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Annual Report 1989

International Fertilizer Development Center

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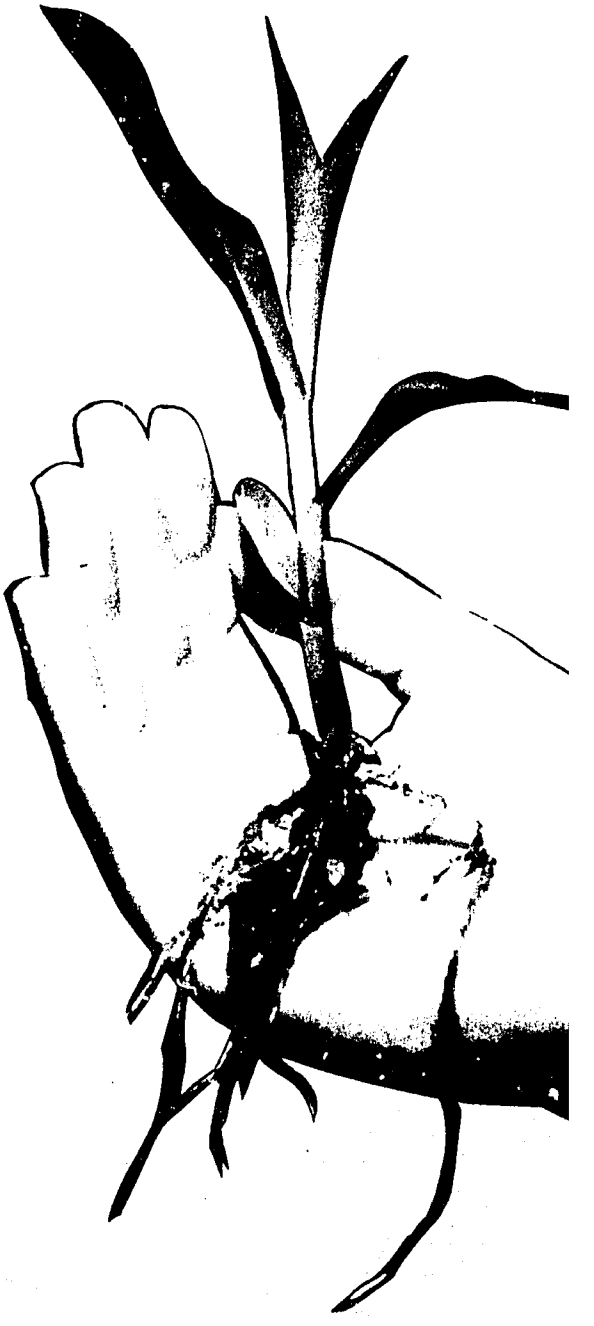


Management Perspective

Encouraging Environmental Sustainability

As inhabitants of planet Earth, we are charged with the responsibility of being good stewards of its resources by using them to feed its growing population and to preserve them for use by future generations. Working in concert with the other international agricultural research centers (IARCs), the International Fertilizer Development Center (IFDC) is committed to doing its share to protect the earth's natural resource base, while it strives to increase food production in the developing countries. The Center's work in Africa, Asia, and Latin America is becoming increasingly sensitized to the impact that fertilizers and their use may have on the environment. The Center's scientists have developed new ways to increase the efficiency of fertilizer by reducing losses of nitrogen and its accumulation in the atmosphere and groundwater. IFDC has been practicing environmentally sound phosphate research in that it has concentrated on taking from the earth an indigenous resource (phosphate rock), exposing it to minimum processing, and returning it to the earth as fertilizer. Future research involving other important nutrients, as well as multinutrient products, will focus on sustainable soil fertility management and promote the use of organic and inorganic sources of plant nutrients that are available in the specific agroecological zones.

Working With Women in Agricultural Research and Training

IFDC is engaging women in all phases of its work. In sub-Saharan Africa, the Center is welcoming women as partners in its efforts to create an environmentally sensitive sustainable agriculture. For example, one objective of IFDC's soil fertility restoration project is to identify the role of women in agricultural development and the means to enhance their contribution.

In its training component, IFDC encourages the participation of women in its programs. Since 1980 attendance by women in IFDC's training programs has trended upward to about 20 women participants per year or 7%-8% of the total annual enrollment during the past 3 years. As more and more national leaders recognize the importance of women to overall economic development, it is anticipated that women's participation will increase. To determine the number of women engaged in the sector and the type of work they perform, IFDC has initiated a survey of the fertilizer sectors in developing countries. This information will assist the Center in formulating future programs to meet women's needs.

Looking Toward the 1990s

The 1990s are likely to be known as the decade of the environment and sustainability—a time to preserve and build upon the gains of the past. As IFDC enters the 1990s, there is a sense of urgency to speed up the development of new fertilizer technology to help feed the world's ever-burgeoning population. As predicted by the United Nations, global population will reach 6.3 billion in the year 2000, up from 5.2 billion in mid-1989. More than 90% of this increase will

occur in developing countries. Thus, the population of the developing countries will increase from 4 billion in mid-1989 to 5.1 billion in 2000. The majority of this increase will occur in areas where there is little opportunity to develop new lands. Thus, food increases must be gained from existing land. The key is fertilizer, preferably the integrated application of inorganic and organic materials.

It is apparent that IFDC is on the cutting edge of environmentally sensitive fertilizer research, and in the future, the Center will develop new products and practices for increasing food productivity in the developing countries while preserving land and water resources. IFDC will be reorganized during 1990 to meet these new challenges.

Dr. David B. Parbery
IFDC Managing Director (Designate)

Dr. Paul J. Stangel
Deputy Managing Director

During 1989 IFDC witnessed the appointment of Dr. David B. Parbery as its second Managing Director, upon the retirement of its founder and first Managing Director, Dr. Donald L. McCune.

IFDC's Environment-Friendly Fertilizer Ready for Transfer to Developing-Country Agriculture

"A simple effective and inexpensive soil test appropriate for use by people with no specialized training or sophisticated equipment would be very helpful in making fertilizer recommendations to boost crop yields while minimizing environmental pollution in developing countries."—
Dr. Raman G. Menon, IFDC Soil Scientist

In recent years, concern has increased over the contribution of nitrogen fertilizers to environmental problems of nitrate pollution of waters and pollution of the earth's atmosphere with the oxides of nitrogen. These gases potentially contribute to the "greenhouse effect" or global warming due to their increasing concentrations in the atmosphere and to the destruction of the ozone layer that protects the earth from ultraviolet radiation.

When nitrogen in either synthetic or natural fertilizers is applied at rates that greatly exceed the amounts used by plants, nitrate can move below the crop rooting zone and may eventually contaminate groundwater. This is particularly true on sandy soils receiving large amounts of water through natural rainfall or irrigation.

According to the Food and Agriculture Organization of the United Nations (FAO), some developed countries use as much as 700 kg of synthetic fertilizers per hectare of arable land and are endangering both the soil and water resource base.

In contrast, the situation is different in developing countries. For example, African countries use an average of 11 kg per hectare, Latin America 48 kg, and Asia 62 kg—not enough to restore the nutrient loss of crop uptake, which FAO estimates to be from 100 to 150 kg of plant nutrients per hectare.

FAO is now calling for a new global strategy of "sustainable soil fertility development," which would promote efficient use of all organic and renewable sources of plant nutrient that are locally available—legumes in rotation, green manures, manure, composts, and crop residues—as well as increased multilateral assistance to fertilizer supply schemes.

In south and southeast Asia, rainfed and irrigated transplanted rice occupies nearly two-thirds of the agricultural area and produces more than 80% of the paddy rice. In these areas, prilled urea conventionally applied by farmers is very inefficiently used by transplanted rice primarily because of serious losses of nitrogen (up to 60% of applied N) through loss as gases (ammonia volatilization and denitrification), and movement as nitrate into water (leaching and/or runoff). This represents a huge financial loss to rice farmers and offers a potentially serious problem to the environment

or sustaining agriculture. Increasing the efficiency of fertilizer not only produces more food but also provides for more efficient use of energy resources and reduces pollution of the atmosphere and groundwater.

In 1975 the International Fertilizer Development Center (IFDC) proposed the use of large urea particles, commonly referred to as urea supergranules (USG), in place of mudballs containing urea fertilizer, used by Japanese farmers in the early 1900s. Deep placement of USG when followed by immediate sealing of the holes left at the placement sites of USG helps to retain nearly all urea-nitrogen near the deep placement sites in medium- to fine-textured rice soils with low percolation rate.

For the past 13 years IFDC has worked independently and jointly with other institutions to evaluate and promote the effective use of USG as an efficient nitrogen source for transplanted lowland rice. The IFDC-developed USG agrotechnology consists of an affordable supply of the right kind of USG fertilizer and an efficient method for its deep placement.

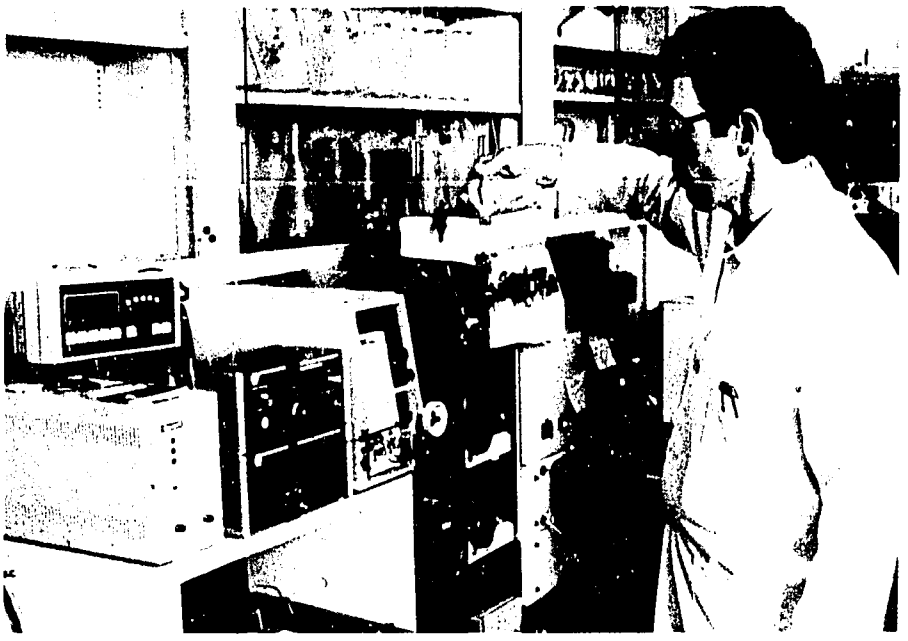
IFDC has worked for several years on developing a low-cost means of supplying USG to the rice farmer in Asia. This supply aspect has been a bottleneck in getting USG technologies adopted by the developing-country farmer.

During 1986/87 IFDC did considerable work in Indonesia to test and modify a Chinese-made village-level briquetter for producing pillow-shaped USG. (Briquetting, a special type of compacting process, is a cost-effective method for producing USG.) At the end of 1989 IFDC designed and constructed a village-level briquetter with a capacity of about 200 kg per hour. This is an improved version of the Chinese-made village-level briquetter. The briquetter is currently undergoing performance tests. These tests will assess the briquetter's performance under continuous operating conditions and will determine if this equipment needs to be further developed before making the technology available outside IFDC. It is estimated that the production cost of USG by briquetting ranges from 5% to 10% more than that of prilled urea.

To provide an efficient method for deep placement of USG, IFDC has developed a plunger-type, completely

"We are enthusiastic about our role in the development of crop simulation models, which are being used to increase crop production in developing countries by providing a more efficient way of gaining knowledge about fertilizer application."—
James E. Brink, Geographic Information Specialist/Programmer and
Glenda Smallwood,
Marketing Research Assistant

Editor's Note: *On the next few pages the reader will meet a few of the people who play a role in helping IFDC fulfill its mission of developing improved fertilizers and fertilizer practices needed to increase food production in the developing world. Regardless of how great or small one group or one person's role may seem, it is the sum of all the varied contributions that helps to make IFDC's efforts successful.*



"Synthetic or natural coatings on fertilizer, especially urea, are used to control the release rate of urea fertilizer. In this way, we can more effectively meet the nitrogen uptake requirement of a plant such as rice. In turn, this will reduce nitrogen losses to the air and water."— Dr. G. Erick Peters, IFDC Chemist

hand-operated polyvinyl chloride applicator. Its proper use for mechanical deep placement of urea briquettes in transplanted rice will nearly eliminate all nitrogen losses.

Field trials conducted in the Philippines and India demonstrate that small-scale rice farmers can use the applicator profitably for nitrogen application at affordable rates and still achieve the same high agronomic efficiency as that achieved with the conventional hand deep placement of USG.

The applicator is affordable, lightweight, simple to construct, easy to use, requires low draft power (about 4 kg), and can save up to 40% of the labor normally required for the hand placement of USG. The applicator reduces the drudgery of hand placing USG after transplanting.

If USG agrotechnology is adopted by millions of economically handicapped, developing-country rice farmers, it will be a major step forward in helping to increase national food production substantially without raising environmental concerns. In fact, results of recent field research in Maharashtra State, India, showed that when USG deep placement technology was used, small farmers received an additional income benefit of US $40 per hectare with a benefit:cost ratio of about 5 or more (anything above 2 is considered profitable) at a rate of 38 kg nitrogen per hectare when compared with traditional farmers' methods of applying prilled urea.

In future research at IFDC, the potential of fertilizers to reduce environmental problems will receive greater

"It is gratifying to be able to share my years of experience in fertilizer market development with people who need this assistance. My job at IFDC gives me the opportunity of contributing to its mission to increase agricultural production in the tropics and subtropics."—
Catalino C. Yaptenco, Jr.,
IFDC Marketing Specialist

emphasis. Applications of fertilizer to better farmlands may help reduce the encroachment of farming into marginal, erodible, or fragile areas in the developing countries. They may also help to reduce the amount of slash-and-burn and shifting agricultural practices, which are used in developing countries to replenish nutrients on very infertile soils. Supergranule fertilizers may also play a key role in the establishment of trees and shrubs in very nutrient-deficient areas where revegetation is desperately needed to reduce soil erosion and desertification.

A Summary of 1989 Activities

The year 1989 marked a turning point in the history of IFDC. It was characterized by changes in management, more intensive focus on Africa, and new research and development directions for the Center in its work in Africa, Asia, and Latin America.

Appointment of New Managing Director

During the year a new Managing Director, Dr. David B. Parbery, was tapped to lead the Center into the 1990s. He was selected to succeed Dr. Donald L. McCune, founder and Managing Director of the Center since its inception in 1974. An Australian international development specialist with 35 years of experience, Parbery's latest service in Australia was as Managing Director of Luminis Pty., Ltd., the technology transfer arm of the University of Adelaide. For the past 5 years, he was engaged in the commercialization of University technology. Prior to that he held a variety of international development positions with the World Bank in Asia and Latin America for more than a decade. In addition, he has served as the managing director of three other research and development organizations.

Africa

"Current research focused on the management of reactive indigenous phosphate rocks as phosphorus fertilizer sources for flooded rice will provide an inexpensive means for the resource-poor farmer to sustain or increase yields on acid soils without adverse environmental impacts."—
Deborah T. Hellums, IFDC Research Associate

"My work at IFDC consists of providing data processing services to the Outreach Division staff; as a result, I am directly and/or indirectly involved in training programs, technical assistance, and research. Probably the most rewarding and interesting part of my work is the training programs since I work with people from other countries and help them solve problems."—
Linda W. Trousdale, IFDC Information/ Marketing Associate

Expansion of Regional Fertilizer Marketing Services

The African Fertilizer Trade and Management Information Network was expanded to include 22 countries. Initial work started on the development of a data base, and a study of the fertilizer sector in the Republic of Benin was published.

New Review Magazine for Sub-Saharan Region

Africa Fertilizer Review, a new biannual publication for the fertilizer sector, was published to provide a forum for information exchange for personnel involved in the promotion and development of fertilizer use in the region.

Agromineral Research and Development Program

Following wide-ranging consultation with national geologists in West African countries followed by regional assessment of research and development needs, nine viable proposals for research were developed in cooperation with officials from national programs.

On-Farm Research Programs in Mali and Nigeria

In March 1989 IFDC, in collaboration with national institutions, began an on-farm fertilizer evaluation and adoption project in three villages in southern Mali and four villages in northern Nigeria. On-farm agronomic and socioeconomic evaluations of nitrogen and phosphorus sources and methods of application for important food crops are being conducted with extensive farmer participation.

"Much of the agro-economic data generated by IFDC has its beginning in the greenhouse, and often it is here that research ideas become reality. Therefore, the greenhouse is a vital link in the chain of developing an effective, efficient finished product."—
Ronnie L. Faires, IFDC
Greenhouse Supervisor

Findings of Socioeconomic Survey of 375 Farmers for Soil Fertility Restoration Project

Baseline socioeconomic and agronomic surveys have been completed for six participating villages: Adjamesu and Hwidiem (Ghana), Naki-Est and Kpembona (Togo), and Tchizon and Maiguero (Niger). These surveys involved a total sample of 375 farmers, and all data are categorized by gender of the farmers. The baseline survey data will be used as a basis for evaluating the socioeconomic and agronomic impact of fertilizer use in the experimental villages of Adjamesu, Naki-Est, and Tchizon as compared with the control village in each country.

Further Development of Agronomic Research Stations in Togo

IFDC's capacity to undertake research in major ecologies representative of West Africa was strengthened through the provision of additional infrastructure. Buildings, roads, support facilities, and utilities were provided at the Amoutchou station in the plateau region.

Progress in Video Production

Work began on the joint IFDC/Radio Nederland Television project to produce a video on soil fertility awareness in West Africa with the shooting of footage in Ghana, Niger, and Togo.

Growth of the Egyptian Fertilizer Development Center

Since 1987 IFDC has been assisting the Egyptian Government in developing a fertilizer development center for that country. IFDC's role is to assist in the development of the organization, its programs of research, and how they interact with the agricultural sector. During 1989 IFDC established a data base facility with computers installed, data bases developed, and personnel trained in the use of the equipment. During the past year IFDC also prepared for installation of a physical properties laboratory, nitrogen and phosphorus bench-scale equipment, and a pilot plant that will manufacture various granular compound fertilizers.

Other Technical Assistance Projects in Africa

In addition to the major project with Egypt, IFDC also provided technical assistance to Burundi, Kenya, Malawi, Tanzania, Togo, Zambia, and Zimbabwe during 1989.

"My main duties at IFDC involve the production of compound granular fertilizers in the laboratory-scale granulation unit. Some of these fertilizers are experimental products, and some are produced at the specific request of IFDC agronomists to be used in greenhouse or field test programs. Some fertilizers are produced to test if raw materials native to a developing country can be used to produce fertilizer in that country."—
Thomas E. Evers, IFDC Technical Aide

Asia

Testing and Modification of Village-Level Briquetter

Continuing its effort to find a low-cost means of supplying USG to the rice farmers of Asia, IFDC designed and fabricated a village-level briquetter to produce USG. Work is underway to ensure that this equipment is appropriate to the developing countries from both a production viewpoint as well as its use.

Development and Evaluation of Cost-Effective USG Placement Methods

Two methods of USG deep placement—the IFDC transplanting guide method and the IFDC applicator method—were developed and evaluated. Preliminary observations in India and the Philippines showed that the transplanting guide can be fabricated by a farmer. After a brief demonstration, field workers were able to use it in line transplanting. Results of field trials in the Philippines and India demonstrate that small-scale rice farmers can use the briquette applicator profitably for applying USG at affordable nitrogen rates and still achieve the same high agronomic efficiency and environmental safety of conventional hand deep placement of USG.

Enhancement of Nitrogen Research in the Philippines

IFDC continued its extensive research to identify and develop strategies for increasing the efficiency of urea on lowland rice. The Center is working closely with the International Rice Research Institute (IRRI) on integrated fertilizer management in legume/rice-cropping systems. One area of research involves the growth of waterlog-sensitive grain legumes with supplemental irrigation prior to the onset of the wet season. Incorporation of cowpea at flowering stage as a green manure or incorporation of cowpea residue remaining after harvest of grain and pods significantly increases yield of rice. IFDC is working closely with IRRI to identify crop and soil management practices that effectively utilize native soil fertility, thereby reducing nitrogen fertilizer requirements for rice. This may reduce the emissions of nitrous oxide, a greenhouse gas formed in the soil during the denitrification process.

Advances in Phosphorus Research in Indonesia

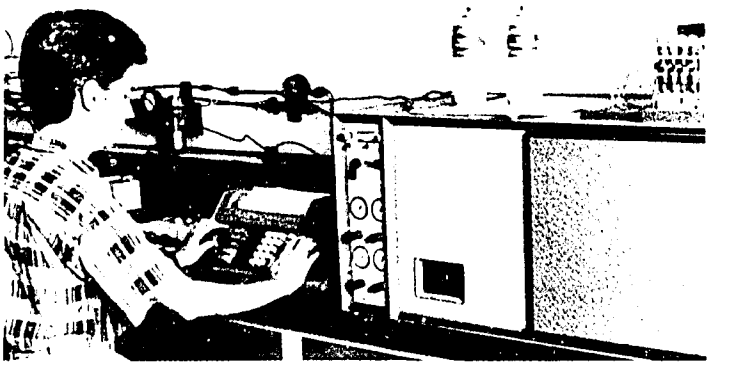
Since 1987 IFDC has been conducting a collaborative research project in Indonesia with the Indonesian Agency for Agricultural Research and Development through the Centre for Soil Research to compare the effectiveness of directly applied medium- and high-reactivity phosphate rocks with triple superphosphate in annual cropping systems. Five 3-year field experiments are being cropped each year with a cereal-soybean rotation. During 1988 and 1989 these experiments completed two cropping cycles during which both phosphate rocks were found to be generally as effective as triple superphosphate in increasing grain yields. In comparisons of annually applied treatments with residual value treatments receiving the same total phosphate application over the two cycles, split (annual) applications produced significantly higher yields than single biennial applications on the less weathered, less acidic soils but similar yields on the more acidic highly weathered soils.

Latest Developments in Sulfur Research in Thailand

Results of collaborative field research with the Nuclear Research in Agriculture Branch of the Thailand Department of Agriculture suggest that high concentrations of fertilizer sulfur in the floodwater during the first week after application could result in substantial fertilizer loss in runoff from paddies with flowing floodwater, particularly after heavy rainfall.

Successes in Bangladesh Fertilizer Marketing Project

The year 1989 marked a decade of continued involvement by IFDC in providing fertilizer policy and marketing services to the Bangladesh Agricultural Development Corporation (BADC). With funding from the U.S. Agency for International Development (USAID), IFDC's technical assistance services to Bangladesh during 1989 centered on consolidating and refining the earlier marketing developments, policy changes, and continuing the process of developing increased private-sector involvement in the fertilizer marketing system. As a result, fertilizer is more readily available and at a lower price to the farmers. In addition, the field testing of urea deep placement technology in Bangladesh has produced positive results. During the dry season, field tests indicated that when USG are deep placed by hand, more paddy output resulted than from traditional application of urea as split broadcast. The total return was approximately US $217 per hectare after compensating for the higher labor and urea costs due to deep placement. In late 1989 the contract was changed from BADC to the Ministry of Agriculture and IFDC.



"As a chemist working in a world of soil scientists, I feel that it's my job to bridge the gap between their scientific concepts and the analytical methodologies that exist."—
Leella S. Holt, IFDC Research Associate

"My assignment is to assist the Pilot-Plant Coordinator, in the preparation, operation, and maintenance of the IFDC pilot plants. The information that I gather during the operation of the pilot plants is the basis of the technical reports on our work. The fertilizer produced is often used in agricultural field tests. Another activity is to provide training in fertilizer processes to personnel from developing countries."—
Robert C. Bosheers, IFDC Engineering Research Technician

Other Technical Assistance in Asia

During 1989 IFDC also provided technical assistance to Malaysia, Nepal, and Turkey.

Latin America

New Nitrogen Research in Colombia

During 1989 the IFDC/Centro Internacional de Agricultura Tropical (CIAT) Soil Fertility Studies Project continued research in the strategies related to polymer-coated urea to delay nitrogen release and urease inhibitors to decrease ammonia volatilization losses.

Continued Progress in Phosphate Research in Latin America

Experiments conducted in various countries in Latin America showed that increasing the amounts of water-soluble phosphate through the use of mixtures (bulk blended or compacted) of phosphate rocks and water-soluble phosphate or use of partially acidulated phosphate rock-based products can extend the use of indigenous phosphate rocks to less acid or neutral soils and to short-term crops like potatoes, beans, and maize.

Beneficial Technical Assistance in Latin America

Colombia—IFDC completed a project for designing major modifications to the nitrophosphate-based granular NPK fertilizer plant of Abonos Colombianos S.A. (ABOCOL). The modifications were designed to increase process efficiency, flexibility in the use of raw materials, and production capacity, while at the same time reduce ambient pollution, corrosion, and maintenance costs.

Other—During 1989 the Center also provided technical assistance to Fiduciara de Inversiones Transitorias, S.A. (FINTRA) in Costa Rica and the Centro de Investigación y Desarrollo (INTEVEP) in Venezuela.

Human Resource Development

During 1989 IFDC conducted 12 general training programs and one workshop. A total of 308 participants from 73 countries participated. Of these, 6 programs were offered at IFDC Headquarters and 7 overseas. In addition, IFDC offered at Headquarters 12 specialized training programs for 20 participants from 7 countries. In all, 25 training programs were offered in 1989. The new offerings included: "Computer Simulation of Crop Growth and Fertilizer Responses," "Supplying Quality Multinutrient Fertilizers in the Latin American and Caribbean Regions," "Finance for Nonfinance Managers in the Fertilizer Sector," and "Fertilizer Supply Options and Constraints in Developing-Country Agriculture."

Global Programs

Innovations in Crop Growth Simulation Modelling

IFDC and the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) jointly developed the CERES-Rice Model V2.0, which incorporates water-balance and nitrogen-balance components that predict crop growth and development under upland and flooded field conditions. The model simulates nitrogen losses that occur due to runoff, leaching, denitrification, and ammonia volatilization in fully upland, fully flooded, or under intermittent flooding and drying conditions. This model was validated with data from several field experiments conducted under collaborative programs between IFDC and IRRI during 1985-89.

Enhancements of the Pi Soil Phosphorus Test

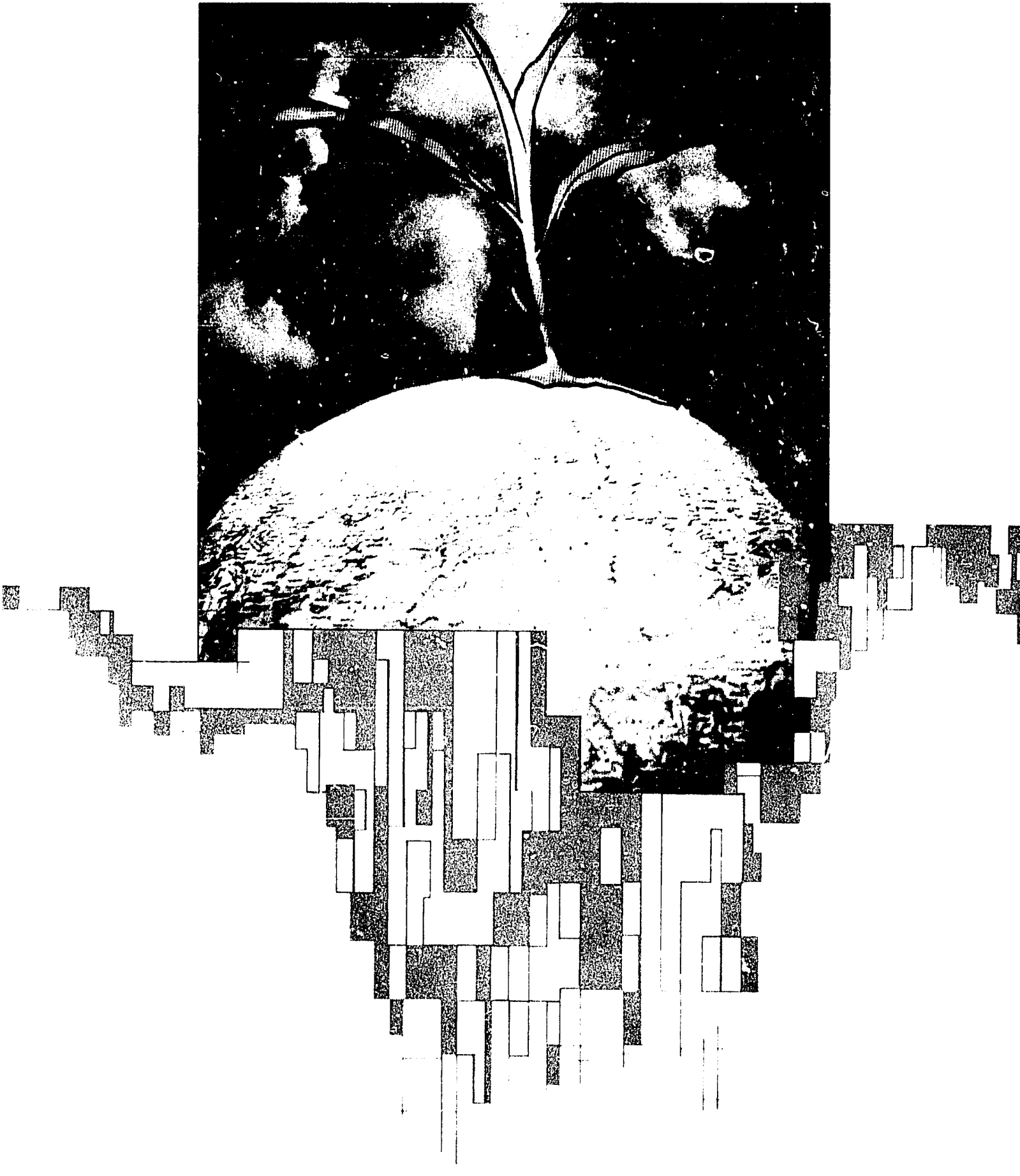
For the past few years, IFDC scientists have been testing a new method for the evaluation of plant-available phosphorus in soils. This innovative technique, the Pi soil test, uses strips of filter paper impregnated with iron oxides as a sink to trap and remove phosphorus mobilized in a soil-solution suspension. During 1989 field studies for the calibration of the Pi test were initiated in Colombia, the Philippines, and East and West Africa in collaboration with IFDC scientists carrying out research in these countries.

New Publications

During 1989, 10 major publications were released by IFDC. They include:

- *Global Fertilizer Perspective, 1960-95: The Dynamics of Growth and Structural Change.*
- *Production of Granular NPKs in Ammonium Phosphate Plants.*
- *Approvisionnement, Commercialisation, et Demande des Engrais en Republique Populaire du Benin.*
- *The Pi Soil Phosphorus Test: A New Approach to Testing for Soil Phosphorus.*
- *Soil Fertility and Fertilizer Management in Semiarid Tropical India, Proceedings.*
- *The Benefits of Fertilizer Use in Developing Countries.*
- *Agroecological Constraints to Crop Production in Western Asia and North Africa and Their Impact on Fertilizer Use.*
- *Fertilizer Production and Supply Constraints and Options in Sub-Saharan Africa.*
- *Venezuela Fertilizer Subsidy and Agricultural Production.*
- *IFDC Annual Report, 1988.*

In addition, 30+ papers were published on nitrogen, phosphorus, sulfur, and other topics in international agricultural research journals, proceedings, and other publications.



Africa Fertilizer Sector

IFDC is building a basis for sustainable agriculture to feed future generations in sub-Saharan Africa.

Fertilizer Research Program in West Africa

Introduction

The high annual rate of population growth overshadows all development activities in sub-Saharan Africa, especially in food crop agriculture where real increases in productivity and output must occur if self-sufficiency in food production is to remain a realizable goal by the year 2000.

FAO estimates that in order to meet food requirements 50% of future gains in food crop yields in the region will come from fertilizer use in conjunction with improved crop varieties and cultural practices. In realistic terms this means that fertilizer consumption in sub-Saharan Africa must be increased from 1.1 million tons of nutrients in 1989 to about 5.7 million tons by the year 2000; this would require an annual increase of 14% in consumption during the remainder of the century. Currently, about 85% of fertilizer consumed in the region is imported, and this situation is unlikely to change for the remainder of this decade.

Most countries in the region face serious economic difficulties with high levels of debt, relatively low levels of investment, stagnant or sluggish economic growth, and severe shortages of foreign exchange. Add to this the pressure exerted on African governments from the World Bank and the International Monetary Fund to remove subsidies on fertilizers and foodstuffs, and it becomes clear that there is an urgent need to develop cost-effective strategies to supply farmers with the right kinds and amounts of fertilizer.

These harsh economic realities add to the difficulties that African governments must overcome if they are to plan, finance, and deliver the increases in fertilizer supply that will be essential for sustained growth in food production.

While African governments are being urged to take the lead in placing high priority on fertilizer sector development, it is also increasingly recognized that governments are not well equipped to play an all-encompassing role in national fertilizer sectors. Governments are well-placed to provide direction, strategic planning, and foreign exchange for national sectors while the private sector is considered to be best placed to procure, market, and distribute fertilizer efficiently and cost effectively to farmers.

IFDC-Africa, in its third operational year, worked closely and interactively with international agencies, donors, and national programs to improve knowledge, understanding, and capabilities to cope with the array of complex factors that affect fertilizer sector

development in the region. Expansion and intensification of existing research and training programs continued during the year to consolidate linkages and partnerships with national programs in the region.

Economics Research and Fertilizer Development Program

Fertilizer Policy Research Project

The aim of research being jointly executed by IFDC and the International Food Policy Research Institute (IFPRI) Fertilizer Policy Research Project (FPRP) is to aid the design of an appropriate fertilizer policy framework for the countries of sub-Saharan Africa. Several fertilizer policy concerns are being addressed that range from the farmer level through to the macroeconomic policy level. Studies are underway to assess the economic potential of fertilizer use in different agroecological zones in the sub-Saharan region. Several smallholder farm-level studies examine the key factors affecting farmer's investment and consumption decisions, the determinants of fertilizer use, and the characteristics of fertilizer users. Studies have been initiated to examine the effects of changes in macroeconomic and sectoral policies as well as changes in institutional arrangements on fertilizer supply and demand in the sub-Saharan region. The opportunities and constraints of indigenous fertilizer production are also being examined.

The FPRP presently has research collaborators within National Government departments and institutions in Benin, Burkina Faso, Cameroon, Gambia, Ghana, Malawi, Rwanda, Senegal, Togo, Zambia, and Zimbabwe. As well, data and information are being collected on a sub-Saharan countrywide basis as part of a fertilizer policy data information system. The exchange of fertilizer policy information is being carried out through a network of fertilizer policy analysts and policymakers composed of host-government collaborators and participants of FPRP workshops.

The core study in the research program identifies the priority crops and subregions within sub-Saharan countries where investments in the fertilizer and supporting sectors can be made if there is to be an accelerated and sustained growth in fertilizer use. Countries within the sub-Saharan region possess limited institutional and financial resources, and if they are to be successful in using fertilizer as a key input in their development programs, priorities must be set to target investment in the fertilizer and supporting sectors. This information will provide the foundation upon which the research results from the other Fertilizer Policy Research studies (macroeconomic, institutional reform, price liberalization, constraints and determinants of fertilizer use) can be drawn together for the design of an appropriate fertilizer policy framework.

Preliminary results from the ongoing research projects suggest that there are subregions within sub-Saharan countries where the value:cost ratios are sufficiently high to make fertilizer use profitable to farmers. For example, in Gambia, value:cost ratios for all crops at current input and output prices range from 3.5 to 5.5, and nearly all value:cost ratios are above 2.0 when all subsidies are removed. However, fertilizer use is only 20% of recommended levels. This suggests that there are constraints to fertilizer use beyond the farm gate for this particular subregion. An analysis of input marketing and distribution revealed that the system failed to deliver fertilizer in the proper quantities and at the proper times.

From another smallholder farm-level study, preliminary results from Burkina Faso indicate that local off-farm income and the level of local infrastructure are variables that have a very positive effect on the probability of fertilizer use by an individual household. These results indicate that liquidity and local infrastructure are two important determinants of fertilizer use and, as such, must be included in the design of policies to accelerate the use of fertilizer in the sub-Saharan region.

Collection and Dissemination of Fertilizer Market Information

AFTMIN

First, the African Fertilizer Trade and Marketing Information Network (AFTMIN) activity is pursuing its objectives through the collection and dissemination of up-to-date trade information. During the year under review, 12 issues of the IFDC-Africa Trade Information Telex in both French and English were sent out to 27 contacts. In addition, a monthly bulletin, the *African Fertilizer Market*, provided readers with relevant information on fertilizer marketing and distribution. Circulation has increased to just under 200 copies, and the mailing list is continuously updated and expanded.

The membership of AFTMIN is also growing. At the end of 1989 the following 16 countries participated in the Network: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Lesotho, Madagascar, Mali, Niger, Nigeria, Rwanda, Senegal, Tanzania, Togo, and Zambia. Zambia joined in February 1989 and Mali in September of that year.

During AFTMIN II, held in Lomé, Togo, delegates concentrated on determining ways to reduce the costs of fertilizer imports and marketing. Measures identified to remove constraints on aid-financed fertilizers included donor coordination, adequate local funding, and an effective national fertilizer policy to improve the efficiency of fertilizer aid.

On an annual basis the marketing group at IFDC-Africa is organizing a meeting that provides an opportunity for African fertilizer marketing officials to meet in an informal manner and discuss their common problems. For AFTMIN II 41 participants, speakers, and observers from 22 countries registered.

The meeting focused on ways to reduce the costs of fertilizer imports and marketing. Besides alternative supply systems in sub-Saharan Africa, fertilizer imports financed by bilateral or multilateral donors were chosen as the second item because fertilizer aid either as balance-of-payments support or as part of structural readjustment programs constitutes an important supply of fertilizers to Africa. Reports and proceedings of AFTMIN meetings have been produced and made available to network participants and other users in the region.

Country Studies

Country studies constitute the second major activity of the marketing program. In 1989 the first country study on the demand, supply, and distribution of fertilizer in the Republic of Benin was published, and studies began in Burkina Faso, Niger, and Togo. The recommendations of the Benin study were discussed during a seminar organized in Cotonou.

Fertilizer Data Base

During March and April 1989 work began on the setting up of fertilizer data bases for trade and marketing information in sub-Saharan Africa. The data base includes nutrient and fertilizer product statistics, marketing costs, subsidies, retail prices, trade information, credit, production units, marketing units, fertilizer use and the economics of fertilizer use, production data per crop, and crop market prices. The information will be retrievable on a per nutrient or product and/or on a country or regional basis.

It is foreseen that the provision of speedy and accurate information services will become more and more important, and the data base is very important to underpin these services in the region. In the future IFDC-Africa may assist in the establishment of national data bases as part of National Fertilizer Secretariats. These systems could be "on-line" with the sub-Saharan fertilizer data base. Thus, AFTMIN members could benefit from the data collected at a regional level, with IFDC-Africa having access to the national data bases.

National Resource Development Projects

Information Dissemination and Technology Transfer

In-Country Training

IFDC-Africa's first in-country training program in fertilizer technology transfer was organized in Kumasi, Ghana. This program was a followup to the recommendations of the 1988 Workshop in Fertilizer Technology Transfer, which identified fertilizer extension communication as an area where national programs in the region need major training inputs. A total of 16 extension officers from the Ashanti and Brong-Ahafo regions participated in the program, which involved a multidisciplinary approach to training in extension communication.

IFDC brought together tutors in areas such as fertilizer technology transfer, communications, and training. This team worked with participants to produce illustrated materials that will strengthen the skills of field extension personnel to communicate fertilizer know-how more effectively to farmers. Ideas and approaches were developed during the program to produce illustrated extension support materials in these regions for three major food crops—maize, yam, and rice.

Guides on subject matter were produced for each crop; illustrations were developed for a special flipchart on maize production for use by field extension personnel. These materials are being further tested and adapted by extension officers in the two regions. National cereal development projects in Ghana, such as the Canadian International Development Agency (CIDA)/Ghana Grains Development Project, have recognized the advantages of illustrated crop production guides for effective extension work and have produced illustrated materials for their project activities throughout the country.

Review of Regional Technology Transfer

While moving ahead to plan and organize in-country training programs in cooperation with national extension systems, IFDC also reviewed food crop technology in the region. As part of the Kellogg Foundation-sponsored program in Communication, Documentation, and Training Program, IFDC-Africa and the National Agricultural Research and Extension Liaison Services (NARELS) in Nigeria cooperated on the preparation of a comprehensive paper on Alleviating Fertilizer Technology Transfer Constraints in the West African region. This paper involved a review of regional progress in agricultural technology transfer and also assessed the methods and achievements of national systems and projects acknowledged to be successful in the region, including NARELS over the past 20 years in Nigeria.

IFDC-Africa conducted its first "In-Country Training Program on the Development of Fertilizer Extension Support Materials" in Kumasi, Ghana, during 1989. This program is part of a project funded by the Kellogg Foundation to develop the information and communications capabilities of national research and fertilizer extension programs in sub-Saharan Africa.

Africa Fertilizer Review

The first issue of *Africa Fertilizer Review*—IFDC-Africa's biannual publication—was produced and published. The issue featured an update on developments in fertilizer production in Nigeria; an overview of African food production; and articles on structural adjustment implications, development strategies, and privatization of the fertilizer sector in sub-Saharan Africa.

Africa Fertilizer Review is envisioned primarily as a forum for information exchange and discussion of the complex issues involved in promoting and developing increased fertilizer use in the region; the review has been started bv IFDC to encourage national personnel in African countries to communicate with each other in relation to the economic, scientific, technical, and sociological aspects of fertilizer sector development in the region.

The proceedings of the 1988 Workshop on Fertilizer Technology Transfer were produced as a resource document in English and French and circulated to participants and national extension programs in the region. Other training resource materials that were produced included core information on fertilizers for field extension personnel and a guide to maize production for field extension personnel in the Ashanti and Brong-Ahafo regions of Ghana. The latter were developed from handout materials produced for the in-country training program in response to the persistent needs of national cooperators for practical training resource materials on fertilizers.

Library and information services were further developed during the year with emphasis on creating greater awareness among our national cooperators in relation to the services that are now available from IFDC in the region. All visitors and trainees were briefed fully on the range of services available and over 150 requests for information and publications were dealt with.

In cooperation with Radio Nederland Television, IFDC-Africa continued work on the production of a video to create awareness on the importance of soil fertility for sustainable farming and food production systems in the region. Shooting of footage for the film was completed in Ghana, Togo, and Niger; final shooting, editing, and production are scheduled for completion in 1990.

As part of the IFDC-Africa/Radio Nederland Television Project, the In-Country Coordinator for Ghana, S. Opoku (left); Nana Kwaku Fobi, Chief of Adjamesu (a village near Kumasi, Ghana); and B. Snit, an RNTV director, discuss plans for a video on soil fertility awareness in West Africa.

Regional Collaboration and Training—1989

One of the reasons for placing IFDC-Africa in Lomé was to provide a base for programs that would promote regional collaboration between IFDC and the various national programs and among the

national programs themselves. The Lomé office also facilitates the conduct of training programs that afford opportunities for participation of more Africans.

During 1989 IFDC-Africa continued the programs on regional cooperation that were initially begun in 1987 and 1988, as well as the West African Fertilizer Management and Evaluation Network (WAFMEN) program, which has been in existence since 1982. In addition, three training programs were held in Lomé; two in cooperation with IFDC Headquarters and the in-country program in technology transfer developed and implemented by IFDC-Africa in Ghana.

Regional Collaboration

The continuing work began with the regional meeting of the WAFMEN national program collaborators, which was held in Ouagadougou, Burkina Faso. The network meeting focused on alleviating soil fertility constraints to increased crop production in West Africa and was attended by 45 representatives from 13 West African countries, 3 European organizations, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and Institut National pour l'Etude et la Recherche Agronomique (INERA) and IFDC. INERA served as IFDC's liaison for the arrangements and logistics in Ouagadougou. Proceedings of this meeting will be published.

The AFTMIN network, which was formed during a meeting in 1987, held its second annual meeting on fertilizer marketing in sub-Saharan Africa in Lomé during 1989. The meeting focused on the area of bulk importation of fertilizers with local bagging. Additionally, the topic of fertilizer imports financed by bilateral or multilateral donors, which account for a sizable portion of the fertilizer supply to the region, was covered in two discussion groups. The meeting was attended by 19 participants from 16 countries of sub-Saharan Africa along with 21 speakers and observers from 13 companies or organizations. The meeting of the fertilizer policy network, which was scheduled for December 1989, was postponed until 1990.

Training Programs

During 1989 two training programs—Statistical and Economic Analysis of Fertilizer Experimental Data and Fertilizer Supply Options and Constraints in Sub-Saharan Africa—were held in Lomé. A discussion of these programs can be found in the section, "Human Resource Development," beginning on page 55.

Engineering

Even though there is not a large engineering staff at IFDC-Africa, there were still several engineering-related projects during 1989. The major emphasis of the engineering group was to provide technical backstopping to the other groups, particularly through input to the studies being performed by the marketing group. Assistance was given to the marketing studies that began in 1988 (Benin) and continued into 1989 (Burkina Faso, Niger, and Togo). Additional work included liaison with the Office Togolais des Phosphates (OTP) on their construction of a phosphate rock beneficiation pilot plant that included coordination of the delivery of equipment and general engineering assistance during the initial construction phase of the project.

Engineering support was provided to the Economic Community of West African States (ECOWAS) Fund in their study of the possible rehabilitation of the Federal Superphosphate Fertilizer Company plant located in Kaduna, Nigeria. One engineer accompanied the ECOWAS team during their visit to the plant to obtain data to be included in the feasibility study. A report was prepared and submitted to ECOWAS.

Meetings were held with representatives of the Project Perkoa, the project to develop a zinc mining operation in Burkina Faso. Their interest was in the use of the recovered pyrites in the production of sulfuric acid. During one week of discussions, the project options and estimated costs of project alternatives were explored. The project representatives were interested in obtaining sufficient information to interest donors in the prospects of developing the sulfuric acid project for possible inclusion in an integrated development plan. The initial portion for zinc recovery is already being developed by a European company.

West African Agromineral Research and Development Program

The West African Agromineral Research and Development Program was initiated by IFDC in 1988 with the technical and financial support of the Federal Republic of Germany through Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ) or the Federal Ministry for Economic Cooperation. This program aims to help West African governments promote the use of local sources of raw materials for fertilizers.

A forum was constituted in 1988 for scientists working on agromineral deposits following the first workshop held at Lomé in 1988. Geologists, representatives of organizations, and institutions operating in the agrominerals field in West Africa met with the following goals:

- Evaluate some of the many phosphate and other agromineral deposits of West Africa.

Visiting IFDC's research station at Davié, Togo, are (from left): Dr. Anton Amberger, IFDC Board member; Dr. Paul L.G. Vlek, Director, IFDC-Africa; Dr. Uzo Mokwunye, Coordinator of Agronomic Research; and Ahli K. Pinto-Toyi, Associate Soil Scientist. Throughout West Africa, IFDC scientists are developing management practices to promote increased crop production while maintaining the natural resource base—the key to sustainable agriculture in the sub-Saharan region.

- Exchange scientific information at a regional level.
- Identify problems related to the identification and exploration of agrominerals and start a systematic process that will assess the potential of these deposits for fertilizer use in support of regional food crop production.

This network of 10 countries in West Africa facilitated the work in:

1. Collection of geologic information and technoeconomic data in six selected countries visited by a joint IFDC-Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) team of geologists and pedologists (Benin, Burkina Faso, Ghana, Mali, Mauritania, and Niger).
2. Development of data base on agromineral resources in West Africa.
3. Development of regional cooperation in the agromineral field and especially in the interaction between ministries and organizations operating in this scope.
4. Implementation of future interaction with agronomists, pedologists, and fertilizer-sector managers for an integration of ideas and abilities to solve national and regional food production problems.

An important resolution at the end of the first workshop was to identify project proposals on agrominerals development with a real chance of success; nine viable projects were selected for submission to potential donors.

The wishes of the officials from the countries visited, all with demonstrated support by the national governments, were (1) to find more cost-effective sources of fertilizer supply through the development of local agrominerals; (2) to have more opportunity to meet with their colleagues, exchange experience, and get training for the technicians and decisionmakers; and (3) to discuss projects and look for the technical and financial assistance required for their implementation.

Agronomic and Socioeconomic Research

Agronomic Research Program

During 1989 an additional benchmark site was opened at Koukombo in Togo to represent the environment of the Northern Guinea savanna zone of West Africa. At the old benchmark sites in Niger and Togo, several on-going trials continued to receive attention. These trials were set up to determine the nutrient needs of important food crops and soils, the effect of continuous cultivation with and without the addition of fertilizers and/or manure on soil productivity, the effect of different management practices, including crop rotation, on crop yield and fertilizer use efficiency, and the interaction between the four key nutrient elements (N,P,K,S) that form the major components of compound fertilizers found on the West African market.

One of these benchmark trials involves the evaluation of the agronomic potential of ground Togo phosphate rock in terms of direct

and residual responses and the ability of the rock to improve the phosphorus fertility of Togo soils.

At both Amoutchou (Plateau Region, Togo; subhumid, bimodal rainfall) and Tchitchao (Kara Region, Togo; subhumid, unimodal rainfall), this trial has gone on for 3 years. As would be expected from the chemical and mineralogical composition of Togo phosphate rock (TPR), the direct effect of the rock is poor when compared with single superphosphate (SSP). In this aspect, our results confirm earlier findings by Togo's National Institute of Soils (working in collaboration with IFDC) and by French institutions. This poor initial or direct response is the primary reason why TPR has not been recommended as material for direct application.

In monitoring the residual effectiveness of the TPR, we have attempted to measure the Residual Effectiveness Index (REI), which is defined as the ratio between the increase in yield from the residual phosphate and the increase in yield from a fresh application of SSP. Such knowledge is essential in the design of cropping systems that can take advantage of the residual effectiveness of phosphate fertilizers. Data in Table 1 demonstrate the trend of the REI values for three phosphorus sources for 1988 and 1989. The initial application was made in 1987. Of particular interest is the superior residual effectiveness of TPR as compared to SSP at both locations. All phosphorus sources were applied at the same rate. The data demonstrate that maize yield was highest where TPR was applied in 1987. These results show that if a Togolese farmer applies the recommended rate of phosphate fertilizers (60 kg P_2O_5/ha) as TPR to his maize and fails to reapply phosphate fertilizers in 2 years he can expect a potential yield equivalent to 73% of the yield he would have obtained had he applied the recommended rate of SSP during that season.

Table 1. Residual Effectiveness Index (REI) of Different P Fertilizer Sources at Two Locations in Togo

	REI[a]			
	Amoutchou		Tchitchao	
P Source	1988	1989	1988	1989
Togo phosphate rock	0.65	0.73	0.61	0.52
50% Togo PAPR	0.64	0.24	0.67	0.56
SSP	0.89	0.38	0.66	0.29

a. Increased yield of residual treatment.

Because of the high residual effectiveness of TPR, it can be surmised that this product can be used by the farmer to gradually improve the phosphate fertility of his soil. Data in Figure 1 show that after 3 years, the same quantity of maize was produced irrespective of the phosphate source.

The Government of Togo mines approximately 3 million tons of the phosphate rock annually. Every ton is exported and none is used locally. Yet, as results from our long-term soil fertility trials prove, phosphorus is one of the two most limiting nutrients in the soils of Togo (Figure 2). Current findings would tend to suggest that a shift in government fertilizer policy, whereby the direct application of phosphate rock is advocated, is in order.

Dr. Paul J. Stangel, IFDC Deputy Managing Director, and Aïssata Traoré, a field technician from Sougoumba, Mali, visit an experimental site where studies in fertilizer evaluation and adoption are being conducted. IFDC is actively engaging women in African agricultural research.

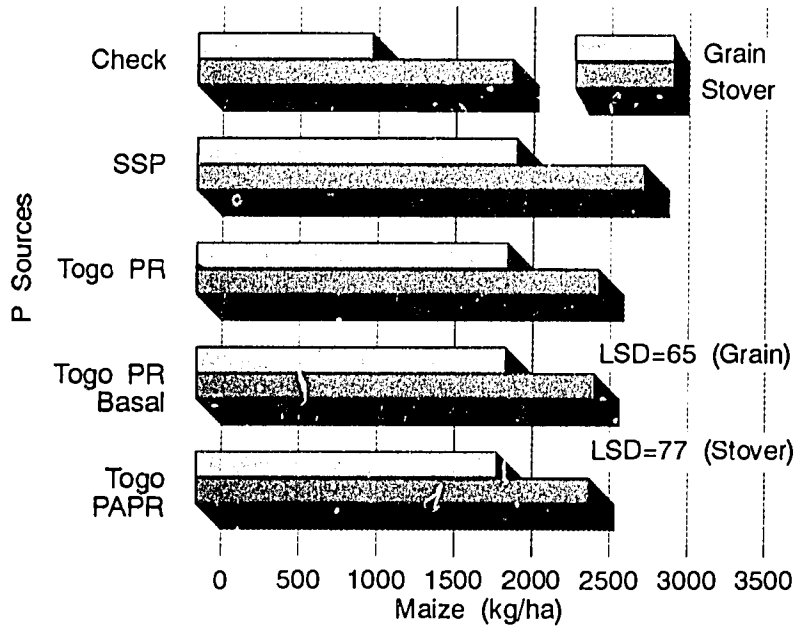


Figure 1. Residual P Trial: Evaluation After 3 Years (sp1) (Tchitchao, Togo, 1989).

The method of placement and time of application of phosphate fertilizer can improve the use efficiency of the fertilizer. The recommended time of phosphate fertilizer application in the Sahel is usually at the time of planting. Farmers however rarely adopt this recommendation and apply phosphate fertilizers only when they are sure that the crop is well established. This is usually 45 days after planting. For the past 2 years, we have conducted trials at two locations in Niger (Diakindi in 1988 and Tara in 1989) to study the effect of time of phosphate application on millet yield. The data shown in Figure 3 for Tara are similar to those obtained in 1988 at Diakindi. The soil is "hungry" for phosphate, and time of application had no effect on millet yield.

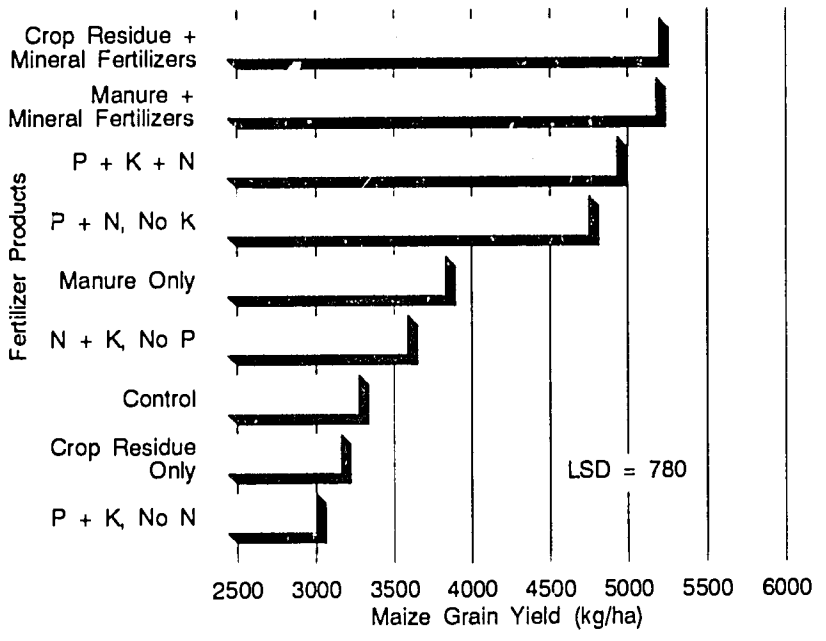
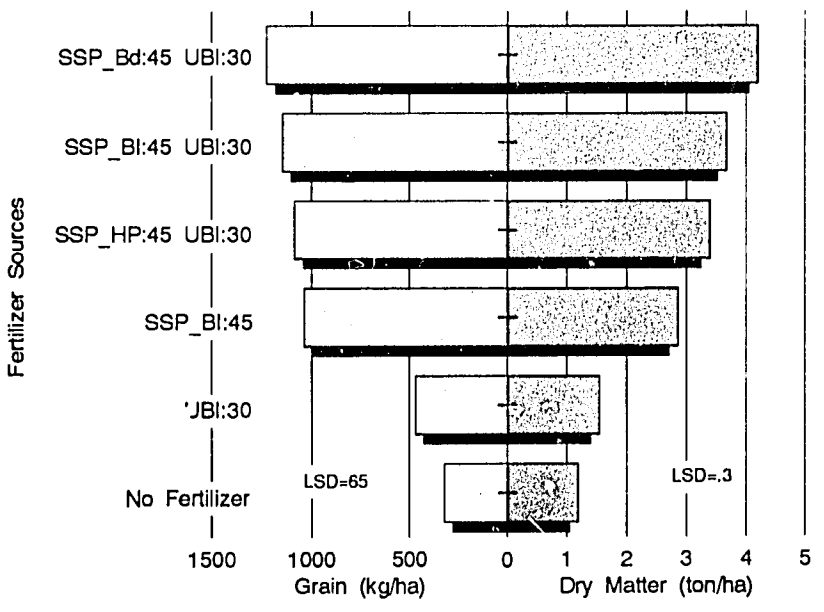


Figure 2. Long-Term Soil Fertility Experiment (Amoutchou, Togo, 1989).



Bd = Banded
BI = Broadcast and Incorporated
UBI = Urea Broadcast and Incorporated

Figure 3. NP Sources and Management: Millet Fertilizer Alternatives (Niger, 1988/89).

Management practices adopted by farmers have a tremendous effect on the response of a crop to fertilizer application. Although the recommended cropping density for millet in Niger is 10,000 plants/ha, farmers have traditionally used lower densities—an average of 5,000 plants/ha. This low density is to conserve moisture. As part of the on-farm research activities at Gobery in Niger, the researchers observed the diverse planting densities of the collaborating farmers and attempted to develop a model describing the effects of nitrogen and phosphate fertilizers and cropping densities and their interactions on millet yield.

The effect of planting density on millet yield and hence on fertilizer use efficiency was evident (Figure 4), and this information suggests that fertilizer packages for farmers must emphasize the importance of following correct agronomic practices such as the use of appropriate cropping densities.

As was emphasized in previous reports, the hub of the activities under the agronomic research program is WAFMEN. Assessing the efficiency with which staple food crops such as maize, sorghum, and millet use nitrogen fertilizers has continued to be a major component of the research conducted under the auspices of WAFMEN. In 1989 nine trials were established in six countries in West Africa using ^{15}N to study the fate and efficiency of nitrogen fertilizers. In previous years, IFDC has reported the need for phosphate in every country in West Africa. More recently the researchers have also noted interactions between various nutrients applied to different crop/soil combinations. The interaction

between nitrogen and phosphate is of such importance that several tests were set up to better study this phenomenon using ^{15}N. At Davie (Togo) and Farako-ba (Burkina Faso) where maize was grown, the application of phosphate increased the fraction of soil nitrogen used by the crop. The implications of this finding in terms of sustainable agriculture are enormous, and work is continuing to validate the results. The situation was reversed in a trial involving millet at Senegal. But in general, phosphate increased the quantity of nitrogen in the plant.

In these studies, the nitrogen was split applied, and ^{15}N was applied either during the first or second split in order to understand the efficiency of nitrogen use at different stages of the crop's growth. Results from Davie (Togo) showed that 75% and 90% of the nitrogen applied in the first or second split, respectively, was found in the plant/soil system. Both urea and nitrate were adequate sources of nitrogen, and maize yield was independent of the source. If this fact holds true, it has far-reaching economic consequences since many West African markets are presently closed to nitrate-N-containing compound fertilizers, which could be cheaper than urea-based compounds at the farm gate. In plots treated with the nitrate source, nitrogen was found at greater depths; this suggested a tendency for the nitrate to leach into deeper layers of the soil.

Examining the data from all locations, it was concluded that nitrogen use efficiency decreased as the rate of nitrogen applied increased.

In another set of trials, we studied the effect of crop residue management on nitrogen-use efficiency. The treatments that were considered included (1) residue removed, (2) residue buried, (3) residue composted and then buried, and (4) use of manure at 5 tons/ha. A cereal/cereal or cereal/legume rotation was adopted. Preliminary results indicate that the preceding legume enhanced the efficiency of nitrogen applied to the cereal. Also, the addition of crop residue or the use of manure improved the soil's contribution to the nitrogen pool used by the cereal.

For 5 days in February 1989, the Burkina Faso capital, Ouagadougou, played host to members of WAFMEN and other experts in tropical soil fertility, fertilizer use, and management. It was the occasion of the second symposium organized every third year to summarize the research findings by IFDC and its collaborating national scientists. The theme of the 1989 symposium was "Alleviating Soil Fertility Constraints to Food Production in West Africa." Thirteen of the 14 member countries of WAFMEN were in attendance. The subjects covered ranged from examination of climatic constraints to crop production and fertilizer use to the role of chemical fertilizers, manures, and crop residues in promoting crop growth and reducing soil degradation. A unique feature of this meeting was the contribution from different countries that summarized for the first time both published and unpublished work on soil fertility and fertilizers in the individual countries or regions of countries. The proceedings of this symposium are being edited and will be published first as a special issue of *Fertilizer Research* and later as a book by Kluwer Publishing Company.

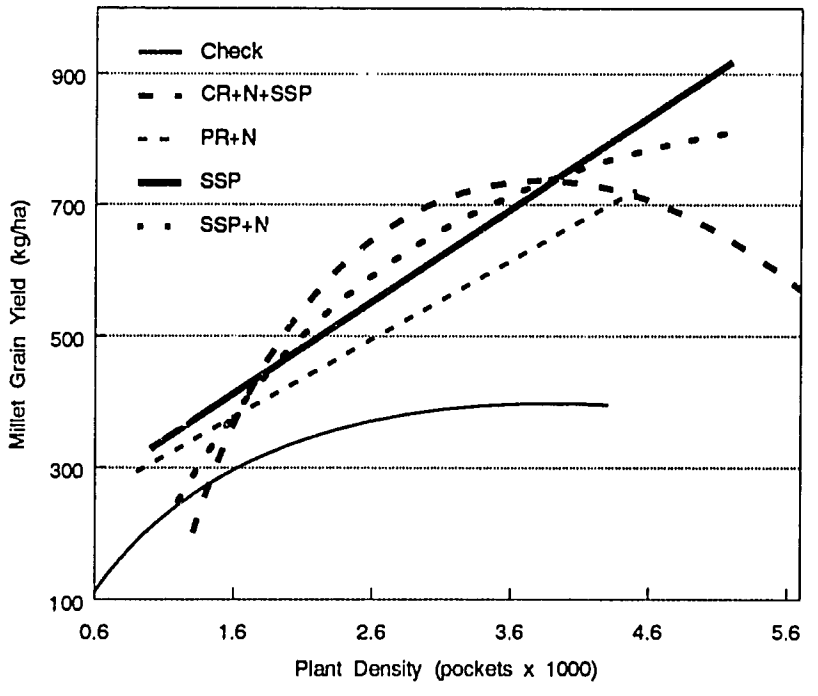


Figure 4. Effect of Cropping Densities on the Yield of Millet Subjected to Different Fertilizer Practices (Niger, 1988/89).

On-Farm Fertilizer Evaluation and Adoption

In the previous years IFDC's researchers have reported on their work with 19 farmers in the village of Gobery in Niger. They showed that during the 2 years of their association with these farmers, yield of millet increased by more than 250%. Equally spectacular was the fact that within 5 years, annual fertilizer consumption in the village increased from 2 tons of products to over 100 tons of products. This research pointed to the fact that

farmer participation in technology generation can play an essential role in the technology transfer process. The question that arises is "Can the Gobery experience be replicated elsewhere in West Africa?"

With funding from the International Development Research Center (IDRC), scientists, sociologists, economists and extension personnel from IFDC, the Institute for Agricultural Research (IAR) of the Ahmadu Bello University, Zaria, Nigeria, and the Institut d'Economie Rurale (IER) of Mali are attempting to answer this question.

The objectives of this research program are:

1. To strengthen Mali's and Nigeria's national research programs in their efforts to promote the judicious use of fertilizers through on-farm research, involving farmer participation.

2. To study the farmer's perceptions of constraints to fertilizer adoption in the participating countries.

3. To train national collaborators on "farmer participatory" approach to validation of research station results.

4. To help national programs to extend the on-farm program nationwide by assisting in the search for bilateral donor support.

5. To expose the participants of WAFMEN to the results of this project in order to stimulate adoption of this approach in other West African countries.

In Mali, the project is being carried out in three agroecological zones within the mandate area of Compagnie Malienne Pour le Developpement des Textiles (CMDT) or the cotton extension service. The villages chosen are Tafla in the Sahelian zone with a long-term average annual rainfall of 600 mm, Sogoumba in the Sudan zone with a long-term average annual rainfall of 800 mm, and Tifouga in the northern Guinea savanna zone with a long-term annual rainfall of 1,200 mm.

In Nigeria, four villages were chosen from the four states within the mandate area of the IAR extension service—Kaduna State, Kano State, Katsina State, and Sokoto State. The villages in the Sudan savanna zone are Yandoto in Sokoto State and Zogarawa in Kano State while the villages in the northern Guinea savanna zone are Malumfashi in Katsina State and Markafi in Kaduna State.

In each country, the technologies chosen to be validated were those developed by the respective national organizations in collaboration with IFDC under the auspices of WAFMEN. Thus, in Mali, the expansion in the use of Tilemsi phosphate rock was the primary technology to be tested. In Nigeria, interest was on the agronomic evaluation of the different compound fertilizers on the

At a farmers' meeting in the experimental village, Tchizon, in the Maradi Department of Niger, IFDC-Africa researchers are getting feedback from farmers and extension agents on proposals for fertilizer use and surveys. Frequent feedback is received from cooperating extension agents and farmers.

Nigerian market and the comparison of these with 50% Togo partially acidulated phosphate rock (PAPR). In addition, methods of nitrogen fertilizer application were evaluated under actual farm conditions.

A total of 81 farmers participated in the two farmer-managed trials conducted in Nigeria in 1989. The trial on the agronomic effectiveness of the compound fertilizers involved 25 farmers in Malumfashi who grew maize and 16 farmers in Zogarawa who cultivated sorghum. The trial on method of nitrogen fertilizer application involved 18 participating farmers in Markafi who cultivated maize and 22 farmers in Yandoto who grew sorghum.

The findings demonstrate that all of the fertilizer sources including SSP, 20:20:20, 27:13:13, and the experimental product PAPR are equally effective in terms of cereal yields. It is of interest to note here that the Government of Nigeria is exploring the possibilities of producing PAPR at the superphosphate factory located in Kaduna. These results agree with earlier results obtained by research personnel in numerous research station experiments conducted since 1984. Similarly, the findings indicate that the method of nitrogen fertilizer application (banded, ring application around plant, and hill placed (covered and uncovered)), had no influence on the yield of the cereals. Evidence from research station work suggests that nitrogen use efficiency is highly influenced by climatic factors, especially rainfall. Therefore, the results obtained during one season could be negated by results obtained in the following season. This evaluation will therefore be continued.

These preliminary results illustrate that factors other than choice of fertilizer material or method of application influence the farmer's decision to adopt a given fertilizer technology. These other factors are being intensively studied in the socioeconomic component of the project. IFDC scientists are still in the process of analyzing and interpreting the results of the first year's studies on the socioeconomic environments of the farmers and farm families.

In Mali the agronomic effectiveness of Tilemsi phosphate rock was tested using a rotation involving a cash crop (cotton or groundnut) and a cereal (maize, sorghum, or millet). In each village 30 farmers were selected; this enabled us to work with a total of 90 farmers in the three villages. The adopted scheme allowed 15 farmers in each village to start with a cash crop while the remaining 15 started with a cereal. In 1990 farmers who planted the cash crop in 1989 will plant cereal and those who planted cereal in 1989 will plant cash crops.

The data in Table 2 justify the efforts of the Government of Mali to attempt to promote the widespread use of Tilemsi phosphate rock. The interest of CMDT in this project ensures a measure of success since this organization traditionally supplies the commercial fertilizer to the cotton farmers.

As noted earlier, the data reflecting the agronomic results tell only a part of the story. It is important to determine how the level of the native fertility of individual farms, farmers' attitudes (including their level of enthusiasm), and the level of farm management skills at the disposal of the farmers affect the use of fertilizers. For example, the data in Table 3 show the difference in performance of maize between a farmer who adopts management practices recommended by the extension service and one who does not follow these practices. Management variables considered in the construction of this table include planting date, planting density, and time of weeding. Preliminary indications are that farmers who are unwilling to adopt good husbandry practices should be discouraged from using fertilizers.

Table 2. Effect of Phosphate Fertilizers on Crop Yield at Three Locations in Mali, 1989

	Tafia		Sougoumba		Tifouga	
Treatment	Groundnut Pod Yield	Millet Grain Yield	Cotton Grain Yield	Sorghum Grain Yield	Maize Grain Yield	Cotton Grain Yield
	(kg/ha)		(kg/ha)		(kg/ha)	
Absolute contribution	780 a	718 b	1,122 b	993 b	1,047 b	866 b
Farmers' practices[a]	884 a	745 b	1,351 ab	979 b	1,818 ab	1,462 a
Recommended[b]	851 a	894 ab	1,646 a	1,275 a	2,296 a	1,595 a
Tilemsi PRA*	825 a	961 ab	1,609 a	1,325 a	1,873 a	1,414 a
Tilemsi PRB**	775 a	1,039 a	1,691 a	1,464 a	2,192 a	1,562 a
LSD	250	279	381	280	818	311

Within a given column, treatments with the same letter are not significantly different.
a. Actual amounts of fertilizers applied by the farmers.
b. Amounts of fertilizer recommended by the extension service.
*PRA Phosphate rock applied at the annual recommended rate of P_2O_5/ha.
**PRB Phosphate rock applied at three times the annual recommended rate of P_2O_5/ha.

Table 3. Maize Grain Yield as Influenced by the Level of Management Adopted by Farmers in Nigeria and Mali

Level of Management	Maize Grain Yield	
	Malumfashi (Nigeria)	Tifouga (Mali)
	(kg/ha)	(kg/ha)
Farmer with best management	5.831	3.839
Farmer with poor management	441	492
Average production/village	2.886	1.815
CV	27	35

Fertilizer Investment for Soil Fertility Restoration

The Fertilizer Investment for Soil Fertility Restoration Project seeks to evaluate the impact of fertilizers and amendments, especially phosphates, on soil fertility, crop production, the evolution of farming systems and the socio-economy of selected villages in West Africa.

On the basis of exploratory surveys conducted in 1988, the experimental villages of Adjamesu, Naki-Est, and Tchizon and the control villages of Hwidiem, Kpembona, and Maiguero were selected in Ghana (humid), Togo (savanna) and Niger (sahel), respectively, for project intervention. These villages were deemed to have good potential for the use of fertilizers on a sustainable basis.

The major intervention of 1989 was to make available in the experimental villages fertilizers/amendments for up to 1 ha, 2 ha, and 3 ha of farmland per household in Ghana, Togo, and Niger, respectively. The fertilizer packages (options) involved the use of indigenous materials such as ground Tahoua phosphate rock in Niger, manures in Togo and Niger, and a material (PAPR 50) produced from the low-cost processing of Togo phosphate rock. The major cropping systems were maize/cassava intercrops in Ghana, millet/sorghum intercrops in Togo, and millet, sorghum, cowpea, groundnut, souchet in sole and/or mixtures in Niger.

Agronomic Research

The evaluation of strategies for restoring phosphate fertility in 1 year or over 2 years followed by maintenance dressings, taking cognizance of residual values, was initiated in 1989 in the form of village-level option plots and on farm trials. Monitoring commenced on soil properties, crop yields, land use, and weather. The objective of these studies is to identify agro-economically sound and environmentally safe strategies of using phosphate materials as investments in West African agriculture.

Preliminary statistical analyses were done on yields of maize in Ghana obtained from the fields (option plots) of approximately 60 farmers (males and females) in the experimental village. These are the farmers who are interviewed in the annual socioeconomic surveys.

There were no significant differences in maize grain yield response to the first-year applications of the following options: 80 kg N/ha + 40 kg P_2O_5/ha + 30 kg K_2O/ha formulated with urea and 15:15:15 compound or with partially acidulated TPR, urea and KCl; 80 kg N/ha + 40 kg P_2O_5 formulated with SSP and urea; 49 kg N/ha + 19 kg P_2O_5/ha + 19 kg K_2O/ha formulated with sulfate of ammonia and 15:15:15.

All options were, however, superior to the check plots in the experimental villages. Grain yields increased from 1,800 kg/ha (check) to 3,570 kg/ha for the option based on 15:15:15 + urea.

Data obtained from yield plots in the control village showed maize yields ranging from 1,326 to 2,989 kg/ha, with a mean of 2,340 kg/ha.

Socioeconomic Research

The objectives of the 1988 baseline socioeconomic surveys were (a) to validate the results of exploratory surveys conducted earlier in the year to select pilot villages and (b) to generate data that will provide a basis for determining the social and economic consequences of fertilizer use interventions in subsequent years in the pilot villages.

A siratified-random sample of a total of 375 farmers, including 133 women, were interviewed in the villages of Adjamesu and Hwidiem (Ghana, humid); Naki-Est and Kpembona (Togo, Savanna); and Tchizon and Maiguero (Niger, Sahel) with questionnaires that contained open- and close-ended items. The survey generated data on farmers' sociodemographic characteristics; resource availability and utilization; cropping systems; disposal and use of crop output; and finally, the perceptions of farmers about constraints to fertilizer use and agricultural production.

The most instructive findings of the surveys are as follows.

- Men in Ghana have the greatest average in years of schooling (7.8), followed by Niger (2.2) and Togo (0.8). Among women, the pattern for average years of schooling shows women in Ghana ranking first with 4.1 years, followed by Togolese women with 0.2 years, and the

sample of women in Niger reported no formal schooling.

- There is a concentration of larger households among farmers in Togo, 11 persons on the average, than among farmers in Ghana and Niger—6 and 8 persons, respectively. Thus, farmers in Togo have more household labor available for agricultural work than farmers in Niger and Ghana.

- Regardless of region, farmers generally own the land they crop. Aside from the collective plots that are predominantly managed by men, women and men manage their individual plots; however, each gender may manage plots of the other in a cooperative exchange. The same principle applies to the allocation of household labor although the use of various categories of labor by men and women varies by region, gender, and task. For all major agricultural tasks that include land preparation, planting, weeding, and harvesting, men contributed 54% of the average workdays, women 39%, and children 7%.

- Cropped area per farm is greatest among farmers in Niger where men cultivate an average of 10 ha, followed by men in Togo (4 ha), and Ghana (0.7 ha). Among women farmers, the Togolese, Nigerien, and Ghanalan samples cultivate 3 ha, 2.1 ha, and 0.6 ha, respectively.

- Ownership and use of agricultural equipment are minimal among men in all of the three sample regions, Ghana (7.4%), Togo (7.3%), and Niger (6.5%). No women farmers reported owning agricultural equipment. Ownership of handtools is virtually universal although the percentage of women owning handtools is always less than

Dr. Daniel Pierre (foreground), IFDC Soil Scientist, takes water samples from a well in Tchizon to monitor the nitrogen and phosphorus contents as part of IFDC's policy to monitor environmental effects of fertilizer applied in the Sahelian zone. Environmental monitoring is one of the commitments of the Soil Fertility Restoration Project with USAID

men. The same principle applies to the ownership of animals.

- With the exception of the Togolese farmers who receive fertilizers on credit to grow cotton, fertilizer use in general is minimal regardless of the region. Farmers in Niger and Togo cited lack of money as the main reason for not using fertilizers. In Ghana, men and women who do not use fertilizers cited the most important constraint as having "no knowledge" about the use of fertilizer products.

- There is a remarkable regional variation in off-farm employment of men and women farmers. In Ghana, the percentages of women and men farmers engaged off farm are equal (30%). In a stark contrast, the percentage of the Togolese women sample that engaged in off-farm work (72%) is much greater than that of the men sample (32%). In Niger, 35% of the men reported off farm, and off-farm employment among women farmers was nil. Overall, the estimated average gross annual income from farm and off-farm activities for men is about twice as much as that for women in all three regions. This is probably due to the type of off-farm activity, intensity of labor, and cropped area per farm.

- Finally, farmers perceive declining soil fertility, inadequate rainfall, and pests as the three most important constraints to agricultural production. This uniform perception of soil fertility as an important constraint clearly demonstrates that the goals of Soil Fertility Restoration Project (SFRP) address one of the most important concerns of farmers in the West African subregion.

East and Southeast Africa Fertilizer Research Program

Continued progress in the East and Southeast Africa Fertilizer Research Program was made in 1989 although funding was reduced by 50%. The World Bank was the principal source of funding during 1989.

Collaborator Networks

The Department of Agricultural Research, Ministry of Agriculture, Malawi, joined the Fertilizer Management and Evaluation Network in 1989. This brings to nine the number of nations collaborating in the Network. The number of geology network collaborators remains at six. Institutions evaluating phosphate products made from indigenous deposits during 1989 include: International Livestock Center for Africa (ILCA), Ethiopia; Department of Soil Science, University of Nairobi, Kenya; National Agricultural Laboratories, Kenya; Australian Centre for International Agricultural Research (ACIAR/Commonwealth Scientific and Industrial Research Organization (CSIRO)), Kenya; Chitedze Agricultural Research Station, Malawi; Department of Soil Science, Sokoine University of Agriculture, Tanzania; National Soil Service, Tanzania; Department of Soil Science, Makerere University, Uganda; Department of Soil Science, University of Zambia; Soil Productivity Research Programme/Mount Makulu Research Station, Zambia; and IFDC/Southern African Development Coordination Conference (SADCC)/ICRISAT, Soil Productivity Research Laboratories, Zimbabwe.

Field Trial Results

Field evaluation of phosphate products made from indigenous deposits continues to expand. In these studies, the agronomic effectiveness of less expensive phosphate fertilizer materials like ground phosphate rock, PAPR, and phosphate rock compacted with superphosphates is being compared with conventional phosphate fertilizers, i.e., SSP, double superphosphate (DSP), and TSP. The available results from Zimbabwe in 1989 indicate that some of these alternative sources can perform well even under poor rainfall conditions. The rainfall during the 1988/89 season was below normal, and crop failures were experienced in a number of areas in Zimbabwe. At Matopos rainfall during the 1988/89 season was 431 mm compared with 911 mm for the previous season (the long-term mean for the site is 572 mm). For maize grown on a small-scale farmer's field at Mutambara, Dorowa (Zimbabwe) phosphate rock (DPR) was 75% as effective as DSP, while 25% PAPR and 50% PAPR were 72% and 91% as effective as DSP during the 1988/89 season. At Matopos under near-neutral soil pH conditions, and using sorghum as a test crop, 50% PAPR was 65% as effective as SSP. Residual effectiveness of 50% PAPR was of the same magnitude as that of TSP (37% versus 36%) but lower than that of SSP (64%). At both sites, all phosphate fertilizer sources significantly increased grain yield. The value:cost ratios are favorable for Dorowa phosphate rock and PAPR.

Network Proceedings

The first workshops in the East and Southeast Africa Fertilizer Research Program were conducted in late 1987. The agromineral workshop was conducted in Lusaka, Zambia, and the fertilizer management and evaluation workshop was held in Nairobi, Kenya. Proceedings of both workshops were published in 1989. The agromineral proceedings has country reports identifying agromineral deposits in each of the participating East African countries. The evaluation proceedings contains country reports discussing current fertilizer research and future needs.

Technical Assistance in Africa

Burundi

Progress continued in assisting the Department of Mines and Geology to assess the Matongo phosphate ore in Burundi for possible fertilizer production. The technical and preliminary economic merits of using the ore for producing SSP, PAPR, organic fertilizers (Bioearth) and for direct application are under evaluation. In 1989 five phosphate samples of Matongo phosphate rock from Burundi were studied in laboratory and pilot plant-scale tests to obtain high-grade phosphate concentrates suitable for SSP and 50% PAPR processing. Samples tested were high in iron oxides, alumina, and silicate impurities. Chemical analyses and mineralogical studies of the rocks also indicated that some of the phosphate is nonapatitic (mainly aluminum phosphates). These nonapatite phosphates and other impurities were reduced to low levels by the beneficiation process developed by IFDC.

Preliminary tests revealed that normal beneficiation procedures failed to produce a high-grade phosphate ore. Similarly, gentle scrubbing failed to reach this goal. However, high-speed scrubbing, attrition scrubbing, and flotation were sufficient to produce high-grade phosphate concentrate.

The phosphate concentrates produced in the laboratory from Matongo phosphate rocks are relatively high in grade (38.7%-40.4% P_2O_5) and low in impurity content (iron, aluminum, and silica). However, the calcium oxide/P_2O_5 weight ratio of the concentrates was lower than the other commercial igneous ores, indicating that even with these relatively sophisticated beneficiation processes some of the phosphate is nonapatitic and cannot be removed.

Based on the laboratory-scale tests, 11.7 tons of Matongo phosphate rock was upgraded by flotation in continuous pilot-plant beneficiation tests conducted by the North Carolina Minerals Research Laboratory, Asheville, North Carolina, under the direction of IFDC.

High intensity wet magnetic separation (HIWMS) pilot-plant processing tests were performed on two samples of the phosphate rock at Eriez Magnetics, Erie, Pennsylvania. The grades and impurity contents of the concentrates produced by the pilot-plant tests were very similar to the concentrates produced in the laboratory at IFDC. The concentrates produced were finely ground to 70% passing through a 0.075-mm (200-mesh, Tyler) opening screen. These concentrates will be used for the production of SSP, PAPR, and a direct application product.

The beneficiation data will be used by IFDC engineers to develop a preliminary mine plan and design a beneficiation plant to feed an SSP/PAPR plant that will be designed to meet the expected demand of the proposed fertilizer market in Burundi.

Egypt

Since 1987 IFDC has been involved with the United Nations Development Programme (UNDP)/ United Nations Industrial Development Organization (UNIDO) to assist the Egyptian Government in developing an Egyptian Fertilizer Development Center (EFDC). In 1989 IFDC signed a subcontract with UNIDO to conduct an opportunity study to assess the potential of specialty (NPK-PLUS) fertilizers in Egypt and to install physical properties, nitrogen, and phosphate laboratories and a pilot plant at EFDC. IFDC is working with the

Egyptian officials to help them develop the concept for the EFDC. They have decided it would be beneficial to combine all of the research and development efforts for the various fertilizer companies in Egypt. The building for the center already exists at Talkha, one of the fertilizer plant sites north of Cairo. The building has been remodeled and is now ready for the equipment and staff to move into.

Much of the equipment will be similar to that at IFDC Headquarters and will be fabricated or ordered according to these specifications. IFDC has already established a data base facility with computers installed, data bases developed, and personnel trained in the use of the equipment.

Ready for installation in 1990 are a physical properties laboratory and nitrogen and phosphorus bench-scale equipment. A pilot plant will be contracted for in 1990 and constructed in 1991. IFDC will provide the small laboratory equipment, assist in installation, and, in most cases, supply the training for the personnel.

IFDC will serve as a consultant in the construction of the pilot plant and operation after it is completed in 1991.

The IFDC role is also to assist in the development of the organization, its programs of research, and how they interact with the agricultural sector. A Technical Advisory Board has been organized and is in operation. Official representatives from the Ministry of Agriculture and the National Research Center as well as the Principal Bank for Development and Agricultural Credit, which is the distribution arm of the Ministry of Agriculture, will assist the Center in determining the developmental direction of new fertilizer products. Their respective organizations will be involved in the evaluation of these new products.

An investment analysis group is also being formed in the Center, and training is in progress. The objective is for EFDC to be able to make investment feasibility studies for the fertilizer industry.

The Center is designed to improve existing fertilizer products, develop new materials for Egypt's changing agriculture, and centralize the fertilizer information for use by the entire fertilizer sector in Egypt.

Kenya

USAID/Kenya Program Assistance

IFDC has made a significant contribution to fertilizer sector reform in Kenya through a series of technical assistance missions funded by USAID during the past 5 years. As a result of this involvement, the Kenya fertilizer market has made the successful transition from a government-controlled system to one in which private-sector firms are responsible for marketing over 75% of the fertilizer used in the country.

As a continuation of IFDC's long-term assistance to USAID/Kenya, in 1989 IFDC marketing specialists conducted an evaluation of the status of the fertilizer marketing system and assessed the need for and scope of the continued involvement of USAID in the Kenyan fertilizer sector. It was recommended that the USAID fertilizer program be phased out by 1995. For the remainder of the program, USAID's focus should be on further reducing the Government's involvement in import allocation and fertilizer pricing—two key areas that impede further development of the marketing system.

Fertilizer Inputs Unit, Ministry of Agriculture

At the request of USAID/Kenya, IFDC provided assistance to the Fertilizer Inputs Unit (FIU), Ministry of Agriculture. The main objectives were (1) to assess the organization, operational guidelines, and performance of the FIU and make recommendations to improve its operations and (2) to assess the adequacy of the fertilizer pricing model methodology used by the Government in setting fertilizer prices.

It was recommended that the FIU be revitalized and provided the necessary support to ensure its success in fulfilling the Government's role in providing a fertilizer data bank and in monitoring performance of the fertilizer sector. The pricing model used in setting fertilizer prices was modified to reflect the current cost of marketing fertilizers. Retail fertilizer prices for the 1989/90 fertilizer year were established. The model was also adapted for use on a desk-top computer.

Malawi

The Republic of Malawi commissioned IFDC to conduct a study of the fertilizer marketing system in Malawi. The study was concluded in August 1989. The principal focus of the study was to assess the marketing system, identify principal constraints, and recommend a system that would make appropriate fertilizer available to smallholder farmers on a timely basis and in a cost-effective manner. The scope of work called for the consideration of involving the private trader in marketing.

The soils and climatic factors in Malawi are favorable for crop production. Research shows that efficient use of fertilizers will increase yields by two to three times the present production levels. Maize is

In future research at IFDC, the potential of fertilizers to reduce environmental problems should receive greater emphasis. Applications of fertilizer may help to reduce the amount of slash-and-burn and shifting agricultural practices, which are often used in developing countries (as seen in Ghana in this photo) to replenish nutrients on very infertile soils.

grown on 66% of the total area in cultivation. The annual survey of agriculture indicated that only 24% of smallholders fertilize local maize, whereas 85% of hybrid maize is fertilized. A timely supply of fertilizers in a cost-effective manner was a key constraint to the use of fertilizer.

The study team found that Malawi's fertilizer marketing system, which is characterized by two channels of distribution (i.e., one for smallholders and one for estates) and a two-tier pricing system, contributed to a number of inefficiencies in the marketplace. The smallholder fertilizer was subsidized at about 42% in 1988, whereas the private sector was not subsidized. It was recommended that the current system be abandoned in favor of a marketing system based upon private-sector business concepts and one which would serve all Malawi farmers. Under the recommended system, the two-tier pricing would be discontinued. Initially, fertilizer marketing would be liberalized at the retailer level; later, private-sector firms would be granted import licenses. The Government of Malawi is considering recommendations of the study.

Tanzania

Minjingu soft rock is being mined and beneficiated by the Minjingu Phosphate Company (MIPCO) to produce a concentrate containing about 30% P_2O_5. The Minjingu soft rock concentrate (MSRC) has up to 6% P_2O_5 soluble in neutral ammonium citrate, which indicates a high degree of reactivity and good potential for use as direct application fertilizer on acid soils. The MSRC is extremely fine and a significant dust problem is associated with handling and application of this product. Its sales potential for direct application is likely to be enhanced if an economical method can be identified to dedust the concentrate. Under contract with the Finnish Department for International Cooperation (FINNIDA), IFDC conducted a study entitled "Macro- and Microeconomic Study of the Minjingu Phosphate Company, Arusha, Tanzania" in 1988. The study indicated a market potential for in-country direct application of MSRC. In addition, there is the potential for export of MSRC to Kenya for direct application, for use in SSP production, and for use in bulk blends.

IFDC proposed that MIPCO perform a study on how to develop products more suitable for handling, transport, and application to intensify its sales for direct application of MSRC. The company will benefit by expanding sales volume to increase earnings and export to Kenya to generate foreign exchange. Having dealt with similar problems in other developing countries, IFDC has considerable expertise to tackle problems of this type.

Under an agreement with MIPCO, IFDC performed a technical and economic study for the production of granular fertilizer materials containing MSRC. The technical study was carried out in the continuous laboratory-scale compaction/granulation unit to produce granular MSRC and combinations of MSRC and other fertilizer materials. Such materials as urea, ammonium sulfate, triple superphosphate, and potassium chloride will serve as binders and in addition will provide plant nutrients for specific crops. The granulation tests were successful, and an economic study for plant investment

and production costs to produce granular fertilizers was generated.

Togo

OTP in Lomé, Togo, contracted IFDC for technical assistance in acquiring and installing a beneficiation pilot plant to be located at their phosphate rock processing facility in Kpéme, Togo. IFDC has provided OTP with the process flow sheet, process equipment specifications, electrical and piping specifications and bill of materials, and plant layout drawings for this pilot plant. The IFDC contract was completed in 1989, and the new facility is expected to begin operating in early 1990. The new pilot plant will be used by OTP to test new local ore types and/or deposits for future production. These ore types and/or deposits are expected to require beneficiation in order to increase the phosphate grade to commercial levels. The information gained from the pilot plant will allow OTP to modify their existing plant to process these new ore types. IFDC is prepared to provide further assistance to OTP for technical problems or personnel training as needed.

Zambia

IFDC completed three technical assistance projects in Zambia during 1989. The initial project involved a USAID-funded evaluation of the fertilizer marketing system. The objectives were to assess the effective demand for fertilizers in Zambia and to evaluate the efficiency of the marketing system in satisfying the fertilizer-related needs of Zambian farmers. The study team concluded that fertilizer use was restricted due to inefficiencies in the marketing system and that the fertilizer subsidy encouraged the sale of Zambian fertilizers to neighboring countries.

It was recommended that the fertilizer sector be restructured with Nitrogen Chemicals of Zambia (NCZ) being responsible for fertilizer importation and domestic marketing activities down to the retail level. Fertilizer marketing would be liberalized with NCZ selecting marketing channels that could best serve the farmer. Retailers would include the cooperatives, parastatals, and private chemical dealers. The Government of Zambia fully endorsed the study and implemented the plan in July 1989. The recommendations called for the new marketing system to be phased in during the first year.

The second technical assistance project involved providing assistance to NCZ in dealing with the immediate and long-term implications of its newly assigned marketing responsibilities. Working documents concerning stock levels, a schedule of import arrivals, and provincial fertilizer requirements were developed for NCZ. In addition, recommendations were made relative to establishing a marketing department within NCZ.

IFDC's final involvement in Zambia in 1989 involved (1) assisting USAID with development of an agricultural sector reform plan and (2) assisting NCZ in developing a

marketing department and outlining its marketing programs for the 1990 fertilizer year. The recommended USAID/Zambia agricultural program plan is being considered and the NCZ marketing program plan has been implemented.

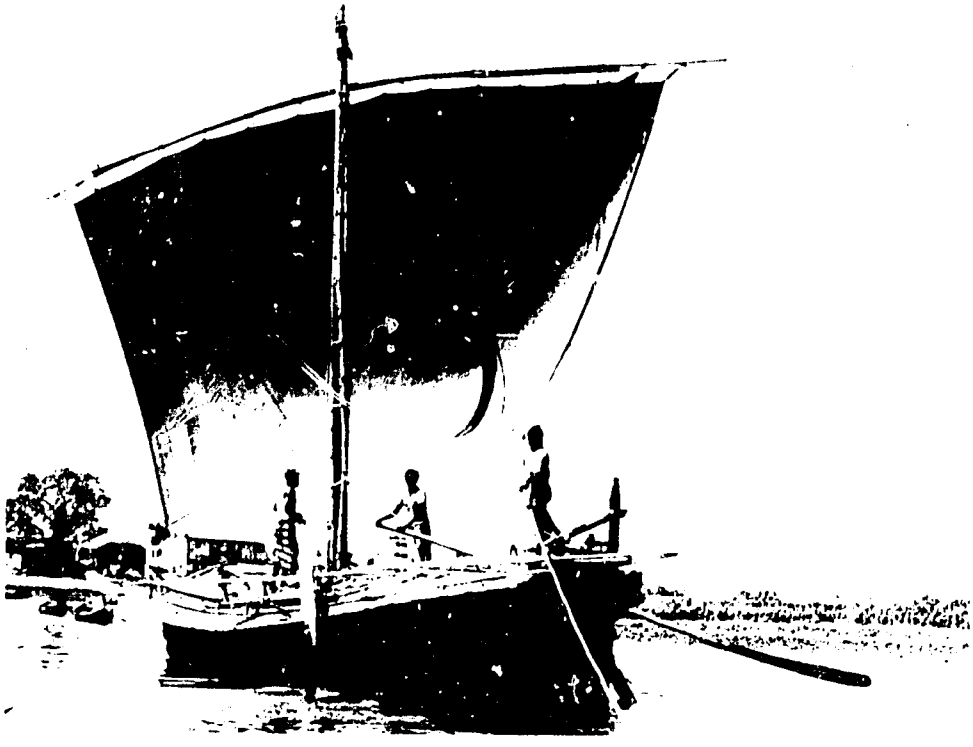
Zimbabwe

The possibility of using phosphate rock or modified phosphate rock as a substitute for soluble phosphates in preparing NPK fertilizers was investigated by a visiting scientist from Zimbabwe. Using Dorowa phosphate rock, a low reactive phosphate rock from Zimbabwe, NPK fertilizers were prepared by mixing urea and potassium chloride with (1) finely ground (-100 mesh) Dorowa phosphate rock, (2) partially acidulated Dorowa phosphate rock (PAPR 50% H_2SO_4), and (3) Dorowa phosphate rock compacted with TSP such that 50% of the total phosphorus in the mixture was water soluble. The agronomic effectiveness of these products was compared with that of SSP mixed with urea and potassium chloride on an acid Hartsells silt loam (pH 4.8) with maize and rye grass as indicator crops.

Fertilizer prepared with a compacted mixture of phosphate rock and TSP as the phosphate source was found to be as effective as the one prepared with SSP in increasing the dry-matter yield of both maize and ryegrass. Dorowa PAPR mixed with urea and potassium chloride was 75% as effective as the SSP-based fertilizer while the phosphate rock mixture was totally ineffective in promoting the growth of the plants. The agronomic effectiveness of the phosphate sources was of the order SSP = compacted (PR + TSP) > PAPR > PR = check.

The results of these studies indicate that compacted mixtures of phosphate rock with soluble phosphate sources can be used effectively in preparing multinutrient fertilizers. Such materials are being further evaluated using soils from Zimbabwe.

Asia Fertilizer Sector



Boats are one means of transporting fertilizer in Bangladesh.

Introduction

In its continuing efforts to create sustainable soil fertility in the developing countries of Asia, IFDC furthered its programs in nitrogen, phosphate, and sulfur research. The Center's scientists developed and evaluated two cost-effective placement methods for urea supergranules. Its nitrogen research in the Philippines made new strides in integrated fertilizer management in legume/rice-cropping systems. In Indonesia the Center advanced its search for cost-effective alternatives to the more expensive conventional phosphate products. In Thailand the Center's scientists concentrated their efforts on increasing the use efficiency of fertilizer sulfur—a nutrient that is becoming increasingly important in supporting a sustainable agriculture. In Bangladesh IFDC's Dhaka-based consultants helped the Government fine-tune efforts toward privatization of the fertilizer sector. The beneficiaries of these successful efforts are the Bangladeshi farmers who now can more readily find fertilizers on a timely basis and at affordable prices. In their rice paddies, Bangladeshi farmers are seeing with their own eyes the results of deep placing urea supergranules—more rice in their baskets, more money in their pockets and, thus, more food for their tables.

Research Activities

Nitrogen Research

Deep Placement of USG

Nitrogen fertilizers have contributed significantly to an increase in food and fiber production and are a key input where nitrogen-responsive crops are grown. One of the most important crops of Asian countries is rice, and it requires substantial quantities of nitrogen. The primary nitrogen fertilizer used on rice at present and probably for the remainder of the century is urea. When urea is applied to flooded rice, however, nitrogen efficiency is low because of loss mechanisms, in particular, ammonia volatilization. Any loss of nitrogen applied to the soil is also a loss of a nonrenewable energy source and an environmental problem. One technique that has been studied for improvement of nitrogen use efficiency in wetland rice production in developing countries is the deep placement of large particles, commonly referred to as USG. One of the main constraints to USG use by the farmers has been the supply of this fertilizer material. Economic studies presented by IFDC showed that USG can be produced by several processes, but the production volume versus the market demand made the production cost of USG for most of these processes too high to be affordable by the farmer.

Design of Briquetter

IFDC, continuing its effort to find a low-cost means of supplying USG to the rice farmers of Asia, tested and modified in Indonesia a small Chinese-made village-level briquetter in 1986 and 1987. From the work performed it was concluded that a relatively simple and economical technology has been found to fabricate small-scale briquetters that will produce USG at an affordable price for the farmers. However, some modifications were required to make the technology acceptable to developing countries. With this in mind, IFDC designed and fabricated a village-level briquetter to produce USG. The IFDC briquetter was originally designed to produce 1-g oblong-shaped briquettes at an approximate production rate of 200 kg/hour. The machine was fabricated using gears, bearings, metals, etc., which should be available in almost any country. The machining needed to fabricate the briquetter could be done in small shops in developing countries. The first briquetter that was fabricated worked well but includes a gear box that may not be available in some countries. For this reason IFDC is planning to design different types of briquetters. The gear box will be substituted with a fly wheel, which can be cast in many countries. At present the briquetter is driven by an electric motor, but the possibility of driving it with a diesel or gasoline motor is on the drawing board. This will be very useful in villages where there is no electric power. Different sizes of urea briquettes (1-2 g) will be produced by changing the rolls' surface design. There are many other ideas that will be developed with time. For the immediate future IFDC plans to test the briquetter for extended periods to determine its endurance and ascertain if further improvements are needed before making this technology available outside IFDC.

George W. Bolds (right), IFDC Pilot Plant Operations Coordinator, demonstrates the IFDC briquetter to these Ethiopian Government officials: Mohamed Getta Omer, Head of Planning, Ministry of Mines and Energy; Mamo Gebremaskel, General Manager, Ethiopian Petroleum Corporation; Tekeze-Shoa Aytenfisu, Minister of Mines and Energy; and Worku Wondimu, General Manager, National Chemical Corporation, as Dr. Paul J. Stangel (far left), IFDC Deputy Managing Director, looks on. Briquetting is a cost-effective method for producing environment-friendly urea supergranules.

Development and Evaluation of USG Placement

Deep placement of USG in transplanted rice (*Oryza sativa* L.) is an additional operation that requires high additional labor. Secondly, USG per se is not an efficient fertilizer, but proper deep placement makes it efficient. Therefore, IFDC's attempts continued (1) to reduce the high labor requirement of the USG placement, (2) to provide additional agronomic benefits for the USG placement that will help compensate (override) its additional labor costs, and (3) to ensure agronomic efficiency of deep-placed USG for increasing probability of obtaining additional yields.

In collaboration with Konkan Krishi Vidyapeeth (KKV), Dapoli, Maharashtra State; Central Rice Research Institute (CRRI), Cuttack, Orissa State; Indian Farmers' Fertiliser Cooperative Ltd. (IFFCO), New Delhi, India; and Philippine Rice Research Institute (PhilRice) in the Philippines, several field trials were conducted during 1989, and the highlights of the results are given below.

Two methods for USG placement —the IFDC transplanting guide and the IFDC briquette applicator—were developed and evaluated.

Additional research involved the investigation of using loppings of nitrogen-fixing trees as a green

manure to enhance the agronomic efficiency of deep-placed USG. Other research concerned the agronomic efficiency of deep-placed USG containing DAP as a nitrogen/phosphorus source for rainfed transplanted rice.

IFDC Transplanting Guide

In collaboration with KKV, a simple inexpensive (US $0.2 to $0.3/unit) bamboo device called a "Transplanting Guide" has been developed. Preliminary field observations in India and in the Philippines showed that this apparatus can be fabricated by a farmer on his farm, and after a demonstration, field workers are able to use it for

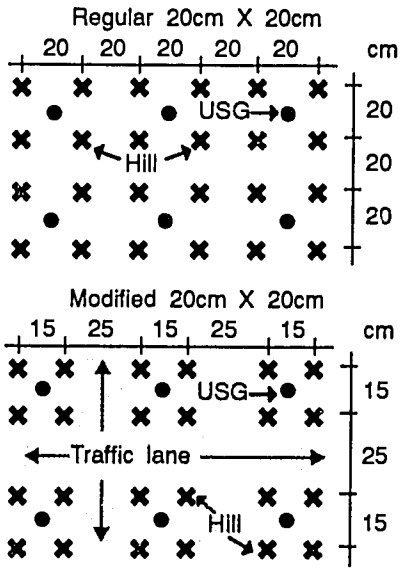


Figure 5. Schematic Sketches of Regular and Modified Spacings With 25 Hills/m².

line transplanting. In the method developed by IFDC, a worker uses a transplanting guide for line transplanting and on the same day or the next day of transplanting deep places USG using "traffic lane" of modified spacing (Figure 5).

Future plans include testing the adoption and acceptance of the IFDC transplanting guide method of hand placement of USG by farmers on their fields.

IFDC Urea Briquette Applicator

A plunger-type, completely hand-operated applicator (Figure 6) has been developed for mechanical deep placement of urea briquettes in transplanted rice primarily for use by small rice farmers. It is made of PVC pipes; therefore, it is lightweight (3.5 kg), rust free, and affordable. Its draft requirement is low (about 4 kg). The results of field evaluation of the applicator, conducted in collaboration with PhilRice in the Philippines during the 1989 dry season, indicated that the prototype worked satisfactorily. The applicator consistently placed urea briquettes at an adequate depth (7-8 cm), which

Figure 6. Urea Briquette Applicator.

resulted in low concentration of urea-N (<7 ppm) in about 4 cm of floodwater one day after fertilizer placement. Average work output of the applicator was 0.20 ha/workday/person and may increase with practice.

With the IFDC applicator method, a worker uses the applicator for mechanical deep placement of urea briquettes in transplanted rice with modified spacing. In collaboration with Indian universities, research centers, and cooperatives (KKV, CRRI, and IFFCO) and PhilRice of

An Indian worker uses the IFDC applicator for deep placement of pillow-shaped urea briquettes in transplanted rice with modified 20-cm x 20-cm spacing. Deep placement of urea supergranules when followed by immediate sealing of the holes left at the placement sites helps reduce nitrogen losses and thus avoids pollution to the atmosphere and groundwater. Thus, increasing the efficiency of fertilizer use not only produces more food but also provides wiser use of energy resources and protects the environment.

the Philippines, 12 field trials were conducted during 1989 wet and dry seasons. The major objective was to evaluate agronomic performance of the urea briquettes deep placed by the applicator and by hand and compare it with that of split-applied prilled urea under different agroclimatic conditions. The main observations are as follows:

1. The yields of transplanted rice for the applicator placement and hand placement of urea briquettes were statistically equal, and the yields for both the placements of urea briquettes were consistently superior to the split-applied prilled urea.
2. Workers need some practice in order to use the equipment properly primarily because of its completely manual operation.

Future plans include the development of a urea briquette applicator attachment to the modified IRRI transplanters, modification of the design of the urea briquette applicator to make it semi-automatic, additional farmer-managed field trials of the applicator in different agroclimatic conditions, and evaluation of the agronomic efficiency of the applicator in direct-seeded rice using a modified IRRI drum seeder.

Evaluation of Agronomic Efficiency of Deep-Placed USG With Limited Gliricidia Loppings as Green Manuring in Rainfed Transplanted Rice

In collaboration with KKV, two field trials were conducted during 1989 wet (Kharif) season in a high rainfall tract of Maharashtra State, India. The main objective was to study the possibility of using limited amounts of loppings of gliricidia, nitrogen-fixing trees growing on bunds and hedges or around paddy fields as a green manure (agroforestry approach), to ensure or to improve agronomic efficiency of deep-placed USG in rainfed transplanted rice. In the trials, the deep-placed USG (35-54 kg N/ha) with 2 tons of loppings/ha as limited green manuring significantly increased grain yields as compared with the same amounts of split-applied prilled urea and gliricidia green manuring. The integration of an agroforestry concept with the agronomic practice of deep placement of USG can offer a potential approach to help develop a low-cost input, environment-friendly, and sustainable rice farming system for economically disadvantaged small rice farmers of the developing countries of Asia.

Evaluation of Deep-Placed USG Containing Diammonium Phosphate (DAP) as an NP Source for Rainfed Transplanted Rice

In collaboration with KKV, two field trials were conducted during 1989 wet (Kharif) season in a high rainfall tract of Maharashtra State, India. The main objective was to study the agronomic efficiency of deep-placed USG containing DAP (USG-DAP) as a nitrogen/phosphorus source for rainfed transplanted rice. The yield responses demonstrated that USG-DAP deep placed at transplanting was agronomically superior to the basal broadcast and incorporated SSP (25-28 kg P/ha) in combination with prilled urea (45-50 kg N/ha) applied in two equal splits. The results imply that the deep placement of USG (with right N:P ratio) at transplanting with modified spacing (Figure 5) can be a judicious choice for improving the agronomic efficiency of prilled urea and DAP in rainfed transplanted rice especially on soils with high P-fixing capacity.

Future plans include the development and evaluation of multinutrient supergranules containing nitrogen (as urea and DAP), phosphate (as DAP), and potassium (as KCl) for wetland rice.

Collaborative Nitrogen Research With IRRI

Nitrogen Fertilizer Sources and Management

Rice is the main food crop of an estimated 40% of the world's population. More than 90% of the rice in the world is produced in Asia. Within Asia an estimated 60% of the nitrogen fertilizer consumed is on rice, with urea being the most important nitrogen fertilizer for rice.

Past research has shown that traditional broadcast urea is prone to high losses as nitrogen gases in lowland rice fields. Consequently, the agronomic efficiency of urea, defined as kilograms of grain produced per kilogram of nitrogen applied, is low. IFDC has been extensively involved in research to identify and develop strategies for increasing this existing low agronomic efficiency of urea. Strategies under investigation include: amendment of urea with inhibitors, alternate timing and incorporation of urea, coating of urea, and deep placement of urea.

Amendment of urea with a urease inhibitor offers the attraction of improving urea effectiveness without modifying the farmers' existing fertilizer application practices. In more than 12 field experiments over the past 10 years in the Philippines, the currently promising urease inhibitors showed little or no increase in agronomic efficiency over conventional broadcast urea. Most recent field results, averaged for two sites in the Philippines, illustrate the very slight yield advantage from amendment of urea with N-(n-butyl) thiophosphoric triamide. Improved management of conventional urea (recommended split application or deep placement) offered more potential for increasing yield than amendment of traditional broadcast urea with a urease inhibitor.

The recommended practice for basal incorporation of urea in puddled lowland rice soils is to broadcast urea and then immediately incorporate it with the final harrowing and land leveling prior to transplanting or seeding. Water buffalo- and single-axle, tractor-drawn harrows are typically used for the final harrowing by small Asian rice farmers. However, basal incorporation of the first urea split has failed to match the agronomic efficiency of all basal-applied sulfur-coated urea (SCU) or deep point-placed USG.

This failure of the recommended urea application practice to match the yield with SCU and USG is at least partially due to high nitrogen losses for incorporated urea. Measurements of floodwater (urea + ammoniacal)-N and partial pressure of ammonia following basal incorporation of urea indicated that tillage implements were only partially effective in incorporating urea. None of the tested implements were as effective as band placement of liquid urea. Considerable scope remains for the improvement of fertilizer incorporation in puddled rice soils.

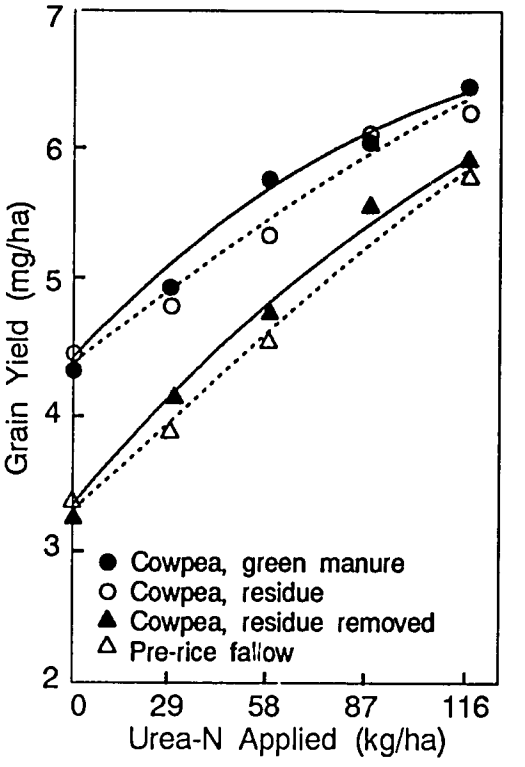


Figure 7. Effect of Pre-Rice Treatment on Response of Lowland Rice to Applied Urea, Averaged for 2 Years in the Philippines.

Integrated Nitrogen Management

The nitrogen taken up by rice is normally derived from soil organic matter, biologically fixed nitrogen, and commercial fertilizer. Integrated nitrogen management in rice-based cropping systems, therefore, involves effective management of native soil nitrogen, biological nitrogen fixation, and chemical nitrogen fertilizers.

Legumes grown either before or after wet-season rice can be a major source of biological nitrogen fixation (BNF) in rice-based cropping systems. Suitability of a legume in the dry-wet transition period prior to wet-season rice depends on the degree of soil waterlogging. Grain legumes, such as cowpea and mungbean, are sensitive to waterlog whereas some green manure legumes, such as *Sesbania rostrata*, are adapted to flooded soil conditions. IFDC is working closely with the IRRI on integrated fertilizer management in legume rice-cropping systems.

One area of research involves the growth of waterlog-sensitive grain legumes with supplemental irrigation prior to the onset of the wet season. Response of the subsequent wet-season rice crop to prilled urea is strongly influenced by management of the prior legume (Figure 7). Growth of cowpea to maturity followed by removal of grain and all aboveground vegetation did not result in a significant

residual nitrogen effect on the subsequent rice crop. However, incorporation of cowpea at flowering stage as a green manure or incorporation of cowpea residue remaining after harvest of grain and pods significantly increased yield of rice by approximately 1 ton/ha. Green manure and residue substituted for 42 and 45 kg urea-N/ha. Growth of cowpea to maturity rather than as a green manure offered the advantage of 1 ton/ha cowpea grain production. This research illustrates that residues of cowpea only partially substitute for urea and that integrated use of urea with residue is essential to meet the nitrogen requirements of irrigated wet-season rice.

Legume green manures, such as *Sesbania*, offer possibilities for substitution of urea fertilizer in environments with poor soil drainage and a high probability of soil waterlogging prior to the rice crop. Collaborative research with IRRI has shown that incorporation of 45- and 60-day old *Sesbania*, which contained 83 and 163 kg N/ha, respectively, totally substituted for urea fertilizer on the subsequent rice crop (Figure 8). In the absence of *Sesbania*, weed control during the fallow prior to rice strongly influenced the yield of the rice crop. Weeds and *Sesbania* significantly reduced native soil nitrate before soil flooding for wet-season rice, thereby reducing losses of native soil nitrogen by denitrification and leaching. At least part of the increased rice yield from incorporated weeds and *Sesbania*, when grown *in situ*, appears due to conservation of native soil nitrogen. Nitrate-N taken up by plants prior to soil flooding is recycled in the plant residues incorporated during land preparation for rice. IFDC is working closely with IRRI to identify crop and soil management practices that effectively utilize native soil fertility, thereby reducing nitrogen fertilizer requirements for rice and reducing the emissions of nitrous oxide, a greenhouse gas formed during denitrification.

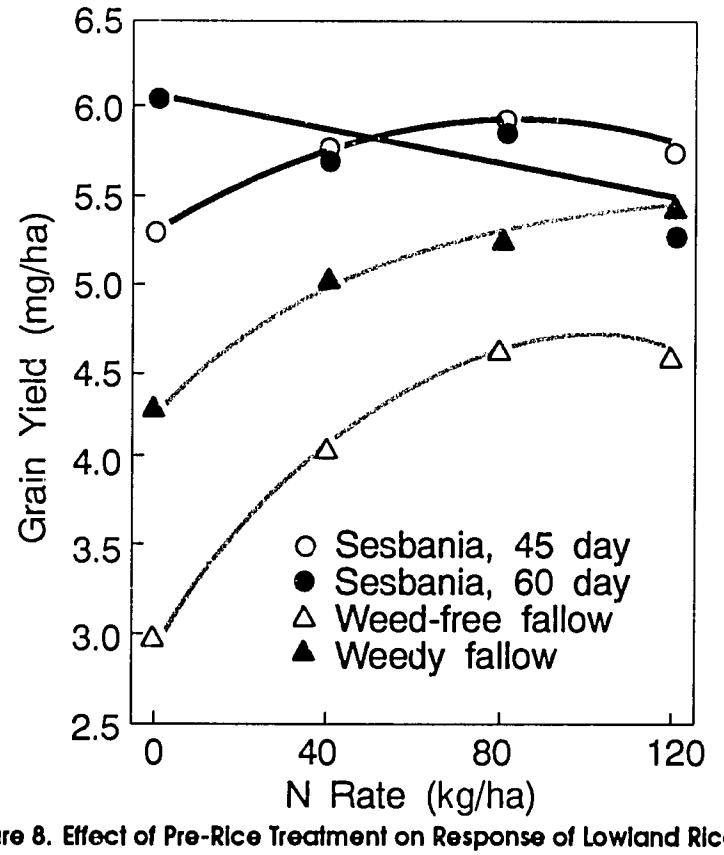


Figure 8. Effect of Pre-Rice Treatment on Response of Lowland Rice to Applied Urea at One Site in the Philippines.

Collaboration in Vietnam

IFDC is collaborating with IRRI and Vietnamese national research organizations on nitrogen fertilizer efficiency research in Vietnam. One objective of ongoing field research in the Red River and Mekong Deltas is to determine the effectiveness of existing nitrogen fertilizer use practices. Partial pressure of ammonia following urea application was used as a relative measure of susceptibility of nitrogen to loss as ammonia. High partial pressure of ammonia following the current practice of urea incorporation with standing water in the Red River Delta during the summer season indicated a high potential for nitrogen loss. Similar high potential for nitrogen loss has been obtained in the Philippines. An alternate practice of incorporating urea without standing water partially reduced the partial pressure of ammonia.

Similar research is ongoing in the winter/spring season in the Mekong Delta in order to identify rice-growing environments with the greatest scope for improving nitrogen use efficiency.

Urease Inhibitors to Increase Nitrogen Efficiency

Research has continued on increasing the efficiency of urea applied to flooded rice, primarily by attempting to reduce the amount of losses of nitrogen through ammonia volatilization, which in some experiments has been one-half of the fertilizer applied. These losses have been shown to depend on the amount of ammoniacal-nitrogen in the floodwater, the pH of the floodwater, and wind conditions.

A method to reduce the amount of ammoniacal-nitrogen in

the floodwater or at the soil surface is to use a urease inhibitor which acts on the soil enzyme (urease) which, in turn, causes the conversion of urea to ammoniacal-nitrogen and carbonates. By slowing this conversion, less ammonia can be lost, and the urea has more opportunity to move into the soil where the nitrogen is less likely to be lost than at the soil surface or in the floodwater.

However, when urea hydrolysis studies were conducted concurrently with ammonia volatilization experiments in the IFDC greenhouse, it was found that large reductions in ammonia loss were not accompanied by equally large reductions in urea hydrolysis. Thus, on day four at 32° (Table 4), the urea treatment lost 31.6% nitrogen as ammonia and showed 85% hydrolysis while the urea plus 0.01% nBTPT had 12.1% loss with 63% hydrolysis. This indicated that reduced nitrogen loss was not solely a function of the direct effect of the inhibitor on hydrolysis. More detailed soil-sampling procedures were therefore initiated to study the mechanism of inhibition. A granule was placed on the soil surface and a 0.9-cm thick vertical section was cut beneath the fertilized point. This 3.6 x 2.0-cm deep section was further subdivided into 45 subsections, and each of these subsections was analyzed for pH, urea, and ammonium concentration.

The data showed that the nBTPT had caused the urea to diffuse into the soil, preventing hydrolysis at the point of application in the soil surface. When the urea had moved away from the point of application, hydrolysis began quickly, resulting in diminished ammonium concentrations at the soil surface and a reduced soil pH. In contrast, the urea-only treatment showed much higher concentrations of ammonium at the soil surface and exhibited a soil pH, 1.25 units higher than for the inhibitor treatment, conditions conducive to nitrogen loss. These data show that the efficiency of an inhibitor relates more to its effect on urea diffusion as affected by hydrolysis rate rather than hydrolysis rate alone.

In ten experiments conducted in southeast Asia, nBTPT did not perform well—unlike all of the greenhouse experiments conducted with flooded U.S. soils. It has been shown that nBTPT is not an actual urease inhibitor but must be converted to its oxygen analog form by contact with the soil if it is to act as a urease inhibitor. Samples of the soils used in several of the Asian field experiments were used in experiments at Headquarters to determine the rate of development of the active form of the inhibitor in these flooded soils relative to the U.S. soils. This was done by measuring the amount of inhibitor in the floodwater with time using an *in vitro* enzyme analysis technique. While the U.S. soils developed concentrations of the active form quickly, the soils from southeast Asia developed very little of the active inhibitor. Research will continue to determine what soil constituents are responsible for the formation of the active inhibitor. Another option to achieve urease inhibition on these soils might be to use the oxygen analogs of the proinhibitors in the flooded soil systems.

Table 4. The Effects of Soil Temperature and Urease Inhibitor Additions on Ammonia Volatilization Losses

Incubation Temperature	Treatment	4 Days Ammonia Volatilization	4 Days Urea Hydrolysis
		(%)	
32°	Urea	31.6	85.1
	Urea + 0.1% nBTPT	4.3	35.2
	Urea + 0.01% nBTPT	12.1	63.0
25°	Urea	12.3	65.1
	Urea + 0.1% nBTPT	0.7	30.7
	Urea + 0.01% nBTPT	1.8	42.0
18°	Urea	10.6	64.9
	Urea + 0.1% nBTPT	0.7	26.5
	Urea + 0.01% nBTPT	1.8	37.9
	LSD	4.0	7.8

Phosphorus Research

Field Research in Indonesia

Phosphate rock has been used for decades in Southeast Asia on acid soils dedicated to the production of perennial crops such as rubber and oil palm. However, the rate of dissolution of these insoluble sources has historically been considered too slow to support the growth of annual crops. Research at IFDC has shown that phosphate rocks vary widely in their solubility in various extracting solutions and that the more reactive rock sources may be viable phosphorus sources for short-term food crops as well.

In 1987 IFDC initiated a collaborative research project with the Indonesian Agency for Agricultural Research and Development through the Centre for Soil Research to compare the effectiveness of directly applied medium- and high-reactivity phosphate rocks (from Jordan and North Carolina, respectively) with TSP in annual cropping systems. Five 3-year field experiments, established on a range of

soil types in Sumatra (*IFDC Annual Report 1988*), are being cropped each year with a cereal (maize or upland rice)-soybean rotation. Treatments were split after the first cycle to permit the estimation of phosphorus source maintenance rates from repeated annual applications and to compare the residual effectiveness of soluble and insoluble sources. During 1988 and 1989 these experiments completed two cropping cycles during which both phosphate rocks were found to be generally as effective as TSP in increasing grain yields (Figure 9). In comparisons of annually applied treatments with residual value treatments receiving the same total phosphorus application over the two cycles, split (annual) applications produced significantly higher yields than single biennial applications on the less-weathered, less-acidic soils but similar yields on the more acidic highly weathered soils.

The effect of liming on crop response to TSP and phosphate rock sources is also being examined in these trials. Although lime applications are often required for optimal growth of food crops on highly weathered acid soils in the tropics, liming is also considered to reduce the effectiveness of phosphate rock because it increases both soil pH and soluble calcium concentrations that tend to discourage phosphate rock dissolution. At the same time phosphate rocks are considered to have an inherent liming value since acid is consumed and calcium released as they dissolve. In the Sumatran trials, only enough lime was applied to reduce soluble aluminum in the soil to nontoxic levels. Initially, in experiments conducted on the more acidic soil types, lime was required to obtain satisfactory phosphorus responses whether the phosphorus source was soluble TSP or an insoluble phosphate rock (Figure 10). On the less acidic soils where lime responses were not initially observed, the development of more acidic conditions with successive cropping has resulted in declining yields in all phosphorus source treatments (TSP and phosphate rock) that did not receive an initial lime application. However, phosphate rock sources appeared to be less severely affected. These results suggest that the liming value of phosphate rock applications is rather marginal and certainly insufficient on the more acidic soils that dominate much of Sumatra.

Sulfur Research

Field Research in Thailand

Previous collaborative field experiments with the Nuclear Research in Agriculture Branch of the

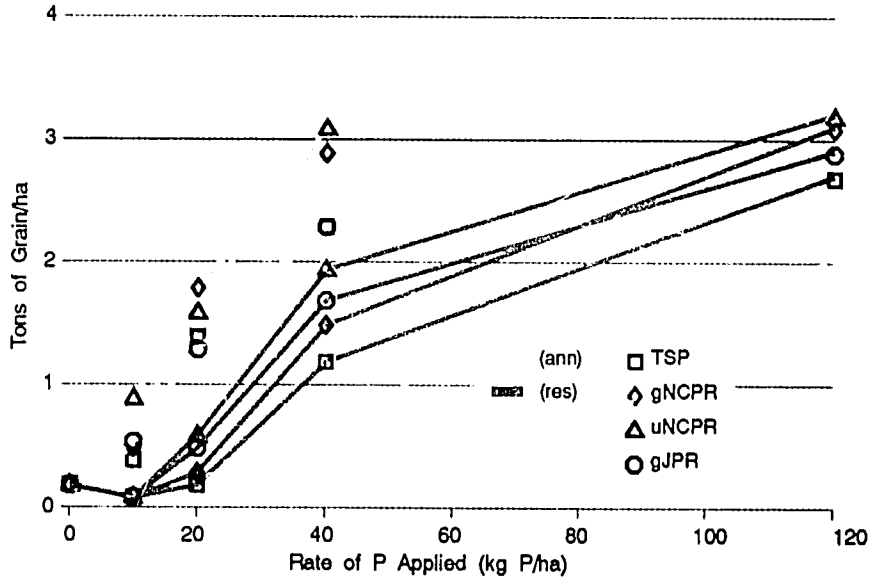


Figure 9. Maize Grain Yields During 1988/89 Wet Season at Palembang, Sumatra.

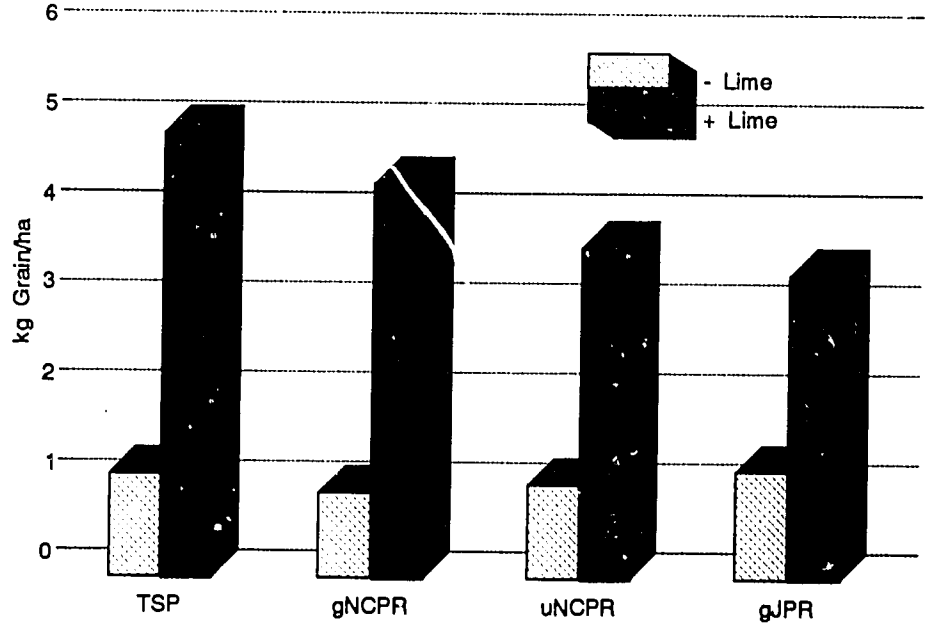
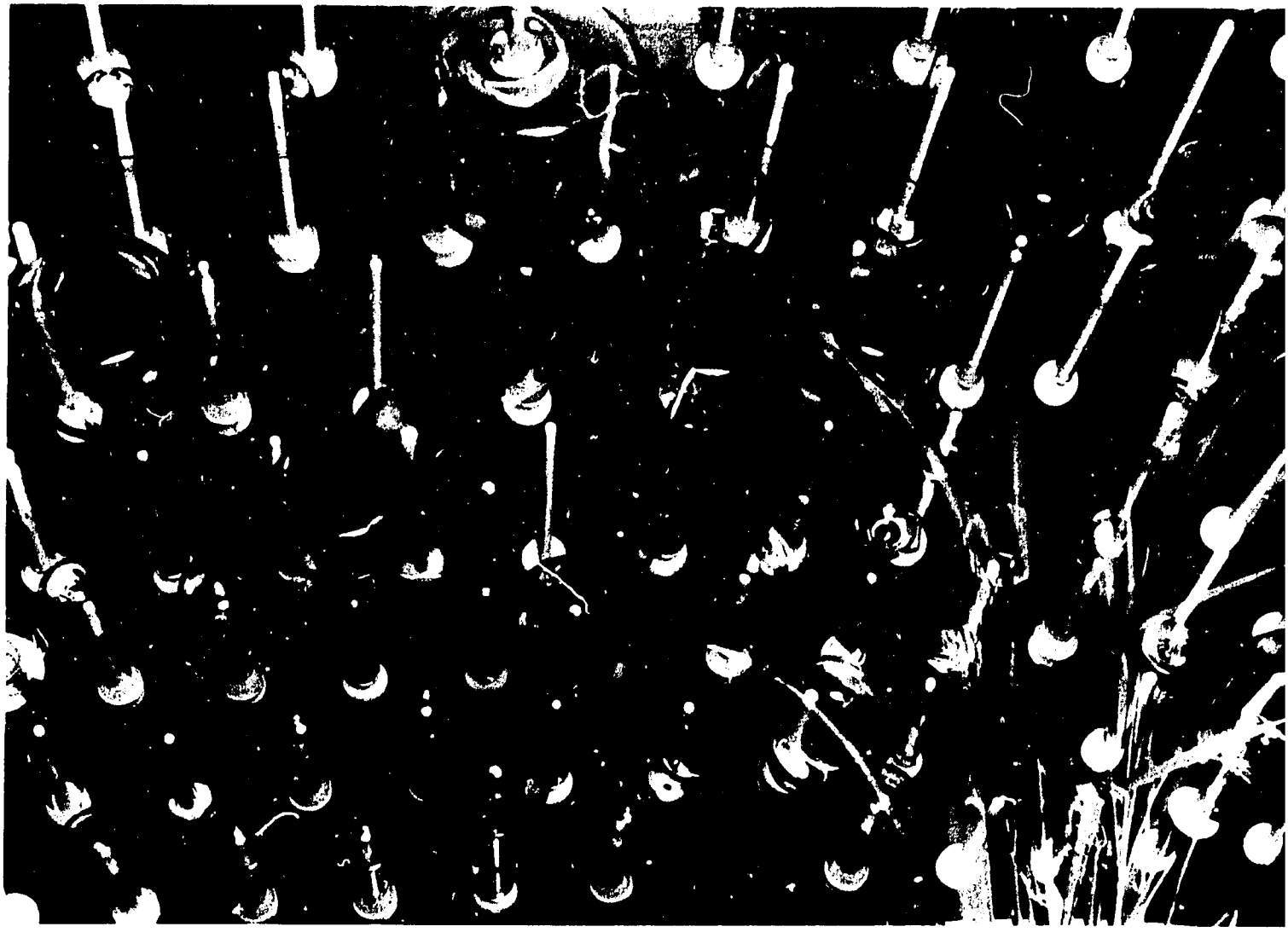


Figure 10. Effect of Lime on Maize Response to Phosphorus Sources at Kuamang, Kuning.

Thailand Department of Agriculture suggested that leaching of applied sulfur is not an important loss mechanism on the lower terrace soils of the northeast plateau. In an experiment on rainfed lowland rice in 1986 (*IFDC Annual Report, 1987*), movement of sulfur below 30-cm depth from both sulfate and elemental sulfur sources was minor although 30%-35% of the applied sulfur could not be accounted for at harvest. Since microplots were inundated during heavy rainfalls in that experiment, a supplementary experiment was carried out in 1989 to assess the susceptibility of fertilizer-sulfur to loss in moving floodwater.

Radioactive ^{35}S from two sources ((SSP, 13% S) and elemental sulfur-fortified TSP (S/GTSP, 16% S)) was monitored in the floodwater of microplots for 9 weeks after incorporation. Approximately 6% of the applied sulfur from both sources was found in the floodwater within 3 hours after incorporation into paddy soil with 4 cm of standing floodwater. Whereas sulfur derived from S/GTSP declined steadily thereafter, floodwater sulfur from SSP increased to 19% of the sulfur applied during the next 7 days and then declined sharply during heavy rainfalls which again inundated the microplots. Elevated fertilizer sulfur concentrations have also been observed in floodwater samples taken from similar IFDC/IRRI collaborative experiments examining the fate of fertilizer sulfur applied to irrigated lowland rice in the Philippines. The results suggest that high concentrations of fertilizer sulfur (and other soluble nutrients) in the floodwater during the first week after application could result in substantial fertilizer loss in runoff from paddies with flowing floodwater, particularly after heavy rainfall events.



Technical Assistance in Asia

Malaysia

The NPK granulation plant operated by FPM Sendirian Berhad, a joint-venture Malaysian Company, completed 7 years of commercial operation in 1989. The granulation process is unique in that it is based on urea as the primary source of nitrogen and unacidulated phosphate rock as the major source of P_2O_5. During 1989 the FPM organization continued work on optimizing its production formulations and product quality. IFDC provided technical assistance to FPM at a low level primarily in the area of optimization of new product formulations and the evaluation of alternative raw material sources.

Nepal

The National Planning Commission, with funding from UNDP, laid plans to initiate a Fertilizer Sector Management Study, beginning in early 1990. Engaged to draft a project design for the study, IFDC's Deputy Managing Director traveled to Nepal during 1989.

The main objectives of the 1-year project are to develop a plan for an appropriate fertilizer supply management system designed to pool donor assistance and Government resources and to increase significantly the total supply of appropriate fertilizers in Nepal. The project is also designed to rationalize Nepal's present transport and distribution system by identifying the appropriate roles for the public and private sectors and the means to realize these roles. Transport, storage, and credit action plans will also be developed to ensure accessibility and affordability of fertilizer to farmers in the Hills and Terai Regions.

All chemical fertilizer used in Nepal is imported and distributed by the Agricultural Inputs Corporation (AIC), which reports to the Ministry of Agriculture. AIC supplies fertilizer to village cooperatives and private dealers. Since 1984/85 total fertilizer consumption has not changed greatly and in some regions may have actually declined. This stagnation appears to be due to both inadequate fertilizer supplies and an insufficient number of retail outlets.

In spite of its significant advances in fertilizer use over the past 17 years, Nepal still ranks among the lowest countries in Asia in intensification of use. Its farmers use fertilizer at only one-third the rate of Bangladesh or Pakistan and one-fourth the average for all Asian countries. In order to meet its food production goals by the year 2000, Nepal will have to more than triple its fertilizer use from 120,000 tons of product per year (1988) to approximately 440,000 tons of product per year by the year 2000.

Yields of maize, rice, and millet have dropped approximately 25% in the Hills Region over the past decade. To avoid a major food crisis by 2000, Nepal must take immediate action to increase its food production. It is believed that improved distribution and a higher volume of imported fertilizer will increase agricultural production and farmer income.

The immediate beneficiaries of the fertilizer sector project will be AIC and the private sector. However, the main beneficiaries will be the Government, the farmers, and the Nepalese people. The Government will benefit because the fertilizer sector will be more efficiently operated, which should result in a lower drain on Government funds and increased agricultural production. The farmer will benefit through additional income resulting from greater yields created by increased use of fertilizer delivered on time, in the proper amount, and at an affordable price. The nation's people will benefit from an increased supply of food, a stronger economy, and a possibly cleaner and safer environment.

Saudi Arabia

Under an agreement between the Governments of Saudi Arabia and the United States, the U.S. Geological Survey contracted with IFDC through NFDC/TVA to undertake studies to evaluate the development potential of the Al-Jalamid phosphate deposit of Saudi Arabia. Others involved in the project include Jacobs Engineering Group, Inc., of Lakeland, Florida; East-West Center in Honolulu, Hawaii; and the

USGS offices in Reston, Virginia, and Denver, Colorado.

IFDC activities include: (1) characterization of four ore types; (2) determination of beneficiation characteristics of these ores using calcination and flotation; and (3) evaluation of beneficiated concentrates for production of wet-process phosphoric acid and diammonium phosphates (DAP). This project was initiated in 1988 and completed in 1989.

Prior to this 1-year study it was shown by others that this material could only be beneficiated by calcination. However, IFDC was also to demonstrate that the flotation route could be used successfully to produce a concentrate that met international specifications. The advantage of using the flotation process is that the capital investment is lower; thus, the overall production costs would be lower.

The concentrate produced during beneficiation tests was successfully converted to phosphoric acid with minor adjustment in processing conditions. This acid was subsequently converted to DAP that conformed to international specifications.

The data generated by IFDC were used by the Jacobs Engineering Group (Jacobs) for preliminary plant design. Jacobs and others used this information to conduct an investment/production cost analysis.

The availability of high-grade phosphate products on the international market is diminishing. With the projected increase of world population and requirements for food, new deposits are needed to supply the fertilizer requirements. Thus, the Al-Jalamid deposit is one of the potential deposits of the coming decades.

Turkey

Akdeniz Gübre Sanayii A.S. (Gübre) of Turkey operates a DAP granulation plant that they wish to convert to NPK production. The proposed NPK production would be based on the use of either urea or calcium ammonium nitrate as the major source of nitrogen.

At the request of Gübre, IFDC fertilizer production specialists reviewed the existing Gübre DAP plant design and recommended changes and additions that would be required to convert the unit to the production of NPKs. Basic process design parameters, including expected production capacity data, were specified by IFDC to enable Gübre management to decide if the proposed conversion would fit their needs.

National Programs

Bangladesh

The year 1989 marked a decade of continued involvement by IFDC in providing fertilizer marketing consulting services in the form of a host-country technical assistance contract with BADC, an agricultural inputs marketing organization sponsored by the Government of Bangladesh (GOB). This technical assistance to BADC is funded under the Fertilizer Distribution Improvement Projects of USAID. In late 1989 the contract was changed from BADC to the Ministry of Agriculture and IFDC.

The goal of the project is to increase agricultural production by increasing fertilizer use through the development of a cost-effective and responsive fertilizer marketing system with adequate supplies nationwide. This is being achieved through the development of large-scale wholesalers and distributors with a potential for nationwide distribution and sale of fertilizer in a competitive marketing system.

Fertilizer is a key input for agricultural production in Bangladesh. A study conducted in 1988 indicated that the annual rate of increase in rice production has been maintained at 2.43% during the last 10 years even though area under paddy leveled off during the last 5 years. Increasing use of fertilizer accounted for about 30% of the increased rice production.

Marketing

During the year 1989, IFDC's technical assistance services centered on consolidating and refining the earlier marketing developments, policy changes, and continuing the process of developing increased private-sector involvement in the fertilizer marketing system.

During the year the structure of fertilizer marketing has changed drastically due to a major Government policy change occurring during the year. GOB, under the advice and help from IFDC resident consultants, allowed direct purchase of urea fertilizer by private distributors as well as BADC from the Ghorasal Urea Factory. Because of the remarkable performance of the private sector, direct sale was subsequently operated from all of the remaining five urea factories. That resulted in higher sales of 15% more fertilizer compared to the corresponding year's sales. The total FY 1989 sales amounted to 1.7 million tons. The aggressiveness and speed with which the private sector entered the fertilizer market and penetrated the countryside has had a sudden and sharp impact on BADC's fertilizer operation and farm-level prices.

From a total monopoly a year ago, BADC's market share of urea fertilizer dropped to 8% of the total. GOB closed down 15 BADC sales outlets and released the warehouse to another government agency for storage of food grain. In September GOB reviewed the marketing systems and further planned to close another 45 sales outlets out of 60 to be operating in early 1990. The remaining 15 outlets may temporarily continue in 1990 before final phaseout.

At the same time, spatial variability in fertilizer prices has significantly narrowed, and the prices at the farm level have sharply declined in all parts of Bangladesh, reflecting improved fertilizer availability to the farm sector and competition during the year.

Encouraged by the marketing developments and persuasive analytical efforts and advice of IFDC, GOB has decided to privatize the imports of fertilizer. IFDC team members are now engaged in detailing the process of private-sector imports to a freely competitive private marketing system in Bangladesh.

Credit

Successful transition to competitive marketing structures must be viewed as an organic process. With the expanded role of the private-sector fertilizer marketing activities,

In developing countries children must help their families overcome the suppression of poverty. This Bangladeshi boy collects coconut shells that his familiy will use for fuel.

credit for private-sector traders for investing inventory and transport emerged as a major constraint. To relax traders' financial constraints, efforts of the IFDC technical assistance team to institutionalize the supply of USAID-provided funds through the commercial banking system have been successful. Through training workshops, a close business relationship of traders with banks has been established. A commercial credit program ($33 million) began in July 1, 1989. From July to December over US $5 million was provided to fertilizer dealers as short-term credit under the program.

In addition to the commercial credit program, IFDC resident consultants helped to monitor and expand the existing BADC in-kind credit program that amounted to approximately US $7 million of USAID support fund for fertilizer dealer credit activity.

IFDC and BADC surveys indicate that (1) the dealers receiving credit improved the profitability of their fertilizer marketing operation and (2) that there is a clear need for increased credit for fertilizer dealers to increase their working capital.

Training

Diffusion of fertilizer technology to farmers through a sound fertilizer dealer development is a complementary objective of this consultancy service. During the year dealer development and training programs continued to strengthen the knowledge in agronomic and economic aspects of fertilizer use so that they could supply more and better information to farmers. IFDC assisted BADC with a transplanted Aman training program for dealers. A total of 27 sessions with 876 dealers including cooperatives attended the courses. As a part of the dealer development program, a total of 278 demonstrations were held in farmers' fields. Resident consultants also organized three credit workshops for fertilizer dealers and distributors, bankers, and BADC officials to identify problems, bottlenecks, and suggestions to expedite credit activity of in-kind and commercial credit programs.

This cattle cart represents another means of transporting agricultural inputs in Bangladesh. Crop residue from rice (straw) is an important source of animal feed.

Technology Transfer

In addition to the success in the area of policy reform, the IFDC Bangladesh country program seems to be achieving another major success in urea deep placement (UDP).

During the year, efforts to field test the UDP technology by hand have had positive results. The UDP program has been further intensified because of interest shown by the farmer in response to last year's test. Field tests during the dry season indicate that when urea supergranules are deep placed by hand, an average increased yield of about 850 kg/ha resulted as compared with that from traditional application of urea as split broadcast. The total return was approximately US $217/ha after compensating for the higher labor and urea cost due to deep placement. A socioeconomic survey of the perceptions of Bangladeshi rice farmers showed very favorable attitudes by farmers about USG technology.

To support the Bangladesh farmers' enthusicsm, IFDC Headquarters donated 20 tons of supergranules to

Demonstrations of urea deep placement technology, conducted by IFDC/Dhaka, provide Bangladeshi farmers with concrete proof of the effectiveness of this environment-sensitive fertilizer management practice.

Special Projects

Under the technical assistance services, IFDC also completed a study of the Government of Bangladesh TSP complex (1) to assess specific factors affecting the cost of producing TSP, (2) to identify possible technical constraints, and (3) based on economic and financial analysis, to develop policy options for the Government to assist in deciding what to do with the TSP complex. IFDC specialists evaluated technical and economic performances of the complex for the last 5 years and alternative production options that could turn the complex into an asset or at least remove it as a liability. The report addressed four central issues relating to the continued operation of the TSP complex. They include: (1) ability of the complex to compete with the imported phosphates without Government assistance and protection, (2) the most appropriate mix for the complex, (3) its potential for privatization, and (4) social and economic consequences of closure or significant reduction in force at the TSP complex. The Government of Bangladesh is now actively considering the implementation of the report's recommendations.

Latin America
Fertilizer Sector

Research Activities

The IFDC/CIAT collaborative research focuses on developing ways to use indigenous phosphate rock to produce fertilizer. By so doing the scientists are helping Latin American farmers produce more food for their families as well as allowing their countries to save money on foreign exchange.

Introduction

After more than 14 years of involvement on the Latin American continent, IFDC is still maintaining its commitment to bring the latest cost-effective fertilizer technology to the farmers in that region. In 1989 new nitrogen research in Colombia concentrated on strategies to use polymer-coated urea to delay nitrogen release and inhibitors to decrease losses of nitrogen to the atmosphere and water. In the area of phosphate research, IFDC continued its long-term studies to find energy-efficient, cost-effective alternatives to conventional phosphate products. The Colombia-based scientists extended the use of indigenous phosphate rocks to less acid or neutral soils and to short-term crops like potatoes, beans, and maize.

In transferring its fertilizer technology, IFDC assisted a Colombia-based fertilizer plant in modifying its operations to increase its efficiency and production capacity while reducing pollution to the atmosphere.

Nitrogen Research

During 1989 the IFDC/CIAT Soil Fertility Studies Project continued research in the strategies related to polymer-coated urea to delay nitrogen release and urease inhibitors to decrease ammonia volatilization losses. Several products were tested in the flooded rice area of Tolima, Colombia.

Polymer-Coated Urea

One flooded rice experiment was established to field test two polymer-coated ureas: 2.9% and 5.0% coating, in a soil classified as Ustic, Isohyperthermic, Arenic Haplustalf. Yield results indicated that although there were no significant differences among treatments, with the highest nitrogen dose (180 kg N/ha), the polymer-coated urea, 2.9% and 5.0% produced higher grain yields (>600 kg/ha) than the application of commercial urea alone. Probably this type of product could be successfully used in cases where farmers cannot have good water control, and they have to delay for several days water flooding after nitrogen application due to unexpected water shortage. Experiments with polymer-coated urea have been planned for 1990 in order to test these materials under stress water conditions—a very common situation for flooded rice farmers in Latin America.

Urease Inhibitors to Increase Nitrogen Efficiency

Field Evaluation of Urease Inhibitors

One field experiment was established in a Ustic, Isohyperthermic Arenic Haplustalf soil from Centro Regional de Investigación (CRI)-Nataima, Tolima, Colombia, in order to test the effectiveness of the

inhibitor nBTPT in an initial application to flooded rice. The inhibitor was tested for its ability to reduce the urea hydrolysis rate, decrease ammoniacal-nitrogen concentrations in the floodwater, and increase fertilizer uptake and grain yield. No yield differences among treatments and among nitrogen doses were observed. Only yields of the check plots were statistically different from the positive nitrogen rates. Although nBTPT controlled during the first 5 days the concentrations of ammoniacal-nitrogen in the floodwater, yields of treatments with nBTPT were lower than yields of treatments with commercial urea. Probably soil, floodwater, and environmental conditions were not sufficiently severe to induce high ammonia volatilization when commercial urea was used.

Phosphate Research

Experiments conducted in various countries in Latin America showed that increasing the amount of water-soluble phosphate through the use of mixtures (bulk-blended or compacted) of phosphate rocks and water-soluble phosphate or use of PAPRs can extend the use of indigenous phosphate rocks to less acid or neutral soils and to short-term crops like potatoes, beans, and maize. This report presents results of research on applications of phosphate rocks + water-soluble phosphate and PAPRs in combination with nitrogen and potassium sources at different NPK rates, use of PAPRs under flooded conditions in neutral soils, and residual effect of low-reactive phosphate rocks.

Phosphate Rock for Direct Application

Field experiments with Huila phosphate rock from Colombia mixed with TSP or monoammonium phosphate (MAP) and different nitrogen, potassium, and sulfur sources done in Pescador, Cauca, Colombia, confirmed the idea that mixtures of water-soluble phosphate with phosphate rocks are good substitutes for pure water-soluble phosphate or PAPRs (Figures 11 and 12). Mixtures of Huila phosphate rock, TSP, urea, potassium sulfate, or potassium chloride in an appropriate NPK ratio could be a good approach to sound and economic fertilization of beans in acid soils of the mid-altitude Andean region.

Studies on residual effects of phosphate sources in acid soils started in 1988 with the collaboration of the Instituto Colombiano Agropecuario (ICA) Soil Program in the Eastern Plains of Colombia. One experiment with upland rice, after two consecutive crops, showed that residual effects of the phosphate applied as Huila phosphate rock (medium reactivity) and Sardinata phosphate rock (low reactivity) were very good and yields were equal or better than

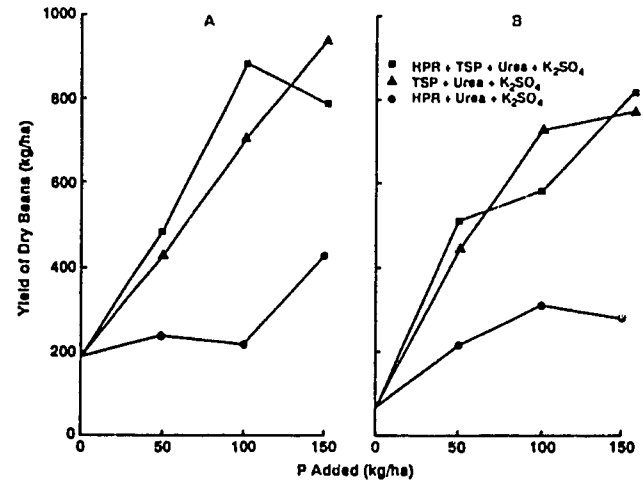


Figure 11. Response of Beans to Applications of Huila PR(HPR), TSP, and a Mixture of HPR and TSP With Urea and K_2SO_4 as N and K Sources. N:P_2O_5:K_2O:S Ratio 1:4:1.5:0.5. A = N. Trujillo, B = J. F. Guatusmal. Pescador Cauca, 1988B-89A.

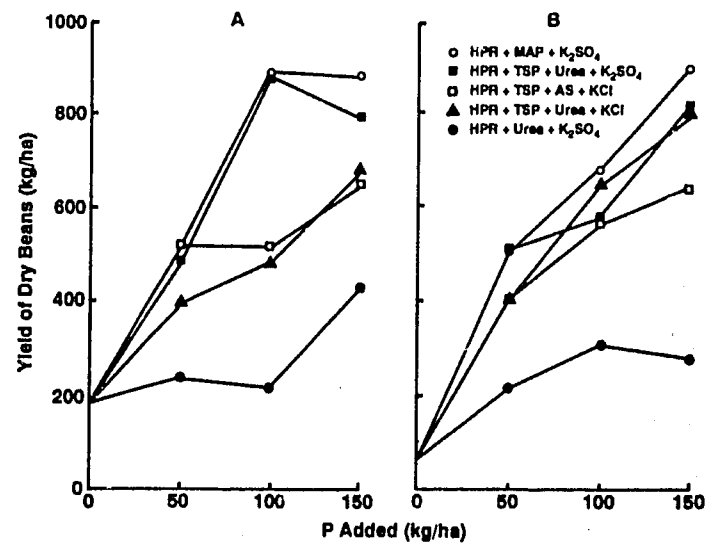


Figure 12. Response of Beans to Applications of Huila PR(HPR), and Mixtures of HPR With MAP and TSP Using Urea, SCU, MAP, and AS, as N Sources and K_2SO_4 and KCl as K Sources. N:P_2O_5:K_2O:S Ratio 1:4:1.5:0.5. A = N. Trujillo, B = J. F. Guatusmal. Pescador, Cauca, 1988B-89A.

those produced in the plots where TSP was originally applied. Other 3-year experiments with *Brachiaria decumbens* showed similar results with very good residual effects of phosphate rocks (Huila, Pesca, and Sardinata) compared with TSP or PAPRs.

Modified Phosphate Rock Fertilizers

In soils of Morales, Cauca, Colombia, classified as non-acid (non-calcareous) loamy, thermic, Entic Dystrandept, three bean experiments were established during late 1989 in farmers' fields. Partially acidulated Media Luna phosphate rock, and partially acidulated Pesca phosphate rock, 50% and 40%, respectively, were used. $N:P_2O_5:K_2O$ ratios, 1:2:1, 1:3:1, and 1:4:1, using urea, potassium sulfate or potassium chloride, were tested. No statistical differences in yields were found between TSP and the PAPRs. Also no significant differences in yields were found between potassium sulfate or potassium chloride, used as potassium sources. No significant differences in yields were obtained among the three NPK ratios tested. Nevertheless, generally higher yields were obtained when the 1:2:1 or 1:3:1 ratios were used. Based on the results obtained from these experiments, one can conclude that it is possible for beans in the region studied to use TSP or PAPR as a phosphorus source mixed with urea and potassium chloride. It is possible to use a mixture of urea, PAPR, and potassium chloride at the $N:P_2O_5:K_2O$ ratios tested, but the final decision depends on the total price of the NPK fertilizer to be used.

Agronomic Evaluation of PAPRs in Neutral Soils

Two flooded rice experiments in neutral soils (pH 6.5-6.7) were established in collaboration with ICA's soil program. Huila phosphate rock, partially acidulated Huila phosphate rock (50%), and TSP were the phosphorus sources tested under non-appropriate conditions for native phosphates. In the soil with low available phosphorus, rice responded to phosphate applications up to 10 kg phosphorus/ha when partially acidulated Huila phosphate rock or Huila phosphate rock was used. At a phosphorus rate of 20 kg/ha the best source was partially acidulated Huila phosphate rock. In the case of the soil high in available phosphorus, rice responded slightly to the first phosphate application rate (10 kg phosphorus/ha), but afterwards no significant responses to applications of the phosphate sources were observed. Results of these experiments indicate that phosphate sources such as PAPRs could be successfully used in neutral soils for flooded rice when the soil analyses indicate low available phosphorus. If the soil is low in sulfur, there is a good possibility of sulfur response from the calcium sulfate present in the modified phosphate rock fertilizer.

Technical Assistance in Latin America

Colombia

A project for designing major modifications to ABOCOL's nitrophosphate-based granular NPK fertilizer plant was completed. The final report, consisting primarily of a Process Engineering Design Package, was completed. ABOCOL is a private company with fertilizer production facilities at Cartagena, Colombia. The modifications were designed to increase process efficiency, flexibility in the use of raw materials, and production capacity, while at the same time reduce ambient pollution, corrosion, and maintenance costs. The modifications were designed to hold to a minimum the changes to the granulation and material handling sections of the existing plant.

The complete Process Engineering Design Package was prepared based on operating conditions found during laboratory and pilot-plant tests performed at IFDC. Process flow diagrams, piping and instrumentation diagrams, process data sheets, and instrumentation data sheets were prepared. The package included heat and material balances for the main NP and NPK products to be made.

The major advantages of the proposed modifications to the plant will be:

1. Simplified plant operations.
2. Enhanced nutrient efficiency and pollution abatement.
3. Reduced corrosion problems.
4. Reduced maintenance requirements.
5. Reduced electricity consumption in the reaction section.
6. Increased production capacity.

An engineering company has been retained by ABOCOL to perform detailed engineering for the modification from the information presented by IFDC. During this phase of ABOCOL's project, IFDC has responded to a series of questions posed by ABOCOL and by the engineering company regarding technical matters related to the Process Engineering Design Package.

Through a contract with Amoniaco del Caribe (AMOCAR), a subsidiary of ABOCOL dedicated to the production of ammonia and nitric acid for the use of ABOCOL and for outside sales, IFDC reviewed the Process Engineering Design Package for increasing the capacity of its nitric acid production facility, prepared by another engineering company. In

performing this review, IFDC answered questions that AMOCAR had regarding the operating conditions of the modified plant and the sizes of some of the new equipment and suggested the purchase of used equipment to be used in their plant revamping. A list of sources for this used equipment was provided to AMOCAR, and assistance was provided in field inspecting some of this equipment in the United States and in Europe.

Technical assistance was also provided to several other entities in Colombia. The main topics covered were:

1. Production of Dicalcium Phosphate (Animal Feed).
2. Out-of-Doors Storage of Bagged Fertilizers.
3. Economic and Technical Comparison of Granular, Compacted, and Bulk-Blended Fertilizers.
4. Solubilities of Fertilizers.
5. Bulk Blending of Fertilizers.
6. Production Cost of Utilities.
7. Information About Beneficiation of a Local Phosphate Rock.
8. Investment Cost for a Nitric Acid Plant.
9. Role of Mechanical Fabrication Shops in the Fertilizer Sector.
10. Sulfuric Acid-Based Partially Acidulated Phosphate Rock.
11. Production of Defluorinated Phosphate Rock.

Some of the Colombian companies to which IFDC provided technical assistance during 1989 were:

ABOCOL; Agroinsumos y Servicios Técnicos Ltda.; ALMACAFE; AMOCAR; CARBOCOL S.A.; Fertiagro Ltda.; Fosfatos del Huila S.A.; MAXBELL Ltda.; Monómeros Colombo Venezolanos S.A. (E.M.A.); Molina y Durango Compañía Ltda.; Porcícola del Caribe Ltda.

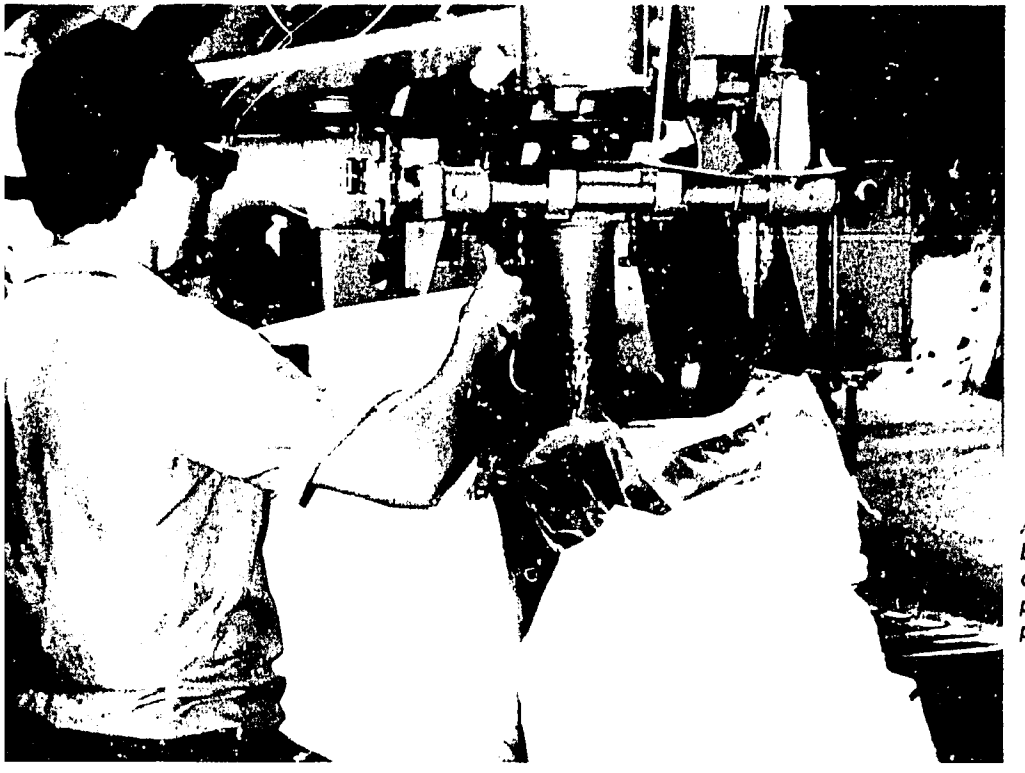
In a Costa Rican fertilizer dealer's store, Dr. W. Edward Clayton (right), IFDC Transportation/Distribution Specialist, inspects a "starter" package of fertilizer for small farmers. The IFDC technical assistance project in Costa Rica investigated dealer activities, services to farmers, and the supply/storage situation.

Costa Rica

Stemming from the results of a preliminary study performed by IFDC for FINTRA in 1988, and from the terms of reference developed during that study, a more detailed analysis of the operations of Fertilizantes de Centro América (FERTICA), Costa Rica, was begun for FINTRA. The detailed study, which will be finalized in early 1990, will provide an assessment of the economic and financial value of FERTICA, the major fertilizer-producing company in the country. The thrust of the study revolves on the required modifications to the installations and to the product mix of FERTICA to make this company attractive to investments from the private sector.

Venezuela

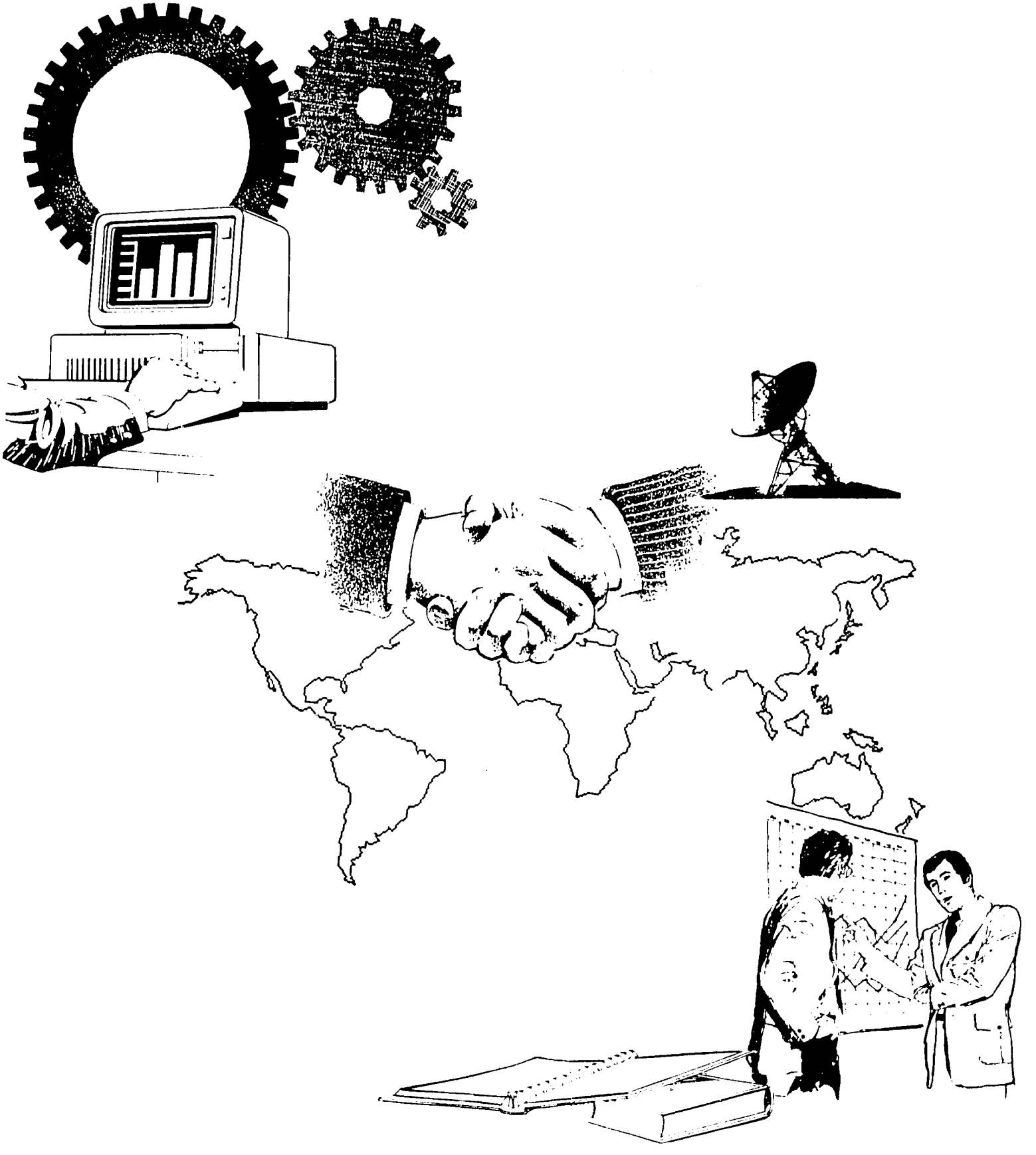
Centro de Investigación y Desarrollo (INTEVEP, S.A.), as research and development advisor to Petroquimica de Venezuela (PEQUIVEN), is studying alternative strategies for the manufacture of various NPK products through wet-type granulation. The NPK fertilizers are currently manufactured by PEQUIVEN in its fertilizer granulation plant located at Moron, using ammonia, sulfuric acid, phosphoric acid, and standard potassium chloride as raw materials. Of these raw materials, phosphoric acid and potassium chloride are imported and the ammonia and sulfuric acid are locally produced. One of the strategies to produce NPK products being considered by INTEVEP is to feed ground Riecito phosphate rock to the drum granulator to replace about 15%-20% of the P_2O_5 (from ammonium phosphates) in their formulations with P_2O_5 from the rock. By substituting some of the P_2O_5 supplied from imported phosphoric acid with acid made from



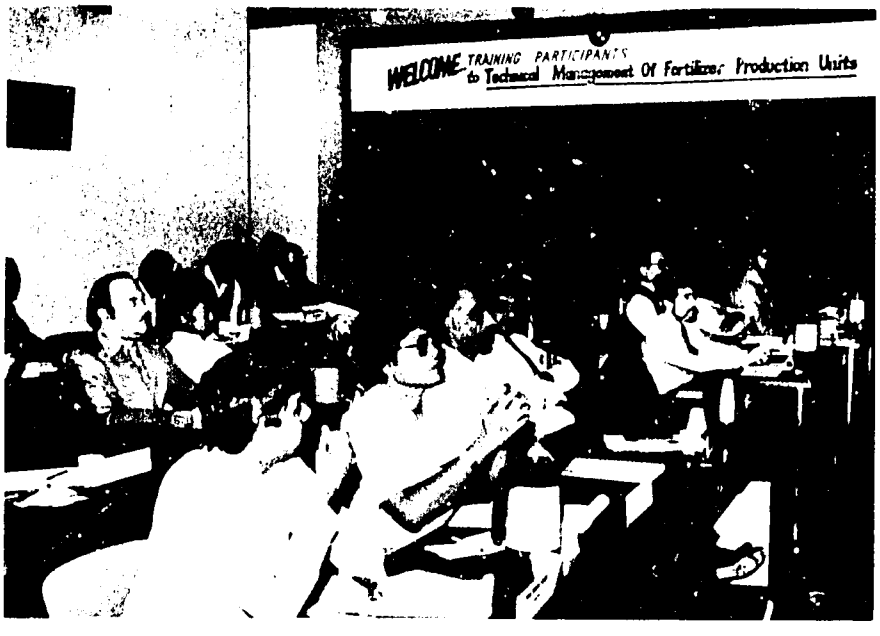
A worker bags fertilizer at the FERTICA blending plant at Moin, Costa Rica. This is one of the two FERTICA plants studied as part of the IFDC technical assistance project.

locally available phosphate rock, Venezuela will save foreign currency.

Three Venezuelan scientists came to IFDC to study the production of NPKs using Riecito phosphate rock as one of the raw materials. One of the scientists is employed by INTEVEP and the other two by PEQUIVEN. The two organizations decided that prior to actual production at the commercial-scale plant in Moron, it was necessary to confirm this option and also to define some operating parameters through tests in IFDC granulation facilities. The granulation test runs were successful. Enough information was obtained and transmitted to INTEVEP so that they can produce these two NPK grades at Moron using Riecito rock. With the information gathered at IFDC, PEQUIVEN intends to produce these grades by early 1990.



Human Resource Development



Participants in the training program, "Technical Management of Fertilizer Production Units," listen attentively to one of the many speakers who addressed them. This was one of 13 IFDC group training programs attended by 328 participants from 73 countries.

Introduction

IFDC has made human resource development a principal and integral part of its overall fertilizer technology development and transfer program. Training programs provided by IFDC through partial funding from UNDP are recognized and used by many developing countries of Asia, Africa, and Latin America. Information on the fertilizer sector covering production, marketing, and use is provided. The basic objectives of IFDC's training programs are to improve the operation and cost effectiveness of national fertilizer supply and marketing systems through better-trained manpower and promote fertilizer use and use efficiency. Training programs are targeted mainly at elevating the level of performance of junior- and middle-level managers and technical professionals who have demonstrated a potential for advancement and senior-level managers and administrators already in decisionmaking roles.

Information dissemination to the participants is accomplished through general (group) training programs, training workshops, and specialized (customized) training programs. These programs are designed to meet the needs of public- and private-sector organizations and other agencies engaged in fertilizer sector development and improvement.

It is recognized that women are playing an increasing role in several fertilizer-sector activities, and IFDC is striving to better cater to their needs by offering a wider range of programs and by tailoring programs that are already established.

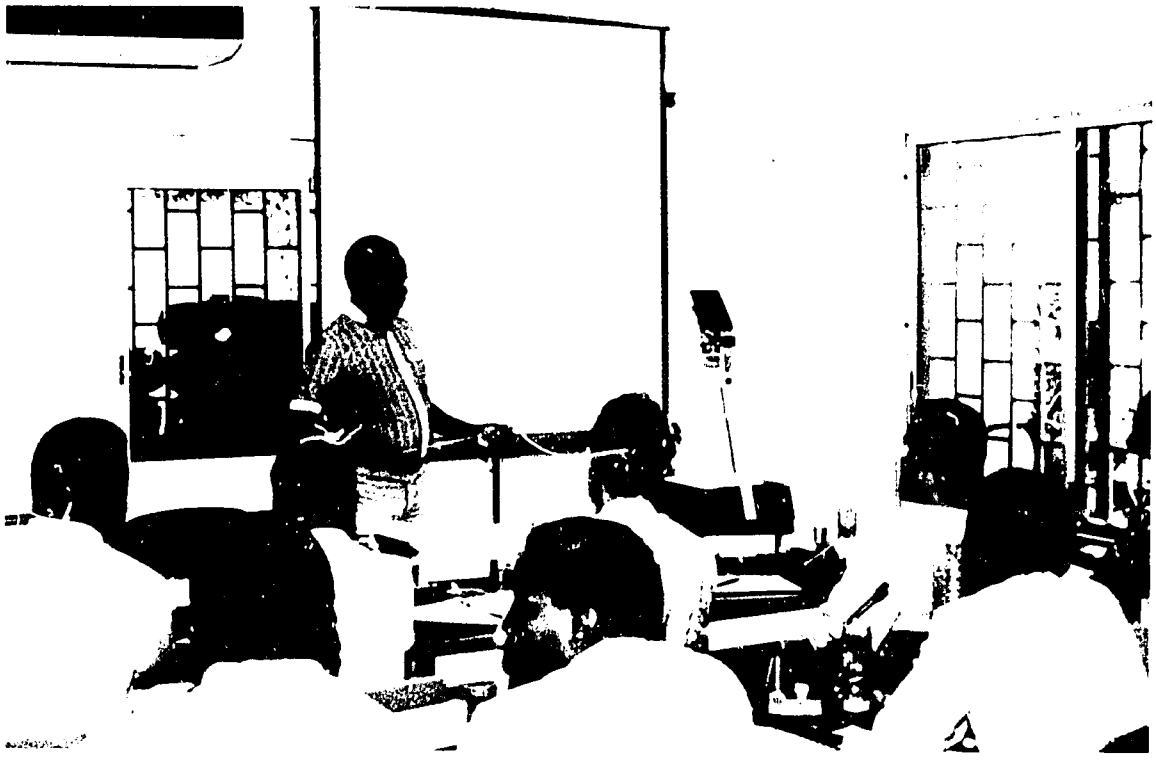
IFDC has a dedicated ongoing effort to determine the impact of its training programs. On a periodic basis IFDC assesses the impact that training is having on the past participants of its training programs. The survey also elicits input from past participants on new training programs or alterations needed to improve the quality of the programs.

It should be noted that IFDC draws heavily from many individuals and organizations in conducting its programs at Headquarters and overseas. Regional programs are usually carried out with a cosponsor.

In 1989 IFDC conducted the following programs involving 328 participants from 73 countries.

- *12 General (group) training programs (233 participants).*
- *1 Training workshop (75 participants).*
- *12 Specialized (customized) training programs (20 participants).*

These programs are discussed in the following section.



Lomé, Togo, was the setting for this training program on "Statistical and Economic Analysis of Fertilizer Experimental Data." Twenty-two economists/statisticians from 13 countries attended.

1989 Training Activities

Overview of General (Group) Training Programs

IFDC conducted a total of 12 general training programs and 1 training workshop in 1989. Six general programs were held at Headquarters and six were held at overseas locations. The training workshop was held in Guatemala.

General training programs range in duration from several days to 6 weeks. Training methodology includes presentations by subject-matter specialists from IFDC and other organizations. Often developing-country specialists participate as speakers. Emphasis is on participatory learning techniques and thought stimulation through organized discussions and practical "case studies." In most cases classroom activities are complemented and supplemented by field trips and "hands-on" demonstrations. The programs use modern training techniques including computer-assisted simulation exercises, videos, slides, overheads, and films.

At the initiation of each program, the participants' interests and expectations are determined through preprogram discussions and completion of a registration form. Participants' knowledge on the subject matter is determined at the beginning and end of the program. In addition, each participant is asked to rank the quality of the program. This critique is very valuable to IFDC in conducting subsequent training programs.

In 1989 a total of 308 participants received training in general training programs and training workshops. These participants were from 73 countries. Developing-country representation was especially high for Bangladesh (12), Guatemala (17), India (38), Indonesia (22), and Sri Lanka (16). Regional distribution from developing countries is shown in Table 5 indicating Asia (43%), Africa (24%), Central and South America (25%), and United States/Europe (8%).

Table 5. Regional Distribution of Participants—General Group Training Programs and Workshops

Region	Number of Participants
Africa	75
North and Central America	66
South America	27
Asia	129
Europe	7
Oceania	4
TOTAL	308

Description of General Training Programs

A brief description of each general training program given in 1989 under the categories of Fertilizer Marketing, Fertilizer Production and Technology, Fertilizer Use Efficiency, and Fertilizer Sector Development is given in this section.

Headquarters' Programs

- *Data Collection, Analysis, and Projections for Fertilizer Sector Studies*

  This program covered current methodologies in collecting data on fertilizer sector and making fertilizer demand projections through microcomputers for use in fertilizer sector studies. The FAO, World Bank, United States Department of Agriculture, Soil Conservation Service, Bureau of Census, The Fertilizer Institute, and the Tennessee State Reporting Service participated in the program faculty. Nineteen economists/statisticians from 10 countries—Egypt, India, Indonesia, Madagascar, Mali, Rwanda, Uganda, Venezuela, Yemen Arab Republic, and Zambia—participated in the program. The program was conducted at Headquarters; Nashville, Tennessee; and Washington, D.C.

- *Computer Simulation of Crop Growth and Fertilizer Responses*

  This program, offered by IFDC for the first time, covered a description of the CERES simulation models and applications of these models to fertilizer cropping and environmental problems. The participants also learned techniques for data base management. Thirteen scientists from 12 countries—Brazil, Colombia, Guyana, Indonesia, Kuwait, Malawi, Malaysia, Nigeria, Puerto Rico, Saint Lucia, Trinidad, and the United States—attended the program. Experts from IBSNAT, ICRISAT, and the University of Michigan assisted IFDC by serving as faculty for the program. The participants were provided computer software.

- *IFDC/Auburn University Soil Testing and Fertilizer Managernent Training Program*

  Eight scientists from six countries—Bangladesh, Indonesia, Malawi, Pakistan, Somalia, and Venezuela—took part in this program. The program, a part of the Auburn University program sponsored by USDA, was held at IFDC Headquarters. The program covered soil testing, soil classification, soil fertility management, and application of soil tests in developing fertilizer recommendations.

The participants and leaders of the training program on "Finance for Nonfinance Managers in the Fertilizer Sector" visit the FPM fertilizer plant in Johore, Malaysia. They are observing the plant's bulk-blending and bagging operation.

- *IFDC/Purdue University Training Program on Fertilizer Sector Development for Tropical and Subtropical Countries*

  The program is designed for developing-country students enrolled in U.S. universities. Its purpose is to interest the students in the opportunities for employment in fertilizer sectors of their countries on completion of their education in the United States. Purdue University collaborates with IFDC and provides graduate credit of 2 hours for the participants attending this program. The program covered all aspects of fertilizer sector development including technologies of fertilizer production, marketing, distribution and use, and environmental issues affecting fertilizer sectors. Management and communication aspects were emphasized. Twenty students from Burma, Burundi, Cameroon, China, Guinea, Indonesia, Kenya, Malawi, Mexico, Niue, Pakistan, and Zambia participated. The students represented 14 U.S. universities.

- *Fertilizer Marketing Management Training Program*

  This program was the 13th such program held annually since 1977. Twenty-three senior marketing managers from Bangladesh, Costa Rica, Ethiopia, India, Indonesia, Kenya, Saudi Arabia, and Sudan participated. Field trips to observe manufacturing, marketing, and distribution operations in Florida, Missouri, and Kansas complemented the classroom presentations at IFDC. The Alpha marketing exercise, a computer simulation, was used to portray a real marketing situation. The program covered marketing functions and organization, factors influencing marketing decisions, distribution systems, pricing, marketing margins, credit, and marketing information systems. Personnel from the Zuari Agro Chemicals, Ltd., a private-sector company in India, assisted by serving on the program faculty. Other organizations assisting with the program in the United States were the National Fertilizer Development Center (NFDC)-Tennessee Valley Authority (TVA), International Minerals and Chemical Corporation, Farmland Industries, University of North Alabama, University of Missouri, and National Fertilizer Solutions Association.

Participants in the IFDC/Purdue University training program on "Fertilizer Sector Development in Tropical and Subtropical Countries" complete an assigned exercise. Pictured are (from left) Mrs. Asongwa Anastasia Akum of Cameroon and Shen Lu of the People's Republic of China.

- *Technical Management of Fertilizer Production Units*

  This program has been held annually since 1980. It covered an overview of the world fertilizer sector, management principles and techniques, an intensive technical management mini course, technical management of fertilizer plant operations including case studies on plant restructuring, and economic and financial analyses of investment in fertilizer sectors. Twenty-two production/plant/maintenance engineers from Bangladesh, Brazil, China, Costa Rica, India, Indonesia, Korea, Pakistan, and Venezuela representing private- and public-sector fertilizer organizations participated in the program. The operation and maintenance of ammonia/urea plants received special emphasis in discussions. Participants visited manufacturing facilities located at the U.S. Gulf Coast, including CF Industries, Arcadian, Agrico's Faustina and Uncle Sam phosphoric acid plant. World Bank, NFDC-TVA, U.S. fertilizer technology and processing companies, ICI of England, and Toyo Engineering of Japan assisted on the program faculty.

Overseas Training Programs

- *FADINAP/IFDC Regional Training Course on Port Handling of Mineral Fertilizers in the Asian-Pacific Region*

  This program, cosponsored with FADINAP, was held in Singapore and Bangkok. It dealt with fertilizers and port handling,

educational technology, and development of training materials. Visits to ports in Singapore and Bangkok provided participants first-hand information on port handling. The nineteen participants were from 11 countries—Bangladesh, China, Fiji, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam.

- *Statistical and Economic Analysis of Fertilizer Experimental Data (French and English)*

  Twenty-two economists/statisticians from 13 countries—Barbados, Botswana, Egypt, Gambia, Ghana, Kenya, Madagascar, Malawi, Niger, Nigeria, Rwanda, Senegal, and Togo—participated. The program, held in Lomé, Togo, dealt with statistical and economic analysis of fertilizer experimental data, regression analysis, statistical models for fertilizer evaluation, fertilizer management, fertilizer decision analysis, and developing fertilizer recommendations. It was conducted in French and English.

- *Modern Techniques in Fertilizer Distribution and Handling*

  This program commenced in Stockton-on-Tees, England, and concluded in The Hague, Netherlands. The traveling program dealt with the theoretical and practical aspects of fertilizer distribution, packaging, transportation, handling, and warehousing. The theoretical aspect was handled through presentations and discussions on development and characteristics of distribution systems, characteristics of fertilizer materials, packaging and packaging equipment, transportation modes, shipping and chartering terms, handling systems and equipment for bags, semibulk and bulk systems, warehousing, and distribution costs. Practical aspects were covered through visits to organizations manufacturing polyethylene bags, weighing and bagging equipment, and intermediate bulk containers in the United Kingdom, Ireland, Belgium, West Germany, and the Netherlands. Visits to Antwerp and Rotterdam Ports were included in the program. Twenty-two senior marketing/distribution managers from Brazil, Dominican Republic, India, Indonesia, Kenya, Malaysia, Nigeria, Saudi Arabia, Taiwan, United Arab Emirates, and Venezuela participated in the program.

- *Supplying Quality Multinutrient Fertilizers in the Latin American and Caribbean Regions*

  This workshop, held in Guatemala City, was cohosted by Fertilizantes Quimicos de Guatemala (FERQUIGUA). Seventy-five delegates from 20 countries of Central and South America, France, Ireland, Portugal, Switzerland, and the United States attended. The workshop examined the status of multinutrient fertilizer production technologies and identified future trends and needs with particular reference to the quality and costs of the products currently marketed, and the practical aspects of raw material supply, plant design, production technology, prescription mixing, production economics, and farm-level use of fertilizer. The workshop was conducted in English and Spanish. The deliberations were conducted in five sessions covering Background, Raw Material Options and Constraints, Market Factors, Plant Design and Operating Criteria, and Guatemala Fertilizer Sector. The proceedings of the workshop are being printed, and copies will be made available for the delegates and other interested persons.

- *Finance for Nonfinance Managers in Fertilizer Sector*

  This program was offered for the first time and was held in Singapore. Eleven participants from six countries—India, Indonesia, Saudi Arabia, Sri Lanka, Western Samoa, and Zambia—attended the program. The program discussed financial structure of the fertilizer sector, significance of financial reports, financial ratios, investment analysis, and fertilizer pricing. The program's purpose was to develop financial skills of the nonfinance managers. The participants visited with the management of FPM in Malaysia to gain exposure to the financial system of a fertilizer plant operation. Personnel from the Fertilizer Pesticide Authority of the Philippines assisted IFDC by serving on the program faculty.

- *Fertilizer Supply Options and Constraints in Developing-Country Agriculture (English and French)*

  The program, conducted in Lomé, Togo, included discussions on estimating and forecasting fertilizer demand, identification of key constraints to cost-effective supplies of fertilizer, supply alternatives and strategies, planning of physical distribution systems, and impact of policy environment on supply alternatives. The participants were asked to identify the most significant constraint to cost-effective fertilizer supplies in their country. Twenty-four participants from 17 countries—Burkina Faso, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Madagascar, Mali, Niger, Nigeria, Portugal, Rwanda, Senegal, Sri Lanka, Sudan, Tanzania, and Zaire—attended the program.

- *Fertilizer Marketing Training Program*

  Designed for junior promotable managers with 1 year's experience in fertilizer marketing, this program covered fertilizer marketing management, marketing communication, fertilizer distribution, pricing, credit, dealer network, fundamentals of plant nutrition,

and constraints in fertilizer marketing. Participants were afforded hands-on experience in analyzing and developing marketing system improvements through the use of IFDC's computer-assisted fertilizer marketing simulation exercise. The program, held in Singapore, was attended by 30 marketing managers from Bangladesh, India, Indonesia, Lebanon, Malaysia, Norway, Pakistan, Saudi Arabia, Singapore, Sri Lanka, Western Samoa, and Zambia.

Workshops

A new regional workshop entitled "Supplying Quality Multinutrient Fertilizers in the Latin American and Caribbean Region" was held; this activity attracted a relatively large number of participants from various countries.

Training workshops are considered to be a very effective way of sharing a relatively large quantity of information in a short period of time. The methodology involves presentation of technical papers on highly focused topics followed by appropriate in-depth discussion. The deliberations of the workshop are incorporated into a proceeding and copies are made available for each attendee. Additional copies are made available from IFDC at a reasonable cost to nonattendees. Based on requests to IFDC, these types of publications have proven to be quite popular.

Specialized Training Programs

Twelve specialized training programs, involving 20 participants from seven developing countries, were conducted during 1989 (Table 6). These programs covered specialized topics such as chemical analysis of phosphate rock, fertilizer use efficiency research, alternative uses of phosphate rock, crop growth simulation models, and building a computerized data base for a fertilizer sector. The program length ranged from 5 days to 120 days. It is to be noted that there was a heavy emphasis on Egypt (50%) since IFDC is assisting the Government in establishing a national fertilizer research center. These programs provided extensive "hands-on" experience in IFDC laboratories and pilot plants.

Table 6. 1989 IFDC Specialized Training Programs

Program	Participants: Country	Participants: Number	Program Length (days)
1. Chemical Analysis of Rock Phosphate	Venezuela	1	5
2. Technology of Nitrogen and Phosphate Fertilizers	Brazil	1	10
3. Phosphoric Acid Production	China	1	20
4. Fertilizer Marketing	Bangladesh	2	5
5. Fertilizer Use Efficiency Research	China	1	60
6. Characteristics of Agronomic Effectiveness of Phosphate Fertilizer Derived From Zimbabwe Rock	Zimbabwe	1	88
7. Validity of ^{15}N Balance Techniques	Egypt	1	80
8. Application of ^{15}N Isotopic Analysis	Panama	1	120
9. Alternative Uses of PR	Venezuela	1	37
10. Crop Growth Simulation Models	China	1	20
11. Fertilizer Data Base Systems in the United States	Egypt	5	5
12. Building Computerized Data Base for Fertilizer Sector	Egypt	4	10
	7 Countries	20	

Participant Evaluation

General training programs are evaluated by the participants at the conclusion of the program. Information gained from this evaluation is especially helpful to IFDC in program development and improvement. The questionnaire seeks to determine information from each participant on: (1) technical aspects, (2) administrative aspects, (3) methodology, (4) field trips, (5) program structure design, and (6) physical facilities for program site. In addition, comments are elicited to assist IFDC staff in better adapting the overall program for future participants.

The evaluation of the 1989 programs reveals that the programs were generally rated as "very good"; one course was rated "good" to "very good."

Training Impact

Every 5 years IFDC conducts a training impact assessment of former participants. The last study was completed in 1984. A new study was initiated in late 1989 in which about 1,100 questionnaires were mailed to former participants. The questionnaire contains fourteen questions, covering information on such areas as: (1) knowledge or skills gained, (2) training versus responsibilities, (3) involvement in in-country training, (4) additional training interests, (5) training program effectiveness, (6) areas for improvement, and (7) interest in receiving further information.

Only preliminary results are available from the impact survey based on 190 respondents. The preliminary results indicate the following:

1. Thirty-nine percent of the respondents have changed jobs or been promoted. Of these 50% have changed jobs or been promoted due to training.
2. Thirty-seven percent of respondents have responsibility for training in their organizations.
3. Most participants use IFDC-developed training materials in their company's training programs.

Table 7. Women Participants in IFDC General Training Programs, 1977-89

Year	Number
1989	19
1988	18
1987	21
1986	21
1985	9
1984	11
1983	13
1982	13
1981	-
1980	7
1979	1
1978	2
1977	-
TOTAL	135

Role of Women

The important and increasing role of women in agriculture and fertilizer-related activities in many developing countries is reflected by their increased attendance at IFDC's general training programs in recent years (Table 7). From 1977 through 1989 a total of 135 women have taken part in IFDC general training programs, accounting for about 6.2% of the total number of participants during that time period. Prior to 1980 few women attended IFDC programs. Although fluctuating from year to year, attendance has trended upward, leveling off at about 20 women participants per year (or 7%-8% of total) during the past 3 years. Table 8 gives country-wise distribution of women participants in general programs during 1989.

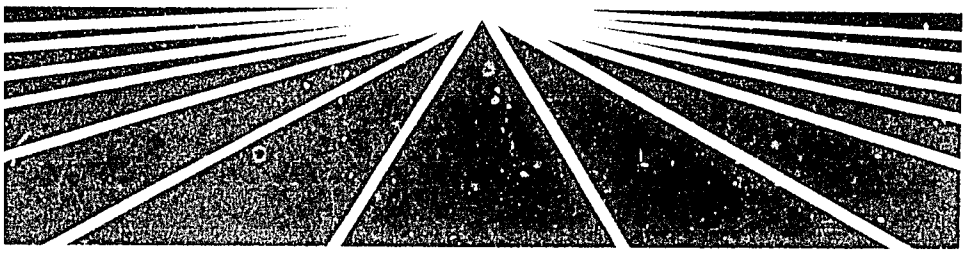
Dr. Upendra Singh (right), IFDC Systems Modeller/Soil Scientist, looks on as a participant in the training program on "Computer Simulation of Crop Growth and Fertilizer Responses" completes an exercise on a microcomputer.

Table 8. Women Participants by Country, 1989, in IFDC General Training Programs

Country	Number
Bangladesh	1
Barbados	1
Cameroon	1
Costa Rica	1
Guatemala	4
Indonesia	1
Kenya	1
Lesotho	1
Madagascar	1
Malawi	1
Senegal	1
United States	1
Venezuela	1
Zambia	3
TOTAL	19

It is anticipated that the number will increase. To determine the number of women engaged in the sector and the type of work they perform, IFDC has initiated a survey of the fertilizer sectors in developing countries. This information will help the Center better develop future programs to meet women's needs.

Global Projects



Agromineral Data Bases

Two agromineral data bases are currently being developed at IFDC: the Fertilizer Raw Materials Database (FRMD) and the IFDC Phosphate Rock Characterization Database (PRCD).

FRMD is a bibliographic listing of references that can be accessed using Pascal-based software on an IBM PC or PC-compatible computer. FRMD was initially developed to catalog and retrieve information in conjunction with the phosphate rock characterization program within the IFDC Fertilizer Technology Division. Thus, the primary subject area of the current version (1.0) is information relating to phosphate rock; many of the other subject areas are closely related to phosphate rock (beneficiation, etc.). Other agromineral data are being accumulated using the same format. The data base also includes information on sulfur, potash, energy sources, and agricultural lime as well as trace elements in phosphates. The data base focuses on information relevant to developing countries. About one-third of the references pertain to Africa. The current version is considered developmental; changes may be implemented in subsequent versions. There are presently about 4,300 reference listings in FRMD. Literature is continually being accumulated and catalogued.

The PRCD contains chemical and mineralogical data on approximately 1,200 samples from 358 deposits in 91 countries. These data are accessed using dBase III+ on an IBM AT-compatible computer. PRCD is used as a reference and a research tool. When samples from a particular deposit are analyzed, these new data are compared to data from previous samples from the same deposit or similar deposits. This method aids researchers in recognizing analytical and calculation errors, and real geologic variations within deposits. These data are also being used to develop statistical crystal-chemical models of various forms of apatite. Modeling techniques that would be extremely time consuming by hand, such as linear and nonlinear regressions and statistical analyses, are quickly and easily performed on the computer.

Simulation Modelling of Crop Growth

CERES-Rice Nitrogen Use Efficiency and Environmental Impact

CERES-Rice Model V2.0 jointly developed by IFDC and IBSNAT incorporates water-balance and nitrogen-balance components that predict crop growth and development under upland and flooded field conditions. The model simulates nitrogen losses that occur due to runoff, leaching, denitrification, and ammonia volatilization in fully upland, fully flooded, or under intermittent flooding and drying conditions. Much of the variability in nitrogen use efficiency can be attributed to variations in amounts of nitrogen lost from rice-cropping systems.

The CERES-Rice Model can be a powerful tool for the following:

1. Large area yield forecasting.
2. Increasing nitrogen use efficiency for maximizing crop yields.
3. Increasing efficiency of nitrogen fertilizers for minimizing their impact as pollutants on the environment.
4. Within-year tactical management decision.
5. Long-term simulations for strategic planning.

Nitrogen is the most important nutrient added to rice. However, despite the large investments in fertilizer nitrogen, the efficiency of nitrogen utilization is generally poor. To improve efficiency, the rice model must capture the dynamics of biological and chemical processes in the soil-plant-water-atmosphere continuum of the rice

field. The model accurately describes the change in floodwater pH, algal/biological activity and subsequent rise in ammoniacal nitrogen concentration, and the simulated losses of nitrogen. It also simulates higher losses of nitrogen when urea is broadcast on floodwater with no incorporation. The degree of nitrogen loss and hence nitrogen use efficiency are highly dependent on water management in rice paddy. Under similar nitrogen-management conditions, the model simulates higher losses of nitrogen from intermittently flooded and drained soils than those soils that are fully flooded (Table 9).

Table 9. Simulated Nitrogen Loss From Flooded and Drained Soils

	N Applied	Loss	N Loss
	(kg N/ha)	(kg N/ha)	(%)
Flooded soil	70	21	30
	100	36	36
Drained soil	70	35	50
	100	54	54

Validation

To ensure that the rice model is a functional and reliable tool, its performance was compared with data from field experiments that had never been used for developing the model. The CERES-Rice V2.0 was validated with data from several field experiments conducted under collaborative programs between IFDC and IRRI during 1985-89. All experiments had nitrogen rates as a variable. Some of the experiments also had water management as one of the treatments.

As depicted in Figure 13, the model's predictions are close to the nitrogen uptake values. To test the model's performance at predictions of nitrogen losses, data from experiments where fertilizers were labeled with ^{15}N were used. Figure 14 illustrates the comparison between ^{15}N unaccounted for in soil and plant pools and the simulated nitrogen losses due to ammonia volatilization, denitrification, leaching, and runoff. The model performance again was very satisfactory. Work is continuing at IFDC to validate the model with data from diverse environment and management conditions.

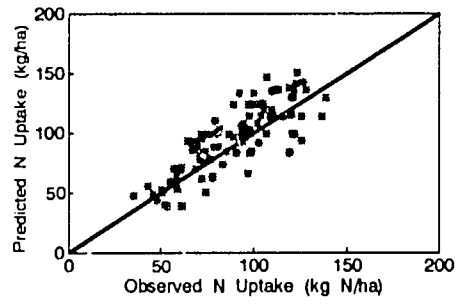


Figure 13. Comparison of Observations and Simulations by the CERES Rice N Model for Nitrogen Uptake at Maturity. The Line Indicated on the Figure is a 1:1 Line.

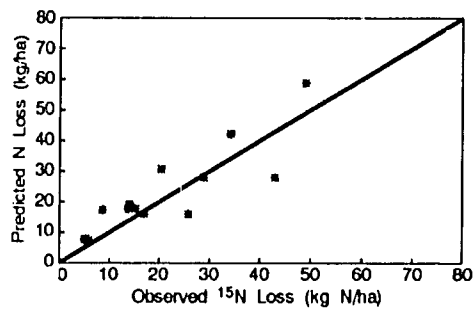


Figure 14. Comparison of Observed ^{15}N Losses and Total N Losses Predicted by the CERES Rice N Model.

Software Release

The CERES-Wheat and CERES-Maize Models, their user's guides, and a user-friendly program for entering and organizing model input data were released by IFDC. Similar packages for the CERES-Rice and CERES-Sorghum Models will be available in 1990.

A major milestone was reached when the IBSNAT Project released the software and user's guide for the Decision Support System for Agrotechnology Transfer (DSSAT) to users worldwide during 1989.

DSSAT is a microcomputer software program that provides the users easy access to soils, crops, and weather data bases and uses this information to drive crop models that simulate outcomes of alternative management practices. It is a result of a collaborative effort among IBSNAT, IFDC, Michigan State University, and the University of Florida.

Training on Computer Simulation for Crop Growth and Fertilizer Responses

A training program to understand the principles of model development, validation, and their application for predicting crop growth, nitrogen dynamics, and water balance was held during 1989 at IFDC with cooperation from IBSNAT and Michigan State University. The CERES models for maize, wheat, and rice were the main focus of the course. The participants were also trained on the use of the DSSAT package.

The Pi Soil Test

For the past few years, IFDC scientists have been testing a new method for the evaluation of plant-available phosphorus in soils. This innovative technique, the Pi soil

test, uses strips of filter paper impregnated with iron oxides as a sink to trap and remove phosphorus mobilized in a soil-solution suspension. The test has been found to have a good potential for use across a wide range of soils including those that are acidic, alkaline, and calcareous.

In an experiment to study the adaptability of the Pi test to predict phosphorus availability in 18 acidic to neutral soils with extractable phosphorus ranging from very low to very high levels, it was found that phosphorus extracted by the Pi strips correlated highly significantly with dry-matter yield of maize and phosphorus uptake. Correlation between phosphorus extracted by various soil test procedures and plant response was of the order Pi-P > Bray 1-P > Bray 2-P > Mehlech-P. In another study with a calcareous soil in which available phosphorus was adjusted to different levels by preincubation with superphosphates prior to planting, Pi-P correlated better with dry-matter yield and phosphorus uptake by maize than Olsen-P, the method routinely used worldwide in such soils.

The better correlation of plant response with Pi-P, compared with phosphorus evaluated by other soil tests, was further demonstrated when phosphorus uptake and dry-matter yield of maize grown on 58 soils were correlated with soil phosphorus. In soils with pH less than 7.0, correlation coefficient of Pi-P with dry-matter yield or phosphorus uptake was better than that between phosphorus extracted by other soil tests and plant response. In soils with pH more than 7.0, Pi-P correlated better with dry-matter yield and phosphorus uptake than Olsen-P.

One of the advantages of the Pi test is that the Pi strips can be used to extract phosphorus not only from soils but also from water, effluents, sediments, etc. Phosphorus from the soil can be extracted by shaking a soil-suspension in the laboratory or *in situ* by burying the strip in moist soil in pots, columns, or in the field itself. Under unsaturated conditions the strips, when buried in soil, extracted phosphorus over a wide range in moisture conditions, though maximum adsorption was found at moisture levels between saturation and field capacity. Phosphorus removed by the strips embedded for 16 hours in moist soil columns correlated significantly with phosphorus extracted in the laboratory by shaking for the same period of time as well as with phosphorus removed by crop from soils (Figure 15).

Field studies for the calibration of the Pi test were initiated in Colombia, the Philippines, and East and West Africa in collaboration with IFDC scientists carrying out research in these countries. Collaboration has also been sought from national scientists from India, Pakistan, Philippines, Malaysia, Syria, Egypt, Zimbabwe, Kenya, and Venezuela.

Research on the Pi technology is continuing.

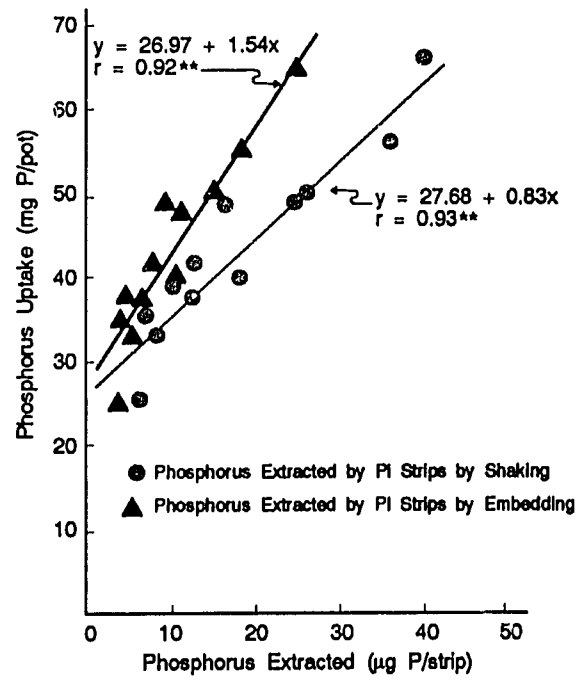


Figure 15. Correlation Between Phosphorus Extracted and Phosphorus Uptake by Beans.

Special Headquarters' Phosphate Projects

Phosphate Rock for Upland Crops

Direct application of phosphate rock as a source of fertilizer phosphorus is an economic alternative to the use of soluble phosphorus fertilizers in the acid soils of the tropics. All phosphate rocks, however, are not suited for direct application. The effectiveness of the phosphate rock varies from source to source and is influenced by its reactivity, particle size, soil properties, and species of crops grown.

In greenhouse trials to compare the agronomic effectiveness of several finely ground phosphate rocks and one unground phosphate rock from West Africa, West Asia, and the United States on maize and upland rice grown on an acidic soil (Hartsells silt loam, pH 4.8), North Carolina phosphate rock from the United States was found to be the

most effective and TPR from West Africa least effective. The effectiveness of phosphate rocks tested in increasing biomass yield of maize and phosphorus uptake was of the order TPR < Central Florida phosphate rock (U.S.A.) < Jordan phosphate rock < unground North Carolina phosphate rock < Arad phosphate rock (Israel) < ground North Carolina phosphate rock (U.S.A.) = TSP. The relative agronomic effectiveness (RAE) values for these phosphate rocks with respect to TSP were 36%, 74%, 79%, 87%, 93%, and 98%, respectively.

The agronomic effectiveness of a phosphate rock is greatly influenced by its particle size because of the effect of surface area on phosphate rock dissolution in soils. When North Carolina phosphate rock, which in its natural state (unground) has a particle size -35 mesh, was screened or finely ground to -35 +65 mesh, -65 +100 mesh, and -100 +200 mesh size particles, both the citrate solubility of the phosphate rock, which is a measure of its reactivity, and agronomic effectiveness were found to increase with decrease in particle size. The effectiveness of the different fractions in increasing biomass production of maize was of the order -35 +65 mesh < -65 +100 mesh < - 100 +200 mesh = TSP, and their RAE values were 78%, 85%, and 96%, respectively. In contrast, with upland rice the effect of particle size of North Carolina phosphate rock was not significant. All three fractions were equally effective as TSP in increasing grain yield of rice. Phosphorus uptake by the plant, on the other hand, increased with greater fineness of phosphate rock.

Likewise, rice yield from soil treated with unground North Carolina phosphate rock was not significantly different from that obtained from soil treated with other phosphate rocks, except in the case of TPR. Togo phosphate rock was less effective than other phosphate rocks tested. These results suggest that, as a rule, with increase in fineness of grinding of phosphate rock increases in phosphorus availability are obtained. In the case of North Carolina phosphate rock which, under natural unground conditions, has fine particle size, direct application of this phosphate rock without alteration is agronomically effective.

A second crop of maize planted after the harvest of upland rice to study the residual effect of the various phosphorus sources showed that North Carolina phosphate rock, regardless of particle size, was more effective than TSP in increasing biomass yield. On the other hand, phosphorus uptake was greater from soils previously treated with TSP. This suggests that the better biomass yield from the residual effect of phosphate rock was due more to calcium than to phosphorus. This was corroborated by the fact that calcium uptake by maize was found to be higher from soils treated with phosphate rock than that fertilized with TSP. This shows that the beneficial effects of phosphate rock include the supply of calcium to plants in addition to phosphorus.

Phosphate Rock for Lowland Crops

Over the years, Headquarters' research on direct application of phosphate rock has been primarily concerned with upland cropping systems common in Africa and Latin America. Less emphasis on phosphorus research for lowland crops of Asia was based on previous evidence that water-soluble phosphorus increased in a flooded system due to several soil chemical reactions including the reduction of iron phosphates and the hydrolysis of aluminum phosphate, which provided nutrient phosphorus required by the plant. However, the use of high-yielding varieties of crops and intensive cropping systems have resulted in increased removal of nutrients from the soil causing phosphorus deficiencies in some rice-producing areas of South and Southeast Asia.

As with the upland cropping systems, direct application of phosphate rock could be an attractive alternative to the use of water-soluble phosphorus fertilizers in the lowland system. Under the lowland system, the management practices, such as time of application, would be important in determining the agronomic effectiveness of direct application of phosphate rock. The influence of some of the management practices on the effectiveness of three phosphate rocks, the low reactive phosphate rock from Togo, moderately reactive Tilemsi phosphate rock from Mali, and highly reactive Sechura phosphate rock from Peru on flooded rice were tested in a greenhouse experiment.

The management practices investigated were:

A. Incorporation of the phosphorus fertilizers in soil and incubation for 2 weeks at field moisture capacity level followed by the addition of other nutrients and transplanting of rice seedlings.

B. Preflooding the soil for 2 weeks prior to incorporation of phosphates and other nutrients and transplanting rice seedlings.

C. Incorporation of phosphorus fertilizers into the soil with flooding 2 weeks prior to the addition of other nutrients and transplanting.

Management A resulted in significantly higher rice grain yield for

each phosphorus source except TSP compared to the continuously flooded Management systems B or C (Table 10). Within the continuously flooded systems, rice yield resulting from the two management systems (B and C) was not significantly different for each phosphorus source except TSP. Monitoring of the soil pH during different stages of growth of rice plants revealed that continuously flooded soils had reached a pH of 6.4 at panicle initiation compared to 5.4 in the case of soils under Management A. The lower pH value was much more conducive to the dissolution of phosphate rock resulting in more phosphorus being available for plant uptake and grain formation.

Table 10. Grain Yields as Affected by Source and Management

P Source	Management	Grain Yield (g/pot)
Check	A	4.97[a]
Tilemsi PR	A	22.50 b
Sechura PR	A	23.10 b
Togo PR	A	8.10 e
TSP	A	26.79 a
Check	B	1.24 g
Tilemsi PR	B	5.40 f
Sechura PR	B	12.97 d
Togo PR	B	1.50 g
TSP	B	25.36 a
Check	C	1.07 g
Tilemsi PR	C	4.97 f
Sechura PR	C	11.97 d
Togo PR	C	1.57 g
TSP	C	18.97 c

a. Means followed by same letter are not significantly different at the 0.05 level of probability.

The more reactive Sechura and Tilemsi phosphate rocks performed favorably compared to TSP under Management A, while the less reactive TPR performed poorly despite having increased yield significantly over the check. While the more soluble TSP was less affected by management practice A and B in terms of grain yield, it did exhibit a significant reduction in Management C. The addition of soluble phosphorus source along with a relatively high organic matter content (4.0%) present in the soil appears to have enhanced microbial activity, which resulted in a more iron reduction that caused iron toxicity which, in turn, reduced yields.

These results indicate that reactive phosphate rock could provide the necessary phosphorus nutrient for flooded rice, if managed properly. Incorporating fertilizer phosphorus and allowing the soil to incubate at field moisture capacity could have potential for use in the acid soils of Asia where rice is grown under rainfed, lowland conditions. The rice could be directly seeded along with incorporation of fertilizers prior to the monsoon season.

Phosphate Rock and Biological Nitrogen Fixation

The importance of phosphorus in BNF by legume crops has been well researched and documented. Little information is available, however, on the relationship between the amount of available phosphorus in the soil and amount of nitrogen fixed by the plant. The relative effectiveness of water-soluble and nonconventional phosphorus sources on yield and BNF in a soybean crop was investigated by a visiting scientist from Panama using the ^{15}N isotope dilution technique. The phosphorus fertilizers tested were the reactive Sechura phosphate rock from Peru, TSP, and a mixture of phosphate rock and TSP at 50:50 phosphorus ratio. The soil (Bladen sandy loam, pH 4.5) was limed to pH 5.2 and incubated with 7.5 mg N/kg of potassium nitrate (^{15}N tagged) for 8 weeks prior to the application of phosphorus and other nutrients and planting.

Significant BNF was found with TSP and TSP + phosphate rock, but not phosphate rock treatments. Of the total nitrogen derived by soybeans from the atmosphere, the labeled nitrogen fertilizer and soil, nitrogen derived from the atmosphere was the highest. From the TSP treatments, 76% of the nitrogen was derived from the atmosphere and 67% in the case of TSP + phosphate rock treatments. The mixture of TSP + phosphate rock was 73% as effective as TSP in promoting BNF in seeds + pods. Sechura phosphate rock alone did not perform well because of liming effect on the dissolution of phosphate rock.

Development of New Plant Digestion Procedures

Nitrogen research at IFDC involves the use of significant amounts of experimental fertilizers enriched with the stable isotope ^{15}N. Use of these materials allows the scientist to trace the path of nitrogen in the soil and plant permitting an estimation of fertilizer efficiency and nitrogen loss. However, the chemical analysis of the plant samples was slow (2-3 hours) and involved the use of heavy metal catalysts that are difficult to dispose of in an environmentally safe manner.

A new procedure for ^{15}N plant analysis, which reduces the problems significantly, was developed at IFDC. The procedure is rapid (13 minutes) and uses no catalysts and only small quantities of acid (3 mL). In a comparison of the new method with that used previously at IFDC, results from the new procedure compared very well both in terms of

nitrogen recovery and ^{15}N enrichment. The new procedure has been adopted in the IFDC laboratory for standard ^{15}N analysis. An additional advantage is that the method can be adapted for use on a bench top allowing the analysis to be performed in areas where expensive laboratory fume hoods are not available or are unreliable.

Laboratory-Scale Urea Prilling

Urea is the most important nitrogen fertilizer in the developing world and the major focus of IFDC's nitrogen program. The use of ^{15}N-labeled urea (urea enriched with the heavier isotope of nitrogen) enables scientists to trace the fate of the urea and is a key part of IFDC's nitrogen research. Because ^{15}N urea is very expensive and available only in crystalline form, it can only be applied in greenhouse and field experiments as an aqueous solution, crystalline powder, or compacted tablets. Because many of the reactions that urea undergoes are affected by the particle distribution, more meaningful research can be obtained if the ^{15}N is applied in a form that is similar to commercially produced urea fertilizer (granules or prills). Also, a spherical shape is advantageous because it permits ^{15}N urea to be coated with water-insoluble materials for research on slow-release coatings.

Two laboratory-scale devices were developed at IFDC to prill urea. The first method employs a 50-mm glass 60° funnel, which was modified by removing all but 15 mm of the stem, sealing off the stem, and making an ~1.5-mm opening in the end of the remaining stem. The bottom one-third of the funnel and stem is heated above the melting point of urea. Powdered or granular urea is fed into the funnel and molten droplets of urea fall from the stem into a container of liquid nitrogen. This produces 4- to 5-mm diameter prills at a rate of ~100 g per hour.

The second method uses a machined stainless steel rotating prilling head consisting of eight radial nozzles connected to a circular trough. This device is attached to a variable-speed motor and heated. In operation, it is rotated at 100-400 rpm and heated above the melting point of urea. Urea powder is fed into the trough from above; it melts and the rotation causes the urea to be expelled through the nozzles. The molten droplets of urea solidify by falling into liquid nitrogen. By varying the speed of rotation, 1- to 3-mm diameter prills can be produced at a rate of ~250 g per hour.

After production by either method, the prills are collected on a screen and dried by a stream of hot air.

These two devices permit the production of spherical urea prills of various sizes for agronomic research and slow-release coating. In addition, small amounts of urea-containing additives, such as urease inhibitors or conditioning agents, can be produced and evaluated.

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*Left in 1989.
**Retired in 1989.
***Deceased.
****Extended leave.

a. Seconded to IFDC by Bundesanstalt für Geowissenschaften und Rohstoffe.
b. Seconded to IFDC by Centre de Coopération Internationale en Recherche Agronomique pour le Développement.

Acronyms

ABOCOL	Abonos Colombianos, S.A.
ACIAR	Australian Centre for International Agricultural Research
AFTMIN	African Fertilizer Trade and Marketing Information Network
AIC	Agricultural Inputs Corporation
AMOCAR	Amoniaco del Caribe
BADC	Bangladesh Agricultural Development Corporation
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BMZ	Der Bundesminister für Wirtschaftliche Zusammenarbeit
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CMDT	Compagnie Malienne Pour le Developpement des Textiles
CRI	Centro Regional de Investigación
CRRI	Central Rice Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organization
ECOWAS	Economic Community of West African States
EFDC	Egyptian Fertilizer Development Center
FADINAP	Fertilizer Advisory Development and Information Network for Asia and the Pacific
FERQUIGUA	Fertilizantes Quimicos de Guatemala
FERTICA	Fertilizantes de Centro América
FINNIDA	Finnish Department for International Cooperation
FINTRA	Fiduciaria de Inversiones Transitorias, S.A.
GOB	Government of Bangladesh
IAR	Institute for Agricultural Research
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICA	Instituto Colombiano Agropecuario
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center
IER	Institut d'Economie Rurale
IFDC	International Fertilizer Development Center
IFFCO	Indian Farmers' Fertiliser Cooperative, Ltd.
IFPRI	International Food Policy Research Institute
ILCA	International Livestock Center for Africa
INERA	Institut National pour l'Etude et la Recherche Agronomique
INTEVEP	Centro de Investigación y Desarrollo
IRRI	International Rice Research Institute
KKV	Konkan Krishi Vidyapeeth
MIPCO	Minjingu Phosphate Company
NARELS	National Agricultural Research and Extension Liaison Services
NCZ	Nitrogen Chemicals of Zambia
NFDC	National Fertilizer Development Center
OTP	Office Togolais des Phosphates
PEQUIVEN	Petroquimica de Venezuela
PhilRice	Philippine Rice Research Institute
SADCC	Southern African Development Coordination Conference
TVA	Tennessee Valley Authority
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
WAFMEN	West African Fertilizer Management and Evaluation Network

Fertilizer Terms and Other Abbreviations

BNF	biological nitrogen fixation
CERES	crop evaluation through resource and environment synthesis
DAP	diammonium phosphate
DPR	Dorowa phosphate rock
DSP	double superphosphate
DSSAT	decision support system for agrotechnology transfer
FIU	fertilizer inputs unit
FPRP	Fertilizer Policy Research Project
FRMD	fertilizer raw materials databases
GEOREF	geological reference file
HIWMS	high intensity wet magnetic separation
KCl	potassium chloride
MAP	monoammonium phosphate
MSRC	Minjingu soft rock concentrate
nBPT	n-butyl phosphoric triamide
nBTPT	n-butyl thiophosphoric triamide
PAPR	partially acidulated phosphate rock
PRCD	phosphate rock characterization database
RAE	relative agronomic effectiveness
REI	residual effectiveness index
SCU	sulfur-coated urea
SSP	single superphosphate
TPR	Togo phosphate rock
TSP	triple superphosphate
UDP	urea deep placement
USG	urea supergranules

NOTE: All "tons" referred to are metric tons.

Financial Report

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Price Waterhouse

Report of Independent Accountants

March 16, 1990

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, of functional expenses and of cash flows present fairly, in all material respects, the financial position of International Fertilizer Development Center (IFDC) at December 31, 1989 and 1988, and the results of its operations, changes in its fund balances and its cash flows for the years then ended in conformity with generally accepted accounting principles. These financial statements are the responsibility of the organization's management; our responsibility is to express an opinion on these financial statements based on our audits. We conducted our audits of these statements in accordance with generally accepted auditing standards which require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management and evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for the opinion expressed above.

Price Waterhouse

100 Years of Service in the United States

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS

ASSETS

CURRENT FUND

	December 31, 1989	December 31, 1988
Cash and cash equivalents	$2,718,855	$2,035,215
Amounts receivable from donors (Notes 1 and 2)	5,504,012	7,027,277
Other accounts receivable	925,421	1,627,557
Advances to employees	132,360	98,789
Supplies inventory (Note 1)	150,281	126,263
Prepaid expenses	383,670	248,637
	$9,814,599	$11,163,738

NONCURRENT FUND

	December 31, 1989	December 31, 1988
Amounts receivable from donors (Notes 1 and 2) - restricted	$1,999,320	$1,110,172

BUILDINGS AND EQUIPMENT FUND

(Note 1)

	December 31, 1989	December 31, 1988
Buildings	$5,904,558	$5,868,910
Equipment	5,378,841	5,190,330
Less - Accumulated depreciation	(6,607,655)	(6,152,255)
	$4,675,744	$4,906,985

LIABILITIES AND FUND BALANCES

CURRENT FUND

	December 31, 1989	December 31, 1988
Accounts payable	$ 319,839	$ 512,066
Accrued annual and sick leave	1,738,269	1,825,801
Deferred revenue (Notes 1 and 2)	6,536,028	7,765,290
Total liabilities and deferred revenue	8,594,136	10,103,157
Fund balance	1,220,463	1,060,581
	$9,814,599	$11,163,738

NONCURRENT FUND

	December 31, 1989	December 31, 1988
Deferred revenue (Notes 1 and 2) - restricted	$1,999,320	$1,110,172

BUILDINGS AND EQUIPMENT FUND

	December 31, 1989	December 31, 1988
Contract retainage	$ 421	$ 215
Lease obligation (Note 4)	56,564	85,456
Fund balance	4,618,759	4,821,314
	$4,675,744	$4,906,985

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES

FOR THE YEARS ENDED DECEMBER 31, 1989 AND 1988

	Current Fund		Buildings and Equipment Fund		Total All Funds	
	1989	1988	1989	1988	1989	1988
Revenue:						
Grants (Note 2)	$ 8,054,003	$ 8,496,430	$	$	$ 8,054,003	$ 8,496,430
Recovered project costs	3,811,690	2,888,667			3,811,690	2,888,667
Other	175,838	82,366			175,838	82,366
Total revenue	12,041,531	11,467,463			12,041,531	11,467,463
Expenses:						
Field programs	3,147,451	2,165,876	127,060	86,670	3,274,511	2,252,546
Research	3,445,819	3,483,505	226,216	305,175	3,672,035	3,788,680
Outreach	2,864,494	2,623,980	50,104	48,082	2,914,598	2,672,062
General and administrative	2,140,078	2,162,814	82,982	140,695	2,223,060	2,303,509
Total expenses	11,597,842	10,436,175	486,362	580,622	12,084,204	11,016,797
Excess (deficiency) of revenue over expense	443,689	1,031,288	(486,362)	(580,622)	($ 42,673)	$ 450,666
Other changes in fund balances:						
Transfers from current fund for equipment acquisitions and capital lease payments	(283,807)	(336,965)	283,807	336,965		
Fund balances, beginning of period	1,060,581	366,258	4,821,314	5,064,971		
Fund balances, end of period	$ 1,220,463	$ 1,060,581	$4,618,759	$4,821,314		

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER
STATEMENTS OF FUNCTIONAL EXPENSES
FOR THE YEARS ENDED DECEMBER 31, 1989 AND 1988

	Field Programs		Research		Outreach		Administrative		Total Expenses	
	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988
Personnel compensation (Note 3)	$1,118,106	$ 770,903	$1,743,871	$1,941,135	$1,252,071	$1,279,717	$1,124,525	$1,143,867	$ 5,238,573	$ 5,135,622
Personnel benefits (Note 3)	464,058	340,116	450,147	415,497	357,810	303,978	279,479	264,557	1,551,494	1,324,148
Travel and transportation	454,127	365,668	261,874	285,433	399,401	446,737	179,011	160,594	1,294,413	1,258,432
Occupancy	32,269	24,900	242,558	253,458	121,351	126,781	121,279	126,729	517,457	531,868
Telephone and telegraph	68,104	40,399	33,449	34,651	32,030	33,969	22,660	21,773	156,243	130,792
Rental of equipment	42,697	45,512		128	1,217		1,598	149	45,512	45,789
Contractual research and development	118,983	81,451	198,903	108,775			70,545	60,830	388,431	251,056
Other contractual services	251,980	184,434	230,375	198,102	418,734	179,426	48,402	61,653	949,491	623,615
Institute of International Education fee (Note 3)							135,973	164,693	135,973	164,693
Materials and supplies	578,752	282,353	236,422	191,215	243,827	196,846	130,287	131,368	1,189,288	801,782
Postage	9,563	8,835	20,421	21,665	24,153	26,903	12,419	10,327	66,556	67,730
Insurance	8,812	21,305	27,799	33,446	13,900	29,623	13,900	16,274	64,411	100,648
Miscellaneous				1,708				55,547		57,255
Total expenses before depreciation	3,147,451	2,165,876	3,445,819	3,485,213	2,864,494	2,623,980	2,140,078	2,218,361	11,597,842	10,493,430
Depreciation of buildings and equipment	127,060	86,670	226,215	303,467	50,105	48,082	82,982	85,148	486,362	523,367
Total expenses	$3,274,511	$2,252,546	$3,672,034	$3,788,680	$2,914,599	$2,672,062	$2,223,060	$2,303,509	$12,084,204	$11,016,797

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER
STATEMENTS OF CASH FLOWS
FOR THE YEARS ENDED DECEMBER 31, 1989 AND 1988

	1989	1988
Cash flows from operating activities -		
Excess (deficiency) of revenue over expenses	($ 42,673)	$ 450,666
Adjustments to reconcile excess (deficiency) of revenue over expenses to net cash provided by operating activities:		
Depreciation	486,362	523,367
Other noncash charges		26,582
Loss on disposal or donation of equipment	2,310	39,380
Changes in assets and liabilities:		
Decrease in receivables from donors	634,117	610,011
Increase in advances to employees	(33,571)	(29,396)
(Increase) decrease in other accounts receivable	702,136	(928,312)
Increase in prepaid expenses	(135,033)	(65,971)
(Increase) decrease in supplies inventory	(24,018)	12,866
Increase (decrease) in accounts payable and accrued expenses	(279,759)	64,751
Increase (decrease) in deferred revenue	(340,114)	300,482
Increase (decrease) in contract retainage	206	(206)
Net cash provided by operating activities	969,963	1,004,220
Cash flows from investing activities:		
Capital expenditures	(257,431)	(330,343)
Net cash used in investing activities	(257,431)	(330,343)
Cash flows from financing activities:		
Principal payments under capital lease obligation	(28,892)	(27,794)
Net cash used in financing activities	(28,892)	(27,794)
Net increase in cash and cash equivalents	683,640	646,083
Beginning cash and cash equivalents	2,035,215	1,389,132
Ending cash and cash equivalents	$2,718,855	$2,035,215

Supplemental schedule of noncash investing and financing activities:

Capital lease obligations of $100,581 were incurred during 1988 when the organization entered into leases for new equipment.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER
NOTES TO FINANCIAL STATEMENTS

NOTE 1 - ORGANIZATION AND ACCOUNTING POLICIES:-

International Fertilizer Development Center (IFDC) is a nonprofit 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 knowledge of fertilizer uses in developing countries through research and development, technical assistance and training and communications.

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

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

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

B. Grants are recorded as receivable in full at the date of the grant with revenue recognition deferred until corresponding expenses have been incurred. Contributions for reimbursable costs are recognized as project costs are incurred.

   Revenue is restricted to the extent it is to be used in accordance with the purpose specified by the grant. Restrictions generally include a specified project or goal within a particular geographic region.

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

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

E. For purposes of the statement of cash flows, IFDC considers certificates of deposit with an original maturity of three months or less to be cash equivalents.

NOTE 2 - GRANTS:-

Grants are summarized as follows:

	Year ended December 31,			
	1989		1988	
	Restricted	Unrestricted	Restricted	Unrestricted
Grants received -				
United States Agency for International Development (AID)	$1,629,500	$3,460,000	$ 2,725,000	$3,535,000
United Nations Development Programme (UNDP)	63,524			
International Development Research Centre (IDRC)	991,123			
Rockefeller Foundation			360,000	
Directoraat Generalaal voor Internationale Samenwerking (Netherlands) (DGIS)	693,457		727,348	
World Bank		1,070,000	270,000	
Der Bundesminister fur Wirschaftliche Zusammenarbeit (BMZ)			919,794	
	3,377,604	4,530,000	5,002,142	3,535,000
Amounts deferred during prior year	7,102,020	1,490,000	6,948,938	1,626,042
	10,479,624	6,020,000	11,951,080	5,161,042
Less - amounts deferred to future periods	(5,863,973)	(2,569,125)	(7,102,020)	(1,490,000)
Other adjustments	(12,523)			(23,672)
Revenue recognized in current period	$4,703,128	3,350,875	$ 4,849,060	3,647,370
		4,703,128		4,849,060
Total restricted and unrestricted		$8,054,003		$8,496,430

In addition to grant amounts deferred to future years, as indicated above, deferred revenue at December 31, 1989 and 1988 includes $102,250 and $283,442, respectively, of cash collected on reimbursable cost projects for which revenue has not been recognized.

The restricted grants received during 1989 relate almost exclusively to fertilizer research projects in Africa. The AID grant provides additional funds for fertilizer policy research under a grant which expires July 30, 1992. One IDRC grant provides $131,645 for development of efficient fertilizer usage techniques and the second provides $859,478 for promoting fertilizer use by African farmers; the first grant is to expire March 31, 1990 and the second expires April 30, 1992. The DGIS grant provides additional funds to support the Togo Center in monitoring, collecting and disseminating fertilizer information in Africa. The UNDP grant relates to fertilizer research and training, but is not restricted to Africa.

During 1988, IFDC received everal restricted grants relating to work in Africa. DGIS awarded $727,348 to be used for the Togo Center. BMZ awarded two grants: $325,162 restricted to development of the Togo Center and $594,632 restricted to research for underdeveloped phosphate deposits in West Africa. The World Bank also awarded $270,000 to be used for the Togo Center. The Rockefeller Foundation awarded $360,000 to be used for fertilizer research in West Africa; this grant expires March 31, 1991. AID awarded $1,620,000 for fertilizer research in West Africa and $1,105,000 for a research project in tropical Africa; both grants represent additional funds for projects which were funded by AID grants in 1987. For all restricted AID grants, the contracts require that unexpended funds be returned to the grantor at the completion of the contract.

Receivables from donors at December 31, 1989 and 1988 are summarized as follows:

	December 31,			
	1989		1988	
	Restricted	Unrestricted	Restricted	Unrestricted
AID	$3,050,871	$1,629,125	$3,380,496	$1,490,000
DGIS	878,977		440,911	
UNDP	940,290		1,549,046	
IDRC	725,278		165,617	
Rockefeller Foundation	60,000		240,000	
Kellogg Foundation			475,000	
BMZ	218,791		396,379	
	5,874,207	1,629,125	6,647,449	1,490,000
Less - Noncurrent portion	1,999,320		1,110,172	
	$3,874,887	1,629,125	$5,537,277	1,490,000
		3,874,887		5,537,277
Total restricted and unrestricted		$5,504,012		$7,027,277

NOTE 3 - INSTITUTE OF INTERNATIONAL EDUCATION:

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

NOTE 4 - CAPITALIZED LEASE OBLIGATIONS:-

IFDC leases office equipment under agreements classified as capital leases. Assets recorded under capital leases are included in property and equipment as follows:

	December 31,	
	1989	1988
Office Equipment	$130,672	$130,672
Less - Accumulated depreciation	29,929	19,040
	$100,743	$111,632

As of December 31, 1989, future minimum lease payments are as follows:

1990	$21,126
1991	21,126
1992	21,126
	63,378
Less - Amounts representing interest	6,815
Present value of minimum lease payments	$56,563

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(as of August 1990)

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