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IFDC is. . .

People Helping People

Through

- Training
- Technical Assistance
- National Programs
- Research

The IFDC staff is people dedicated to helping other people. IFDC works to upgrade the quality of life of the people of the world by increasing food production through improved fertilizers and fertilizer practices.

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 14, 1977, 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 187, 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 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 fertilizer 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 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

Recognizing that it cannot carry out its mission alone, IFDC cooperates with many international, regional, and national institutions. IFDC has 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.

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TWX-810-731-3970 IFDEC MCHL

ISSN-0734-4376

Edited by Marie K. Thompson
Illustrated by Kathy H. Creamer

IFDC publications are listed in *Publications of the International Fertilizer Development Center*, General Publication IFDC-G-1, which is available free of charge.

Managing Director's Report

The IFDC staff represents a group of people dedicated to improving the quality of life of the world's people by helping to solve their food production problems.

An effective means that IFDC employs to achieve this end is to train the personnel of fertilizer-related fields in the marketing, production, and use of fertilizers. IFDC realizes that a country's people are its most valuable resource.

Technical assistance to governments, fertilizer companies, and other organizations remains an integral part of IFDC's program. In transferring fertilizer technology, IFDC provides answers to unique problems confronting the fertilizer sector of the developing world. In 1981 IFDC's staff provided on-the-spot technical assistance to 15 major clients. Besides this in-country assistance, IFDC answered more than 900 inquiries, handled through 1-day visits, cables, letters, or other communications means.

National programs represent a most essential link in the chain connecting fertilizer technology with the end user or farmer. Participating in this unique liaison, IFDC's multidisciplinary teams coordinate research with similar teams in the developing countries. During 1981 Mali became the third country involved in the national program component of IFDC's efforts.

As revealed in a major IFDC study conducted in 1981, fertilizer production is highly energy intensive. For example, the production of one 50-kilogram bag of urea requires as much energy as is contained in about 15 U.S. gallons of gasoline. Furthermore, the average international price of crude oil has increased from approximately US $3.3/barrel in 1973 to US $32.0/barrel in 1981.

Thus, it is imperative that present fertilizer plants be operated at top efficiency and that new energy-efficient processes be adopted to keep fertilizer prices reasonable. While substantial savings of energy in manufacturing are possible, a more promising prospect is more efficient use of fertilizers by farmers.

In an effort to increase fertilizer use efficiency, IFDC's Nitrogen Research Program continued in 1981 to identify the causes and magnitude of nitrogen losses; develop products and practices to reduce these losses and improve the fertilizer uptake by plants; and evaluate this technology in the greenhouse and field. Under some circumstances, half of the nitrogen that a developing country farmer uses is lost. The farmer benefits from only half of every US $1 that he spends on fertilizer. Experimental materials developed for IFDC's flooded rice program could give the farmer benefit from 85% of the money he invests. In the Phosphate Research Program, IFDC continued to assist developing countries in using their indigenous phosphate resources. These countries included Mali, Colombia, and Upper Volta.

Since its journey began almost 8 years ago, IFDC has grown tremendously. Its future appears as dynamic and positive as its past. Dedication, hard work, and vision have brought us this far. As long as we have the will to work, our vision will carry us farther still.

Donald L. McCune

A Prestigious Award

In London on March 12, 1981, Dr. Donald L. McCune, Managing Director of IFDC, received the 12th Francis New Medal from The Fertiliser Society. This award of excellence honors an individual who has made valuable contributions to the scientific and technical aspects of the production, use, and application of fertilizers.

Francis New, a world-renowned fertilizer technologist, was one of the first organizers of the Society, which is composed of more than 500 chemists, engineers, agronomists, and economists throughout the world.

Since the inception of this prestigious award program in 1959, The Fertiliser Society has awarded the Francis New Medal to only 12 persons. Dr. McCune is one of three Americans who have received it. Mr. Travis P. Hignett, Special Consultant to the Managing Director of IFDC, and previously with TVA, received the award in 1969.

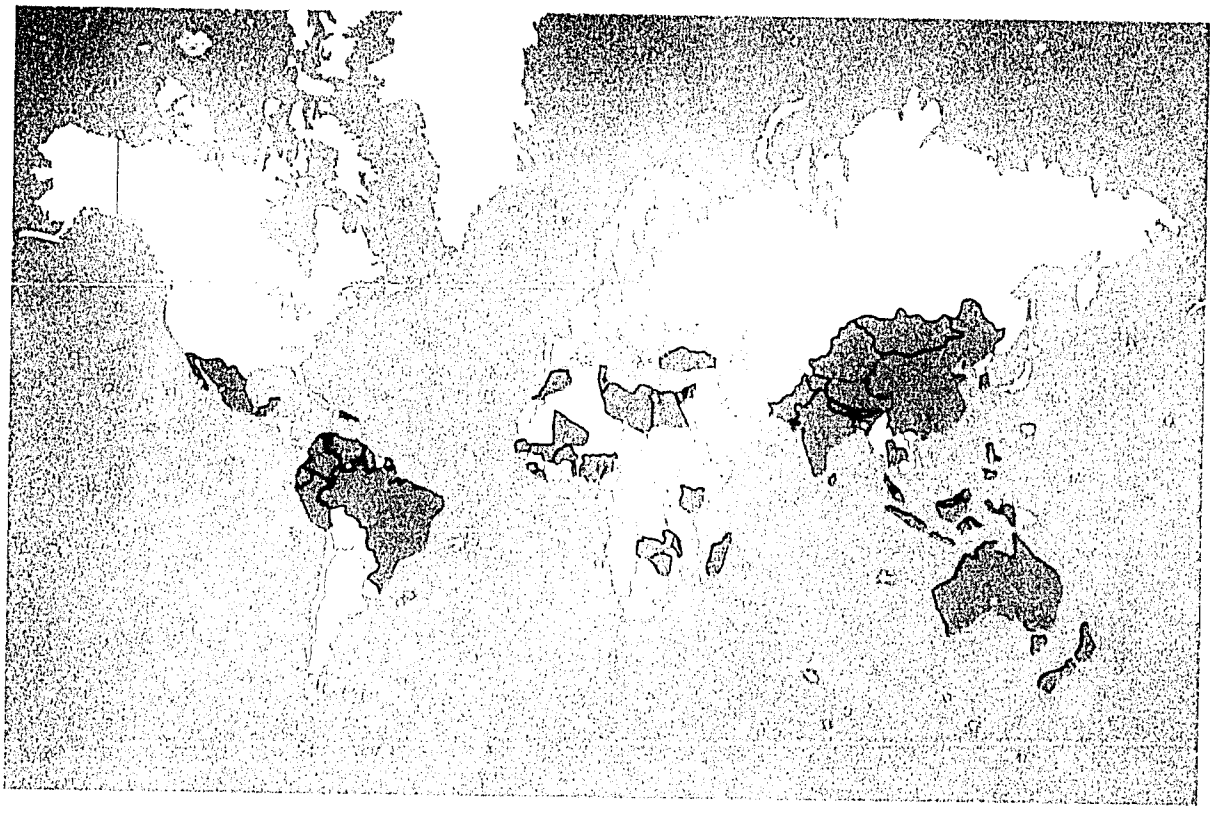
When he received the Medal, Dr. McCune delivered the Francis New Memorial Lecture entitled "Fertilizers for Tropical and Subtropical Agriculture." "Agriculture in the tropics and subtropics must become much more efficient and productive if the food, fiber, building materials, and energy needs of developing countries are to be met," he said. "Increasing amounts of the right kinds of fertilizers must be physically and economically available to farmers of these areas if these agricultural goals are to be attained."

Dr. McCune noted that world population has doubled in his lifetime and much of this increase is in tropical and subtropical regions. Because the climate in many of these areas permits multiple cropping (two or three crops per year), fuller advantage of this more intensive agricultural production potential must be taken by using much larger quantities of fertilizer.

He emphasized that the conventional primary nutrient (nitrogen, phosphorus, and potassium) approach to fertilizers may not be adequate in tropical agriculture. The possibility for multiple cropping and even year-round agriculture wherever rainfall is adequate or irrigation potential exists requires additional major nutrients and a different approach to supplying the secondary and micronutrients.

During the 25 years of his professional career, Dr. McCune has authored or coauthored approximately 40 papers or publications and has done short-term work in more than 20 countries.

In receiving the award, Dr. McCune credited the entire IFDC team when he said, "I accept this honor as a tribute more to the organization that I represent than to me personally. IFDC is committed to ensuring that the fertilizers for increasing agricultural productivity in the developing countries become a reality."



In-Country Involvement

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

IFDC is People Helping People. . . Through Training

Mr. Cisse Alpha Cheick (right of center) from Timbuktu, Mali, and other marketing management training participants observe the improved cultural practices used by the Farmland Training Institute, Kansas City, Missouri (U.S.A.).

Mr. Cisse Alpha Cheick, a fertilizer marketing manager from Mali, received training at IFDC during 1981 that will benefit the people of his country. He attended a 6-week course in fertilizer marketing management at IFDC Headquarters.

Mr. Cheick is head of the Marketing Division of the Societé Nationale de Recherche Minière (SONAREM), a government-owned mineral exploitation company. He is responsible for developing the use of its phosphate rock deposits that are now being mined in the Tilemsi Valley of northern Mali. For Malian farmers, directly applied rock fertilizer could be lower in cost than some other fertilizers since it is produced in their own country.

One of the purposes of the training that Mr. Cheick received at IFDC was to help him more effectively introduce the new fertilizer product into the market.

Training Program

If the world is to meet its food production needs through enhanced fertilizer use, its fertilizer workforce must be increased rapidly. Skilled personnel must build or reinforce fertilizer research, manufacturing, and marketing institutions.

To help meet this need, during 1981 IFDC trained 312 key personnel from 37 countries in programs dealing with fertilizer marketing, production, and use efficiency. In this effort, the Center worked closely with the United Nations Industrial Development Organization (UNIDO), the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the international agricultural research centers (IARCs), and governments or organizations in developing countries.

Training programs ranged from individual (on-the-job) activities to formal classroom instruction for large groups. During 1981 the Center conducted four group programs at its Headquarters and four in Africa, Asia, South America, and the Caribbean Basin.

Group Training

Marketing

Management

Marketing managers from 13 countries participated in the fifth annual marketing management program at IFDC Headquarters, August 17 to September 25. The program instructors emphasized planning, systems development, and implementation. They covered such topics as the world industry and current situation; government policies; supply economics; and product selection, pricing, promotion, and distribution. In a computer simulation competitive game, the participants learned how to make better marketing decisions.

Field trips to manufacturing plants, shipping and warehousing facilities, retailers, and farmers' cooperatives illustrated a complete fertilizer marketing system. At the University of Missouri at Columbia, Missouri, U.S.A., participants witnessed the close linkage between a university, state and federal extension services, cooperatives, and experiment stations. Here they realized the importance of this linkage to fertilizer market development.

FMMT program participants visit the bulk-handling facilities at the Tampa, Florida (U.S.A.) port.

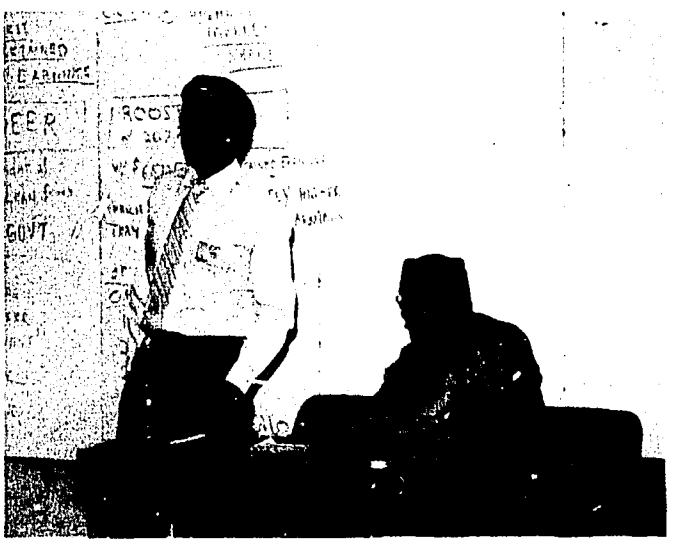
Regional Marketing Management

In cosponsorship with the Economic and Social Commission for Asia and the Pacific (ESCAP), IFDC conducted the second regional fertilizer marketing training course in Bangkok, Thailand. Thirty-eight marketing managers participated in a unique learning experience that provided techniques to improve marketing efficiency, October 18-30. Specialists from IFDC, ESCAP, and FAO presented the 2-week program focusing on consumer-oriented marketing. Besides engaging in classroom activities, the participants visited the Thai Central Chemical Company, two private-sector fertilizer/pesticide dealers, and a cooperative fertilizer union.

The Thailand fertilizer industry, particularly Metro and Thai Central Chemical Company, gave outstanding support to the program.

Special Training

To provide basic marketing and production information for executives of the Saudi Basic Industries Corporation (SABIC), the Center presented an intensive 6-day specialized course. The instructors emphasized the world fertilizer situation and outlook, international urea trade patterns, prices and practices, ammonia and urea production, and international marketing strategies.



FMMT program participants present their company's stockholder reports as part of the Alpha exercise in fertilizer marketing management.

Production

Management

To improve the operation of factories in the handling and processing of raw materials into fertilizers, IFDC conducted a second course in Maintenance and Production Management. Thirty-two plant managers from 11 countries participated in the 2-week program of classroom lectures and workshops. One aspect of the program that received high acclaim by the participants was the training in program evaluation and review technique (PERT). This technique emphasizes the importance of setting objectives, planning, organizing, and achieving a particular goal.

One week of field trips was allotted to give the participants a first-hand view of maintenance and production management practices.

The demand for this training calls for offering it again in 1982.

Maintenance and production managers actively participate in project planning and scheduling workshop.

Training for Engineers

A group of engineers from Fertilizantes Mexicanos, S.A., (FERTIMEX) received technical and management training at IFDC Headquarters in December. This course was the second of its kind specifically designed for FERTIMEX engineers. The topics concerned supply and demand, technology, engineering production, and industrial orientation. The engineers were made aware of technology that is not being used in the Mexican fertilizer industry. This technology was for the production of complete fertilizers using the pipe-cross reactor system (a simplified method for reacting phosphoric acid and ammonia).

The engineers visited five production facilities, in addition to installations at IFDC and TVA.

FERTIMEX production engineers are briefed on agronomic research being conducted in the IFDC Greenhouse.

Regional Granulation and Bulk Blending

Production managers in Latin America and the Caribbean regions learned of solutions to unique problems in fertilizer granulation and the increased use of bulk-blended fertilizers in a 5-day seminar held at Freeport, Bahamas. The 24 participants studied

process design, operating techniques, plant organization and management, formulation, inventory control, quality assurance and control, and environmental protection.

CEFER Seminars

Since 1979 IFDC has assisted the Centro de Estudos de Fertilizantes (CEFER) with its staff development and fertilizer research technology. Seminars in Sao Paulo, Brazil, have covered superphosphates, ammonium phosphates, pipe-cross reactor technology, pollution assessment and control, fluid fertilizers, and the evaluation of technical production problems.

During 1981 IFDC organized six seminars which covered computer use, fluid fertilizers, preparation and use of organic materials, soil conditioners and/or fertilizers with emphasis on the composting process, pollution assessment, and process problems caused by dustiness. These seminars were attended by 115 production personnel.

FERITT participants harvest maize field trials in Nigeria.

Use

Fertilizer Efficiency Research in the Tropics Training Program

The International Institute of Tropical Agriculture (IITA) of Ibadan, Nigeria, hosted the third Fertilizer Efficiency Research in the Tropics (FERITT) Training Program for Africa. The objectives were to improve the participants' abilities to test and evaluate fertilizer materials and application methods and to analyze and interpret data generated from field trials.

The program emphasized specific procedures for conducting fertilizer trials with new or improved fertilizer materials and application techniques and the agronomic, economic, and statistical analysis of results. A few of the subjects studied were the characterization of tropical soils in relation to crop production, soil fertility, management of tropical soils, role of biological nitrogen fixation, cultural practices affecting fertilizer-use efficiency, and analysis and interpretation of research data to compare fertilizer material. The program was conducted in English and French.

The training program also afforded practical field experience for the participants. As in previous FERITT courses fertilizer trials had been preplanted so that the students could have the experience of harvesting the crop and analyzing the data.

The thrill of accomplishment shows on this FERITT participant's face during graduation exercises in Nigeria.

Individual Training

IFDC also provides training that is designed to meet the specific needs of individuals. Such assignments may be for a few days or several months.

In 1981 participants studied fertilizer marketing, production, and use; phosphate rock beneficiation; production of wet-process phosphoric acid and nitric phosphate; plant maintenance; and characterization of phosphate rock.

Seventeen participants from Bangladesh, Brazil, Colombia, Egypt, Gambia, Indonesia, Kuwait, Mexico, and Nigeria received personal training equal to 45 participant workmonths.

Training Evaluation

Evaluation of IFDC's training programs is designed to meet five objectives. They are: (1) to obtain feedback from training participants about the program in which they participated, (2) to determine each program's effectiveness in achieving its objectives, (3) to identify ways to improve each program's content and organization, (4) to assist in the identification of training needs and in the followup of participants upon completion of their training, and (5) to inform donors about IFDC training programs.

The evaluation report prepared for each training program is made available to those individuals who were directly involved in the planning and management of that program and are currently involved in the development of upcoming programs in the same area of training.

IFDC is People Helping People. . . Through Technical Assistance

A Sri Lankan farmer mulches young coconut nursery palms with shredded coconut husks to provide moisture retention, weed control, and added fertilization.

W. K. Silva is one of many Sri Lankan coconut farmers who will reap the benefits of IFDC technical assistance to their country. Coconut production is tremendously important to the economy of Sri Lanka.

At the request of the Sri Lanka Ministry of Coconut Industries, IFDC conducted in 1981 a study to determine what could be done to reverse the declining coconut production in Sri Lanka. This study was funded by USAID.

If Sri Lanka follows a plan developed by IFDC, the increase in coconut production will feed the 1.7% increase in its population during the next 5 years. An annual per capita consumption of 130 nuts will be provided, plus a surplus of 55 million nuts for export.

It is profitable for the farmer to apply fertilizer to his coconut crop. The cost:benefit ratio based on 1981 prices is a return of about 4 rupees for each one invested in fertilizer. Experimental results at the Coconut Research Institute show that unfertilized palms yield about 20 nuts, whereas fertilized palms can yield 70 nuts or more per palm.

The Sri Lanka Coconut Fertilizer Study is one example of what IFDC technical assistance means to the future prosperity of the world's people.

Technical Assistance Program

During 1981 IFDC continued to provide worldwide technical assistance to international organizations, national governments, and other organizations. Examples of this technical assistance include studies of local ores for fertilizer production, transfer of fertilizer production and marketing technology, institution building, prefeasibility studies, and development of fertilizer efficiency-use strategies. These IFDC activities provide plans for implementation by sponsors.

Technical bulletins, reference manuals, circulars, reprints of journal articles, newsletters, technical reports, and other communication means served to support the transfer of fertilizer technology.

Africa

African Center for Fertilizer

In 1979 the Organization of African Unity (OAU) considered the creation of a fertilizer center for Africa. Subsequently the Scientific Technical and Research Committee (STRC) of OAU requested IFDC to assist in the preparation of a project proposal for such a center.

During 1981 a committee was formed to evaluate potential sites for the center, review its objectives, and examine matters related to its formation and operations. Committee members represent OAU/STRC; the Egyptian Institute of Soil and Water; the Ministry of Agriculture, Madagascar; the Ministry of Agriculture, Liberia; and IFDC. The committee plans to present its recommendations to the OAU Council of Ministers in mid-1982.

With the possible exception of sulfur, Africa has adequate natural resources to become self-sufficient in fertilizer production. If each country in Africa is to fully develop its potential for crop production and become self-sufficient in food, an effective fertilizer industry is needed in Africa.

Objectives of the Proposed Center

1. Provide and/or arrange for training personnel in fertilizer production, marketing, and efficient fertilizer use.
2. Assist member States in searching for fertilizer-related indigenous raw materials and exploring their use.
3. Assist countries in assessing the suitability of raw materials and resources for national fertilizer production and other uses.
4. Assist in conducting engineering, geological, economic, social, policy, and agronomic studies for increasing fertilizer production, marketing, and use.
5. Assist in the collection, documentation, and dissemination of data concerning the latest innovations in fertilizer production, marketing, and use so that the African fertilizer community can be informed and able to make effective and rational decisions.
6. Provide advisory services to member countries when required for the development of their fertilizer industry.
7. Develop cooperation among fertilizer organizations to aid in the development of the regional fertilizer industry.

Linkages

The center would provide the connecting links and stimulus for cooperation between national institutions in OAU member states and regional and international organizations.

The center is expected to have an especially close working relationship with IFDC, which will provide guidance during the formative period and technical assistance in the center's operations.

Staff

It is intended that the center strive to attract the most experienced and capable African staff. If they are not available, staff would be recruited worldwide on a contractual basis. At all times, there should be positions filled by international experts of high reputation in order to infuse new talents into the center.

Egyptian National Research Centre

In 1981 IFDC continued to assist the Egyptian National Research Centre (NRC) in strengthening its research and development capability. Sponsored by the U.S. National Academy of Sciences (NAS), NRC engineers studied various processes for fertilizer granulation at IFDC.

The NAS is supplying NRC with a bench-scale wet-process phosphoric acid unit. IFDC is assisting in procurement and fabrication of some items not available from suppliers.

Nigeria Marketing Strategy Development

IFDC provided the M.W. Kellogg Company marketing assistance for their proposed fertilizer plant to be located at Port Harcourt, Nigeria. The Federal Republic of Nigeria awarded Kellogg a contract to build a nitrogen complex that will produce 1,000 metric tons per day of ammonia, 1,500 metric tons per day of urea, and 1,000 metric tons per day of complete fertilizers (including diammonium phosphate [DAP] and other compounds). Kellogg is responsible for developing a marketing system to offtake the facility's production. The marketing system as recommended in the Nigeria Fertilizer Marketing Study conducted by IFDC for the Nigerian Government in 1980 provides the basic marketing concepts.

IFDC continues to assist Kellogg's marketing effort in the following four areas: (1) developing a fertilizer marketing plan, (2) designing an organizational structure that will carry out the marketing functions, (3) developing a list of criteria for determining a capable partner or organization to manage the Nigerian Fertilizer Marketing Company, and (4) conducting a technical audit of the marketing system components.

Zambia Fertilizer Supply Study

A study was carried out in September 1981 to evaluate a USAID proposal to lend Zambia US $20 million to be used through a Commodity Import Program. The loan would: (1) provide short-term balance-of-payment relief to Zambia, (2) contribute to the long-term objective of the Government of the Republic of Zambia (GRZ) to accelerate agricultural development and diversify the structure of the economy, and (3) support GRZ/USAID goals to increase food production and raise small farmers' incomes.

The team consisted of staff from USAID, Washington and Nairobi; the U.S. Office of Commodity Management, Washington; and IFDC.

The Zambian plan includes importing the fertilizer raw materials required for the Kafue Nitrogen Chemicals fertilizer

plant expansion program to produce compound fertilizers. The studies conducted specifically by IFDC staff had several objectives: (1) to review the plan to import fertilizer raw materials and to determine its viability, (2) to survey the fertilizer plant and facilities in light of the possibility of producing compound fertilizers, (3) to review Zambian fertilizer consumption statistics and to determine fertilizer availability and its consumption by small farmers, and (4) to assess the present marketing system and its capability of handling the volume projected by Zambian officials.

The IFDC report serves as the basis for the U.S. loan to Zambia for purchasing fertilizer materials to operate the new compound fertilizer plant and fulfill 1981 fertilizer requirements.

Zimbabwe Fertilizer Sector Study

In response to a request from the Industrial Development Corporation of Zimbabwe (IDC), a three-member IFDC team examined that country's fertilizer industry in mid-1981.

Zimbabwe agriculture has rapidly expanded, and fertilizer consumption has outstripped production facilities. With three small phosphate rock deposits, Zimbabwe has experienced self-sufficiency in superphosphate manufacture for 25 years. Pyrites are indigenous, but some sulfur is also imported.

Ammonium nitrate has been produced for the past 15 years using electrolytically derived hydrogen for ammonia (NH_3) production. This production consumes about 20% of the total electricity produced in the country. Zimbabwe is currently importing electricity. Rising power costs make future nitrogen production based on electricity economically questionable.

Fertilizer consumption in 1980/81 was 476,400 product tons or 164,400 nutrient tons, of which 30% was imported. As agriculture expands, the proportion of imported fertilizer will increase unless a major investment program to expand local fertilizer production is instituted.

In Zimbabwe agricultural production is divided into two groups—commercial agriculture and that on tribal trust lands (TTLs). Commercial agriculture comprised 5,200 farms in 1981. However, small-scale farmers, almost wholly in the TTLs, total about 850,000.

IFDC investigators concluded that the available fertilizer grades are not tailored to meet the needs of TTL-farming conditions. A major consumption potential would exist in TTLs if (1) marketing and supply points were established at accessible locations within the TTL, (2) credit were made available to savings clubs, and (3) fertilizers were made available to meet the needs of the TTL soils, rainfall patterns, and economic crop yield potentials.

The development of a national long-range fertilizer sector plan is essential; this sector plan must complement the agricultural plan. The IFDC specialists recommended 13 long-range programs to revitalize the Zimbabwe fertilizer industry.

Asia

Economic Evaluation of Fertilizer Supply Strategies for the ASEAN Region

IFDC undertook a study to illustrate the use of a dynamic linear programming model for planning the development of a fertilizer industry. The model was applied to the countries of the Association of Southeast Asian Nations (ASEAN) region: Malaysia, Thailand, Indonesia, and the Philippines.

The IFDC model permits evaluation of different supply strategies, specifically in reference to least cost supply patterns, optimum production levels, cost of not having optimum production, and estimates of variable and total costs and of capital investments.

To evaluate the impact of different fertilizer supply strategies in the region, the IFDC economists created four scenarios. They are: (1) each country in the region can secure its fertilizer needs from least cost sources, (2) a 100% regional self-sufficiency in nitrogen production is required, (3) a 100% regional self-sufficiency in nitrogen production and 50% self-sufficiency in P_2O_5 production are required, and (4) each country acts independently of each other and uses its own facilities, as far as possible, to meet its needs.

The study clearly demonstrates the potential economic effect of different supply strategies on fertilizer costs. It measures savings that could be realized through cooperative agreements. It also shows the added costs that the region will have to pay to achieve different degrees of self-sufficiency. As would be expected, the lowest fertilizer prices are for scenario 1 and the highest for scenario 4. This provides an indication of the possible consequences of alternative supply strategies on fertilizer prices and use.

Malaysian FPM Sendirian Berhad Granulation Project

IFDC continues to serve as technical advisor to FPM Sendirian Berhad (FPM) on equipment and process details for their granulation plant at Johore Port in southern Malaysia. Based on a process design developed by IFDC, the facility will produce a 3- to 5-millimeter granule, an ideal size for aerial application. The typical grade will be 14-6-21-4 MgO, which is made for application on the oil palm and rubber stands of large plantations. IFDC staff will assist in the initial plant startup.

Pakistan Agricultural Inputs Study

A study team from IFDC, USAID, and the Department of Transportation, Oakland, California, visited Pakistan in late 1981. The team developed agricultural input recommendations for the U.S. Government relative to its $1.6 billion military/economic assistance package for the Government of Pakistan.

One part of the financial agreement is concerned with increasing the availability of fertilizers and agricultural equipment, with emphasis on strengthening private-sector service activities.

The team recommended that Pakistan be given credit for the purchase of DAP and a grant to buy irrigation equipment or tractors.

The construction site of the FPM Sendirian granulation plant near Johore port, Malaysia.

Turkey Feasibility Study

At the request of the World Bank, IFDC provided an engineering team to assess the possibility of incorporating a pipe-cross reactor system into a fertilizer plant in Turkey. The purpose of this project was to provide the World Bank with information that could be used in the Turkish Fertilizer Industry Rehabilitation Plan.

The operation of the DAP plant at Akdeniz Gübre Sanayii A.S. (Akgübre) at Mersin was studied, and the practicability of installing a pipe-cross reactor system was determined. The DAP plant was found to be well designed and well constructed. During the visit sustained operation at or above the design rate was achieved for more than 16 days. From an overall operational or equipment standpoint, problems within the DAP unit were classified as minor. Major limitations to the production of DAP were due to production problems in the phosphoric acid and sulfuric acid plants.

The engineers concluded that economic returns could result from modification of the process to incorporate the pipe-cross reactor. However, they recommended that this action be withheld because of more serious problems within the complex. During the rehabilitation phase II, emphasis will be placed on improving the efficiency of the plant by upgrading the emission control system. This action will decrease the dust evolution from the unit. When a reliable supply of raw materials (primarily phosphoric acid) is obtained for the DAP facility, the proposed conversion to the pipe-cross reactor should again be considered.

An engineer of the Akgübre plant at Mersin, Turkey and an IFDC chemical engineer examine product from Akgübre's DAP unit.

Sri Lanka Coconut Fertilizer Study

IFDC made a 2-month study of coconut production for the Ministry of Coconut Industries, Government of Sri Lanka, and USAID. The purpose of the study was to determine what steps could be taken to increase Sri Lanka's consumption of fertilizer for coconuts.

The study objectives were:

1. To evaluate the suitability of the fertilizer mixtures now recommended by the Coconut Research Board (CRB) and to recommend changes if necessary.
2. To analyze the existing storage systems and to project the future needs of the Coconut Cultivation Board (CCB).
3. To develop a plan for increasing fertilizer use by small farmers.

Experimental results at the Coconut Research Institute show that a fertilized palm can produce 50 more nuts than an unfertilized palm.

During the field survey, 10 constraints to the use of fertilizer for coconuts were identified. They include nonavailability of fertilizer, inadequate educational and credit programs, low prices for coconuts, fragmentation of land holdings, inadequate work incentives for extension workers and fertilizer dealers, and a rapid and substantial increase in fertilizer prices.

The IFDC-recommended plan integrates research, education, inputs, promotion, and marketing. It proposes that the CCB maintain a fertilizer warehouse and retail sales point at each palm nursery. The CCB should phase out all other fertilizer warehouse and retail stores over a 3-year period and turn the fertilizer operations over to an autonomous organization.

The plan recommends the formation of a 17-man task force within the Ministry of Coconut Industries. Such a task force would coordinate the supply of fertilizers to all retailers; coordinate research on coconuts; coordinate a farmer credit program; conduct educational programs with extension workers, dealers, and farmers; carry out promotional activities; develop coconut producer associations to service farmers on holding actions, prices, credit, etc.; advise the Government of Sri Lanka on the constraints to the use of fertilizers for coconut production; and implement corrective measures.

After the plan is implemented, the increased production of coconuts will more than pay for the inherent costs.

PHILPHOS Project

IFDC is assisting the Philippines Phosphate Fertilizer Corporation (PHILPHOS) in establishing a phosphoric acid/ammonium phosphate complex in the Philippines. IFDC is providing technical personnel and conducting wet-process phosphoric acid studies in its research laboratories.

Exploratory geologic studies of the Leyte phosphate rock deposit in the Philippines are underway. IFDC will determine the suitability of this rock in wet-process phosphoric acid production in comparison with other rocks such as Nauru, Jordan, Morocco, China, and possibly other phosphate rocks. The total project involves phosphate rock characterization, beneficiation, acidulation, and optimization of use of Leyte phosphate rock.

China Cooperative Technical Study

At the invitation of the China National Chemical Construction Corporation (CNCCC), an IFDC team visited China in late 1981. During the visit several areas of potential cooperation were identified.

A phosphate rock sample was supplied to IFDC for characterization. Single superphosphate (SSP) produced locally is a major phosphate fertilizer. Ammonium bicarbonate, which is produced in small plants, continues to be an important source of nitrogen in China.

The CNCCC is anxious to combine these and other raw materials to produce a complete fertilizer. IFDC agreed to make some exploratory tests of granulation and compaction. The Chinese want to maintain at least 50% water-soluble phosphate in the product.

In cooperation with the Fujian Academy of Agricultural Science, IFDC will cosponsor in April 1982 a workshop to discuss methods for producing and applying large particles of urea and

A Sri Lankan worker husks coconuts in preparation for the market. Husks are used to make brooms, mats, brushes, and rope.

ammonium bicarbonate for deep placement. In addition, this research group in cooperation with the International Rice Research Institute (IRRI) is experimenting with two types of solid fertilizer applicators for deep placement.

Latin America

Ecuador

Fertilizantes Ecuatorianos, S.A.

IFDC performed a fertilizer supply study for Fertilizantes Ecuatorianos, S.A. (FERTISA). The objective of this work was to develop an economic analysis of three selected alternative fertilizer supply schemes. These would enable FERTISA to meet projected sales requirements. The schemes were (1) the addition of a bulk-blending and bagging facility to the Guayaquil complex, (2) the construction of a bulk-blending and bagging facility at a new site, and/or (3) the addition of a DAP/NPK granulation plant and phosphoric acid receiving and storage terminal to the Guayaquil complex.

Projected fertilizer demand for Ecuador and projected FERTISA fertilizer sales were developed. The latter figures were used for the determination of plant capacities for comparison of the alternative supply schemes.

In addition to the general objective, the following specific items were studied: (1) preliminary investment and production cost estimates for a new sulfuric acid plant, (2) development and assessment of cost estimates for maintenance/modification projects for existing FERTISA manufacturing facilities through 1985, and (3) assessment of the use of existing facilities under a bulk-blend NPK fertilizer supply scheme.

The study showed that the most economical and expedient means for FERTISA to increase its NPK fertilizer supply capacity is the addition of a bulk-blending and bagging facility to the existing plant. It is estimated that this project could be implemented in 6-9 months as compared with about 2 years for the other two supply schemes.

IFDC recommendations included (1) the use of existing facilities, (2) technical considerations for increasing viability, and (3) project implementation. Detailed specifications for a bulk-blending and bagging system were prepared. A preliminary recommendation was also included for a proposed site of the bulk-blending and bagging facility.

Chinese farmers come to the fertilizer factories in concrete boats such as this one to buy aqueous ammonia. The boat is equipped with a tank for holding the liquid fertilizer.

Venezuela Fertilizer Supply Strategy

At the request of Petroleos de Venezuela, S.A. (PDVSA), IFDC proposed a plan to develop a fertilizer supply strategy to enable Venezuela to meet its domestic needs during 1981-90.

Agriculture plays a secondary role in Venezuela's oil-dominated economy, which depends heavily on imports to satisfy the needs of the increasingly affluent population. The agricultural sector contributes about 6% to the gross territorial product. Food production lags behind population growth and demand.

The application of improved technology could almost double the 2% of Venezuela's land area now considered suitable for general crop production. However, because the resulting cultivatable acreage will still remain quite limited, the need for expanding and improving the efficiency of fertilizer use is emphasized.

Fertilizer Demand Projections

Time trend and structural demand models were used for making projections of annual nutrient demand. Projections were categorized by product and region to provide the information needed to prepare production, marketing, and distribution strategies.

Fertilizer use, which increased steadily in the last decade, reached about 554,000 metric tons in 1980 and contained 108,000 metric tons nitrogen, 74,000 metric tons P_2O_5, and 54,000 metric tons K_2O. Nutrient use in 1990 is projected at 117,000 metric tons nitrogen, 138,000 metric tons P_2O_5, and 114,000 metric tons K_2O. If fertilizers are made in the form of the highly concentrated grades recommended by IFDC, fertilizer volume in 1990 will reach approximately 840,000 metric tons.

Raw Materials

Natural gas reserves are adequate to support sufficient production of ammonia and urea. Manufacture should be expanded and the delivery system improved.

Of the several phosphate rock deposits, only Riecito deposit presently has commercial development potential. Processing techniques and plant modifications must be developed before this phosphate rock can be satisfactorily used in phosphoric acid production. Abundant quantities of sulfur are available at the Amay and Cardon petroleum refineries. There are no known potash mineral deposits in Venezuela.

Production

In 1979 about 75% of Venezuela's fertilizer supply was imported, mainly as multinutrient NPK fertilizers. The remainder, mostly urea, was obtained from ammonia-urea plants operated at Moron and El Tablazo by Petroquimica de Venezuela, S.A. (PEQUIVEN). IFDC identified the factors impeding production and made recommendations for overcoming these constraints.

Supply Strategies

Based on maximizing the use of local raw materials and existing production facilities at Moron and El Tablazo, eight domestically oriented fertilizer production schemes to supply projected demand were devised and evaluated. The most attractive schemes were those alternatives based on blending granular urea, to be produced at Moron, with DAP produced at Moron or imported.

If the recommended production schemes are implemented as scheduled, domestic production in 1990 would provide nearly 90% of the projected fertilizer supply requirements. Imports of finished fertilizers would be limited to straight materials and specialty fertilizers.

Marketing

To improve the efficiency of the marketing system and to lower overall farm-level delivered costs, IFDC suggested that this system be coordinated more closely with production. As fertilizer is produced it would be shipped from the production facility to storage sites as close as possible to the ultimate point of use.

Recommendations for reducing distribution costs included measures to lower transportation expenses, reduce inter-warehouse movements, expand rail transport usage, mechanize handling procedures, rationalize warehouse storage capacity, and improve inventory control.

If projected demand is to be attained, soil fertility research programs are needed to establish fertilizer recommendations. Extension and marketing development services of public and private organizations should be improved to educate farmers in the proper use of fertilizers.

IFDC is People Helping People. . . Through National Programs

An IFDC assistant pilot-plant coordinator and a PUSRI shift foreman inspect product from the new PUSRI urea granulation plant.

Mr. Kuswawi, a urea shift foreman at P. T. Pupuk Sriwidjaja (PUSRI), Palembang, Indonesia, is learning about IFDC's national programs component.

During August 1979 Mr. Kuswawi came to IFDC with a group of 11 PUSRI personnel for a 4-week training program to learn how to operate a urea granulation plant. He is in charge of one shift at the PUSRI granulation plant. After he returned to PUSRI, he transferred the training that he received at IFDC to other operators to aid in the plant startup.

Since 1977 IFDC has been assisting PUSRI in its efforts to convert the finishing section of one of its fertilizer plants from the production of prilled urea to that of granular urea. The PUSRI I granulation unit is the first of its kind in the developing world. In early 1981 a team of IFDC staff members assisted PUSRI in the smooth startup of the urea granulation unit. According to Ir. Dede Sudarsana, PUSRI Chemical Engineer, "a major factor contributing to the success of the granulation unit was the complete and carefully planned training program that IFDC conducted for PUSRI operating personnel."

National Programs

National programs in the developing countries provide the mechanism through which fertilizer-related problems can be identified and investigated and the applicability of IFDC's solutions to these problems can be evaluated. Within the developing countries, the major responsibility for improving agricultural production and the quality of life of millions of people rests with government agencies. However, in this endeavor, organizations such as IFDC have a vital role to play. The IFDC function is to join into a catalytic partnership with key national institutions in order to train, guide, and technically participate in the development of these nations.

In assisting national programs, IFDC achieves a unique effectiveness by meshing multidisciplinary task force teams with those of a particular country. To satisfy a specific need, it can draw from its multinational professional staff of agronomists, soil scientists, chemists, economists, engineers, geologists, managers, and specialists in market development, communications, and personnel development.

A key IFDC contribution is its development of fertilizer personnel from developing countries. These scientists and managers are reabsorbed into the national agencies that work on fertilizer problems and projects.

As a result of IFDC participation in many national programs in recent years, increased fertilizer production and an improved understanding of fertilizer supply, demand, pricing, government policy, and marketing have been facilitated. A greater number of farmers use fertilizers properly.

Bangladesh

Bangladesh Agricultural Development Corporation Project

IFDC provides Bangladesh a wide range of technical assistance. To attain the 1985 food grain self-sufficiency goals of the government's current Medium-Term Foodgrain Production Plan (MTFPP), fertilizer usage will have to more than double. A great number of supply and demand related constraints will have to be relaxed or removed if the needed quantities of fertilizers are to be made available to Bangladeshi farmers on an equitable, timely, and economic basis.

Marketing

Recognizing the need to stimulate food production through fertilizer use, USAID funded a Fertilizer Distribution Improvement Project in 1978 to address the marketing problems that have limited fertilizer availability.

In 1981 IFDC continued to provide marketing and distribution consultancy services to Bangladesh Agricultural Development Corporation (BADC). BADC is the government entity charged with the responsibility of marketing fertilizers in Bangladesh.

IFDC provides day-to-day technical assistance to BADC management and staff through full-time resident consultants posted at BADC Headquarters in Dacca. IFDC supplies staff specialists to resolve specific marketing problems. The IFDC/BADC program is coordinated with USAID and implemented with the active participation of BADC counterparts and staff. Such involvement gives them the opportunity to develop and diffuse fertilizer knowledge and skills for a broader and lasting impact.

In 1981 IFDC provided a resident distribution specialist and a resident marketing specialist. They work to improve management of the fertilizer marketing component and evaluate the recently reorganized marketing system.

Working with BADC counterparts, the distribution specialist identified and initiated remedial actions to overcome administration deficiencies in the distribution system. Specific activities included the following:

1. Preparation of a warehouse operation and maintenance manual to restructure and improve the warehouse management system.
2. Completion of a stock control and accounting system to monitor fertilizers from supply points to retail warehouses. The proposed system is being evaluated on a trial basis at several warehouses.
3. Continued assistance to BADC in adopting administrative reforms on improved fertilizer procurement, transportation, and handling of contracts and procedures.

To develop a least cost transportation system, the BADC physical distribution system was reviewed. Recommendations were made for the control and monitoring of fertilizer movements by road, rail, and water.

In 1981 the New Marketing System (NMS) was adopted nationwide. It transfers the retail marketing responsibility to private independent dealers. It is thought that competitive forces will compel wholesale and retail dealers to be more responsive to serving farmer needs in a more cost-effective manner.

In 1981 the IFDC marketing specialist performed the third evaluation of the NMS to determine its effectiveness in serving the national interest through expanding the fertilizer market and evaluated its impact on fertilizer cost and availability to farmers. More than 1,000 fertilizer dealers and a randomized selection of farmers were interviewed in this study.

While dealers and farmers agreed that the NMS represented a distinct improvement over the old marketing system (OMS), several weaknesses were identified. They were the slow rate of closure of Thana sales centers and the need for BADC to enhance its other marketing functions. Specifically, BADC must develop and motivate its dealer organization to effectively promote fertilizer sales and expand its farmer assistance programs. To support these actions IFDC will post a marketing specialist and a dealer development and training specialist in Dacca.

IFDC also provides training for BADC personnel in various aspects of fertilizer production, marketing, and use. In 1981 BADC staff members participated in IFDC's Fertilizer Marketing Management Training Program and in the IFDC/ESCAP-sponsored Regional Fertilizer Marketing Training Program for Asia. Four staff members from the Bangladesh Chemical Industries Corporation (BCIC) attended IFDC's Fertilizer Maintenance and Production Management Training for Fertilizer Producers. Eleven Bangladesh participants sponsored by the United Nations Development Program (UNDP) and FAO also attended these training programs.

There is an increasing incidence of zinc and sulfur deficiencies in crops grown in Bangladesh. To study how such deficiencies can be overcome, a team of Bangladeshi scientists from BADC, BCIC, Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), and the Directorate of Agriculture visited India, the Philippines, and the United States.

Agricultural Production, Fertilizer Use, and Equity Considerations

This joint study by IFDC and the Bangladesh Agricultural Research Council (BARC) represents expanded research by IFDC on the equity effects of fertilizer use and the identification of various farm-level constraints to fertilizer use and agricultural production in Bangladesh. The objectives and results of the current research studies are presented in the Economics Research section of the Research Program section.

Fertilizer Policies

Bangladesh agricultural and food policy planners recognize the urgent necessity for supplying and promoting the use of the large quantities of fertilizer required to meet established food production targets. In view of this need, BADC requested IFDC to assist in formulating more clearly defined and coherent fertilizer supply and use policies. Senior Bangladeshi scientists prepared background papers on specific subject-matter areas.

They presented and reviewed these papers at a seminar in Dacca and later at a workshop at IFDC Headquarters

where Bangladeshi and IFDC scientists developed preliminary recommendations for coordinated national-level policies and strategy options. Bangladesh government planners and policymakers have reviewed these recommendations.

Indonesia

Cooperative ADAB/IFDC Fertilizer Research Program

During 1981 IFDC and the Australian Development Assistance Bureau (ADAB) agreed to cooperatively conduct programs aimed at improving the efficiency and use of fertilizers in the ASEAN countries.

The work aims to develop, evaluate, and introduce more efficient fertilizer products and fertilizer practices for rice and other crops in the region. Indonesia was selected first because of the expressed interest and desire to implement programs rapidly.

The ADAB/IFDC Project will contribute to the overall Indonesian effort by emphasizing:

1. Research on the fate of nitrogen applied to wetland rice soils.
2. Evaluation and modification of fertilizer placement equipment to facilitate deep placement.
3. Agronomic research on alternative fertilizer management strategies for rice and other crops including interactions of nitrogen, phosphorus, sulfur, and other nutrients.
4. The introduction and testing of new fertilizers and technologies at the farm level.
5. Studies of the socioeconomic consequences of more efficient fertilizers and their use.

Training courses will be held at IFDC Headquarters, at the University of New England in Australia, and in the People's Republic of China.

PUSRI Urea Granulation Project

A joint Indonesian/IFDC project to convert a urea prilling unit of PUSRI, the Indonesian fertilizer manufacturer, to the production of granular urea has been completed. IFDC staff members participated in the startup of the new granulation facility.

Based on the pan-granulation process developed by TVA of the United States, the plant has a design capacity of 350 metric tons per day of urea granules. This is equivalent to the output from the PUSRI I urea plant.

The project represents the first commercial unit in Asia designed to manufacture modified urea products. It emphasizes PUSRI management's vision for technical improvement throughout their organization. As a result of this project, the opportunity exists to further modify urea produced by PUSRI by size variation or through the use of coatings to improve the agronomic efficiency of urea as a fertilizer material.

Through IFDC's concerted efforts and involvement in the various phases of the project, Indonesia was able to complete the transfer of this technology while enhancing the engineering capability within the country. IFDC involvement not only covered the technical aspects of the project but included training for PUSRI engineers and supervisors using the pilot-plant facilities at IFDC Headquarters. PUSRI engineers and supervisors were trained in operating the pan-granulation system and comprised the startup team to supplement the IFDC team.

This first successful step in modification of urea production/technology provides a basis for additional work by IFDC and others in improving the efficiency of urea as a fertilizer.

IFDC personnel inspect pan granulation unit at P.T. PUSRI, Indonesia.

In Mali IFDC is assisting with field experiments to obtain information on responses to phosphate rock. In the above evaluation trial, workers are laying out individual sorghum plots.

Mali

Efficient Use of Phosphate Fertilizer

IFDC has started a phosphate project for the Government of Mali. The project's objective is to select the most efficient and economic source of phosphate to supply to Mali's farmers.

Mali has a deposit of about 20 million metric tons of phosphate rock located in the Tilemsi Valley, north of Gao. The benefits of using this material are being studied.

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. The results should be invaluable for most Sahelian west African countries; the project points the way for developing similar action programs in these countries.

There will be four developmental phases, as follows:

1. Fertilizer evaluation trials will be established on experiment stations that represent the major soils, climatic patterns, and cropping sequences. In 1981 ten experiment stations (Figure 1), typical of most agroecological and climatic zones in Mali, were selected. Soil profiles were described, and a tentative classification was established. Depending on ecological zones, crops of millet, sorghum, or maize were grown with uniform nitrogen and potash treatments to determine the variability within fields and to decrease available phosphorus levels in soils.
2. Socioeconomic studies will be conducted concurrently with Phase 1. Already there is evidence that farmers may be reluctant to adopt ground Tilemsi phosphate rock for direct application because of the powder form and the low crop response in the initial year of application.
3. Farm-level tests and evaluation of the most promising products and fertilization practices as determined by agronomic performance, economic potential, and socioeconomic acceptance are expected to begin in 1984.
4. An appropriate strategy to supply phosphate fertilizers and to achieve their adoption by Malian farmers will be developed.

All experiments have been designed to provide information on comparative responses to Tilemsi ground phosphate rock, granular and powdered forms of partially acidulated phosphate rock, and totally water-soluble phosphate. In all experiments sufficient rates of phosphate from each source and for different methods of application will be used to develop crop response curves for each phosphate material being tested.

Figure 1. Ten Experiment Stations Representing the Major Soils, Climatic Patterns, and Cropping Sequences in Mali.

IFDC is People Helping People... Through Research

Humberto Garcia, a Colombian farmer, uses localized placement in applying ground phosphate rock in his field.

Humberto Garcia, a small farmer in Colombia, is benefitting from IFDC's research program. IFDC is working with his country to find ways to use its indigenous phosphate ores.

On his farm, Humberto has recently been using *fosforita huila*, or ground phosphate rock, from the nearby Huila phosphate mine. He has been pleasantly surprised. His crops are growing well, and the ground rock fertilizer cost him only one-half of what he normally spends on a bag of fertilizer.

An IFDC sociologist and a soil scientist outposted to the International Center for Tropical Agriculture (CIAT) in Colombia are investigating how phosphate rock from local deposits can be most effectively used in the traditional crop management systems of small farmers. This is one part of the overall IFDC phosphate project, based at CIAT, involving the acid infertile soils of tropical Latin America.

Research Program

Research at IFDC focuses on the creation of more appropriate technology to solve the fertilizer-related problems of the developing world. Research that leads to improved fertilizer efficiency and increased use of indigenous raw materials can materially assist food production by improving yields.

At this time research at IFDC is concentrated primarily on problems associated with nitrogen, phosphorus, and sulfur fertilizers and the constraints to their use.

The Nitrogen Research Program consists of three phases. First, the losses of applied nitrogen fertilizer and constraints to its efficient use are identified. Then, practices and products are developed to reduce these losses and improve the uptake of nitrogen fertilizers by plants. Finally, this technology is evaluated in certain geographical areas.

The IFDC Phosphorus Research Program is oriented toward helping the less developed countries make better use of their indigenous phosphate ore resources and developing a range of phosphatic fertilizers for inputs into agricultural systems.

In view of the increasing incidence of sulfur deficiencies in the tropics and the declining popularity of sulfur-bearing fertilizers, IFDC has focused on this important element. Research is directed toward the development and evaluation of phosphorus-sulfur and nitrogen-sulfur fertilizers for use by subsistence farmers in the tropics and subtropics.

Nitrogen Research

IFDC's initial effort in nitrogen research was aimed at lowland crops (flooded rice) and started in Asia. In 1979 the upland phase of the nitrogen program was initiated. This program includes major food crops grown under upland conditions in specific agro-climatic zones. The zones of interest are the semiarid tropics, the arid regions, and humid tropics.

Nitrogen research in 1981 continued to be dominated by the overall objective of improving nitrogen fertilizer efficiency for the lowland and upland crop programs. Several experimental products were tested and evaluated, but urea received the most attention. Other products tested included ammonium nitrate and other NPK multinutrient products.

IFDC researchers conducted process research in the following areas: (1) modification of urea particle size to facilitate deep placement, (2) coating and evaluation of water-soluble nitrogen fertilizers for controlled nutrient release, (3) studies of organic nitrogen compounds having limited water solubility, and (4) evaluation of urease and nitrification inhibitors.

After acquiring a new machine for briquetting/compacting urea, IFDC researchers examined a new alternative method for producing modified urea. Most of this work was performed on a laboratory scale.

These products and practices were evaluated at IFDC Headquarters, IRRI, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Agricultural Research in the Dry Areas (ICARDA), and several national research centers.

New and Modified Products

Urea Particle-Size Modification

Briquetting/Compacting of Urea and Urea Mixtures

Formation of discrete particles by briquetting/compacting is a method to convert powders, crystals, or prills into products having improved physical properties. To facilitate deep placement on paddy rice, during 1981 IFDC began to investigate the potential of briquetting urea to produce relatively large particles.

IFDC procured a laboratory-scale machine capable of briquetting or compacting, depending on types of rolls used. With pocketed rolls, pillow-shaped particles are made. Corrugated rolls are used for compacting.

When compared with granulation, briquetting/compacting appears to offer several advantages. When a dry feed material is used, neither heating nor cooling is required; the feed material can be readily changed; small units can be used; a heat-sensitive feed material can be used; only electrical energy is needed; dust generation is relatively low; and products are relatively hard. A basic requirement is that the feed material be dry, nonsticky, and flowable.

Briquetting to form large urea particles was tested. The briquettes were strong and uniformly sized. There was a high degree of weight uniformity. On the basis of this work and previous studies commissioned by IFDC, the technical and economic factors for production of 1-gram briquettes are being evaluated.

Through compacting, granular material is made from a solid flake (sheet), which is crushed and screened to give granules of the required size. Urea dust is particularly suitable for the briquetting and compacting processes. It gives a stronger product and higher yield when compared with prilled urea. Since these processes operate with a cold dry material, biuret is not formed. This process for production of granular urea from crystallized material or for treating recycled dust offers an alternative to the redissolution and evaporation of a melt.

The process of forming granular products by compacting was extended to various mixtures of fertilizers, including ammonium phosphates (MAP/DAP), potassium chloride plus MAP, urea plus DAP, urea plus phosphate rock, and urea plus gypsum. Investment and production costs for this process will be determined.

Pan Granulation of Urea

Pilot-plant studies were made for pan granulation of urea to produce large particles (supergranules, 0.25-1 gram each). For a given plant, actual output was reduced as particle size increased. The technical data are now being used to prepare a preliminary investment/production cost estimate.

Coating of Soluble Fertilizer

In 1981 IFDC continued work on the coating of water-soluble nitrogen fertilizer for controlled release. In an attempt to identify a suitable coating material that would be available in developing countries, IFDC researchers tested sulfur, neem cake, rice bran wax plus rice bran oil mixture, and latex.

The researchers prepared coated products of urea supergranules, tablets,

An IFDC chemist demonstrates the production of urea materials using the briquetter/compactor machine.

or granules. In the bench-scale rotary drum equipped with a falling curtain, they prepared products coated with sulfur or rice bran wax plus rice bran oil mixture.

Because natural rubber latex is available in some developing countries, preliminary research was completed using prilled or granular urea and various types of latex for coating. This was accomplished in IFDC's fluidized-bed coating apparatus. Nitrogen release rates in water were relatively high.

Nitrogen Compounds of Limited Water Solubility

IFDC researchers prepared oxamide and melamine, two nitrogen compounds having a relatively low water solubility. These compounds may provide controlled nutrient release on the basis of particle size. Monomethylol urea was added to melamine to facilitate tableting. Oxamide contained 32.0% nitrogen, and melamine contained 63.4% nitrogen. The materials were prepared and supplied for testing in the lowland rice program.

Urease and Nitrification Inhibitors

Phenyl Phosphorodiamidate

Urease is an enzyme that is present in soils. When exposed to the soil containing urease, urea undergoes rapid hydrolysis (decomposition) to ammonia and carbon dioxide. If the ammonia is not absorbed by the soil, substantial losses can occur. A potential method to reduce ammonia loss from urea is to inhibit this urease activity or hydrolysis. In 1981 IFDC researchers studied the inhibitory effect of the chemical, phenyl phosphorodiamidate (PPD), on urea hydrolysis.

They tested tablets prepared from granular urea and finely powdered PPD. The researchers used two procedures to develop a procedure for determining the effect of PPD on urea hydrolysis. Procedure 1 involved incubation of a mixture of urea, PPD, soil, and water. Procedure 2 consisted of placing the urea-PPD mixture on the soil surface with controlled water addition.

From these studies, it appears that 1%-2% PPD in granular urea is adequate for an agronomic evaluation of the urease inhibitory effect of PPD. The use of procedure 2 is recommended for laboratory evaluation of chemical urease inhibitors in soil for dryland conditions.

Dicyandiamide

IFDC researchers prepared a small quantity of urea mixed with the chemical, dicyandiamide (DCD)—a nitrification inhibitor. Tablets of urea-DCD were also coated with sulfur or rice bran wax. Both PPD and DCD inhibitors are relatively expensive, and more work is needed to determine their cost effectiveness.

(From left) Compacted urea product and briquetted urea particles of three particle sizes.

Metal Salts and Metal-Urea Complexes

Metal salts and metal-urea complexes could be useful for increasing the efficiency of urea and also for supplying micronutrient requirements. In 1981 IFDC researchers began to evaluate metal complexes as urease and nitrification inhibitors. They prepared and chemically analyzed several compounds containing iron, aluminum, copper, and zinc sulfate or nitrate salts plus urea. These compounds were made into tablets alone or with excess of urea (where the metal-urea ratio is 1:2). These tablets will be tested to determine inhibition activity. Preparation and characterization of other metal complexes were initiated.

Fertilizers as Carriers for Inoculants

Rhizobia constitute a family of bacteria that can take nitrogen from the air and make it available to legumes. The bacteria form nodules on plant roots. The nodules are the site of a symbiotic relationship between the plants and the bacteria: the plant supplies the bacteria with energy and minerals while the bacteria fix the gaseous nitrogen in the air and make it available to the plant in a usable form.

When commercial *Rhizobium* inoculants are applied to seeds, a moist peat carrier is usually used, but substitutes for peat are being sought. Inactive inoculants are also available in an oil suspension.

IFDC and Mississippi State University began an exploratory cooperative project in 1979 to determine if fertilizers would be suitable carriers for oil-suspended, inactive *Rhizobium*.

Exploratory tests indicated good survival when oil-suspended *Rhizobium* were mixed with 0-20-20 grade fertilizer, even when stored at 65°C. However, the physical quality of the oil-treated product was not acceptable because of its excessive oil content and nongranular characteristics.

During 1981 the researchers continued to study various fertilizer and oil types and *Rhizobium* survivability. The best fertilizer carriers appear to be those exhibiting low acidity and salt concentration in water.

Determination of Impurities in Urea by High-Performance Liquid Chromatography

IFDC developed an analytical method for the simultaneous determination of impurities in urea such as biuret, triuret, and methylenediurea, using high-performance liquid chromatography. The method is suitable for determination of biuret and methylenediurea in the 0.1%-3.0% range and triuret in the 0.01%-0.25% range. The analytical range was determined by the levels of these components typically found in commercial urea samples.

Liquid Versus Solid Fertilizers for Rice

A visiting scientist sponsored by the Rockefeller Foundation conducted literature reviews to assess the use of liquid fertilizer on rice and to determine why its use is insignificant in developing countries.

Agronomic data in the literature from rice experiments in Texas (U.S.A.), 1951; Louisiana (U.S.A.), 1965/66; IRRI, 1965-69; India, 1971-77; and Egypt, 1972-75 show that anhydrous ammonia is an effective source of nitrogen for rice.

It would appear to be possible to apply either anhydrous or aqua ammonia at a 10- to 20-centimeter depth as part of land preparation. An application of nitrogen as ammonia could be placed at a 20-centimeter depth, as part of the final puddling or leveling operation prior to transplanting. Unfortunately, the commercial marketing, transportation, and application technology have not progressed sufficiently for the deep placement of either urea or anhydrous ammonia. Deep placement is essential for efficient use of nitrogen, and the agronomic response is probably equal for either form of nitrogen.

Lowland Nitrogen Program

Rice commonly recovers only 20%-30% of the fertilizer nitrogen applied to it. IFDC agronomic research has focused on determining the causes of this poor efficiency (especially the importance of nitrogen losses), developing improved nitrogen products or practices, and evaluating the improved products in the greenhouse and the field.

IFDC's initial focus in lowland nitrogen research was on the efficiency of nitrogen applied to continuously flooded soils, but recently the emphasis has been changed to rainfed rice, which represents more than 60% of the rice grown in Asia. Much of the field research on rice is a cooperative program with the International Rice Research Institute (IRRI) in Los Banos, the Philippines.

Identification of Causes of Poor Nitrogen Efficiency

Continuously Flooded Rice

Magnitude of Nitrogen Losses

During the past 3 years, field experiments were conducted at IRRI to determine the effects of nitrogen

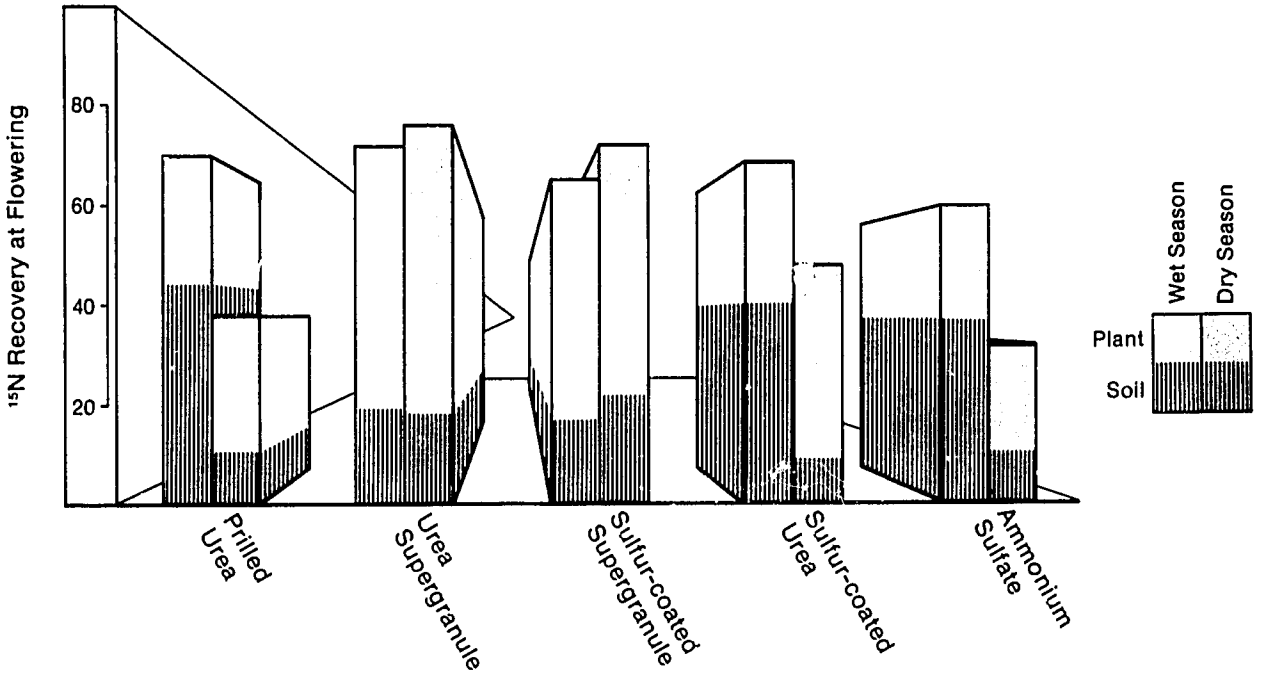


Figure 2. ^{15}N Recoveries of Different Fertilizers Applied to Rice (IRRI paddies).

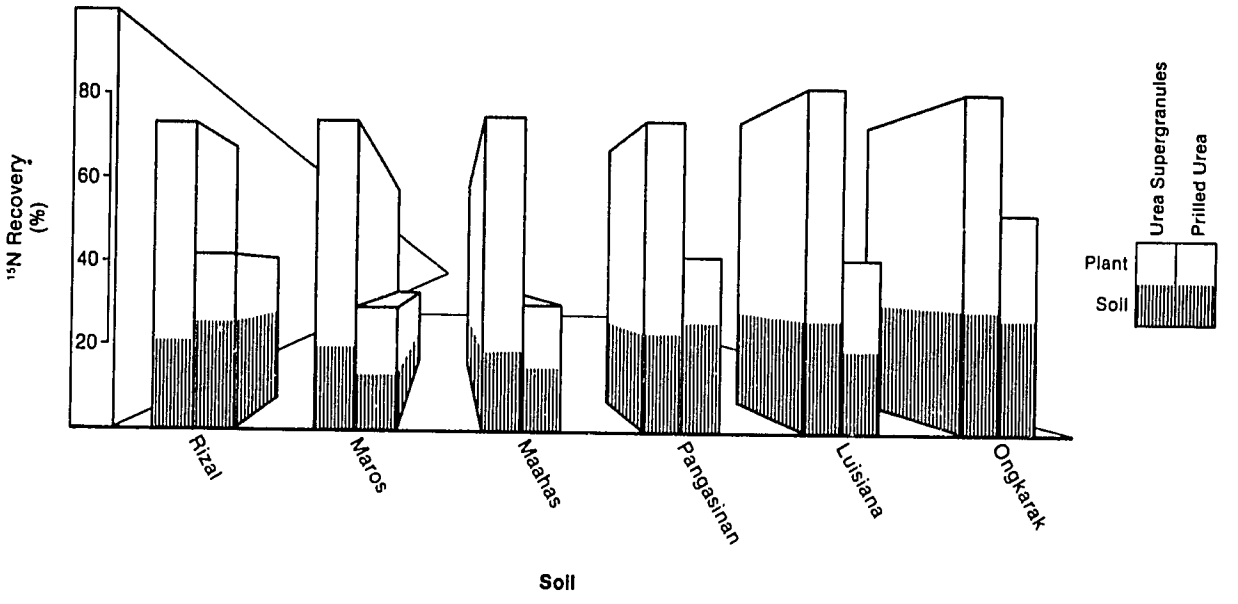


Figure 3. Recovery of ^{15}N From Fertilized Plant-Soil Systems Using Six Different Tropical Soils.

fertilizer source and management on the magnitude of nitrogen losses. Figure 2 shows that the results obtained were strongly influenced by the season. Under wet season conditions, nitrogen losses ranged from 28% to 41%. Losses of the various nitrogen sources were not significantly different. The recoveries of nitrogen from broadcast urea and ammonium sulfate by the rice plants were 26% and 23%, respectively. The recovery of nitrogen broadcast as sulfur-coated urea (SCU) and uncoated urea was not different.

The wet season data confirm that supergranules improve nitrogen recovery by the rice crop. However, rather than nitrogen losses, the immobilization of nitrogen in the soil organic pool was a major factor in reducing plant nitrogen recovery where urea and ammonium sulfate were broadcast.

Data obtained during the dry season show extensive losses of nitrogen from broadcast urea (62%) and ammonium sulfate (70%), which are double those found in the wet season. The use of supergranules reduced losses to 24%-28%, and SCU reduced nitrogen losses to 54%. Plant recovery of supergranule nitrogen (57%) was more than double the recovery of broadcast urea (27%).

Effect of Soil Properties on the Fate and Efficiency of Fertilizer Nitrogen

IFDC researchers conducted a greenhouse study with a wide range of soils from Southeast Asia to evaluate the effect of soil properties on the fate of ^{15}N-tagged fertilizer materials. Prilled urea was broadcast and incorporated, while urea supergranules were deep point placed.

In the case of supergranule treatments, recovery was largely unaffected by soil type (Figure 3). The lowest ^{15}N recoveries were obtained from the soils treated with prilled urea. The plant recovery of ^{15}N was highest from the urea supergranule treatments and

An IFDC soil scientist checks equipment for measuring ammonia volatilization in the field at IRRI.

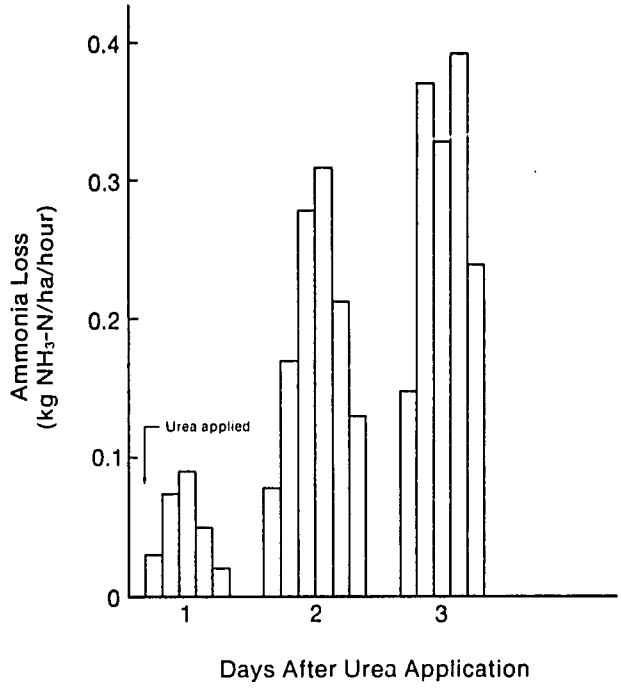


Figure 4. Ammonia Fluxes From Urea Topdressed 14 Days After Transplanting.

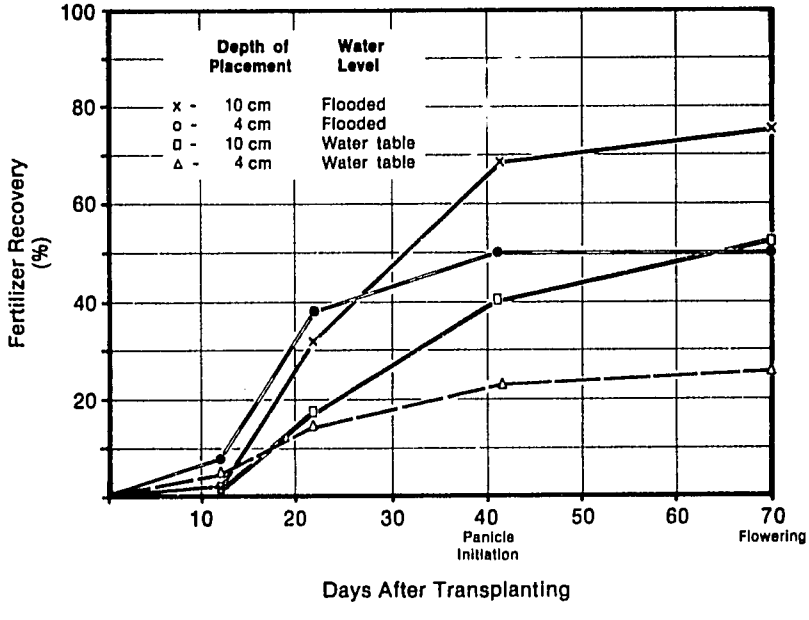


Figure 5. Pattern of ^{15}N-Labeled Fertilizer Recovery by Rice.

lowest in the urea broadcast and incorporated treatments (Figure 3). With the latter treatment, the highest plant recoveries were obtained from the more acidic soils. No close relationships can be seen between soil properties and the final ^{15}N recovery when prilled urea was broadcast and incorporated.

Measurement of Ammonia Volatilization

IFDC began in 1981 a program to measure ammonia volatilization (vaporization) using a method which allows the loss to be measured in the field under natural wind conditions. At IRRI in the dry season, ammonia losses were measured immediately after urea was surface broadcast into the floodwater of a rice field, 14 days after transplanting (Figure 4). The ammonia loss was at a peak in the middle of the day (0.4 kilogram of nitrogen per hectare per hour) when the temperature and pH of the water was very high. This rate represents 1% loss of the applied fertilizer every 2 hours. Unfortunately, bad weather conditions caused this experiment to be terminated. Nevertheless, these results confirm that ammonia volatilization is a serious problem and further research using this technique is in progress.

Simulated Rainfed Rice

Rice does not efficiently recover nitrogen fertilizers in rainfed systems where the soil becomes alternately flooded and dried. To help explain why it does not, IFDC expanded field, greenhouse, and growth chamber experiments in 1981.

To determine the effect of placement depth of urea supergranules on nitrogen recovery by rice, IFDC researchers conducted a greenhouse experiment, using two water management systems: continuous flooding and simulated rainfed.

Research indicated that deeper placement resulted in higher nitrogen recovery under both watering regimes (Figure 5). At the flowering stage, rice recovered more nitrogen when continuously flooded than when rainfed.

In rainfed soils both nitrate and ammonium forms of nitrogen may be present at the same time. To clarify how the simultaneous presence of both

forms may influence nitrogen uptake, IFDC researchers conducted a solution culture experiment in the growth chamber. Similar uptake of either form of nitrogen occurred when only one was present. However, if both were present at the root surface, little nitrate was absorbed whereas ammonium uptake proceeded at the normal rate. These results suggest that nitrate nitrogen formed in the rainfed soils will be absorbed more slowly by rice than will ammonium nitrogen. The nitrate could be subject to leaching or denitrification and thus lead to lower fertilizer recovery.

In cooperation with IRRI, IFDC conducted a field experiment during the 1981 dry season to determine the efficiency of nitrogen fertilizers applied to simulated rainfed rice. The results show that grain yields were highest in continuously flooded plots and lowest in plots that underwent significant wetting and drying. Use of deep-placed urea supergranules increased grain yield by 300-400 kilograms per hectare over that of broadcast and incorporated prilled urea.

Intermittently flooded rice recovered only 20% of the added fertilizer nitrogen compared with 41% for the continuously flooded rice (Table 1). Use of urea supergranules almost doubled fertilizer recovery in these treatments. This result concurs with the results of the greenhouse experiment. Under continuous flooding, losses of broadcast urea were only 14% in this experiment because the fertilizer was very thoroughly incorporated. With intermittent flooding, losses were 35% and 39% for broadcast urea and supergranules, respectively.

Table 1.
Percent ^{15}N Recovered at Final Harvest as Influenced by Water Regime and N Management, IRRI, 1981

Fertilizer Management	Distribution of ^{15}N	Floodwater Regime[a]	
		Continuously Flooded	Intermittently Flooded[b]
Urea broadcast and incorporated	Soil + roots	45	45
	Plants	41	20
	Total	86	65
Urea supergranules point placed at 10-cm depth	Soil + roots	24	22
	Plant	73	39
	Total	97	61

a. All plots maintained flooded from 0-12 days after transplanting (DT) and from 38 days DT to harvest.
b. Floodwater condition 12-38 DT. Water added using a line source sprinkler.

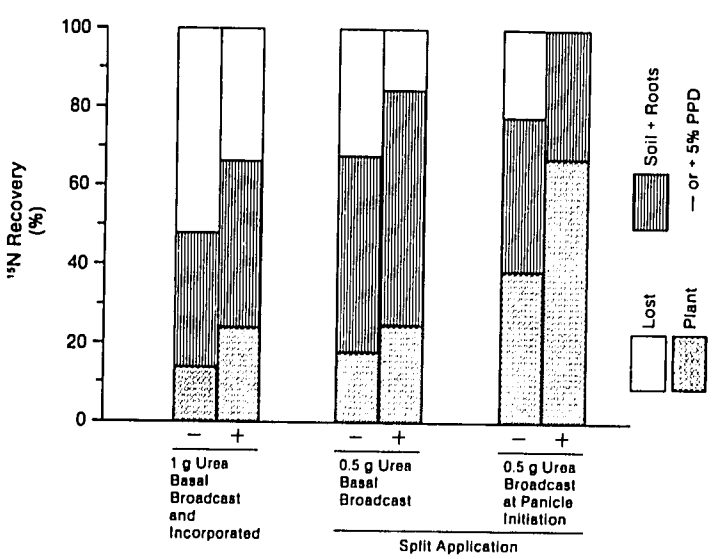


Figure 6. Inhibitory Effect of PPD on Conversion of Urea to Ammonia.

Evaluation of Products and Practices

Evaluation of Urease Inhibitors

During 1981 IFDC expanded studies to evaluate PPD, a compound which inhibits the hydrolysis of urea to ammonia. In both greenhouse and laboratory experiments, PPD added to the floodwater or to the urea fertilizer inhibited the conversion of urea to ammonia. The high aqueous ammonia concentrations that lead to large volatilization losses were decreased. In a greenhouse experiment, PPD increased the uptake by rice of the fertilizer by about 10% for a single basal incorporation while increasing the recovery in the soil by another 10% (Figure 6). The application of PPD with the first split application of urea (broadcast and incorporated) gave similar results to the single basal application. PPD applied with the second split application at the panicle initiation stage increased the plant utilization by 25% and gave 100% retention of the fertilizer in the plant-soil system.

Polymer-Coated Urea Evaluation

In a joint laboratory project initiated in 1978, IFDC and the Korea Advanced

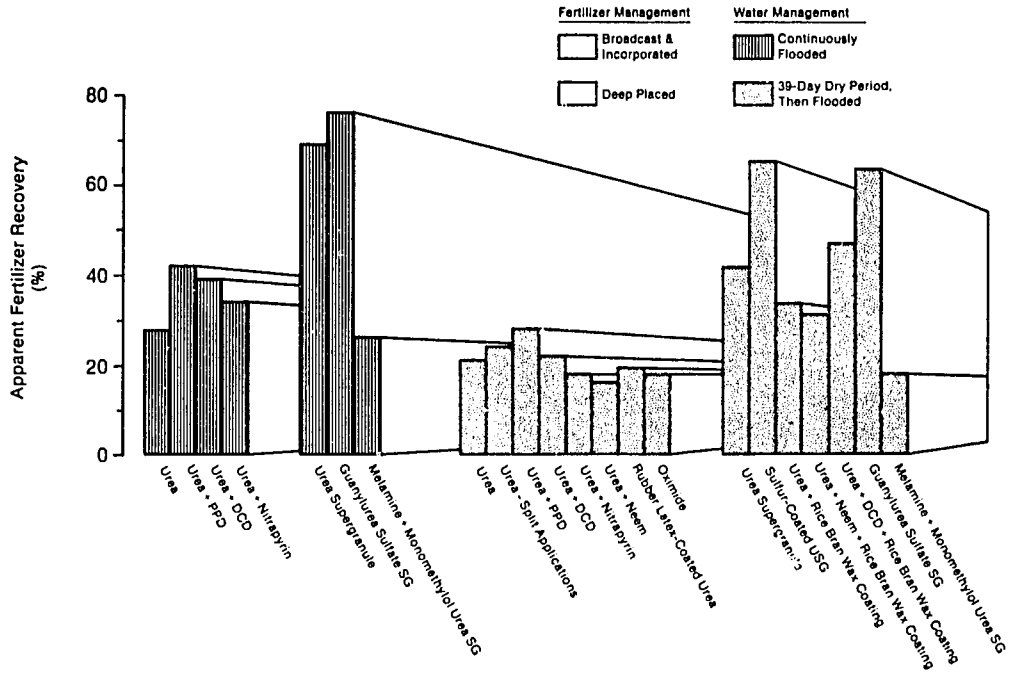


Figure 7. Apparent Fertilizer Recoveries by Rice Under Different Water and Fertilizer Management Treatments.

Institute of Science and Technology (KAIST) developed a promising silica-polymer (sodium silicate with acrylic latex) coating for urea (PCU). KAIST is continuing the coating studies in an attempt to lower the cost and to simplify the coating process.

Subsequent to determining 15-, 25-, and 50-day nitrogen release rates in the laboratory, a field experiment was conducted at IRRI during the 1981 dry season to evaluate the fertilizer efficiency of PCU.

The grain yield of rice tended to increase as the rate of nitrogen applied was increased. At all rates of nitrogen, the PCU 25-day delayed-release treatment produced the highest yield. Averaging the yields for four nitrogen rates showed that coating forestry-grade urea with silica polymer delayed the release of nitrogen and increased the grain yield of transplanted rice.

An IFDC technician checks a nitrogen fertilizer screening experiment for rice in the greenhouse.

Greenhouse Testing

In 1981 IFDC scientists determined the relative uptake of nitrogen by rice from urea-based fertilizers. They compared the effectiveness of coatings, enzyme inhibitors, slowly soluble compounds, and supergranules under simulated flooded and rainfed conditions. The apparent nitrogen recoveries determined in this greenhouse experiment are shown in Figure 7. When the fertilizers were broadcast and incorporated in the soil, urea plus the urease inhibitor PPD proved to be superior. Of the fertilizers that were deep point placed, guanylurea sulfate showed exceptional performance under both water management systems. The sulfur-coated urea supergranule performed best under these simulated rainfed conditions.

Evaluation in Farmers' Fields

India

The joint program for evaluating modified-urea products was continued by IFDC and the Hindustan Fertilizer Corporation of India (HFC). The objective of the program is to make agronomic and economic evaluations of rice yield responses to prilled urea, urea supergranules, and SCU. In seven eastern Indian states, 162 trials have been conducted.

Preliminary results of the agronomic analysis of 94 experiments indicate that in 45% of the experiments response to urea supergranules is greater than response to urea, and in 34% of the experiments response to SCU is greater than response to urea. In approximately 6% of the trials, response to urea was greater than response to urea supergranules or to SCU. At the optimum economic application rates, farmers can expect to obtain 16 kilograms of rice per kilogram of nitrogen as urea or 20 kilograms of rice per kilogram of nitrogen applied as urea supergranules.

Philippines

National Fertilizer Efficiency Program

During 1981 IFDC assisted the Philippine Council for Agriculture and Resources Research (PCARR) with the development of a plan for a National Fertilizer Efficiency Program. IFDC recommended 11 program components arranged in two priority groups to PCARR. They are as follows:

Priority I

(1) Nitrogen efficiency for lowland rice
(2) Nitrogen efficiency for upland crops
(3) Constraints to fertilizer use
(4) Refining fertilizer recommendations
(5) Developing improved varieties
(6) Correcting soil acidity

Priority II

(7) Organic material use
(8) Nitrogen fixation
(9) Fertilizer demand forecasting
(10) Fertilizer subsidy policy
(11) Use of indigenous phosphate rock

Most of these programs could consist of a number of projects. Many require multidisciplinary efforts, designed to provide a correlation of crop response to fertilizer nutrients. These programs are executed on defined site characteristics: soils, climate, varieties, cropping systems and patterns, and production practices.

Sulfur-Coated Urea

In the Philippines 368 farm trials showed that SCU is a more efficient fertilizer than urea.

On the average, farmers can produce the same yield by applying only two-thirds as much SCU as split-broadcast prilled urea. At optimum rates, farmers can expect to obtain 12 kilograms of rice per kilogram of nitrogen applied as urea or 18 kilograms of rice per kilogram of nitrogen applied as SCU.

On the basis of farm-level prices (the price of nitrogen in SCU is assumed to be 50% higher than that in urea), Philippine farmers can expect to receive equal net returns.

Upland Nitrogen Program

At present most of the fertilizer used in the tropics is on irrigated crops and cash crops. The major food crops grown under dryland conditions (for example, sorghum, millet, wheat, and maize) generally receive little or no fertilizer. Among the reasons for this limited fertilizer use is the farmers' uncertainty about the economic benefit of fertilizer use. With the current need for increased food production and the introduction of new fertilizer-responsive crop varieties, a better understanding of the role and requirement of fertilizers in dryland farming is required.

To identify major nitrogen fertilizer problems, IFDC is conducting cooperative research programs in cooperation with ICRISAT in the semiarid tropics of India and with ICARDA in the arid areas of West Asia. A collaborative program with IITA and the Institute for Soil Fertility in the Netherlands (IB) was started in the humid tropics of Africa in 1981.

Identification of Causes and Magnitude of Nitrogen Losses

Only a fraction of the fertilizer nitrogen applied to soil is taken up by crops. Some of it is utilized by microorganisms in the soil and rendered temporarily unavailable to the crop. Also, some of the soil-applied fertilizer nitrogen is converted to nitrogen gases, which are lost to the atmosphere.

Nitrogen Transformations

Priority was given to the study of urea transformations in soil because urea is expected to remain the most important fertilizer source in the developing world for the foreseeable future. Urea applied to soil breaks down to ammonia, which under certain conditions can be lost as a gas to the atmosphere.

Research indicated that the breakdown of urea to ammonia was much faster in wet than in dry soil. The breakdown to ammonia and subsequent gaseous loss of the ammonia occurred immediately after soil was wetted by a light rain; the loss became small or negligible once the soil dried. Thus, application of urea fertilizer on the soil surface before a light rainfall is not recommended. Under such conditions urea should be incorporated in the soil so that the formed ammonia is adsorbed by the soil rather than lost as a gas. Heavy rainfall following urea application on the soil surface can leach the fertilizer into the soil where the formed ammonia is adsorbed and not lost. The findings, once thoroughly evaluated in the field, may be helpful in providing recommendations on the best timing and placement of urea fertilizer to prevent losses.

Fate and Efficiency of Nitrogen Sources

IFDC conducted greenhouse studies to determine the fraction of the applied fertilizer nitrogen utilized by sorghum, an important food crop in the Indian semiarid tropics. A clay soil similar to a major soil type in the Indian semiarid tropics was selected for this experiment. The soil/plant system was subjected to three rainfall regimes that are characteristic of the semiarid region of India.

The uptake of nitrogen fertilizer by sorghum for five different fertilizer treatments is shown in Figure 8. The uptake by sorghum of nitrogen from urea was similar in magnitude to that observed in field experiments at

ICRISAT in India. Sorghum recovery of incorporated and broadcast urea nitrogen was between 47% and 60% in both the field and greenhouse experiments. The fraction of the broadcast urea nitrogen taken up by sorghum was measurably greater than the 20%-40% uptake previously found by IFDC scientists for urea broadcast in flooded rice paddies.

Most of the fertilizer nitrogen not taken up by the sorghum remained in the soil. The total recovery of nitrogen fertilizer is shown in Figure 9. The unrecovered nitrogen was lost in gaseous form. Greatest losses (23.1% and 16.3%) occurred from broadcast urea, presumably by the process of ammonia volatilization. This loss of broadcast urea nitrogen is less than that found by IFDC scientists for urea broadcast in flooded rice fields.

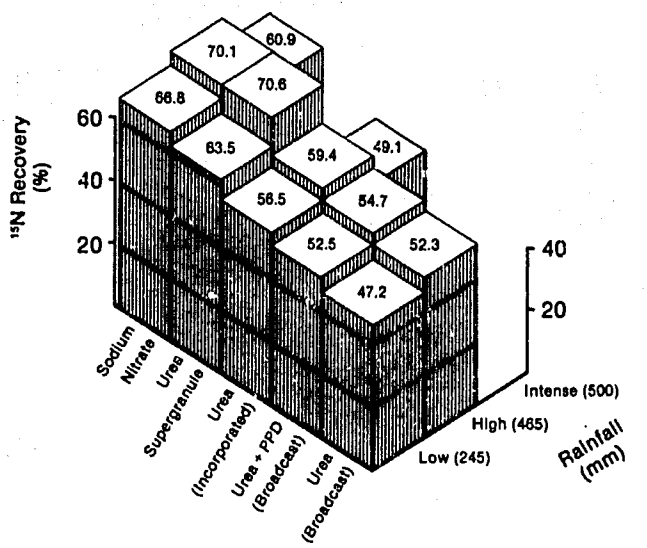


Figure 8. ^{15}N Recovery by Sorghum.

Evaluation of Products and Practices

IFDC scientists use research results on inefficient use of fertilizer nitrogen by crops to develop improved materials and management practices. Those fertilizer sources that appear promising in IFDC greenhouse experiments are then evaluated in the field at ICRISAT and ICARDA.

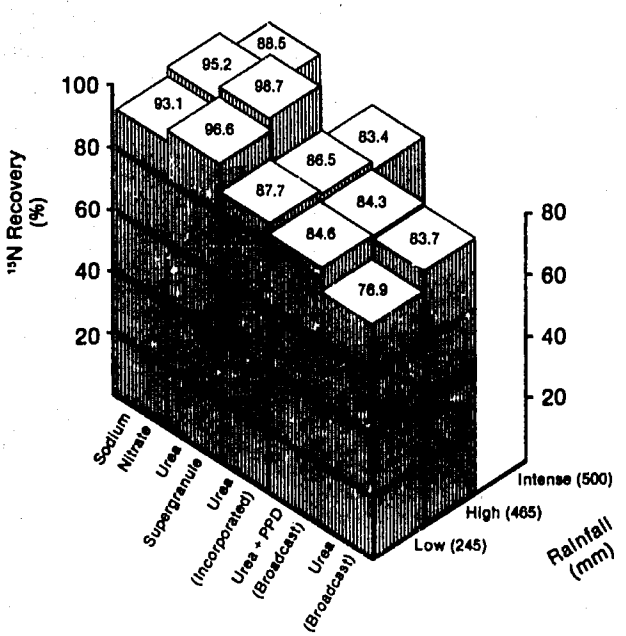


Figure 9. Total ^{15}N Recovery in Sorghum and Soil.

Evaluation at IFDC Headquarters

A greenhouse experiment with sorghum showed that the uptake of nitrogen from urea was markedly greater when urea was applied as large granules below the soil surface than when it was applied as prills either broadcast on the soil surface or incorporated in the top 2 centimeters of soil (Figure 8). Loss of nitrogen from urea was substantially reduced by the application of urea as large granules (supergranules). Less than 4% of the nitrogen from urea supergranules was lost over the growing season (Figure 9).

Additives to urea fertilizer were evaluated for their effectiveness in reducing gaseous loss of urea nitrogen. One additive tested was PPD. Addition

An IFDC soil scientist outposted to ICRISAT (India) describes microplots to ICRISAT personnel prior to planting sorghum.

of 2% PPD to urea granules did not measurably decrease the nitrogen loss from urea (Figure 9) or the uptake of urea nitrogen by sorghum (Figure 8). Although the addition of PPD to granular urea reduced ammonia loss from flooded rice paddies (see section on Evaluation of Urease Inhibitors in Lowland Nitrogen Program), it did not reduce the loss from urea broadcast on the surface of the several dryland soils used in the 1981 experiments.

Evaluation at Other International Centers

An IFDC soil scientist has been conducting fertilizer studies with scientists at ICRISAT in India since May 1980. Field experiments were conducted on a sandy, red soil (an Alfisol) and a black, cracking clay soil (a Vertisol) during the 1981 rainy (summer) season.

The research revealed that nitrogen fertilization dramatically increased yields of sorghum grain on both the red and black soils. Timing and placement of nitrogen fertilization markedly influenced yield. Greatest grain yields on both the black and red soils were

Table 2.
Fate of Urea Fertilizer Applied to Sorghum on a Black, Clay Soil

Mode of Fertilizer Application	Timing of Fertilizer Application	Percentage Fertilizer N Uptake by Sorghum	Percentage Fertilizer N Lost	Grain Yield
				(kg/ha)
Incorporated	Planting	30	25	4,110
Broadcast	Planting	30	28	4,260
Banded adjacent to plant row	2 and 4 weeks after planting	57	6	5,220

An ICARDA soil chemist and an assistant take a soil sample in a collaborative ICARDA/IFDC project on nitrogen fertilizer.

obtained when nitrogen fertilizer was divided into two applications (1 and 3 weeks after emergence of the sorghum) and placed in the soil near the plant row. Yields were lower when all the nitrogen fertilizer was applied at planting (Table 2).

Only a fraction of the applied nitrogen fertilizer was actually taken up by crops on both the red and black soil. Sorghum took up between 30% and 65% of the applied nitrogen fertilizer. The remainder of the applied nitrogen fertilizer was either left in the soil or lost as gases before it could be taken up by the crop.

During 1981, a particularly wet year, approximately one-fourth of the urea fertilizer either broadcast on the soil surface or uniformly incorporated into the soil at planting was lost as volatile gases on the black soil (Table 2). Losses of nitrogen fertilizers on the red soil were less than those on the black soil. They ranged up to 20% of the applied nitrogen fertilizers and, as with the black soil, were greater during the wet year. Losses of urea fertilizer were substantially reduced by placement of urea in the soil adjacent to the plant row. It is imperative that fertilizer sources and application methods be developed to eliminate nitrogen losses since the loss of nitrogen fertilizer results in decreased plant-available nitrogen in the soil and lower subsequent uptake of nitrogen by the crop.

Crop production on the Vertisols in assured rainfall areas can be increased by growing a crop during both the rainy and dry seasons in a year. Research revealed that nitrogen would be a major constraint to such crop production.

IFDC also conducted cooperative research with ICARDA scientists on nitrogen fertilizers in dryland farming in West Asia. Research indicated that uptake of nitrogen fertilizer by cereals (wheat and barley) is increased by more rainfall and available soil water. The experiments during the 1981/82 growing season were extended to additional sites with different rainfall patterns.

Phosphate Research

The phosphate research program continued to focus on developing lower cost and improved phosphate fertilizers for soils and climates of the tropics and subtropics using indigenous resources where appropriate. Major activities conducted during 1981 include (1) modifications of phosphate rock to improve physical quality and/or agronomic performance, (2) the use of various phosphate rocks or concentrates in wet-process phosphoric acid production, (3) evaluation of processes to upgrade phosphate rock by removal of impurities (beneficiation), (4) the use of phosphate rock directly as fertilizer, and (5) use of intermediates and raw materials in the production of finished fertilizers.

This year there was less emphasis on specialty phosphates such as Rhenania-type, fused calcium/magnesium, and calcined phosphates primarily because of the high energy requirement for their production.

A number of experimental products were made for the Latin American IFDC/International Center of Tropical Agriculture (CIAT) project and for projects in Africa. An in-depth project was completed for Colombia to evaluate two phosphate ores in various chemical processes.

Fertilizers From Indigenous Phosphate Ores

Partially Acidulated Phosphate Rock

Partial Acidulation With Sulfuric Acid

IFDC continued efforts to reduce costs, simplify processes, and efficiently use phosphate rocks from developing countries. Many rocks are relatively unreactive, which means that relative agronomic performance is low when compared with superphosphate for initial crop response.

Partially acidulated rock using less sulfuric acid than is normally used for SSP received considerable attention. IFDC was particularly interested in a continuous single-step process for partial acidulation and granulation in a pan granulator. A relatively unreactive rock from Kodjari, Upper Volta, was studied. In this continuous process, IFDC researchers used the water required for granulation to improve acidulation. Water was sprayed near the feed inlet, and the sulfuric acid was sprayed onto the wet materials (Figure 10). In these laboratory-scale trials with Kodjari rock, the researchers attained 92% of the calculated water-soluble P_2O_5. When this same rock was used for conventional SSP, it gave only a 51% efficiency, which did not improve with curing. (Efficiency is defined as the ratio of measured water-soluble P_2O_5 to the calculated water-soluble P_2O_5, based on the acid:rock ratio.)

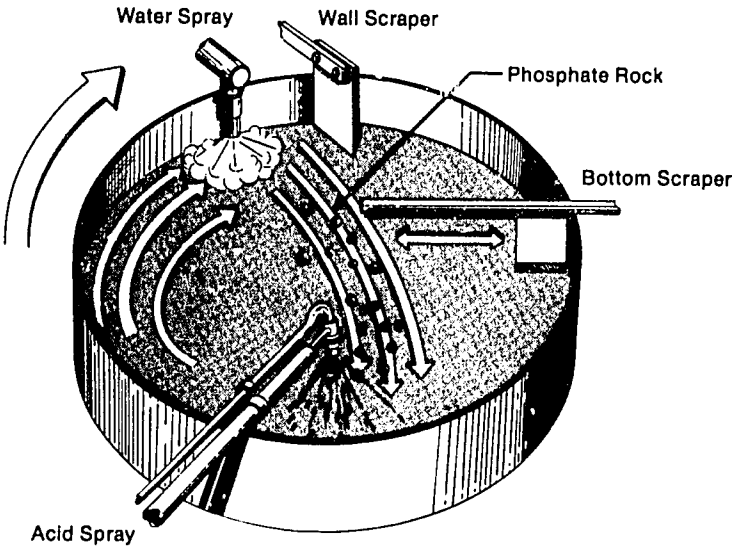


Figure 10. Pan Granulator for Single-Step Sulfuric Acid Partial Acidulation.

Partial Acidulation With Nitric Acid and A Nitric/Sulfuric Acid Mixture

In 1981 IFDC researchers studied the use of nitric acid and a mixture of nitric and sulfuric acids for the partial acidulation of Kodjari and central Florida phosphate rocks. Both batch and single-step acidulation and granulation processes were used. When nitric acid was used alone, its concentrations were 60% and 70%. An equal molar mixture of nitric and sulfuric acids was also used. Acidulation of 100% indicates the quantity of acid required to convert the calcium to calcium nitrate or calcium sulfate.

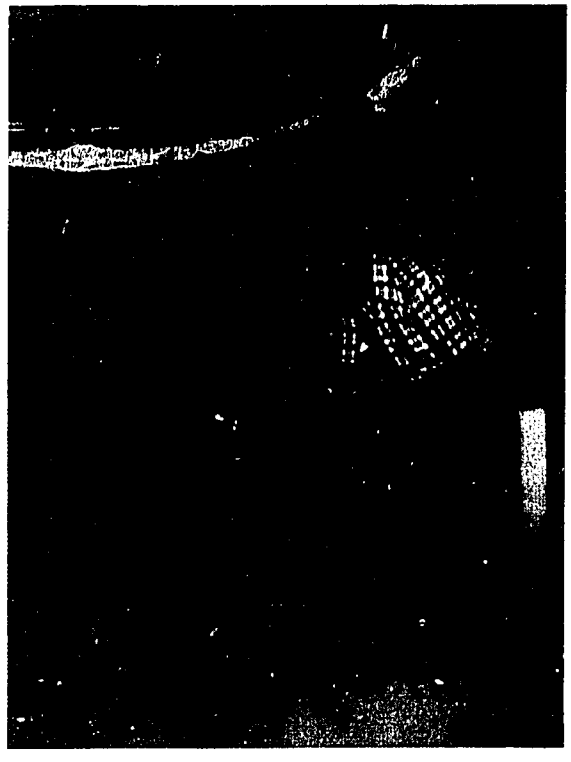
For all acids and both rocks the fluid time or the time required for the mixture to reach a homogeneous state decreased as the acidulation level increased. Central Florida rock foamed badly, whereas Kodjari rock did not. Dilution of the acid decreased the fluid time. The set time or the elapsed time after mixing when the mixture begins to solidify increased rapidly at high acidulation levels for both rocks. Set times for Kodjari were higher than those for central Florida rock. With central Florida rock a grade of 10-18-0 was typical; with Kodjari rock the grade was 10-15-0. At a low acidulation level (10%-30%), the rock was generally unchanged in physical appearance. At a high level (70%-100%) the reaction product was very hygroscopic and difficult to handle. At 40%-60% acidulation the product appeared to be suitable as a feed for granulation.

Kodjari rock was processed using a mixture of nitric and sulfuric acids in the single-step partial acidulation and granulation process. It had been shown that when sulfuric acid alone is used at high levels with unreactive rocks, the extra water required is more than that needed for granulation. Such products have a high free acidity and lower-than-calculated values of water-soluble P_2O_5.

Efficient acidulation is limited to about 40%. With a sulfuric to nitric acid mole ratio of 1.0, the water-soluble P_2O_5 obtained was higher than the calculated value. Nitric acid could substitute for water and be beneficial at high acidulation levels. Ammoniation of the product will add extra nitrogen and improve moisture resistance but will decrease P_2O_5 availability.

Minigranulated Phosphate Rock and Improved Handling

For improved handling of finely ground phosphate rock for direct application, a method was needed to produce granules of a small particle size range. It was also necessary that the granules disintegrate to the original finely ground form when applied to the soil.



An IFDC chemical laboratory analyst prepares the constant temperature/humidity room for determination of moisture penetration and absorption of fertilizer samples.

Relatively small, spherical granules can be produced in an experimental pinmixer granulator. Cohesive strength is provided through the use of a binder. When finely ground rock was used, a single pass through the machine and dryer gave 60% by weight of the granulator discharge as onsize product. Because of the small particle size, screens require frequent cleaning. Thus, air classification may be a better alternative.

Comparisons of physical properties such as bulk density, disintegration rate, and dustiness were made on mini-granules and finely ground rock.

Cogranulated Phosphate Rock and TSP

Another alternative for reducing the quantity of acid required for superphosphate production is to add finely ground phosphate rock. A combination of water-soluble and water-insoluble P_2O_5 from these materials may have an agronomic advantage on certain soils. Thus, IFDC needed a standardized procedure for preparation of experimental materials that would give predicted values of P_2O_5 solubility. Conditions affecting granulation and physical and chemical analyses of cogranulated phosphate rock, TSP, and extended phosphate were studied. In previous work, it had been found that the final water-soluble P_2O_5 content of cogranulated rock and TSP after drying was 20%-40% lower than that of the initial mixture.

Different materials containing water-soluble P_2O_5 (TSP, SSP, etc.) were cogranulated with different proportions of a locally available central Florida phosphate rock, and the effect of drying on the solubility of P_2O_5 in the products was studied.

Wet-Process Phosphoric Acid Production

Phosphate rock is digested in sulfuric acid to produce phosphoric acid. Periodically IFDC engineers operate the bench-scale wet-process phosphoric acid unit using commercially available phosphate rocks to obtain baseline data. They then make comparative tests for characterization of unknown rocks.

To determine whether IFDC's laboratory-scale unit adequately models an industrial plant, five tests using central Florida concentrate and two tests using Khouribga, Morocco rock were conducted.

In one test central Florida concentrate, the feed material, contained 33.5% P_2O_5, while in the remaining tests with central Florida rock the concentrate contained 31.5% P_2O_5. The Morocco rock contained 33.0% P_2O_5.

Typical values for wet-process acid were obtained. Gypsum from all tests with central Florida rock was in the form of agglomerates of crystals of varying sizes. The filtration rates increased as the size of the agglomerates increased. Gypsum from Morocco rock was in the form of single rhombic plates of varying sizes.

Recoveries obtained from the central Florida and Morocco rocks were consistent, ranging between 97% and 98% of the P_2O_5 in the central Florida rock and 96% of the P_2O_5 in the Morocco rock. Reaction efficiencies were between 98.5% and 99.0% for central Florida rock and 97.2% for the Morocco rock. There was no significant effect on efficiencies at the retention times studied.

In comparison with industrial data, these baseline tests demonstrated that IFDC's laboratory-scale wet-process phosphoric acid unit is an adequate model of an industrial plant.

Soil and Phosphate Reaction Studies

IFDC continued to evaluate factors affecting reactions between phosphatic fertilizers and soils and means of improving fertilizer efficiency in soil. The purpose was to gather data that can be correlated with greenhouse and field data to predict agronomic results from various fertilizer types and the behavior of these fertilizers in selected soil and cropping conditions.

Recent tests on calcareous soils at IFDC indicated that a small amount of pyrophosphate (2%-8%) has an inhibitory effect, which temporarily reduces phosphate sorption and ammonia volatilization from ammonium phosphates.

Preliminary results with calcium carbonate and two calcareous soils from Egypt suggest that pyrophosphate acts as a nucleation and/or crystal growth inhibitor for dicalcium phosphate

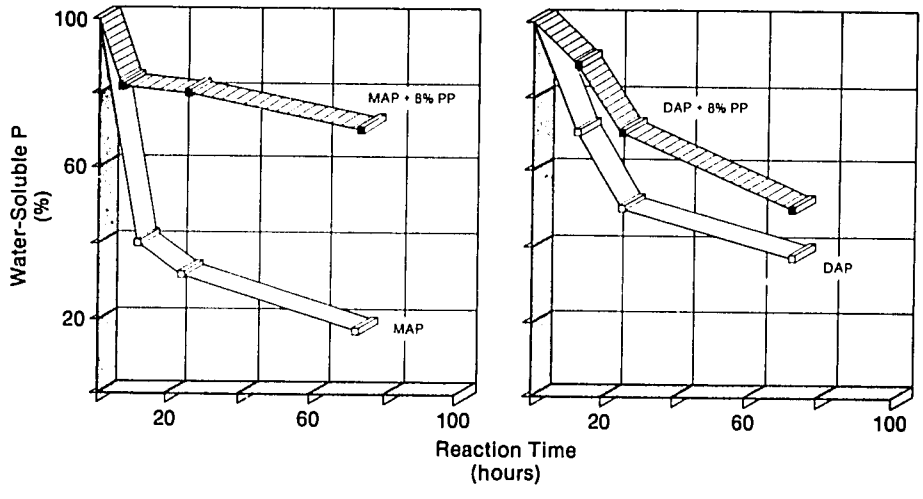


Figure 11.
Effect of Pyrophosphate (PP) Addition to MAP and DAP on Water-Soluble Phosphate Recovered From a West Nubaria Soil (Egypt).

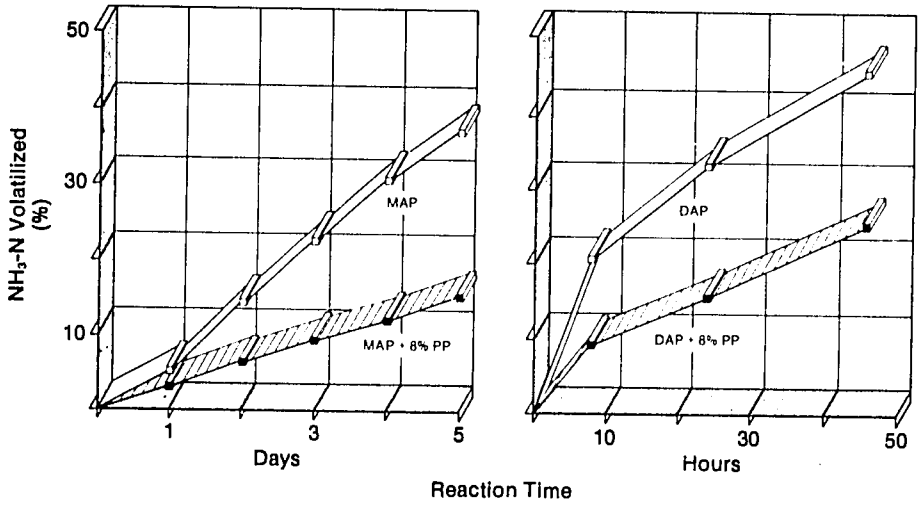


Figure 12.
Effect of Pyrophosphate (PP) Addition to MAP and DAP on NH_3 Volatilization From a West Nubaria Soil (Egypt).

dihydrate (DCPD). A higher phosphate concentration in soil solution extracts was maintained (Figure 11). Because pyrophosphate inhibits the formation of DCPD, the pH of the soil was lowered by its addition. This reduced ammonia volatilization (Figure 12). Further agronomic work is needed to determine if this inhibitory effect is translated into crop response in calcareous soils.

Granulation Laboratory Improvements

During 1981 IFDC installed a granulation laboratory (Figure 13). It has greatly facilitated preparation of experimental materials and is useful for research and training. Its capacity is 15-20 kilograms per hour for granulation of powders and 4-6 kilograms per hour for granulation of slurries. Various types of granulators (pan, rotary drum, and pin-mixer) can be used for particular processes. The operation can be batch or continuous. Products that can be made include (1) ammonium phosphates (MAP/DAP), (2) granulated phosphate rock, (3) partially acidulated and granulated phosphate rock, (4) NPK using various raw materials, (5) single and triple superphosphates, and (6) urea-based NPK.

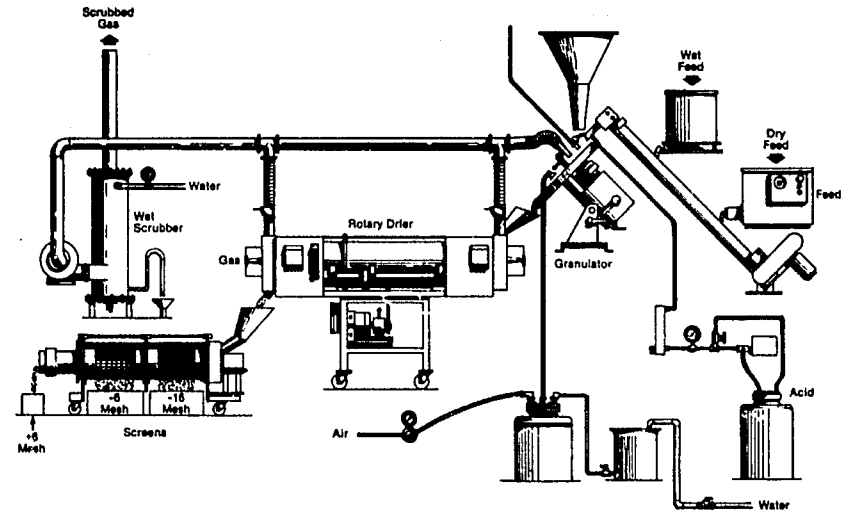


Figure 13. Improved Granulation Laboratory.

Using a laboratory-scale pinmixer, an IFDC chemical engineer prepares experimental products for field testing.

Pilot-Plant Studies

Two granulation pilot plants were operated for various types of processes and raw materials. The largest pilot plant has a nominal capacity of 1 metric ton per hour although it can be satisfactorily operated at reduced rates. It is equipped with pan, rotary-drum, and pug-mill granulators. It can use a wide variety of raw materials. Several methods for dust recovery, screening, and automation can be demonstrated.

A smaller, intermediate-scale granulation pilot plant with a capacity up to 200 kilograms per hour employs a pan or pinmixer granulator. It is used for special processes and preparation of experimental materials. Recent tests were carried out on granular ammonium phosphates and TSP.

Granular Ammonium Phosphates

Some developing countries are considering the use of indigenous phosphate

ores for production of wet-process phosphoric acid and conversion to ammonium phosphates.

During 1981 IFDC carried out pilot plant-scale tests of MAP and DAP production using the conventional preneutralizer process. Future tests will usually compare the performance of phosphoric acid from indigenous phosphate ores with that of a known commercial acid. The main objectives of the test runs performed were to determine the mechanical and process performance of the plant, to establish the similarity between the pilot-plant runs and commercial operation, and to gather baseline data with a known phosphoric acid (central Florida). No significant difficulties were encountered with the process or equipment.

Granular Triple Superphosphate

In a recent study involving phosphate ore from Latin America, IFDC engineers adapted the pilot plant for producing granular triple superphosphate (GTSP) by the direct slurry process. No significant process or equipment problems were encountered. The total P_2O_5 content of the GTSP product was about 45.5%, of which about 80% was water soluble and about 93% was available (sum of water- and neutral ammonium citrate-soluble P_2O_5 as a percentage of total P_2O_5). The free acidity of the GTSP product ranged from 5.5% to 5.8%, expressed as P_2O_5.

The product was subjected to a number of physical property tests. Small-bag (moistureproof) storage tests indicated that there was no caking after 3 months. The crushing strength averaged 4.8 kilograms per granule; a crushing strength of 2.3 kilograms per granule is considered satisfactory.

Beneficiation of Phosphate Ores

Another pilot-plant capability at IFDC is flotation-type beneficiation. This unit having a capacity of 100 kilograms per hour of feed was constructed to develop data on processes for improving the phosphate grade and chemical quality of ores that exist in developing countries. During three previous test programs on a siliceous ore and two dolomitic ores using this unit, it became apparent that some plant modifications were necessary to facilitate its use. The modifications that were carried out made the plant more flexible and adaptable to complex flotation processes and improved the mechanical reliability of the various system components.

IFDC/CIAT Collaboration

Preparation of Experimental Materials

Preparation of experimental phosphate materials is an integral part of the overall IFDC/CIAT project, which was initiated with a grant from IDRC in 1977. Phosphate raw materials come from various deposits in Latin America that are currently not utilized or are underutilized. The technology of production emphasizes low investment, less raw material consumption, and simplicity compared with the production of conventional products. In addition, the fertilizer products would be produced only for domestic consumption rather than for export. Since the project is regional, the characteristics of the phosphate ores available for evaluation vary widely in reactivity and level of impurities. The P_2O_5 content also varies widely, depending on impurities.

In 1981 experimental products were made from three Colombian ores (Pesca, Huila, and Sardinata), one Peruvian ore (Fosbayovar), and two Venezuelan ores (Lobatera and Riecito). For comparison of agronomic performance, central Florida (medium reactivity) and uncalcined North Carolina (high reactivity) ores were also used in materials preparation. Product types were (1) finely ground, (2) minigranular, and (3) granular. Partial acidulation was with sulfuric acid at 20%-50% of the acid required to make superphosphate. Cogranulated products were made by mixing and granulating finely ground rock with TSP (extended phosphate).

Direct Application and/or Modified Phosphate Rock

The IFDC/CIAT Phosphorus Project using Latin American phosphate rocks continued with research on the agronomic effectiveness of phosphate rock sources and modified products based on these rocks.

Investigations were aimed at obtaining a better understanding of how and where indigenous phosphate rock sources can be used to increase crop production in the acid, infertile soils of Latin America.

IFDC researchers sought the answers to many questions. They included: (1) How is the efficiency of finely ground phosphate rock, partially acidulated phosphate rock (PAPR), and extended superphosphate (ESP) influenced by a range of soil properties? (2) Does finely ground, low-solubility phosphate rock have a greater residual value of phosphorus than high-solubility phosphate fertilizers such as TSP? (3) How is phosphate rock effectiveness influenced by interactions with other fertilizers, lime, and crop type? (4) How does the use of phosphate rock fit into traditional fallow systems used by small farmers? and (5) How do farmers make their decisions regarding soil fertility management and fertilizer selection?

The chemical solubility or reactivity of the apatite in phosphate rock greatly influences its agronomic effectiveness. Phosphate rock reactivity classifications are high, medium, or low when the neutral ammonium citrate extractable phosphorus is >17%, 12%-17%, or <12% of the total P_2O_5, respectively. Rocks that are in the high or medium reactivity class are generally of sedimentary origin. Igneous rocks predominate in the low reactivity class.

Differences in agronomic effectiveness of ground phosphate rock due to chemical solubility tend to diminish with the number of cropping cycles.

Soil and crop properties are critical in determining the situations in which finely ground phosphate rocks or other products may be used most effectively. For example, on both acid Oxisols and Ultisols in Colombia and Peru, the direct application of ground phosphate rock often approaches the effectiveness of TSP on cowpeas, cassava, pastures, and rice. Figure 14 shows the rice production achieved on an Oxisol of the "Llanos" of Colombia under the influence of different phosphate sources with and without potassium, magnesium, sulfur, boron and zinc. The data illustrate that Huila phosphate rock from Colombia was as effective as TSP. Modifications of phosphate rock, such as partial acidulation or cogranulation or

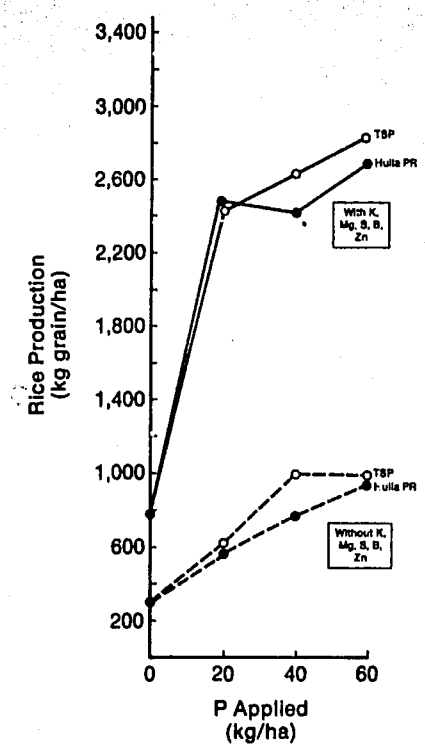


Figure 14. Response to P by Upland Rice Variety in the Presence or Absence of Support Nutrients.

TSP production, do not appear to be warranted under this type of cropping system.

Data from experiments on volcanic soils (Andepts) in Colombia and Ecuador show a positive response from the direct application of phosphate rock to beans and potatoes. However, response is much lower than that observed in Oxisols and Ultisols. Bean production was observed to significantly increase as the amount of water-soluble phosphate applied in the form of TSP in a mixture with phosphate rock increased. In two separate experiments with potatoes, PAPR was found to be essentially equal to TSP. Finely ground phosphate rock gave significantly poorer results. It is under these conditions that modifications of the indigenous phosphate rocks appear to be most important.

Experiments to evaluate phosphate availability show that the residual value of finely ground phosphate rock extends to a maximum of 6 years of crop production following application. Plant response from residual phosphate depends on factors such as the rate of phosphate extraction by the crop, the soil's phosphate retention capacity, and the rate of product application. There does not appear to be any significant difference in the residual value of different sources of phosphate.

Observations have shown that initial crop response is highest with highly soluble fertilizers. With time, however, low-solubility products become as effective as the soluble fertilizers.

Socioeconomic Research

IFDC/CIAT field research investigated the socioeconomic and agronomic factors that are important to the farmer in making his selection of fertilizer type. A multidisciplinary approach is being used for the agro-socioeconomic evaluation of phosphate rock under on-farm conditions.

When low-cost finely ground phosphate rock fertilizers were readily available, small-farm operators were more likely to adopt and use them at higher rates than were larger farm operators. The latter use a fallow system to rejuvenate the fertility of their soil rather than purchase fertilizer. Small-farm operators experimented with mixtures of low-cost fertilizers in preference to using complete fertilizers, thereby confirming phosphate rock's potential as a low-cost alternative.

In a practical trial of the broadcast and incorporation method, farmers found the handling properties of the powdered phosphate rock acceptable when it was mixed with soil before application. Farmers perceived a risk of costly overapplication with broadcast and incorporation when compared with traditional localized placement.

Availability of cash at planting time and traditional minimum tillage practices can also affect farmer acceptance of the broadcast and incorporation method. Stability of land tenure affects farmer evaluation of phosphate rock's residual effects. Cultivators with short-term land tenure evaluate yields on the basis of one season since the subsequent cultivator captures residual effects. Research findings also stress the importance of evaluating the absolute cash cost of recommendations in relation to the small farmers' seasonal cash flow, yields, and profitability. In addition, the farmer will more readily accept the broadcast method if he understands its effect on yields and if he learns a simple method of calculating field areas and rates of application.

Special Phosphate Projects

Use of Phosphate Rock in Upper Volta for Fertilizer Production, Phase II

On the basis of greenhouse testing, two products were selected for field trials in Upper Volta: PAPR using sulfuric acid and phosphate rock mixed with sulfur.

In 1981 IFDC supplied the PAPR, and the Upper Voltans prepared the rock-sulfur mixture. For the next 2 years, the

Upper Voltans and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) will study the effectiveness of these two materials. Depending on these results, more technical and economic studies may be made, including considerations involving commercial production.

Togo Phosphate Rock Characterization Studies

At the request and sponsorship of the World Bank, IFDC completed a chemical/physical characterization of 335 phosphate rock samples. IFDC tested six flotation procedures for upgrading the ore. At present, high-grade phosphate is being mined by Office Togolais des Phosphates (OTP) at Kpogame and Hahotoe in a bed designated as Bed 1. The purpose of this study was to evaluate the ore characteristics of underlying beds designated as Bed 2 and Bed 3. It determined whether additional phosphate could be recovered and the type of processing that would be needed to prepare a marketable concentrate.

Evaluation of Phosphate Ores in Colombia

Empresa Colombiana de Minas (ECOMINAS), an agency of the Government of Colombia, engaged Singmaster & Breyer, Inc., to determine the feasibility of commercial exploitation of Colombia's Pesca and Sardinata phosphate ores. IFDC performed the studies relating to fertilizer production for Singmaster & Breyer, Inc., during the period July 1980-September 1981. The objective was to determine the technical feasibility of using Pesca and Sardinata phosphate ores for production of wet-process phosphoric acid and several superphosphate-based solid fertilizers. Tests were carried out in laboratory- and pilot plant-scale equipment.

Three types of Pesca ore, two types of Sardinata ore, and a special blend of two materials were used. Central Florida phosphate concentrate was employed for comparative baseline data. Pesca ore contains about 18%-22% P_2O_5, and Sardinata ore contains 33%-35% P_2O_5. Silica is the main impurity in Pesca run-of-mine ore.

Five types of operations were conducted: (1) wet-process phosphoric acid production in laboratory scale, (2) wet-process phosphoric acid production in pilot-plant scale, (3) superphosphate production in laboratory scale, (4) granulation and ammoniation of superphosphates in laboratory scale, and (5) production of GTSP in pilot-plant scale without ammoniation.

No chemical, mechanical, or equipment problems were identified that would preclude using these ores for fertilizer production. The data obtained on the particular characteristics of these ores should be used in plant design.

Sulfur Research

The Sulfur Research Program focused on the development and evaluation of modified phosphorus-sulfur and nitrogen-sulfur fertilizers for farmers in the tropics and subtropics and on the development of analytical methods and diagnostic criteria for sulfur deficiency in soils and plants.

Many soils in the tropics are deficient in phosphorus, nitrogen, and sulfur. Increases in the incidence of sulfur deficiency can be attributed partly to the increased use of high-analysis phosphorus and nitrogen fertilizers that contain little or no sulfur.

Sulfur requirements for most crops are quite small, i.e., 10-30 kilograms of sulfur per hectare. Such amounts could be incorporated in presently available high-analysis fertilizers without substantially reducing nitrogen and phosphate in these fertilizers.

It is possible that a country could provide its sulfur fertilizer requirements through partial acidulation of its indigenous phosphate rock with sulfuric acid. Although the phosphate-supplying capacity of PAPR has been extensively studied, there is no information presently available on its agronomic efficiency under multiple phosphorus- and sulfur-deficiency conditions.

Modified Phosphorus-Sulfur Fertilizers

During 1981 IFDC conducted greenhouse experiments to assess the effect of incorporating gypsum in high-analysis phosphate and sulfur fertilizers. The experiments were conducted on two plantings of maize grown 5 weeks apart on sandy loam soil. This soil was deficient in phosphorus and sulfur. Phosphogypsum, a byproduct of the wet-process phosphoric acid fertilizer industry, was used as the sulfur source.

The phosphate- and sulfur-modified products studied were TSP granulated with gypsum, DAP granulated with gypsum, and PAPR.

In both harvests, SSP and all the gypsum-amended materials ranked significantly better than TSP and the PAPR in terms of dry-matter production (Figure 15) and sulfur uptake.

Modified Nitrogen-Sulfur Fertilizers

Trials were conducted on rice with several modified nitrogen-sulfur materials. The fertilizers investigated were gypsum-coated urea; gypsum-urea, cogranulated; powdered urea and elemental sulfur; and urea-elemental sulfur granules (tablets) prepared by TVA. The test materials were applied by banding at 8-centimeter depth and broadcasting (left on the surface or soil incorporated); the soil had been precropped to maize to deplete available sulfur.

The highest dry-matter production and sulfur uptake were with gypsum-coated urea and the lowest with urea-elemental sulfur granules (Figure 16). The effect was particularly evident with banded materials.

From these experiments it appears that modified gypsum-containing nitrogen and phosphate sources may provide plants with the needed sulfur at a lower cost than the conventional nitrogen and phosphate sources.

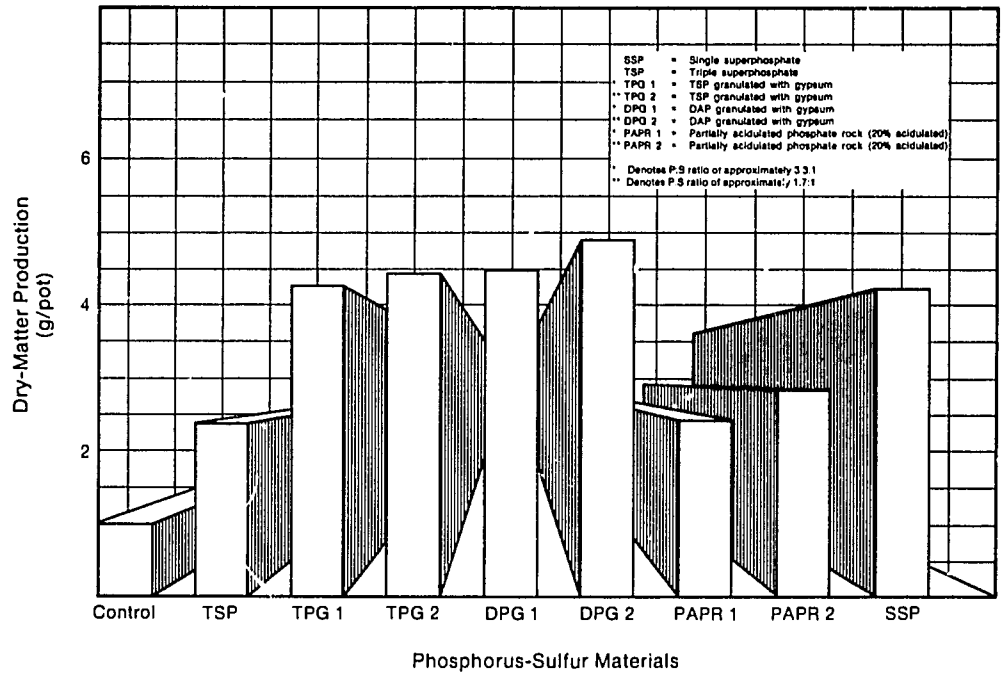
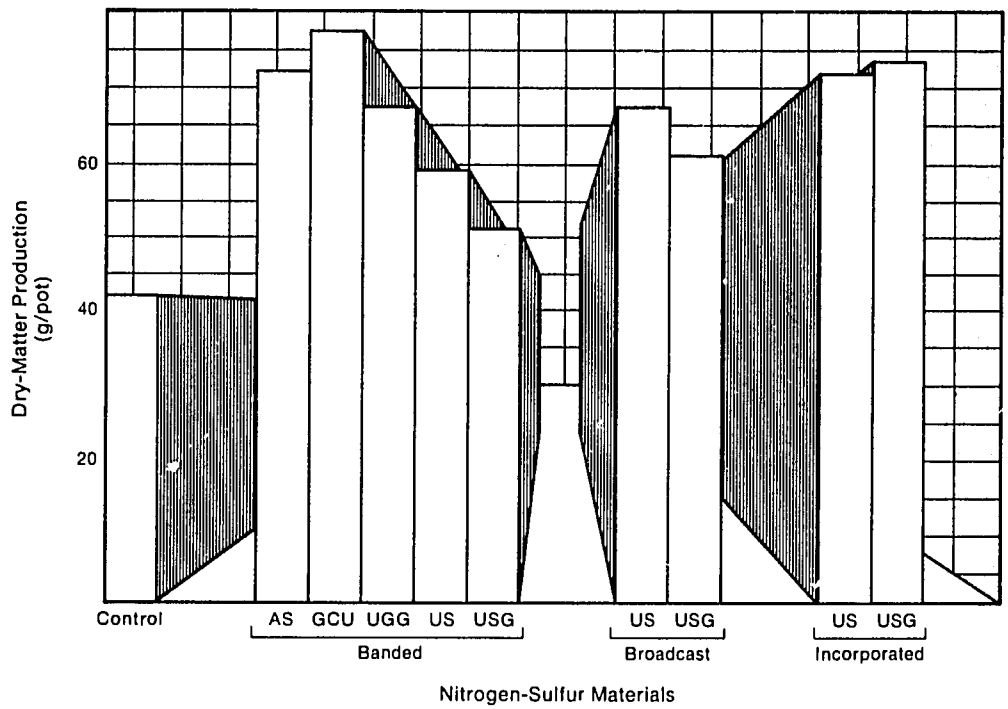


Figure 15. The Effect of Various Phosphorus-Sulfur Fertilizers on Dry-Matter Production of Maize.



AS = Ammonium sulfate GCU = Gypsum-coated urea UGG = Gypsum-urea, cogranulated
US = Powdered urea and elemental S USG = Urea-elemental S granules

Figure 16. The Effect of Various Nitrogen-Sulfur Fertilizers and Their Placement on Total Dry-Matter Production of Rice.

Collaborative Sulfur Analytical-Methods Project

In a greenhouse of the Royal Tropical Institute (KIT) in Amsterdam, preliminary trials with sulfur-deficient soils from northern Nigeria were conducted in a joint IFDC-KIT project. Phosphate-extractable sulfate levels in soil did not correlate well with plant sulfur levels, dry-matter production, or sulfur plant uptake. It appears that soil sulfur tests, especially phosphate-extractable sulfate, may not be a good indicator of the sulfur status in soil.

Progress has been made in developing manual turbidimetric methods for soil and plant analyses. Methods to prevent various interfering factors, particularly soil organic matter and plant oxalate levels, have been developed.

Potassium, Calcium, and Magnesium Research

IFDC, in cooperation with the Potash and Phosphate Institute, completed one portion of a study to determine the need for potassium, calcium, and magnesium on the new lands in Africa, South America, Central America, Indonesia, and Malaysia. IFDC is in the process of determining its role in research and development programs on potassium, calcium, and magnesium and the resources that would be required to conduct such programs.

Research data from 15 countries were collected and analyzed. Information gathered by this study will contribute to recommendations for new multinutrient fertilizers to be developed by IFDC.

Economics Research

IFDC develops improved fertilizer technologies suitable for developing countries in the tropics and subtropics so that these countries will be better able to meet their food and agricultural requirements at the lowest possible costs. The acceptance of the new fertilizer technologies, however, is influenced by many other factors including physical resources, socioeconomic environment, and public policies.

The IFDC economics program is designed to generate the information necessary for economic analysis and decisionmaking. Not only is such information necessary for the transfer of improved fertilizer production, distribution and use technologies but also for the formulation of fertilizer-related public policies.

Agricultural Production, Fertilizer Use, and Equity Considerations

At the request of USAID/Bangladesh and BADC, IFDC, in cooperation with BARC, investigated the equity effects of fertilizer use in Bangladesh. Since then, the study has been extended to 1,800 farms in 16 locations.

The overall objectives of the study were to determine (1) the benefits of fertilizer use to farmers in Bangladesh, (2) the degree to which these benefits are shared by different classes of farmers, (3) the extent to which fertilizer helps create employment in agriculture, (4) the extent to which various factors (constraints) influence fertilizer use and crop production, and (5) the implications of the findings for policies of the Government of Bangladesh for promoting efficient fertilizer use and increasing food production.

The results of the expanded study corroborate the findings of the 1980 report that (1) farmers who own smaller farms (compared with those who own larger farms) use more fertilizer per unit of cropped area, and they obtain higher crop yields, (2) the benefits of fertilizer use are fairly well distributed among different farm classes, and (3) the use of fertilizer increases farm employment.

Net benefits from fertilizer use were higher for winter-planted paddy compared with other crops. In general, benefits were the highest for transplanted paddy using high-yielding varieties. The weighted average financial net benefit per acre per season due to fertilizer use only was approximately US $5.40.

Irrigation augmented the net benefits of fertilizer use to a considerable degree. There is considerable potential to increase the benefits of fertilizer use through the expansion in area under irrigation and high-yielding varieties (HYVs). However, weather conditions contribute significantly to net benefits of fertilizer use.

Smaller farms (low-income farmers) obtain higher net benefits of fertilizer use per acre of cropped land and receive a proportionately larger share of incremental income than do the farmers who own larger farms. However, because of larger cropped areas per farm, the total net benefits of fertilizer use obtained by large farms are higher than those obtained by smaller farms.

The income distribution effects of fertilizer use depend on the areas cropped by each farmer. The higher net benefits per acre of cropped land obtained by farmers who own and crop smaller areas only partially offset the higher net benefits obtained by farmers who own and crop larger areas. Thus, fertilizer use increases income of all farmers but does not improve the distribution of income among farmers. It does increase in a greater proportion the income of farmers who own small farms, but farmers who own larger farms receive a greater absolute income.

In addition to the direct benefits, fertilizer use has important indirect benefits in the form of increased employment and input use. In fact, fertilizer use was the most important single variable factor influencing farm employment per acre of cropped land.

The results also indicate that irrigation, HYVs, availability of family labor, credit, and farmer education have an important positive influence on the

amount of fertilizer used per acre of cropped land. On the other hand, higher fertilizer prices, unfavorable fertilizer/crop price ratios, sharecropping of land, and poor drainage of land have negative effects on fertilizer use. Low levels of irrigation, lack of use of suitable HYVs, and large areas of poorly drained cropped land appear to be the three major constraints to fertilizer use and crop production in Bangladesh. Sharecropping as a constraint is considerably less important than these other factors.

Aspects of this study that relate to credit indicate that (1) only a small number of farmers use institutional credit, (2) there is considerable variation in the use of agricultural credit across districts and across seasons, (3) farmers who own larger farms use more credit than farmers who own smaller farms, and (4) the use of credit does influence fertilizer demand even though only to a small extent.

General Policy Studies

The major focus of the general fertilizer policy studies was Latin America. The objectives were to evaluate the intraregional performance and outlook of the fertilizer sector and to determine the role of government in accelerating the contribution of fertilizer to economic development in 22 Latin American countries. The preliminary findings are discussed below.

1. Despite the large potential for land development, the role of fertilizer in agricultural development will continue to expand. This is because of the fact that development of new land is not only very expensive but is a long-term process. In the short run, however, the use of land under cultivation must be intensified. This can be achieved through multiple cropping and the use of modern technology.
2. Brazil is the region's leader in phosphate fertilizer production (79%) and consumption (67%). Mexico is foremost in nitrogen fertilizer production (43%) and consumption (31%). The aggregate nutrient consumption in Latin America is projected to increase from 6.6 million metric tons during 1979/80 to 9.1 million metric tons during 1984/85. Several countries are vigorously pursuing policies to expand domestic fertilizer production capacity. This may be a desirable policy especially for those countries that have a comparative economic advantage and possess needed fertilizer raw materials.
3. Despite the fact that one-half of the fertilizer consumed during 1979/80 was imported, the domestic fertilizer industry is protected through tariffs and/or import quotas. In the long run, such trade intervention policies are not preferred since they result in a higher fertilizer price to the farmer, possible reduction in growth in fertilizer use, and hence loss in potential agricultural output.
4. The fertilizer marketing system appears to serve mainly the large farmers. Furthermore, most Latin American countries face serious technical and economic inefficiencies in the marketing system. A need exists to remove these inefficiencies and to encourage competition at the retail level.
5. The average fertilizer use for Latin America during 1979, estimated at 42 kilograms per hectare, was much lower than the recommended dosages. Well-targeted agricultural research, extension, fertilizer supply, credit, and incentive policies are needed to accelerate fertilizer use. Furthermore, an abrupt shift in a particular fertilizer policy should be avoided since it creates serious farm-level adjustment problems.
6. The share of government budget allocated to agricultural research, extension, and irrigation is much less than the corresponding contribution of agriculture to gross domestic product. There is a need to allocate more resources to the development and transfer of fertilizer and crop technology.
7. The process of fertilizer policy formulation and implementation can be improved through the establishment of an institutional framework consisting of (a) a National Fertilizer Policy Committee, (b) a Fertilizer Evaluation and Monitoring Unit, and (c) fertilizer legislation.

Crop-Specific Rice Policy Studies

The project on rice policies in Southeast Asia is a continuation of the project initiated during 1979 in collaboration with the International Food Policy Research Institute (IFPRI) and IRRI. The main objective of the project is to evaluate policy alternatives for expanding national rice production and maintaining rice price stability. Fertilizer is a critical input in expanding rice production.

Two components of the fertilizer policy project that are being studied as part of phase II include (1) rice response to fertilizer use and public policy and (2) fertilizer marketing efficiency and public policy. The Australian Development Assistance Bureau (ADAB) approved funding for the Indonesian part of the rice policy project on a bilateral basis. The project dealing with rice response to fertilizer use and public policy was initiated in Thailand in collaboration with Kasetsart University. The data collection phase for Thailand was completed.

Energy Policy Study

Fertilizer production is highly energy intensive. This is especially the case with respect to nitrogen fertilizers. The production of one 50-kilogram bag of urea, for example, requires as much energy as is contained in about 15 U.S. gallons of gasoline. Furthermore, the average international price of crude oil has increased from approximately US $3.3/barrel in 1973 to US $32.0/barrel in 1981.

In response to a request from USAID, IFDC initiated an energy and fertilizer policy study. The economic and technical analyses of the linkages among energy, fertilizer, and agricultural sectors were analyzed. The main objectives of the study were (1) to estimate energy requirements for fertilizer manufacturing, distribution, and application; (2) to evaluate the policy implications of energy supply and prices; and (3) to evaluate alternatives for reducing the adverse impact of energy supply and prices on fertilizer and agricultural sectors.

About 3.5% of the total commercial energy in the world is used for agricultural production, and fertilizer accounts for about 45% of this energy use. Approximately 81% of the total commercial energy consumed in the fertilizer sector is for fertilizer manufacture. Of this, 90% is for nitrogen fertilizer alone. The average energy requirements for manufacturing selected nitrogen, phosphate, and potash fertilizers are shown in Figure 17.

The study analyzes ways to save energy and to improve energy efficiency in fertilizer manufacture, distribution, and use. The most promising way to save fertilizer energy is to use fertilizer more efficiently. This is especially true of nitrogen use in developing countries where the use efficiency may be substantially lower than 40%. Assuming that nitrogen use efficiency in the world could have been doubled, a potential annual saving of 20.6 million metric tons of nitrogen (worth US $11.3 billion) would have resulted during 1978/79. This is equal to a saving of energy equivalent to 262 million barrels of oil (worth US $7.8 billion) or production of 200-300 million metric tons of additional grain. Efficiency can be increased through improved fertilizer technology and management. Fertilizer energy can also be saved through integrated nutrient management, including organic fertilizers, biological nitrogen fixation, and energy-efficient fertilizer recommendations.

The best way to improve energy efficiency in manufacturing, especially in developing countries, is through the use of energy-efficient fertilizer manufacturing processes and efficient use of fertilizer plants. Most of the energy-saving innovations may result in small savings when used individually. However, the sum of these savings amounts to a substantial total. In an ammonia/urea complex, for example, the energy saving could be as much as 25.4 gigajoules per metric ton of nitrogen as urea (about 32% of present use). One gigajoule is equal to 0.948 million Btu.

The potential for saving energy in fertilizer distribution is likely to be small in the short run. However, in the long run, energy saving could result from better planning, greater use of rail and waterways for transport, shipping in

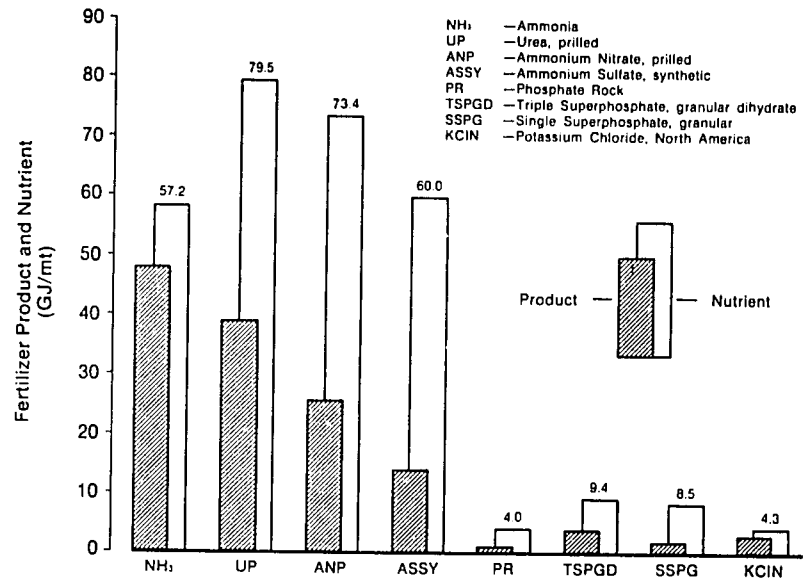


Figure 17. Average Energy Requirements for Manufacturing Selected Nitrogen, Phosphate, and Potash Fertilizers.

Dr. Mohinder S. Mudahar, IFDC Economist, and Mr. Travis P. Hignett, Chemical Engineer and Special Consultant to the Managing Director, present a copy of their recent publication, "Energy and Fertilizer," to Dr. Donald L. McCune, IFDC's Managing Director.

bulk when practical, importing a few selected fertilizers in large shiploads, and using high-analysis and compound fertilizers.

World Fertilizer Study

In 1981 IFDC published a bulletin entitled *World Fertilizer Progress Into the 1980s*. This publication analyzes and evaluates the major fertilizer trends that occurred in the 1970s. Based on an evaluation of the changes during the 1970s and projections made by the FAO/UNIDO/World Bank Working Group on Fertilizers for the first half of the 1980s, the publication provides useful analyses of fertilizer production, consumption, and trade.

The past decade with its many special events was dynamic and unusual in many respects. It is important to remember, however, that it takes 4-6 years for new plants to become operational after an investment decision is made. A time lag occurs before the fertilizer sector can adjust to changes in the economic environment. Therefore, many trends that started in the 1970s are likely to become significant only during the decade of the 1980s.

The world fertilizer sector depends today more than ever on developments in production and consumption in the developing countries and the centrally planned economies of eastern Europe. Many of these countries have not attained self-sufficiency in food supply. Increased use of fertilizers seems to be their best option to increase crop yields and productivity.

The availability of cheap raw materials is likely to be the factor dictating the location of fertilizer production facilities in the future. The new nitrogen exporters of the late 1970s consist mainly of developing countries that possess large reserves of natural gas. Countries in the Middle East, Central America, and Southeast Asia that have flared gas have chosen to sell energy through nitrogen production. The present price structure favors expansion of phosphate fertilizer production at commercially exploited phosphate rock deposits. Sulfur prices and availability have become increasingly important in expansion considerations.

The cost of building and operating plants in remote areas of these developing countries and the cost of transporting the finished or intermediate products to consuming countries have been high. However, as energy costs increase in other parts of the world, improved plant efficiency and use of new infrastructure facilities are making these new locations the low-cost production areas. The full impact of these new facilities has not been felt. More countries in the developing world are establishing new production facilities. Because several of these have only a small domestic consumption, their impact on regional trade is expected to be much more significant in the 1980s.

The shifts in regional distribution of the world fertilizer industry are resulting in more ownership and control by the public sector. Such shifts toward increased public-sector involvement reflect the importance that national planners place on fertilizer and the role it plays in food production, economic stability, and economic development. This trend in the developing countries has been accompanied by a similar trend to coordinate exports in the developed countries through export associations.

Financial Report

Price Waterhouse

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

March 12, 1982

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, 1981 and 1980, and the results of its operations and changes in fund balances for the years then ended in conformity with generally accepted accounting principles consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Price Waterhouse

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS

CURRENT FUND
(unrestricted)

ASSETS

	December 31, 1981	December 31, 1980
Cash	$ 239,146	$ 384,481
Certificates of deposit	1,660,313	1,475,141
Amounts receivable from donors (Notes 1 and 2)	3,337,392	3,960,181
Other accounts receivable	745,272	478,549
Advances to employees	92,528	42,337
Supplies inventory (Note 1)	108,409	97,177
Prepaid expenses	302,052	31,836
	$6,485,112	$6,469,702

LIABILITIES AND FUND BALANCES

	December 31, 1981	December 31, 1980
Bank overdraft	$ 190,226	
Accounts payable	190,615	$ 277,429
Accrued annual and sick leave	869,980	698,680
Deferred revenue (Notes 1 and 2)	3,337,392	3,960,181
Total liabilities and deferred revenue	4,588,213	4,936,290
Fund balance	1,896,899	1,533,412
	$6,485,112	$6,469,702

PROPERTY AND EQUIPMENT FUND
(NOTE 1)

Buildings	$5,741,090	$5,605,640
Equipment	4,104,765	3,934,341
Construction in progress		57,855
Less - Accumulated depreciation	(2,270,167)	(1,691,739)
	$7,575,688	$7,906,097

Accounts payable	$ 17,073	$ 34,860
Contract retainage	21,121	21,121
Total liabilities	38,194	55,981
Fund balance	7,537,494	7,850,116
	$7,575,688	$7,906,097

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF FUNCTIONAL EXPENSES

YEAR ENDED DECEMBER 31, 1981 WITH COMPARATIVE TOTALS FOR 1980

	1981			Total Expenses	
	Research	Outreach	General and Administrative	1981	1980
Personnel compensation (Note 3)	$2,134,548	$ 907,275	$ 883,191	$3,925,014	$3,499,792
Personnel benefits (Note 3)	299,406	154,753	138,231	592,390	523,763
Travel and transportation	282,721	340,013	77,134	699,868	648,987
Occupancy	201,894	74,995	74,995	351,884	351,883
Telephone and telegraph	52,828	31,377	21,738	105,943	118,614
Rental of equipment	9,814	3,369	3,280	16,463	37,229
Contractual research and development	133,328	36,458		169,786	270,548
Other contractual services	436,559	177,535	102,450	716,544	497,502
Institute of International Education fee (Note 3)			107,333	107,333	101,480
Materials and supplies	339,363	120,841	57,954	518,158	535,085
Postage	15,070	6,828	4,531	26,429	18,933
Insurance	40,964	20,482	20,482	81,928	46,795
Miscellaneous			28,390	28,390	560
Total expenses before depreciation	3,946,495	1,873,926	1,519,709	7,340,130	6,651,171
Depreciation of furniture and equipment	468,224	44,610	87,180	600,014	566,663
Total expenses	$4,414,719	$1,918,536	$1,606,889	$7,940,144	$7,217,834

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENT OF REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES

YEAR ENDED DECEMBER 31, 1981 WITH COMPARATIVE TOTALS FOR 1980

	1981		Total All Funds	
	Current Fund	Property and Equipment Fund	1981	1980
Revenue:				
Grants received (Note 2)	$5,786,416		$5,786,416	$5,296,198
Recovered project costs	1,982,770		1,982,770	1,689,573
Other	221,823		221,823	150,714
Total revenue	7,991,009		7,991,009	7,136,485
Expenses:				
Research	3,946,495	$ 468,224	4,414,719	4,207,581
Outreach	1,873,926	44,610	1,918,536	1,548,381
General and administrative	1,491,319	115,570	1,606,889	1,461,872
Total expenses	7,311,740	628,404	7,940,144	7,217,834
Excess (deficiency) of revenue over expenses	679,269	(628,404)	$ 50,865	($ 81,349)
Other changes in fund balances:				
Property 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		

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

NOTES TO THE 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 following is a summary of significant accounting policies:

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

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

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

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

NOTE 2 - GRANTS:-

Grants received are summarized as follows:

	Year ended December 31, 1981	1980
United States Agency for International Development (AID)	$4,000,000	$4,000,000
International Fund for Agricultural Development	880,000	
International Development Research Centre (IDRC)	887	558,125
Rockefeller Foundation	25,388	66,550
Israel Chemicals Ltd.	50,000	25,000
Australian Development Assistance Bureau (ADAB)	207,352	137,375
	5,163,627	4,787,050
Amounts deferred during prior year	3,960,181	4,469,329
	9,123,808	9,256,379
Less - Amounts deferred to future periods	(3,337,392)	(3,960,181)
Revenue recognized in current period	$5,786,416	$5,296,198

The current grant from AID was amended to provide additional funds of $4,000,000 during each of the years ended December 31, 1981 and 1980, and to extend the grant period from June 30, 1981 to June 30, 1982. The amount of $1,900,000 had not been received at December 31, 1981 and 1980 and was not clearly designated for a specified program period and, accordingly, was deferred. 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 $25,705 from the Rockefeller Foundation grant, the amount of $259,187 from the International Development Research Centre grant, the amount of $492,500 from a United Nations Development Programme grant and the amount of $660,000 from the International Fund for Agricultural Development were deferred at December 31, 1981.

NOTE 3 - INSTITUTE OF INTERNATIONAL EDUCATION:

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

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As of December 31, 1981
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