need and designed various low-cost structures that could be built quickly under local conditions of skilled labor and material supply shortages. Economic analysis showed the soundness of the design proposals.

The fertilizer marketing and related extension activities also were identified as constraints due mainly to inadequate staff training and lack of mobility. Measures to correct these deficiencies were proposed and costed for the sector credit.

Finally, because of the major activity in small farm support and development projects in Bangladesh, IFDC proposed that an in-depth baseline survey and continuous monitoring of all factors affecting the economics of the small-farm operation were needed, not only in the project area but in all areas of currently restricted development.

INDONESIA

PUSRI Urea Granulation Project

P.T. PUSRI is converting the finishing section of their oldest urea plant (PUSRI I) from prilled urea production to the production of granular urea. IFDC has been involved with this project since its inception. As part of its overall technical assistance agreement with PUSRI, IFDC provided three engineers for review of the engineering, design, and layout work prepared by PUSRI engineers.

In total, about 90 drawings were reviewed during a visit to the installation at Palembang. In general, the engineering, design, and procurement phases of the project were going well. The IFDC representatives prepared a list of suggested modifications which could be considered in the main design details to make the plant more flexible and provide greater ease of operation. Most of the suggestions dealt with placement of inspection ports, design of chutes and ducts, operation of scrubber systems, and operation of the recycle system.

Orders have been placed for all major items; however, delays in delivery of several items, the major one being the rotary cooler, probably will result in delay of completion of the plant until mid-1980. Demolition work on the prilling tower was well underway, and construction of pilings and foundations was projected for late March and began as scheduled.

In April 1979, IFDC provided one engineer to accompany an engineer from PUSRI to inspect the completed pan granulator at the J. A. Lanvermeyer fabrication works in Melle, Federal Republic of Germany. The pan granulator was assembled and tested, and an inspection report was submitted to PUSRI. The overall impression of the pan granulator was that design and construction was of high quality and no flaws in design, materials, or workmanship were found.

Two representatives from P.T. PUSRI visited IFDC during early 1979. The purpose of their visit was twofold: (1) to review the draft of the operating manual for the urea granulation unit and (2) to obtain information on design of an SCU plant.

The draft copy of the operating manual was reviewed. Conclusions and recommendations were submitted. Additional time was spent in discussing the design, operation, and construction of the SCU demonstration-scale plant at TVA.

The P.T. PUSRI representatives also visited the Ag. Industries Mfg. Company, Columbia, Alabama, which operates the only privately owned, commercial-scale SCU production plant in the United States. During this visit, discussions were held with the plant manager and project engineer.

Urea Granulation Training Course

In August 1979, a 1-month training program for 11 engineers and supervisors from P.T. PUSRI was held at IFDC. The program consisted of both classroom and practical instruction in urea granulation utilizing TVA's pan-granulation process. The purpose of the training program was to prepare a cadre of PUSRI personnel for operation of the modified PUSRI I facility.

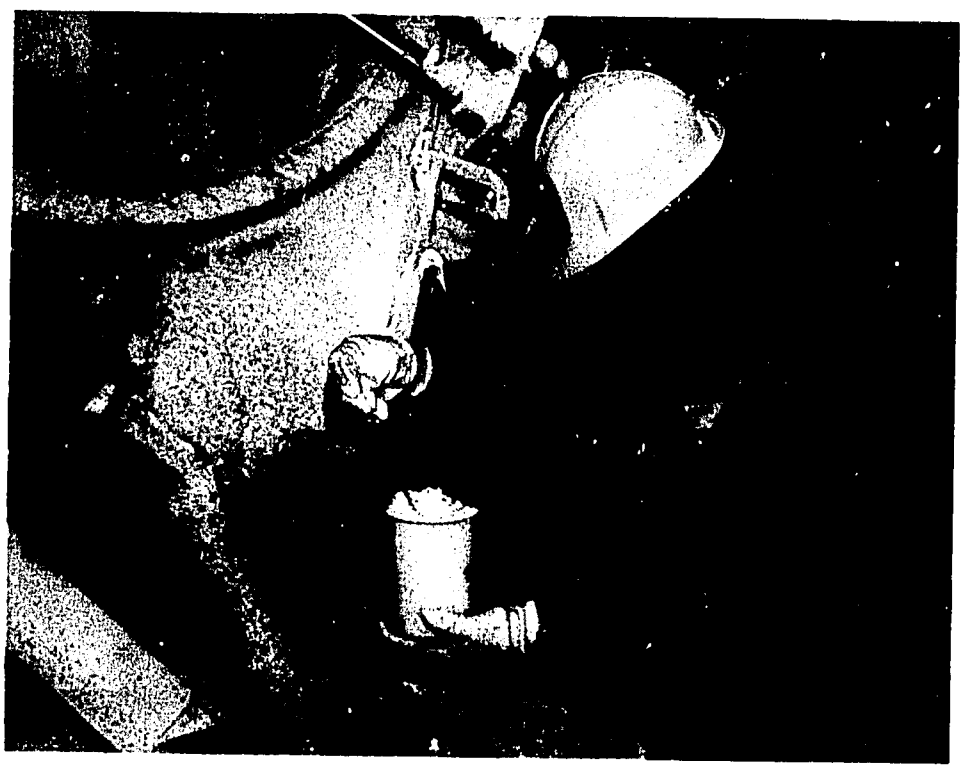
The program was a joint effort of IFDC's Fertilizer Technology and Outreach Divisions. The program ran for 25 workdays consisting of 7 days of classroom instruction, 14 days of pilot-plant operation, and 4 days of plant visits.

During the plant operation portion of the training program, the participants progressed from observing and aiding IFDC staff in plant operation to independent operation of the plant. Each participant had an opportunity to work in every area of the pilot-plant facility and was exposed to every facet of the urea granulation process.

Fertilizer Efficiency Workshop

A workshop was conducted at IFDC Headquarters, September 4 through 21, 1979, to discuss strategies and to prepare a planning document that would lead to a program of improved fertilizer use efficiency for major food crops in Indonesia. Participants included five representatives from the Indonesian Ministry of Agriculture, two from PUSRI, two from IRRI, and numerous staff members from IFDC. The participants prepared a document that outlined an integrated program involving work on soil fertility, socioeconomics, fertilizer production, and marketing needed to improve the efficiency of fertilizer use in Indonesia.

Upon returning to Indonesia, the national participants presented the document to their administrators and obtained the joint approval of the different organizations to implement the proposed program. A workshop will be conducted at Jakarta in early 1980 to present the plan to other senior officials of the Government of Indonesia and to obtain support so that the plan will become an integral part of an overall national effort to increase food production.



PUSRI engineer gains hands-on experience in the production of granular urea.

Engineering input to the workshop identified different projects that are undertaken for the overall program. Projects developed include briquetting (to produce materials for specific placement studies), bulk blending (to provide materials for agronomic testing), and future production of cogranulated urea-phosphate rock, urea-ammonium sulfate, or urea-based nitrogen-phosphate-potassium materials.

Important aspects of the marketing component include the introduction of granular urea and the evaluation and possible introduction of briquetted urea. Included will be a study of the handling, distribution, and farmer acceptance of these materials. The effectiveness of the present fertil-

izer distribution system will also be evaluated.

Proposed soil fertility work includes investigations on nitrogen loss mechanisms, sulfur transformations in soils, and the relative efficiencies of nitrogen, phosphate, and sulfur fertilizers as affected by source, management practices, crops, soil properties, and climate. Also included are surveys to better define areas of nutrient deficiencies, to introduce improved fertilization practices to farmers, and to evaluate and disseminate information on fertilizer efficiency.

The proposed socioeconomic component of the program includes research in five areas—fertilizer policy studies, demand and supply studies, economic evaluation of fertilizer sources and application, socioeconomic constraints to fertilizer use, and socioeconomic consequences of increased fertilizer use efficiency.

The program is expected to benefit all people of Indonesia by leading to increased food production through more efficient use of fertilizer.

MALAYSIA/SINGAPORE

Process Development and Technical Assistance

IFDC has an interest in working on technology for granulating urea-based fertilizers. Behn, Meyer & Company of Singapore requested IFDC to develop a process for the production of special nitrogen-phosphate-potassium products that would be suitable for aerial application on oil palm and rubber estates in Malaysia. This specialized market required that a single granular fertilizer contain nitrogen, phosphate, potassium, magnesium, and sulfur as nutrients. Rock phosphate was preferred as the major source of phosphate, and large granules that would be stable in the humid climate and suitable for aerial application were needed. Once applied, the granules were required to disintegrate rapidly.

After much pilot-scale experimentation at IFDC Headquarters, acceptable products were made. The acceptance of the products was confirmed by shipping material to Malaysia where it was successfully stored and applied to oil palm and rubber plantations using airplanes. A representative from Behn, Meyer & Company assisted IFDC staff during the pilot-plant test program to gain experience in granulation techniques and to begin making plans for the design and construction of a commercial-scale plant. The plant is now in the design stage and is expected to be operational in early 1982. IFDC is serving as technical consultant to the project, which is developing as a joint venture between Behn, Meyer & Company, the Development Bank of Malaysia, and the Federal Land Development Authority of Malaysia.

THAILAND

Strategy for Fertilizer Development

Thailand is a major exporter of food. The level of these exports has declined in recent years. Fertilizer use is low, but the potential for substantial increases is great. However, Thailand lacks a basic fertilizer industry, even though it has the necessary raw materials to produce large quantities of nitrogen and perhaps commercially exportable potash reserves.

Following consultation with officials of Thailand's National Committee on Fertilizer and Pesticide Industry Development (NCFPID) and The World Bank,

Technical assistance to Thailand can benefit all peoples of Thailand, particularly the small farmer.

IFDC, early in 1979, entered into an agreement with these organizations to jointly fund and engage in a study having the general objective of formulating, on a prefeasibility basis, an overall short-term fertilizer strategy to better serve the fertilizer requirements of Thai agriculture. The study, as structured by IFDC, was designed to characterize the development of the Thai fertilizer sector in terms of past, present, and future supply and demand factors as well as the marketing and distribution resources required to provide the farmer's growing fertilizer needs. IFDC coordinated this tripartite effort.

The in-country data gathering phase of the study was implemented during the period March 1 to April 5, 1979. Data analysis, evaluation, and report preparation were carried out at IFDC Headquarters. A draft of the report was reviewed by Thai officials and a World Bank representative at IFDC Headquarters early in September. The final report was submitted to the Thai NCFPID and The World Bank in October, and an oral presentation was made to the NCFPID in Bangkok in December.

Fertilizer demand has increased threefold in Thailand in the past decade; growth has been particularly strong since 1975. Apparent consumption in 1978 was estimated at 965,000 mt of product containing 339,000 mt of nutrients which included 168,000 mt of nitrogen, 134,000 mt of phosphate, and 37,000 mt of potash. Rice accounts for about 50% of total fertilizer use, upland crops about 30%, and trees, fruits, and vegetables the remainder. Based on historical and anticipated trends in the relationship between crop and fertilizer prices, the development of irrigation, and availability of credit, 1985 fertilizer consumption was projected at 260,000 mt of nitrogen, 190,000 mt of phosphate, and 60,000 mt of potash.

Thailand has relied almost completely on imports to satisfy its fertilizer demand. In 1978, fertilizer imports totaled about 846,000 mt; c.i.f. value was in excess of $115 million. However, the recent discovery and impending development of natural gas reserves in the Gulf of Thailand give rise to the potential for producing ammonia and ammonia-based nitrogen fertilizers. Potash exploration programs have discovered large bodies of carnallite but only limited showings of sylvinite, the preferred raw material source of potash. Additional drilling tests will be required to confirm the possible presence of a commercial sylvinite ore body. Phosphate rock deposits are small and of limited commercial appeal.

Thailand's 1985 demand for fertilizer nitrogen is sufficient to justify the construction of a 1,200-mt-per-day ammonia plant, providing that the recommended feasibility study confirms that the project is economically viable. Based on the potential availability of ammonia, various fertilizer production schemes were developed including the production of urea, nitrogen-phosphate, and nitrogen-phosphate-potassium fertilizers of the types deemed necessary to meet Thailand's future crop needs. Capital and production cost estimates were prepared for each of the alternative supply strategies.

Recommendations for improving Thailand's fertilizer marketing and distribution system included reducing the number of grades sold; increasing the number of retail outlets; improving transportation, storage, and handling facilities; strengthening the fertilizer control law; and improving extension, demonstration, and farmer education programs. A preproduction seeding program was outlined to acquaint extension personnel, distributors, retailers, and farmers with the properties and use of new or different types of fertilizer that may be produced at a proposed fertilizer complex to be built in Thailand.

The report gives Thailand a good basis from which alternative strategies that fit national policies may be selected for detailed study and development. The study can benefit all peoples of Thailand through the assistance offered toward the development of a national fertilizer sector.

Latin America

BRAZIL

Technical Assistance to the Centro de Estudos de Fertilizantes

The Centro de Estudos de Fertilizantes (CEFER) is a relatively new organization established as a unit within the Instituto Pesquisas Technologicas (IPT) located in Sao Paulo, Brazil. CEFER was formed to do research and development on fertilizers for Brazil. CEFER is in many ways a similar kind of organization serving Brazil as IFDC serves the whole of the developing world.

In mid-1979, IPT/CEFER contracted with IFDC to provide

training and technical assistance for the newly formed CEFER staff as well as for the fertilizer industry of Brazil. Two training courses were conducted at CEFER Headquarters.

Training in Fertilizer Quality Control Round Table and Technical Assistance—This work was carried out during the latter half of August. The formal training was conducted during a 3-day period for participants representing the fertilizer industry, universities, and CEFER. An additional 7 workdays were spent providing technical assistance to CEFER and selected industries on an individual basis. To assure a well-rounded approach, IFDC was assisted by representatives from TVA (representing an R&D organization), Purdue University (representing control officials), and USS Agrichemicals (representing the industries point of view).

Physical Properties and Bulk-Blending Workshop—This assistance was carried out during the first 2 weeks of December. The formal training portion of this work was to train CEFER staff and selected fertilizer industry representatives to measure physical properties of fertilizers and to make blends that meet both the chemical and the physical standards to assure the consumer (farmer) that he is buying a uniform, high-quality, and effective fertilizer. There were 12 participants in the formal training course. The team then consulted with CEFER and the fertilizer industry on an individual basis to help them select equipment and develop methodology to rapidly measure physical properties and to improve their final blended products. A TVA chemist and a retired TVA chemist assisted IFDC in the conducting of this training and technical assistance.

IFDC provides technical assistance and training support to CEFER.

Technical Assistance Related to Pilot Plants—IFDC has continuously provided assistance to CEFER in the design and installation of pilot-plant equipment. Two trips were made to CEFER totaling about 2 weeks, and CEFER engineers spent time at IFDC Headquarters on this assignment.

Technical Assistance to Industrias Luchsinger Madorin, S.A.

In late 1979, Industrias Luchsinger Madorin, S.A. (ILM) of Brazil requested assistance from IFDC aimed at improving the overall production efficiency of their large nitrogen-phosphate-potassium granulation complex in Rio Grande, RS. Two IFDC production engineers visited the Rio Grande factory and together with ILM staff developed a plan designed to (1) improve process equipment, (2) optimize formulation and process techniques, (3) train and develop plant technical staff, and (4) decrease process losses and pollution.

Essentially all of the IFDC recommendations have been implemented with many on a temporary basis until appropriate equipment can be designed and installed. As a result of the process and equipment modifications, the production efficiency of the largest of two granulation units was increased about 50%. The effort to further improve the overall efficiency of the factory is continuing. Major emphasis, with a large amount of technical input from IFDC, is now being focused on methods for decreasing process losses and environmental pollution. By the end of 1980, most of the major process and equipment modifications will have been implemented on a permanent basis.

COLOMBIA

Feasibility Study for Development of Phosphate Rock Deposits

IFDC, as part of a consortium that includes the Colorado School of Mines Research Institute, has initiated a feasibility study for the development of Pesca and Sardinata phosphate rock deposits in Colombia. The use of these indigenous phosphate deposits could satisfy part or all of Colombia's domestic needs and possibly provide material for export. This project is a part of IFDC's continuing effort to assist developing countries in making better use of indigenous resources under the specific constraints existing in each country.

IFDC's contribution to the study consists of a market survey and post-beneficiation processing of the phosphate rocks. The market survey to analyze the present demand for phosphate fertilizers in Colombia and to project future demand will be completed in early 1980. Data from the market survey will serve as a guide for the economic evaluation of manufacturing facility capacity in relation to future markets.

The post-beneficiation processing portion of the project will consist of laboratory and pilot-plant studies at IFDC Headquarters, which are to be initiated in mid-1980. The first step in this experimental work will be the production of nominal 30% and 54% phosphate wet-process phosphoric acid from Pesca and Sardinata beneficiated phosphate rock.

DOMINICAN REPUBLIC

Fertilizer Distribution Study for Small Farmers

There is growing concern to ensure that the small landholders fully benefit from increases in fertilizer use. This is particularly true for densely populated areas of developing countries. Under a contractual agreement with Kent State University, IFDC is providing limited funding support and technical assistance to complete a fertilizer distribution study for the Dominican Republic.

The overall objective of the study is to develop information that will assist the Ministry of Agriculture, agricultural research organizations, and the private fertilizer sector in the Dominican Republic in developing a fertilizer distribution system to meet the needs of small farmers in that country. IFDC's responsibilities include consultation on study approach, review of the draft report of the study, assistance in preparation of a joint publication, and organization of an in-country workshop to present study findings and recommendations. The initial draft of the study report is targeted for completion by September 1, 1980.

GUYANA

Shell Beach Lime Project

A large percentage of the agricultural soils in Guyana are low in productivity because of high acidity. No suitable liming material is available commercially to correct this problem.

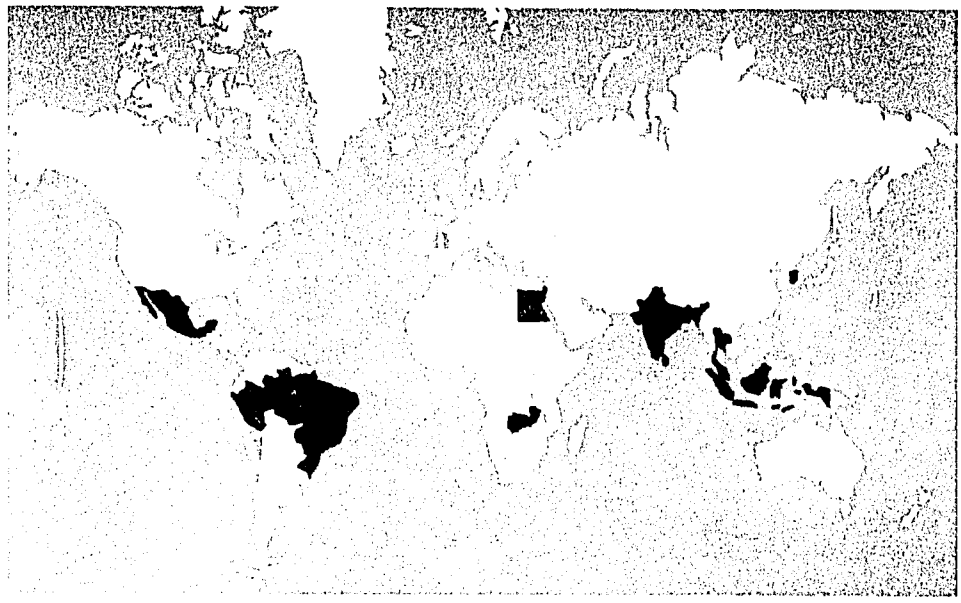
At the request of USAID, IFDC provided one engineer to review the Shell Beach Lime project in Guyana and prepare a scope of service for a feasibility study for this project. The project was discussed with officials from USAID and the Ministry of Energy and Natural Resources, Geology and Mines Department. A trip was made to survey the conditions of the shell beaches.

Shell deposits at the coastline are significant and include one deposit 10 miles or more in length, about 50 yards in width, and an average depth of 11 feet. Another deposit (Kamwatta beach), which reportedly contained 1.5 million tons of shell resources in 1977, was practically nonexistent in 1979 due to severe erosion. Many other beaches appear to be under the same conditions of severe erosion. This erosion is one reason for the feeling of urgency for beginning the shell beach mining project.

A draft scope of service was prepared for review by the USAID staff. USAID requested that IFDC consider performing the feasibility study under the scope of service prepared. IFDC has proposed to provide two engineers, with one engineer as chief-of-party, to develop transport, handling, processing, and storage costs for the shells and crushed product. Consultants have been located for mining and naval considerations. A project proposal was prepared for USAID consideration.

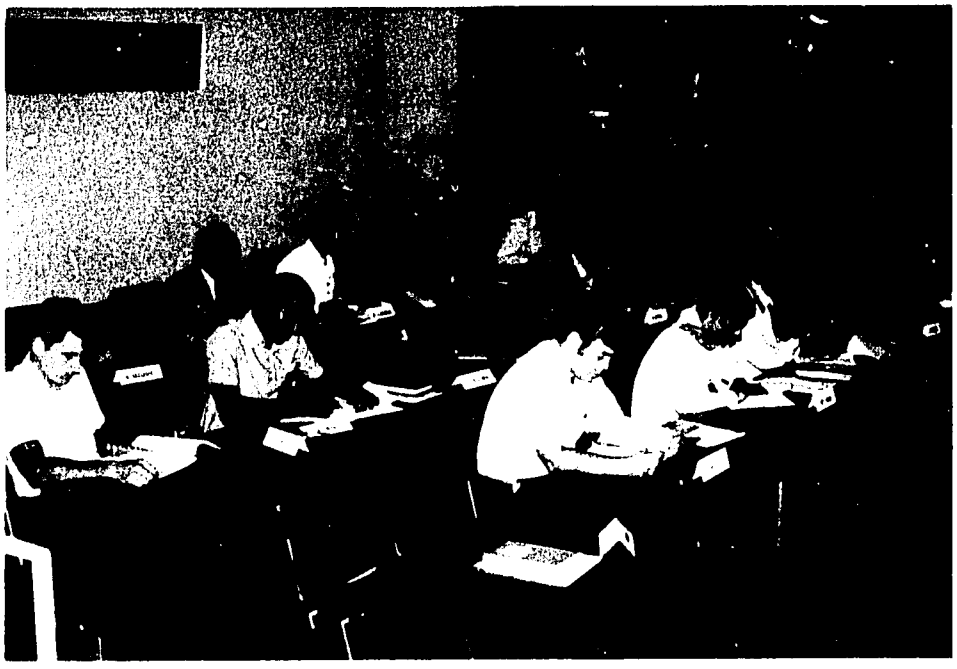
Training

A major constraint to effective evaluation and transfer of fertilizer technology is the scarcity of properly trained manpower at national institutions of developing countries. IFDC recognizes this and has devoted a large portion of its program and facilities toward ensuring that the necessary manpower will be trained and placed in institutions in developing countries interested in working on solutions to fertilizer problems. This training takes the form of developing manpower needed not only to carry out research and development of fertilizers but also in the practical aspects of production, marketing, and use.



TRAINING COUNTRY INVOLVEMENT

Bangladesh
Brazil
Egypt
India
Indonesia
Israel
South Korea
Malaysia
Mexico
Peru
Sri Lanka
Thailand
Zambia



Training is directed toward developing the manpower that is necessary for developing countries to become self-sufficient in agriculture.

Marketing and Distribution

Recognizing the need for developing trained manpower required to man and improve fertilizer marketing systems in developing countries, IFDC has organized since 1977 an annual training course for fertilizer marketing executives at the middle-management level. The 1979 Fertilizer Marketing and Distribution Course was conducted at IFDC Headquarters during August 13 through September 21. Twenty-seven executives involved in fertilizer marketing

in Bangladesh, India, Indonesia, Israel, Malaysia, Peru, Sri Lanka, and Zambia and one expert from FAO participated in the course.

The main thrust of the course was the development of an integrated marketing concept with concentration on product mix, transportation, and distribution systems specifically related to the needs of developing countries. An update of the world fertilizer situation, developing fertilizer marketing plans, evolving fertilizer-related policies, managing the marketing functions, international fertilizer trade, and a review of fertilizer production and technology were some of the areas covered. Twenty-three experts from IFDC, TVA, the fertilizer industry, and universities served as discussion leaders.

Field trips to farms and factories were conducted to study national and international fertilizer production, marketing, and use. The participants also visited the University of Illinois College of Agriculture, Experiment Station, and Extension Service and the Brownstown Illinois Experiment Station.

IFDC staff plus 30 high-level managers from 20 industries and TVA's National Fertilizer Development Center.

Field trips to fertilizer companies in northern Alabama, Tennessee, Kansas, Louisiana, Missouri, and Florida made it possible for the participants to see the fertilizer industry in action and to discuss problems and opportunities with local plant managers.

Evaluation

Three IFDC training programs were evaluated during 1979— (1) PUSRI Granulation Training Course, (2) FERTIMEX Fertilizer Production Training Program, and (3) Training Program on Fertilizer Marketing and Distribution (FMD).

Table 3, reporting on improvements in participant knowledge during the 1979 FMD program, indicates the program's success in increasing participant knowledge about fertilizer. However, Table 3 also makes clear that "marketing and distribution" is the area in which the relative improvement in knowledge is the smallest (44%). This, in part, may be explained by the fact that, on the average, the participants' highest pre-test scores (50%) were in the "marketing and distribution" area. These results indicate that future FMD programs should continue a strong emphasis on "fertilizer basics" as well as include a more rigorous curriculum in terms of distribution and marketing.

Other results from the evaluation of IFDC training programs provide evidence that the programs, in addition to imparting specific skills and knowledge, are also helping participants to broaden their understanding of their roles in the fertilizer sector. This broadened understanding is essential for the many participants who will eventually assume positions of greater responsibility in fertilizer production, marketing, or use.

By providing feedback to program participants as well as to IFDC's training staff and management, training evaluation is assisting in identifying areas in which each

FERTIMEX

Nineteen production and maintenance engineers from Fertilizantes de Mexico (FERTIMEX) attended a fertilizer production training program at IFDC Headquarters from October 15 through December 5, 1979. The program covered all phases of fertilizer production, with major emphasis on process technology, equipment design and selection, and maintenance management. Course faculty included professionals from

FERTIMEX engineers receive training in fertilizer production at IFDC Headquarters.

TABLE 3. SUMMARY OF PARTICIPANT KNOWLEDGE IMPROVEMENT DURING THE 1979 TRAINING PROGRAM ON FERTILIZER MARKETING AND DISTRIBUTION, AS MEASURED BY MULTIPLE-CHOICE EXERCISES NEAR THE BEGINNING (BASELINE) AND END (FOLLOWUP) OF THE PROGRAM

Exercise	Baseline Exercise	Followup Exercise	Absolute Improvement	Relative Improvement	Higher Than 75% on on Baseline	Higher Than 75% on on Followup
	%					
A. Fertilizer basics	37	70	33	89.2	3.7	36
B. Fertilizer products	42	77	35	83.3	11.0	56
Overall (A + B)	39	73	34	87.2	3.7	52
C. Fertilizer marketing and distribution	50	72	22	44.0	3.7	28
Overall (A + B + C)	43.2	72.2	29	67.1	3.7	52

training program can be strengthened. For example, following completion of the 1979 FMD program, the program's instructors were provided with a detailed summary of the participants' evaluations (or perceptions) of the importance of program subject matter areas, value of the information presented by instructors in each area, and quality of the instructors' presentations. This information provides the instructors with a more informed basis with which to identify ways to improve their presentations for the following year's FMD program.

The information gained in evaluating each training program is additionally helpful in identifying areas in which fertilizer-related training is needed as well as some of the questions which need to be further investigated in post-training followup studies.

1980 Programs

The group training programs are divided into three broad classifications covering fertilizer marketing, fertilizer production and technology, and fertilizer efficiency research. Two programs in each of these areas will be conducted during 1980.

FERTILIZER MARKETING

IFDC Fertilizer Marketing and Distribution Program

This program was first conducted in 1977 and has been scheduled annually since that time. With the help of UNDP funds in 1979, improvements in the program were made, and the program was carefully evaluated. As a result of the special evaluation efforts, the 1980 program will be upgraded by (1) improving selection process of participants, (2) improving time effectiveness of field trips, and (3) intensifying the program by adding (a) a section on leadership effectiveness and (b) a computer-based marketing exercise.

Schedule—The program will begin August 11, 1980, and continue through September 19, 1980. The program is designed primarily for middle-level managers and planners responsible for all or part of the marketing chain of fertilizers from the factory or receiving location to farmers. Participants should have a minimum of 1 year of management experience and be identified as being promotable to a higher level management position. In addition, executives in fertilizer promotion and extension work will find the program invaluable.

Location—IFDC Headquarters is the principal venue, with the third week to be in the Corn Belt of the Midwest working from the Farmland Training Institute and the last 3 days in the phosphate industry area of Florida.

Objectives—The three main objectives are to:

1. Increase the participants' breadth of knowledge of the fertilizer

industry from production or procurement to the end user (farmer) with particular emphasis on marketing concepts and the elements of marketing systems.
2. Demonstrate how to analyze, develop, adapt, or modify system(s) to fit conditions in participants' countries to meet the needs of farmers.
3. Develop plans for specific marketing improvements in the participants' work responsibility areas.

Regional Fertilizer Marketing Training Program

This program fills an identified regional need for middle-management executives and promotable junior-level executives.

Schedule and Location—The first regional fertilizer marketing training program for Asia will be held in India during November 17 through December 3, 1980. The Fertiliser Association of India has agreed to cosponsor the program. New Delhi is the venue. Participants will visit ports, fertilizer plants, and other facilities around Bombay.

Objectives—The objectives of the regional fertilizer marketing training program are to:
1. Raise the participants' level of knowledge of fertilizer marketing from points of production/importation to the farm.
2. Expose the participants to the latest marketing techniques.
3. Demonstrate how to analyze, develop, adapt, or modify marketing systems to fit conditions in participants' countries to meet the needs of farmers.
4. Develop plans for specific marketing improvements in the participants' work responsibility areas.

FERTILIZER PRODUCTION AND TECHNOLOGY

Regional Granulation Seminar

Several requests have been received by IFDC from organizations in Asia and Latin America that have difficulties with granulation in various types of fertilizer plants or are building or planning to build granulation plants. Because there have been several requests, the decision was made to conduct regional seminars rather than handle the requests for assistance on an individual basis. The target audience will be plant managers, production managers and supervisors, and others who have production responsibility or involvement.

Schedule and Location—The first regional granulation seminar will be held July 21 through 25, 1980, at the Indra Regent Hotel in Bangkok, Thailand. The Ministry of Industry of the Royal Government of Thailand will cosponsor the seminar.

Objectives—The main objectives of the seminar are to:
1. Provide the participants with a broad overview of traditional and emerging granulation technologies.
2. Provide instruction related to granulation processes, process design, and operating techniques suited to regional climate and requirements.
3. Discuss fundamentals of fertilizer granulation plant organization and management.
4. Address fundamentals of formulation, inventory control, quality assurance and control, safety, and environmental protection.

Maintenance Management Training for Fertilizer Producers

IFDC has conducted an intensive long-term course for junior-level maintenance executives. In addition, several individuals have been trained in certain phases of maintenance. Many requests for maintenance training have not been filled. Consequently, a program in maintenance management will be offered by IFDC in 1980. The program is designed for fertilizer plant managers, maintenance superintendents, maintenance scheduling and procurement engineers, and line maintenance supervisors such as shop foremen.

Schedule and Location—The program is scheduled for November 24 through December 12, 1980, at IFDC Headquarters. Field trips are planned to fertilizer plants in the area.

Objectives—The main objectives of the training program are to:
1. Provide the participants with instruction on the theoretical and practical aspects of organizing and managing maintenance units for a variety of fertilizer production situations.
2. Identify and relate the task of maintenance planning to the realization of factory production goals.
3. Teach the basic techniques and methods used to plan, schedule, and implement maintenance tasks.

FERTILIZER EFFICIENCY RESEARCH

FERITT (Fertilizer Efficiency Research in the Tropics)

In late 1978, IFDC cosponsored with IITA at IITA Headquarters a course called "Fertilizer Use in the Tropics." It was aimed at researchers who work at the field rather than at the institute research level. The program was limited to 25 participants and more than 60 made application for enrollment. With UNDP funding, IFDC will conduct two programs during 1980. The first will be for Latin America and the second for Africa.

Each program is developed and tailored to the requirements of each region and its scientific-institutional level of technical capability. One course is not a repeat of the other. The participants will be practicing agronomists and soil scientists. They will continue working in areas of fertilizer research or related work upon return to their home country. The minimum qualification for admission is a B.S. degree in agronomy or soil science.

Schedule and Location—The first FERITT program will be held from September 15 through October 4 at CIAT Headquarters, Cali, Colombia. CIAT is cosponsoring the program. The second FERITT program will be organized for the east African region and will be held in Kenya. IITA and the University of Nairobi will cosponsor the program. This program will be held in Nairobi from November 24 through December 11, 1980.

Objectives—The objectives of the program are to:

1. Develop and improve skills of research workers in conducting fertilizer trials at experiment stations and farmer's fields.
2. Impart the necessary techniques to process, analyze, and interpret data generated from trials.
3. Improve the participants' ability to test new and conventional fertilizer materials using the latest methodologies in field research situations.

Financial Report

Price Waterhouse & Co.

1200 FIRST NATIONAL · SOUTHERN NATURAL BUILDING
BIRMINGHAM, ALABAMA 35203
205-328-8700

April 4, 1980

To the Board of Directors of

International Fertilizer Development Center

In our opinion, the accompanying balance sheets and the related statements of revenue and expenses and changes in fund balances and of functional expenses present fairly the financial position of International Fertilizer Development Center (IFDC) at December 31, 1979 and 1978, and the results of its operations and changes in fund balances for the years then ended in conformity with generally accepted accounting principles consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Price Waterhouse + Co.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS

ASSETS

CURRENT FUND (unrestricted)

	December 31, 1979	December 31, 1978
Cash	$ 865,523	$ 702,468
Certificates of deposit	607,943	91,109
Short-term investments (Note 1)	210,000	
Amounts receivable from donors (Notes 1 and 2)	4,469,329	3,103,898
Other accounts receivable	616,609	105,248
Advances to employees	33,116	18,360
Supplies inventory (Note 1)	61,418	42,646
Prepaid expenses	27,955	44,120
	$6,891,893	$4,107,849

PROPERTY AND EQUIPMENT FUND (Note 1)

Buildings	$5,605,640	$5,577,896
Equipment	3,524,900	2,949,737
Less - accumulated depreciation	(1,127,991)	(586,518)
	$8,002,549	$7,941,115

LIABILITIES AND FUND BALANCES

CURRENT FUND (unrestricted)

	December 31, 1979	December 31, 1978
Accounts payable	$ 429,657	$ 214,019
Accrued annual and sick leave	499,554	317,286
Deferred revenue (Notes 1 and 2)	4,469,329	3,103,898
Total liabilities and deferred revenue	5,398,540	3,635,203
Fund balance	1,493,353	472,646
	$6,891,893	$4,107,849

PROPERTY AND EQUIPMENT FUND (Note 1)

Accounts payable	$ 9,904	$ 55,474
Contract retainage	21,121	21,079
Total liabilities	31,025	76,553
Fund balance	7,971,524	7,864,562
	$8,002,549	$7,941,115

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES

YEAR ENDED DECEMBER 31, 1979 WITH COMPARATIVE TOTALS FOR 1978

	1979		Total All Funds	
	Current Fund	Property and Equipment Fund	1979	1978
Revenue:				
Grants received (Note 2)	$5,648,525		$5,648,525	$5,806,531
Recovered project costs	1,493,468		1,493,468	254,265
Other	32,707		32,707	21,638
Total revenue	7,174,700		7,174,700	6,082,434
Expenses:				
Research	2,954,375	$ 431,848	3,386,223	2,583,285
Outreach	1,403,681	45,102	1,448,783	1,029,451
General and administrative	1,147,299	64,726	1,212,025	1,020,316
Total expenses	5,505,355	541,676	6,047,031	4,633,052
Excess (deficiency) of revenue over expenses	1,669,345	(541,676)	$1,127,669	$1,449,382
Other changes in fund balances:				
Property and equipment acquisitions from unrestricted funds	(648,638)	648,638		
Fund balances, beginning of period	472,646	7,864,562		
Fund balances, end of period	$1,493,353	$7,971,524		

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF FUNCTIONAL EXPENSES

YEAR ENDED DECEMBER 31, 1979 WITH COMPARATIVE TOTALS FOR 1978

	1979			Total Expenses	
	Research	Outreach	General and Administrative	1979	1978
Personnel compensation (Note 3)	$1,636,784	$ 691,426	$ 622,877	$2,951,087	$2,336,717
Personnel benefits (Note 3)	234,562	119,115	100,651	454,328	368,693
Travel and transportation	236,107	233,280	91,117	560,504	435,314
Occupancy	141,470	70,735	70,735	282,940	197,249
Telephone and telegraph	23,222	13,662	24,027	60,911	120,042
Rental of equipment	14,331	37,948	41,359	93,638	76,228
Contractual research and development	98,462	26,737		125,199	75,955
Other contractual services	199,651	92,521	46,280	338,452	229,262
Institute of International Education fee (Note 3)			64,400	64,400	64,950
Materials and supplies	364,034	115,403	46,504	525,941	279,890
Postage	5,752	2,854	2,900	11,506	7,863
Insurance			36,449	36,449	31,604
Miscellaneous	162			162	72
Total expenses before depreciation and amortization	2,954,537	1,403,681	1,147,299	5,505,517	4,223,839
Depreciation of furniture and equipment and amortization of leasehold improvements	431,686	45,102	64,726	541,514	409,213
Total expenses	$3,386,223	$1,448,783	$1,212,025	$6,047,031	$4,633,052

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

NOTES TO THE FINANCIAL STATEMENTS

NOTE 1 - ORGANIZATION AND ACCOUNTING POLICIES:-

The International Fertilizer Development Center (IFDC) is a non-profit organization incorporated October 7, 1974 under the state laws of Alabama. On March 14, 1977, IFDC was designated as a public international organization by executive order of the President of the United States. The purpose of the organization is to improve fertilizers and fertilizer know-how in developing countries through research and development, technical assistance and training and communications.

In the event of dissolution, the articles of incorporation provide that the residual assets of the organization will be turned over to one or more tax exempt organizations or to the federal, state or local government for exclusive public purpose.

The following is a summary of significant accounting policies:

A. Property and equipment is stated at cost. Depreciation and amortization is computed on the straight-line method over estimated useful lives ranging from three to thirty years.

B. Revenue and expenses are accounted for on an accrual basis. Grants are recorded as receivable for the full amount at the date of the grant. Amounts not clearly designated for a specified program period are deferred in the balance sheet and reflected in revenue when received. Contributions for reimbursable costs are recognized as project costs are incurred.

   Revenue is restricted only to the extent it is to be used in accordance with the purpose of the organization unless otherwise indicated.

C. Short-term investments are stated at cost, which approximates market.

D. Inventories of supplies are valued at the lower of cost or replacement cost, cost being determined on a first-in, first-out basis.

NOTE 2 - GRANTS:-

Grants received are summarized as follows:

	Year ended December 31, 1979	1978
United States Agency for International Development (AID)	$4,000,000	$4,000,000
United Nations Development Programme (UNDP)	2,635,000	
International Development Research Centre (IDRC)	328,956	
Rockefeller Foundation		11,870
Israel Chemicals Ltd.	50,000	50,000
Fertilizer and Pesticide Authority of the Phillipines		10,000
Espindesa		12,000
	7,013,956	4,083,870
Amounts deferred during prior year	3,103,898	4,826,559
	10,117,854	8,910,429
Less - Amounts deferred to future periods	(4,469,329)	(3,103,898)
Revenue recognized in current period	$5,648,525	$5,806,531

The current grant from AID was amended to provide additional funds of $4,000,000 during each of the years ended December 31, 1979 and 1978, and to extend the grant period from June 30, 1979 to June 30, 1980. The amounts of $1,900,000 and $3,070,249 had not been received at December 31, 1979 and 1978, respectively, and were not clearly designated for a specified program period and, accordingly, were deferred. The current amendment to the grant provides funds for basic core/operating costs. The use of funds by area is unrestricted except that equipment purchases may not exceed $3,022,000. Funds not legally committed at the grant expiration date will revert to AID.

The amount of $11,870 from the Rockefeller Foundation grant, the amount of $188,388 from the International Development Research Centre grant and the amount of $2,369,071 from the United Nations Development Programme grant were deferred at December 31, 1979.

NOTE 3 - INSTITUTE OF INTERNATIONAL EDUCATION:

IFDC has a contract with the Institute of International Education (IIE) relating to the employment of personnel of IFDC. All payroll administrative functions are performed by IIE; IFDC makes advances quarterly to fund salaries, employment taxes and fringe benefits.

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As of December 31, 1979
*Left during 1979

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