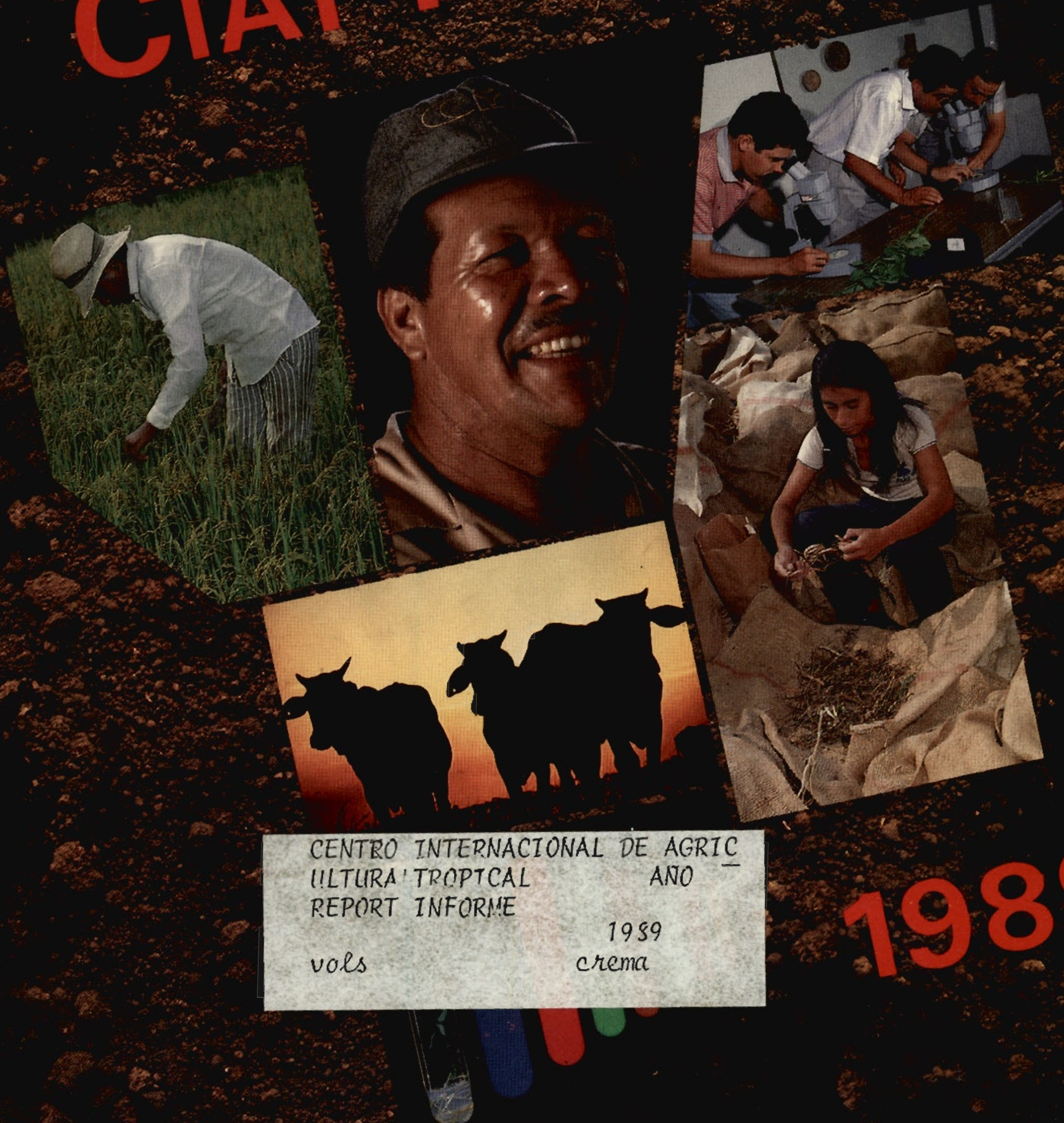
CIAT REPORT



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Centro Internacional de Agricultura Tropical CIAT

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FOREWORD

It is with a deep sense of pleasure, pride, and gratitude that we present this report, giving a sample of the achievements being made by CIAT and its national-program partners; pleasure and pride because these results, and many not reported here, demonstrate solid progress in the urgent task of generating and transferring new technology that is helping to alleviate poverty and hunger in developing countries; gratitude because these achievements would not be possible without the productive cooperation of many institutions, nor without the generous, continuing financial and moral support of our donors.

Readers of this Report will notice a strong emphasis on **sustainability**. This is in response to the growing and legitimate concerns of the global community in sustainable agricultural development. We hasten to add, however, that this is not a sudden switch in emphasis to keep up with current trends. Readers who go beyond the brief summaries on this subject for each research program will note from the individual vignettes that many report exciting progress in specific technology components that contribute to making increased production lasting and environmentally sensitive.

Examples include the progress on biological control of insect pests, reduction of soil erosion, and a better understanding of the mechanisms for resistance to water stress in the Cassava Program; the development of resistance to hoja blanca disease and the related promotion of integrated pest management by the Rice Program; new mechanisms for resistance to spittlebug and demonstration of the importance of legumes in pastures to maintain high-nitrogen status—essential to soil biological activity—by the Tropical Pastures Program; and progress in achieving better biological nitrogen fixation, as well as in developing cropping systems to improve soil conservation in Africa, by the Bean Program.

That such substantial achievements have been made and are already reaching farmers' fields demonstrate that a sustainability perspective is not a recent fad, but has been a long-standing philosophical pillar in all CIAT's programs.

These achievements related to sustainability and the environment, however, do not make us complacent. We are currently developing a strategic plan for the 1990s. An important part of this process is to ask ourselves what more the Center can do to contribute to lasting increases in agricultural productivity, to reduce environmental degradation, and to preserve genetic diversity. We are convinced that CIAT must and will make a major contribution to help counter the descending spiral of poverty and environmental deterioration.

We also recognize that increased productivity in currently farmed areas is one of the most important ways to reduce the need for farmers to move their production onto more marginal lands and fragile ecosystems. Thus, the more traditional approaches to increased production through varietal improvement and better agronomic practices must not be neglected. These are being aided by new, high-tech methods applied to solving intractable production constraints.

CIAT's programs represent an essential balance between upstream and downstream activities; between on-station and on-farm, participatory research; between technology generation and technology transfer; all in support of and in cooperation with our partners in the national agricultural research and development systems.

Much of this work cannot be reported in a highlights document; but the sum of what is being achieved is sufficient to keep us excited that great progress is being made in the fight against hunger and poverty. The purpose of this Report is to share some of this excitement. We are deeply grateful for all who share in these noble goals and who work with us in this quest.

John L. Nickel
Director General

F. E. Hutchinson

Frederick E. Hutchinson
Chairman of the Board

RESEARCH AND RESEARCH SUPPORT PROGRAMS


CASSAVA PROGRAM

Sustainable Agricultural Production in the Cassava Program

Soil degradation—erosion and the depletion of soil fertility—is a growing threat to agricultural production in the tropics. Since cassava is a widely grown tropical crop, the Cassava Program and national program scientists are collaborating to develop appropriate production systems to reduce erosion and fertility decline that occurs when cassava is cultivated. New technology emphasizes intercropping cassava with different crops or with pasture grasses planted in contour ridges. With the judicious use of fertilizers, soil erosion is reduced and higher yields can be sustained.

In Southeast Asia, where erosion is particularly severe, the Program has supported a research network that links national and university research programs to develop methods to effectively limit soil degradation and fertility decline.

Since erosion is also a problem in Latin America, especially where cassava is grown on steep land, CIAT has conducted research on improved production practices that can be effective under these conditions.

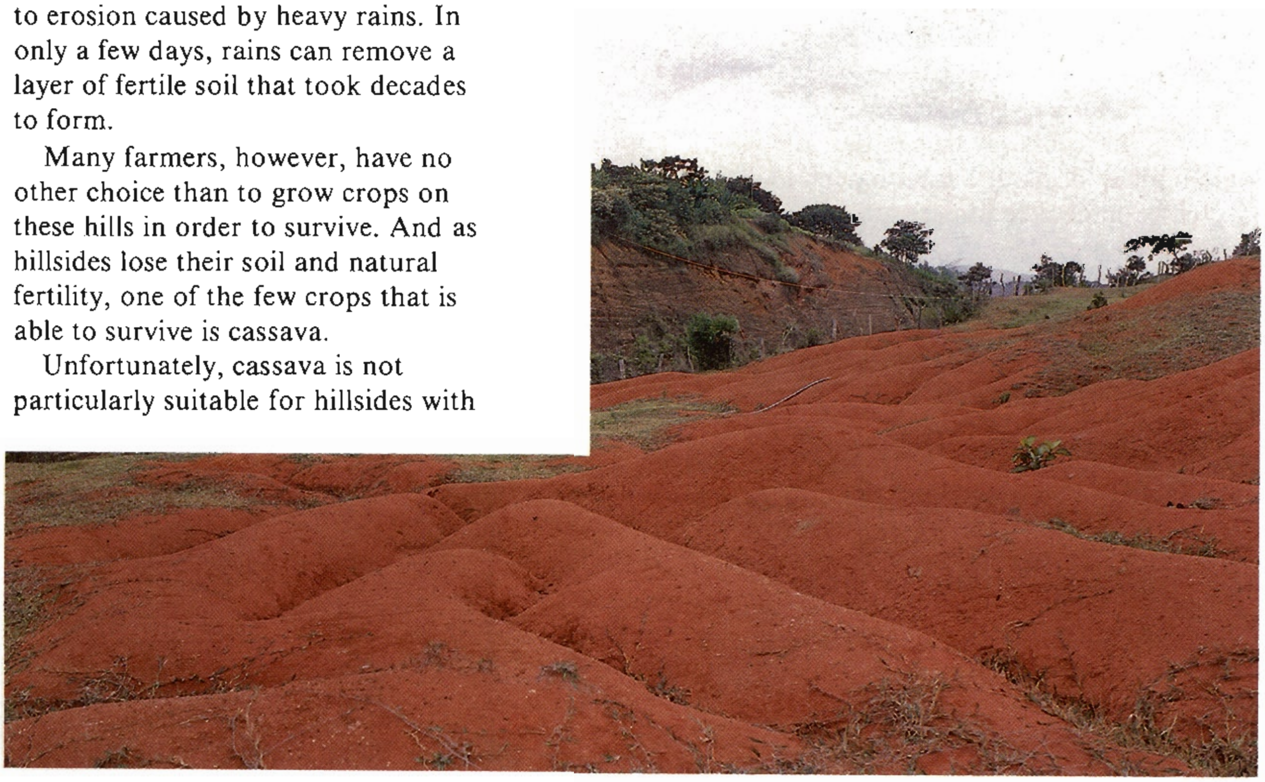
MANAGING SOIL EROSION IN THE TROPICS

By using some simple and inexpensive farming practices, cassava farmers can significantly reduce the erosion of their land and increase yields

The increasing scarcity of land in the tropics is forcing small farmers to plant crops on steeper areas. Tropical hillsides, though, once cultivated, are particularly susceptible to erosion caused by heavy rains. In only a few days, rains can remove a layer of fertile soil that took decades to form.

Many farmers, however, have no other choice than to grow crops on these hills in order to survive. And as hillsides lose their soil and natural fertility, one of the few crops that is able to survive is cassava.

Unfortunately, cassava is not particularly suitable for hillsides with slopes of more than 10% unless proper erosion-control methods are used.



Once some soils have been destabilized by cutting the natural vegetation or when farmed inappropriately, rain and water runoff can cause severe erosion.

Growing cassava with legume mulch is a good way to prevent soil erosion.

Depleted land on Colombia's north coast shows the effects of continuous use (foreground). Crop residues used as manure can recover it (background).

Controlling the Problem

CIAT Cassava Program scientists have been searching for solutions to this problem for several years. They found that while cassava has a reputation for being associated with erosion, this is mainly true in the initial phase of plant establishment. Actually, annual soil losses are generally lower than those caused by most short-cycle crops. Soil loss by erosion, too, is determined more by the way the crop is managed than by the crop itself.

Continuously growing cassava on slopes without adequate fertilization will sooner or later produce a decline in yield due to the accumulated loss of surface soil and nutrients. This occurs because the soil remains unprotected by foliage during cassava's slow early-establishment phase; and soil is radically disturbed when the crop is harvested. In many cassava-growing areas of the world, the landscape can be reduced to bare soil or rocks by erosion.

Practices That Work

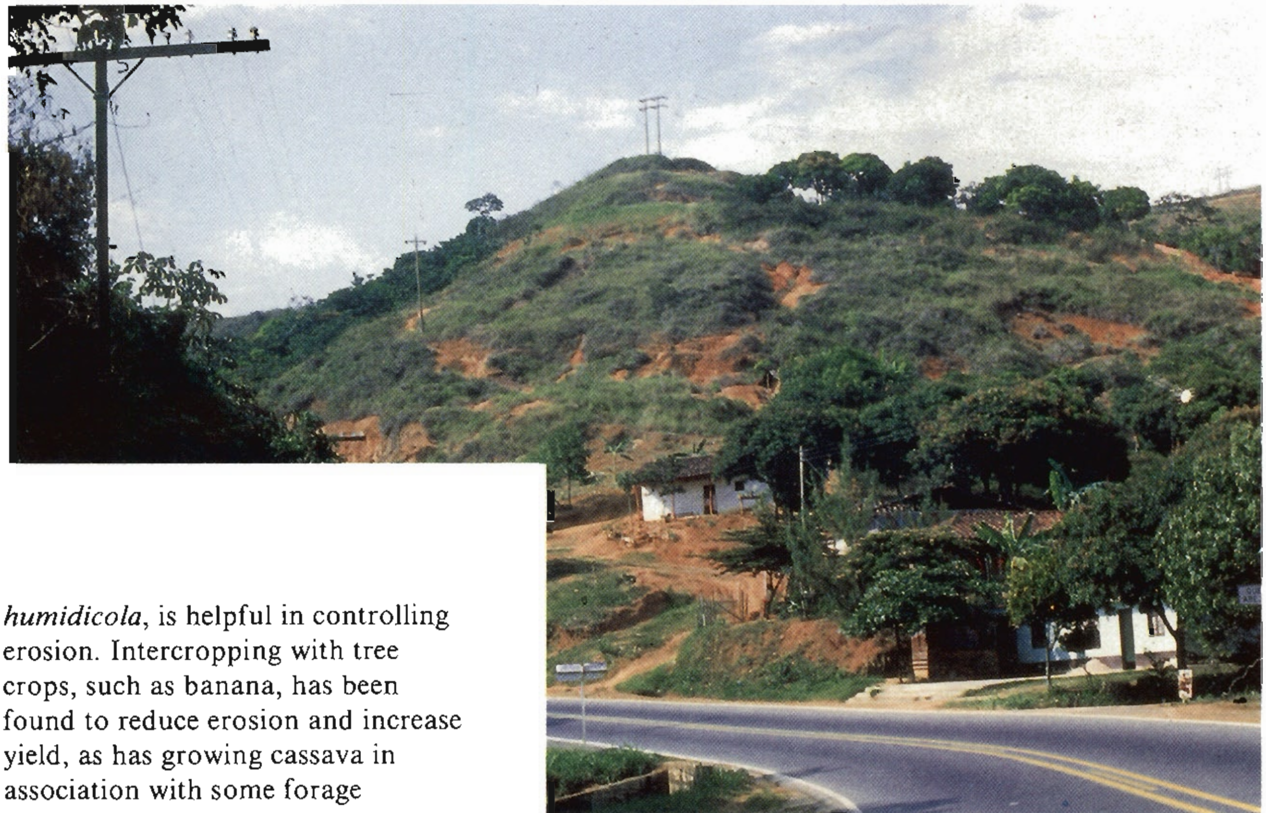
As part of its emphasis on sustainable agricultural production, the Cassava Program recommends that an appropriate amount of fertilizer be used when growing cassava continuously on the same land. Moderate fertilizer usage not only produces high yields but it also helps to control erosion. In various field tests in Colombia in hillside situations, fertilizer markedly increased growth and vigor, resulting in better soil cover, less soil loss, and a near doubling of yields.

Effective agronomic practices, such as using adapted varieties of cassava, selecting healthy stakes, and controlling weeds, not only improve yields but also make the crop grow quickly and vigorously which further protects the soil from rain and water runoff.

Growing cassava with grass barriers, such as *Brachiaria* *humidicola*, is helpful in controlling erosion. Intercropping with tree crops, such as banana, has been found to reduce erosion and increase yield, as has growing cassava in association with some forage legumes, such as kudzu.

When working with soils having good physical structure, one of the best and cheapest erosion-control practices is minimum or zero tillage with the cassava stakes planted on contour ridges. Covering the soil with crop residues helps cut down on erosion. Alternatively, killing weeds with the proper herbicide and leaving the dead material as mulch decreases soil loss.

Improved soil productivity and high cassava yields can be achieved as long as the nutrients removed by the crop harvest are replaced and if the crop is properly managed to prevent excessive erosion. The erosion and depletion problem could become worse, however, if the small farmers of the world are forced by economic and political factors to continue to grow food on land that would be better maintained with its natural vegetation.



A hillside at Mondomo, Colombia, shows the first stages of erosion. Deforestation and poor farming practices are some precipitating causes.

'Soil loss by erosion...is determined more by the way the crop is managed than by the crop itself.'

BIOLOGICAL CONTROL OF THE CASSAVA HORNWORM

The virus of hornworm larvae offers a less expensive and safer way to control a major cassava pest

The cassava hornworm *Erynnyis ello* is a major pest in the tropics. Hornworm larvae feed on cassava leaves and on the young, tender stems and leaf buds. Attacks, however, can occur at any plant age and often completely defoliate a field of cassava, thus reducing root production and quality. Farmers generally deal with attacks by using excessive, ill-timed applications of pesticides. This can result in repeated and more severe attacks, and pesticide use often leads to outbreaks of other pests, such as mites.

More than 40 natural enemies of the hornworm have been identified in the tropics and several of these have been studied in detail. Natural enemies include egg and larval parasites and predators, and larval and pupal pathogens.

THE CASSAVA HORNWORM VIRUS

In 1980 at CIAT, hornworm larvae were found to have disease symptoms which caused considerable larval death. Some of the diseased larvae were sent to Boyce Thompson Institute (Cornell University, Ithaca, N.Y.) where a virus was identified as the causal agent. This led researchers to speculate that this virus could be used to control the hornworm.

To test the theory, virus-infected larvae were liquified in a blender and filtered. The liquid was diluted with water to a 30% concentration. Five and ten cc each of this solution were mixed with one liter of water and sprayed on cassava fields. The hornworm larvae were allowed to feed on the virus-infected fields for 24 hours.

'The hornworm virus offers a natural enemy that can be manipulated, maintained, and managed at a relatively low cost....'

With the 10-cc dose, 48 hours after application, larval mortality was 82%;

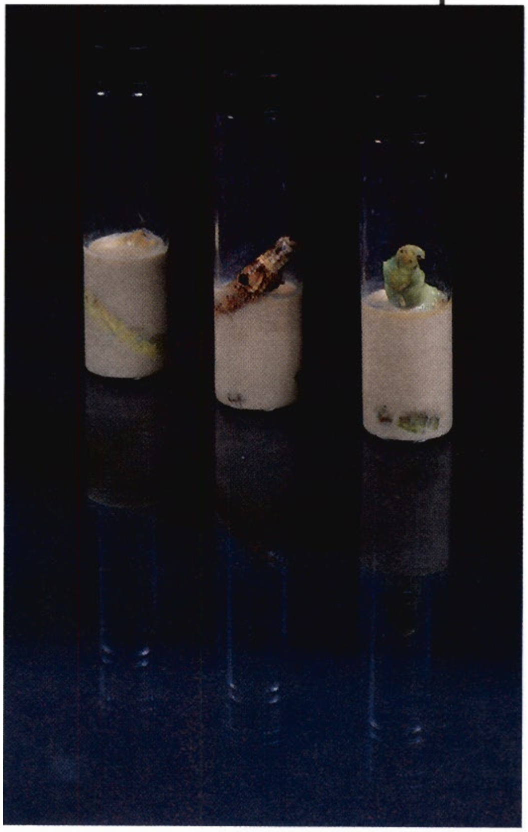
MAJOR STAGES OF THE EFFECTS OF THE VIRUS ON THE HORNWORM

1. *The skin of the infected caterpillar turns pale and dark spots appear.*

2. *Spots become more noticeable. Movements become slower and feeding is reduced.*

3. *The worm loses the ability to eat foliage. It tends to hang from the last pair of anal and abdominal false feet. The body wrinkles.*

4. *The internal organs of the cartepillar dissolve and become localized in the lower part of the hanging larva. Finally, the larva bursts, releasing the virus. The skin dries up. These four steps take about five days.*



5. *The virus may be recovered by storing larvae in containers and refrigerating them. When properly mixed with water, it can be applied in the field to control the hornworm.*

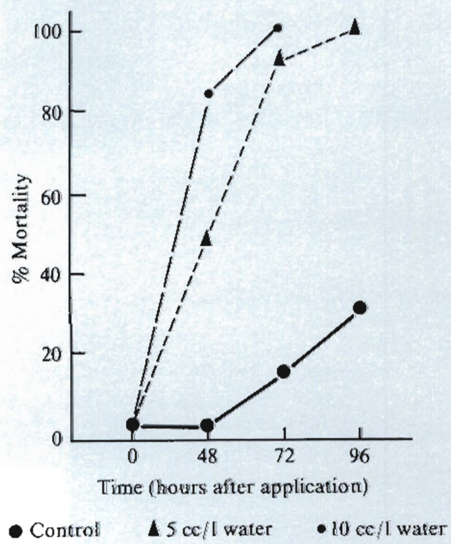
100% in 72 hours. With the 5-cc dose, larval mortality reached 88% at 72 hours and 100% at 96 hours.

Further research has shown that virus-infested hornworms can be stored in frozen form for several years and then be used when hornworm attacks occur. A freeze-dried form of the virus can also be stored until needed.

PROSPECTS

In spite of the large complex of natural enemies, hornworm outbreaks continue to occur periodically in cassava plantations throughout the tropics. Part of this can be attributed to the fact that hornworm adults are migratory and able to fly considerable distances.

A combination of factors, including food supply, natural enemies, and environmental conditions probably influence the migration of the *E. ello* adults. This mobility makes its control in cassava ecosystems especially difficult. Rearing parasites and predators is costly and the timing of releases is difficult due to the migratory and cyclic habits of the adults.



Effect of *Baculovirus* treatments on cassava hornworm mortality.

The hornworm virus offers growers a natural enemy that can be manipulated, maintained, and managed at a relatively low cost. The virus can be easily stored in refrigerated form until required.

The virus can easily be applied with a backpack sprayer and the farmer or technician can maintain the virus culture by collecting infested larvae from the field and storing them. This avoids having to use expensive pesticides or to maintain a perpetual colony of predators or parasites. The hornworm virus, combined with the timely detection of hornworm outbreaks, offers an effective and economical control of this pest.

A hornworm virus *Baculovirus erinnyis* has been found naturally infesting cassava hornworms in the Santa Catarina area of Brazil. The frozen form of the virus is available on a semicommercial basis from the Santa Catarina State Research Institute (EMPASC) to scientists, extension workers, and farmers who request it. Various media are used to instruct farmers on collecting, storing, and using the diseased larvae. The virus is being used effectively by farmers in several areas of Brazil.

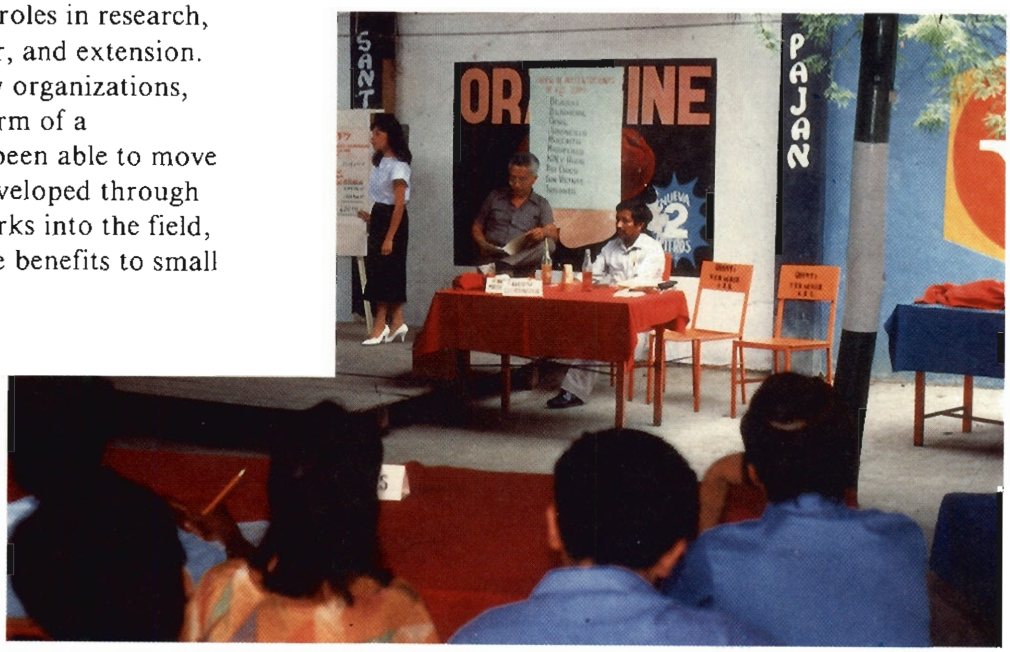
Farmer organizations in technology adaptation and transfer

Local farmer organizations are proving to be a key factor in the process of technology transfer

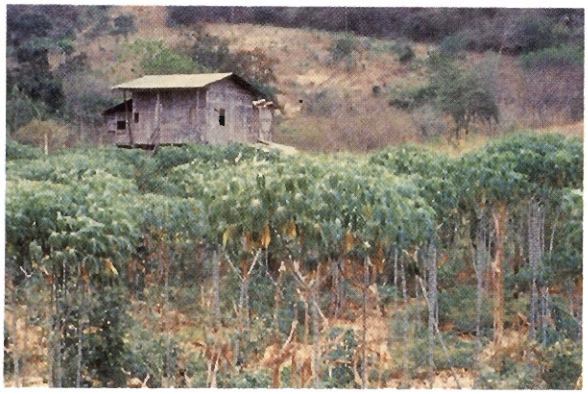
What is the best way to promote cooperation and communication among researchers, farmers, and extensionists? CIAT social scientists are looking at several ways. Some of the interesting options involve farmer organizations which in several South American countries are playing important roles in research, technology transfer, and extension. These intermediary organizations, often taking the form of a cooperative, have been able to move new technology developed through the research networks into the field, bringing immediate benefits to small farmers.

How they work

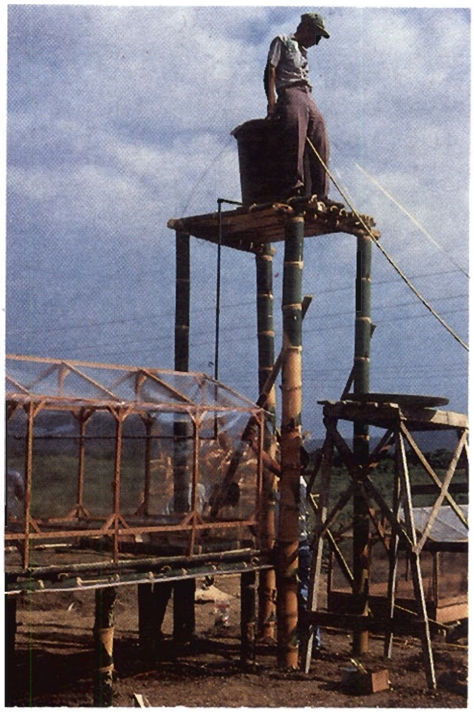
The local farmers' organizations are primarily involved in agroindustry or marketing, but they can collaborate



Members of the UAPPY cooperative gather in Portoviejo, Ecuador, to discuss future business. Thorough planning has enabled them to streamline operations.



Cassava-maize intercropping is a common cropping system used by small farmers in Manabí, Ecuador.



A cassava rapid-propagation plant constructed by the Ecuadorian national agricultural research institute (INIAP). Funds for the facility were provided by UAPPY.

with research institutions. Their resources, contacts with farmers, and administrative capacities allow them to participate in a range of undertakings, including technology design, research, testing, evaluation, and adaptation activities. Some implement technologies with long-term payoff, such as planting trees, erosion control, and regional insect management.

One example includes the groups organized to grow and sell cassava for animal feed, a particularly successful enterprise in Colombia, Ecuador, Brazil, and Mexico. Today in Colombia, there are nearly 50 small-farmer-managed cooperative drying plants spread over three regions of the country.

Ecuador's success

In 1985, Ecuadorian agricultural authorities and CIAT began collaboration to establish cassava-drying plants similar to the successful plants operating on the Colombian north coast. Ecuador's provincial branch of the Ministerio de Agricultura y Ganadería (MAG) organized two small-farmer associations in a cassava-growing area and proposed that they build drying plants and process the product into flour. The Ecuadorian national agricultural program —Instituto Nacional de Investigaciones Agropecuarias (INIAP)— and CIAT assisted.

A CIAT anthropologist was intimately involved in designing the research and extension techniques to make promotion more efficient. For example, a cassava farmer and leader of one of the cooperatives from the Colombian north coast was hired as a

'This farmer-to-farmer technology transfer approach has proven to be a very effective form of extension.'

In Ecuador, family members of a cooperative stand beside cassava-drying trays. This method is particularly effective in humid areas.

consultant to advise the new Ecuadorian associations. This farmer-to-farmer technology transfer approach has proven to be a very effective form of extension.

In just three years, the number of cassava-drying farmer associations in Ecuador has grown to more than 20 (nearly 400 members) and output now exceeds 1000 metric tons of flour. Equally striking, the cost of extension and applied research was cut to about one-third of what it had been, mostly by eliciting the cooperation of organized farmers.

The farmers' associations in the Manabí Province have combined to form a common association: the Unión de Asociaciones de Productores y Procesadores de Yuca (UAPPY). Through this union they have been able to streamline production, transportation, and marketing of the processed cassava. This year, several UAPPY members have visited CIAT to study the operation of artificial driers, starch-making technology, sifters, and mills.

Making changes

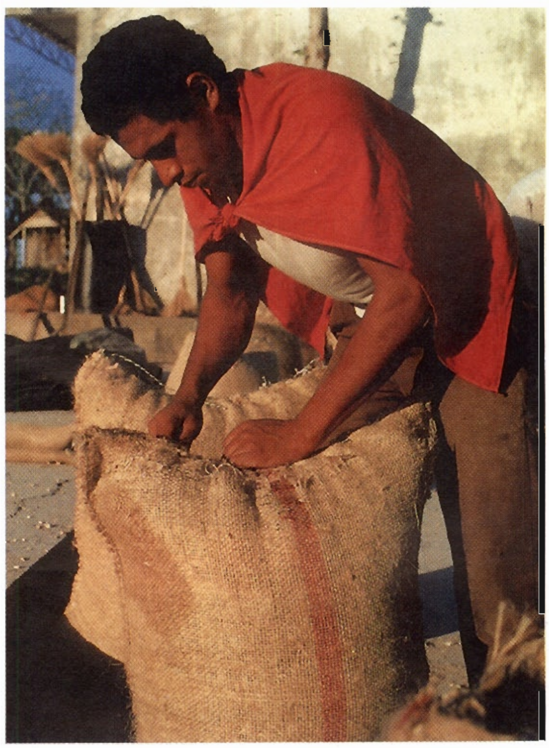
The degree to which the UAPPY is taking on complex tasks is impressive. New farmer groups are being formed by farmers promoting the UAPPY concept with government participation. The UAPPY not only collaborates with research institutes but also runs trials of modified processing technology; it organized and implemented 30 training events in 1988. The assistance of government agencies is still important, but the UAPPY is becoming an independent catalyst of rural development.

A national organization is actively promoting this kind of project. FUNDAGRO, a private Ecuadorian foundation, has been assisting the institutions in coordinating their efforts and to integrate research, extension, training, and farmer organization. The interinstitutional team includes the national farmer training institute (INCCA). Funding comes from bilateral programs of Great Britain, Canada, the United States, and from participating Ecuadorian agencies.

UAPPY has proven to be a successful example of linking technology adaptation, extension, and development to a social and agronomic scheme through a farmer organization. The association accomplished it by establishing relationships with research and extension agencies, both government and nongovernment. The agencies and organizations received technical assistance from CIAT and, in one subproject, from the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico.

Experience in Colombia and Ecuador has shown that experimental development projects with farmer organizations can work where cassava-drying projects are the focus. They are a model that can be modified and replicated in other parts of the world to make extension efficient and to reduce the cost of applied research.

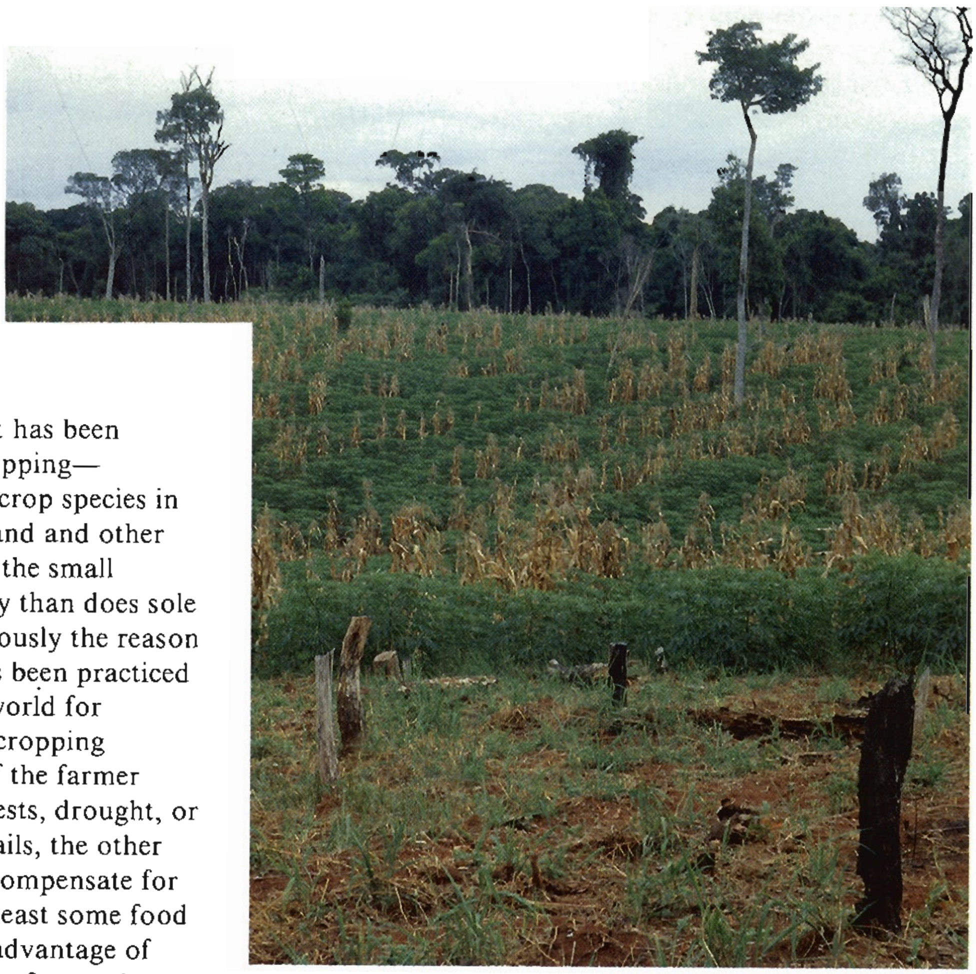
On the Atlantic coast of Colombia, members of a cassava-producers cooperative dry cassava chips on a concrete patio. The moisture level of the chips is reduced to around 14%.



A Colombian farmer packs dried cassava to send to the market. By producing, processing, and marketing the product, the cooperatives stabilize the price of cassava and reap more profits.

INTERCROPPING IMPROVES LAND-USE EFFICIENCY

Growing two or more crops together is an effective and efficient way for some farmers to get the most out of their land



Cassava and maize are intercropped on land that was once a secondary forest in Paraguay. Forty percent more land would be needed for the same total production when sole cropped.

In many situations it has been shown that intercropping—growing two or more crop species in the same plot—uses land and other resources available to the small farmer more efficiently than does sole cropping. This is obviously the reason why intercropping has been practiced in many parts of the world for centuries. Associated cropping reduces the chances of the farmer losing everything to pests, drought, or diseases. If one crop fails, the other may survive and will compensate for the loss or provide at least some food or earnings. Another advantage of intercropping is that it often makes more efficient and intensive use of available labor. Most researchers agree that unless socioeconomic conditions change radically during the next few years, small farmers will continue to practice intercropping.

INTERCROPPING TECHNOLOGY

Agricultural research institutions have often concentrated on developing technology for sole cropping even though intercropping is widely practiced by small farmers. There has been a great need to develop technology which is specifically designed for intercropping systems or for modifying technology components developed for sole-cropping conditions.

One of the most common associations used by small farmers in the tropics are systems involving maize and cassava. The farmers have discovered by trial and error that if they lose their maize they can fall back on their cassava. Cassava is well known as a hardy crop that can withstand very stressful conditions.

CIAT Cassava Program scientists, in conjunction with Colombia's national program, the Instituto Colombiano Agropecuario (ICA), are conducting research designed to make this time-proven practice even better. The country's northern coastal plains have been the laboratory for this research. The region is ideal because intercropping of maize, cassava, and even yams has been done there for a long time.

'With natural or chemical nutrients difficult to obtain, [farmers] must make as efficient use of the land as possible.'

Intercropping cassava and maize is a widely used system on small farms in the Ecuadorian mountains because it makes more efficient use of the land.

Some farmers on the Atlantic coast of Colombia plant cassava and maize in double rows.

For farmers in the region, the most common problem is lack of land, caused by a combination of rural population growth and the traditional pattern of land inheritance. Constant division of available land has left north coast farmers with an average of 5-6 ha, about 50% of which is maintained in natural pastures or left fallow to restore soil fertility. With natural or chemical nutrients difficult to obtain, they must make as efficient use of the land as possible.

THE RESULTS

In farmers' fields on the north coast, scientists compared several improved varieties of maize, developed mostly by ICA, with local maize varieties, in association with the most commonly grown cassava varieties.

The scientists were surprised to find that the local maize varieties competed more aggressively with cassava than the improved varieties. Grown under farmers' conditions, cassava yielded an average of 16 t/ha of roots in sole cropping and 11 t/ha in association with the improved varieties of maize. Yet, when cassava was grown with traditional maize varieties, it only yielded 8.8 t/ha. Improved maize varieties, on the other hand, yielded 2.6 t/ha in sole cropping and 2.0 t/ha in association. Traditional varieties yielded 1.5 t/ha in sole cropping and 1.3 t/ha in association. This indicates that ICA's improved maize varieties not only yield higher in monocropping but also in intercropping, while cassava intercropped with these improved maize varieties also yielded more.

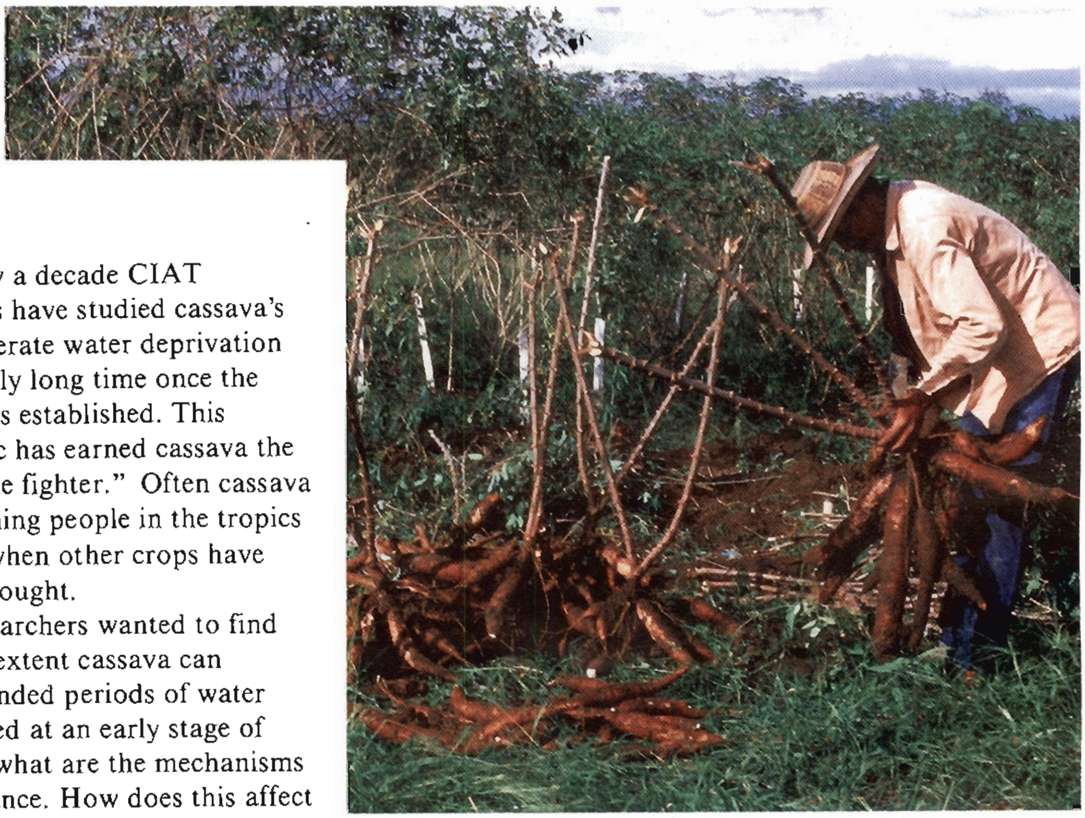
The intercrop produces a land-equivalent ratio of 1.4. That is, 40% more land would be necessary to obtain the same production as from sole cropping.

The preliminary results are promising. As the studies proceed, CIAT continues supporting ICA's field work with germplasm, on-farm research methodology, training, and scientific exchange.

Cassava and maize grown in association in Ecuador. Intercropping is common in the Andean region of South America.

STRETCHING THE WATER-STRESS LIMITS OF CASSAVA

Cassava again proves its hardiness by producing under water stress yields that equal those of a well-watered crop



In Cauca, Colombia, several varieties of cassava which were tested under water stress are harvested for evaluation.

For nearly a decade CIAT scientists have studied cassava's ability to tolerate water deprivation for a relatively long time once the crop becomes established. This characteristic has earned cassava the name "famine fighter." Often cassava is the only thing people in the tropics have to eat when other crops have died from drought.

CIAT researchers wanted to find out to what extent cassava can tolerate extended periods of water stress imposed at an early stage of growth and what are the mechanisms of this tolerance. How does this affect yield, the hydrocyanic acid (HCN) content, and eating quality? The findings were surprising.

THE EXPERIMENT

Using several popular cassava clones, a four-month period of water stress was imposed 60 days after planting by covering the ground with plastic. Following this stress period the crop was allowed to recover for the rest of the growing season of five months with the aid of rain and irrigation. A nonstressed control was used for comparison.

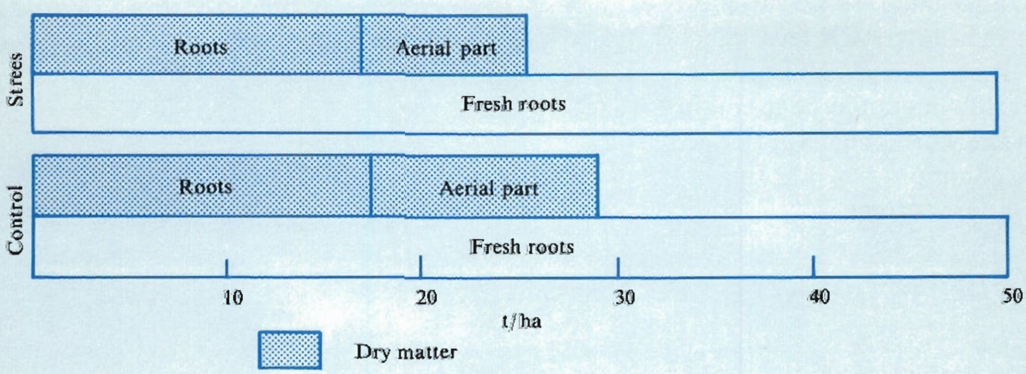
Contrary to what might have been expected, the yield at 11 months was not greatly affected by the deprivation of water at this presumably critical period in growth. Also, the percentage of dry matter in the roots of the eight cultivars compared in the two groups was similar—36% for the control group and 35% for the stressed group. The percentage of root to total biomass—the harvest index—was actually higher in the latter: the control group had a harvest index of 61% and the stressed group climbed to 67%.

Leaf photosynthesis measured in the field with portable equipment during the stress period remained at 70% of the maximum level—another surprising and encouraging finding.

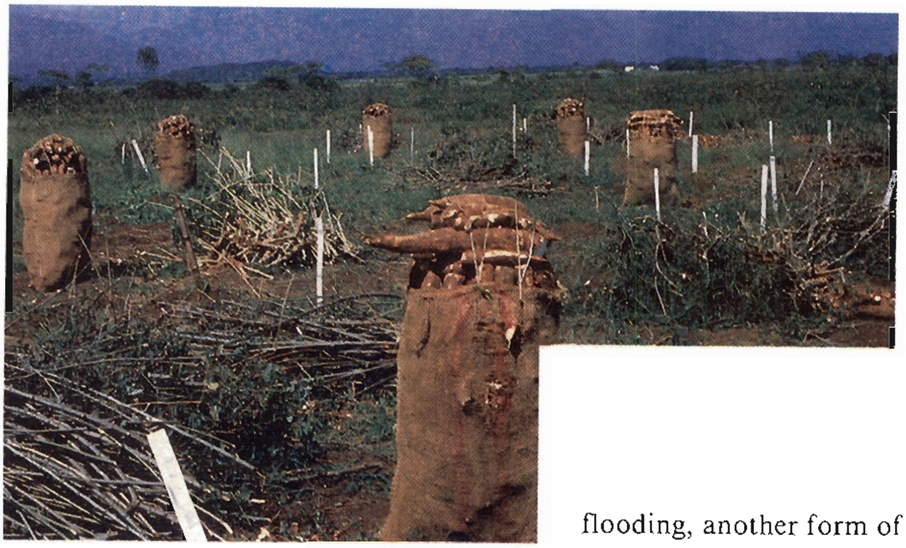
HCN CONTENT

Cyanide content in cassava can pose a serious health risk to humans and animals who consume it if roots high in HCN are not processed adequately. Typically, water stress will increase the level of HCN in the root—often to an unacceptable level.

The quality of the roots of two cassava varieties which were water stressed for four months was not affected.



Average production from eight cassava cultivars as affected by an early and prolongued period of water stress.



The test plot where CIAT scientists evaluated cassava grown under water stress. Forty tons per hectare were harvested, testimony to the plant's hardiness.

Researchers found that the HCN content did increase when some of the clones were subjected to water stress; but it remained basically unchanged in two advanced CIAT lines. This finding has important implications in the process of selecting "sweet" clones because some cassava cultivars that are considered sweet under favorable conditions can become bitter when stressed.

On the other hand, some varieties grown for their low HCN level can maintain these levels even under stress. Such clones could be useful in regions of the world where prolonged drought is common—such as the Sahel or eastern Africa.

Effects of flooding

Scientists were interested in identifying cassava cultivars that for a short period could withstand flooding, another form of water stress. To screen for flood tolerance at an early stage of cassava growth, breeders and physiologists tested several clones grown in pots filled with soil or a soil and sand mixture. The plants were exposed to flooding for 24 to 72 hours and differences in the cultivars' tolerance to flood were compared. The scientists concluded that the differences in leaf retention and root formation were apparently related to the plant's response to flooding. Researchers are zeroing in on the physiological and pathological factors that affect this tolerance.

'Often cassava is the only thing people in the tropics have to eat when all other crops have died from drought.'

RICE PROGRAM

Sustainable Agricultural Production in the Rice Program

In the developing world, an important prerequisite to increase and to sustain agricultural production is establishing integrated and effective research and extension programs. The Rice Program facilitates these efforts by helping policy makers in Latin America develop comprehensive rice research and technology transfer plans.

The Program's research benefits national programs, many with limited resources, by developing improved lines and rice-growing methods that can be adapted for local use. These lines incorporate resistance or tolerance to principal stresses which may upset rice production. Lines adapted to acid soils could improve rice productivity in the tropical savannas. Recognizing the interdependence between agriculture and the environment, the Program develops integrated crop-management technologies which contribute to sustainable cropping systems.

Research and training networks are also being strengthened. These networks facilitate technology adoption enabling the national programs to more effectively transfer integrated crop-management methods.

INTEGRATED PEST MANAGEMENT TO COUNTER EXCESSIVE PESTICIDE USE

Many rice growers misuse pesticides which increases costs unnecessarily and does not improve yields

Excessive use of pesticides over many years to control the rice pest *Sogatodes oryzicola* has caused it to develop resistance to them. A study by CIAT Rice Program scientists has found that ten times the level of insecticides were required to kill insects collected from two high-insecticide-use areas of Colombia than was necessary for a control group unexposed to these. Past evidence shows that many Colombian rice growers are misusing insecticides on their crops, which can lead to a dramatic ecological imbalance and actually increase production costs without improving yields.

Integrated pest management may require the use of insecticides if pest populations are high. Products to be used should be carefully selected.

Beneficial organisms such as sogata-predating spiders are found on the crop during its entire vegetative cycle. Biological control with natural enemies is a fundamental component of integrated pest management.

THE CAUSE

The use of too much pesticide in an area can cause a resurgence of insect pests due to the extermination of their predators and parasites. In the case of *S. oryzicola*, misuse has likely caused the pest to develop resistance to insecticides, causing farmers to apply more chemicals to achieve the same level of control. In some areas of Colombia, farmers have been increasing their use of chemicals against the pest, suggesting that resistance has indeed developed.

To confirm this, scientists began by determining the dosage of the insecticide monocrotophos required to kill half (LD50) the insects taken from a population of insects reared in a controlled environment and which

The sogata insect can develop resistance to insecticides if they are used excessively.

had not been exposed to insecticides for three years. Other LD50s were determined for colonies established with insects collected from several rice fields in Tolima, Colombia, where insecticides had been extensively used for many years. By comparing their LD50s with that of the control group, scientists found that those insects collected in Tolima had resistance to monocrotophos.

The conclusion: the irrational use of pesticides sets off changes in the environment which have unknown consequences, besides reducing the profitability of the crop. A better solution is to use an integrated crop-management plan which can include the judicious use of insecticides. This will not only make farmers more aware of the benefit of proper crop management, but it will also help stem the evolution of resistance to insecticides and prolong the useful life of these compounds.

'A better solution is to use an integrated crop-management plan....'

This concept has led to integrated pest-management (IPM) demonstrations in Colombia and Ecuador, countries where national rice plans are in effect. Farmers, seeing the success, are beginning to adopt IPM practices. Already there is evidence that there is a substantial reduction in the amount of pesticide used in these experimental areas.

Sogata populations are evaluated by counting those caught in net sweepers. If the population is high, or if the variety is susceptible, a decision could be made to use an insecticide.

Record-time Development of New Rice Varieties in Colombia

Proven screening methods are reducing the release time for new rice varieties by years

Two new rice varieties for irrigated and favored-upland conditions, recently released by Colombia's national program (ICA), were developed in record time. The speed with which these lines moved through the extensive evaluation process indicates that it is now possible to accelerate the rate of varietal release in many countries.

Background

In 1985, production in the important rice-growing area of the Colombian Eastern Plains (Llanos) was being threatened by disease and high production costs. Available varieties were susceptible to a major disease, rice blast. At the same time, a major epidemic of hoja blanca virus was encouraging farmers to use excessive amounts of pesticides in an effort to control the insect which transmits the virus to rice.

At La Libertad Regional Research Center, ICA and CIAT investigators observe new varieties. These were developed in record time by the ICA-CIAT-FEDEARROZ research team.

Varieties resistant to both diseases were urgently needed.

Scientists from ICA, CIAT, and the Colombian rice growers association (FEDEARROZ) launched an accelerated selection, evaluation, and generation-advancement plan to meet these challenges as part of the overall Colombian national rice-improvement plan. This exemplary case shows how an international agricultural research center, a national program, and a private commodity organization can successfully plan and work together.

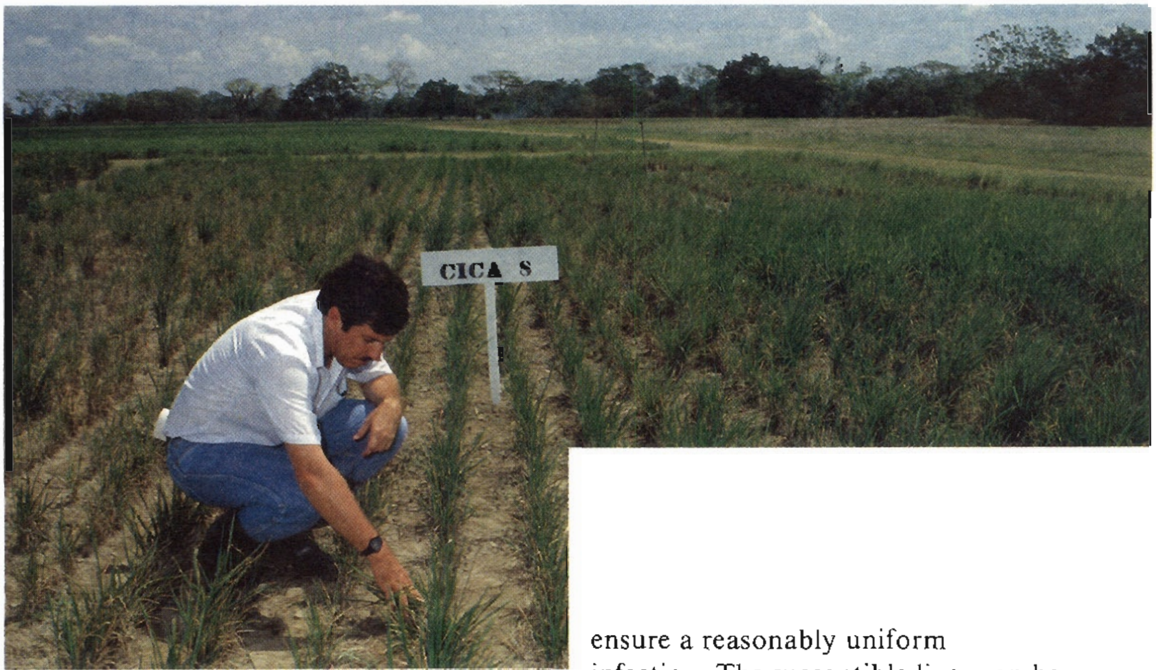
RICE BLAST

The two new varieties were the first to pass through CIAT's Santa Rosa experiment station from the second generation onward. Santa Rosa's 26-hectare, favored-upland site is located at the edge of the Colombian Llanos and is a disease "hot spot." The high rainfall (as much as 3000 mm/yr) and high humidity during the growing season are favorable for the development of the rice blast fungus.

'These lines are the first hoja blanca-virus- and sogata-resistant lines to reach commercial production.'

An ICA researcher addresses farmers from the Llanos attending the field day marking the release of the new rice varieties. The Llanos produces 30% of Colombia's rice.

The resistance of Oryzica Llanos 4 and Oryzica Llanos 5 to rice blast will help farmers reduce their crop-protection costs and increase their profitability.



Varieties traditionally grown in the Llanos such as CICA 8, have a low level of resistance to the main diseases present there.

Blast, the most serious and widespread rice disease in Latin America, is endemic in the region, so rice breeding lines are selected and advanced under severe blast pressure. Also, at Santa Rosa, the soil acidity and rainfall pattern are similar to the favored-upland conditions of many parts of Latin America.

Hoja blanca

The new lines passed through the highly successful hoja blanca-virus-screening process developed at CIAT three years ago. For the hoja blanca virus, special colonies with a high proportion of sogata, the insect vector, are raised which, when released in fields containing the genetic material to be characterized, ensure a reasonably uniform infection. The susceptible lines can be distinguished readily from resistant lines.

These lines are the first hoja-blanca-virus-and sogata-resistant lines to reach commercial production. Varieties with virus and sogata resistance are a necessary precondition for the implementation of integrated pest management in the American tropics. Without them there is a risk of serious virus outbreak and overreaction by farmers applying pesticides indiscriminately, endangering human life as well as upsetting the ecological balance.

In addition to their resistance, the new varieties are also high-yielding and have good grain quality.

National plan successful

The speed with which the varieties were screened and released reflects the successful implementation of the Colombian national program's breeding plan.

Oryzica Llanos 5 has strong and flexible stems. It is resistant to lodging and is recommended for both irrigated and upland areas.

Oryzica Llanos 4 and Oryzica Llanos 5 are the first commercial varieties with resistance to the sogata-hoja blanca complex. This characteristic is important in an integrated pest-management scheme.

Researchers from the above organizations were able to respond rapidly to the needs of growers for blast-resistant varieties in several areas of Colombia. With a clear set of objectives, well-defined responsibilities, and the evaluation tools and sites in hand, varieties Oryzica Llanos 4 and Oryzica Llanos 5, obtained from lines assessed from crosses made in early 1984, will be in farmers' fields in 1989. This is in contrast to previous procedures where it typically took 6-8 years to develop a new variety.

CARIBBEAN RICE NETWORK GAINS MOMENTUM

New varieties of rice, improved agronomic practices, mechanization, and better-trained researchers reflect progress

The Caribbean Rice Improvement Network (CRIN) was established in 1986 by CIAT and the International Rice Research Institute (IRRI), with funding by the United Nations Development Program (UNDP) and the Canadian International Development Agency (CIDA), to benefit rice-producing countries such as Belize, Cuba, Dominican Republic, Guyana, Jamaica, Haiti, Surinam, and Trinidad and Tobago. Its impact is already evident, although the region is a major net importer of rice.

For example, with respect to germplasm, a total of 2118 lines have been evaluated and 538 have been selected for the various rice-production ecosystems in the area. In June 1986, the Network and the Centro de Investigaciones Arroceras (CEDIA), Dominican Republic, established regional trials of advanced lines at several sites. In 1989, demonstration plots will multiply five promising dwarf lines. The lines mature in 130-140 days, they have good yield potential—between 5.3 and 7.5 t/ha—and good grain quality. The release of one or two new varieties is expected this year or next.

The Network and CEDIA advocate better agronomic practices, such as preparation and proper leveling of the soil, fertilization, and pest, disease, and weed control. Tests of these

A group of technicians in the Dominican Republic identifies commercial varieties growing in the field as part of an international course on rice production.

Agriculturalists at the Mauge experiment station, Artibonito, Haiti, practice hand-transplanting rice.

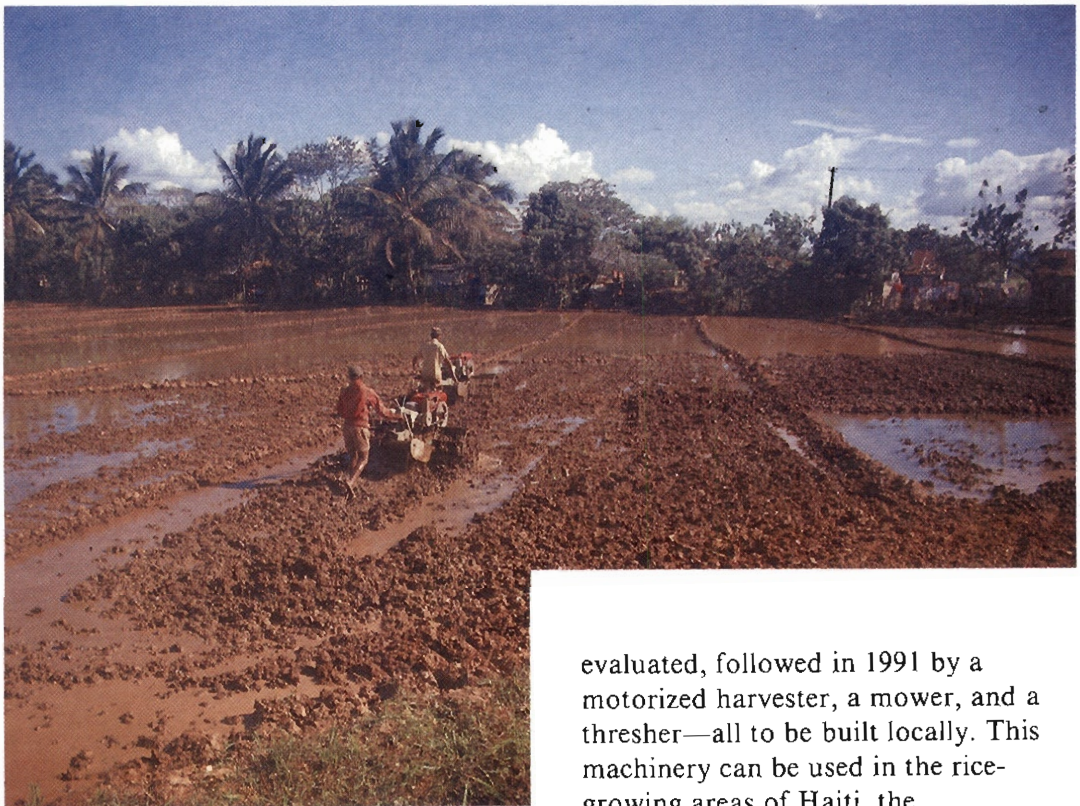
practices conducted on small farms show that it is possible to reduce red rice infestation 70%, production costs by at least 19%, and increase productivity up to 53%.

The Network also trains researchers. A total of 75 professionals have participated in activities dealing with rice production and research, seed production and certification, evaluation and selection of genetic material, and lowland reclamation for rice production in the last two years. In 1988, a course on modern production technology for irrigated rice attracted 25 researchers from the Dominican Republic, Haiti, and Cuba.

Machinery for the Small Farmer

In the Caribbean area, rural labor is generally scarce, particularly for land preparation and harvesting. These two activities currently comprise 50% of the total production cost. These

This small, motorized cultivator, designed by IRRI, has been tested in the Dominican Republic. Here, it is being used for soil leveling.



Motorized cultivators are used to prepare a rice field. Appropriate machines could reduce production costs in the Caribbean area.

expenses could be reduced by a third using appropriate machinery, according to findings in the Dominican Republic.

In view of this, Network specialists in 1987 initiated an agricultural mechanization project by introducing and modifying a motorized cultivator, a cutter, and a thresher developed at IRRI in the Philippines. Used on small farms, it produces very good results. One of the main goals of the project is to promote the manufacture, use, and field evaluation of such machinery which might also be used in other agricultural work.

This year and next, a motorized cultivator with harrows, plows, and a soil leveler will be fabricated and evaluated, followed in 1991 by a motorized harvester, a mower, and a thresher—all to be built locally. This machinery can be used in the rice-growing areas of Haiti, the Dominican Republic, Jamaica, Belize, and Trinidad and Tobago.

'It is expected that these advancements will [make]...these countries self-sufficient in rice production.'

It is expected that these advancements will make it possible to develop production systems relevant to the economic and ecological conditions of each region, making these countries self-sufficient in rice production.

NEW RICE-CROSSING METHOD AIDS NATIONAL PROGRAMS

A time-, land-, and labor-saving crossing method can help national programs release new rice varieties sooner

A new crossing method developed at the Centro Nacional de Pesquisa de Arroz e Feijão (CNPAF), Brasil, and the Institut de Recherches Agronomiques Tropicales et de Cultives Vivriéres (IRAT), France, drastically reduces the time, labor, and cost of breeding new varieties. The hybridization method was modified and adapted by CIAT rice scientists for the needs of national agricultural research systems. It will enable rice breeders to overcome several major limitations to their ability to develop effective crossing programs.

The continuous development of improved rice varieties is necessary for national rice programs if their farmers are to stay ahead of ever-changing insect and disease complexes. Genetic variability must be maintained and new genetic combinations generated so that new materials will be available, either for release as new varieties, or to be used for crossings as plant parents. But breeding new, improved plants requires substantial investment in facilities and in scientific materials. Add to this the labor required, and the demand commonly outreaches the resources of most national research institutions. The new method requires minimum investment in resources, and most national programs already are in a position to make great use of its breeding potential.

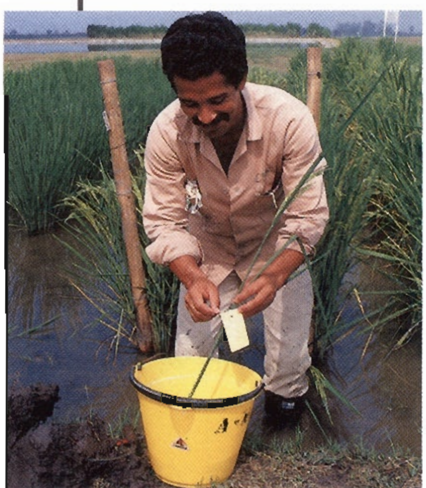
THE STEPS

The new hybridization process consists of two essential steps: emasculation and pollination. The former involves removing and cutting open the anthers, the male part of a plant, from a floret and putting pollen on the stigma (the female part). These two steps have been modified and simplified in the new method to reduce the amount of land, labor, and time needed.

The conventional method requires that female parents be dug up in the field, placed in pots, transported to

STEPS IN THE HYBRIDIZATION METHOD

1. *The stems on which the parent panicles are found are cut in the field.*



2. *These are placed immediately in buckets containing water and labeled with the code or name for the line or variety and the date.*

3. *The next day, emasculation, or the removal of the six anthers from the florets, is done with a small tweezer. The panicles are then covered with glacine paper.*

and maintained in a greenhouse. This process is extremely inconvenient, time-intensive, and requires a lot of greenhouse space, as each simple cross requires at least one pot—a hundred crosses, a hundred pots—and more for more complex breeding.

The modified method entails cutting the stems (tillers) at the soil level from parents in the field and putting them in water in a greenhouse. Thus, rather than transporting entire plants from the field in large pots, only tillers are moved; they can be kept in one container, as opposed to many on several benches.

Emasculation is done by cutting open the floret with scissors so the anthers can be removed by tweezers. The florets are then covered with small bags.

4. *A day later, the emasculated panicle is pollinated by placing it underneath the pollen-donating panicle. Once they are together, the upper panicles are gently shaken so that the pollen falls to the lower panicle.*

5. *The pollinated panicle is covered with glacine paper to prevent it from becoming contaminated by alien pollen.*

6. *The panicles are kept under optimal light conditions and in containers with fresh water. The paper is removed 5-7 days after pollination and 25-30 days later, the seed is ready for harvest.*

THE POLLINATION PROCESS

Pollination can be carried out by either bringing the pollen parents into the greenhouse or transporting the emasculated panicles to the field. It is done by shaking pollen-containing panicles of male-designated parents over the stigmas which are then covered for a week.

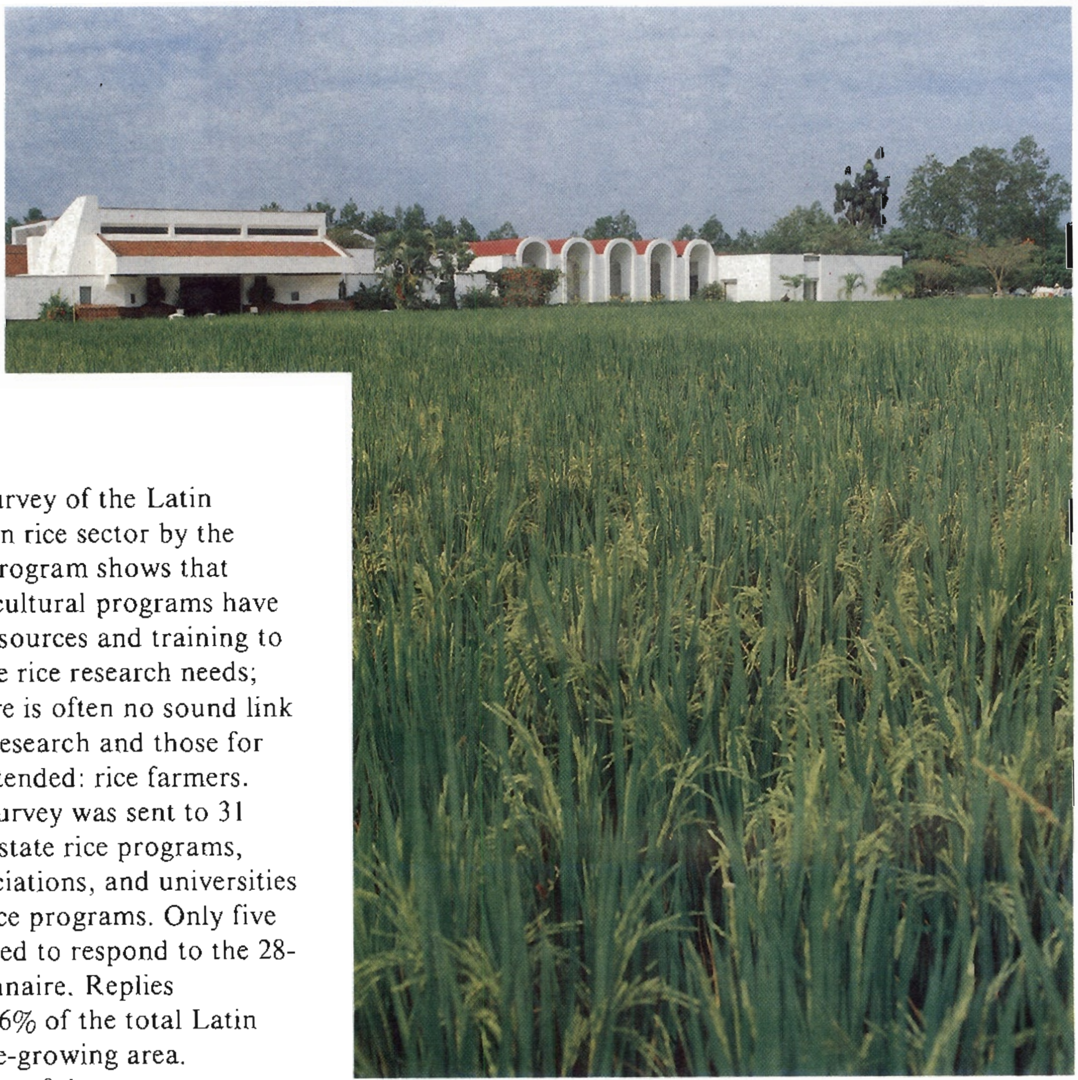
This method is quite efficient: if 200 triple crosses are performed a year, the saving in labor is as great as nine man-months, 80% less greenhouse space is needed, and seed set is 20%-30% greater than by the conventional method.

This new method will go a long way towards helping national programs get new varieties in the field to meet the changing needs.

'The hybridization method...will enable [national] rice breeders to overcome several major limitations to their ability to develop effective crossing programs.'

SURVEY OF NATIONAL RICE PROGRAMS

A comprehensive look at national rice programs turns up some encouraging and challenging points



Future Rice Program strategies are being based on the results of the survey of 31 Latin American rice programs.

A recent survey of the Latin American rice sector by the CIAT Rice Program shows that national agricultural programs have the human resources and training to address future rice research needs; however, there is often no sound link between the research and those for whom it is intended: rice farmers.

The 1988 survey was sent to 31 national and state rice programs, growers associations, and universities with active rice programs. Only five programs failed to respond to the 28-page questionnaire. Replies represented 96% of the total Latin American rice-growing area.

The purpose of the survey was to gain a clearer picture of these programs' structures, strengths, emphases, and activities. It covered three general areas: resources, research activities, and relations with international centers. The Rice Program was interested also in knowing how the international centers involved in rice research were perceived.

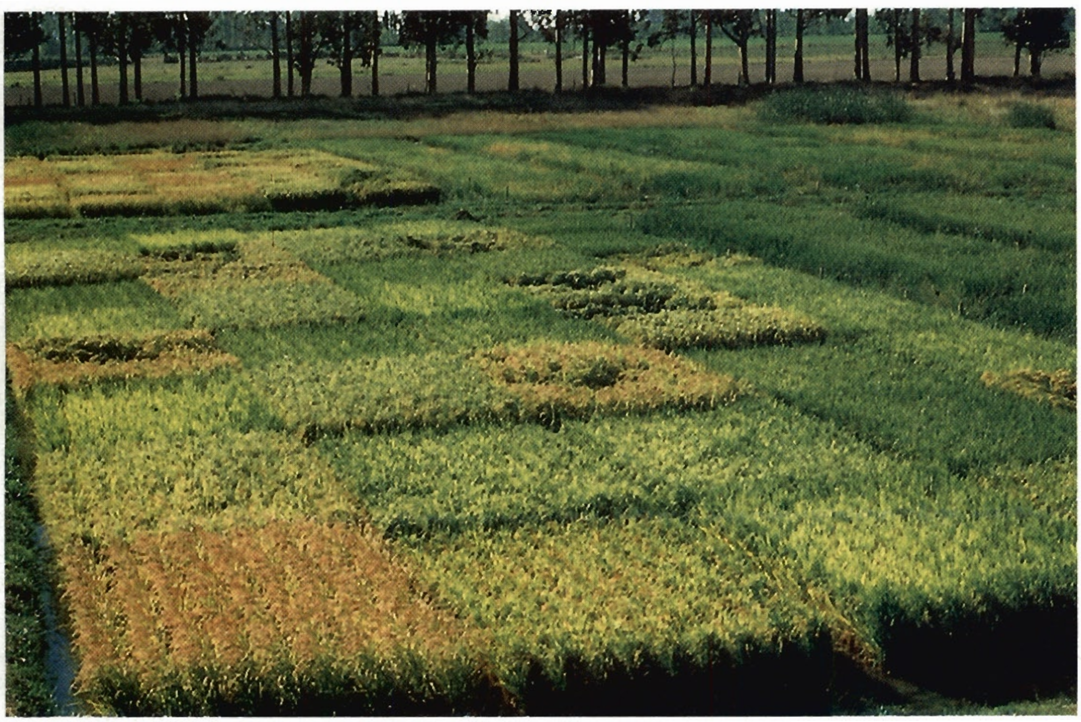
Now completed, the findings are helping the Rice Program establish priorities and develop its long-term strategies for the region. They also will serve as a gauge to measure future progress.

THE FINDINGS

It is clear from the survey that the Latin American rice programs have the skilled scientists to deal with the region's future rice-production needs. There are almost 300 professionals working on rice—over 50% of them have seven or more years of experience.

Their academic level is impressive: 80% hold the specialized degree of agronomic engineer or higher; 35% the Master of Science or higher.

Seventy percent of the scientists' work is in research-related activities, dealing primarily with agronomy and breeding. However, other fields are poorly represented—especially seed technology, the social sciences, extension, and training. Typically, these disciplines are not tied directly with the research side, indicating that technology transfer and socioeconomics may be viewed, unfortunately, as a distinct rather than a related discipline.



Experimental rice plots in Quilamapu, Chile. Half of the rice research programs in Latin America generate genetic variability.

Thus, although the research component of the equation is strong, an area of potential weakness in the system appears to be in the social sciences: areas which can contribute materially to the evaluation of old and new technologies, provide different perspectives on crop management and technology transfer problems, and assist in orienting research and managing priorities. Weak extension links have limited adoption of superior technology simply because the research is not reaching extensionists.

Germplasm use

National programs are taking advantage of germplasm generated by other programs by using them in their advanced-yield tests and their crossing and varietal-development programs. Half of them, representing 90% of the Latin American rice-growing area, generated their own genetic variability during the period 1983-1987 by making an average of nearly 1900 crosses per year, a figure higher than that of CIAT's.

During the same period, in the yield trials, there were more introduced lines than those locally developed; however, the 53 released varieties from both sources were about the same.

Although the process leading to the release of a new variety is being accelerated, it is still taking too long. More than half of the lines recently released spent six years in yield trials. The situation is exacerbated by the delay in producing basic seed which often are not available until after a variety is already released.

Relation to the centers

Each program was asked to indicate how CIAT and the International Rice Research Institute (IRRI) are viewed as sources of training, germplasm, bibliographic materials, methodology development, and in identifying production constraints.

'It is clear from the survey that the Latin American rice programs have the skilled scientists to deal with the region's future rice-production needs.'

In Rio Hato, Panama, technicians evaluate rice cultivars. Agronomist and plant breeders compose 70% of Latin America's rice researchers.

CIAT, it seems, is responding well to the germplasm needs of most of the programs. The Center, though, is not seen as a prime source of new methodologies, as a partner in assessing production constraints, and in supplying bibliographic materials. The survey respondents indicate that CIAT should do more in these areas, and broaden the scope of training beyond the basic course.

Survey as a guideline

The Latin American survey will be an important guideline to structure the Rice Program's priorities for the future. It will help the Program assist national programs in problem diagnosing and developing methods to help the latter make more efficient use of the resources of both.

Rice-production trainees participate in a manual rice-transplanting practice. The rice programs have the skilled personnel to cope with future rice-production needs.

BEAN PROGRAM

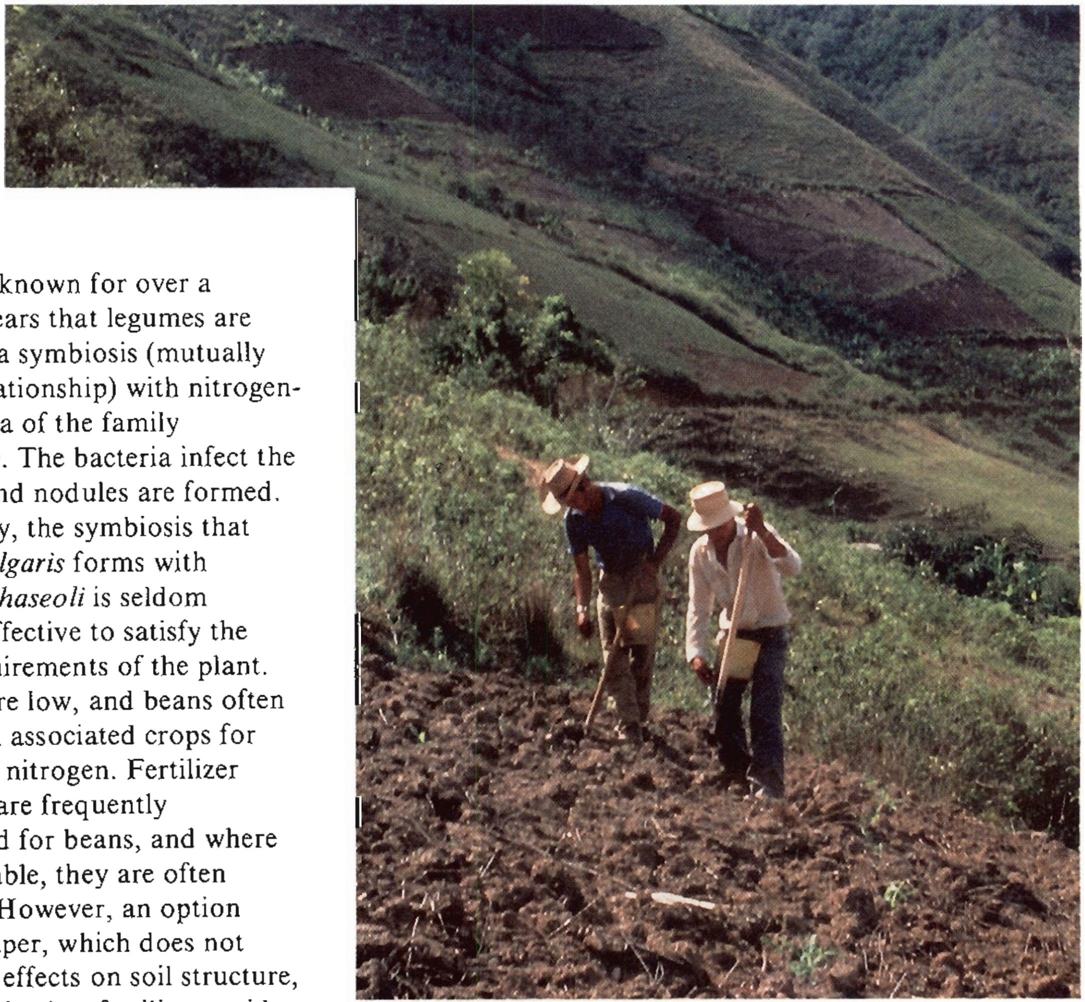
Sustainable Agricultural Production in the Bean Program

Each year the world's increasing population demands more from its crop lands. But sustainable intensification of agricultural production is a necessity in the more densely peopled places of the earth. On the other hand, the chemical and organic products like fertilizers and fungicides used to maintain soil fertility or control diseases are unavailable or too costly for many small farmers.

A goal of the Bean Program is to reduce farmers' need for these inputs by developing sustainable, inexpensive technology for intensively cropped, small-farm systems threatened by erosion. Regional Bean Program scientists stationed in Rwanda are conducting research on these issues in the country with the highest population density in Africa.

THE QUEST TO IMPROVE BIOLOGICAL NITROGEN FIXATION

Manipulating the symbiosis between beans and *Rhizobium*, and better agronomic practices, may improve biological nitrogen fixation



It is important that farmers' management practices be taken into account when evaluating inoculation technologies.

It has been known for over a hundred years that legumes are able to form a symbiosis (mutually beneficial relationship) with nitrogen-fixing bacteria of the family *Rhizobiaceae*. The bacteria infect the plant roots and nodules are formed. Unfortunately, the symbiosis that *Phaseolus vulgaris* forms with *Rhizobium phaseoli* is seldom sufficiently effective to satisfy the nitrogen requirements of the plant. Seed yields are low, and beans often compete with associated crops for available soil nitrogen. Fertilizer applications are frequently recommended for beans, and where readily available, they are often economical. However, an option which is cheaper, which does not have adverse effects on soil structure, and does not lead to fertilizer-residue buildup in soil or water, is to improve the nitrogen-fixing symbiosis.

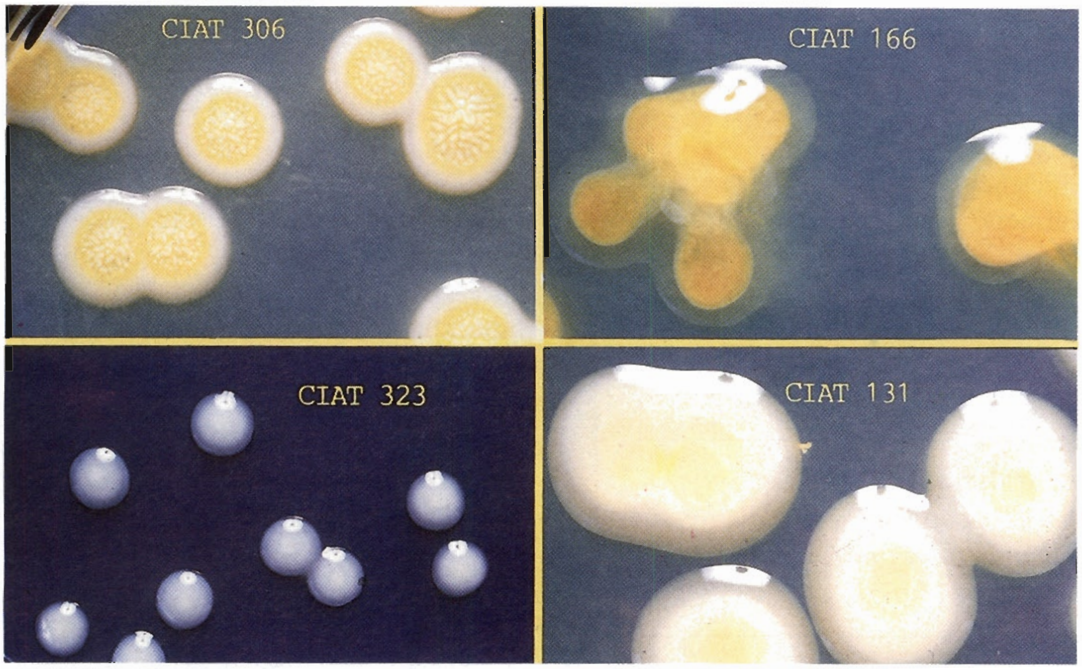
This option involves improvement of both the bean genotype and the *Rhizobium* strain components of the symbiosis and development of agronomic practices which will enhance the efficiency of the symbiosis in farmers' fields.

'...it is expected that commercial genotypes with much greater capacity to fix nitrogen, and which yield well on poor soils, will be available shortly.'

THE BEAN GENOTYPE

As compared to other grain legumes, such as soybean and peanut, most commercial bean genotypes have moderate to poor capacity to support the nitrogen-fixing symbiosis. However, considerable genetic diversity for this trait has been found. Breeding efforts to incorporate good fixation potential into commercial genotypes have made some progress, with RIZ (*Rhizobium*) lines now reaching final evaluation stages in several countries. Recently identified germplasm from Central America and Rwanda shows exciting promise. Certain landraces from these regions form nodules very quickly after the plants germinate, while others are able to maintain the activity of the nodules much longer than

Some bean genotypes are able to form effective nodules very quickly after germination. Here, Chingo (above), an early-nodulating landrace from Central America, is compared to a bred line (below), XAN 90.



There is considerable diversity among Rhizobium *strains that nodulate beans. Unfortunately, a significant proportion of these form nodules that fix little or no nitrogen.*

conventional genotypes. Maximum nodule size and number, the ability to nodulate in the presence of soil mineral nitrogen (usually nodulation and nitrogen fixation are inhibited by mineral nitrogen), and high rates of fixation per nodule are other promising traits detected recently in germplasm from other areas.

Crossing and selection to combine these different components of fixation is underway, and it is expected that commercial genotypes with much greater capacity to fix nitrogen, and which yield well on poor soils, will be available shortly.

Mean yield of five bean genotypes under different nitrogen treatments in Candelaria de la Frontera, El Salvador.

Treatment	Yield (kg/ha)[1]
Urea at 180 kg/ha	2476a
Inoculated strains 3, 12, and 22	2224a
No urea nor inoculation	1654b

1. Numbers with the same letters are not significantly different at $P \leq 0.01$, according to Duncan's Test.

ELISA is being used to study survival and competitiveness of inoculated strains in different soil environments.

The Rhizobium Strain

Many strains of *Rhizobium* will nodulate bean plants and they occur naturally in most agricultural soils. However, a large proportion of these strains form nodules that fix little or no nitrogen. Screening *Rhizobium* germplasm both for good fixation potential and for ability to survive and compete in the soil environment is an important activity of CIAT and collaborating national program scientists. Strains better than the native bacterial populations have been identified for some regions and are being used to inoculate beans in on-farm trials. Improvements in nitrogen fixation and crop yields have shown up in such experiments in El Salvador, Costa Rica, Peru, Colombia, and Rwanda.

These results make CIAT scientists and their collaborators at other institutions optimistic that the dual strategy of improving both the bean and *Rhizobium* components of the symbiosis will open the door to alleviating the nitrogen constraint to production for the resource-poor bean farmer.

NEW BEAN-DISTRIBUTION MAP FOR LATIN AMERICA

A new map, relating characteristics to bean-growing areas, takes the guesswork out of testing new cultivars

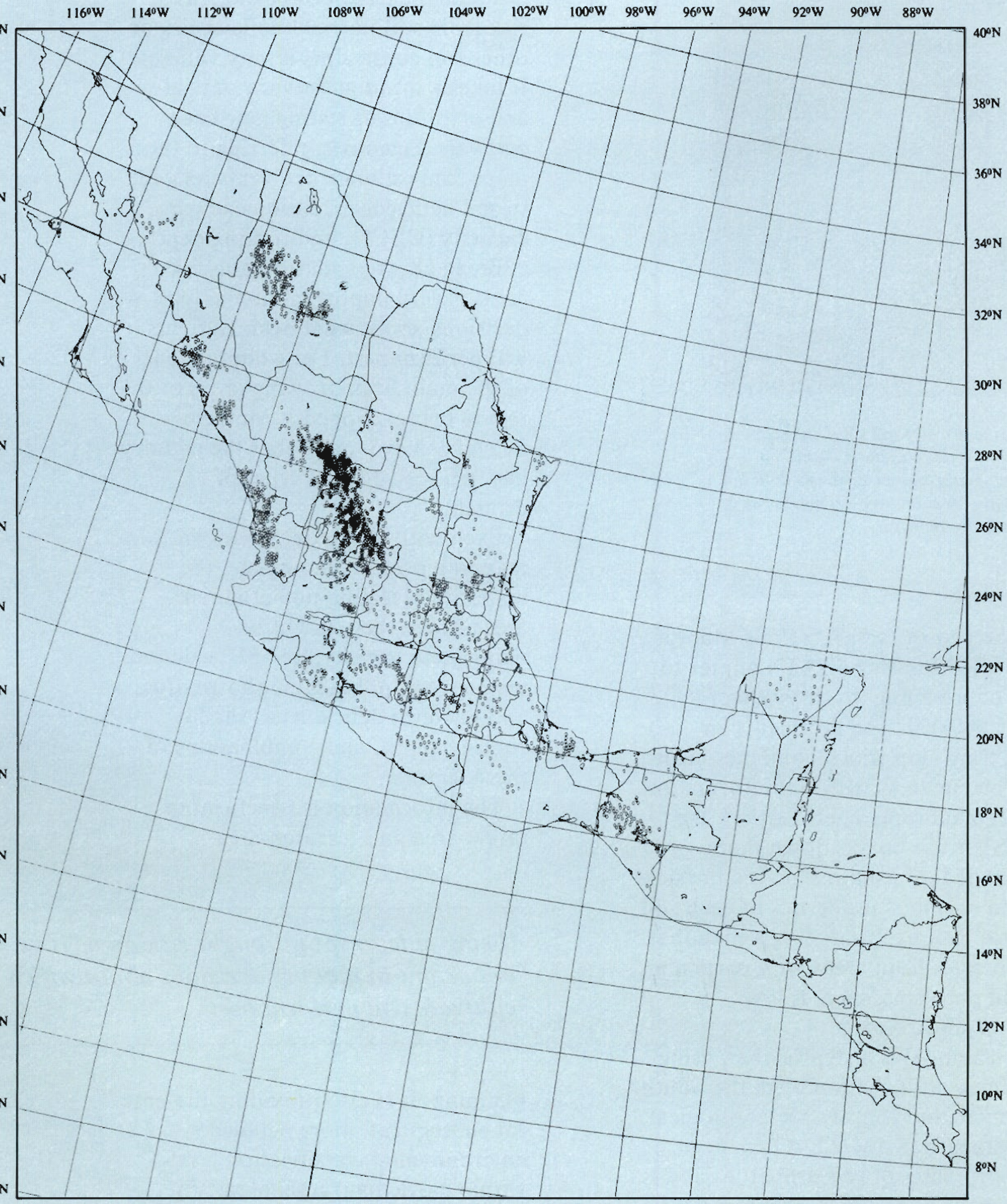
CIAT's Agroecological Studies Unit (ASU) is developing a map showing soil properties and climatic characteristics of bean-growing areas of Central and South America and the larger islands of the Caribbean. The undertaking, involving 14% of the earth's land, will provide researchers and planners with high-level, previously unavailable information on the occurrence and extent of potential soil and climatic problems where beans are grown. The project is proving to be an outstanding example of international scientific cooperation and exemplifies the role an international agricultural research center can play in accomplishing a project that individual national programs would be unable to carry out on their own.

The information comes from national agricultural census, agricultural production statistics, regional extension publications, as well as from personal information from CIAT and visiting, national-program researchers.

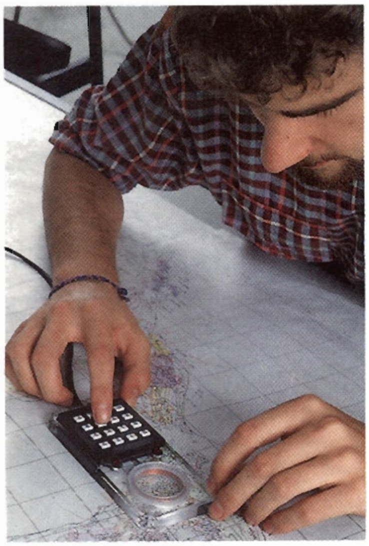
The soil conditions in bean-growing areas are analyzed by relating the FAO soil-mapping units with their respective soil profiles.

PRODUCING THE MAP

From this information, a digitizer is used to produce a dot map of bean-growing areas on a scale of 1:1,000,000. The dot map is then



A map of Mexico, Latin America's second largest bean producer after Brazil, showing the crop's distribution. Each point represents 1000 hectares of production, with the main concentration in the highland plains of Zacatecas and Durango.



As the first step in identifying the agricultural soils, the soil-unit boundaries must be established. In the photo, Mexican bean-production areas are being digitized.

matched to the FAO Soils Map of the World using CIAT's plotter to produce a map to the scale of 1:5,000,000. The product is an overlay map which combines bean-growing areas with soil information.

To aid researchers further, the ASU team breaks down more detailed information on the physical and chemical properties of each soil type by area, producing a map that indicates bean areas with particular soil problems, such as low phosphorus levels.

Taking this a step further, using climate information from the South American Monthly Meteorological Database (SAMMDATA), bean coordinates of soil properties and climatic conditions are merged into one comprehensive map. These maps, for example, can be used to predict isolated areas where both low pH soils and waterlogging are likely to occur, suggesting risk of manganese toxicity.

To researchers, being able to estimate the extent of bean areas at risk from soil-nutrient deficiencies or other soil constraints is very valuable. It takes a lot of guesswork or trial-and-error out of testing new bean cultivars. Scientists, referring to the maps, can estimate problems related to soil deficiencies, cation exchange capacity (CEC*), and rooting depth.

Being able to spot drought-risk areas is very important in making decisions about what bean cultivars will perform best. For example, one of the main bean-growing areas of the region being mapped is Mexico. Scientists have found that the country has two very distinct types of drought.

Even with the Latin American mapping project incomplete, the maps are revealing potential risk areas where there might be manganese toxicity, low pH, calcium, magnesium, potassium, phosphorus, and nitrogen deficiencies, shallow rooting depth, and combinations of these factors.

The information is beneficial to target-area and research-area planning. It is also providing the base for subsequent, more detailed, environmental classification levels within particular target areas. By assessing each level, the most efficient scale for information collection can be determined.

'Being able to spot drought-risk areas is very important in making decisions about which cultivars will perform best.'

* CEC is a measure of the total of the exchangeable, positive-charged ions.

AFRICAN BEAN-BASED CROPPING SYSTEMS CONSERVE SOIL

Along with developing technology to increase bean production in Africa, CIAT is helping national programs conserve soil fertility and retard erosion


Distributing manure on a sloping field in Rwanda. When applied to beans in early stages of growth, yields can be increased 60%. Note horizontal erosion-control barriers.

Low soil fertility is as important as disease in limiting bean production in Africa. This is especially true in areas of high population growth. More people to feed means that land that once could be left fallow and allowed to recover its nutrients must be constantly used. Less good land to farm leads to more cultivation of steep slopes and marginal soils. In any case, constant working of any soil inevitably leads to depletion of its nutrients and erosion. Bean Program scientists, and researchers from the Great Lakes region of Central Africa, are working

on solutions to production and soil problems by conducting on-farm research with farmers. The reason for this is that farmer participation makes any new technology more acceptable to them.

Planting on-farm trials in Mivo commune, in Buyenzi, Burundi. New technology is more readily adopted by farmers if they participate in its development.

A NEW CULTIVAR

In response to the need to increase production and conserve the soil, CIAT is strongly promoting sowing climbing beans in the Great Lakes area. These beans generally yield higher than traditional bush beans; and when climbing beans grow upward rather than spreading across the ground, the plants are better protected from soil-borne pathogens and the damage caused by standing water.

But climbing beans need something to climb on. Having enough vegetative material suitable for making stakes is a major impediment to farmers growing this kind of bean. CIAT scientists, together with others from agroforestry projects, are identifying appropriate kinds of trees to plant to solve the stake shortage.

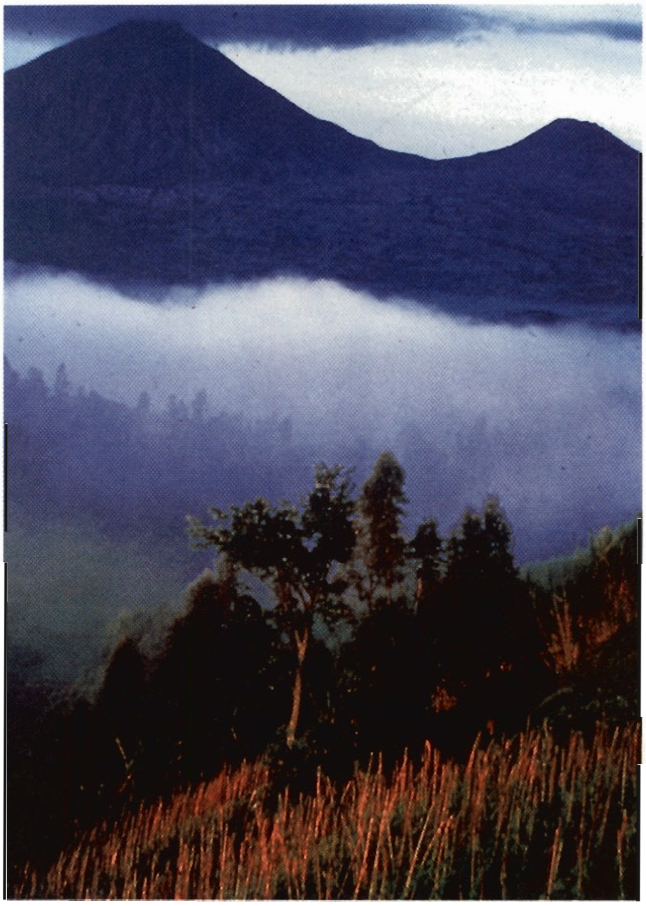
A farmer in northern Rwanda uses Pennisetum *to stake his climbing beans. Since the beans grow upward, they are better protected from soil-borne pathogens.*

These trees or bushes would have several purposes: they would serve as stakes; they would conserve the soil by fixing nitrogen; they would produce organic matter which could be used as green manure or animal feed; and they would counter erosion by stabilizing the soil with their roots and by providing windbreaks.

Other technologies

Research conducted on Rwandan farms has shown that timely manure applications are important in increasing yield and reducing erosion. Studies show that if manure is applied at a certain stage of growth of the bean plants—the third trifoliate stage—yields can be increased by 60%. This can help farmers maximize the benefit of their limited fertilizer resources.

CIAT scientists in Africa are also studying traditional soil conservation practices so that accepted methods can be used as guidelines for proposing improvements. For example, in Zambia, farmers concentrate soil fertility through dirt mounds consisting of organic compost. On the other hand, Tanzanian farmers dig pits and compost grass to enrich the soil. In other areas, farmers grow their crops



The majestic peaks of volcanoes loom over a field of climbing beans in Rwanda. The beans give higher yields than bush beans.

In Gisenyi, Rwanda, climbing beans carpet the hillsides. CIAT is working with agroforest projects to solve the stake-shortage problems.

'...[it] *is vital...that the demands on the land do not ultimately destroy the very foundation of farming: the soil itself.'*

In Rwanda, living hedges retard erosion by providing windbreaks. Lack of land has led to the cultivation of hillsides and marginal soils.

on contoured ridges which reduce erosion.

But population pressures on land are threatening these traditional systems and, in turn, increasing soil erosion. Finding solutions to these problems is vital so that the demands on the land do not ultimately destroy the very foundation of farming: the soil itself.

SOIL FERTILITY WORKSHOP

The First Workshop on Soil Fertility Research for Bean Cropping Systems in Africa was held in Ethiopia in September 1988. Participants included 21 agronomists and soil scientists from 11 African countries as well as regional scientists from CIAT and the International Council for Research in Agroforestry. An Africa-wide standing committee on soil fertility was formed to monitor and discuss soil issues in the coming years.

TROPICAL PASTURES PROGRAM

Sustainable Agricultural Production in the Tropical Pastures Program

Clearing Latin America's tropical rain forests for agricultural use is causing increased concern. When grazing the former forests is coupled with inappropriate technology, environmental degradation is inevitable. In response, the Tropical Pastures Program is developing germplasm and technology to restore this land. Ecologists and agricultural scientists agree that one of the best ways to check this destruction, traceable to the migration of farmers looking for better land, is to develop stable production systems in the degraded lands.

Pasture grasses and legumes, when adapted to the soils of the rain forests and properly managed, are seen as an important component in the process of salvaging any of the estimated ten million hectares of degraded land.

In addition, technology developed for another vast and underused area of Latin America, its savannas, could increase the productivity of these areas. Making this land more productive offers an alternative to the migration of the landless rural poor into the rain forests.

LEGUMES: THE KEY TO PRODUCTIVE PASTURES

Four- and nine-year studies confirm legumes' role as an essential component in improved pastures

Animals grazing a pasture of Brachiaria dictyoneura *and* Desmodium ovalifolium. *The association produces more weight gains than the grass alone in the dry season.*

In order for pastures in the tropics to have stable productivity, it is necessary to incorporate a legume component with the sown grass. Four years of experiments by CIAT Tropical Pastures Program scientists using *Desmodium ovalifolium*, a legume, and *Brachiaria dictyoneura*, a grass, provide convincing evidence.

Persistence and productivity is related to the presence or lack of nitrogen in the pasture. Without nitrogen—either in the form of fertilizer or fixed by a legume from the air—pastures soon degrade because the stability of the living system breaks down. The grass ultimately succumbs to weeds and nonnutritious undergrowth, and the level of grazing that the pasture can sustain falls.

WHEN LEGUMES DECLINE

In one major trial, grass available for grazing remained relatively constant during the course of the experiment. What varied was the amount of the legume available for the animals to eat. In the beginning, the proportion of the legume in the pasture was about 60%, but by chance the pasture was attacked by a root-feeding scarabeid beetle which reduced the legume content to 15%. Later the legume content gradually fell to less than 5%.

As this occurred, the liveweight gain of the animals also fell steadily from nearly 700 g/day to just over 250 g/day at the end of the fourth year—a reduction of about 65%.

The scientists found that the proportion of the legume in the diet of the cattle was initially high in proportion to the amount of legume in the pasture. However, when the legume content fell to very low levels, the cattle ate no more than about the same proportion of legume that remained in the pasture.

As the legume content of the pasture fell, the crude protein content of the grass also dropped. The obvious conclusion is that when the legume content of a pasture disappears, and as the pasture becomes less productive of nutritious forage, cattle weight declines in response. Stable productivity, then, depends on maintaining an adequate proportion of legume with the grass.

'...the legume-based pasture maintains a stable level of production in the long run, while productivity of a pure grass pasture steadily declines.'

Pasture of Brachiaria decumbens. *In the long run, the productivity of the grass alone is gradually reduced. The low level of nitrogen in the soil, either applied or fixed by a legume, causes the degradation of the pasture.*

Pasture association of Brachiaria decumbens *and* Pueraria phaseoloides. *Associations sustain persistence and productivity over a long period of time.*

More evidence

A nine-year experiment in the Colombian eastern plains compared liveweight gains of animals grazing pure grass (*Brachiaria decumbens*) and a grass-legume pasture (*Brachiaria decumbens* and *Pueraria phaseoloides*). From the first four years, the association offered a slight advantage: in the rainy season about 5%. After four years, however, the advantage of the association increased exponentially, leading at the end of nine years to a 65% advantage.

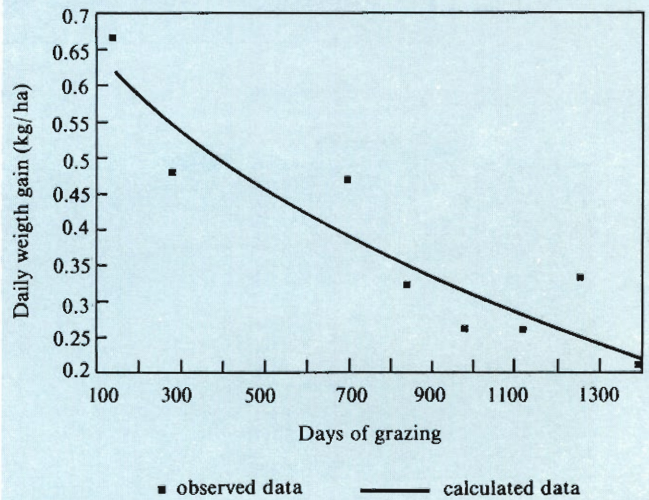
The animals grazing the association always had higher weight gains in the dry season and showed less variation in gains in the wet season as compared with those feeding on grass alone. This shows that the legume-based pasture maintains a stable level of production in the long run, while productivity of a pure grass pasture steadily declines.

Pastures program trend

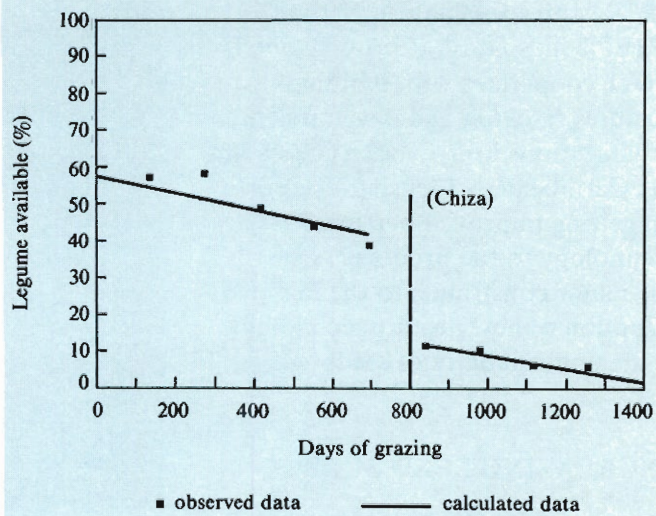
When the Tropical Pastures Program began, the emphasis was on finding and promoting the use of plants—well adapted to the poor, acid soils of the tropical savannas—which withstood the diseases and pests that attack them. Emphasis was on finding plants that were able to yield well with minimum use of fertilizers.

Since then, the Program has emphasized using well-adapted, efficient plants, but also using plants that are more persistent, more productive, and which contain more protein. Thus, the Program is emphasizing stability of production and composition, and, therefore, long-term persistence of pastures.

The species showing considerable promise are *Centrosema acutifolium*, *Centrosema macrocarpum*, *Desmodium ovalifolium* and *Arachis pintoi* among the legumes; and the grasses *Brachiaria dictyoneura* and *Andropogon gayanus*.



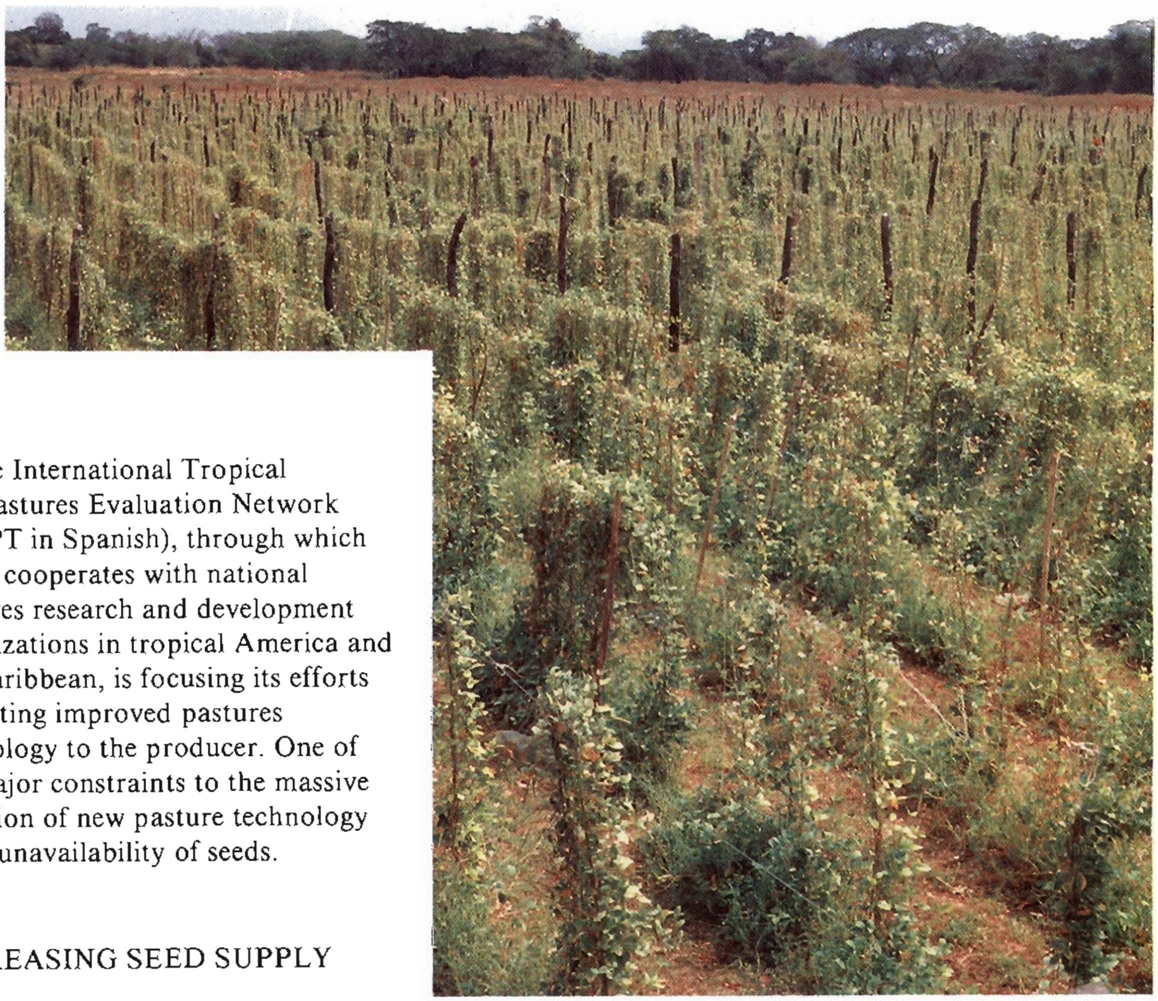
*Daily weight gain through time with an association (*B. dictyoneura *and* D. ovalifolium*) under rotational grazing at Quilichao.*



Dynamics of available legume in a pasture of Brachiaria dictyoneufa *and* Desmodium ovalifolium *under rotational grazing at Quilichao.*

OVERCOMING SEED-PRODUCTION PROBLEMS

To free up the spread of pasture technology, the Tropical Pastures Program is promoting seed production with farmers and seed companies



In the Valledupar area of Colombia, a seed crop of Vichada (Centrosema acutifolium) grows on post-and-wire trellises. The legume is adapted to the soils and climates of the tropical savannas.

The International Tropical Pastures Evaluation Network (RIEPT in Spanish), through which CIAT cooperates with national pastures research and development organizations in tropical America and the Caribbean, is focusing its efforts on getting improved pastures technology to the producer. One of the major constraints to the massive adoption of new pasture technology is the unavailability of seeds.

INCREASING SEED SUPPLY

The Program is doing several things to promote pasture seed supply development. Activities are well

*A tractor-mounted beater is used to harvest Llanero (*Brachiaria dictyoneura*) in the Andean foothills of Colombia. The pasture grass is a good seed producer.*

underway in Colombia, Peru, Mexico, Ecuador, and Costa Rica.

The idea is to promote the progressive participation of private seed enterprises in the production and commercialization of the new materials being developed.

In Colombia, for example, the Instituto Colombiano Agropecuario (ICA) and CIAT's Seed Unit are encouraging pasture seed enterprises to produce the newly released cultivars and a few highly promising selections e.g., *Stylosanthes capitata* cv. 'Capica', *Centrosema acutifolium* cv. 'Vichada' and *Brachiaria dictyoneura* cv. 'Llanero'. Production contracts as well as technical assistance are offered to these enterprises. Eight of the 10 existing seed companies committed themselves to some degree of participation. Seed crops have been established in five different geographic regions of the country. In 1988, a total of 280 ha of seed crops were involved in the project, including 100 ha of new plantings and 180 ha of previously established areas. It is estimated that about 6 tons of seeds will be harvested. This is enough seed to expand by about 2000 ha the area planted with improved grass-legume pastures in the Colombian savannas.

Participants in a Pasture-Seed Workshop observe the multiplication of Desmodium ovalifolium *CIAT 350 at a coconut plantation in Tarapoto, Peru.*

A project in Peru is quite dissimilar because the problems are different than those in Colombia. Therefore, a different approach is being used to solve the problems of expanding seed supply for farmers. In Peru's case, there are no seed enterprises operating in the humid tropics. So, as a starting point, the Tropical Pastures Program is involving selected farmers as novice, artisanal seed multipliers. Assistance is being given from a nucleus of agronomists with experience. The Peruvian national program, Instituto Nacional de Investigaciones Agrícolas y Agroindustriales (INIAA) and the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), are major participants in the effort, along with regional development organizations, such as Corporación Regional de Desarrollo de Ucayali (CORDEU) and Corporación Regional de Desarrollo de San Martín (CORDESAM). To get greater production capacity with very limited resources, the project operates on the basis of share-farming agreements with selected participants. This approach is being used in both the Pucallpa and Tarapoto regions. A total of 12 farmers are now participating and seeds are becoming available. In 1988, approximately one ton of grass seeds and one-half ton of legume seeds were produced, principally *Andropogon gayanus*, *B. decumbens*, and *S. guianensis*.

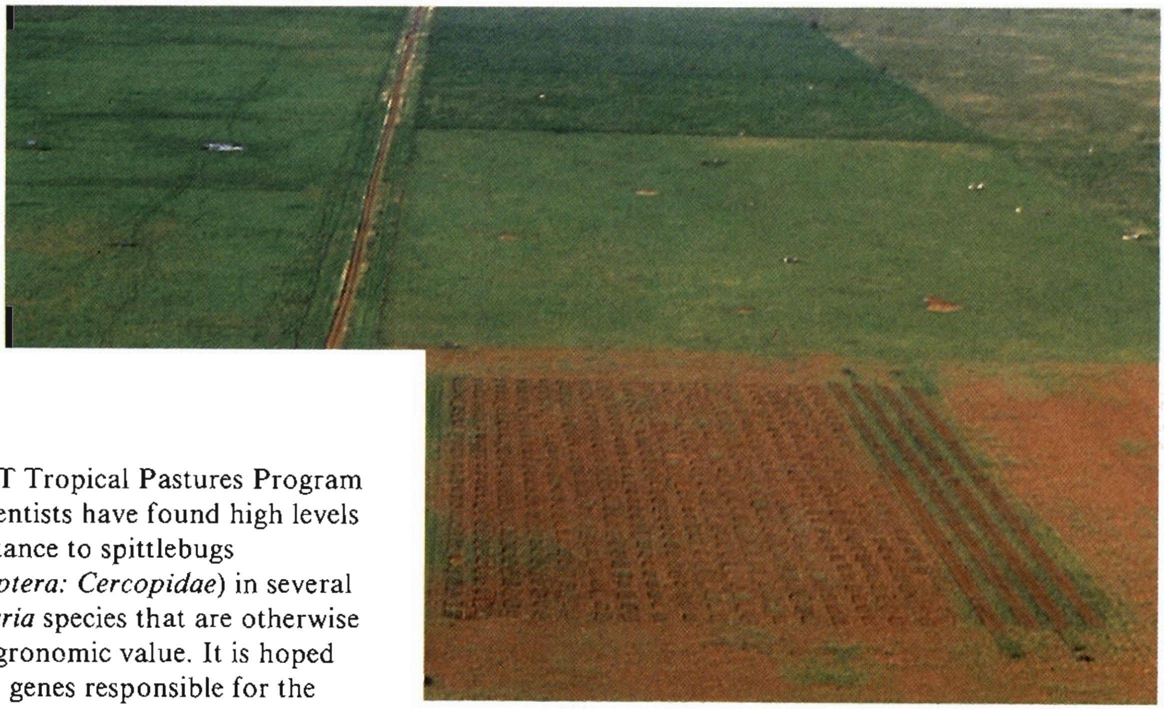
'The Pastures Program scientists recognize that overcoming the problem of seed supply is a must.'

The Pastures Program scientists recognize that overcoming the problem of seed supply is a must. The participation of various national research and development entities to promote the new cultivars along with private enterprises, either existing or novice, to produce and sell the seed are essential components. A guaranteed purchase price is an important catalyst to both promote participation and reduce risk to the seed multipliers. There is good reason to believe that with an expansive participation, seed supply can be increased, and that one of the major constraints to adoption of new technology will be progressively overcome.

Using an easily constructed, inexpensive, yet practical device, Brachiaria decumbens *is hand-harvested from an established pasture in peru.*

CLOSING IN ON CONTROLLING SPITTLEBUG

A chemical found in a *Brachiaria jubata* accession could be the raw material to breed resistance to spittlebug into a major tropical pasture grass

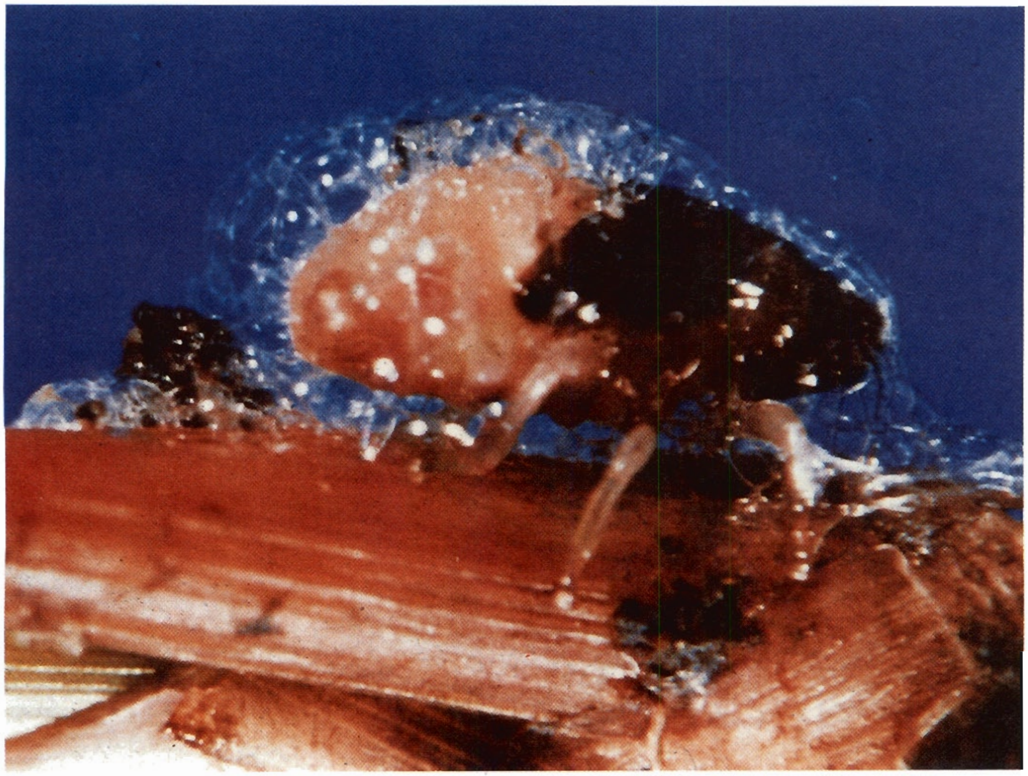


Collection of Brachiaria *species at Carimagua research station attacked by spittlebugs. The plot in the foreground had a traditional management, and the adjoining plot received improved management practices.*

CIAT Tropical Pastures Program scientists have found high levels of resistance to spittlebugs (*Homoptera: Cercopidae*) in several *Brachiaria* species that are otherwise of no agronomic value. It is hoped that the genes responsible for the resistance can be transferred to adapted cultivars to make them spittlebug-resistant. This comes in the wake of research which is well along the way to developing sexual plants of *Brachiaria* (see article 'Breaking *Brachiaria's* breeding barrier'). This is exciting news because the various genera and species of spittlebugs are the major biotic enemy of Brachiaria species, the most widely used forage grasses in Latin America.

SPITTLEBUG PROFILE

The adult insect lays its eggs in the soil. Upon hatching, the nymphs surround themselves with a frothy, spittle-like mass at the base of the



Well-formed spittlebug adult has just emerged from the last nymphal state. The insect owes its name to the frothy mass that surrounds the nymphs which feed at the base of the plant.

plant. The nymphs feed on the plant by sucking its sap, withdrawing water and nutrients, and ultimately causing the grass to yellow, wilt, and die.

Biological control of the pest has not been effective, perhaps because of the excellent protection from predators, parasites, and pathogens afforded the nymphs by the froth that surrounds them. Cultural control is possible, to an extent, but is often impractical due to conflicting demands on the way a *Brachiaria* pasture needs to be managed. Chemical control is not feasible due to the low economic value-per-unit area of pastures, the difficulty in identifying the presence of the pest at the right time, and the undesirable and harmful effects of chemical residues in pastures on animals, the

Nymph at the last instar, which could not develop into an adult. Note the chitinized structures in the head, the absence of wings, and the poor development of pods. This is due to the antibiotic effect of B. jubata *CIAT 16531.*

environment, and even on human health.

Until now, CIAT scientists have had to direct their search toward selecting well-adapted *Brachiaria* grasses which show tolerance or antibiotic resistance to the insect. So far, no strong resistance has been found; use of tolerance alone carries the inherent danger of large populations that could threaten susceptible pastures. Now, with the possibility of being able to cross previously incompatible *Brachiaria* species, scientists believe they will be able to transfer resistant genes into the genome of an already agronomically-adapted *Brachiaria* cultivar.

WHAT SCIENTISTS FIND

To test for resistance to spittlebug, Tropical Pastures Program scientists infest *Brachiaria* accessions with spittlebug eggs in the screenhouse. On hatching, the nymphs begin feeding on the plant. Typically, close to 100% of the nymphs survive when reared on commercial *B. decumbens* or *B. dictyoneura*.

However, some highly resistant accessions reduce survival to less than 30%. Systematic screening of CIAT's collection by this method has identified several promising accessions. For example, *B. jubata* CIAT 16531 has a high level of resistance of an unusual kind.

Nymphs reared on this *B. jubata* develop normally until the last stage of their development. When they

'Scientists believe that B. jubata *CIAT 16531 contains a chemical that is disrupting hormonal control of the molting process.'*

General damage caused by a heavy spittlebug attack on a B. decumbens *plot at the Carimagua research station.*

begin to molt from their last nymphal stage to adult, they begin dying. Interestingly, death occurs after the beginning of the molting process but before complete metamorphosis into an adult insect. Scientists believe that *B. jubata* CIAT 16531 contains a chemical that is disrupting hormonal control of the molting process. Insect molting is controlled by two hormones: one determines the type of molt, the other the timing of the molt.

Some plants possess a chemical known as a phytoecdysteroid. The word designates a class of plant steroids that are identical or similar to the insect-molting hormone ecdysone. If an insect is exposed to a phytoecdysteroid before it is physiologically ready to molt, it becomes malformed and dies, similar to what scientists find in spittlebugs feeding on the *B. jubata* CIAT 16531. Studies are being conducted to prove if spittlebug mortality on *B. jubata* CIAT 16531 is traceable to these plant compounds that disrupt the hormonal events involved in molting.

Regardless of the precise mechanism of resistance operating in the case of *B. jubata* CIAT 16531, the identification of accessions with high levels of resistance to spittlebug is providing the raw material necessary for future breeding efforts. The now routine evaluation of grass accessions to spittlebug has already identified high levels of resistance that would have gone undetected in field screening because the resistance is present in a genome poorly adapted to soils or climates in Latin America. Such resistance could be one solution to the spittlebug problem in *Brachiaria*.

An example of the difference between a plant with leaves affected by the sucking action of the insect (left) and a plant that has not been attacked.

BREAKING *BRACHIARIA*'S BREEDING BARRIER

Researchers foresee the day when they can breed even better grasses using a proven pasture grass

The contrast between one species of spittlebug-susceptible Brachiaria *and one which is resistant can be seen in these experimental plots at the Carimagua research station in Colombia.*

Research at CIAT in 1988 brought closer the day when scientists can mount effective plant-breeding programs to develop improved cultivars in the genus *Brachiaria*, the most widely sown pasture grasses in the tropics. *Brachiaria* species are generally well adapted to the acid soils of the lowland tropics as well as being productive and persistent.

Currently used cultivars, however, were developed from African germplasm and have several serious limitations—the principal one being susceptibility to spittlebug.

THE SEARCH FOR RESISTANCE

The Tropical Pastures Program's mandate is to develop persistent, productive pastures to improve meat and milk production on the acid, infertile soils of the lowland tropics. To this end, much effort has gone into collecting and introducing *Brachiaria* germplasm in hopes of finding lines superior to currently used cultivars. This natural germplasm has been reasonably successful. Experience shows that otherwise well-adapted species are commonly limited by some specific deficiency; for instance, susceptibility to spittlebug. Scientists have dreamed of the time when they could breed improved cultivars which, in addition to resistance to spittlebugs, would have disease resistance, high seed yield and quality, seedling vigor, good nutritional quality, and vigorous growth.

'...scientists hope that they can genetically fine tune pasture plant cultivars....'

Collecting Brachiaria *species in Kenya, in search for new accessions to be used in improvement programs.*

BREEDING IS DIFFICULT

Brachiaria breeding is not the same as rice, maize, or bean breeding because the common commercial *Brachiaria* species are polyploid apomicts; that is, they have more than the normal two sets of chromosomes, and, although they can reproduce by seed, reproduction is normally asexual.

This has been the basic barrier to breeding improved cultivars, as new plant varieties are obtained from sexual reproduction. What has been needed is a source of sexuality which could be used to obtain, through hybridization, new plants with desirable characteristics.

Recent work done in Belgium on *Brachiaria ruziziensis*, a sexually

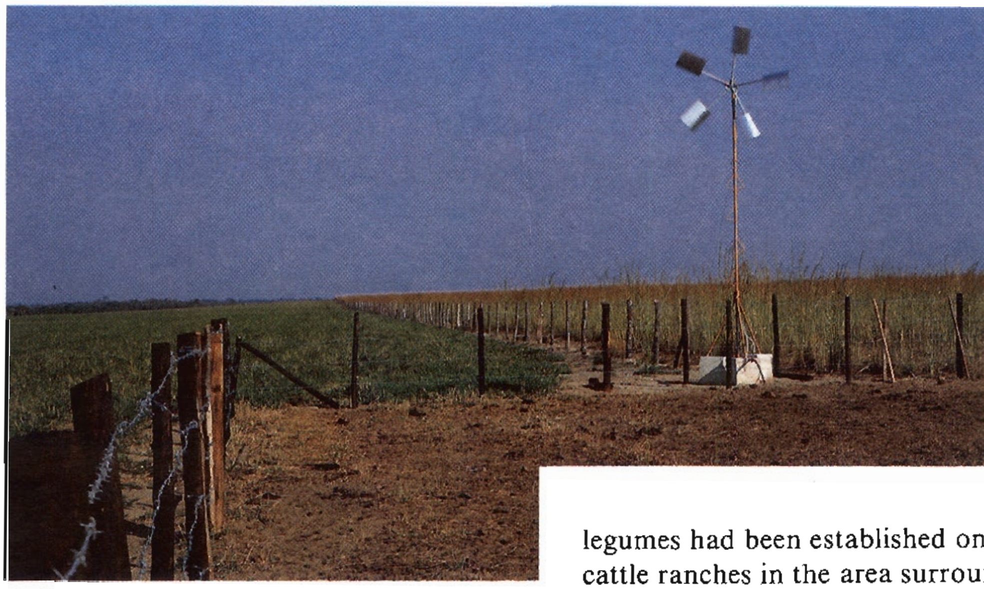
Pollinating B. decumbens. *Researchers genetically improve forage species to correct problems through hybridization.*

reproducing species, has exciting implications for breeders. Artificial polyploids of this diploid species were produced which has allowed scientists to obtain, on a limited scale, experimental hybrids with the polyploid, apomictic, commercial species. The possibility of creating new variation through hybridization has given scientists hope that they can genetically fine tune pasture plant cultivars to counter the constraints that now exist.

A major screening of CIAT's *Brachiaria* germplasm collection (approximately 450 accessions) to determine how they reproduce was conducted by an authority on the reproductive mechanisms of tropical grasses, Cacilda do Valle, from the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil. Based on what she found during a year spent at CIAT, scientists have developed simple methods to produce large numbers of interspecific hybrids in the glasshouse and also in the field. By using electrophoretic markers, scientists have unequivocally confirmed the hybrid nature of these progenies. In short, the barrier of apomixis—asexual reproduction—has been effectively broken in the genus *Brachiaria*, and breeders are now in a position, as the results of the germplasm screening become available, to begin breeding new cultivars.

ON-FARM TESTING VALIDATES PASTURE RESEARCH

New pastures technology is getting a boost from Colombian ranchers who are multiplying their own grass and legume seed



Establishment of associated pastures as part of the CRECED-ICA-CIAT project. On the left, an association of Brachiaria decumbens *and* Stylosanthes capitata; *on the right,* Andropogon gayanus *and* S. capitata.

Since 1985, CIAT and the Instituto Colombiano Agropecuario (ICA) have been conducting an on-farm pasture technology validation and transfer project as a basis for developing large-scale technology transfer schemes.

By late 1988, more than 6500 hectares of improved grasses and legumes had been established on 120 cattle ranches in the area surrounding Puerto López and Puerto Gaitán, in the eastern plains of Colombia. The number of ranchers who offered to participate in the experiment exceeded the resources of the project. For example, during 1988, about 100 offers to participate were made, but only 36 could be included.

Several findings have resulted from this effort. The majority of the ranchers chose to grow an association of *Andropogon gayanus* cv. 'Carimagua 1' and *Stylosanthes capitata* cv. 'Capica'. This choice further confirmed the association's

Small-scale rancher establishes a seedling of Brachiaria dictyoneura *with vegetative material at his eastern plains ranch.*

reputation for persistence and productivity. It now has completed more than eight years of use in commercial farms.

The ranchers also sowed associations of Carimagua 1 and new legumes, such as *Centrosema acutifolium* cv. 'Vichada' or *C. brasilianum*, and associations of Capica with the well-known grass *Brachiaria decumbens* or the recently released *B. dictyoneura* cv. 'Llanero'. Planting of the more recent releases was limited by the seed supply. The most common problems ranchers found are related to the lack of inputs, such as basic fertilizers, *Rhizobium* inoculants, and machinery to establish the pastures. In one way or another, this is a consequence of a poor transportation system and the fact that there has been no tradition in the eastern plains of planting pastures. Fortunately, work seems to be underway by the respective authorities to improve the area's roads. From this experience it is clear that establishment methods, as part of larger technology-transfer schemes, must be designed for the particular conditions of the plains ranchers.

The project has encouraged some ranchers to produce the seed themselves, since commercial seed is seldom available. It takes seed companies time to become interested in producing seed of new cultivars that are not highly demanded yet. This has been the case with the grass Llanero, a cultivar released in 1988 but whose seed are being multiplied by a few ranchers who have never produced forage seed. More than four tons of its seed were harvested in 1988 from five ranches participating in the project—two of which produced nine tons of Capica seed.

The project is demonstrating to these ranchers the value of improved pastures. The interest and enthusiasm that they have shown for the various cultivars will, no doubt, increase demand for good-quality seed to a level where established seed companies will enter into their production and marketing.

Regional support centers

'The interest and enthusiasm that [farmers] have shown for the various cultivars will, no doubt, increase demand for good-quality seed....'

In 1989, more ranches will be able to participate in the project, thanks to the creation by ICA of regional centers for technology validation and farmer and extensionist training, called CRECED (Centro Regional de Educación, Capacitación, Extensión y Desarrollo). The Puerto López CRECED, with two branches in other eastern plain towns, is staffed by seven professionals and an equal number of technicians. This center is supporting the Tropical Pastures Program's on-farm activities. Even though it only became operational in late 1988, the center has already offered a one-week course for ranchers dealing with pasture and livestock management and it has held on-farm demonstrations and field days on pasture establishment and management. The CRECED will work with annual crops as well.

Producers from the eastern plains receive instructions about the way to prepare the savanna soils for planting.

Fine tuning technology

CIAT's Tropical Pastures Program is evaluating these and other on-farm trials in order to develop practical ways to promote pasture technology in Latin America. Scientists are looking at on-farm pasture performance and how it is affected by specific factors, such as farmers' management methods and different soil conditions. Traditional management practices are being monitored, and the effectiveness of the techniques used by researchers to measure pasture and animal productivity are being scrutinized. It is expected that the knowledge gained from this project will be used to fine tune the development of new technologies. It will help make the transition between pasture research and development a smoother process, which will promptly benefit the cattle industry in eastern Colombia, as well as in other marginal-land areas with poor, acid soils.

TRAINING AND COMMUNICATIONS SUPPORT PROGRAM

The Training and Communications Program supports sustainable agriculture

The Training and Communications Support Program (TCSP) is a key factor in CIAT's cooperation with national agricultural research and development systems. Working closely with the Center's four research programs and with national institutions, it enhances and supports the latter's technology generation and transfer capacities for the commodities in the Center's mandate as well as their interaction with CIAT.

A high degree of integration is needed to succeed in this mandate, not just with CIAT's commodity programs but also with the various institutions in a particular region or a particular country. The TCSP carries out three major activities: training national scientists, preparing and distributing technical information and training materials, and improving communication among institutions and individuals.

Training and Communication: Key Components in Technology Generation and Adoption

Interinstitutional collaboration and human-resource development combine to make a major success story in El Salvador

Technicians and small-scale Salvadorian farmers learn how to multiply promising materials through an artisanal seed-production program.

During 1988, training at CIAT headquarters was provided to 209 professionals from 34 countries in Africa, Asia, Latin America, and the Caribbean.

In-country training events were supported in 15 countries of Latin America and the Caribbean.

The Program's Publications Unit edited and published 38 titles, and it distributed over 60,000 copies of CIAT publications to customers in 179 countries.

Thirteen new titles were added to the over 100 audiotutorials already produced by the Program. Nearly one thousand audiotutorials were distributed during the year, together with more than 5000 study guides.

The Publication Unit Supports CIAT's technology transfer by publishing books, newsletters and other materials.

The abstract journals (3 issues per year) on field beans, cassava, and tropical pastures were distributed to more than 800 institutions and 900 individual subscribers in over 100 countries. Nearly 350 bibliographic searches were requested from the data bases of the specialized information centers and their documentation service issued photocopies of 26,000 scientific documents.

CIAT's Graphic Arts Unit prints 4.5 million pages and 3.5 million photocopies with technical and scientific information every year.

A REAL-LIFE EXAMPLE

The cold figures of professionals trained, documents produced, and conferences held are not sufficient, however, to reflect the nature of the activities real people are doing to fulfill the ultimate goal of the Center and its national partners which is to alleviate hunger and poverty in the developing world. As a complement to these figures, a case study will illustrate the complexity of institutional buildup and participation in the overall scheme of international agricultural development, aided by an effective training and communications element. A training program in bean technology, extending over a three-year period (1986-1988) in El Salvador, is a remarkable example of interinstitutional, human resources development for the generation, transfer, and use of improved technology. El Salvador is one of the countries that most urgently needs to improve its bean production.

The institutions

Involved were El Salvador's Centro de Tecnología Agrícola (CENTA) and Ministry of Agriculture (MAG), Guatemala's Instituto de Ciencia y Tecnología Agrícolas (ICTA), and CIAT's Central American Bean Project, the Bean Program, the Training and Communications Program, and the Seed Unit.

CIAT and ICTA have had a long partnership. It dates back to the early 1970s and led to Guatemala becoming self-sufficient in beans and CIAT being awarded the CGIAR's King Baudouin Prize for its contribution to this success.

No doubt, this relationship has been instrumental in effecting ICTA's move toward collaboration with neighboring El Salvador's CENTA to enhance its technology-transfer capacity.

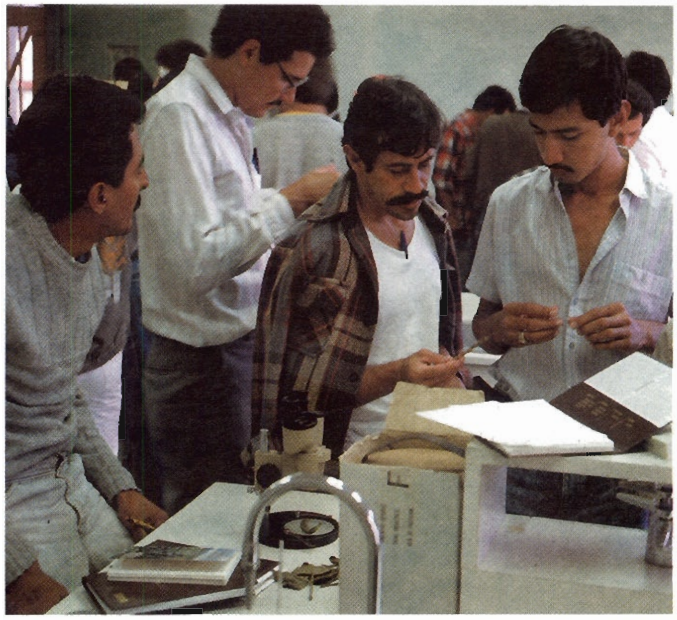
Also, over the last decade, bean researchers from CENTA participated in CIAT's training programs to the extent that by 1986 most Salvadorian bean scientists had received training at CIAT's headquarters or in CIAT-supported events, either in their own or in neighboring countries; and two of these alumni progressed to become CENTA's Research Director and Bean Program leader. Their support and participation as instructors in the various events over the 31-month period were absolutely essential to the success of the program.

The program

With El Salvador's research capacity well in place, CENTA and the

On-farm research training in El Salvador began in 1986.

country's Ministry of Agriculture designed a program to increase the flow of technology to farmers in three of the country's main bean-producing areas: San Miguel, Santa Ana, and San Vicente. Central to the plan was hands-on training of extension agents and farmers, in cooperation with CIAT, the Central American Bean Research Network, and ICTA.



Long-time cooperation helped to articulate the generation, evaluation, and transfer of bean technology which lead to its adoption in El Salvador. Human-resource development, which began with the training of scientists at CIAT more than a decade ago, was fundamental to success.

FIRST STAGE

The first training event leading to this goal was a nine-month, three-phase, on-farm-research course where the new knowledge and abilities learned in one phase (10-15 days long) were applied inmediately thereafter in the field. It was here that ICTA's Bean Program leader and several of his Guatemalan colleagues stepped in to participate as resource persons.

In addition to developing the human resources, the course yielded another specific achievement: two varieties of beans —CENTA-Izalco and RAB 204—were found to outperform the locally-grown ones and met with high farmer acceptance. The first, although released in 1982, had not yet been adopted by the farmers; the second was a product of CIAT breeding.

Also, natural leadership — necessary for the continuity of these efforts— developed among the participants: one participant from San Vicente emerged as the leader of his region's bean team; and of the two participants from the Department of San Miguel, one similarly took the leadership for his region and the two developed their own training programs and established a regional bean team. As in San Vicente, tangible results soon developed: CENTA-Izalco and the CIAT variety RAB-383 were found to be outstanding performers.

THE SECOND STAGE

For lack of a formal bean seed multiplication and distribution system, a nontraditional alternative was followed to overcome the dearth of seeds from the superior varieties identified in the previous step. An artisanal seed production program in San Vicente took place in August 1987 and January 1988 when technicians and small farmers learned how to produce high-quality seed; they multiplied the promising materials discovered in the previous on-farm research course.

This done, the activity shifted to the Department of Santa Ana where another course dealt with bean production technology and the diagnosis of production problems. In this event, too, a participant emerged as the team leader for the region, thus completing the set of three regional leaders. Here, also, superior varieties were identified, and for the same reasons as in San Vicente, a course on artisanal seed production and multiplication was carried out.

The Santa Ana and San Miguel regional leaders served as instructors in all the training events after the first course in San Vicente, no matter where they took place. The Santa Ana leader joined the others in this approach.

As a final note, the bean varieties which were found to be so successful in the initial events continued living up to their reputation. CENTA-Izalco, multiplied in the artisanal seed production courses, found the success that it did not enjoy in 1982: farmers adopted it enthusiastically. RAB 204, in turn, was officially released by El Salvador in September 1988 and named CENTA-Jiboa.

EPILOGUE

This has been a complex story showing the intricacies of the international agricultural technology generation and transfer system in general, of the linkages within it, and of the development of the human-resource capacities that give life to it.

Training courses in on-farm research conducted in Colombia for regional Salvadorian leaders complemented courses held in their own country.

Hardly any function of international technical cooperation has been missing in it. The generation, evaluation, transfer and adoption of technology have been present in the development of the improved varieties, both by the national research institution and by the international center; the cooperation between countries, often called horizontal cooperation, has been represented by the generous contribution of Guatemala's ICTA to the development of El Salvador's extensionists; the in-country articulation between research and extension was enhanced; and an alternative to overcome the severe bottleneck of the lack of an effective seed multiplication and distribution system was put into place. And *training* played a fundamental role in all of them.

ANNEXES

FINANCIAL INFORMATION

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

EXPENDITURES IN 1988

(Expressed in thousands of US dollars)

	Actual Expenditures		
	Core	Special Projects	Total
Research Programs:			
Beans	3,598	2,487	6,085
Cassava	2,011	305	2,316
Rice	1,319	464	1,783
Tropical Pastures	3,690	182	3,872
Subtotal	10,618	3,438	14,056
Research Support:			
Visiting Scientists and Post-Doctorals	553		553
Genetic Resources Unit	396	155	551
Biotechnology Research Unit	291	12	303
Virology Research Unit	287	19	306
Research Services	326		326
Station Operations	866		866
Carimagua Station	658		658
Data Services Unit	501		501
Agroecological Studies Unit	176		176
Seed Unit	531		531
Subtotal	4,585	186	4,771
Total Research	15,203	3,624	18,827
Training and Communications:			
Training and Conferences	1,375	301	1,676
Communication and Information	1,322	184	1,506
Total International Cooperation	2,697	485	3,182
Administration:			
Board of Trustees	203		203
Office of the Director General	602		602
Office of the Directors	676		676
Central Administrative Support	1,453		1,453
Total Administration	2,934		2,934

	Actual Expenditures		
	Core	Special Projects	Total
General Operating Expenses:			
Physical Plant	1,360		1,360
Motor Pool	616		616
General Expenses	238		238
Total General Expenses	2,214		2,214
Total Operations	23,048	4,109	27,157
Capital:			
Replacement	728	136	864
Construction	982		982
Equipment	593	218	811
Total Capital	2,303	354	2,657
Total	25,351	4,463	29,814

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

SOURCES OF FUNDS

(Expressed in thousands of US dollars)

Core Operations	
Government of Belgium	163
Government of Canada	1,501
People's Republic of China	15
European Economic Community (EEC)	2,045
The Ford Foundation	80
Government of France	206
Government of the Federal Republic of Germany	688
Inter-American Development Bank (IDB)	4,640
International Development Research Centre (IDRC)	119
Government of Italy	851
Government of Japan	2,630
Government of the Netherlands	392
Government of Norway	559
The Rockefeller Foundation	175
Government of Spain	60
Government of Sweden	260
Government of Switzerland	2,884
Government of the United Kingdom	943
United Nations Development Program (UNDP)	168
United States Agency for International Development (USAID)	4,820
World Bank (IBRD)	1,150
Others	103
Subtotal	24,452
Income applied in the year	899
Total Core Operations	25,351
Extra Core and Cooperative Projects	
Government of Australia	45
Government of Belgium	70
Canadian International Development Agency (CIDA)	1,346
Food and Agriculture Organization of the United Nations (FAO)	16
The Ford Foundation	18
Foundation for Agricultural Development (FUNDAGRO)	83
German Agency for Technical Cooperation (GTZ)	39

Inter-American Development Bank (IDB)	11
International Board for Plant Genetic Resources (IBPGR)	155
International Development Research Centre (IDRC)	220
International Fertilizer Development Center (IFDC)	18
International Institute of Tropical Agriculture (IITA)	180
International Maize and Wheat Improvement Center (CIMMYT)	163
International Rice Research Institute (IRRI)	268
Government of Israel	19
Government of Italy	129
Government of Japan	165
The Kellogg Foundation	225
Mississippi State University—INTSORMIL	55
Government of the Netherlands	62
The Rockefeller Foundation	32
Government of Switzerland	324
United Nations Development Program (UNDP)	98
United States Agency for International Development (USAID)	745
Other Donors and Income	195
Total Extra Core and Cooperative Projects	4,681
Total Grants and Income	30,032

COLLABORATIVE PROJECTS WITH RESEARCH INSTITUTIONS AROUND THE WORLD IN 1988

CIAT collaborates with many advanced research institutions on a range of projects which will further the state of knowledge in prioritized research areas in which the Center does not have an immediate comparative advantage within its on-going programs. Many of these projects are funded by the national donor agencies in the countries where the collaborating institutions are located. The current projects are alphabetically listed with their respective institutions and, if applicable, the funding source.

Institution	Description	Funding Agency
Faculté des Sciences Agronomiques de Gembloux, Départment de Phytotechnologie Tropicale. Belgium	Legume germplasm research	Administration Générale de la Coopération au Dévelopment (AGDO)
Fondo de Desarrollo Rural Integrado. Colombia	Agroindustrial development of cassava in Colombia	Fondo de Desarrollo Rural Integrado (DRI)
Institute of Horticultural Research. United Kingdom	Pathogenic variation of *Pseudomonas syringae* pv. *phaseolicola*, the halo blight pathogen of *Phaseolus* beans	Overseas Development Administration (ODA). United Kingdom
Institute of Horticultural Research. United Kingdom	Third-country quarantine of African beans	CIAT
Istituto d'Agronomia e Coltivazione Erbacea. Rome, Italy	Evaluation of existing and creation of new variability in *Phaseolus vulgaris* germplasm	Italian Government
Istituto di Biologia Agraria. Viterbo, Italy	Development of a tissue culture cycle in common beans (*Phaseolus vulgaris*)	Italian Government
Istituto di Fitovirologia Applicata (IFVA). Rome, Italy	Characterization of the main bean yellow mosaic virus isolates in North Africa, West Asia, and China	Italian Government
Istituto Nazionale della Nutrizione (INN). Rome, Italy	Research on antinutritional factors in common beans (*Phaseolus vulgaris*)	Italian Government
Istituto Sperimentale per L'Orticoltora. Milan, Italy	Development of a protocol for agrobacterium-based transformation in bean (*Phaseolus* spp.)	Italian Government
Institut für Viruskrankheiten der Pflanzen (IVPB). Braunschweigh. Federal Republic of Germany	Distribution and importance of viruses naturally infecting *Phaseolus vulgaris* and its relatives in Africa	Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ)
International Institute for Tropical Agriculture (IITA). Nigeria	Exploration and evaluation of cassava mite predators	IITA
International Rice Research Institute (IRRI). Philippines	IRRI-CIAT collaborative project	IRRI
Louisiana State University, Department of Biochemistry. USA	Development of gene-transfer techniques in cassava	United States Agency for International Development (USAID)

Institution	Description	Funding Agency
Ministry of Agriculture. Iran.	Scientific and technical cooperation in research and training on *Phaseolus* bean improvement	Government of Iran
Mississippi State University, Office of International Programs. USA	Sorghum research in Latin America (INTSORMIL)	USAID
Overseas Development and Natural Resources Institute (ODNRI). United Kingdom	Organoleptic and biochemical evaluation of storage life of cassava	ODA.
Technical University, Bonn, Federal Republic of Germany	Plant regeneration of *P. vulgaris* in tissue culture (Ph.D. thesis)	Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). West Germany
Technische Universitat Berlin. Federal Republic of Germany	Research on dual-purpose systems and the role of improved grass-legume pastures for milk and beef production in acid soils of tropical America	GTZ
Tel Aviv University. Israel	Identification and characterization of genetic strains in *Bemisia*	USAID
Universitat Marburg. Federal Republic of Germany	Competition and survival of *Rhizobium* bv. *phaseoli* strains	BMZ
University of California. Davis, USA	Molecular markers for evolutionary studies in *P. vulgaris*	
University of Florida. Gainesville, USA	Development of genetic molecular markers in *Phaseolus vulgaris*	USAID
University of Munich, Institute for Economic and Social Sciences. Federal Republic of Germany	Social benefits and costs of rice research in Brazil	BMZ
University of Wisconsin, Department of Horticulture. USA	Interspecific hybridization in *Phaseolus* spp. through embryo culture	USAID
Vrijes University. Brussels, Belgium	Transformation of cassava tissues	
Washington University, St. Louis, Missouri. USA	Conferring virus resistance in cassava in introduction and expression of virus coat protein gene	Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM)-Rockefeller Foundation

PUBLICATIONS IN 1988

PUBLICATIONS BY CIAT PERSONNEL

Articles for conferences, workshops and seminars	77
Books	17
Articles in periodical publications (newsletters, journals)	105
Brochures	4
Working documents	4
Press articles in newspapers	20
Press articles in magazines	14

CIAT PUBLICATIONS IN 1988

Bean	
Newsletters	4
Abstracts	2
Bibliography	1
Technical manual	1
Poster	1
Audiotutorial Units	4
Cassava	
Newsletters	5
Brochures	2
Poster	1
Abstracts	2
Bibliography	1
Audiotutorial units	2
Videotutorial units	2
Rice	
Newsletters	2
Technical manual	1

Seed	
Newsletters	2
Manuals	2
Tropical Pastures	
Journals	3
Technical report	1
Abstracts	1
Audiotutorial units	2
Videotutorial units	1
Other	
Institutional newsletters	4
Annual report (bilingual edition)	1
Proceedings	1
Brochures	3
Insert	1

BOARD OF TRUSTEES
(1988-1989)

* Left in October 1988

Helio Tollini
Director
Planning and Economic Analysis Division
International Fund for Agricultural Development (IFAD)
Rome, Italy

Lucía de Vaccaro
Facultad de Agronomía
Instituto de Producción Animal (IPA)
Universidad Central de Venezuela
Maracay, Aragua, Venezuela

Frederick Joshua Wang'ati
Secretary
National Council for Science and Technology
Nairobi, Kenya

Armando Samper Gnecco
Chairman Emeritus of the Board
Director General
Centro de Investigación de la Caña de Azúcar (CENICAÑA)
Cali, Colombia

PRINCIPAL STAFF
(as of December 1988)

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Director General

Douglas R. Laing, Ph.D.,
Deputy Director General

Filemón Torres, Ph.D.,
Deputy Director General

* Gertrude Brekelbaum, Ph.D.,
Assistant to the Director General

Randy Treichler, M.S.,
Assistant to the Director General

Jack Reeves, J.D.,
Senior Writer, Head, Public Information

BEAN PROGRAM

Senior staff

Douglas Pachico, Ph.D.,
Agricultural Economist, Leader

* Aristeo Acosta, Ph.D.,
Breeder (stationed in Kawanda, Uganda)

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Stephen R. Beebe, Ph.D.,
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Entomologist

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Plant Breeder, Regional Coordinator of the Great Lakes Program (stationed in Butare, Rwanda)

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Plant Pathologist, Regional Coordinator, Andean Regional Bean Research Program (stationed in Lima, Peru)

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Economist

Judith Kipe-Nolt, Ph.D.,
Microbiologist

Roger Kirkby, Ph.D.,
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Jonathan Lynch, Ph.D.,
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Shree P. Singh, Ph.D.,
Plant Breeder

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Michael D. Thung, Ph.D.,
Agronomist (stationed in Goiania, Goias, Brazil)

Peter Trutmann, Ph.D.,
Pathologist, Great Lakes Bean Program (stationed in Butare, Rwanda)

* Joachim Voss, Ph.D.,
Anthropologist, Great Lakes Bean Program (stationed in Butare, Rwanda)

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Agronomist

Jeffrey White, Ph.D.,
Physiologist

* Jonathan Woolley, Ph.D.,
Cropping Systems Agronomist

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Associate Cropping Systems Specialist, Great Lakes Bean Program (stationed in Butare, Rwanda)

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Guy Henry, Ph.D.,
Agricultural Economist

* Left during 1988.

Joseph Tohme, Ph.D.,
Plant Breeder

Visiting research fellow

Louise Sperling, Ph.D.,
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CASSAVA PROGRAM

Senior staff

James H. Cock, Ph.D.,
Physiologist, Leader

Anthony C. Bellotti, Ph.D.,
Entomologist

Rupert Best, Ph.D.,
Chemical Engineer, Utilization

Mabrouk El-Sharkawy, Ph.D.,
Physiologist

Clair Hershey, Ph.D.,
Plant Breeder

Reinhardt Howeler, Ph.D.,
Soil Scientist, Asian Regional Cassava Program (stationed in Bangkok, Thailand)

Kazuo Kawano, Ph.D.,
Plant Breeder, Asian Regional Cassava Program (stationed in Bangkok, Thailand)

J. Carlos Lozano, Ph.D.,
Plant Pathologist

* John K. Lynam, Ph.D.,
Agricultural Economist

Raúl Moreno, Ph.D.,
Agronomist

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Anthropologist (stationed in Quito, Ecuador)

Senior research fellows

Carlos Augusto Pérez, Ph.D.,
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Christopher Wheatley, Ph.D.,
Physiologist, Utilization

Postdoctoral fellows

Ann Braun, Ph.D., Entomologist

* Edward Carey, Ph.D., Plant Breeder

Visiting scientists

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Food Technologist, Utilization

* Yamel López, Ph.D., Agronomist

Daniel Sullivan, Ph.D., Entomologist

RICE PROGRAM

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Plant Pathologist, Leader

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Agronomist/Plant Breeder, IRTP Coordinator for Latin America (Associate Member Senior Staff-IRRI)

* James Gibbons, Ph.D.,
Plant Breeder (stationed in Villavicencio, Colombia)

César Martínez, Ph.D.,
Plant Breeder

* Edward Pulver, Ph.D.,
Agronomist

* Manuel Rosero, Ph.D.,
Plant Breeder, IRRI Liaison Scientist, IRTP Coordinator for the Caribbean (stationed in Santo Domingo, Dominican Republic)

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* Left during 1988.

Luis R. Sanint, Ph.D.,
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Surapong Sarkarung, Ph.D.,
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* Georg Weber, Ph.D.,
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CIAT fellow

Patricio Vargas, Ph.D.,
Agronomist

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André Leury, M.S.,
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Postdoctoral fellow

Fernando Correa, Ph.D.,
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TROPICAL PASTURES PROGRAM

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Pasture Agronomist, Leader

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Soil Microbiologist

John E. Ferguson, Ph.D.,
Agronomist, Seed Production

Myles Fisher, Ph.D.,
Ecophysiologist

Bela Grof, Ph.D.,
Agrostologist, Cerrados Agronomy (stationed in Planaltina, Brazil)

Gerhard Keller-Grein, Dr.agr.,
RIEPT Humid Tropics Agronomist (stationed in Pucallpa, Peru)

Stephen Lapointe, Ph.D.,
Entomologist

Carlos Lascano, Ph.D.,
Animal Scientist, Pasture Quality and Nutrition

* Jillian M. Lenné, Ph.D.,
Plant Pathologist

John W. Miles, Ph.D.,
Plant Breeder

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José G. Salinas, Ph.D.,
Soil Scientist, Soil and Plant Nutrition (stationed in Pucallpa, Peru)

Rainer Schultze-Kraft, Dr.agr.,
Agronomist, Germplasm

Carlos Seré, Dr.agr.,
Agricultural Economist

James M. Spain, Ph.D.,
Soil Scientist, Pasture Development (stationed in Planaltina, Brazil)

Derrick Thomas, Ph.D.,
Forage Agronomist, RIEPT Llanos

Raúl R. Vera, Ph.D.,
Animal Scientist, Cattle Production Systems

CIAT fellows

* Cacilda do Valle, Ph.D.,
Plant Breeder

* Left during 1988.

* Armando Peralta, M.S., Agronomist

Senior research fellows

Yoichi Nada, Ph.D., Pasture Scientist, assigned to CIAT by TARC, Japan

* Yasuo Ogawa, M.S, Pasture Development, assigned to CIAT by TARC, Japan

Roberto Sáez, Ph.D. Economist, (stationed in Planaltina, Brazil)

Postdoctoral fellows

Miguel A. Ayarza, Ph.D., Soil Scientist

William Loker, Ph.D., Anthropologist, Economist (CIAT/ IFPRI Liasion Scientist stationed in Pucallpa, Peru)

Alvaro Ramírez, Ph.D., Economist (stationed in Quito, Ecuador)

Visiting scientist

* Robert Davis, Experimental Officer, Agronomist/ Plant Pathologist

TRAINING AND COMMUNICATIONS SUPPORT PROGRAM

Senior staff

Gerardo E. Häbich, Ph.D., Leader

Susana Amaya, Ph.D., Communication Specialist, Senior Editor, Head, Publications/Editing

Senior research fellow

Cynthia Connolly, Ph.D., Head, Training Materials

General administrative services staff

Alfredo Caldas, M.S., Admissions Administrator, Training

Walter Correa, Ph.D., Head, Graphic Arts/Production

RESEARCH SUPPORT

Agroecological studies unit

Senior staff

Peter Jones, Ph.D., Agrometeorologist, Computer Scientist, Head

Postdoctoral fellows

Simon Carter, Ph.D., Agricultural Geographer

Daniel Robison, Ph.D., Soil Scientist

José Ignacio Sanz, Ph.D., Soil Scientist

Biotechnology research unit

Senior staff

William M. Roca, Ph.D., Physiologist, Head

Senior research fellow

René Chávez, Ph.D., Plant Breeder

Postdoctoral Fellows

Mornan Kuonade, Ph.D., Biologist, Physiologist

María Luisa Marín, Ph.D., Plant Physiologist

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* Left during 1988.

THE CGIAR SYSTEM

The Consultative Group on International Agricultural Research (CGIAR) was formed in 1971. The CGIAR is an association of countries, international and regional organizations, and private foundations dedicated to supporting a system of agricultural research centers and programs around the world. There are currently 13 of them: nine research centers and four associated organizations which provide research support. The purpose of the research effort is to improve the quantity and quality of food production in developing countries.

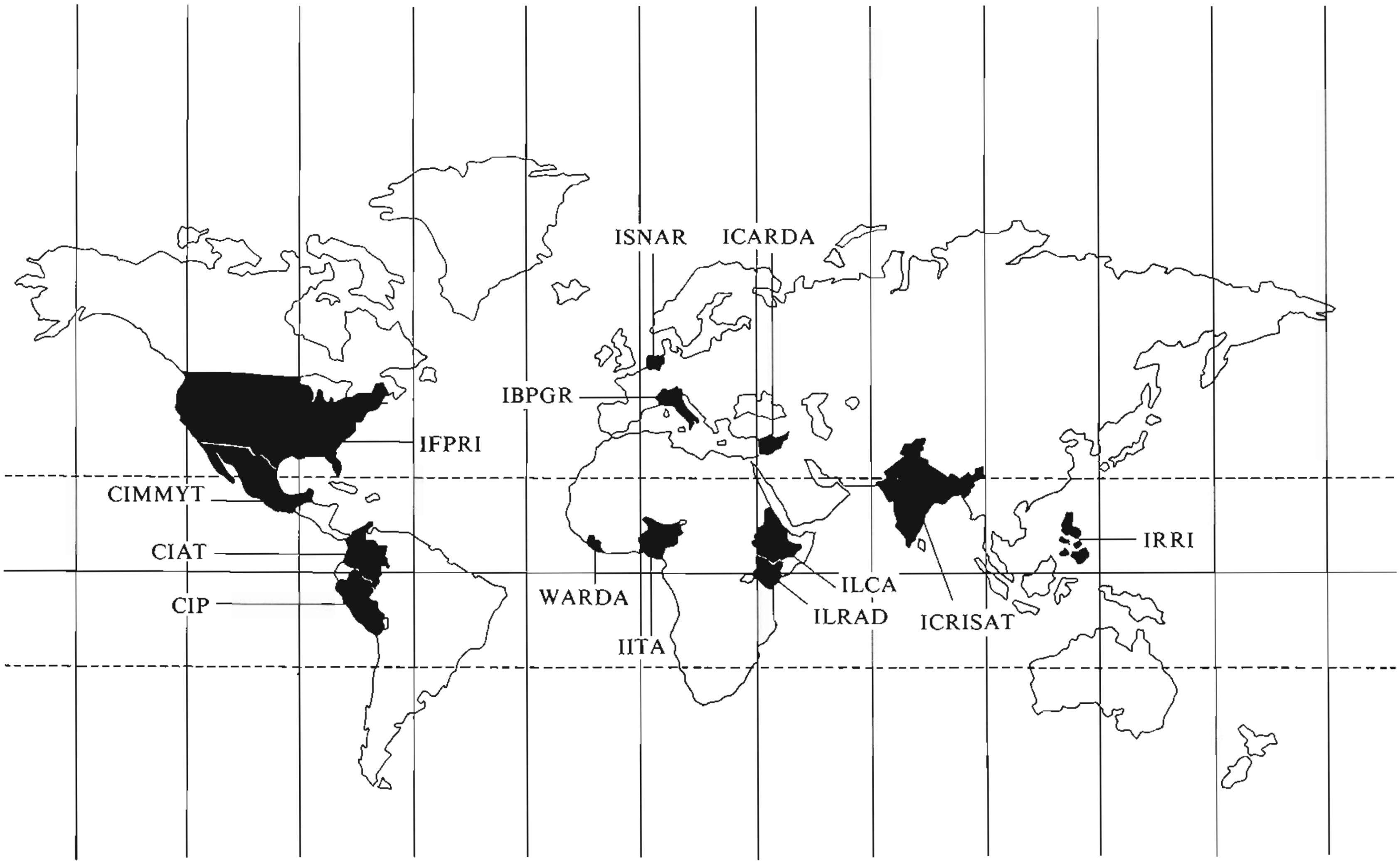
The World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Program (UNDP) are cosponsors of the effort. The World Bank provides the CGIAR's chairman and secretariat. The CGIAR has a Technical Advisory Committee whose secretariat is provided by the three cosponsors and located at FAO headquarters in Rome.

In 1989, the CGIAR has some 35 contributing donors and about US$228 million to support the system.

The nine international agricultural research centers and four associated organizations have the following headquarters and research responsibilities:

AFRICA

- International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima beans, soybean).
- International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia: livestock production systems.
- International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya: trypanosomiasis and theileriosis of cattle.
- West Africa Rice Development Association (WARDA), Monrovia, Liberia: rice.


ISNAR
ICARDA
IBPGR
IFPRI
CIMMYT
CIAT
CIP
WARDA
IITA
ILCA
ILRAD
ICRISAT
IRRI

Asia

- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India: chickpea, pigeonpea, pearl millet, sorghum, groundnut, and farming systems.
- International Rice Research Institute (IRRI), Los Baños, Philippines: rice.

Europe

- International Board for Plant Genetic Resources (IBPGR), Rome, Italy: plant varieties collection and information.
- International Service for National Agricultural Research (ISNAR), The Hague, Netherlands: research support.

United States

- International Food Policy Research Institute (IFPRI), Washington, D.C., USA: analysis of world food problems.

Latin America

- International Center for Tropical Agriculture (CIAT), Cali, Colombia: cassava, field beans, rice, and tropical pastures.
- International Center for Maize and Wheat Improvement (CIMMYT), El Batán, Mexico: maize and wheat.
- International Potato Center (CIP), Lima, Peru: potatoes.

Middle East

- International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria: farming systems, cereals, food legumes (broad bean, lentil, chickpea), and forage crops.