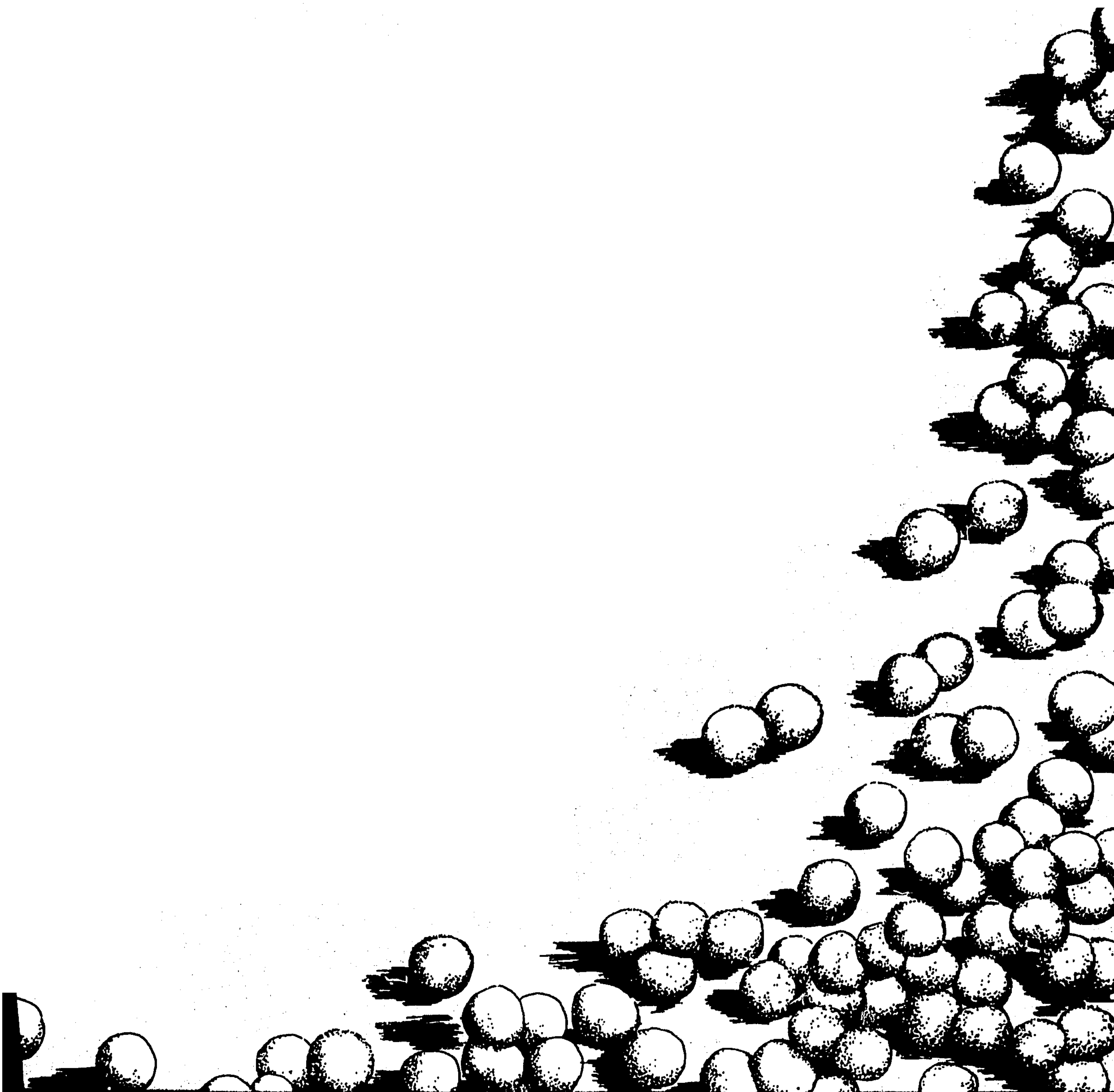
International Fertilizer Development Center

Annual Report 1982



IFDC Profile

Origin and Mission

In 1974 the U.S. Secretary of State in a speech before the General Assembly of the United Nations urged the establishment of an international fertilizer center. This center would focus on the development of appropriate fertilizer technology and related knowledge to increase food production in the developing countries, especially those in the tropics and subtropics.

The center that evolved is today known as the International Fertilizer Development Center (IFDC). On October 7, 1974, IFDC was officially registered in the State of Alabama as a private, nonprofit corporation. On March 1[illegible], 19[illegible], IFDC was designated as a nonprofit, public international organization.

Funding

Planning funds to establish IFDC came from the United States Agency for International Development (USAID) and the International Development Research Centre (IDRC) of Canada. In addition to the continuing support of these two organizations, funds for training, technical assistance, and research and development come from a wide range of national and international agencies.

Location

IFDC is located in Muscle Shoals, Alabama. Its proximity to the Tennessee Valley Authority's (TVA) National Fertilizer Development Center (NFDC) facilitates a sharing of research information and a comprehensive fertilizer library.

Board

Program directions are shaped by a Board of Directors that is fully international and was established in accordance with standards set by the Consultative Group on International Agricultural Research (CGIAR). The members of the Board bring together a wide range of fertilizer expertise.

Staff

The IFDC staff of 191, recruited from 21 countries is both internationally and technically diverse with almost half of this number being chemical engineers, chemists, economists, agronomists, geologists, soil scientists, and sociologists. IFDC is able to conduct unique fertilizer research and development because of three complementary factors: (1) the multidisciplinary structure of the task teams used for research planning; (2) the ability to produce and test experimental fertilizers in laboratories, pilot plants, and greenhouses; and (3) linkages with research institutions around the world.

Framework

IFDC has three divisions—Agro-Economic, Fertilizer Technology, and Outreach. The Office of the Managing Director is the administrative section of IFDC. The Agro-Economic and Fertilizer Technology Divisions are research oriented and focus on the development of products and practices to solve immediate and long-term problems. The Outreach Division is responsible for training information dissemination, identification of problems of regional and global importance, and national field programs of an adaptive research nature.

Facilities

The three divisions are supported by facilities that include laboratories; greenhouses; growth chambers; specialized instruments essential for laboratory research; bench-scale and pilot-plant units used in studies such as beneficiation of ores, acidulation, and granulation of fertilizers; and audiovisual, communications, and word processing centers capable of disseminating information through various media.

Linkages

Since it cannot carry out its mission alone, IFDC cooperates with many international, regional, and national institutions. IFDC has 17 staff specialists posted at a number of these institutions. Technology developed by IFDC scientists and engineers is tested under a wide range of conditions before its applicability is established for specific areas.

Transferring Fertilizer Technology to the Developing World

During the past 7 years, the International Fertilizer Development Center (IFDC) has taken the lead in developing a fertilizer that, if adopted by the rice farmers of the developing world, could put more rice in the mouths of the world's hungry and money in the pockets of the rural poor. This fertilizer, the urea supergranule, produces an average of 30%-50% more rice compared with equal nitrogen rates applied in the conventional manner. This product is the result of concentrated cooperative research between IFDC scientists, the International Rice Research Institute (IRRI), national institutions of major rice-growing countries of Asia, and commercial fertilizer companies.

IFDC transfers this and other fertilizer technology to the developing world through—

Research
National Programs
Technical Assistance
Training

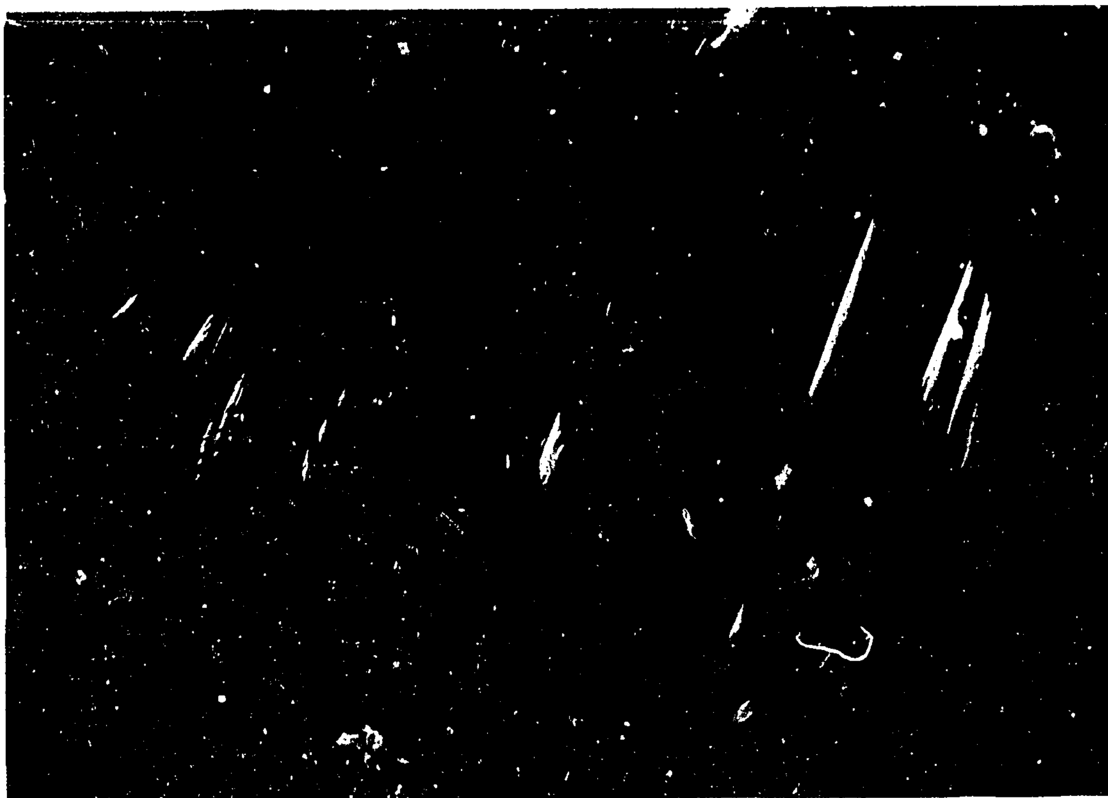


Photo Courtesy of *Times-Daily*—Jon Killen.

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"These colorful flags reflect the international makeup of IFDC's staff."—Donald L. McCune

Management Report

The Year In Review

Some economic planners say that there are not enough resources in the world to go around and never will be, but IFDC does not hold to this negative philosophy. During 1982 the Center's staff continued to explore ways to use the world's resources to produce cheaper, more effective fertilizers. These fertilizers, in turn, will be used to produce more food and consequently create a higher standard of living for people around the globe.

During the past year IFDC continued to evaluate several alternatives to improve nitrogen use efficiency in both upland and lowland crops. Research on urease and nitrification inhibitors to reduce nitrogen losses gained momentum and produced promising results. The briquetting/compacting process, which holds potential advantages for developing countries, received increased emphasis during 1982.

Lowland nitrogen research during 1982 revealed that ammonia volatilization, although extremely important, is not the only nitrogen loss mechanism; research is being initiated to find and quantify the other missing pieces of the puzzle. Upland nitrogen research during the past year focused on other food crops besides rice—sorghum, maize, millet, and wheat.

A new phase of research—nutrient interactions—was begun in 1982. We began investigating means of increasing the potential value of multinutrient fertilizers through improvements of their physical and chemical characteristics.

IFDC's scientists continued their research on the possibilities of using indigenous phosphate resources in forms that are less costly to process than conventional fertilizer. Field research results are showing that indigenous phosphate, either directly applied in a finely ground or minigranulated form or partially acidulated form, can produce results similar to those of conventional fertilizer. In 1982 our phosphate research expanded significantly in west Africa.

A sulfur study conducted during 1982 analyzed the economic importance of sulfur in the fertilizer industry, food production, and the agricultural sector in the tropical countries of Africa, Asia, and Latin America. This study will provide guidelines for new directions in IFDC sulfur research.

With increasing crop production levels in developing countries, the role of potassium and the trace elements is becoming increasingly important and IFDC continues to undertake studies that will identify activities involving these nutrients to help developing countries increase food production.

IFDC economics research continued to help pave the way for the transfer and acceptance of economically favorable developments in fertilizer technology. An energy policy study, published during 1982, pointed out ways of conserving energy in the production, distribution, and use of fertilizers.

The national program component continued to expand. The Bangladesh program, which began in 1979, experienced expansion in scope and personnel commitments during 1982. The program in Indonesia, dating back to 1980, became more diversified and focused not only on fertilizer efficiency research but also on fertilizer marketing and distribution. The Mali program, beginning in 1981, is progressing well in its efforts to supply an efficient and economical source of phosphate for that country's farmers.

The technical assistance segment involved 15 major missions during 1982; in addition, more than 700 inquiries were answered by brief visits, cables, and letters.

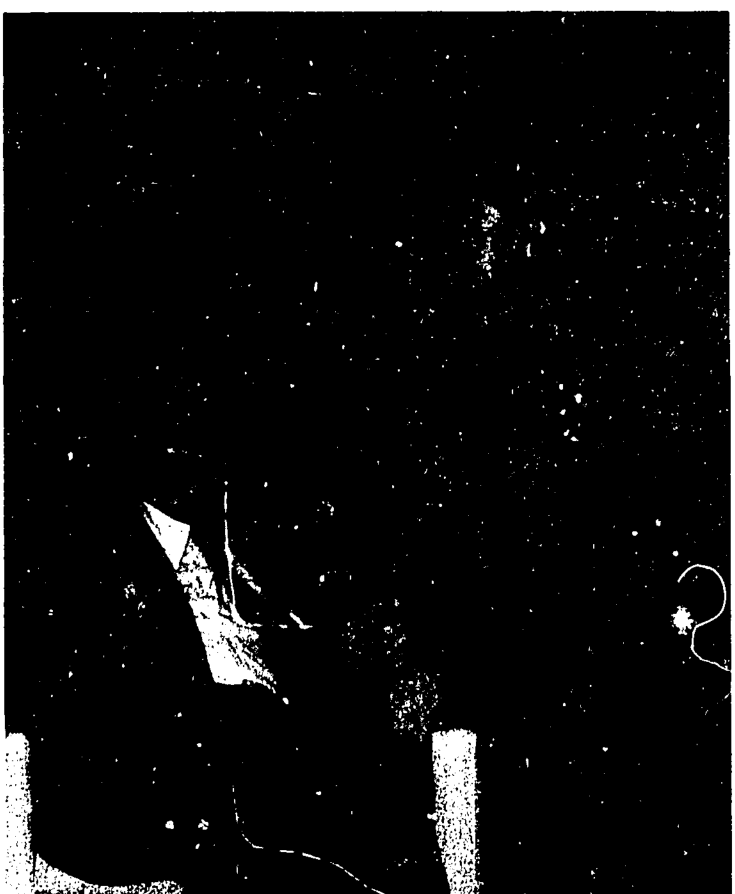
IFDC is in a unique position in that it can conduct an unbiased evaluation of the fertilizer sectors of developing countries. It can draw upon a cadre of expertise representing a wide variety of disciplines to carry out these studies.

IFDC's training program has grown from 1 course in 1977 to 11 courses in 1982. Our regional training offerings have increased dramatically. In 1981 four regional programs were offered and four Headquarters programs; in 1982 there were nine regional and two Headquarters programs. In 1982 a total of 399 participants received training in various aspects of fertilizer production, marketing, and use; programs were presented in Africa, Asia, Latin America, and at Headquarters.

Challenges of Tomorrow

As IFDC faces new challenges of the future, it will have to call on all of its resources, as well as collaboration with other institutions, to measure up and be increasingly sophisticated at providing answers to the hunger problem around the world.

Our newest challenge is that of serving as Executing Agency for the planning, formation, implementation, and operation of the African Center for Fertilizer Development. Provided adequate financial support is given to this new venture, IFDC will begin to realize its long-time goal of establishing regional centers, and the African people should enjoy the benefits in terms of increased production of food and fiber.



In conclusion, we are pleased to acknowledge the outstanding contribution of IFDC's competent and dedicated men and women. Their loyalty, diligence, and resourcefulness account for the progress that the organization has experienced over the years.

Donald L. McCune
Managing Director

Paul J. Stangel
Deputy Managing Director

IFDC Transfers Fertilizer Technology to the Developing World Through...

Research

The ultimate objective of IFDC research—this colorful market scene was captured by a photographer in Turkey.

RESEARCH PROGRAM

The purpose of research is to find solutions to problems. IFDC maintains its original philosophy of problem identification and solution, with emphasis on applied research. Since its beginning in 1974, IFDC has adhered to the original mandate of improving fertilizer technology, management, and use to increase food production in developing countries of Asia, Africa, and Latin America.

In the forefront of nitrogen research is the goal of (1) determining the extent of nitrogen losses, (2) improving use efficiency through modification of materials, and (3) developing and testing new fertilizer management techniques for lowland and upland cropping situations. The program is enhanced by several linkages with national and international institutions.

A number of developing countries are striving to use their indigenous phosphate resources effectively. IFDC plays a vital role in helping to solve technical and economic problems associated with the use of indigenous phosphate ores.

Recognizing that sulfur deficiencies in the tropics are becoming increasingly evident, we are undertaking an expanded sulfur research program. This program is focusing on identifying sulfur requirements, determining sulfur's effect on crop yield, measuring interactions with other nutrients, and evaluating methods of incorporating sulfur into formulations. During 1982 we expanded a sulfur study that will provide valuable information for future IFDC research as well as assist tropical countries in the development of their fertilizer policies.

During 1982 we significantly broadened our overall research program by giving more emphasis to other nutrients and a combination of nutrients. A rather comprehensive survey was completed on the potash, calcium, and magnesium situation in selected countries.

Economics research at IFDC is playing an increasingly vital role. Farm-level studies during 1982 revealed some crucially important results. The energy policy study, published during 1982, is proving to be a valuable tool for policymakers around the world.

NITROGEN RESEARCH

It is generally recognized that an improvement in the efficiency of nitrogen use can have a significant impact in increasing the world's food supply. The most urgent problem in food shortages exists in Asia, which also has the highest absolute population growth rate and density. A key input necessary to achieve higher food production is fertilizer, especially nitrogen fertilizer.

In view of this need, we are evaluating several alternatives to improve nitrogen use efficiency in both upland and lowland crops. In Asia where urea is the primary fertilizer available, our scientists are studying such concepts as deep placement of urea supergranules, urea combined with chemical additives, coated forms of urea, and modified compounds containing urea.

The briquetting/compacting process, which holds potential advantages for developing countries, received increasing emphasis during 1982. Research on urease and nitrification inhibitors to reduce nitrogen losses gained momentum and produced promising results.

The Center maintains strong cooperative nitrogen research programs with the International Rice Research Institute (IRRI), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Institute of Tropical Agriculture (IITA), and numerous national research organizations.

New and Modified Products

Urea Particle-Size Modification

Briquetting/Compacting of Urea and Urea Mixtures—IFDC researchers continued experiments using the briquetting/compacting process to produce discrete particles of fertilizer. Briquetting provides relatively large particles that are pillow shaped or nonspherical in form and nearly uniform in weight; they are suitable for individual application. Compaction yields smaller, irregular-shaped particles with a size range controlled by screening. Large particles of urea are used for manual or machine deep placement in rice paddies. IFDC continued to monitor experiences of others—mainly in India and the People's Republic of China (PRC)—in using large fertilizer particles. At this time urea particles weighing about 1 gram each are only available in limited experimental quantities. Commercial production awaits more data on the technological, economic, and agronomic aspects of the manufacture and use of these particles. Research data have already proved that deep-placed urea is

The IFDC briquetter/compactor is improved for continuous operation; a wide range of products can be made.

more efficient, and in many locations the use of this application method translates into significant yield increases for rice.

It is relatively easy to incorporate other materials with urea during briquetting or compacting if these materials are dry and free flowing and do not subsequently react with urea; some reactions destroy particle strength and/or cause caking. As in granulation, such materials as superphosphates and gypsum are not compatible with urea for long-term storage because a chemical reaction releases water and causes caking. Some superphosphates cause problems in the feed system of the briquetting/compacting machine because of their sticky nature.

The briquetting/compacting process has a number of potential applications and advantages for developing countries. Some of these are as follows:

1. The process is applicable to N, NP, or NPK products, plus additives such as micronutrients or inhibitors (see Table 1 for typical products made by IFDC).
2. Only dry solid raw materials (powders, crystals, prills, or granules) are required.
3. The process is relatively simple.
4. The investment cost compares quite favorably with that of steam and water granulation.
5. The operating cost also compares favorably with that of steam and water granulation.
6. The process is adaptable to small plants.
7. A wide variety of product grades can be made because of process flexibility.
8. No drying or cooling of the product is required.
9. It can be used with heat-sensitive raw materials.

Because of the high interest expressed by some developing countries, IFDC will install and demonstrate a continuous compacting process in 1983 for a more detailed evaluation.

Coating of Soluble Fertilizer

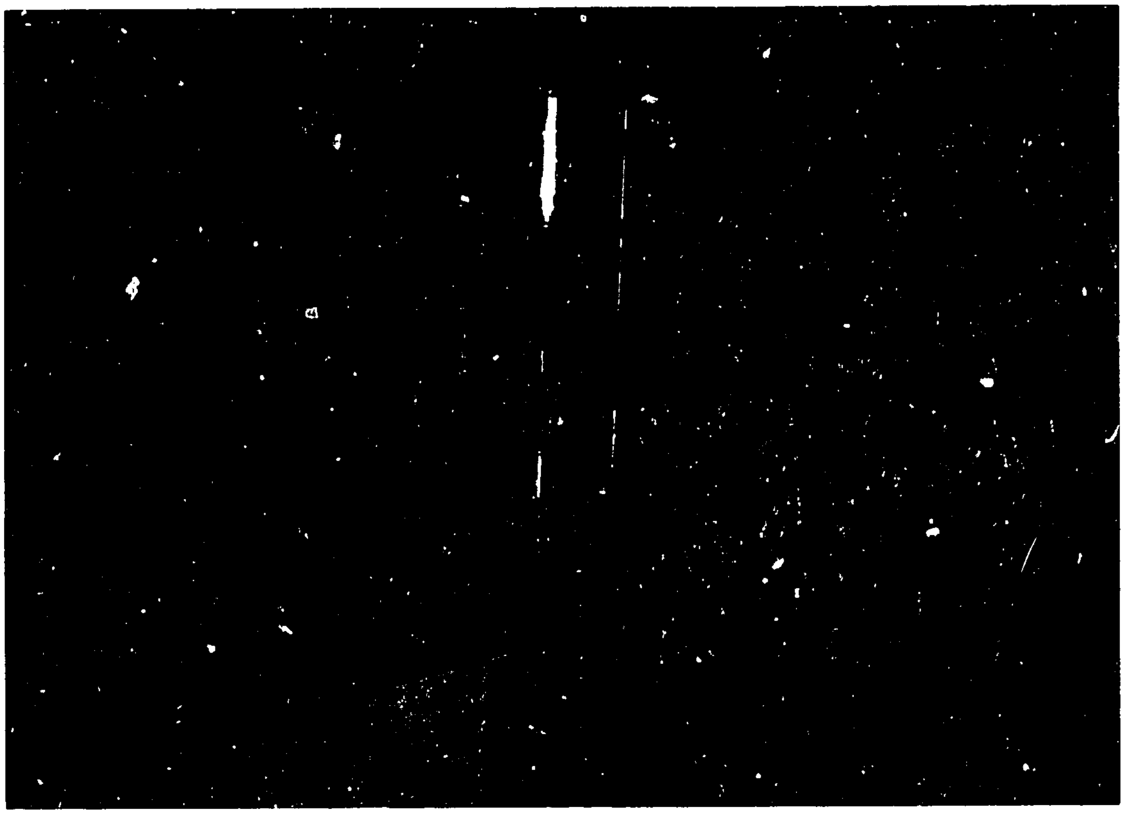
Researchers have established that certain forms of coated urea surface applied to paddy rice significantly improve nitrogen use efficiency (and increase yield) in certain situations. However, results vary with the site. This idea has prompted IFDC to continue the search for coating materials and/or process conditions that will make coated urea more cost effective. One obvious way is to increase the urea particle size; this decreases the area to be coated.

Coating techniques are constantly being refined at IFDC using a rotary-drum or fluidized-bed process. IFDC scientists are now using latex as a coating material with both types of equipment in laboratory scale for a Malaysian project sponsor, Petroliam Nasional Berhad (PETRONAS).

At the request of PETRONAS, we initiated a research project to evaluate natural rubber latex as a coating for urea and urea-based NPK. IFDC and PETRONAS personnel will work jointly at Headquarters for several months during 1983 to prepare and evaluate experimental products. The purpose of the coating is to reduce ammonia volatilization losses from surface-applied urea in Malaysia. IFDC researchers will use a fluidized-bed and modified rotary-drum process for applying the various rubber formulations as specified by PETRONAS. Promising products have been made by the fluid-bed process. Successful results in

Table 1.
Typical IFDC Fertilizers Made as Briquettes

Feed Material	Typical Analysis			
	N	P_2O_5	K_2O	S
	(wt %)			
Ammonium bicarbonate	17.7	-	-	-
Potassium chloride	-	-	60.0	-
Urea + potassium chloride	26.8	-	26.2	-
Urea + sulfur	42.2	-	-	9.5
Urea + potassium sulfate	21.8	-	26.9	9.1
Diammonium phosphate	17.2	46.9	-	-



One type of coating equipment, the fluidized bed, is being used for the application of natural rubber latex to urea.

Phase I will lead to economic and agronomic evaluation and larger scale production in a pilot plant.

Evaluation of Properties of Nitrogen Materials

The most common method of applying urea in developing countries is by surface application (broadcasting). When urea is surface placed, it undergoes urease-catalyzed hydrolysis that leads to a rapid buildup of ammonium-N and alkalinity (high pH). This situation favors ammonia volatilization losses from the surface soil and results in decreased nitrogen efficiency.

IFDC researchers have carried out a variety of soil incubation experiments in order to better understand the hydrolysis of surface-placed urea under simulated field conditions. Hydrolysis of surface-placed urea granules was markedly influenced by movement of urea and water and their distribution in the soil. Hydrolysis was faster when urea was transported with the water than when it moved by diffusion. Urea hydrolysis in soil appears to be a complex, heterogeneous process largely occurring at the soil solution-soil solid interface and apparently controlled by the presence of urease sorbed on the soil particles.

Urease and Nitrification Inhibitors

The effects of various chemicals as urease inhibitors were evaluated using an IFDC-developed soil column incubation technique. Examples of compounds that were studied were phenols, quinones, sulfur compounds, phenylphosphorodiamidate (PPD), their related and substituted compounds, and mixtures of urea and various metal salts. The researchers found that PPD was the most effective soil urease inhibitor of those evaluated.

Phenylphosphorodiamidate and Dicyandiamide—Using the briquetting/compacting machine IFDC technologists prepared a number of urea products containing the urease inhibitor, PPD, or the nitrification inhibitor, dicyandiamide (DCD). These materials are being evaluated at Headquarters or overseas. The particle-size range of the compacted granular product was 1.18-3.35 millimeters, which was used for surface-application ammonia volatilization studies. The level of PPD added ranged from 1% to 5%; the levels of DCD ranged from 1% to 7%. If these or other inhibitors are to be used on a large-scale commercial basis, a practical method must be found to add the compounds to urea melt for prilling or granulation.

Metal Salt-Urea Complexes—Although the inhibitory effect of metal salt-urea complexes on urea hydrolysis in soils is very slight, some complexes do reduce ammonia volatilization by as much as 25% from surface-applied urea in pot tests. IFDC chemists prepared a number of complexes involving aluminum, copper, iron, and zinc in relatively pure form and characterized these materials by x-ray diffraction and thermogravimetric methods. The reaction replaces the water of hydration in the metal salt with urea. Reduced ammonia volatilization may result when the metal salt chemically reacts with ammonia liberated by hydrolysis. Our soil scientists conducted screening tests of some complexes with acidic and basic soils without growing plants; then they tested some promising products (copper and zinc salts of urea) in the greenhouse. Of the compounds made thus far, those containing zinc are the most effective. These materials have only been made in the laboratory.

Urea Reaction With Formaldehyde

During urea production, formaldehyde is often used as a conditioner to improve physical strength and resistance to caking and decrease dust formation. Complex urea-formaldehyde reaction products have been detected by using high-performance liquid chromatography techniques. The quantities of reaction products formed account for nearly all of the formaldehyde added; thus, little unreacted formaldehyde remains in the product. Some concern has been expressed that unreacted formaldehyde can be hazardous to health. This IFDC-developed procedure has now been adapted by other laboratories as a new analytical method for formaldehyde-conditioned urea.

Lowland Nitrogen Program

The poor efficiency of urea applied to rice has been a major concern of IFDC researchers over the last 6 years. Agronomic research has been concentrated on determining the causes of the poor efficiency and developing and testing improved nitrogen products in the greenhouse and the field. Much of the field research has been conducted cooperatively with IRRI where one of our staff members has been posted since 1978. The scope of work at Headquarters and in the field was recently broadened to include rainfed rice as well as continuously flooded rice.

Identification of Causes of Poor Nitrogen Efficiency

Ammonia Volatilization Losses in the Field—Greenhouse research at Headquarters has shown that ammonia volatilization is an important nitrogen loss mechanism in continuously flooded rice fertilized with urea. However, few measurements of ammonia loss have been undertaken to directly determine these losses in fields in the tropics. A micrometeorological technique was used in the field in 1982 at two sites in the Philippines to measure directly ammonia loss where urea was topdressed into floodwater or surface incorporated before transplanting. Ammonia volatilization followed a diurnal pattern with peak ammonia loss midday and lower ammonia loss overnight. Ammonia volatilization was found to account for 47% of the urea-N topdressed 14 days after transplanting at the Maligaya Rice Research Training Center (MRRTC) (Figure 1). A lower loss of ammonia (27% urea-N topdressed 21 days after transplanting) was found in a comparable experiment at IRRI. Incorporation of urea before transplanting reduced the ammonia loss to 13%-15% of the nitrogen applied at both sites. Ammoniacal nitrogen levels in the floodwater were appreciably higher when urea was topdressed (broadcast) to the floodwater. In the MRRTC study in which the topdressing was delayed, the pH of the floodwater showed a pronounced diurnal pattern. This pattern implies that organisms, especially algae, may help create the high floodwater pH values required to support significant ammonia loss.

Studies conducted concurrently with the ammonia volatilization measurements showed that 47% and 60% of the ^{15}N-labeled urea was unaccounted for 10 days after urea was topdressed at the MRRTC and IRRI, respectively (Figure 1). In comparison, only 18%-23% of the ^{15}N was unaccounted for when urea was broadcast and incorporated before transplanting. These losses were low, possibly as a result of thorough incorporation after the floodwater was drained.

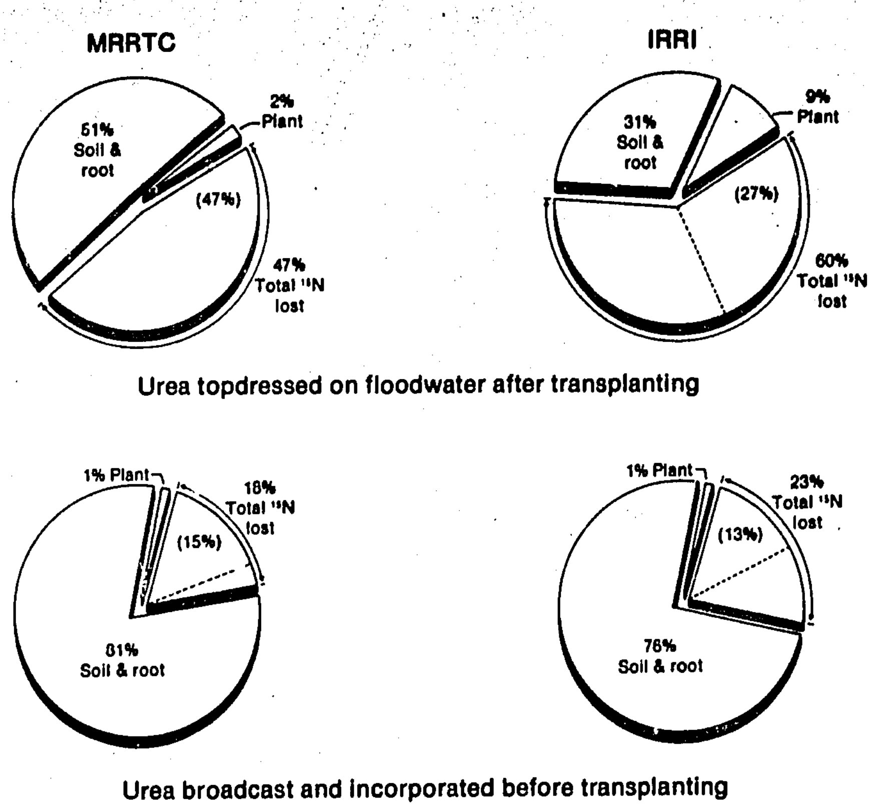


Figure 1. Fate of ^{15}N-Urea and Significance of Ammonia Volatilization With Various Fertilizer Treatments. (Ammonia loss is shown in parentheses as percentage of nitrogen applied.)

At the MRRTC, ammonia volatilization as measured directly appeared to account for the total nitrogen unaccounted for in the ^{15}N balance (Figure 1). However, at IRRI ammonia volatilization accounted for only about one-half of the losses for both the incorporated and topdressed urea treatments. These results suggest that ammonia volatilization was not the only loss mechanism. Research is now being initiated to determine the other mechanisms of nitrogen loss and to evaluate the effect of urease inhibition on losses.

Denitrification Losses—Most tropical paddy soils are puddled (the soil structure is broken down by flooding and then working the soil) before the rice is transplanted. Much of the research on denitrification, however, has been done either on structured soils or air-dried soils. The effect of soil puddling on denitrification has particular importance on rainfed soils subject to intermittent flooding and drying.

Research conducted at Headquarters showed that ammonia volatilization losses from the puddled and the structured soil were essentially the same; about 32% of the applied urea was lost in 3 days. However, as the soil dried, nitrate accumulated in the structured soil but not in the puddled soil. When the soil was then reflooded after 1 week, the 30% of the fertilizer which had been converted to nitrate was lost from the structured soil by denitrification. Losses attributed to denitrification from the puddled soil occurred at a slower, continuous rate. This research is important because it will influence the choice of biological inhibitors (such as urease or nitrification inhibitors) that would have the greatest potential for decreasing losses in particular water and soil management systems.

Effect of a Urease Inhibitor on Ammonia Volatilization—Previous work at IFDC has shown that PPD added to urea can reduce nitrogen losses from flooded rice by slowing the conversion of the urea to ammonia. This conversion is brought about by an enzyme (urease), which is naturally present in soil. By inhibiting the enzyme, PPD

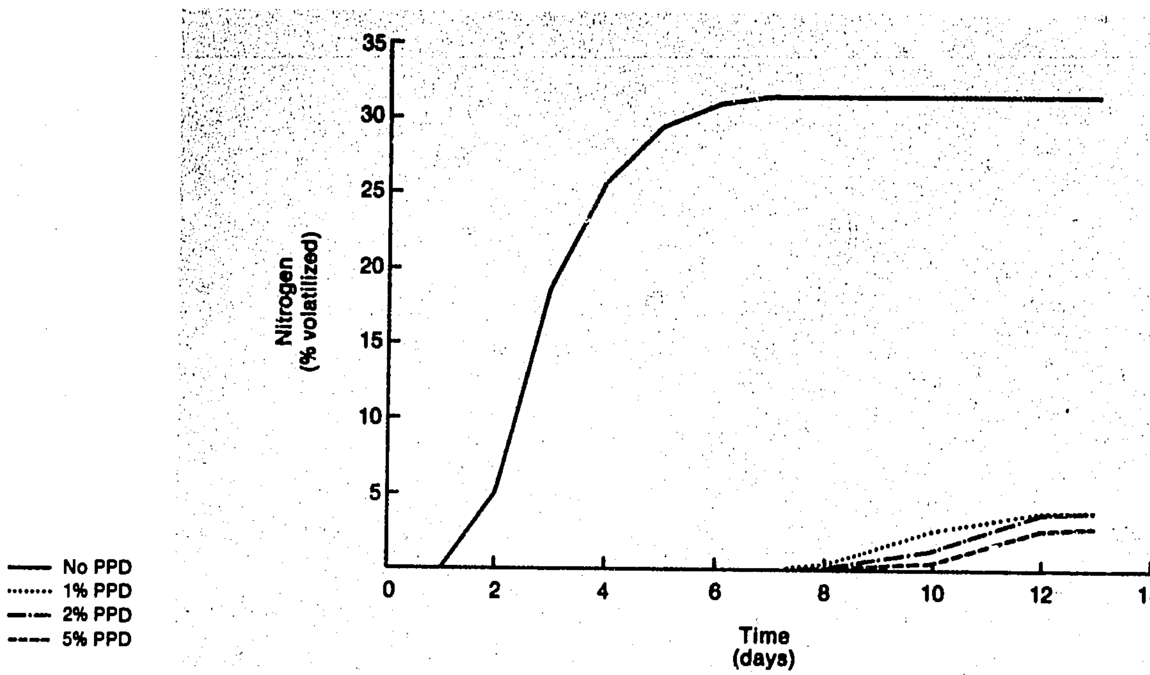


Figure 2. Cumulative Fertilizer Loss With Time and Varying Amounts of PPD.

reduces losses through ammonia volatilization, a major way in which urea can be lost from flooded rice soils.

Ammonia volatilization losses measured in the greenhouse were 32% when PPD was not used and only 3%-5% when PPD was applied (Figure 2). PPD concentrations of 1%-5% were equally effective in reducing nitrogen losses. PPD is expensive; therefore, it is important to know how much of the chemical is needed to reduce the nitrogen losses. In an experiment in which the urea and ammoniacal nitrogen in the floodwater was measured, IFDC researchers found that the addition of 0.25% PPD in urea may be enough to slow down the conversion of urea to ammonium, while 0.1% is probably not enough. There was no difference in its effectiveness when applied at any level above 0.25%.

Effect of a Urease Inhibitor on Fertilizer Uptake—The use of an agent such as a urease inhibitor to reduce losses could be detrimental to fertilizer nitrogen uptake through its effect on the form of available nitrogen or through a physiological effect on the plant's root system.

A greenhouse experiment was conducted on rice treated with ^{15}N-labeled fertilizer to determine how urea with PPD broadcast 20 days after transplanting affects fertilizer recovery efficiency. After the fertilizer was applied, the floodwater was covered with plastic to prevent ammonia volatilization losses. This allowed the study of the nitrogen uptake process without the confounding effects of differing losses between treatments with and without PPD. The researchers monitored fertilizer uptake for 2 weeks following fertilizer application and found that the urease inhibitor produced no detrimental effect on fertilizer uptake. Using urease inhibitors such as PPD should not therefore reduce or delay fertilizer N uptake or reduce plant growth.

Evaluation of Products and Practices

Collaboration With Fujian Academy of Agricultural Sciences and IRRI—Promising greenhouse results with the urease inhibitor PPD led IFDC to cooperate with the Fujian Academy of Agricultural Sciences (FAAS), Fuzhou, People's Republic of China, and IRRI in conducting field tests with the material. In field experiments at IRRI the effect of the inhibitor on floodwater chemistry has appeared promising for reducing losses, but no grain yield increases have been found. In a similar experiment at FAAS, both grain yield and plant fertilizer recovery were improved by PPD. IFDC will conduct further field trials with PPD in Asia.

Collaboration With Hindustan Fertilizer Corporation, Limited (HFC)—The joint IFDC/HFC program continued to compare responses of wetland paddy to deep-placed urea supergranules (USG), to incorporated sulfur-coated urea (SCU), and to split applications of prilled urea. During 1982 IFDC scientists analyzed results from 162 trials conducted over the 1977-80 period on farmers' fields in six states of eastern India.

The results indicate that the agronomic efficiencies of USG and SCU are equivalent, and both fertilizers show greater efficiencies than prilled urea when split applied. It was determined that nitrogen application in the form of USG or SCU could be reduced by approximately 25%-45%, as compared with prilled urea, and still produce a 1-metric ton increase in yield. Grain yield increases from an application of 50 kilograms of N per hectare in the form of USG or SCU were 25%-60% higher than those increases obtained from prilled urea.

In 40% of the experiments, response to USG and SCU was statistically superior to that from prilled urea. In 55% of the experiments response to all materials was equivalent, and in 5% of the experiments response to prilled urea was better than response to USG and SCU.

At the economic optimum, the average agronomic efficiencies from the 162 experiments were 15.9, 21.0, and 21.8 kilograms of rice per kilogram of nitrogen applied in the form of prilled urea, USG, and SCU, respectively. However, the average added value:cost of fertilizer ratios were equivalent at the optimum conditions. The assumptions were made that USG cost 10% more than prilled urea and required 15 workdays per hectare to apply and that SCU cost 50% more than prilled urea and required 2 workdays per hectare to apply. The average value:cost ratios for the three materials were equal to 2.7, 2.8, and 2.6 for prilled urea, USG, and SCU, respectively.

International Workshop on Efficient Nitrogen Management—FAAS, IRRI, and IFDC cosponsored the International Workshop on Efficient Nitrogen Management, held in Fuzhou, People's Republic of China, April 26-May 4, 1982. The primary focus of the workshop was to evaluate the potential of deep placement of nitrogen fertilizers as a means of improving nitrogen efficiency and rice production in developing countries, especially for the Association of Southeast Asian Nations project.

A six-member technical team from IFDC made presentations during the workshop, which was attended by 54 fertilizer specialists from 14 countries. Twenty-five

Participants in the International Workshop on Efficient Nitrogen Management held in Fuzhou, PRC, discuss the progress of that meeting.

A Chinese laborer prepares to use a machine applicator to deep place supergranules.

technical papers were presented on the various aspects of improving nitrogen efficiency, particularly through deep placement of supergranules.

The workshop also featured four workgroups that concentrated on: (1) production of modified-urea products, (2) agroeconomic evaluation of urea supergranules in farmers' fields, (3) applicator research and development, and (4) future agronomic research on more efficient use of nitrogen fertilizers.

The IRRI representatives brought to the workshop manually operated machines for deep application of urea, and participants used these and the Chinese equipment in the fields.

Several field trips were included as part of the workshop. In Jiangyang county, the participants observed large-scale production of briquettes and their application in farmers' fields. Visits to FAAS and an ammonium bicarbonate factory near Fuzhou were also on the itinerary.

As a result of this workshop, FAAS, IRRI, and IFDC plan cooperative projects to develop and improve equipment to manufacture and deep place fertilizer. The workshop also developed pilot projects to be established in several countries (Burma, India, the Philippines, and Thailand), whose representatives were interested in evaluating these technologies. These projects will test the precision and reliability of various urea applicators. This will also allow an opportunity to measure farmer acceptance of this technology and identify areas for improvements.

International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)—INSFFER is composed of agronomists and soil scientists from national institutions that are conducting research to improve fertilizer efficiency on rice. This network, organized jointly by IRRI and IFDC, deals with the evaluation of new and/or improved fertilizer products and management practices.

During 1982, 110 trials were conducted in 11 countries. The trials were conducted to study four subject areas: (1) nitrogen efficiency, (2) phosphorus sources, (3) long-term fertility, and (4) Azolla use on rice.

Results of the nitrogen efficiency trials show that during the dry season both slow-release nitrogen fertilizer and deep-point placement of urea gave significantly greater responses than split broadcast urea in 50% of the trials. During the wet season, sulfur-coated urea was superior to split broadcast urea in 11 trials, and deep-point placement of urea was superior in 17 of 34 trials.

Trials on phosphorus sources for flooded rice have now been repeated at several locations through five crops, and at four locations three to six crops have been harvested to determine the response to residual phosphorus. For those locations during the dry season, responses to single superphosphate were greater than to either of the phosphate rocks except on an acid sulfate soil. During the wet season, all sources produced similar, small responses.

In the long-term fertility trials, results have been obtained from more than 10 successive crops at four locations. Responses to phosphorus have increased with time on the trial in Indonesia and one trial in the Philippines (Luisiana). Only at the Luisiana site have responses to potassium tended to increase with time.

The fourth trial on Azolla use on rice was conducted in 1982. Data from 15 sites show that applications of 60 kilograms of nitrogen per hectare of urea and 20 tons per hectare of fresh weight of Azolla plus 30 kilograms of nitrogen per hectare of urea produced similar yields of rice. However, treatments of Azolla only produced lower grain yields than Azolla plus 30 kilograms of nitrogen per hectare of urea.

Nitrogen fertilizer materials, including deep-point placed urea supergranules, sulfur-coated urea, urea, and ammonium sulfate, were evaluated in ^{15}N mininetwork experiments conducted in China, India, Korea, Philippines, and Thailand. With the exception of the India (Ludhiana) experiment, deep-point placed urea supergranules gave the highest ^{15}N plant recovery (50%-75%) and the lowest ^{15}N loss. At Ludhiana, in a strongly leached soil, ^{15}N plant recovery of urea supergranules accounted for only 12% of the ^{15}N applied while 75% of the ^{15}N was unaccounted for.

Upland Nitrogen Program

Since 1979 we have expanded our nitrogen research program to include other food crops of the tropics besides rice. Emphasis has been placed on major cereal crops (sorghum, maize, millet, and wheat) grown without irrigation because irrigation is not practiced in large areas of the tropics. Unfortunately, little is known about the role and effectiveness of nitrogen fertilizer used in growing food crops under rainfed conditions. Enhanced food production on land without irrigation is critical because the poorest farmers in the tropics are generally engaged in rainfed agriculture, and rainfed areas are usually the most prone to widespread crop failures.

Identification of Causes and Magnitude of Nitrogen Losses

Because of the limited information on the fate of fertilizer nitrogen in rainfed agriculture, our research effort has been focused on construction of N balance sheets in various agroecological zones of the tropics and subtropics. Emphasis is placed on quantifying fertilizer nitrogen losses and the identification of factors influencing the use of fertilizer nitrogen by the various crops. The collected data help identify agroecological systems with poor plant uptake of nitrogen fertilizer and in turn guide agronomists, chemists, and engineers in the development of improved fertilizer practices or products to overcome losses and increase uptake of nitrogen by crops. International institutes such as ICRISAT, IITA, and ICARDA are active partners in this research effort.

Fate and Efficiency of Fertilizer Nitrogen—Upland nitrogen research has been focused primarily on urea because it is the most used and most available nitrogen fertilizer in the tropics. Within a few days after application, urea breaks down to ammonia and subsequently to nitrate, both of which can be lost from soil. Using ^{15}N-labeling techniques to construct the fertilizer nitrogen balance, our soil scientists conducted studies to determine the conditions under which significant amounts of nitrogen from urea are lost from soil.

Using maize, sorghum, millet, and wheat as the test crops, researchers laid out field studies on representative sites in the perhumid (extremely wet) tropics, humid tropics, and subhumid tropics (Nigeria), the semiarid tropics (India and Niger), and the Mediterranean subtropics (Syria). Table 2 summarizes some of the information collected to date for urea. The application methods are those commonly practiced or recommended in the region of study. Surprisingly, plant uptake of nitrogen fertilizer is relatively high in most of these agroecological zones, except on the sandy

Table 2.
Efficiency of Nitrogen Recovery by the Crop and in the Soil-Plant System in Various Agroecological Zones of the Tropics

Ecological Zone	Location	Mean Annual Rainfall	Soil Type	Clay	Crop	Fertilizer Application Dose	Time	Mode[a]	Plant N Recovery	N Loss
		(mm)		(%)		(kg/ha)			(%)	(%)
Humid tropics	Ikenne, Nigeria	1,500	Alfisol	15	Maize	120	Split	Inc.[R]	61	10
	Ibadan, Nigeria	1,270	Alfisol	14	Maize	150	Split	Inc.[R]	34	ND[b]
Subhumid tropics	Mokwa, Nigeria	1,070	Alfisol	12	Maize	120	Split	Inc.[R]	62	0
Semiarid tropics	Sadore, Niger	570	Alfisol	6	Millet	30	Basal	Inc.[P]	25	34
						30	Split	Banded[R]	30	TBD[c]
	Hyderabad, India	620	Alfisol	29	Sorghum	80	Basal	Inc.[P]	50	17
						80	Split	Banded[R]	64	8
	Hyderabad, India	620	Vertisol	51	Sorghum	74	Basal	Inc.[P]	29	26
						74	Split	Banded[R]	56	6

a. P = fertilizer application as often practiced by farmers;
R = fertilizer application as recommended (banded 2.5 cm deep).
b. ND = not determined.
c. TBD = to be determined.

soils in the African Sahel. The mode of fertilizer application affected the crop's recovery of fertilizer nitrogen on the heavier textured soils in India but not on the sandy soils of the Sahel. Losses of fertilizer nitrogen were negligible in the subhumid region and were considerable (34%) in the Sahel.

Our researchers are continuing their efforts to verify and diversify the data base on the fate and efficiency of fertilizer nitrogen in various agroecological zones. They are presently analyzing data from the perhumid zone of Nigeria and from the dry Mediterranean region in Syria; experiments are planned in Senegal and Kenya.

Ammonia Volatilization—The low plant recovery of nitrogen under limited moisture supply, particularly if the fertilizer is broadcast at planting (basal application), has led to a research program at Headquarters on nitrogen-moisture interactions, with particular emphasis on nitrogen losses due to ammonia volatilization.

In many regions of the tropics and subtropics, precipitation is erratic; thus, there are variable periods of drought and heavy rainfall during the crop-growing season. Previous studies by IFDC scientists have shown low recovery of nitrogen fertilizer by plants under conditions of limited moisture supply, particularly if the fertilizer is broadcast at planting (basal application). This has led to an intensified research program at Headquarters on nitrogen-moisture interactions with particular emphasis on nitrogen losses due to ammonia volatilization. During 1982 our soil scientists conducted studies in the Greenhouse to assess the influence of variable rainfall and soil moisture content on the behavior of nitrogen fertilizer.

Most studies at IFDC have shown a trend of increased crop uptake of nitrogen fertilizer with increased crop-available water in the soil.

IFDC personnel have conducted a greenhouse study to assess the effect of rainfall on ammonia loss from broadcast urea on a calcareous, clay soil (Figure 3). Throughout the experiment they maintained soil conditions dry enough to prevent leaching and denitrification. The greatest losses occurred when the soil surface was wetted by simulated frequent light rainfall and decreased dramatically with heavier rainfall. In this particular soil, nearly 50% of the urea was lost as ammonia

Table 3.
Effect of Environmental Conditions and Application Method of Urea on Ammonia Loss From a Calcareous Soil (Wind Tunnel Study, 25°C)

Fertilizer Application Method	Wind Velocity at 10 cm	Relative Humidity	Rainfall Events and Amount	Fertilizer Loss in 200 Hours
	(m/s)	(%)		(%)
Broadcast and incorporated	2.21	35-50	3 x 8 mm	13
Broadcast and incorporated	3.45	35-50	3 x 8 mm	8
Broadcast and incorporated	1.74	35-50	3 x 8 mm	19
Broadcast and incorporated	1.74	35-50	6 x 2.7 mm	10
Broadcast and incorporated	1.74	80-95	0	25
Broadcast and incorporated	1.74	35-50	1 x 24 mm	0
Banded at 2.5 cm	1.80	24-26	3 x 8 mm	3

when 0.5 centimeter of simulated rainfall was added every 3.5 days. More intense rainfall apparently leached urea and ammonium into the soil where it was protected against volatilization.

IFDC sponsored more detailed studies on ammonia volatilization with the same soil in a wind tunnel facility at Michigan State University in the United States. Direct measurement of ammonia volatilization losses using the micrometeorological technique confirmed the effect of rainfall on loss by ammonia volatilization. Table 3 summarizes the effects of environmental conditions and application method for seven experiments conducted in the wind tunnel following application of 50 kilograms urea-N per hectare. Rainfall of approximately 8 millimeters per event promoted ammonia loss while 3 millimeters of rain tended to reduce it apparently as a result of rapid soil drying. Prevention of soil drying by prehumidifying the air maximized ammonia volatilization. Application of 2.4 centimeters of rain soon after fertilizer application or placement of urea in bands at 2.5-centimeter depth almost entirely prevented ammonia loss.

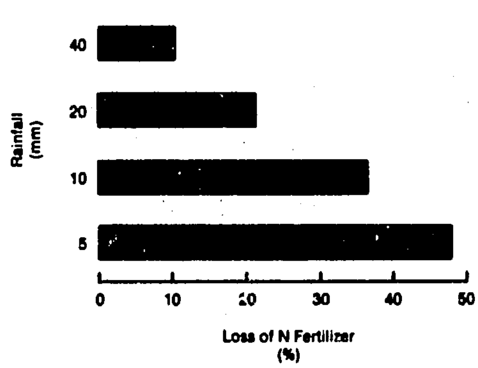


Figure 3. Influence of Rainfall on Nitrogen Loss From Broadcast Urea in a Simulated Semiarid Environment.

Evaluation of Products and Practices

Headquarters' Evaluation—Research results have suggested that ammonia loss from broadcast urea might be a problem on certain upland soils. Therefore, our researchers evaluated additives for their effectiveness in reducing ammonia loss from urea.

One additive was PPD which has proven to reduce losses from flooded rice paddies (see section on Lowland Nitrogen Program). Results with PPD have not been very promising on calcareous, clay soils. Research is being continued on soils with varying properties to evaluate PPD and other additives to urea.

An alternative method to soil-applied broadcast nitrogen fertilizer is foliar application. IFDC soil scientists examined foliar application of urea to wheat in a preliminary greenhouse experiment. Under moist soil conditions plant recovery of nitrogen from urea was similar for broadcast and foliar applications. However, under dry soil conditions plant recovery was greater for foliar application. The results

A field assistant harvests sorghum heads in a cooperative experiment at ICRISAT in India.

A young Indian village girl grinds grain.

suggest that foliar application of urea to wheat might be an alternative to broadcasting urea when rainfall is insufficient to move the broadcast fertilizer into the crop root zone. Our future research will focus on defining the condition under which foliar fertilization may be an attractive alternative.

Field Evaluation—Our field evaluation at collaborating institutions has been largely limited to a comparison of application methods of commercially available nitrogen sources. Such studies have been underway at ICRISAT in India and ICARDA in Syria since 1980. Research in India has clearly demonstrated the advantages of splitting and banding at depth, both in yield and plant recovery (Table 2). Field research was significantly expanded in 1982 when experiments were conducted in collaboration with ICRISAT in Niger and IITA in Nigeria.

In a parallel research effort, IFDC continues to cooperate with the U.S. Department of Agriculture in the development of computer simulation models of crop growth and nitrogen fertilizer response. Initially this activity has taken advantage of existing knowledge on nitrogen behavior in arid regions to construct a model describing soil and plant processes that affect the growth response of wheat to nitrogen and the uptake of nitrogen by wheat. Sets of data on wheat growth and response to nitrogen have been collected from numerous locations around the world to aid in the development and evaluation of the simulation model. The ultimate objective is to develop a model to aid in the evaluation of fertilizer practices and sources over a range of climatic environments.

COMPLEX FERTILIZERS AND NUTRIENT INTERACTIONS

The maximum efficiency of an individual fertilizer nutrient to increase crop yield is dependent upon the presence of all the other essential elements in balanced proportions. When it is suspected that crop production is being limited by a deficiency or imbalance of more than one nutrient, these nutrients may be supplied by a single multinutrient fertilizer. The nutrient uptake and the yield of the crop are expected to increase, therefore, as a result of the reciprocal inducement effects that the various nutrients have on their relative uptake.

We are investigating means of increasing the efficiency of such multinutrient or complex fertilizers through technological improvements of their physical and chemical characteristics. The initial approach has been to evaluate fertilizer source interaction with respect to nutrient uptake to select efficient combinations irrespective of source compatibility. This can then be followed by development of techniques to induce source compatibility.

Preliminary studies were made by IFDC during 1982 to evaluate nitrogen and phosphorus source interactions under greenhouse conditions. To determine the uptake of nitrogen and phosphorus by flooded rice, the scientists included these variables: rate and placement of urea as influenced by source, rate, and placement of phosphorus. The results indicate that deep placement of urea supergranules was superior to broadcast application of urea. This supports findings reported in the studies on nitrogen efficiency for flooded soils.

A source interaction was observed with respect to the question whether or not phosphorus might be efficiently used if included in a complex fertilizer form and deep placed to enhance nitrogen efficiency. While broadcast application generally enhanced phosphorus uptake by the rice, phosphorus availability from a soluble source (TSP) was equally as effective when deep placed with the urea. However, there was a significant decrease in uptake when sparingly soluble phosphate rock was deep placed as opposed to a high degree of effectiveness when it was broadcast and incorporated.

These results indicate a potential for development of a supergranule type of fertilizer containing both urea and soluble phosphate for deep placement.

PHOSPHATE RESEARCH

Naturally occurring phosphate rock is the source of all of the common types of commercial phosphate fertilizers. Phosphate rocks of varying composition have now been identified in several developing countries, but many of them have not been exploited for use in fertilizer. IFDC scientists have conducted research to determine whether it is possible to use indigenous phosphate resources in forms that are less costly to process than conventional fertilizer forms. These scientists have been attempting to determine the effectiveness of directly applied phosphate rock in a finely ground or minigranulated form and the effectiveness of partially acidulated phosphate rock.

Basic laboratory and greenhouse research at IFDC Headquarters and with collaborating institutions has been focused on the phosphorus reactions in soil that influence phosphorus availability from different sources. Cooperative field tests with a number of institutions have been conducted to evaluate basic research ideas and soil-crop-management interactions on phosphate efficiency.

Initially our phosphate field research program was centered in Latin America, where collaborative research is conducted with the International Center of Tropical Agriculture (CIAT). However, in 1982 this type of research expanded significantly into west Africa where we now collaborate with IITA and ICRISAT.

Fertilizers Based on Phosphate Rock

Partially Acidulated Phosphate Rock

To develop low-cost, simple, efficient processes for using phosphate rocks from developing countries, IFDC continued to focus on the single-step partial acidulation/granulation process and emphasized use of sulfuric acid. Less sulfuric acid is used to produce partially acidulated phosphate rock (PAPR) than is required to produce single superphosphate. The actual acidulation levels tested varied between 15% and 50%. The agronomic effectiveness of such products is being evaluated in Latin America, Africa, and Asia.

During 1982 our researchers studied five different rocks (Table 4) that varied in both chemical reactivity and impurity content (aluminum oxide and iron oxide) in the continuous process. Water required for granulation in the process helped improve acidulation. Water was sprayed near the feed inlet, and the sulfuric acid was sprayed onto the wet materials. In these laboratory-scale trials, the acid use efficiencies for all phosphate rocks were above 90%, including those containing relatively high amounts of aluminum oxide and iron oxide (Table 5).

Table 4.
Chemical Compositions of the Partially Acidulated Phosphate Rocks Produced in IFDC Laboratory-Scale Granulation Unit

Rock Source	Acidulation Level[a]	Chemical Composition Total P_2O_5	Water-Soluble P_2O_5	Citrate-Soluble P_2O_5
	(%)	(wt %)		
Parc W (Niger)	25	25.2	4.9	3.4
Parc W (Niger)	50	21.9	11.1	2.0
Pesca (Colombia)	20	17.6	2.5	3.9
Pesca (Colombia)	40	16.4	6.3	4.4
Huila (Colombia)	50	14.6	7.1	2.8
Hahotoe (Togo)	25	29.9	7.2	2.4
Hahotoe (Togo)	50	27.4	11.4	3.8
Tilemsi Valley (Mali)	15	24.4	3.3	4.2
Tilemsi Valley (Mali)	30	21.8	7.1	4.0

a. Indicates amount of acid used expressed as percentage of that needed to produce single superphosphate.

Table 5.
Chemical Analyses of Phosphate Rocks Used in Partial Acidulation/Granulation Process

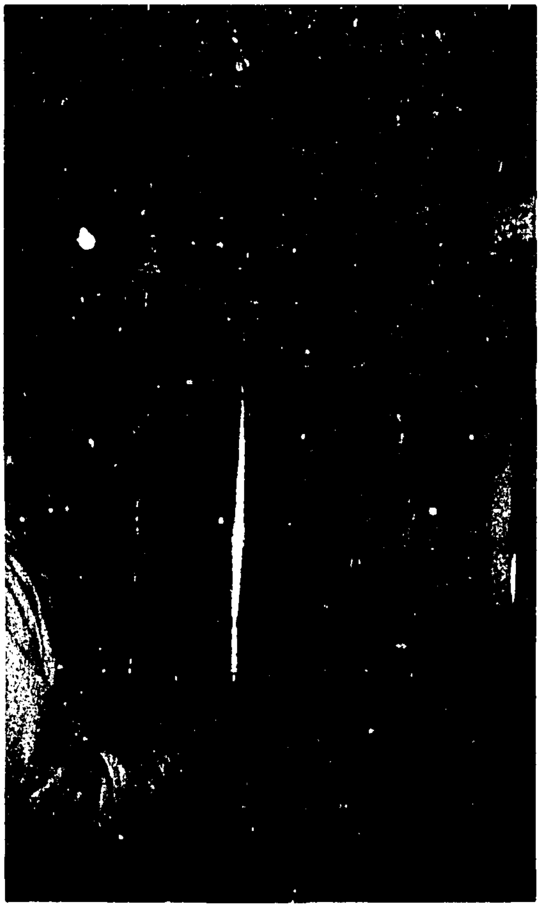
Rock Source	Chemical Composition					
	P_2O_5	CaO	Al_2O_3	Fe_2O_3	F	CO_2
	(wt %)					
Parc W (Niger)	28.8	39.6	1.10	1.80	3.4	1.1
Pesca (Colombia)	19.8	27.9	1.40	1.00	2.1	1.3
Huila (Colombia)	19.4	39.1	1.70	0.67	2.7	9.0
Hahotoe (Togo)	36.5	50.4	0.94	0.90	3.4	1.8
Tilemsi Valley (Mali)	26.2	39.5	2.5	6.3	3.1	2.3

The products were granular (in the size range of 1-4 millimeters) and had physical properties (crushing strength, abrasion resistance, and hygroscopicity/moisture penetration) similar to those of commercial fertilizers. The potential use of this phosphate material in making compound fertilizers is being investigated.

Wet-Process Phosphoric Acid

Our researchers continued the evaluation of phosphate ores for the production of wet-process phosphoric acid. Specific highlights are given under the Special Projects section. Certain improvements were made in procedures, and some new equipment was installed.

Continuous operation is achieved through actual measurement of process control variables, such as the phosphate and sulfate contents of the filter-grade phosphoric acid and solids content in the digestor slurry. Pretest calculation procedures were developed to predict values of these flows. Also, heat of reaction, heat of dilution of the



Left:
This new continuous laboratory-scale phosphoric acid concentrator has greatly increased IFDC's research capability.

Right:
This continuous acidulation unit is used to characterize phosphate rock dissolution in mineral acids.

sulfuric acid, and evaporation losses were calculated. The system was modeled in BASIC computer language, and the program is called BALANCE. It has proven to be a very valuable and time-saving aid for operating the bench-scale or pilot-plant unit.

The filter-grade phosphoric acid must be concentrated before being used to make fertilizer. A new laboratory-scale, continuous, vacuum concentrator, which simulates a typical concentrator using the forced-circulation, vacuum-evaporation concept, was fabricated and placed into operation. This new unit provides more complete data than the batch equipment used previously. It has the capacity to concentrate 0.5-0.8 kilogram of filter-grade feed acid (28%-30% P_2O_5) per hour to merchant-grade acid (50%-54% P_2O_5). The unit has the capability of measuring the heat input and determining the fluorine balance. Corrosion testing of metals used to construct commercial concentrators also can be conducted in this equipment. This unit permits a more comprehensive evaluation of the performance of the phosphoric acid during concentration.

Ammoniated Granular Triple Superphosphate

Mixtures of urea and superphosphate, without ammoniation, form an adduct accompanied by the release of water; this causes severe caking during prolonged storage periods. Ammonium phosphates (monoammonium and diammonium) are compatible with urea. During 1982 the IFDC granulation pilot plant was used to produce ammoniated granular triple superphosphate. The ammoniated granular triple superphosphate provides an alternative raw material for use in bulk blending. A typical analysis is 5% nitrogen and 44% total P_2O_5; about 55% of the P_2O_5 is water soluble and 77% is available (water plus neutral ammonium citrate soluble). Thus, a portion of the P_2O_5 is considered to be in a slow-release form that will eventually become available particularly on acid soils (pH 4.0-5.5).

The process involves continuous digestion of phosphate rock with phosphoric acid to form a slurry. The slurry is fed to a rotary drum where ammonia is added. The moist granules are dried and screened, and the product is cooled in a conventional manner.

The ammoniated granular triple superphosphate exhibited excellent granule hardness and good resistance to absorption of atmospheric moisture and caking. Blends made with various combinations of ammoniated granular triple superphosphate, urea, and potassium chloride had good storage properties.

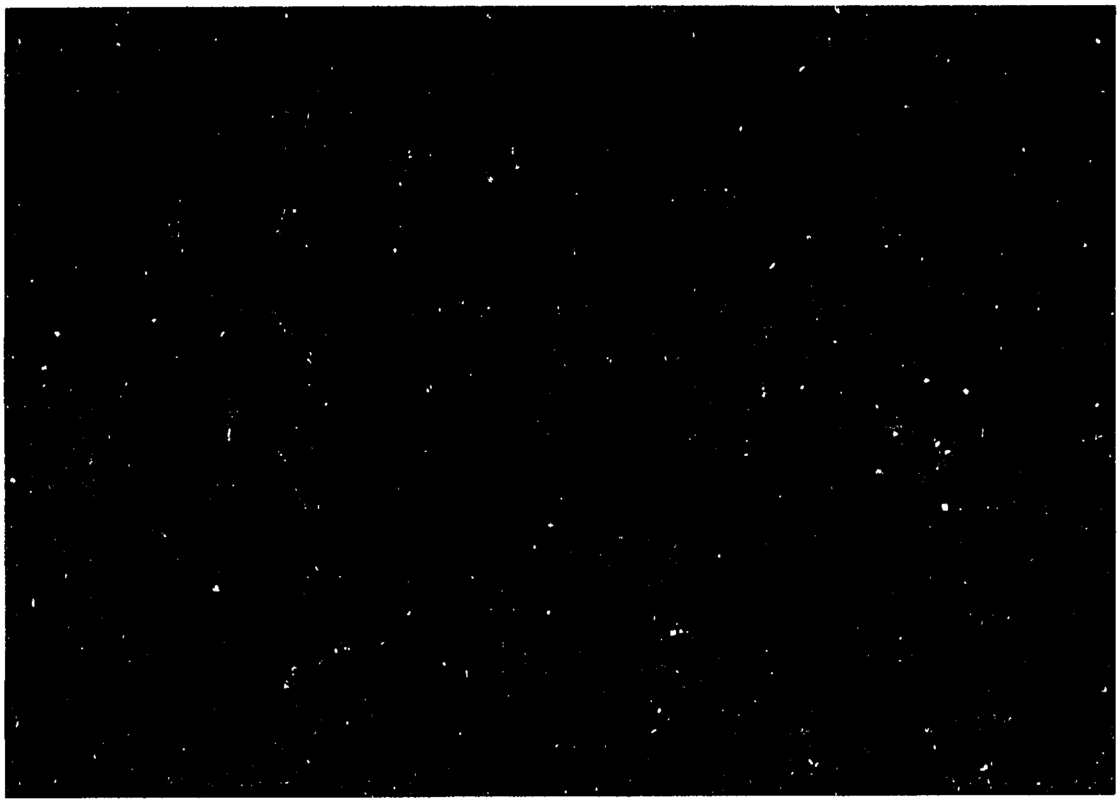
Studies of Soil and Phosphate Reactions

During 1982 one of our soil scientists conducted research at the University of Reading in England; he characterized the reaction products of Colombian soil that had previously received applications of soluble fertilizer and phosphate rocks. TSP and six sources of phosphate rock had been applied to the soil. The soils were collected after 5 years from the time the TSP and/or rocks had been added at a rate of 400 kilograms of P_2O_5 per hectare.

The rate of decomposition of phosphate rocks in this soil appeared to be greater than what is expected in temperate soils. Data indicated that the quantity of unreacted rock was only 2.5% for the highly reactive Sechura (Fosbayovar), Peru rock and 20.9% for the low-reactive Pesca, Colombia rock. These results suggest that the reaction products rather than the unreacted phosphate rock fraction provided the residual available phosphorus to the plant. Available phosphorus as measured by Bray P_1 solution increased with the addition of fertilizer phosphorus and correlated with crop yield (dry-matter yield of *Brachiaria decumbens*) in two distinct curves—one for phosphate rocks and one for TSP. Results suggest that the reaction products from phosphate rocks may differ from those from TSP, even though the reaction products are probably in the same form as aluminum phosphate and iron phosphate. No distinction was made between these forms in this study.

Laboratory and Greenhouse Research

Research was conducted at Headquarters to study the effect of time of application of phosphate rock on its agronomic effectiveness. It would seem that incubation of soil with slowly dissolving phosphate rock prior to cropping could increase the plant-available phosphorus, thereby promoting seedling growth. The extent to which improvements in both seedling growth and agronomic effectiveness of the



The x-ray fluorescence unit, one of the many laboratory instruments, is used in IFDC's research program.

rock occur would lepend on the characteristics of both the soil and the phosphate rock. IFDC researchers used Sechura, a highly reactive phosphate rock from Peru, and Kodjari, an unreactive rock from Upper Volta, in the trial. The soils were Mountview silt loam (Typic Paleudult) and Hartsells silty clay loam (Typic Hapludult).

In both soils addition of a small quantity of lime to some of the treatments raised the pH of the soil by approximately 0.5 units but did not influence the performance of the phosphate rocks. Incubating the Fosbayovar phosphate rock for 6 weeks in the Mountview soil before cropping did not affect the yield of maize. On the other hand a 6-week incubation in the Mountview soil improved the performance of the Kodjari phosphate rock by 22%. Yields were generally lower in the Hartsells soil, and the mean yield from the Kodjari phosphate rock treatments was decreased by 66% as compared with yields with the Mountview soil. For both phosphate rocks incubation for 6 weeks in the Hartsells soil significantly depressed yield. It would seem that phosphate rocks perform better in soils with reduced tendency to immobilize soluble phosphorus. If unreactive phosphate rocks such as Kodjari phosphate rock have to be applied, especially to low P-fixing soils such as Mountview silt loam, application of the rock well before cropping could be advantageous (Table 6).

IFDC also continued the evaluation of west African phosphate rocks. Several of the phosphate rock deposits in west Africa are classified as unreactive. They are considered unsuitable for direct application especially for short-season, high phosphate-demanding crops such as maize. Four of the west African rocks were partially acidulated to varying degrees with sulfuric acid. In a greenhouse experiment with sorghum, 44% acidulated Kodjari (Upper Volta) phosphate rock whether crushed (-20 mesh) or as conventional granules was as effective as single superphosphate (SSP) in terms of grain weight of sorghum at harvest. Mixing the phosphate rock with elemental sulfur in the ratio of 1:0.6 P:S reduced the effectiveness of the phosphate rock as compared with the unreacted rock. In another experiment with maize, the relative agronomic effectiveness (RAE) of Togo phosphate rock and PARC-W phosphate rock (Niger) compared with TSP increased from 37% and 7%, respectively, for the finely ground unacidulated form to 84% and 72%, respectively, for the 25% acidulation

Table 6.
Response of Maize to Phosphate Rocks of Different Reactivities as Influenced by Soil Type and Time of Application (g/pot)

P Application Rate	Mountview Soil		Hartsells Soil	
	No Incubation	6-Week Incubation	No Incubation	6-Week Incubation
(ppm P)				
(A) Fosbayovar Phosphate Rock				
0	7.35	6.05	2.39	2.53
100	42.05	42.99	35.91	23.47
200	57.55	58.15	50.65	41.35
400	73.59	72.07	55.84	48.28
(B) Kodjari Phosphate Rock				
100	7.49	9.45	2.60	2.68
200	10.41	11.51	2.97	2.52
400	12.01	15.64	4.52	3.08

rate. Acidulating to 50% increased the RAE to 98% for both phosphate rocks. With maize as the test crop, the RAE of 44% acidulated Kodjari phosphate rock increased from 7% to 90%.

Field Research—Latin America

Our scientists stationed at CIAT conducted field research in Latin America, in collaboration with institutions including the National Institute for Agricultural and Livestock Research (INIAP) in Ecuador and the National Institute for Agriculture and Livestock Research and Promotion (INIPA) and La Molina University in Peru. The purpose of this project is to evaluate selected Latin American rock sources and modified forms of the rocks as fertilizer. Research was focused on management of

Workers establish a bean experiment in a Colombian farmer's field.

repeated applications of phosphate rock, PAPR, and mixtures of phosphate rock with superphosphate, varietal differences in phosphate use efficiency, and residual effects related to single applications of phosphate sources.

Preparation of experimental products for agronomic testing is an important part of the project. The processes that were used emphasize low investment, minimum raw materials consumption, and simplicity compared with conventional processes. In 1982 a total of about 2 tons of materials was made using Pesca and Huila rocks and shipped to Colombia. The granular products were made by partial acidulation with sulfuric acid using 20% or 50% of the acid normally used to manufacture superphosphate. With 50% acidulation of Huila rock, the product contains 14.6% total P_2O_5, 7.1% water-soluble P_2O_5, and 2.8% citrate-soluble P_2O_5. At 40% acidulation of Pesca, the total P_2O_5 was 16.4%, 6.3% water-soluble P_2O_5, and 4.4% citrate-soluble P_2O_5.

Our outposted scientists, using these materials, initiated a number of experiments. Among these was one to evaluate the effectiveness of mixtures of TSP and Huila phosphate rock and the management of these mixtures during 1981 using beans as a test crop. Two more crops were planted in the same plots during 1981 and 1982. Reapplications of the initial phosphate sources, rates, and mixtures were performed for these two new crops. Results of the first experiment indicate that the response of the beans to added phosphate was systematically reduced as the proportion of TSP in the mixture was reduced. In the case of the second and third harvests, TSP alone was generally better than the mixtures, but mixtures of 50% TSP banded and 50% Huila phosphate rock broadcast and incorporated produced almost equal yields to the 25% TSP - 75% Huila phosphate rock mixture. This was not the case when the TSP and the phosphate rock were mixed and band applied; with this method of application, the TSP remained significantly superior.The results confirm that after three crops the major portion of the applied phosphate used by the plant was still provided by the water-soluble phosphate carrier. In general, yields of the third crop were higher than those of the first and second crops, indicating that the phosphate fertility level of the soil is showing significant improvement due to the presence of both the TSP and the lower cost indigenous material.

Partial acidulation of phosphate rock in varying proportions with either sulfuric acid or phosphoric acid increases initial plant-available phosphate. For this reason partially acidulated (20% and 40%) Pesca phosphate rock and cogranulated mixtures of Pesca phosphate rock with 18% and 9% TSP have been tested. In an experiment conducted in CIAT-Popayan during 1981 and 1982, IFDC scientists evaluated the effectiveness of partially acidulated Pesca phosphate rock and mixtures of TSP and Pesca phosphate rock and the residual effect with beans. The initial response to 40% acidulated phosphate rock was generally greater than that of cogranulated TSP and Pesca phosphate rock. Only at the highest rate of application in the experiment was it observed that the crop response from cogranulated material was equivalent to that of partial acidulation. At a lower degree of acidulation (20% PAPR), yields were approximately equivalent to those obtained with a mixture containing 9% TSP. At all phosphate rates yields decreased as the water and citrate solubility of the fertilizer decreased.

During 1982 the researchers repeated this experiment in the same plots with reapplication of the same phosphate sources at the same rates of phosphorus. Plots that had received 352 kilograms of phosphate per hectare during the first crop were planted, but no additional phosphate was added in order to determine the residual effect of the different phosphate sources. In the second harvest reapplication of soluble phosphate sources resulted in better yields than those of low phosphate solubility (Figure 4). Reapplication of the high phosphate rates (176 kilograms of phosphorus per hectare) produced no yield differences among the Pesca phosphate rock modified products. Apparently the yield increase was due to the soluble phosphate present in each of the products tested because the response of beans to residual phosphate showed yield differences among the phosphate sources; higher yields were produced by those with highly soluble phosphate like TSP and partially acidulated (40% and 20%) Pesca phosphate rock.

IFDC researchers established an experiment on an Andept soil during 1982 to determine whether differences exist among

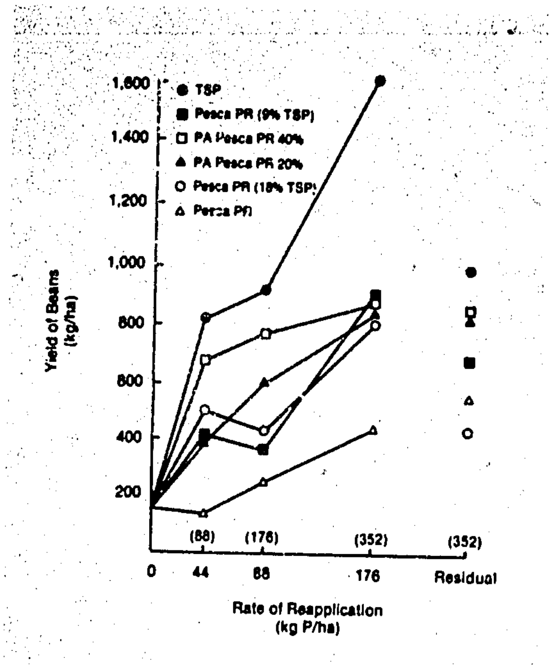


Figure 4. Effect of Partial Acidulation and Cogranulation of TSP With Pesca PR on the Production of Beans on an Andept From CIAT-Popayan. (Numbers in parentheses represent total P applied for the two crops.)

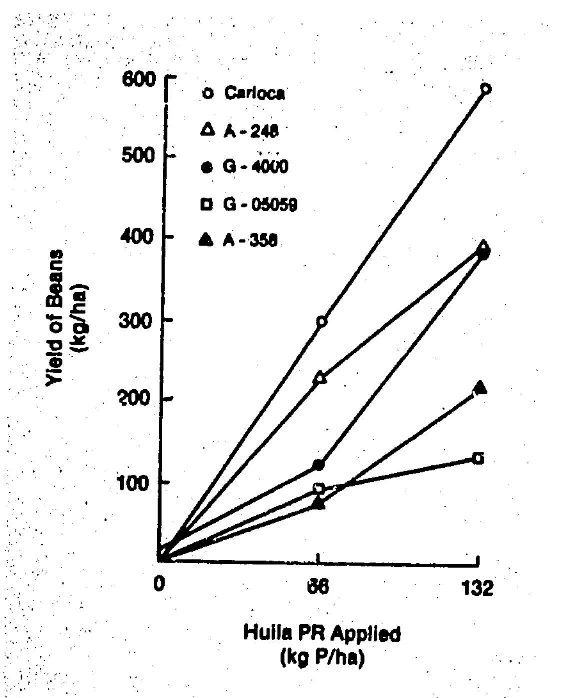


Figure 5. Response of Five Bean Varieties to Applications of Huila PR on CIAT-Popayan Andept.

varieties in their relative efficiency in use of phosphate from sources of low phosphate solubility, to determine the need for soluble phosphate in a soil with high phosphate fixation capacity, and to investigate the soluble phosphate/lime interaction. The researchers measured the response of five bean varieties to phosphate rates applied as TSP, Huila phosphate rock, and a mixture of 50% phosphate as TSP and 50% as Huila phosphate rock. Large differences were observed both between the different varieties (Figure 5) and the source of phosphorus. However, with each variety the RAE of the phosphate sources followed the order: TSP > TSP + Huila phosphate rock > Huila phosphate rock, but when the rate of phosphate applied was only 66 kilograms per hectare, the mixture of TSP and phosphate rock produced yields equal to those of TSP alone. Different varieties responded differently to Huila phosphate rock applications (Figure 5). In this case, three of the varieties showed a higher response to Huila phosphate rock when compared with the other two varieties.

A very important factor that must be considered in the determination of the suitability of the phosphate sources is the residual value. Unlike the mobile nutrients, phosphate remains in the vicinity of application for long periods of time and remains available to provide a portion of the crop's requirements for a number of cropping periods. Previous experiments established in Las Guacas, Popayan, showed that the highly reactive phosphate rocks were equal to or better than TSP in providing residually available phosphorus in each of the three consecutive seasons following the initial cropping period. The medium and low reactivity phosphate rocks tended to increase in effectiveness until they became equal or very close (82%) to residual TSP in the third crop.

IFDC scientists established experiments with beans in the CIAT-Popayan station in 1981; the results were discussed in the *IFDC Annual Report, 1981*. Those results and data obtained in 1982 show that a reduction in effectiveness of phosphate rocks was observed on Andepts that exhibit higher phosphorus retention and higher reactive aluminum than Ultisols and Oxisols.

It should be pointed out that the results discussed above represent attempts to determine whether the agronomic effectiveness of reduced solubility products can be improved under the difficult conditions encountered with high phosphate-fixing soils of volcanic origin. As discussed in previous annual reports, forage grasses and legumes, rice, cowpea, and other crops have produced excellent results on acid Oxisols and Ultisols. Our researchers initiated farm-level testing of finely ground phosphate rock and PAPR during 1982 under a wide range of soils and cropping systems.

Field Research—West Africa

The decline of agricultural production in Africa in the decade of the 1970s is, in part, the result of declining soil fertility and limited use of fertilizers.

In September 1981 the Executive Board of the International Fund for Agricultural Development (IFAD) approved funding for a fertilizer research program in sub-Sahara Africa. The objectives of this program were: (1) to conduct research on production of cheaper sources of phosphate fertilizers for different cropping and fallowing systems in sub-Sahara Africa making use of indigenous resources, (2) to study more efficient methods of management of nitrogen fertilizers, and (3) to devise more effective and efficient integrated nitrogen and phosphorus fertilizer application systems.

In this program, we are working collaboratively with IITA and ICRISAT through the Sahel Center in Sadore near Niamey, Niger.

Two experiments were set up at Ikenne in the subhumid forest zone of Nigeria and at Mokwa in the Southern Guinea Savanna zone. The agronomic effectiveness of Togo phosphate rock, 25% and 50% partially acidulated (with sulfuric acid), and Togo phosphate rock, was measured against two standard commercial phosphate fertilizers, TSP and SSP. High initial phosphorus levels in the soils from previous fertilizer applications prevented dramatic responses to the phosphate fertilizers.

A similar experiment to evaluate the effectiveness of Niger (PARC-W) phosphate rock, 25% and 50% partially acidulated (with sulfuric acid) and Niger (PARC-W) rock, was established at Sadore in Niger. Response to phosphorus was highly significant in Niger. The effectiveness of 50% PAPR was equal to that of TSP (Figure 6).

Socioeconomic Research

The primary objective of the 1982 socioeconomic research portion of the Colombian

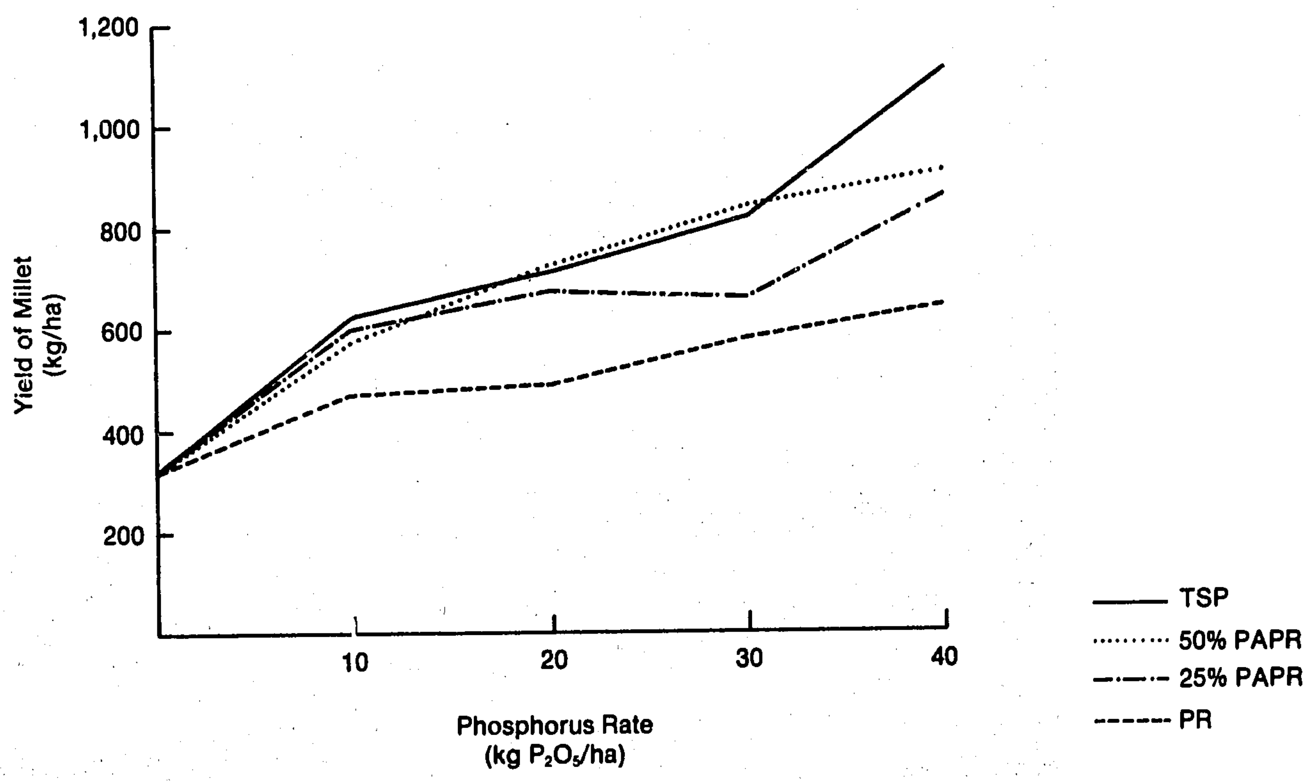
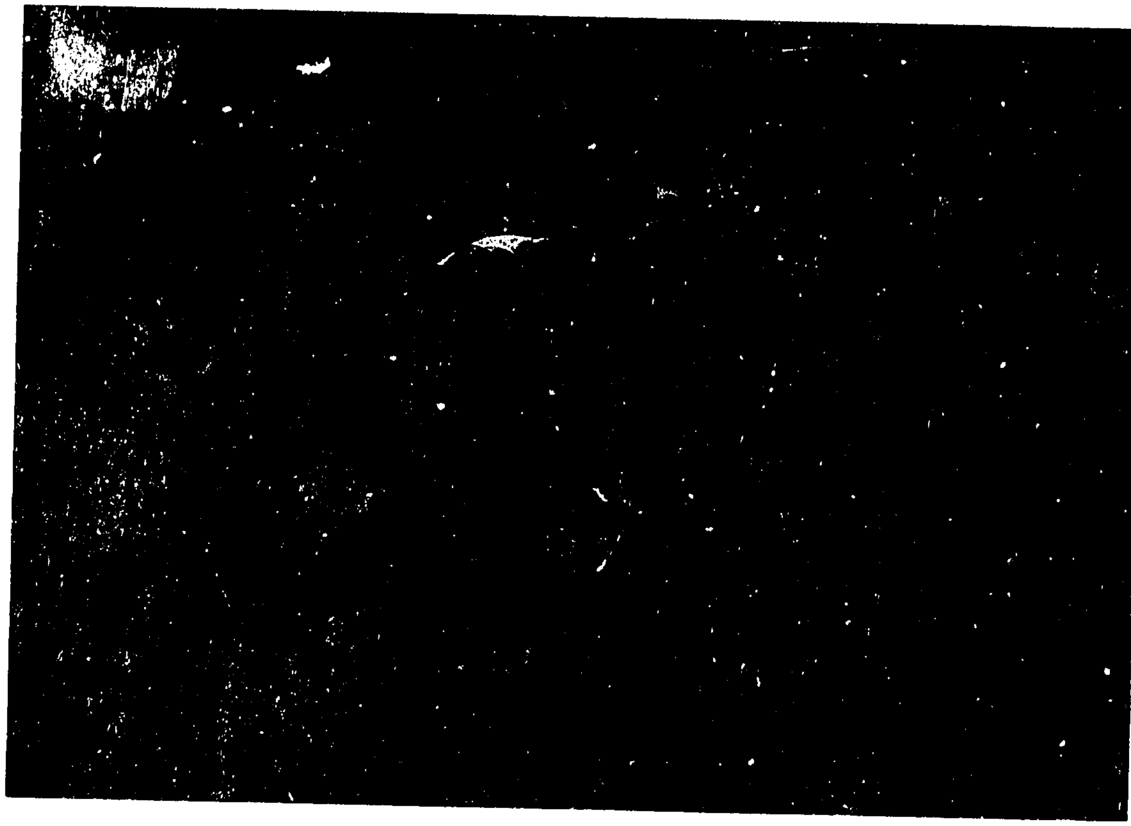


Figure 6. Response of Millet as Affected by Sources of Phosphorus Fertilizer.



Farmers in southern Colombia participate in the layout of a potato experiment with partially acidulated phosphate rock and ground phosphate rock. This experiment is being conducted by IFDC at CIAT.

phosphate project was to provide information on the environment in which farmers manage soil fertility. This information was used as a guide in the design of on-farm trials, in identifying potential adopter groups, and in evaluating results of farm trials.

Research in 1982 included the use of on-farm trials to help evaluate the applicability of previous findings of the phosphate project to cassava production in the Cauca department, Colombia. This research also assisted in the design of further cassava trials. Data collected on 102 farms indicate that with a long fallow, direct application of 50 kilograms per hectare of phosphorus from phosphate rock on less degraded soils appears economically more advantageous than more costly applications of TSP. However, on less fertile soils or for a succession of cassava crops, TSP gave a higher net benefit, especially when applied with support nutrients (nitrogen and potash). The study found that farmers who practice the traditional shifting cultivation and who lack education on the nutrient concepts of fertilizer prefer a fertilizer that "goes further." This is one that is relatively bulky, such as phosphate rock, and enables them to apply fertilizer at a lower cost per unit of area. Using the less expensive phosphate rock enables the farmer to diversify planting dates and locations and thus reduce susceptibility to drought, hail, pest, and disease attacks. However, if they concentrated their resources in a small area of land and used a relatively costly fertilizer such as TSP, their overall exposure to these risks would be increased.

Another phase of the socioeconomic research was a soil erosion study in the Cauca department. This study examined the socioeconomic incentives for over-exploitation of soil resources in a Colombian cassava farming system. Cassava farmers in the Cauca department farm small plots that are located on steep hillsides. After one plot's fertility is depleted, they move up the hill and slash and burn off a new plot. Under this traditional farming system, it is more profitable on a short-term basis to plant newly cleared plots than to cultivate successive crops on a plot, despite government efforts to restrict clearing new land. Most of the farmers do not perceive the long-term effects that their current practice of slash and burn with short periods of fallow has toward inducing soil erosion and a subsequent decline in soil fertility. In addition, land tenure arrangements and the social traditions of sharing land among family members are short term and contribute to the farmer's discounting soil losses. Those farmers who do perceive the problem do not have the financial resources to make the necessary short-term investment in adequate fertilizer so that they can cultivate successive crops on the same plot.

Because farmers in the Cauca department do not have a working knowledge of the importance of fertilizers and their long-term effects on maintaining crop yields, they resist shifting from the slash and burn system as a means of renewing soil fertility to continuous cultivation of cassava using good conservation practices and liberal doses of chemical fertilizer. Farmers in the Cauca department cannot continue the wasteful practice of the slash and burn technique without further accelerating soil erosion.

A third component of the socioeconomic research portion of the phosphate project dealt with farmers producing upland rice. A survey was made of fertilization practices of 31 growers of upland rice in the Meta department in eastern Colombia. One of the most striking results of the survey was the low use of phosphorus on these acid, infertile soils. On the other hand, many of the farmers used more than the recommended amount of nitrogen. Sources of phosphorus included compound fertilizers such as 15-15-15, DAP, TSP, basic slag and phosphate rock. Many of the farmers who used phosphate fertilizers did not use them according to research recommendations. Phosphate should be applied before or at the time of planting, but many farmers applied it in split applications 20, 50, or 70 days after planting when they applied nitrogen. Delayed application of nitrogen is recommended because it is thought to decrease vulnerability of rice to disease (piricularia). It was suggested that phosphate rock would be an especially appropriate source of P in this area if applied before or at planting time, with delayed split applications of nitrogen fertilizers. A larger survey of farmers' practices is planned for 1983.

Fertilizer information being generated through the IFDC/CIAT phosphate project including the socioeconomic component is being provided to the Instituto Colombian Agropecuario (ICA)—Colombian extension service—to assist farmers in improving food production.

Special Projects

Use of Local Phosphate Resources in Upper Volta—At the request of the Government of Upper Volta, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) sponsored the preparation of additional material for field tests in Upper Volta. The granular product is made by reacting finely ground, Kodjari, Upper Volta rock with sulfuric acid. This process appears technically attractive for unreactive rocks having a relatively high level of impurities. A typical product using 47% of the sulfuric acid normally used for SSP contains 18.9% total P_2O_5 with 7.0% water soluble and 3.3% soluble in neutral ammonium citrate.

Senegal Slimes Utilization—Our technologists investigated two methods for recovering phosphate from byproduct slimes produced by beneficiation in Senegal. Two approaches were used: (1) preparation of weak phosphoric acid from dilute slimes and (2) direct production of filter-grade (28% P_2O_5) acid from concentrated slimes. The main problem in the use of slimes is handling or separation of impurities during phosphoric acid recovery. Although preliminary results were promising, considerable research would be required to develop a basis for commercial production.

Diammonium Phosphate from Impure Phosphoric Acid--Diammonium phosphate (DAP) is a leading fertilizer in international trade; much of it is used in developing countries. A number of factors affect DAP production in commercial scale. A commercial company sponsored a pilot-plant project at IFDC to evaluate the effect of specific impurities in phosphoric acid on DAP. The sponsor expects that phosphate rocks mined in the future will contain higher levels of impurities, such as magnesium, iron, and aluminum, that are solubilized into phosphoric acid; this factor will affect the use of the acid in chemical processing. Developing-country fertilizer producers will be interested in results to be made available by the sponsor.

Negev Phosphates (Dicalcium Phosphate Granulation)—Laboratory-scale tests for granulation of wet (30% moisture) dicalcium phosphate with technical-grade phosphoric acid using a continuous pinmixer-type granulator produced an acceptable product as indicated by physical properties evaluation. A 10% maximum moisture content in the solids feed facilitates good operation in the pinmixer. This type of feed could be achieved by using two technically feasible methods. About 50% of the dryer discharge was produced in the desired product particle-size range (minus 1.19-plus 0.295-millimeters). The pinmixer produces spherical granules and is being used to produce several experimental granular products.

Negev Phosphates (Israeli Zin Rock for Phosphoric Acid)—Israeli Zin rock was evaluated for use in the bench-scale wet-process phosphoric acid unit operating in the dihydrate mode. Since this rock is reactive, relatively coarse material can be used. No significant problems were encountered with operation at two free sulfate levels. Reaction efficiency and recovery were acceptably high. There were no unusual corrosion problems. Filtration rates using this rock were somewhat lower compared with those of other rocks.

Taiba (Senegal) Rock for Phosphoric Acid Production—At the request of a sponsor, we tested Taiba rock from Senegal in the bench-scale wet-process phosphoric acid unit in the dihydrate mode. Because this is a high-grade material, both sulfuric acid consumption and solids production were relatively low. The acid indicated a low corrosion tendency. The recovery of P_2O_5 and the filtration rate were high. The Taiba rock performed well in comparison with other known standards being used for phosphoric acid.

SULFUR RESEARCH

The importance of supplying sulfur to increase crop production is becoming more widely recognized in many parts of the tropics. In the past 10-20 years, new crop varieties have been introduced, and increased levels of NPK fertilization have been common throughout the tropics. Thus, yields have increased and sulfur uptake from the soil has increased at a corresponding level. Unfortunately, the replacement of sulfur to the soil has decreased because of the change to high-analysis nitrogen and phosphate fertilizers devoid of sulfur.

Despite the recognition of this problem, relatively small advances have been made in correcting the sulfur deficiency problems where they exist. Methods to identify the exact locations and magnitude of sulfur deficiencies are inadequate. IFDC is, therefore, undertaking a program that will address the following areas of research.

1. Evaluation of chemical methods to identify the most appropriate techniques for identification of sulfur fertilizer requirements.
2. Investigations of the effect of sulfur fertilization on crop yield and quality.
3. Research on the reactions of potential sources of sulfur with respect to plant availability interactions with other nutrients, susceptibility to loss, and long-term effects under both upland and flooded conditions.
4. Evaluation of methods for incorporating sulfur into fertilizer formulations for use in the tropics.

Reactions of Sulfur-Containing Fertilizers in Soil

During 1982 we conducted greenhouse evaluations to determine the effect of incorporating phosphogypsum into a high-analysis phosphate fertilizer. It is recognized that a product such as single superphosphate has been an excellent source of soluble phosphorus while additionally providing substantial quantities of sulfur in the form of gypsum. The benefit obtained from the sulfur component has been eliminated by the trend to change to materials, such as TSP, that increase the fertilizer grade with respect to phosphorus by removing the gypsum.The objective of the greenhouse evaluation was to determine if a P:S ratio lower than that of SSP could provide sufficient sulfur to a sulfur-deficient soil with minimal reduction of the phosphorus grade.

Preliminary evaluation of the yield results from this test indicates that sulfur as phosphogypsum can be incorporated into TSP, thereby resulting in improved agronomic effectiveness in a sulfur-deficient

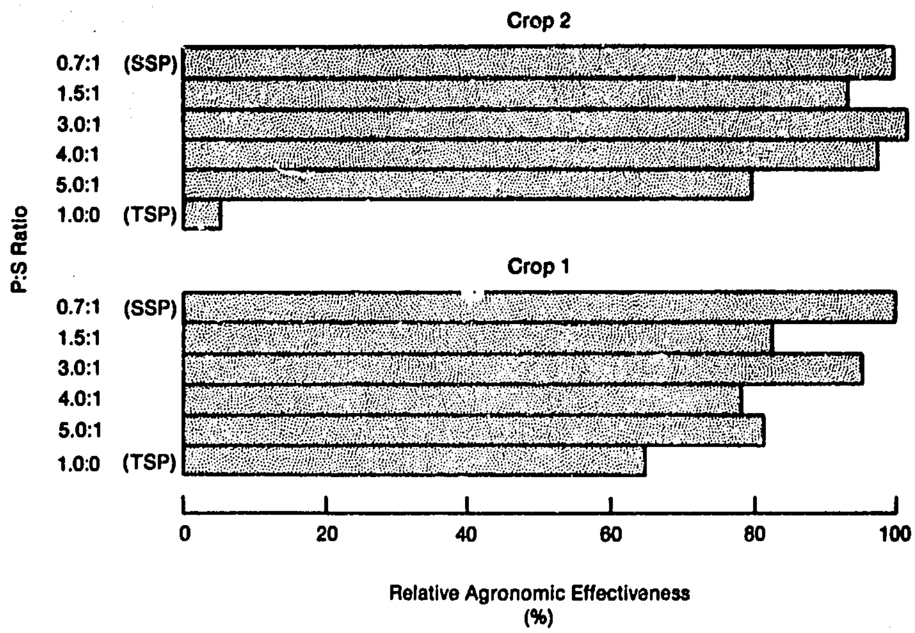


Figure 7. Relative Response of Maize to Sulfur-Containing Phosphorus Fertilizers.

soil (Figure 7). Our researchers observed a definite response to sulfur with TSP in which phosphogypsum had been included as compared with TSP without sulfur. This response was most apparent in the second cropping period when native sulfur had been depleted and TSP alone was only 5% as effective as SSP. On the other hand, sulfur-containing TSP was equally as effective as SSP with only 28% of the quantity of sulfur included in SSP.

Analytical Methods and Crop Response

During 1982 our researchers continued their investigations into the reliability of analytical techniques to predict sulfur deficiency. Evaluation of data from laboratory tests and from other sources indicates that phosphate-extractable sulfate measurements with turbidimetric techniques of sulfate analysis are not ideal but remain the most appropriate means of evaluation at the present time.

To gain a more complete understanding of sulfur testing, use, and crop response in the tropics, a visiting scientist initiated an in-depth analysis of both published and unpublished information from the tropics during 1982 (See the section on Economics Research Policy Studies.).

POTASSIUM RESEARCH

The International Potash Institute (IPI), the Phosphate and Potash Institute (PPI), and IFDC developed a project to identify and quantify, to the degree possible, the need for, and use of, potassium in tropical agriculture. From this information, guidelines to appropriate policies and action programs leading to enhanced crop production were obtained.

A visiting scientist developed a questionnaire which was completed by 41 developing countries. Follow-up visits were then made to selected countries in Asia and Africa.

The reasons for the interest in potash are twofold. First, the quantity of potash in relation to N and P used in developing countries is much less than that used in developed countries. While over 40% of the world's nitrogen and 30% of the phosphate are used in developing countries, only 16% of the potash is used there. The main point developed from the study is that where yield-increasing technologies are being rapidly adopted and where potash removal (in grain and straw) is high, current potash recommendations may quickly become quantitatively inadequate. A careful monitoring of the potash status of the crops in highly productive systems is needed.

Additionally, it was felt as a result of the study that if fertilizer costs are being subsidized in a country, then all required nutrients should be treated in a similar fashion in order to avoid skewing the farm-level demand away from fertilizer recommendations.

ECONOMICS RESEARCH

Successful development of improved fertilizer technologies and their adoption by the developing countries depend upon the economic return that these technologies can generate. IFDC's economics research program carries out economic analyses and enlarges the information base upon which various research and development policies concerning fertilizer technology development and transfer are formulated. This information is not only vital to the work of IFDC's fertilizer technologists, soil scientists, and engineers, but also it is important to the decisionmakers in developing countries. The work of the economists helps to pave the way for the transfer and acceptance of economically favorable developments in fertilizer technology.

During 1982 data pertaining to the 1979/80 crop year generated by an in-depth farm survey in eastern and central India were analyzed. The survey was carried out to investigate the farmers' circumstances and behavior in relation to fertilizer use and food production. These analyses produced some very useful results.

An energy policy study, analyzing the economic and technical links among the energy, fertilizer, and agricultural sectors, pointed out ways of conserving energy in the production, distribution, and use of fertilizer. Since the energy used to produce a 50-kilogram bag of urea is equal to 58 liters of gasoline, energy conservation is vitally important to the fertilizer industry. The publication of the energy study has proved to be a very popular, useful tool for policymakers around the world.

Farm-Level Studies

Agricultural Production and Fertilizer Use

In collaboration with the Hindustan Fertilizer Corporation (HFC), our economists carried out a farm-level investigation of the constraints to increasing fertilizer use and food production in India. The study covered about 2,400 farms in 20 locations in the States of Assam, Bihar, Madhya Pradesh, Orissa, and West Bengal, where fertilizer use and food production are relatively low. The study locations have now been selected for an in-depth fertilizer program of farm-level demonstration work aimed at educating farmers in the use of fertilizer and related technology.

The overall objectives of the study were (1) to determine the extent to which various constraints influence fertilizer use and crop production; (2) to develop the implications of the findings for policies of the government, HFC, and other fertilizer companies for efficient fertilizer marketing and use and increasing food production; and (3) to generate appropriate information about farm practices and farmer behavior for the design of fertilizer educational programs in the selected areas of the five states. The results of this study show that most of the farms are small. The average operational farm size is less than 2 hectares, and over 74% of the farmers operate farms smaller than the average and control about 34% of the total farm land. A typical farmer cultivates about five plots that contain less than one-half hectare each.

The results relating to farmers' knowledge and use of fertilizer indicate that most farmers in the study areas are aware of fertilizers, and over 25% have used fertilizer for at least 10 years. A sizable proportion (over 10%) have known about fertilizers for at least 21 years. Most farmers used fertilizer first on paddy or wheat crops. However, about 40% of the farmers do not regularly use fertilizer. This percentage varies across seasons, locations, and by farm size. A larger percentage of farmers use fertilizer during the summer season. On an average about 46% of the plots are fertilized during summer and 30% during winter.

Results relating to fertilizer availability and farmers' purchase behavior indicate that at most locations fertilizer is available within less than 2 kilometers and that on an average farmers buy fertilizer and visit fertilizer depots once during the season. These results imply that fertilizer availability is less of a constraint to fertilizer use and that farm-level constraints are more important.

Paddy and wheat are the crops on which most of the fertilizer was used in the sample areas. During the summer 96% of the fertilizer consumed was used on paddy alone, and during the winter 95% of the fertilizer consumed was used on paddy and wheat. Urea, calcium ammonium nitrate, Gromor (28:28:0), and Suphala (15:15:15) are the main sources of nitrogen. During the winter season ammonium nitrate phosphate (20:20:0) is also important. Gromor, Suphala, SSP, DAP, and other mixtures are the major sources of phosphate. During the summer potash is supplied by Suphala and muriate of potash, but during the winter it is supplied only by Suphala. During the summer single-nutrient fertilizers have a 47% share in total fertilizer use and 57% in winter. The use of farm manures is mainly confined to the summer season when farmers use six times more of it than during the winter season; it constitutes a more important source of phosphate and potash than chemical fertilizers.

Results of the study show that fertilizer use is adversely affected by soil erosion. On a per-hectare basis this effect is more evident in the case of summer paddy than with winter paddy. However, since a larger proportion of winter paddy is cultivated on steeply sloped land, soil erosion is a more important constraint to fertilizer use on rice during the winter season.

Soil erosion influences not only fertilizer use but also crop yields. The results of this study indicate that paddy yields are adversely affected by soil erosion. For summer and winter paddy crops, the yields on steeply sloped lands subject to erosion compared with those on flat lands were lower by 90 and 289 kilograms per hectare, respectively. At the same time, fertilizer use on paddy lands subject to erosion is also adversely affected. These results imply a social cost of soil erosion, in terms of foregone income from paddy, of about $20 per hectare per year. Assuming 12% per year opportunity cost for capital and an effective life of 30 years, an investment of about $160 per hectare for erosion control may be justifiable on economic grounds.

The results of this study that relate to credit indicate the following:

1. About 35% of the farmers use credit from some source.
2. More farmers use credit in larger farm-size groups.
3. Except in the case of West Bengal, more farmers use credit during the summer season compared with the winter season.
4. The cooperatives, commercial banks, and moneylenders, in that order, are the major sources of credit.
5. Approximately 65% of the credit is received as cash.
6. There is an approximate time delay of 45 days to obtain credit.
7. The average loan term is 15 months.
8. The departments of agriculture, the commercial banks, and the cooperatives are the cheapest sources of institutional credit and the average interest rate in the case of loans from moneylenders and landlords is about 35%.

The results also indicate that the use of high-yielding varieties (HYVs), pesticides, labor, and animal power all have an important positive influence on the amount of fertilizer used per hectare of cropped land. When other factors were held constant, growing HYVs increased fertilizer use by 17 and 22 kilograms of NPK per hectare during the wet summer and dry winter seasons, respectively. But a low level of HYV use (only 8% of plots) is a serious constraint to fertilizer use during the summer. Pesticide use also increases fertilizer use more during the winter season.

The study revealed that the variable factors of production (fertilizer, HYVs, labor, and animal power) contributed more to paddy yields in the winter season than in the summer season. For example, the contribution of fertilizer to yields for winter paddy was 631 kilograms per hectare compared with 175 kilograms per hectare for summer paddy. Net benefits from fertilizer use per hectare were approximately 53% higher for winter paddy ($23.5 per hectare) than for summer paddy ($15.5 per hectare), and these benefits are affected by the pH of the soils. In increasingly alkaline soils (pH >6.5), yield increases from fertilizer use on summer paddy are considerably less than in the case of soils with a pH lower than 6.5. Irrigation and use of HYVs augmented the net benefits of fertilizer use to a considerable degree but more so in winter paddy. Also the level of fertilizer use for winter paddy is quite high (115.5 kilograms per hectare).

During the crop year (1979/80) to which these results pertain, there was a very severe drought over all of India, which significantly affected the yields and net benefits of fertilizer use in summer paddy and winter wheat crops. For these crops, respectively, farmers expected to obtain yields that were 55% and 44% higher than they actually obtained. For winter paddy, however, this uncertainty was only 3%. The high levels of yield uncertainty for summer paddy and winter wheat also significantly affected fertilizer use on these crops. On the other hand, the magnitude of uncertainty of crop prices received by farmers is much smaller than the yield uncertainty. The results imply that the main source of uncertainty that the farmers face about obtaining benefits of fertilizer use is the uncertainty of crop yields rather than prices.

Policy Research

Fertilizer policy research at IFDC is designed to generate information appropriate for formulating public policies related to fertilizer research, production, distribution, and use in developing countries.

Energy Policy Study

During 1982 we published a technical bulletin entitled *Energy and Fertilizer: Policy Implications and Options for Developing Countries.* The study deals with estimating energy requirements for fertilizer manufacturing, packaging, transportation, and application; analyzing policy implications of energy supply and prices on fertilizer production, distribution, and prices; and evaluating policy options to reduce the adverse impact of energy supply and prices on fertilizer and agricultural sectors.

The study produced several major findings. For example, average energy requirements for manufacturing fertilizer nitrogen are approximately 9 times that of phosphates and 11 times that of potash. Approximately 81% of the total commercial energy used in the world fertilizer sector is for fertilizer manufacture, and the remaining 19% is used for fertilizer packaging, transportation, and application. Nitrogen alone accounts for 90% of the total energy used in fertilizer manufacturing.

The authors of the energy report found that the probable maximum energy saving using current proven technology is 25% for ammonia, 32% for urea, and 72% for TSP. The most promising means for saving fertilizer energy, however, is more efficient use of fertilizer. In fertilizer manufacturing, the greatest energy saving is likely to come from operating existing plants more efficiently.

This study revealed certain implications for policymakers. For example, every effort should be made to encourage efficient and balanced use of fertilizers, especially in favor of less energy-intensive fertilizers. In addition, energy efficiency, along with reliability and cost, should be given high priority in making decisions concerning the selection of fertilizers to be produced and manufacturing processes to be used.

Sulfur Study

During 1982 IFDC initiated a study entitled "Fertilizer Sulfur and Food Production: Research and Policy Implications for Tropical Countries." The primary objective of the study was to analyze the economic importance of sulfur in the fertilizer industry, food production, and the agricultural sector in the tropical countries of Africa, Asia, and Latin America.

Broadly the study deals with identifying sulfur deficiency problems and causes of sulfur deficiency; determining the magnitude and location of sulfur deficiency problems, both at farm and national levels; and examining the implications with respect to fertilizer research strategies and public policies needed to correct the sulfur problem.

Aggregate sulfur supply is declining because sulfur-containing fertilizers are being replaced by sulfur-free fertilizers, the new NPK requirements are being met through sulfur-free fertilizers (Figure 8), and the environmental concern for cleaner air has reduced the supply of sulfur from the atmosphere. On the other hand, sulfur requirements have been constantly expanding because of the shift in cropping pattern, expanding crop yields, and multiple cropping. The net result of increased demand and declining supply is that the sulfur gap is widening over time.

In addition to analyzing sulfur uptake and response in the context of tropical crops and soils, the study deals with (1) the role of sulfur in designing strategies for food production; (2) aggregate fertilizer sulfur requirements, supplies, and implied sulfur gaps in selected tropical countries and regions from 1960 to 2000; (3) past performance, current economic situation, and future outlook with respect to sulfur

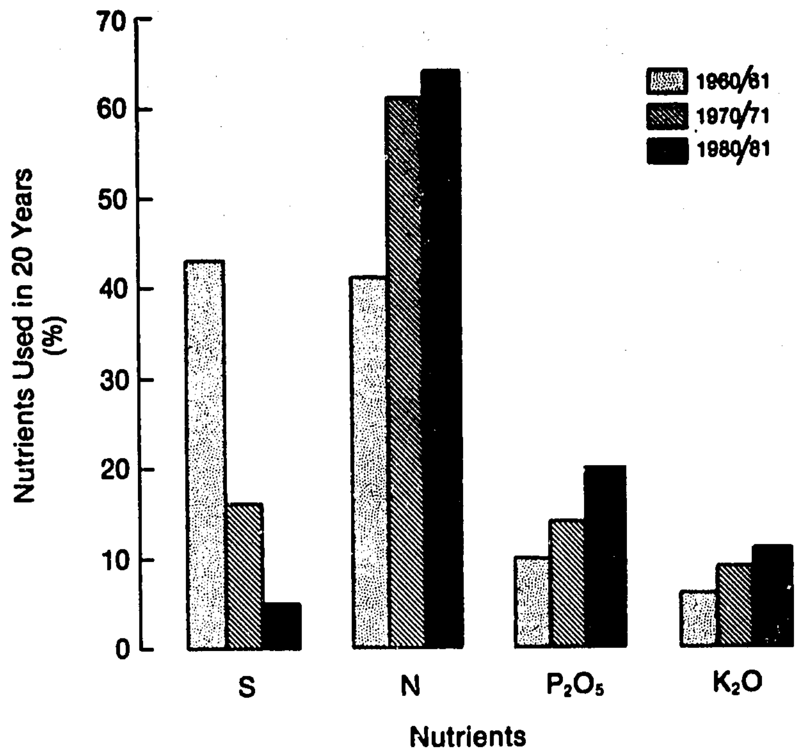


Figure 8. Evolution of Sulfur Use in Relation to Use of Other Nutrients in Indian Agriculture: Two Decades of Experience.

demand, supply, prices, resources, and trade; and (4) alternative fertilizer sulfur supply strategies.

Selected Agricultural Development Policies

As a part of the Bangladesh report, "Policy Options for the Development of the Fertilizer Sector," our economists carried out analyses of selected agricultural development policies of Bangladesh to assess their impact on food-grain production and employment based on IFDC/Bangladesh Agricultural Research Council (BARC) farm survey data.

The results of the analysis indicate that, assuming all other factors are held constant, a 10% increase in irrigated area would increase (1) the area under HYVs by 12%, (2) fertilizer demand by 5.16%, and (3) paddy and wheat yields by 3.73%. With respect to the policy to improve drainage and flood control, the results indicate that an addition of 10% in properly drained areas in Aus and Aman seasons would increase (1) area under HYVs by 7.2%, (2) fertilizer use by 1.9%, and (3) food-grain production by 0.56%.

Market Situation and Outlook

Fertilizer Price Analysis

During 1982 our economists collected and analyzed two types of price data: (1) monthly farm-level prices of principal fertilizer products and crops in Asian, African, and Latin American countries and (2) weekly international spot prices from North America for key fertilizer products and materials. Data on farm-level prices are received regularly from some 30 countries and used to determine comparative price differentials among countries for each fertilizer product or crop. Our economists prepare a monthly update of farm-level prices summarized by country and distribute it within and outside IFDC. The economists closely monitor and analyze farm-level prices to determine the changing trends in a farmer's ability and incentive to use fertilizer within and among countries. Each month our economists plot trends of international prices for different products and materials within and between years. Using these data they determine comparative economics of alternative sources. These data analyses assist fertilizer policymakers and suppliers in developing countries in strategic planning of market development, supply procurement, and production capabilities.

Fertilizer Use Statistics in Crop Production

During 1982 we completed our first attempt to assemble statistics on fertilizer use for different crops on a country basis. This type of information is usually not readily available, but it can be of great value to government planners, marketing specialists, and the fertilizer industry.

Our economists collected data through an extensive literature review and a questionnaire that was mailed to about 300 persons or organizations around the world. Data were obtained from 78 countries. Results of the analysis indicated that cereal crops were the main users of nitrogen, phosphorus, and potassium in most countries, followed by industrial crops. Rice was the main fertilizer user crop in Asia; maize and wheat were the main users in Europe, North America, and South America. Sugarcane and cotton are important fertilizer users in Africa and some countries in Latin America. The report also contains information about fertilization rates for different crops and the type of fertilizer products used.

IFDC Transfers Fertilizer Technology to the Developing World Through...

National Programs

An Indonesian agronomist examines tea leaves to determine their quality.

NATIONAL PROGRAMS

The effective identification, investigation, and solution of a country's fertilizer-related problems require a mechanism through which these actions can occur. To accomplish this, we have established a reciprocal partnership with key national agencies in three countries to help solve their fertilizer problems and thus assist these countries to better provide food for their people.

Our uniqueness is that we have the technical expertise in fertilizer production, marketing, d use to conduct an unbiased fertilizer sector study and provide solutions to a country's particular problems. To accomplish this endeavor, we can assemble multidisciplinary task teams composed of professionals such as agronomists, soil scientists, chemists, economists, engineers, and specialists in market development, communications, and personnel development.

We now have national programs operating in three developing countries—Bangladesh, Indonesia, and Mali. The Bangladesh program, which began in 1979, experienced expansion in scope and personnel commitments during 1982. The national program in Indonesia, dating back to 1980, became more diversified and focused not only on fertilizer efficiency research but also on fertilizer marketing and distribution. The Mali program, beginning in 1981, is progressing well in its efforts to help supply an efficient and economical source of phosphate for that country's farmers.

BANGLADESH

Marketing and Distribution Assistance

We have been engaged in a continuing technical assistance program in Bangladesh since 1979. This program, funded by USAID, is directed primarily toward assisting the Bangladesh Agricultural Development Corporation (BADC) in overcoming the fertilizer marketing- and distribution-related constraints that impede the expanded and more efficient use of fertilizer needed to raise food-grain production to government planned self-sufficiency levels.

Our program is implemented primarily by a three-member team of full-time resident consultants in Dhaka, who assist BADC staff and management in planning, instituting, and monitoring improvements in its fertilizer delivery system. Our Headquarters staff specialists and outside experts act as short-term consultants to resolve specific fertilizer supply and use problems.

The year 1982 saw a strengthening and broadening of our technical assistance program in Bangladesh. A third resident consultant was added to the Dhaka staff to meet increased assistance needs.

Distribution

The IFDC resident distribution specialist continued activities related to improving the management and cost effectiveness of the physical distribution component of the New Marketing System (NMS). In 1982 the distribution specialist did the following:

1. Reviewed and modified the warehouse management program to facilitate adoption by BADC. The program will be implemented on a trial basis at selected warehouses.
2. Initiated the stock control and accounting system in all of the fertilizer plants and many district warehouses and offices. Expanded implementation is underway.
3. Completed the least cost fertilizer transport study and applied the findings to the operation of the transport system. Use of lower cost movement routes, involving rail, road, and water modes of transport, should result in significant reductions in the cost of transporting fertilizers from the points of supply to BADC sales outlets.
4. Reviewed the National Fertilizer Storage Plan to reconcile longer term storage and transport requirements

The Manager of BADC Dealer Development and Training and an IFDC Training Consultant discuss the development of promotional materials for BADC dealer training.

Left:
Fertilizer is loaded onto a truck from a Bangladesh warehouse.

Right:
Bangladesh farmers wait to buy fertilizer at a dealer's shop in Dhaka.

with changes in projected fertilizer demand.

5. Studied Bangladesh fertilizer import procurement and receiving practices to determine the feasibility and cost consequences of increasing the importation of fertilizers in bulk rather than bagged form, currently the more common practice. Significant savings in total and foreign exchange cost should be realized by increasing the quantities of fertilizer imported in bulk form.

Marketing

In 1982 the resident marketing specialist made notable progress in strengthening several aspects of the BADC marketing system. Activities included the following:

1. Preparation of an abbreviated annual marketing plan for 1982/83. This plan will serve as a model for the development of a more comprehensive marketing plan for 1983/84.
2. Study of the compatibility of BADC's fertilizer marketing organization and management system with the objectives and goals set for the NMS. BADC is reviewing suggestions relating to changes in organizational structure and staffing patterns.
3. Development of a credit scheme whereby BADC would provide credit to qualified wholesalers on a short-term, revolving basis. The scheme will be tested on a trial basis. As part of the proposed credit program, fertilizer dealers are being encouraged to extend credit to farmers.
4. Monitoring of the implementation status of the NMS through regular monthly fertilizer dealer and farmer price and use surveys.

Dealer Training and Development

The NMS, adopted on a nationwide scale in 1981, relies heavily on an expanded private-sector fertilizer retail-dealer network to promote the sale and proper use of fertilizer. Restricting BADC sales to dealers to a limited number of primary distribution points increases dealer fertilizer transportation costs. In 1982 IFDC added a dealer development and training component to its technical assistance program to assist dealers in assuming increased responsibilities.

The main objectives of the BADC/IFDC dealer training program are (1) to increase dealers' fertilizer product and use knowledge to enable them to provide better technical assistance to farmers, (2) to enhance their business management expertise as a means of improving their operational efficiency and profitability and thus motivating them to devote more time and effort to promoting fertilizer sales, and (3) to improve dealers' fertilizer sales and market development skills and programs as a means of stimulating increased fertilizer demand.

Activities of the dealer development and training resident included:

1. Organization of a study tour of fertilizer dealer operations and training programs in India for BADC marketing personnel prior to the start of its dealer training program.
2. Establishment of a dealer training unit within BADC and training of senior BADC staff members to function as dealer trainers; preparation of dealer training course curricula and materials; and initiation of a series of dealer training programs.
3. Preparation of fertilizer merchandising aids; organization and implementation of a trial sales promotion campaign.
4. Development of a plan for establishing a fertilizer dealer association for BADC review. The dealer association would serve as a means by which dealers could assist each other in building their marketing and management skills and improving farmer assistance capabilities.

Special Consultancies

IFDC undertook two new consultancies during 1982. First, we initiated a 3-month study of ways to improve BADC's fertilizer procurement practices to improve availability and lower costs.

The establishment of an agronomic services consultancy marked a new direction in the extension of our technical assistance program. Under this consultancy, we are conducting a Coordinated Fertilizer Efficiency Project (CFEP) with the assistance of the BARC and related agricultural research organizations. The CFEP will feature studies on the efficiency of fertilizer and fertilization practices and contribute to the further development of Bangladesh's crop response data base and improved fertilizer recommendations. The latter will be used by fertilizer dealers and extension personnel to assist farmers in the more efficient use of fertilizers.

A terms of reference and workplan were developed for a study of ways to improve the handling and use properties of byproduct gypsum produced at the Chittagong triple superphosphate plant. Improvements in byproduct gypsum quality should lead to its expanded use as a source of sulfur to overcome sulfur deficiencies, which are becoming more evident in Bangladesh.

Personnel Training

IFDC continued to provide training in fertilizer marketing, production, and use for personnel from BADC and other government organizations.

Policy Options for the Development of the Bangladesh Fertilizer Sector

At the request of BADC, IFDC completed a study on Bangladesh fertilizer supply and use issues and policy options for their resolution. The study was carried out by IFDC and Bangladeshi fertilizer specialists. Its purpose was to develop and recommend more clearly defined and coordinated national-level fertilizer supply and use policies consistent with the government's plans for achieving agricultural and food supply development plans. A government-appointed committee is reviewing a revised draft of the report with the view to selecting and setting priorities for possible future policy action.

INDONESIA

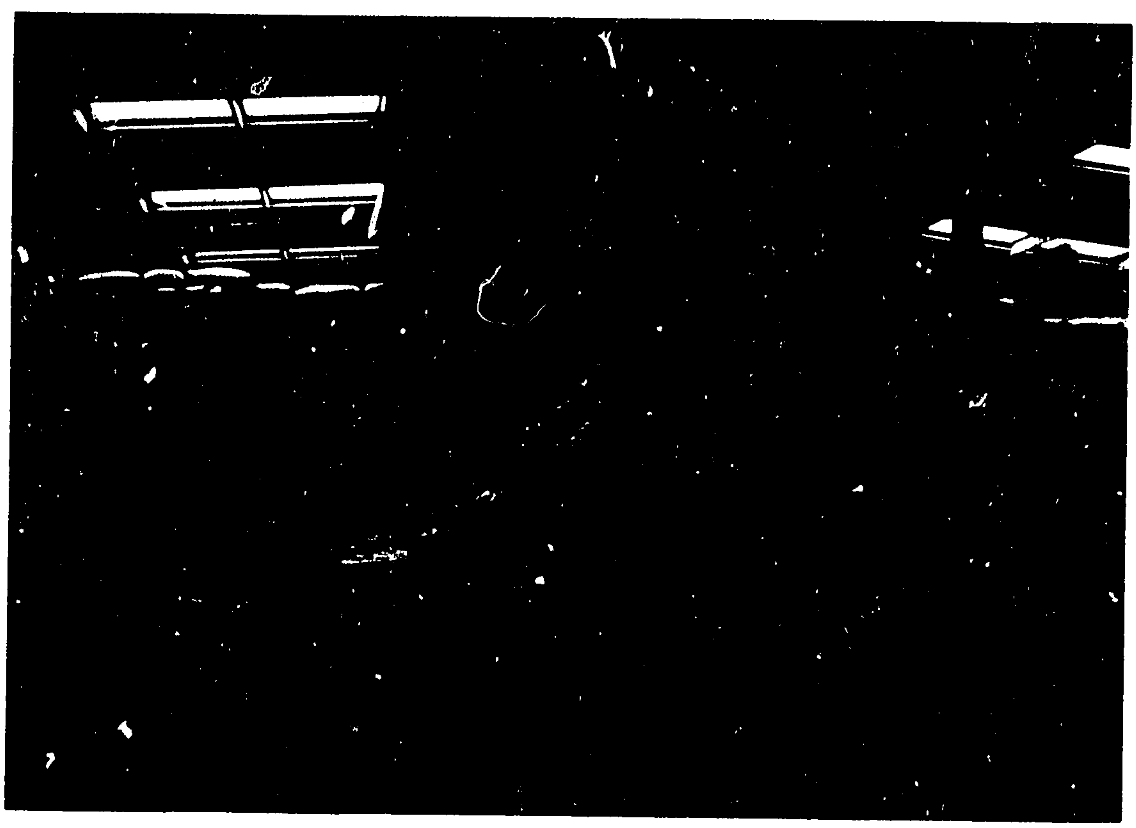
Fertilizer Efficiency Research

The Australian Development Assistance Bureau (ADAB) has provided IFDC support for a program of research into the more efficient use of fertilizers in Southeast Asia. Initially the program is focused on Indonesia where the Agency for Agricultural Research and Development is coordinating a National Fertilizer Efficiency Program. This program is composed of three working groups—lowland crops, upland crops, and socioeconomic—which include representatives of the fertilizer industry, extension agencies, and research centers in Indonesia. To assist the fertilizer efficiency program, IFDC has appointed three resident consultants, one for each workgroup, who are based at the Center for Soils Research in Bogor.

In October 1982 the three workgroups of the National Fertilizer Efficiency Program met to finalize plans for the 1982/83 crop season.

The upland working group plans a series of phosphate, nitrogen, sulfur, and crop residue management experiments on the acid soils of the Outer Islands of Indonesia,

Indonesia's sophisticated distribution system involves all types of transportation.



Indonesian workers neatly stack fertilizer bags in well-planned storage.

which are being developed for the government transmigration scheme. Experience gained in Indonesia is being extended to other countries in Southeast Asia through cooperation with the IRRI Cropping System Network.

The lowland crops' group is conducting field experiments to evaluate modified-urea products for rice in Java, including a large experiment with nitrification and urease inhibitors and slow-release materials at Sukamandi Research Station. The socio-economic workgroup plans fertilizer policy, supply/demand, and constraint studies as well as research to evaluate economically at the farm level the consequences of using slow release and deep placement of urea for rice in Java.

Fertilizer Distribution Study

P.T. Pupuk Sriwidjaja (PUSRI) requested IFDC to assist in the evaluation of proposals for the development of systems for distribution and handling of fertilizer throughout Indonesia. Consumption of fertilizer in Indonesia increased fairly rapidly during the 1970s and totaled over 3 million tons in 1981; it is expected to increase to over 8 million tons by 1990. PUSRI is responsible for the distribution and marketing of all of the output from the existing and planned production units. In 1981 Indonesia produced over 2 million tons of urea and 0.5 million tons of TSP. Production will increase to over 5 million tons of urea and 1.5 million tons of TSP by 1990.

Indonesia has a relatively sophisticated distribution system, involving movement of bulk urea in specially designed, self-offloading ships, from the production units on Sumatra to bagging stations in the main ports of Java and on other islands. On Java, which consumes about three-quarters of the fertilizer in Indonesia, the bagged material is moved in trainloads by specially designed rail wagons and by truck to inland storage depots. Bagged product is also moved from the production and bagging units to the Outer Islands in general cargo vessels.

Over the years, PUSRI has undertaken considerable development of the system in association with the World Bank and various consultants and is currently planning further major expansions.

The IFDC Transportation/Distribution Specialist visited Indonesia for a series of field trips to production centers, bagging stations, storage depots, and transportation facilities and for discussions with PUSRI technical staff in their headquarters in

Workers harvest tea in the Bogor area of Java.

Jakarta. PUSRI technical staff also visited IFDC for further discussions on plans for development of the system. A variety of proposals and recommendations have been made to PUSRI, which will assist in their continuing expansion of the system in an efficient manner and which will permit them to distribute the increasing tonnages of fertilizer from a number of production centers to farmers throughout Indonesia.

Production and Marketing of Ammonium Nitrate Products

P.T. Pupuk Kujang is considering construction of facilities to manufacture ammonium nitrate (AN) for the domestic commercial explosives market. If the facility is to be of economic size, the company will need to produce fertilizers based on AN. These could be AN, calcium ammonium nitrate (CAN), or ammonium nitrate sulfate (ANS). The selected products could be marketed domestically, in the Association of Southeast Asian Nations (ASEAN) countries, or in Australia. To determine the appropriate products and the size and location of these markets, an IFDC team made appropriate studies in Indonesia, Malaysia, the Philippines, Thailand, and Australia in October-December 1982.

The CAN market with the largest agronomic potential was found to be for use on upland soils to produce estate crops on Java, 476,000 tons. Not only is this market of sufficient size, but also it is near the production plant at Cikampek.

Because no ammonium nitrate-based fertilizers are now being consumed in Indonesia, a special research and development program is required to create the demand for CAN. Crop response curves for applications of nitrogen and calcium need to be determined for each crop under the environmental conditions existing on each estate. Because of the extreme diversity of the soils, crops, and irrigation water, analysis and interpretation of these factors are required to support the development program. Marketing the CAN directly to the estates from the Cikampek plant site will minimize the cost of distribution and promotion. The CAN would be competitively priced with ammonium sulfate, plus an added value for the calcium that the CAN contains.

Additional markets are available for (1) CAN to be used on Java soils in the production of vegetables, 252,000 tons; (2) explosive-grade ammonium nitrate, 35,000 tons; and (3) fertilizer-grade ammonium nitrate, 69,000 tons.

Researchers examine a fertilizer experiment on sorghum in northern Mali.

MALI

Efficient Use of Phosphate Fertilizer

Of the west African countries having phosphate deposits, Mali offers the greatest potential for IFDC to assist in formulating strategies for supplying a least cost phosphate fertilizer to farmers. Mali has a deposit of about 20 million tons of phosphate rock located in the Tilemsi Valley, north of Gao. IFDC is studying the potential benefits to Mali of using this material in crop production. The results should be invaluable for most west African Sahelian countries; the project points the way for developing similar action programs in these countries. The objective of the Mali Phosphate Project is to select the most efficient and economical source of phosphate to supply to Mali's farmers.

IFDC has assisted with the establishment of experiments on 11 experimental stations. All experiments are providing information on comparative responses to Tilemsi ground phosphate rock, granular and powdered forms of PAPR, and totally water-soluble phosphate. In 1982 IFDC supplied about 2 tons of experimental materials for the field trials, including both powdered and granulated forms of partially acidulated phosphate rock from Mali. Sulfuric acid (15% or 30% of that required to make superphosphate) was used for acidulation and the product contains 22%-27% total P_2O_5; use of more acid reduces this total. The granular product is typically minus 6- plus 14-mesh, Tyler. Water-soluble and neutral ammonium citrate-soluble P_2O_5 contents depend on reaction conditions.

Four experiments were designed as follows:

1. Response to annual application of phosphate rock, PAPR, and superphosphate, at four application rates, supplementary to a one-time basal application of phosphate rock at three application rates.
2. Response to basal application of phosphate rock, PAPR, and superphosphate at five application rates.
3. Response to annual application of phosphate rock, PAPR, and superphosphate at five application rates.
4. Response to annual application of phosphate rock, PAPR, and superphosphate at four application rates and comparison of three placement methods—broadcast, banded, or hill placement.

These fertilizer evaluation trials have been established on experiment stations

Malian research workers visit an IFDC sorghum field that has just been harvested.

that represent the major soils, climatic patterns, and cropping sequences.

The data on the first cropping season gave interesting information for the extension service but need to be confirmed during the following cropping season.

Basal application of phosphate rock is beneficial and gives a yield increase of 30% as of the first year. The effectiveness of a supplementary application of any soluble phosphate depends on the region concerned and the crop with which we deal. This supplementary application seems needless where rainfall is a limiting factor; elsewhere, cereals generally give the best response. In the experiments groundnut did not respond very well to additional phosphate application, whereas cotton did not give clear response. When applicable, the supplementary application rate should be around 15 to 25 kilograms of P_2O_5 per hectare.

With respect to phosphate sources and application rates, partially acidulated phosphate rock applied solely either as basal or annual application gave (as of the first year) similar or even slightly higher yield response than superphosphate. With maize, for instance, yield increase can be as high as 75% of the check. Regarding phosphate rock, yield response was also good the first year. After the first year, annual application rates of 20-30 kilograms of P_2O_5 per hectare and 60 kilograms of P_2O_5 per hectare may be suggested for soluble or partially soluble phosphates and phosphate rock, respectively. Powdered PAPR gave higher yield response than granular product. Yields were usually also higher with 30% acidulation than with 15% acidulation.

The socioeconomic study was also initiated and will be divided into two major phases. These phases include:

1. A general and preliminary survey of 150 farmers representative of most of the agricultural environments in Mali.
2. An in-depth study involving 20-30 farmers in the five major agricultural zones in Mali.

Several of the extension departments in the rural development offices recently undertook actions to promote the use of Tilemsi phosphate rock, and there are signs that the farmers are using phosphate rock because it is cheap and effective. Therefore, in 1983 we will initiate a series of trials on farmers' fields and make an accurate economic evaluation of phosphate rock use on farmers' fields.

IFDC Transfers Fertilizer Technology to the Developing World Through...

Technical Assistance

Brazilian workers bag elemental sulfur pellets.

TECHNICAL ASSISTANCE

Another avenue through which IFDC furthers its mission of increasing food production is technical assistance. Often a particular request may require short-term or long-term visits to a developing country to provide onsite assistance in solving problems that may run the gamut from fertilizer production to marketing to use.

During 1982 our staff were involved in 15 major technical assistance missions. In addition, our fertilizer specialists answered more than 700 inquiries through brief visits, cables, letters, or other means of communication.

Recipients of this assistance included national agencies, fertilizer complexes, governments, corporations, and research and development organizations.

AFRICA

Egyptian National Research Centre

At the request of the Egyptian National Research Centre, IFDC supplied some specially fabricated equipment for a bench-scale acidulation unit. With it they can evaluate local phosphate ores and concentrates for wet-process phosphoric acid production. Further training and technical assistance will be needed in the future. The U.S. National Academy of Sciences is sponsoring the program.

Nigeria Marketing Strategy Development

A nitrogen complex will be constructed at Port Harcourt, Nigeria; an IFDC staff member is providing guidance in this project's development. Plans call for the plant to be constructed in 30 months and come on stream about July 1985. The plant will produce:

- 1,000 tons per day of ammonia
- 1,500 tons per day of urea
- 1,000 tons per day of complete fertilizers, including DAP and other NPK compounds

The marketing system recommended in the 1980 Nigeria Fertilizer Marketing Study conducted by IFDC will serve as the model to be followed in building the proposed marketing system. The system will employ an integrated marketing approach with all activities directed toward supplying the farmer in the most efficient manner while satisfying his needs for fertilizers.

We will continue to assist in the development of a detailed marketing plan and formulation of the most efficient organizational structure. In addition, we will help determine the personnel required to manage the marketing system and help train the selected staff.

Senegal Marketing Study

The purpose of the Senegal study was to provide an agronomic, economic, and technical basis for the importation of fertilizer materials under a USAID grant. In the short term, the Economic Support Grant would allow the Government of Senegal to acquire fertilizer and establish an economically efficient fertilizer distribution system. The grant would also provide the resources for stabilizing farm-gate and consumer prices for sorghum and millet.

We recommended that Senegal import the following amounts of products (tons per year): urea, 20,000; potassium chloride, 10,000; and sulfur, 10,000. The distribution system for the USAID-grant materials provides for a direct flow of urea to farmers for use on millet. Industrial Fertilizer Society of Senegal (SIES) would use the potassium chloride and sulfur to manufacture NPK grades for groundnuts and millet.

IFDC staff made analyses regarding fertilizer subsidies and prices and recommended policies on the use, supply, and marketing of fertilizers for the Government of Senegal.

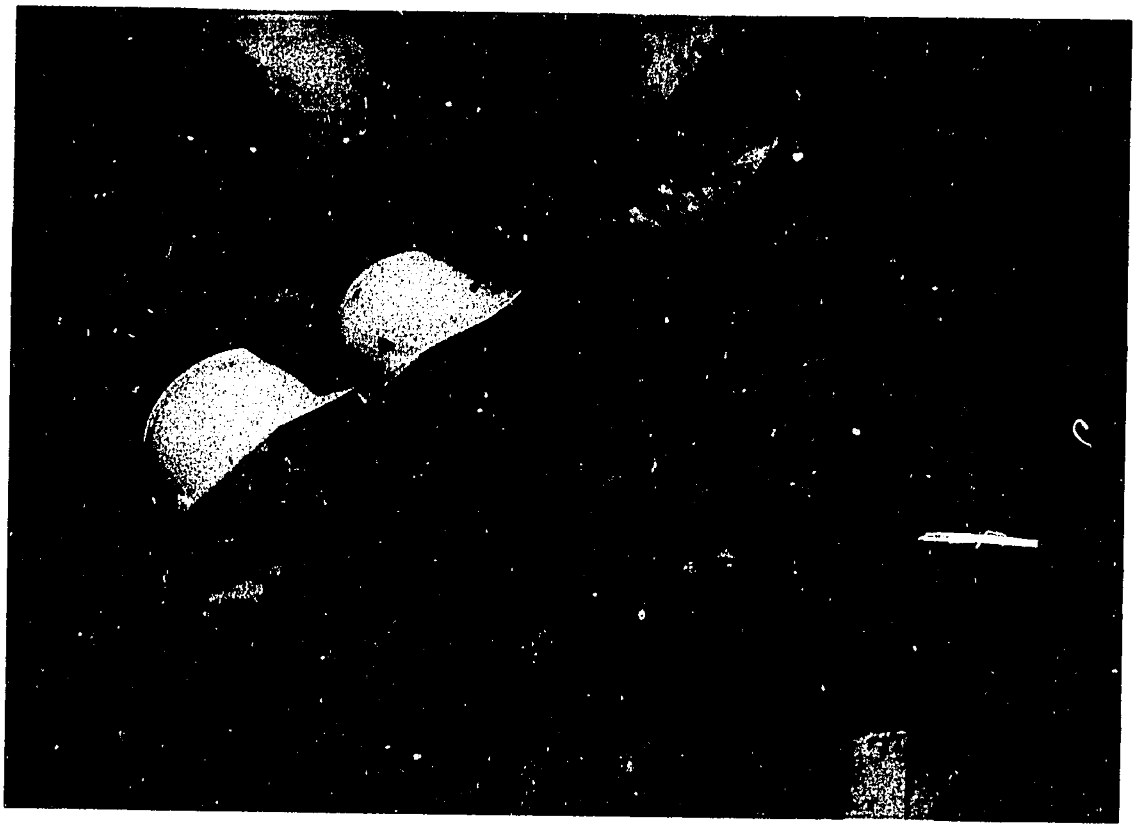
ASIA

Malaysian FPM Sendirian Berhad Granulation Project

FPM Sendirian Berhad completed the construction of a urea-based granulation plant near the Johore port in Malaysia in late 1982. Process and product development studies made in the Headquarters' pilot plant provided the basis for the engineering design of the granulation plant. During 1982 we provided FPM with approximately 4 months of onsite assistance in (1) coordinating detailed engineering and construction projects not included in the major construction contracts, (2) training FPM plant operations and maintenance personnel, and (3) startup and testing of equipment and preliminary production of NPK fertilizers.

With our assistance FPM built the factory for a significantly lower project cost because they were able to do all of the construction and project management themselves. FPM had most of the machinery built locally; thus, they saved a large amount of foreign exchange.

The FPM factory is operating at a rate of about 120,000 tons of fertilizer per year—about 65% of design capacity. The design capacity of about 180,000 tons per year will be achieved when construction of the raw material reclaiming and feed system is completed in mid-1983.



The FPM General Manager and an IFDC Production Consultant inspect the first production from the new NPK plant.

Philippines Phosphate Fertilizer Corporation Project

Our assistance to PHILPHOS was continued during 1982. We evaluated the Bantigue, Leyte Island, phosphate rock from the Philippines. This local rock and others outside the Philippines were studied for use in phosphoric acid production. The Philippine ore will require some beneficiation because of the presence of carbonates, iron, and aluminum.

Our staff used a high-grade sample (34.3% P_2O_5) of Bantigue, Leyte Island, rock for phosphoric acid production in the bench-scale unit. They encountered no problems in operation, filtration, and corrosion. Some solids (10% by volume) formed after concentration of the acid to 52% P_2O_5.

As part of the PHILPHOS project, we used Nauru Island phosphate rock to make phosphoric acid in the bench-scale unit. This rock, containing 38.4% P_2O_5, was very acceptable for this process; it gave a high filtration rate, low corrosion rate, and high P_2O_5 recovery.

PHILPHOS requested IFDC to develop a simple computer program to estimate the effect of delivered rock cost and quality on phosphoric acid cost. Our researchers wrote the program in BASIC computer language and then rewrote it for a small personal computer.

Nepal Marketing Management Study

During 1982 an IFDC marketing development specialist carried out a management study of the Nepal Agriculture Inputs Corporation (AIC). This study, financed by the World Bank and the United Nations, fulfilled a consultancy agreement with the International Agricultural Development Service. Our specialist made an in-depth study of AIC and its management system.

AIC is a wholly owned government corporation responsible for the procurement and distribution of all seed, pesticides, fertilizer, and agricultural tools marketed in Nepal.

In 1980/81 nutrient consumption totaled 22,600 metric tons, a 10% increase over the previous year. Nutrient consumption per cropped hectare averaged only 9 kilograms, one of the lowest consumption rates in Asia.

The study concluded that AIC should strengthen its operational efficiency and improve its procurement and marketing practices to ensure its financial viability.

While reductions in operating costs should be stressed, increases in revenue will obviously be necessary to restore AIC to solvency. AIC personnel often lack the expertise necessary to perform their assigned tasks; more selective recruitment and training are needed. To provide for the timely and adequate availability of proper types of fertilizers, greater emphasis must be directed to longer range planning and closer coordination with foreign donors. The planning and procurement functions should be strengthened and better coordinated with foreign aid donors to ensure more timely arrivals of imports. Sales promotion, market development, and farmer assistance programs should be instituted.

Yugoslavia Agricultural Consultancy Mission Sector Study

IFDC participated in a World Bank consultancy mission to analyze Yugoslavia's fertilizer sector during 1982.

The objectives of the mission were to evaluate fertilizer production efficiency, capacity utilization and technology, research programs related to fertilizer, marketing and distribution networks, and the efficiency with which fertilizer is used.

Yugoslav agricultural production is based on three systems: the social sector or the state-farm sector, the farmer cooperatives, and the private sector.

Social-sector farms are often very large and are modern agroindustrial operations, while the cooperating farms and private-sector farms are restricted to no more than 10 hectares. The latter farms vary from very intensively run units to scattered subsistence-type farming plots.

Fertilizer is an essential input for high crop yields and is already used at high rates by the social sector. The cooperative and private-sector farmers, as would be expected, use on the average much less fertilizer; to some degree this low level of fertilizer use is compensated for by the use of animal manures. The adoption of improved practices, including increased use of fertilizers, is however needed to increase agricultural production.

Yugoslavia has a serious balance-of-payments problem. Since all of the phosphate and potash and much of the natural gas used in making nitrogenous fertilizers is being imported, foreign exchange must be made available; otherwise, fertilizer production, and consequently agricultural productivity, will be reduced.

The mission suggested possible solutions to the problems governing fertilizer production. A special research and extension effort to involve the small farmer in improved production practices was also recommended.

LATIN AMERICA

Brazil

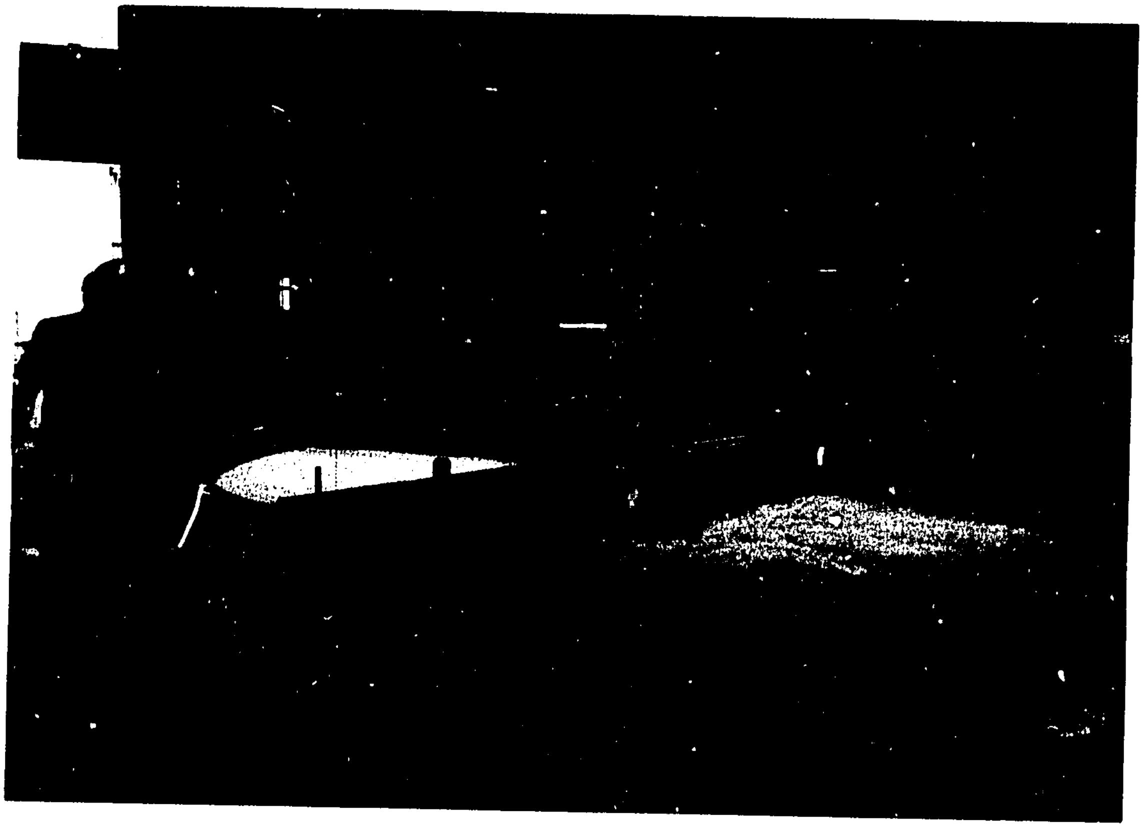
Assistance to Centro de Estudos de Fertilizantes (CEFER)

Technical assistance to CEFER during 1982 involved seminars and consultations with the Brazilian fertilizer industry. At CEFER our staff conducted a seminar on briquetting and compacting as an alternative to granulation. IFDC engineers completed two in-depth studies covering pollution control techniques and assessment of production and process-related problems of the Brazilian fertilizer industry. The purpose was to suggest the role of CEFER and other organizations in helping to solve these problems.

As a result of CEFER/IFDC assistance, some Brazilian fertilizer companies are using pipe reactors; in mid-1983 a fertilizer company will install a pipe-cross reactor to produce NPK compound product. In combination with other equipment to be installed, the pipe-cross reactor will reduce the energy requirement and atmospheric pollution. CEFER, IFDC, and TVA will work cooperatively with the Brazilian engineering company selected for detailed design. IFDC and TVA will assist in the initial startup and operation.

Assistance to Nitrofertil

We provided technical assistance to Fertilizantes Nitrogenados do Nordeste S.A. (Nitrofertil) of Brazil on urea treatment using formaldehyde compounds. Nitrofertil was considering the installation of a formaldehyde-conditioning system in their urea plant to improve the quality of the prilled urea product. On the basis of the



A CEFER Chemical Engineer observes the operation of a phosphoric acid filter during a visit to a Brazilian fertilizer plant.

experience of IFDC, TVA, and industry, IFDC made recommendations on the following with respect to a Nitrofertil formaldehyde-conditioning system: (1) types of formaldehyde compounds, (2) addition point, (3) equipment design considerations, and (4) product urea moisture content.

Mexico

Fertilizantes Mexicanos S.A. (FERTIMEX)

One of our engineers, at the request of FERTIMEX, visited a DAP production unit near Coatzacoalcos, Mexico, to determine the reasons for a relatively low production rate. FERTIMEX had modified a granular triple superphosphate unit to produce DAP. The engineer made a number of recommendations involving equipment and operating conditions, which resulted in an increase in production from 350 to about 750 tons per day, the maximum expected from such a unit.

Venezuela

Petroquimica de Venezuela S.A. (PEQUIVEN)

At the request of Petroquimica de Venezuela (PEQUIVEN), two of our engineers provided short-term technical assistance to the NPK granulation plant located at Moron. The process for NPK production is a modification of a DAP process. The engineers made a number of recommendations involving the process, plant operation, and equipment additions and/or modifications in a detailed report. They made several suggestions to improve operational ease and product quality. They provided PEQUIVEN with formulations for such grades as 12-12-17, with and without urea, 12-24-12, and 15-15-15. In addition, the engineers described special operating techniques for those formulas containing urea.

Colombia

Fertilizer Study for MONOMEROS

IFDC performed a fertilizer supply study for Monomeros Colombo Venezolanos, S.A. (MONOMEROS). The objective of the study was to assess MONOMEROS's position in the supply of fertilizers for the domestic (Colombian) and export markets and to develop supply strategies to enable MONOMEROS to maintain and enhance its supply position.

The study covered the use, supply, and marketing/distribution of fertilizers from

MONOMEROS's standpoint. Our staff developed fertilizer demand projections for Colombia and fertilizer sales projections for MONOMEROS for the 1982-87 period. They analyzed MONOMEROS's manufacturing and supply capabilities with respect to demand and sales projections. Our specialists developed and compared product cost estimates for the current and alternative supply schemes; they reviewed and analyzed MONOMEROS's marketing and distribution activities related to fertilizers. The organization of MONOMEROS's Commercial Division, which is responsible for fertilizer marketing and distribution, was reviewed. Our recommendations presented possible ways for MONOMEROS to improve its fertilizer business with respect to its manufacture, supply, marketing, and distribution operations.

Paraguay

In-Country Marketing Study

At the request of USAID, an IFDC marketing specialist and a soil scientist conducted an in-country analysis of Paraguay's fertilizer markets and use. The review focused on the analysis of present levels of fertilizer use in Paraguay and the design of a program to increase crop production through expanded use of fertilizer. Interest on fertilizer use in Paraguay is increasing because of the depletion of "new land" for expanding the crop production area as well as a desire to use surplus energy from the new Itaipu Dam for production of nitrogen fertilizer.

The development program for fertilizer consumption in Paraguay was presented as a long-term effort. The work should be undertaken in phases (Figure 9). Phase I, requiring 2 years, should focus on essential research, manpower development, and the establishment of a fertilizer authority. Phase II consists of the development of a comprehensive marketing plan. Phase III involves the initiation of the marketing plan and a shift in crop production to those cropping systems that can use nitrogen efficiently. Phase III must focus on promotion and intensive development of use of all fertilizers and soil amendments. When the nitrogen fertilizer consumption has increased at least to 10,000 tons per year, it would be advisable to enter Phase IV, consisting of a feasibility study for indigenous production of nitrogen fertilizers.

Our staff made several recommendations to improve the fertilizer situation in Paraguay. Among those recommendations were suggestions for a fertilizer policy-coordinating body, a soil improvement program, a comprehensive marketing plan, credit availability plan, information dissemination, and quality control legislation.

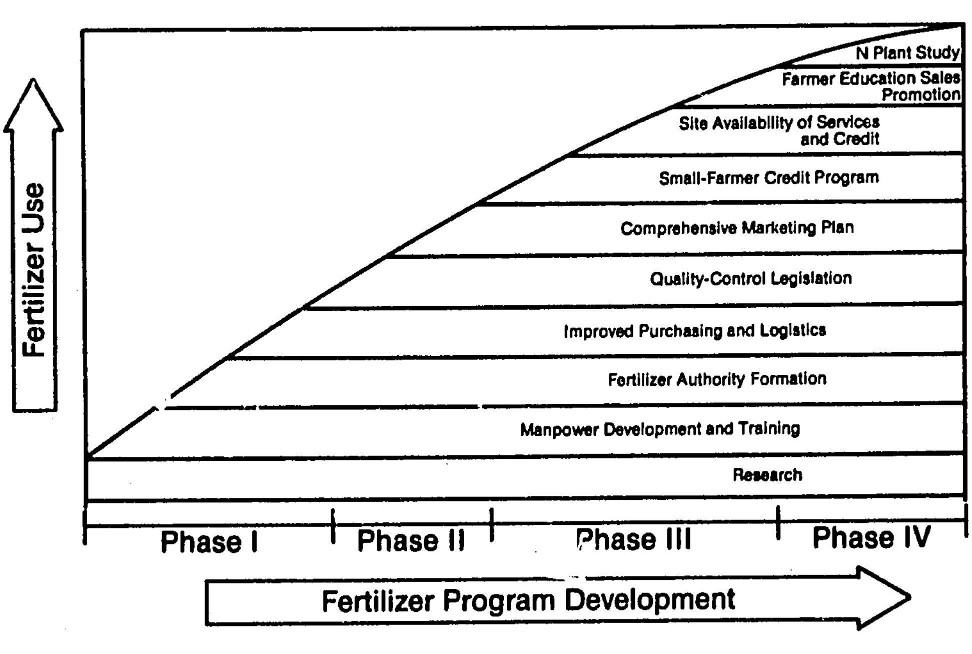
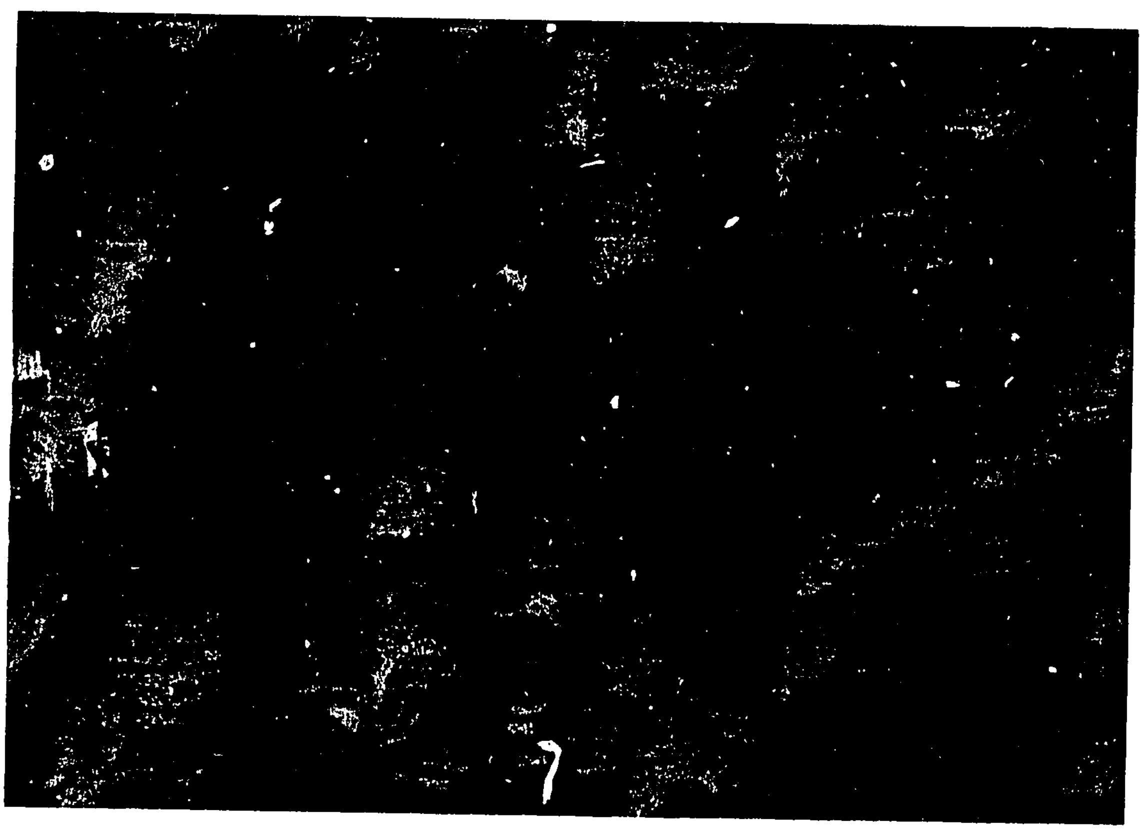


Figure 9. Recommended Development Program to Increase Paraguay's Fertilizer Consumption.

An IFDC Soil Scientist examines the shoots of yerba mate from which Paraguayan tea is made.



A Paraguayan farmer loads his tung harvest before transporting it to a processor.

IFDC Transfers Fertilizer Technology to the Developing World Through...

Training

An IFDC Training Program Manager discusses a marketing problem with participants in the Fertilizer Marketing Management Training Program.

TRAINING PROGRAM

We at IFDC believe that people will make the difference in solving the problem of world hunger. To help people gain the necessary fertilizer knowledge and skills for this task, we have rapidly increased the size and scope of our training program.

The program has grown from 1 offering in 1977 to 11 in 1982. IFDC's regional training offerings have increased dramatically. In 1981 four regional programs were offered and four Headquarters programs; in 1982 there were nine regional and two Headquarters offerings. In 1982 a total of 399 participants received training in many aspects of fertilizer production, marketing, and use; programs were offered in Africa, Asia, Latin America, and at Headquarters.

IFDC's training programs draw upon the experience of a multidisciplinary, multinational team of scientists, engineers, marketing specialists, social scientists, and other experts in international agricultural development to provide innovative training sessions. Outside experts supplement the IFDC staff in the various training programs. Our training program provides practical training in such activities as marketing, decisionmaking, installation of fertilizer trials and analysis of data, plant maintenance case studies, laboratory exercises, and fieldwork. Because of the international scope of our training program, participants can exchange ideas with people representing various companies, institutions, and governments of many countries of the world. Appropriate field trips complement the classroom-type portion of the sessions.

GROUP TRAINING

Marketing

Management

Eighteen marketing managers from 11 countries participated in the sixth annual marketing management training program at Headquarters, August 16-September 24, 1982. The participants were from Bangladesh, Burma, Indonesia, Israel, Pakistan, Trinidad, Venezuela, Zambia, Colombia, Nepal, and India.

The purpose of the program was to improve the participants' marketing management skills by pointing out ways to improve the marketing systems in their countries. The program covered all aspects of fertilizer marketing, international trade, world fertilizer situation, soils and crops, and effective management communications. The 45 presentations were made by representatives of IFDC, TVA, and the fertilizer industry.

Field trips enabled participants to see marketing management in practice. By visiting the Farmland Industries Training Institute, Kansas City, Missouri, and the College of Agriculture, University of Missouri, Columbia, Missouri, the participants witnessed a close working relationship between a university, extension services, cooperatives, and experiment stations. They realized the value of this liaison to a complete fertilizer marketing system.

The participants witnessed fertilizer production and distribution at the International Minerals and Chemical Corporation in Lakeland, Florida; the Tampa port, Tampa, Florida; and the Phosphate Rock Export Association, Tampa, Florida.

Regional Marketing Management

The P.T. Pupuk Kujang Training Center was the site of our third Regional Fertilizer Marketing Management Training Program, November 6-19, 1982. Twenty-eight marketing managers from seven Asian countries participated in this program, which was cosponsored by the Indonesian Fertilizer Producers' Association (APPI). The participants were from Burma, India, Indonesia, Malaysia, Nepal, Pakistan, and Sri Lanka.

A variety of training techniques, including lectures, films, discussions, case studies, simulations, and field trips provided the participants an opportunity to acquire the skills and knowledge essential for efficiently marketing fertilizers to farmers. A unique treatment of fertilizer marketing problems was given through a case study on "Reaching the Small Farmer." In this exercise, participants developed a fertilizer marketing plan to serve farmers.

Specialists making presentations were from IFDC, the Fertilizer Advisory Development and Information Network for Asia and the Pacific (FADINAP)/Economic and Social Commission for Asia and the Pacific (ESCAP), Food and Agriculture Organization of the United Nations (FAO), and IPI/PPI. Also several Indonesian specialists assisted with the program.

Field trips added another dimension to the program's agenda. The participants visited the Central Research Institute of Agriculture and the Center for Soils Research (both located at Bogor), the P.T. Pupuk Kujang urea complex at Cikampek, the National Rice Research Experiment Station at Sukamandi, a P.T. PUSRI inland supply depot, and a village-unit cooperative (KUD).

The Indonesian fertilizer industry, particularly P.T. Pupuk Kujang and P.T. PUSRI, gave outstanding support to the program.

Regional Distribution and Handling

Designed for senior and middle managers in governmental or private organizations, a new IFDC training program focused on the development of professional skills needed in the physical distribution of fertilizer. The dual-centered program was held April 11-24 in India and Indonesia; in India it was cosponsored by the Fertiliser Association of India (FAI) and in Indonesia, by P.T. PUSRI.

The 21 participants were from Burma, India, Indonesia, Malaysia, Pakistan, Sri Lanka, and Thailand. This program dealt with the theoretical and practical aspects of physical distribution, including system operation, packaging, handling, transportation, and warehousing. Representatives of P.T. PUSRI, FAI, Indian companies and organizations, and IFDC made presentations on the program topics.

A wide range of field trips provided the participants with an opportunity to see how distribution works in practice in different countries. In India they toured Kandla port, the Indian Farmers Fertiliser Company (IFFCO), and Bombay port. In Singapore they observed modern bulk facilities at the Jurong wharves. At P.T. PUSRI in Palembang, the participants witnessed sophisticated systems using mechanical equipment for loading bagged and bulk fertilizer into ships. In Jakarta the group saw modern handling equipment in operation at P.T. Pupuk Kujang.

In-Country Program for Sri Lanka

Sri Lanka was the site of our first country-specific fertilizer marketing training program. Sponsored by USAID and the Federal Republic of Germany, the program served middle-level managers who are involved in fertilizer marketing in Sri Lanka.

This program evolved as the result of an IFDC technical assistance project conducted for the Sri Lanka Ministry of Coconut Industries. A segment of the IFDC-developed plan to increase Sri Lanka's coconut production called for the training of a special task force for the marketing of fertilizer for coconut.

Presentations were given on such topics as "Components of an Integrated Fertilizer Marketing System Designed to Meet Sri Lankan Requirements," Fertilizer Products in Sri Lanka—"What's in the Bag," and "Economics of Fertilizer Use in Sri Lanka."

Two field trips—one to the Central Agricultural Research Institute and another to the Mayo fertilizer warehousing complex—added an interesting sidenote to the program.

Upon completion of the program, the participants carried out mini-training programs involving staff members of their own individual organizations.

Regional Fertilizer Marketing in Africa

Cosponsored by the University of Ibadan, our first regional fertilizer marketing training program for Africa was conducted August 3-13. Participants came from five countries: Nigeria, Sierre Leone, Sudan, Swaziland, and Upper Volta.

Program emphasis was on helping the participants develop the skills required for analyzing marketing systems, identifying constraints to effective marketing, and planning and implementing an effective fertilizer marketing system in their own countries. Program topics included the elements of marketing, modern marketing management, sales forecasting, fertilizer legislation for developing countries, and the economics of fertilizer use.

Lecturers included representatives from the University of Ibadan, IITA, the Institute of Agriculture Research and Technology, the University of Ife, and IFDC.

During field trips to IITA the participants gained an overview of their research programs; at an agroservice center in Oyo State they saw firsthand the practical problems of fertilizer marketing.

Data Processing and Analysis

At the request of USAID and BADC, six Bangladesh staff members participated in a special 2-month training program in data processing and analysis. Although for 4 years they had supervised the collection of farm-survey data for the BADC/IFDC/USAID Fertilizer Equity Study, they lacked the necessary skills to conduct computer analysis of the data that they had been collecting. During the specially designed training program they learned how to process and analyze data using the computer packages—Statistical Analysis System (SAS) and the Statistical Package for the Social Sciences (SPSS)—and are now able to do such work in Bangladesh.

Production

Management

Our third annual training program in Maintenance and Production Management for Fertilizer Producers was held at Headquarters, October 11-29.

Focusing on increasing the participants' knowledge and skills regarding organizing and managing maintenance and production activities, the program benefited 17 fertilizer production and maintenance engineers from 11 companies in 8 countries.

Experts from TVA, commercial fertilizer production units, and IFDC made presentations covering maintenance and production management methods in both theory and practice. The participants learned of the tasks of maintenance and production planning and the relationship to factory production goals. Workshops permitted interaction among the participants in solving problems and in applying the basic techniques of planning, scheduling, and implementation of maintenance and production tasks.

One program highlight was a 1-week field trip to U.S. fertilizer production facilities. The firsthand view of the industry offered the participants an opportunity to discuss maintenance and production programs and problems with plant management and technical staff.

Regional Granulation and Bulk Blending

Latin American engineers gained insight into the various practical and technical aspects of fertilizer granulation and bulk blending at a 5-day seminar held in Cancun, Mexico.

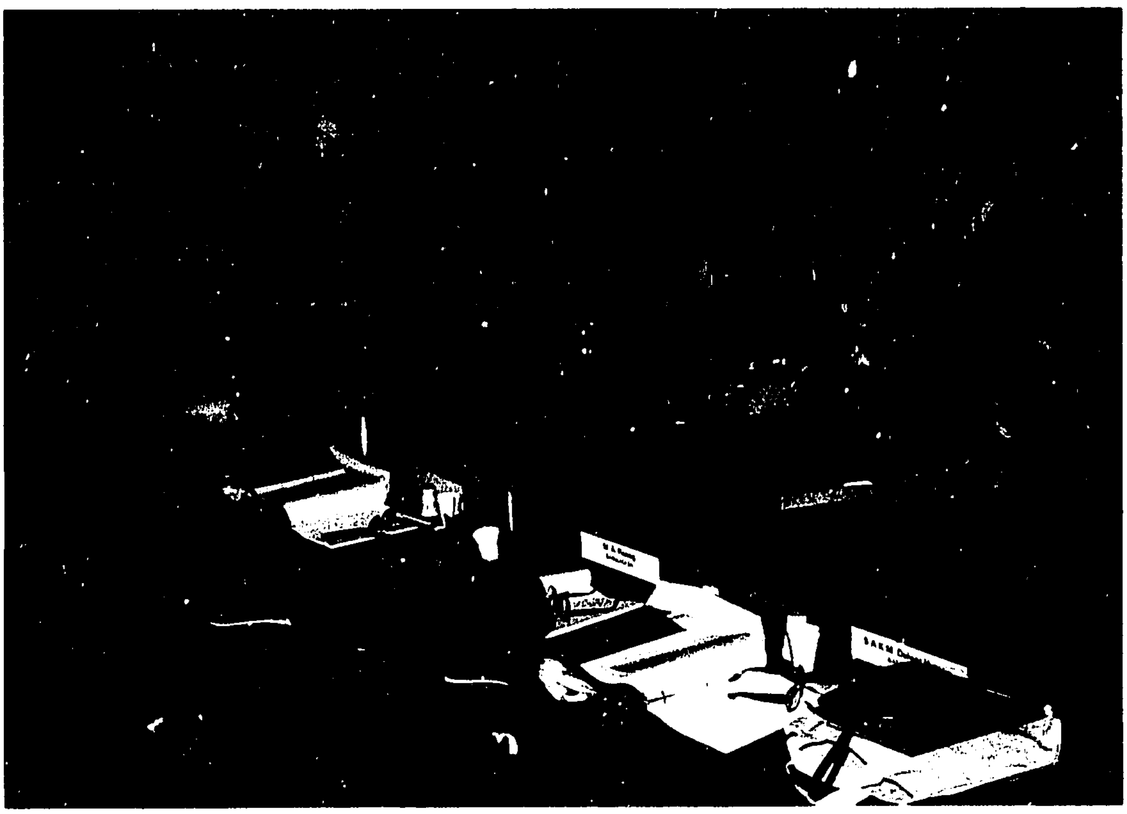
The 23 participants from nine countries studied the fundamentals of granulation, pollution control, bulk-blending practices in developing countries, and methods for formulation of fertilizers. Cosponsored by FERTIMEX, the seminar was presented in Spanish.

The Cancun seminar was the first regional granulation and bulk-blending seminar in which commercial companies made presentations related to their equipment and company experience with specific projects in the Latin American region. These presentations were offered in the evenings as an addendum to the program, and the participants attended on a free-choice basis.

Bulk-Blending and Mixing Workshop for Asia

To improve the production of bulk-blended and mixed fertilizers, IFDC cosponsored a Regional Workshop on Bulk Blending and Mixing of Fertilizers for Asia and the Pacific with FADINAP and the National Farmers Association of Malaysia (NAFAS). Fourteen participants and 31 observers attended the workshop that was held in Penang, Malaysia.

The participants became aware of the latest techniques for the physical blending of fertilizers. They learned of different types of blending equipment and various methods of handling blended products to



The Program Manager for the training program, Maintenance and Production Management for Fertilizer Producers, addresses the program participants.

Participants in the training program, Maintenance and Production Management for Fertilizer Producers, view rice experiments being conducted in an IFDC Greenhouse.

Mr. Adolfo Sisto V. of FERTIMEX makes a point during the Fertilizer Granulation and Bulk-Blending Seminar in Cancun.

The Secretary General of Malaysia's Ministry of Agriculture addresses the Regional Workshop on Bulk Blending and Mixing of Fertilizers for Asia and the Pacific.

ensure the delivery of high-quality material to the user.

A case study on bulk blending in the Caribbean region constituted another interesting aspect of the workshop.

Phosphorite Geology Workshop

This 3-week course, held at Macquarie University, Sydney, Australia, was organized to train 14 geologists from 11 Asian countries to explore for phosphates more efficiently. The course presented the geologic principles involved and reinforced these principles by demonstrating their application using specific geologic examples.

The course was funded by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and ADAB; IFDC was the only non-Australian institution invited to participate. The course instructed participants in phosphate geology exploration, area selection, and field procedures. Case studies explaining feasibility studies, mining methods, and mineral processing procedures to be used when phosphate is discovered were presented.

The course was concluded with a visit to the Queensland Basin area, where actual field application of the classroom instruction was demonstrated using an Australian phosphate deposit as an example.

Use

^{15}N Techniques for Nitrogen Balance Studies

IRRI hosted our third training course on ^{15}N techniques for nitrogen balance studies with rice. We had previously conducted similar courses at Headquarters with participants from Korea, India, Thailand, and the People's Republic of China.

Funded by the Australian organization, ADAB, the course trained five Indonesian scientists in experimental, sampling, and analytical techniques involved in field research with ^{15}N on rice.

Like previous participants, the Indonesian scientists will use this knowledge in conducting an experiment to determine plant recovery, losses, and immobilization in soil of different nitrogen fertilizer sources for rice. This cooperative research program is called the ^{15}N mininetwork which is an outgrowth of INSFFER. Cosponsored by IRRI and IFDC, the course involved not only laboratory work but also direct involvement in field activities.

International Training Program on Nitrogen Management

In conjunction with the International Workshop on Efficient Nitrogen Management, we conducted an in-depth training course on nitrogen management in Fuzhou, People's Republic of China.

Fourteen participants from five countries discussed subjects such as experimental design, statistical and economic analysis, data interpretation, fertilizer properties and fate in soil, biological nitrogen fixation, and integrated nitrogen management.

Laboratory sessions included hands-on operation of briquetting machines and applicators and field tours.

To gain a practical insight, the participants visited an ammonium bicarbonate factory in Fuzhou, the INSFFER trials, and other fertilizer trials.

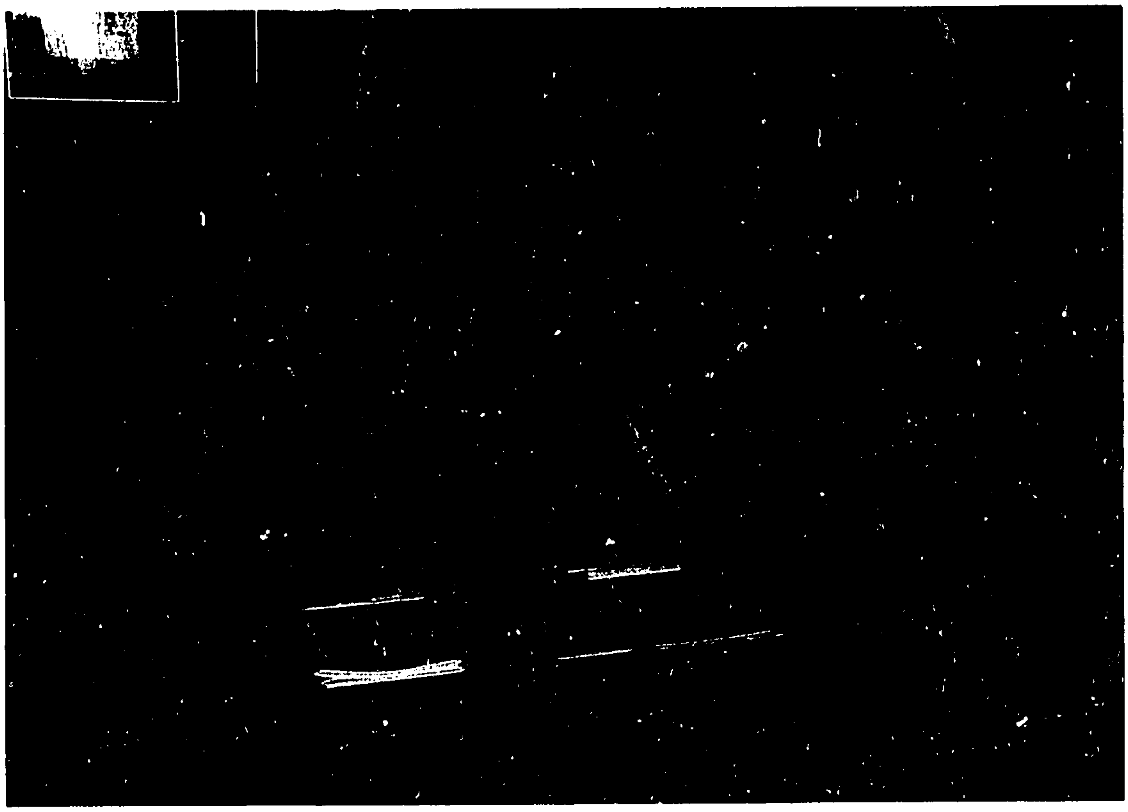
INDIVIDUAL TRAINING

IFDC provided specialized training programs for 11 individuals during 1982. The length of the programs ranged from 2 weeks to 2 years. Program objectives focused on learning the latest techniques of fertilizer technology, marketing, and use.

TRAINING EVALUATION

Training evaluation is conducted as an integral part of planning and executing each of IFDC's fertilizer training programs. The evaluation process provides information to identify ways that our training programs can be strengthened and better meet the needs of the participant. During 1982 evaluations were made of nine group training programs conducted by IFDC. These programs, covering the fertilizer production, marketing, and use efficiency research areas, were all highly rated by participants.

The results of training evaluation indicate the progress that we are making in meeting the more general objectives of our training evaluation program. These objectives include: (1) obtaining feedback from participants about the program, (2) determining each program's effectiveness, (3) identifying ways to improve each program, (4) assisting in the identification of training needs, and (5) informing donors about IFDC training programs.



Dr. Donald L. McCune, IFDC's Managing Director; Dr. A. O. Williams, Executive Secretary, OAU/STRC; and Dr. John A. Hannah, Chairman, IFDC's Board of Directors, discuss plans for the African Center for Fertilizer Development.

NEW HORIZONS

African Center for Fertilizer Development (ACFD)

One of IFDC's long-time goals—establishing regional fertilizer centers in developing countries—is nearing realization. The Organization of African Unity/Scientific Technical and Research Commission (OAU/STRC) has selected IFDC to serve as Executing Agency for planning, formation, implementation, and operation of the ACFD for a period of 5 years or longer.

The overall objectives of ACFD will be to improve and stabilize the agriculture of Africa through proper production and use of fertilizers and to make maximum use of Africa's indigenous materials and resources.

The initial planning for ACFD began in early 1979 when the Executive Secretary of OAU/STRC asked IFDC to prepare a proposal for an African center. In February 1981 the Council of Ministers of OAU approved the Center's establishment and proposed a meeting of the Inter-African Committee on Fertilizers. This meeting was held in June 1981 in Cairo where the center concept was approved and a Site Selection Committee was appointed.

Using criteria established by the Inter-African Committee on Fertilizers, the Site Selection Committee considered 10 different countries. During a meeting held at IFDC, January 18-22, 1982, the Committee shortened this list to four countries: Cameroon, Kenya, Senegal, and Zimbabwe. Members of the Committee visited each of the four countries and finally selected Zimbabwe as the most desirable country for location of ACFD.

IFDC is prepared to undertake this project through the use of appropriate in-house expertise and consultants. As needed, IFDC will provide technical support through its Headquarters research, development, and training facilities until ACFD has developed capabilities in these fields.

A Donors' Meeting is slated for March 29, 1983, in Vienna, Austria. Provided adequate financial support is given to this new venture, the die will be cast for a new fertilizer center for Africa, and the African people should reap the benefits in terms of increased production of food and fiber.

Financial Report

Price Waterhouse

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

April 26, 1983

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, 1982 and 1981, and the results of its operations and changes in its 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

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS

CURRENT FUND
(unrestricted)

ASSETS

	December 31, 1982	December 31, 1981
Cash	$ 301,176	$ 239,146
Certificates of deposit	1,653,574	1,660,313
Amounts receivable from donors (Notes 1 and 2)	6,165,318	3,337,392
Other accounts receivable	838,089	745,272
Advances to employees	52,046	92,528
Supplies inventory (Note 1)	136,989	108,409
Prepaid expenses	173,486	302,052
	$9,320,678	$6,485,112

LIABILITIES AND FUND BALANCES

	December 31, 1982	December 31, 1981
Bank overdraft		$ 190,226
Accounts payable	$ 301,728	190,615
Accrued annual and sick leave	1,035,152	869,980
Deferred revenue (Notes 1 and 2)	6,165,318	3,337,392
Total liabilities and deferred revenue	7,502,198	4,588,213
Fund balance	1,818,480	1,896,899
	$9,320,678	$6,485,112

BUILDINGS AND EQUIPMENT FUND
(NOTE 1)

ASSETS

	December 31, 1982	December 31, 1981
Buildings	$5,741,090	$5,741,090
Equipment	4,225,667	4,104,765
Less - Accumulated depreciation	(2,862,607)	(2,270,167)
	$7,104,150	$7,575,688

LIABILITIES AND FUND BALANCES

	December 31, 1982	December 31, 1981
Accounts payable	$ 6,866	$ 17,073
Contract retainage	20,924	21,121
Total liabilities	27,790	38,194
Fund balance	7,076,360	7,537,494
	$7,104,150	$7,575,688

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES

YEAR ENDED DECEMBER 31, 1982 WITH COMPARATIVE TOTALS FOR 1981

	1982		Total All Funds	
	Current Fund (unrestricted)	Buildings and Equipment Fund	1982	1981 (Note 4)
Revenue:				
Grants (Note 2)	$6,728,152		$6,728,152	$5,786,416
Recovered project costs	2,367,755		2,367,755	1,982,770
Other	186,402	$ 6,452	192,854	221,823
Total revenue	9,282,309	6,452	9,288,761	7,991,009
Expenses:				
Research	5,173,751	464,213	5,637,964	4,414,719
Outreach	2,320,160	47,206	2,367,366	1,918,536
General and administrative	1,736,963	86,021	1,822,984	1,606,889
Total expenses	9,230,874	597,440	9,828,314	7,940,144
Excess (deficiency) of revenue over expenses	51,435	(590,988)	($ 539,553)	$ 50,865
Other changes in fund balances:				
Equipment acquisitions from unrestricted funds	(129,854)	129,854		
Fund balances, beginning of period	1,896,899	7,537,494		
Fund balances, end of period	$1,818,480	$7,076,360		

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF FUNCTIONAL EXPENSES

YEAR ENDED DECEMBER 31, 1982 WITH COMPARATIVE TOTALS FOR 1981

	1982			Total Expenses	
	Research	Outreach	General and Administrative	1982	1981 (Note 4)
Personnel compensation (Note 3)	$2,401,884	$1,064,395	$ 964,875	$4,431,154	$3,925,014
Personnel benefits (Note 3)	400,375	203,733	156,617	760,725	592,390
Travel and transportation	458,623	471,073	111,295	1,040,991	699,868
Occupancy	246,494	95,923	105,253	447,670	351,884
Telephone and telegraph	58,902	36,250	22,331	117,483	105,943
Rental of equipment	71,215	23,031	16,802	111,048	16,463
Contractual research and development	650,180	36,951		687,131	169,786
Other contractual services	290,610	180,322	126,285	597,217	716,544
Institute of International Education fee (Note 3)			115,235	115,235	107,333
Materials and supplies	541,102	181,299	91,087	813,488	518,158
Postage	18,194	9,097	9,097	36,388	26,429
Insurance	36,172	18,086	18,086	72,344	81,928
Miscellaneous					28,390
Total expenses before depreciation	5,173,751	2,320,160	1,736,963	9,230,874	7,340,130
Depreciation of buildings and equipment	464,213	47,206	86,021	597,440	600,014
Total expenses	$5,637,964	$2,367,366	$1,822,984	$9,828,314	$7,940,144

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS

NOTE 1 - ORGANIZATION AND ACCOUNTING POLICIES:-

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 accounts of IFDC are maintained on the accrual basis. The following is a summary of significant accounting policies:

A. Buildings and equipment are stated at cost. Depreciation is computed on the straight-line method over estimated useful lives.

B. Grants are recorded as receivable for the full amount at the date of the grant with revenue recognition deferred until corresponding expenses have been incurred. 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. Inventories of supplies are valued at the lower of cost or replacement cost, cost being determined on a first-in, first-out basis.

D. IFDC is exempt from federal income taxes as a publicly supported organization under Section 501(c)(3) of the Internal Revenue Code.

NOTE 2 - GRANTS:-

Grants are summarized as follows:

	Year ended December 31, 1982	Year ended December 31, 1981
Grants received -		
United States Agency for International Development (AID)	$ 4,000,000	$4,000,000
United Nations Development Programme	3,566,000	
International Fund for Agricultural Development		880,000
Australian Development Assistance Bureau (ADAB)	1,599,888	207,352
International Development Research Centre (IDRC)	304,490	887
Rockefeller Foundation	25,200	25,388
Israel Chemicals Ltd.	30,000	50,000
Ford Foundation	20,500	
Philippines	10,000	
	9,556,078	5,163,627
Amounts deferred during prior year	3,337,392	3,960,181
	12,893,470	9,123,808
Less - Amounts deferred to future periods	(6,165,318)	(3,337,392)
Revenue recognized in current period	$ 6,728,152	$5,786,416

The current grant from AID was amended to provide additional funds of $4,000,000 during each of the years ended December 31, 1982 and 1981, and to extend the grant period from June 30, 1982 to June 30, 1983. The amount of $1,900,000 was deferred at December 31, 1982 and 1981. The current AID grant provides funds for basic core/operating costs. The use of funds by area is unrestricted except that equipment purchases are not allowed. Funds not legally committed at the grant expiration date will revert to AID.

The amount of $25,200 and $25,705 from the Rockefeller Foundation grant, the amount of $396,040 and $259,187 from the International Development Research Centre grant, the amount of $3,200,000 and $492,500 from the United Nations Development Programme grant, the amount of $220,000 and $660,000 from the International Fund for Agricultural Development grant and the amount of $424,078 from the Austrailian Development Assistance Bureau grant were deferred at December 31, 1982 and 1981, respectively.

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 monthly to fund salaries, employment taxes and fringe benefits.

NOTE 4 - SUMMARY OF 1981 REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES AND OF 1981 FUNCTIONAL EXPENSES:-

Revenue and expenses and changes in fund balances for 1981 are summarized as follows:

	Current Fund (unrestricted)	Buildings and Equipment Fund
Revenue -		
Grants (Note 2)	$5,786,416	
Recovered project costs	1,982,770	
Other	221,823	
Total revenue	7,991,009	
Expenses -		
Research	3,946,495	$ 468,224
Outreach	1,873,926	44,610
General and administrative	1,491,319	115,5[illegible]0
Total expenses	7,311,740	628,404
Excess (deficiency) of revenue over expenses	679,269	(628,404)
Other changes in fund balances -		
Building and equipment acquisitions from unrestricted funds	(315,782)	315,782
Fund balances, beginning of period	1,533,412	7,850,116
Fund balances, end of period	$1,896,899	$7,537,494

Functional expenses for 1981 are summarized as follows:

	Research	Outreach	General and Administrative
Personnel compensation (Note 3)	$2,134,548	$ 907,275	$ 883,191
Personnel benefits (Note 3)	299,406	154,753	138,231
Travel and transportation	282,721	340,013	77,134
Occupancy	201,894	74,995	74,995
Telephone and telegraph	52,828	31,377	21,738
Rental of equipment	9,814	3,369	3,280
Contractual research and development	133,328	36,458	
Other contractual services	436,559	177,535	102,450
Institute of International Education fee (Note 3)			107,333
Materials and supplies	339,363	120,841	57,954
Postage	15,070	6,828	4,531
Insurance	40,964	20,482	20,482
Miscellaneous			28,390
Total expenses before depreciation	3,946,495	1,873,926	1,519,709
Depreciation of buildings and equipment	468,224	44,610	87,180
Total expenses	$4,414,719	$1,918,536	$1,606,889

International Fertilizer Development Center Board of Directors

IFDC Board of Directors: (front row, from left) Mr. Richard Freeman, TVA Board of Directors, U.S.A.; Dr. Robert E. Wagner, President, Potash & Phosphate Institute, U.S.A.; Dr. Ibrahim F.I. Shihata, Director, OPEC Special Fund, Arab States; Dr. Donald L. McCune, IFDC Managing Director, U.S.A.; and Dr. Entol Soeparman, Director of Research & Development, P.T. Pupuk Sriwidjaja (PUSRI), Indonesia. (Back row, from left) Dr. Bukar Shaib, Special Advisor to the President, Lagos, Nigeria; Dr. John A. Hannah, Chairman of the Board of Directors, President Emeritus, Michigan State University, U.S.A.; Mr. Adolfo Sisto, General Manager, Industrial Operations, FERTIMEX, Mexico; Mr. Miguel Zosa, President, PHILPHOS, Philippines; Dr. David Hopper, Vice President, South Asia Region of the World Bank, Canada; Dr. Ola Heide, Rector, Agricultural University of Norway, Norway; Mr. Eliseo Restrepo, Formerly General Manager, Monomeros Colombo Venezolanos, Colombia; and Dr. Anton Amberger, Head of the Institute of Plant Nutrition, Technical University—Munich, Federal Republic of Germany.