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CIAT Report 1983

Centro Internacional de Agricultura Tropical
Apartado Aéreo 6713
Cali, Colombia

October 1983

CIAT Report 1983 is published in English and Spanish and is written to inform donors, collaborators, and the interested public of the highlights of our work. Results reported here are those achieved through the end of 1982.

Individual annual reports (in either English or Spanish) for commodity programs—Beans, Cassava, Rice, and Tropical Pastures—may be ordered from:

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CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The government of Colombia provides support as a host country for CIAT and furnishes a 522-hectare site near Cali for CIAT's headquarters. In addition, the Colombian Foundation for Higher Education (FES) makes available to CIAT a 184-hectare substation in Quilichao and a 73-hectare substation near Popayán, the Colombian Rice Federation (FEDEARROZ) also makes available to CIAT a 30-hectare farm—Santa Rosa substation—near Villavicencio. CIAT co-manages with the Colombian Agrarian Institute (ICA) the 22,000-hectare Carimagua Research Center in the Colombian Eastern Plains and carries out collaborative work on several of ICA's experimental stations in Colombia; similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR).

Foreword

The readers of *CIAT Report 1983* will find two interrelated threads woven throughout the robust fabric of solid technical progress. Decentralization and networking, which bind CIAT's programs ever more firmly to the larger canvas of the national research systems, have always been key components in CIAT's philosophy. Their growing importance today, however, is a result of substantial recent progress. The impressive technological achievements summarized in this report demonstrate that a solid scientific base has been laid at headquarters so that a stronger move toward decentralization is now possible. This cannot be implemented without the continued strengthening of the corresponding programs in national research systems to provide a strong partnership for networks of collaborative activities.

The most obvious example of decentralization is in the area of crop improvement, where national programs play an increasingly important role in the advanced selection of segregating materials to develop new improved varieties for their own specific conditions. As national programs become ever stronger partners in the generation of improved production technology, the role of networking becomes more important in order for the technology developed by various components of the network to be tested and shared in a system of horizontal transfer. Such networking activities also provide the national programs with an important voice in the design and execution of the collaborative international testing nurseries.

Another aspect of decentralization, building on the fruits of previous training and cooperation, is the increasing proportion of CIAT's training efforts devoted to helping national programs conduct their own in-country training courses.

The achievements summarized in this report were accomplished during a period of consolidation. During 1982, in preparation for the reduced budget in 1983, it was necessary to phase out a number of program activities in order to decrease the number of senior staff positions from 62 in 1982 to 54. The fact that the programs remained so productive and the scientists enthusiastic about their work in the face of these painful reductions is a testimony to the high quality and dedication of CIAT staff and the stimulation that comes from the progress being made.

John L. Nickel
Director General

CIAT donors in 1982:

The governments of Australia, Belgium, Canada, the Federal Republic of Germany, Japan, the Netherlands, Norway, Spain, Switzerland, the United Kingdom and the United States; the World Bank; the Inter-American Development Bank (IDB); the European Economic Community (EEC); the International Fund for Agricultural Development (IFAD); the OPEC Fund for International Development; the Ford Foundation; and the Rockefeller Foundation. In addition, special project funds are supplied by various of the aforementioned donors plus the United Nations Development Programme (UNDP), the German Agency for Technical Cooperation (GTZ), the International Development Research Centre (IDRC), the International Fertilizer Development Center (IFDC), and the W.K. Kellogg Foundation.

Board of Trustees in 1982/83:

CIAT's Mandate

The purpose and approach of CIAT—one of several agricultural research centers under the aegis of the Consultative Group on International Agricultural Research (CGIAR)— is given in the following statement of objectives:

To generate and deliver, in collaboration with national and regional institutions, improved tehnology which will contribute to increased production, productivity, and quality of specific food commodities in the tropics—principally countries in Latin America and the Caribbean—thereby enabling producers and consumers, especially those with limited resources, to increase their purchasing power and improve their nutrition

The CIAT strategy to accomplish these objectives is summarized by the following statements regarding resource emphasis, commodity choice, institutional role, and scope of activities.

Resource emphasis. CIAT's strategy emphasizes enhanced production through increased resource productivity on farms with limited resources and on underutilized land areas. By contributing to the improvement of productivity on small- and medium-scale farms, the center seeks to provide for increased rural income and employment, moderate and stable food prices, and improved diets, especially of the low-income, urban and rural population. Technology which contributes to expansion of agricultural production of suitable commodities on the less fertile frontier lands makes possible the release of the more fertile lands for maximum crop cultivation, thus achieving more efficient food and animal production using both poor and fertile land resources, to meet consumer demands.

Commodity choice. Commodities to be included under CIAT's mandate are predominantly food staples.

All CIAT's activities are viewed as complementary to those of other international and national organizations.

Each commodity has one or more of the following attributes: it is a relatively inexpensive source of calories; it is a relatively inexpensive source of protein; it is an important component in the food budget of low-income consumers in the geographic region of emphasis. Commodities are selected for their potential to augment the productivity and incomes of farmers with limited resources and/or to contribute to increasing agricultural production on existing cultivated lands or in the agricultural frontier.

Institutional role. A basic premise of CIAT's strategy is that it represents only one small segment of the agricultural research and development matrix. All center activities, therefore, are viewed as complementary to those of other organizations. Linkage to other closely related activities is essential in developing effective research networks that capture economies of scale in research on the chosen commodities. Such activities include the following three groups: national research and extension systems, specialized research institutions, and related international programs

The most important interface is with national research systems. In partnership with these programs, CIAT concentrates on activities for which CIAT has a clear comparative advantage and the results of which have international transferability. Such activities include the assembly of germplasm banks; large-scale screening, crossing, and selection; methodology development; and information services. CIAT attempts to strengthen collaboration and to encourage horizontal technology transfer among national programs by helping to develop and strengthen research networks. Active training and conference programs serve to fortify national research systems, as well as the network activities.

Basic research institutions in both developed and developing countries are linked with CIAT activities to provide selected research inputs and specialized research services that complement and support CIAT's more problem-solving research.

The principle of complementarity also applies to other international institutions, especially sister centers within the CGIAR system. Through informal discussions and formal agreements, cooperation and division of labor is defined to maximize the benefits of comparative advantage and minimize duplication.

Scope of activities. CIAT's efforts are predominantly focused on the American tropics. Its commodities are selected for their importance in this region. Yet, given that within the CGIAR systems the center has been assigned broader responsibilities for given commodities, CIAT is differentiating functional responsibilities on the basis of the following categories: (1) Principal, and (2) Regional.

Principal. For commodities for which CIAT is assigned a principal mandate, CIAT assumes the following responsibilities:

1. Assemble, maintain, and make available the world germplasm collection;
2. Conduct specialized, strategic research;
3. Generate improved production technology components for, and develop cooperative activities with, national research systems in all regions in the developing world where the commodity is important, and no sister CGIAR center is assuming regional responsibilities;


4. Provide in-service training for professionals in the specialized/strategic areas of research on a global basis;
5. Provide specialized in-service and production-oriented training for professionals from countries where no other CGIAR center has area-specific responsibilities;
6. Collect, process, and disseminate information on the commodity on a global basis;
7. Backstop the activities of other institution(s), if any, with regional responsibilities for that commodity.

Regional. This category applies when a sister CGIAR center has worldwide responsibilities for a commodity, and, in close cooperation with that center, CIAT takes on selected responsibilities, especially No. 3 and No. 5. Together with national research systems it identifies principal production constraints, and, in close collaboration with the center having responsibility, seeks to facilitate such activities as are required to overcome such constraints.

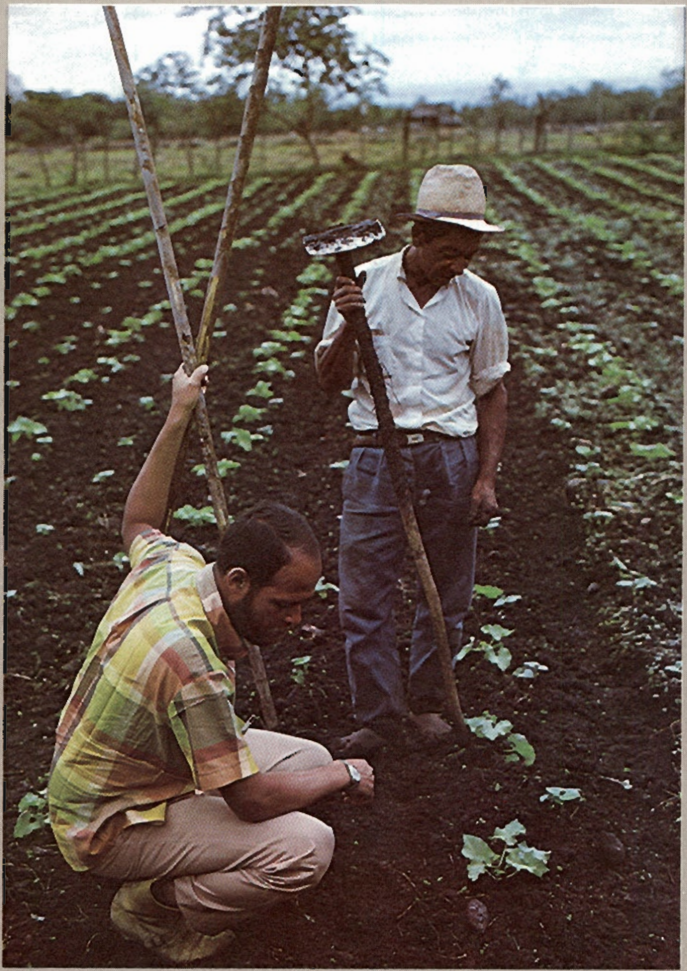
Current Mandate

In order to achieve the objectives and apply the strategy described above, and, taking into account the results of socioeconomic studies and the mandates of other centers, the CIAT programs have evolved to currently encompass the following responsibilities:

1. Principal responsibilities for beans (*Phaseolus vulgaris* and related species) and cassava (*Manihot esculenta*);
2. Principal responsibilities for tropical pastures (specific responsibilities for the acid, infertile soils of the American tropics);
3. Regional responsibilities for rice (specific responsibilities for the American tropics).

Contents

BEAN PROGRAM
PROGRAMA DE FRIJOL



First priority is assigned to breeding for improved characters and then combining these to meet location-specific needs and consumer preferences.

Within the framework of CIAT's philosophical and operational approach to agricultural development, the objective of the Bean Program is to develop, in close collaboration with national agricultural research and development agencies, technology that will increase production and productivity of beans.

A wealth of information collected by CIAT and its collaborators shows that the large majority of bean farmers in the tropics and subtropics are small holders with limited capital and restricted access to credit and reliable technical information to raise farm level productivity. Current yields are low: in Latin American countries they range from 350 to 1200 kg/ha, with an average of 550. Productivity in other major bean-producing regions in Africa and the Middle East is also within this range. Farmers, however, have demonstrated potential yield levels of over 3000 kg/ha.

The principal factors responsible for these low yields are high disease and insect pressures: more than 200 diseases and insect species have been identified that can cause economically significant damage to *Phaseolus vulgaris*, for instance. Other problems include traditional low-density plantings and the general reluctance to use fertilizers to correct poor soils, due to the risk that diseases or droughts might severely damage the farmer's crop.

Thus, the CIAT Bean Program assigns first priority to breeding for improved bean varieties that provide reliable yield performance over time; this is accomplished by developing varieties with multiple disease and pest resistance and with acceptable levels of drought tolerance. For the longer term, the Bean Program aims to genetically develop bean plants with tolerance to moderately acid soils and with improved symbiotic N_2 fixation. In addition, the Program seeks to improve crop management practices to further enhance varietal performance. In all its technology development efforts, the Bean Program focuses on the production problems of the small farmer and stresses the concept of minimum-purchased inputs to assure that production technology is within the reach of the bean farmer. The Program, however, also cooperates with large farmers in such areas as Argentina, Brazil, Mexico and Kenya.

For widespread acceptance, the new varieties must meet consumer preferences for seed size and seed coat color and fit into the farmers' cropping systems, which often include maize in direct association or relay cropping. Such requirements often block use of the varieties that are most disease- and pest-resistant and highest yielding, which have become available from the crop improvement efforts.

Given the multitude of cropping systems, ecological zones, and consumer preferences for which improved bean varieties must be developed, it is evident that success can only be achieved through a two-tiered approach. First, the CIAT Bean Program identifies and develops promising parental material and other basic elements of production technology; then, from these materials, collaborating national bean programs will develop their own improved bean varieties and attendant cultural practices in accordance with their particular needs. Such decentralization in technology development requires a high level of technical competence at the national level. To help bring this about and nurture it, extensive and persistent manpower development efforts are undertaken by the Bean Program to develop a true international cooperation.

In 1982, the 10th year of interdisciplinary bean improvement work by CIAT, the Bean Program had sections devoted to plant breeding, pathology, entomology, microbiology, nutritional quality, agronomy, on-farm research, economics, international testing, and germplasm collection/systematization. Technology development is achieved through three general phases. First, production constraints and research

Intensive collaboration with the Colombian national legume program of ICA enables germplasm evaluation in contrasting environments. At ICA-Obonuco at 2700 masl, for instance, beans and maize in association are being tested.

priorities are monitored; then, they are tackled by systematic genetic development of maximum levels of the desired character expression. Finally, resulting lines with high levels of specific trait expressions are used, both at CIAT and at the national level, to obtain multiple-factor recombinations in commercially acceptable bean cultivars.

Newly developed lines enter a three-stage, uniform nursery evaluation scheme:

1. VEF — *Vivero del Equipo de Frijol* (Bean Team Nursery). Evaluation of agro-ecological adaptation and disease resistance.
2. EP — *Ensayo Preliminar de Rendimiento* (Preliminary Yield Trial). Confirmation of disease resistances and evaluation of yield potential and seed quality.
3. IBYAN — *International Bean Yield and Adaptation Nursery.* International evaluation in various agroecological areas.

All three nurseries are conducted on a calendar-year basis. National programs also enter their best hybrid lines into this testing scheme to help ensure that superior materials are freely available to anyone who wishes to receive the full nurseries or selected parts of them. Separate yearly reports on these nurseries are available from CIAT.

A series of disease- and insect-resistance nurseries are also evaluated within the international network to sort out race complexes of pathogens, to identify sources of wide resistance, and to identify area-specific parental adaptation. International nurseries for drought, nitrogen fixation (*Rhizobium* strains as well as bean lines), and selected diseases and insects not ocurring in Colombia, are also organized.

Collaborating national agencies now have increased capacity to develop bean lines uniquely suited to the complex of given production constraints, production systems, and consumer preferences. This allows the Bean Program to devote more attention to developing segregating populations and early generation progenies for specific bean-growing regions for further evaluation and selection by technical personnel of collaborating national programs. The Bean Program is thus fast approaching the stage at which the already firmly established international bean research network becomes an international research program of mutually interdependent factors.

Summary of Achievements

At this time, improved parental materials have been identified by the Bean Program to help overcome the major limiting production factors. For the last 2 years, resistance to bean common mosaic virus, one of the principal diseases, has been incorporated into all lines leaving CIAT. Resistance breeding for, among others, angular leafspot, *Ascochyta* leafblight, bean golden mosaic virus, common bacterial blight, and rust has already resulted in the availability of bean varieties resistant to these diseases. Similar progress has been achieved in breeding for resistance to such insect pests as the bean podweevil, the beanfly, bruchids, and the leafhopper. New plant types have been developed with improved plant architecture; bean lines with enhanced capacity to fix atmospheric nitrogen have been bred; and bean lines with superior performance under low phosphorus availability have been identified.

A large number of improved lines combining up to five desired characters has already advanced successfully through the entire series of evaluation tests organized by the Bean Program. Commercially acceptable improved lines are now available for nearly all principal bean production areas in Latin America and the Caribbean, and they are now being tested extensively in Africa.

By the end of 1982, seven collaborating countries had already launched a total of 13 commercial varieties based on materials received from CIAT. An additional 12 lines had been identified by eight countries as varieties to be released shortly and were undergoing seed multiplication. A further 24 promising lines were in advanced evaluations in 10 countries. The three major bean-producing countries in Latin America, Argentina, Brazil, and Mexico, have already released improved lines from CIAT as new varieties. And, in Costa Rica, Cuba, Guatemala, Honduras, and Mexico, improved varieties have reached the farmer level, where they are beginning to have an impact on total production In Africa, in Burundi and the Republic of South Africa, the first bean lines have just been released.

Germplasm Base for Genetic Improvement

Phaseolus beans are distributed worldwide: they are cultivated in the tropics, the subtropics, and the temperate zones, and in many regions they are considered staple foods. While more than 30 *Phaseolus* species have been described, only four are cultivated. Of the latter, the common bean, *P. vulgaris*, is the most widely grown. The remaining three cultivated species are scarlet runner beans (*P. coccineus*), tepary beans (*P. acutifolius*), and lima beans (*P. lunatus*).

Within the international center's system, CIAT has global responsibility for collection and preservation of germplasm of the genus *Phaseolus*. In late 1982, six years after formally assuming this responsibility, the CIAT germplasm collection contained more than 32,000 accessions embracing the four cultivated species, their wild ancestors, and the noncultivated species (Table 1). This germplasm has been obtained through donations from national germplasm banks and collection expeditions to the centers of origin and dispersion. Also included in the bank are the most promising progenies resulting from the hybridization efforts at CIAT.

In a Colombian regional trial, small farmers in the town of Pescador thresh beans from small evaluation plots to measure the response to fertilization with rock phosphate.

Aside from the obvious task of gathering as much as possible of the existing variability in *Phaseolus* beans to prevent loss of genetic variability, a major challenge is to measure, or quantify, the variability of the germplasm, especially for the common bean. Another challenge is to make effective use of the related species (tertiary gene pools), as a means not only to improve the common bean but also to pursue the possibility of using those species as crops in environments where *P. vulgaris* cannot be adapted or has many limitations. A better understanding of the real variability and of the phylogenetical relationships will be a powerful tool for bean breeders in making more efficient use of the available germplasm base.

Origin and Representation in CIAT's Collection

Distribution of *P. vulgaris* as a crop ranges from 0 to 3000 masl, and from 0 to 42° latitude, N and S, requiring a broad genetic variability.

Archeological findings in Mesoamerica and the availability of a large number of wild ancestral and wild noncultivated forms of the genus there suggest that the Mexico/Guatemala area is the center of origin for the common bean. However, since the expeditions of Colombus, the common bean was geographically dispersed and thus has been adapted to many new areas outside the Americas. This has resulted in several secondary centers of dispersion, which, in many cases, are 400 years old. About 70% of the nearly 29,000 accessions of *P. vulgaris* in the CIAT germplasm bank have their origins in the Americas, but almost 9000 accessions have been obtained from Europe, Africa, and Asia/Oceania (Table 2). Such materials are also sources for local adaptation in improvement programs. Active collection efforts for *P. vulgaris* continue to be assigned high priority by CIAT in narrow collaboration with the

Table 1. Status of *Phaseolus* bean collection held at CIAT (December 1982).

Species	Accessions (no.)
Cultivated spp. and their wild ancestors	
P. vulgaris	28,874
P. lunatus	2,344
P. coccineus	1,082
P. acutifolius	148
Wild, noncultivated spp. (10 species)	84
Total	32,532

Table 2. Geographical origin of *Phaseolus vulgaris* germplasm held at CIAT.

Region	Accessions (no.)
North America	9568
Central America	5217
Caribbean	84
South America, Andean Zone	3692
South America, non-Andean Zone	1361
Europe	6463
Africa	2065
Asia/Oceania	424
Total	28,874

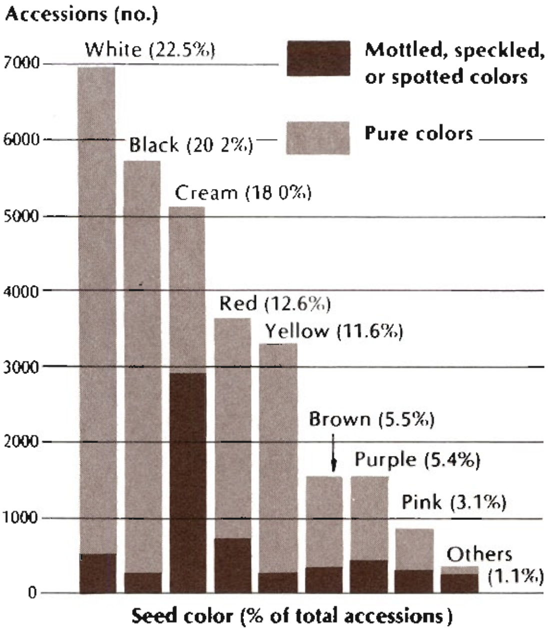


Figure 1. Seed color distribution of germplasm bank accessions of P. vulgaris.

International Board for Plant Genetic Resources (IBPGR),[1] with special emphasis being placed on areas with advanced genetic erosion and with a high probability of finding land races and wild forms of the cultivar.

Processing of New Accessions

Small seed samples of new accessions are received and increased at CIAT, in collaboration with the Colombian Agricultural Research Institute (ICA), which has national responsibility for phytosanitary controls. Since seed quality is of utmost concern, the first increase is slow and laborious, and some 700 accessions are processed in each of the four yearly cycles. The resulting seed is taken to an isolated field in a dry area, where the incidence of bacteria and fungi is low. After a second increase, seed samples are provided to breeders for identification of potential progenitors. The remaining seed is stored, and part of it is used for morphoagronomic characterization. To date, some 15,500 accessions—more than 50% of the present germplasm collection—have undergone seed multiplication.

Morphoagronomic Characterization of Primary Gene Pool

In the morphoagronomic characterization process, each accession is described in terms of 27 variables, including collection information, taxonomical identification, and readily discernible heritable characters. To date, more than 12,000 accessions have been characterized and the information maintained in computer files.

To produce improved, commercially viable bean lines, the description of seed size, shape, color, and brilliance are important variables for the bean breeder. Figure 1 summarizes the distribution of seed color of all common bean accessions currently available in the germplasm bank. Characterization data are being used to cluster germplasm accessions into groups of similar values on the various parameters. This will help breeders in selecting parents with a widely different genetic base.

Evaluation of Potential Usefulness of Secondary and Tertiary Gene Pools

While the primary gene pool (i.e., extant cultivars and landraces) of *P. vulgaris* contains a considerable genetic variability, a large degree of additional variability could be harnessed through access to the secondary gene pool (i.e., wild relatives or ancestors) of the species, or even the

1. Many of the CIAT-organized collection expeditions are cosponsored by IBPGR, since 1978, such cosponsored collection trips included expeditions to Mexico, the Iberian Peninsula, Peru, Brazil, and several African countries. In 1982, IBPGR has greatly expanded its capacity to contribute to the collection of several crop species in Latin America—including field beans—with the appointment of a regional IBPGR officer posted at CIAT. Future collections will concentrate on Mexico and the Andean highlands

CIAT's answer to the challenge of increasing agricultural production is to modify the plant's genetic composition as a low-external input alternative.

tertiary gene pool of the common bean (i.e., other species that can exchange genes with the cultivar in spite of some genetic barriers).

The secondary gene pool of *P. vulgaris* has already proved highly relevant as a source of resistance to stored grain insects (*see* CIAT Report 1982). To explore the possibility of having access to the tertiary gene pool, CIAT and the University of Gembloux (Belgium) are collaborating in a project aiming at increasing the variability of the common bean through interspecific hybridization with other species of the genus, especially *P. coccineus*.

Seed Distribution

In its germplasm-management operation, the CIAT Bean Program provides seed and seed-related information services to bean workers as requested. In the period 1977–1982, a total of 262 requests, from all parts of the world, for nearly 22,000 bean samples were processed. In addition, the bank sent more than 45,000 samples for preliminary selection in pest and disease nurseries to the CIAT Bean Network.

The Central American Bean Project serves as a liaison between national programs and CIAT in the development and release of improved varieties for commercial production (left). *These cultivars, carrying a package of desirable characteristics, have resulted from the prolonged and continuous breeding efforts of national and international agencies, such as those carried out in CIAT by the University of Gembloux, Belgium* (right).

Identification and Development of Desirable Characteristics

A large portion of the differential between potential and actual yields is due to the numerous biotic and edaphic factors that severely limit bean production in Latin America and Africa.

One way to confront such negative production-influencing factors is through improved control of the environment, using insectides, fungicides, irrigation, drainage, fertilization, and the like. However, the average Latin American bean farmer—a small farmer—can ill afford the high external input costs required by this approach.

A more realistic approach, and one emphasized by the Bean Program, is to counter these factors by modifying the plant genetic composition, allowing the plant to naturally resist them. This implies incorporation into the bean plant of such desirable characteristics as resistances to diseases, drought, and so on. This is CIAT's answer to the challenge of increasing agricultural production. It clearly is a low external-input alternative; it offers moderately high and stable yields; it is environment friendly; it implies low risk to the producer; and it is applicable to the low resource farmer. It has not been possible to find levels of resistance or tolerance sufficient to genetically resolve all principal constraints, however.

The genetic improvement process used by the Bean Program follows two distinct, consecutive phases: *character improvement*—the development of high-level and stable expression of individual characters in bean lines, irrespective of color and seed sizes (this section); and *character recombination*—the development of cultivars that incorporate a combination of improved characters and meet agronomic and consumer requirements specific to the intended production region (next section).

The process of prioritizing characters for further improvement goes beyond the mere consideration of economic benefits (yields) to be reaped from improved varieties. To be sure, the quest for protection against such widespread and devastating pests as anthracnose and

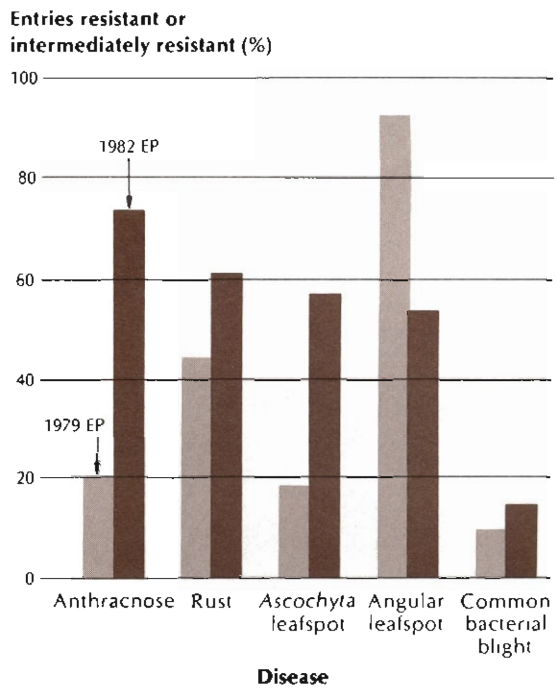


Figure 2. Comparison between the percentage of entries resistant and intermediately resistant to various diseases in the 1979 EP (total of 180 entries) and in the 1982 EP (total of 304 entries). In the case of angular leafspot, the technique used to identify the disease was properly established after 1979; thus, the 53.6% reported in 1982 is a more accurate figure.

Germplasm is carefully evaluated for desirable characteristics, such as resistance to pests and diseases, before moving into the recombination phase.

leafhoppers—which can completely wipe out a bean crop—have moved the search for genetic resistance to these problems to the top of the priority list. A less widespread problem—bacterial blight—is as important, however, because it is virtually impossible to control it by any other means. Although the seed-borne disease bean common mosaic virus (BCMV) causes less severe yield losses than others, genetic resistance to it is assigned high priority because it eliminates one of the most important phytosanitary barriers to free international movement of bean seed.

A still different criterion for priority assignment is represented by the case of webblight, a devastating disease in the lower humid tropics that effectively limits large-scale bean production in these areas. Only low levels of resistance have been identified in the germplasm thus far; also missing is a reliable screening methodology for webblight resistance. These reasons, and the fact that this disease has not been studied elsewhere, which would provide data upon which CIAT could build, traditionally caused CIAT to relegate webblight to a lower priority class. Recently, however, after encouraging progress has been registered with high priority disease resistances, the Bean Program has been able to pay increased attention to webblight.

Such varied considerations help the Bean Program bring some order into the perplexing spectrum of diseases and insects that attack beans in the tropics where no severe winters reduce pest incidences and where often more virulent isolates of pathogens exist than in cooler production zones. With so many biotic factors competing for attention, it can readily be seen why initial emphasis must often be placed on simple, inherited disease resistance that results in quick solutions which may be relatively short-lived, but nevertheless provide the opportunity to simultaneously tackle a series of biotic problems and provide time to develop more stable types of resistance, enhanced by integrated control methods, which reduce dependence on high levels of resistance. In addition, improved pest resistances are not the only characters that vie for attention; equally important factors are related to the use of available nutrients, drought tolerance, nitrogen fixation capacity, and architectural characteristics.

Continued progress in character improvement is shown in Figure 2, which compares the first EP, conducted in 1979, with the 1982 EP in terms of percentages of the respective entries that were either resistant or intermediately resistant to angular leafspot, anthracnose, *Ascochyta* leafspot, bacterial blight, and rust.

Already, a high percentage of the new bean lines produced at CIAT are resistant to the high-priority diseases. With the availability of a considerable pool of lines—representing a variety of commercial bean types resistant to any one priority disease—the Bean Program has reached the stage where many of the basic building blocks for the development of commercial lines that meet consumer and agronomic requirements for most bean-growing regions are in place.

Below is a summary of the status of character improvement efforts in the Bean Program, with special emphasis on achievements in 1982

Angular leafspot. Extensive testing in Argentina and Brazil of large numbers of newly developed bean lines with different sources of resistance has allowed the differentiation between races of the angular leafspot fungus, caused by *Isariopsis griseola*, in Argentina, Brazil, and Colombia. While CIAT lines A 160, A 210, and BAT 332 are resistant in Colombia, they are susceptible in Brazil; the reverse holds true for lines A 339 and A 340 Lines A 140 and A 154, among others, are resistant in both countries.

Anthracnose. Anthracnose-resistant bean cultivars have been grown extensively and successfully in Europe, North America, and some regions of Latin America. Many of these materials—most prominently, Cornell 49-242—have been used as sources for resistance breeding. Nevertheless, resistance by these sources conferred upon commercial cultivars in many regions of Latin America and Africa is effective only for short periods, or is not effective at all. Data obtained shows the pathogenic variation present in Latin America to be far greater than that in temperate regions. Thus, some cultivars with resistance to all known races in Europe and in the United States (BAT 841, BAT 44, Amapola del Camino) are susceptible to several Mexican isolates of the pathogen *Colletotrichum lindemuthianum* under both field and greenhouse conditions.

To identify new and broadly applicable sources of resistance, since 1978, 15,500 bean lines have already been evaluated. Several of these, including lines G 2338, G 3991, G 4032, G 5653, G 6975, G 7199, G 8519, and G 1106, are also resistant to angular leafspot. After a series of trials, these newly identified sources have maintained their resistance under field conditions in several locations throughout Latin America; under greenhouse conditions, they have held their own against isolates from different parts of the world. These sources of resistance represent a range of grain colors, growth habits, and geographic origins and are now being used in the crossing blocks. Selected lines that have already been developed combine up to four different anthracnose-resistance sources.

The Bean Program is also investigating intermediate levels of resistance and resistance related to certain development stages of the bean plant. In the latter research, for example, seedlings of ICA-Llanogrande (E 1056), a variety resistant under field conditions in anthracnose-endemic areas, showed a marked susceptible reaction when inoculated under greenhouse conditions. Plants older than 3 weeks, however, showed only very mild or no anthracnose susceptibility under greenhouse conditions, suggesting some form of adult resistance Work on this aspect is continuing.

Bean common mosaic virus (BCMV). In 1982, the Bean Program confirmed the availability of BCMV-resistant lines with red seed color, successfully breaking the negative linkage between BCMV (I gene) susceptibility and the desired red seed coat color. With this development, Canario remains the only important grain type for which BCMV resistance has not been identified. Due to the importance of necrotic-inducing BCMV strains in selected bean-growing areas, such as Chile and Eastern Africa, the Program has stepped up the development of tropically adapted lines containing I-gene resistance to BCMV, combined with the recessive genes, a combination that confers more stable resistance.

Bean golden mosaic virus (BGMV). Breeding for resistance to BGMV began in 1975 with the evaluation of germplasm accessions in Central America and Brazil. Hybrid lines with black opaque seed and high levels of BGMV tolerance were selected in a collaborative program with the Institute of Science and Agricultural Technology (ICTA) in Guatemala. They were identified in the late 1970s and gave rise to several outstanding bean varieties (e.g., ICTA-Quetzal, ICTA-Jutiapan, etc.), which, in several countries, have already been passed on to bean producers. Another offspring from these selections, line D-145, was released in Mexico in 1982 under the name of Negro Huasteco 81.

Progress in small-seeded red varieties for El Salvador and medium-sized red-mottled, determináte varieties for the Dominican Republic has been slower. Nevertheless, through the international BGMV nurseries conducted in 1979 and 1980, several nonblack resistance sources were identified from hybrid lines produced at CIAT in Brazil. From interspecific crosses, BGMV resistance lines were also identified in Guatemala. Additional crosses were made, and promising red-seed selections are currently being tested in preliminary yield trials.

Bean chlorotic mottle virus (BClMV). BClMV resistance is particularly important to selected bean-growing regions in the southern cone (Argentina and Chile) of Latin America. In 1981, for example, Argentina lost over 50,000 ha of beans due to this virus. Most BGMV-resistant varieties developed by CIAT have proved to be also resistant to BClMV, which, like the BGMV virus, is transmitted by the whitefly. After extensive evaluations, line DOR 41, released as ICTA-Quetzal in Guatemala, was registered in Argentina in 1982 and is rapidly replacing the local variety, Negro Comun.

Rust. Data from the International Bean Rust Nursery (IBRN) since 1974 show that the best cultivars are resistant to rust, caused by *Uromyces phaseoli*, at most locations. However, many cultivars initially found resistant at a given location later became susceptible to rust at the same location. This phenomenon is true of many national, commercial cultivars: since they are resistant to only a few races of the rust pathogen, they are resistant in only a limited area and often for but a short time.

Nevertheless, the IBRN has identified a series of national cultivars (Redland Pioneer, Redland Greenleaf B, Redland Greenleaf C, Cuilapa 72, Cocacho, Mexico 309, Mexico 235) and CIAT-bred lines (BAT 66, 67, 93, 256, 261, 308, 429, 447, and 520) with rust resistance having considerable geographic and temporal stability. These broadly resistant cultivars are now being used in crossing blocks as sources of rust resistance with the objective of obtaining more durable (stable) resistance to one of the most variable bean pathogens known.

In this search for durable resistance, different disease-resistance mechanisms and breeding

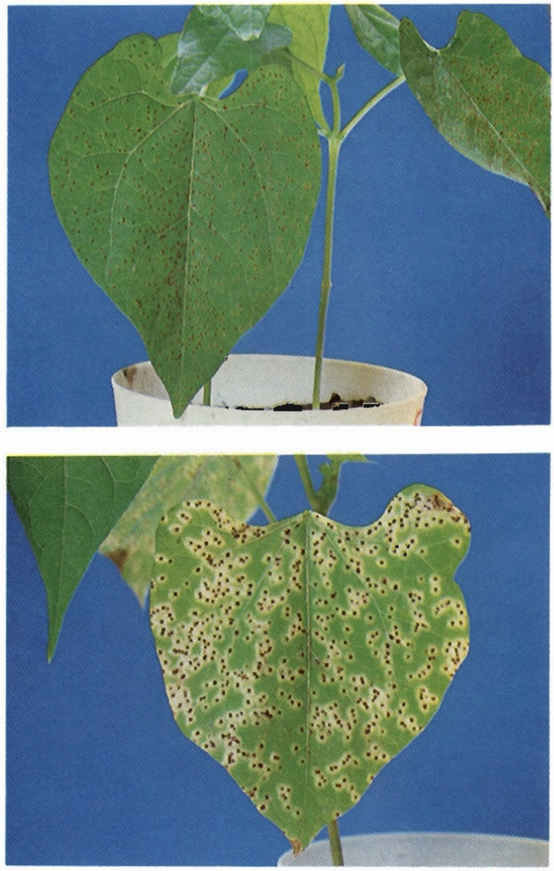


Figure 3. Selected CIAT lines with rust resistance across many locations have been found. Some (top) are characterized by small pustules (300 microns). Preliminary data collected at CIAT-Palmira indicated that even under heavy rust pressure, the yield of these lines is not affected, while the yield of susceptible lines (bottom), characterized by large pustules (500 microns or more), is severely reduced.

Figure 4. No resistance to storage insects has been found in commercial, large-seeded bean varieties (red). In small-seeded wild types (cream), however, high levels of resistance to Acanthoscelides obtectus have recently been determined.

strategies are being evaluated. Among the mechanisms, such bean plant characteristics as small pustule type (Figure 3), long latent period, and low receptibility to rust may be associated with durable resistance. Some breeding strategies aim to obtain durable resistance. For example, pyramiding different resistance genes or resistance sources into lines with commercial grain types is sought.

Storage insects. Good levels of resistance to the storage pests *Acanthoscelides obtectus* and *Zabrotes subfasciatus*, as reported in 1982, have been confirmed.

Podwalls of bean accessions resistant to *Acanthoscelides* were nonpreferred for penetration by both adults and larvae of the pest (Figure 4). In one trial, the number of eggs laid in pods of the susceptible variety Calima was 136.4, while only 36.8 eggs were laid in pods of the resistant line G 12949. Currently, progenies are being evaluated that have resulted from crosses between small-seeded resistant accessions and commercial, large-seeded varieties that are susceptible to *Acanthoscelides*. Similar results have been obtained with *Zabrotes*.

Drought. In 1982, weather conditions permitted nearly ideal drought-evaluation nurseries. Type I bean materials were generally found to be more susceptible to drought than Types II, III, and IV. Even so, CIAT line A 195 (Type I, determinate) yielded 1060 kg/ha, close to the 1253 kg/ha obtained with the drought-tolerant check G 5059. Highest yields were obtained with Type IV (climbing) materials, the best of which—V 8024—produced 1757 kg/ha. It is assumed that both the large plant size and the vigor of Type IV lines are associated with the high levels of drought tolerance observed. Another outstanding line was EMP 105 (Type II), the only red-seeded line, which in another trial yielded 2265 kg/ha. With these developments, this character-improvement project is making significant headway in the direction of finding high levels of drought tolerance in a range of grain types.

Snap beans. Recently, the Bean Program has initiated a modest effort for the improvement of snap beans. By the end of 1982, 400 germplasm accessions had been evaluated and a crossing program initiated. Blue Lake, the leading commercial snap bean variety, was outyielded by several bank entries. For example, Haricot-a-Rame yielded 1519 kg/ha at 48 days (versus 1010 for Blue Lake) and 2575 kg/ha at the final and second harvest (versus 1788 for Blue Lake). These early evaluation data seem to indicate that rapid headway can be made in the further improvement of snap beans.

Nitrogen fixation. In 1978, the Bean Program started an intermating and selection program for improvement of the bean plant's genetic capacity to fix nitrogen. In 1982, the fifth cycle of recurrent selection and intermating was completed. Seventeen breeding lines with good ability to fix N_2 were coded; included are lines with different colors (other than black or cream) and lines with improved anthracnose resistance.

Plant architecture. Some gross morphological differences occur among bush bean varieties.

Today, a wide variety of beans are cultivated throughout the Americas, Africa, and Asia; each region has different requirements for genetic improvement.

These include plant height and stem erectness, branching pattern, leaf type, node number and distribution, and pod length. Since mid-1977, these traits have been used to improve disease avoidance, better grain quality, improve lodging resistance, and increase yield. Useful genetic variation for each of these architectural components was found primarily in agronomically nonacceptable varieties, which were subsequently improved.

As a result, the following lines were developed: A 55 and A 56, with suppressed branching (mono culm); A 57, A 124, A 126, and A 155 with upright branches; A 132, A 154, and A 156 with short internodes, high node number, and stem erectness; A 207 with small pods; and A 209 with lanceolate leaf. In preliminary yield trials, none of these lines yielded better than the highest yielding check cultivars, ICA Pijao and Carioca, which indicated that the selection of any one of these characters alone should be discouraged while breeding for high yield. Nonetheless, in Nebraska line A 55 seemed to show a high level of avoidance/tolerance to white mold (*Sclerotinia sclerotium*), a disease for which a high level of genetic resistance has yet to be found.

From the yield trials, it was also evident that the determinate Type I bush bean varieties respond differently than do indeterminate Types II and III to increased population densities and environments. The degree of indeterminacy, lateral branches, and nodes/m² seems to be consistently associated with high pod number, and, hence, yield in small-seeded bush bean cultivars. The high negative correlation of pods and nodes/m² with the seeds/pod and seed size or weight might explain, to some extent, the apparent difference in yielding ability of small- and large-seeded bush bean varieties and the difficulty in the development of large-seeded types with the yield potential of high-yielding small-seeded cultivars. This further emphasizes the need for more intensive study of large-seeded bean varieties and identification of highly heritable selection criteria for improvement of their yielding ability.

In the second cycle of improvement, two or more architectural traits are being combined together and transferred into high-yielding cultivars. Some F_3 and F_4 progenies of growth habit Types I and II with strong, upright stems and lodging resistance seem to bear higher pod load than their parents. These will be evaluated in yield trials, along with other high-yielding check varieties, including the prostrate or sprawling types, which have a general tendency to outyield the upright varieties.

Line A 207 and its original parental source with the smallest pods (about 3 cm length) in cultivated *Phaseolus vulgaris* had small seeds (about 15 g/100 seeds). Some F_4 progenies of essentially similar pod length with seeds at least twice as large have been selected. However, it will take additional breeding cycles to improve their general agronomic characteristics and overall usefulness.

Recombination into Desirable Commercial Cultivars for Specific Locations

Until the mid-1930s, genetic improvement of beans in the tropics, including the tropical Americas, was limited to the natural selection pressures and preferences of farmers. Systematic collection, evaluation, and selection of germplasm by national agricultural programs was initiated only

Table 3. Production regions, bean types, cropping systems, production problems, and year breeding was initiated at CIAT.

Production region	Bean type: Size & color	Bean type: Growth habit	Cropping system	Production problems[a]	Year breeding initiated
Central America					
Lowlands	Small red & blacks[b]	Bush & semi-climbing	Intercropping	BCMV, BGMV, rust, CBB, webblight, etc.	1974
Highlands	Small blacks	Climbing	Intercropping	Anthracnose, ALS, *Ascochyta*, rust	1978
Andean highlands (Panama Belize, Caribbean) & East Africa	Medium & large red, pink, purple, cream solids, & mottleds	Bush & climbing	Monoculture & intercropping	BCMV, rust, CBB, ALS anthracnose, drought, low P, *Ascochyta*, bean scab, bean fly	1978
Argentina, North Africa, & Middle East	Large white	Bush	Monoculture	BCMV, BYMV, BClMV, rust, CBB, anthracnose, ALS, drought, low P, bean fly	1980
Brazil	Small cream, brown, pink, & beige	Bush & semi-climbing	Monoculture & intercropping	BCMV, BGMV, rust, CBB, ALS, anthracnose, *Empoasca*, drought, low P, root rots	1974
Chile, Ecuador, coastal Perú, & Mexico	Medium white, cream, yellow, & small white	Bush	Monoculture & intercropping	BCMV, BGMV, rust, drought, root rots	1979
Mexican highlands	Medium cream, pink, solids, striped, & spotted	Semi-climbing & climbing	Monoculture & intercropping	Drought, anthracnose, ALS, rust, *Apion*, *Epilachna*, CBB	1979

a. ALS = angular leafspot; CBB = common bacterial blight; BCMV = bean common mosaic virus; BClMV = bean chlorotic mottle virus; BGMV = bean golden mosaic virus; BYMV = bean yellow mosaic virus.

b. Also grown in Argentina, Brazil, Chile, Cuba, coastal México, and Venezuela.

In all its work, the CIAT Bean Program gives high priority to consumer preferences for seed color and size.

in the second quarter of the present century. Brazil, Chile, Colombia, Costa Rica, Mexico, and Peru were among the first countries to establish bean improvement programs designed to meet their national needs. At CIAT, the first group of crosses was made in the latter part of 1974 for the improvement of small-seeded bush bean varieties—principally black, cream, and red grain colors—adapted to the lowland tropical regions of coastal Brazil, Central America, and coastal Mexico. By 1982, CIAT was working in tandem with 25 countries in 3 continents, recombining improved characters to meet their specific agronomic and consumer needs.

In general, beans are characterized by their seed size and color, growth habit, and adaptation to specific climatic regions. Between the extreme expressions of any of these traits, the genetic variation is nearly continuous, thus pointing to a wide variety of forms, especially in subtropical and tropical America. As a result, both the native Indian tribes and immigrant settlers in each of the principal ecological niches had a diversity of bean types to choose from for cultivation, consumption, and marketing. Today, a wide variety of beans continue to be cultivated throughout the Americas, Africa, and other bean-growing regions of the world (Table 3).

For bean improvement, each ecological region has a different set of production problems, in addition to different commercial bean types. Beans of different seed sizes, growth habits, and maturities have significantly different yield potentials; need to be evaluated in different cropping systems; differ in consumer acceptance; and are encountered at distinctly different stages of varietal improvement. For these reasons, each basic bean type has a unique set of requirements for genetic improvement, a circumstance which has led the Bean Program to consider each major type of bean as an essentially different crop. This greatly complicates the breeding process of the Bean Program and demands an efficient use of available resources and a decentralized program.

On a global scale, the Bean Program seeks to have a major impact on three distinct bean production areas: Latin America and the Caribbean, Eastern Africa, and, in the future, West Asia/North Africa. These three areas account for 53% of all dry beans produced in the tropical and subtropical belt. In 1981, Latin America and the Caribbean produced some 4,813,000 metric tons of beans, followed by Eastern Africa with 1,361,000 tons, and West Asia/North Africa with 316,000 tons.

Estimates of highest potential grain yield at CIAT-Palmira for different bean types in monoculture are given in Figure 5. In general, determinate varieties have lower yields than indeterminate ones. Also, small-seeded varieties outyield those with medium and large seeds. In monoculture, yield of all bean types is higher than in associated cropping.

Evidence thus far indicates that there is no association between seed coat color and yield. Thus, in a traditional bean-producing region such as Huila, Colombia, where medium- and large-seeded, red and red-mottled bean varieties of determinate Type I habit are grown in association with maize, grain yields could readily be increased by 75 to 100% by changing to small-seeded, indeterminate varieties grown in monoculture. However, since beans are often grown as a subsistence crop for local consumption, maize is an important part of the daily diet. Furthermore, local preferences for grain size and color are so stridently adhered to—not only in that bean-growing region but throughout Latin America and Africa—that such a varietal change has not been possible so far, and is unlikely to succeed.

The highest recorded experimental yield of indeterminate bush beans is about 5 t/ha of line A 83 (Type I) in Chile (a result obtained in the 1981 IBYAN); for climbing beans, the record is 5.4 t/ha (Type IV) with artificial support at CIAT-Palmira. In the former case, the record yield obtained was probably due to a combination of a genetically improved variety, long optimum growing conditions, cool nights, and the relative absence of disease and insect pests. In the case of climbing beans, good agronomic management, high inputs, and long growing cycle played important roles in realizing the inherent genetic potential of the climbing cultivar. These yields contrast with average commercial yields of about 500–600 kg/ha and occasional site-specific yields up to around 2000 kg/ha.

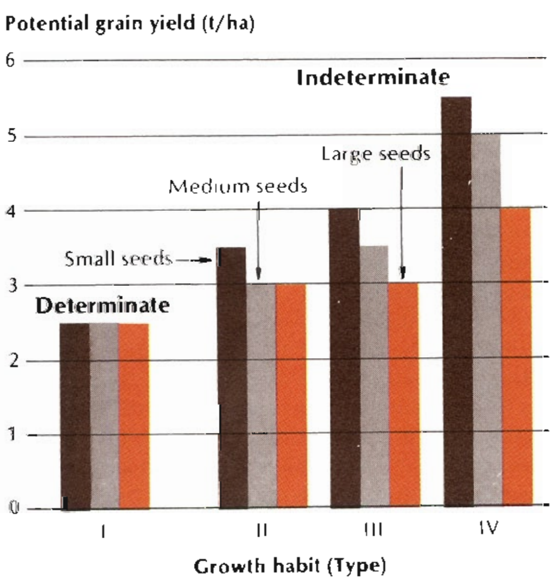


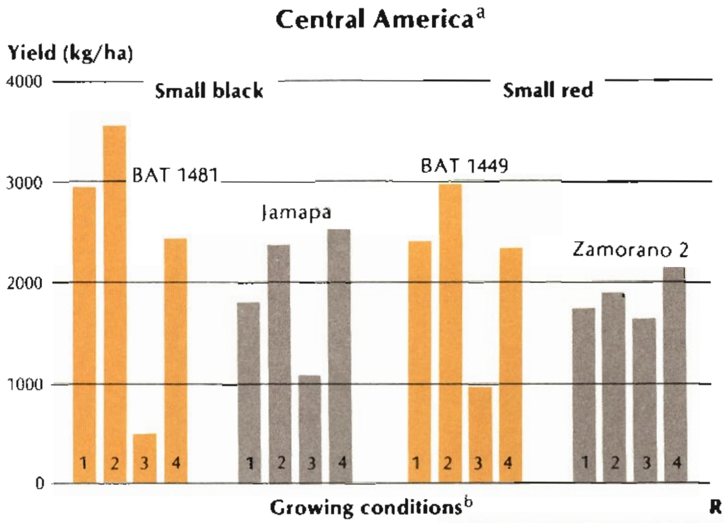
Figure 5. Grain yields may be doubled by choosing Type IV beans over Type I beans. Yield losses also result by selecting large-seeded beans over small-seeded.

As shown in Table 3, varietal improvement of different major bean types was initiated at CIAT in various years. Primary emphasis has been on the stabilization and recovery of actual yield potential of commonly grown cultivars, rather than on maximum yield potential per se. A brief account of progress achieved to date in varietal improvement for different bean-production regions follows.

Central America. The lowlands and the highlands of Central America are two distinct production regions, each characterized by its own set of problems. Varietal improvement of the Central American lowlands was among the first to be undertaken at CIAT and has received high attention ever since. Farmers commonly have very small holdings and plant their red or black beans in intercropped systems. Farmer-grown varieties are most susceptible to BCMV and are either upright, semi-climbing, or climbing. Traditionally the highest and most stable yielding beans were all black-seeded varieties, such as Porrillo Sintético, ICA Pijao, Jamapa, Rico 23, Iguacu, and Rio Tibagi.

Breeding at CIAT for bush and climbing beans for these areas was initiated in 1975. A large number of experimental lines of bush beans with potential for these areas has now been developed and new varieties were named and released for commercial cultivation: Revolucion 79 (BAT 41) and 81 (A 40) in Nicaragua and Acacia 4 in Honduras, for example, are now grown in over 10,000 ha each. Further improvements in seed color and other factors were made, and these lines were available at the end of 1982 for testing.

As expected, it was in Central America that the first group of CIAT-bred lines of red and black



	CIAT line (BAT 1481)	International check (Jamapa)	CIAT line (BAT 1449)	International check (Zamorano 2)	Reaction to:[c]
	R	R	R	S	BCMV
	R	S	I	S	Rust
	S	S	R	I	Anthracnose
	R	S	R	S	Angular leafspot
	S	S	I	S	Common bacterial blight
	S	S	I	S	*Empoasca*

a Also grown in Argentina, Brazil, Chile, Cuba, Coastal Mexico and Venezuela.

b 1 and 2 = trials conducted at Palmira with low and high levels of inputs, respectively, 3 and 4 = trials conducted at Popayan with low and high levels of inputs, respectively.

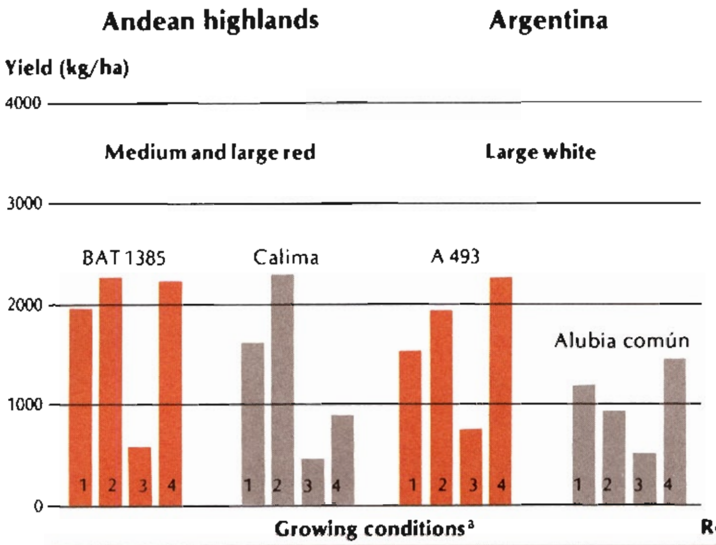
c R = resistant, I = intermediately resistant, S = susceptible.

Figure 6. CIAT and national programs have bred a large number of varieties of each of the different bean types adapted to the lowlands of Central America. These varieties maintain the high yield levels of the best international checks and are resistant to a majority of the pests and diseases attacking bean production (1982 EP data).

beans demonstrated their superiority over the local cultivars. This was followed by varietal releases in practically all countries of the region where these two grain types are preferred. The principal advantage of the new red-seeded varieties was their resistance to BCMV. New black-seeded varieties were stable yielding and possessed either earliness (BAT 304) or tolerance to BGMV (ICTA Quetzal, ICTA Jutiapan, and ICTA Tamazulapa). Some black-seeded varieties bred for this area were also released in Argentina, Brazil, and Mexico. It is interesting to note that none of these released lines had been among the highest yielding lines under Colombian conditions at CIAT experimental sites, which indicates the great value of, and need for, evaluation in the region for local adaptation. Recently developed experimental lines of both colors now also carry resistance, in various combinations, to common bacterial blight, rust, anthracnose, angular leafspot, and other priority diseases, and are significantly higher yielding (Figure 6).

While in past years, red-seeded lines were somewhat deficient in grain color, newly available lines are free from any such deficiencies. Newly developed experimental lines of nonblack colors are equal or even better in yielding ability than the traditional standard-setting black varieties.

Andean highlands, Panama, Belize, Caribbean, and East Africa. There are two principal bean types grown in these areas: under relatively warm conditions, determinate bush beans with medium-to-large seed of solid and mottled red, pink, purple, and cream colors are grown; in the cooler areas, climbing beans



CIAT line	International check	CIAT line	International check	Reaction to:[b]
R	S	R	S	BCMV
I	S	R	S	Rust
R	S	R	S	Anthracnose
I	S	S	S	Angular leafspot
S	S	I	S	CBB
S	S	S	S	*Empoasca*

a. 1 and 2 = trials conducted at Palmira with low and high levels of inputs, respectively; 3 and 4 = trials conducted at Popayan with low and high levels of inputs, respectively.

b. R = resistant, I = intermediately resistant, S = susceptible.

Figure 7. Performance of the 1982 EP of medium and large red and large white bean types bred for the Andean highlands and Argentina demonstrated sustained high yields and increasing resistance to most pests and diseases.

of similar grain colors and sizes are used. As a group, the majority of the cultivars in these geographic areas are susceptible to BCMV; in cooler areas, production suffers heavily from angular leafspot, anthracnose, *Ascochyta*, powdery mildew, rust, and other diseases. In Caribbean countries, beans also suffer from BGMV.

ICA in Colombia has developed very successful varieties of bush beans for these areas (e.g., Andino, Calima, Nima), which have now been grown for over 15 years. Experimental lines of climbing beans from ICA-Tibaitata have been available for about 8 years and now have entered the international evaluation program.

Due to their long growing season (5–10 months) and problems of specific adaptation only to the highlands (above 1800 masl), climbing beans have been improved in a relatively slower process. Based on its high yields and early maturity, an introduction from Ecuador, E 1056, was released in Colombia in 1982 under the name of ICA Llanogrande.

Experimental lines of bush beans from the first cycle of breeding have been deficient in grain quality and have lacked resistance to BCMV. This, however, has been corrected in subsequent cycles: lines with resistance to anthracnose, BCMV, and rust, and with good yielding ability, are now available (Figure 7).

The recent extension of the Bean Program's activities into Central and East Africa has added some new problems (poor soil fertility, beanfly, necrosis-inducing strains of BCMV, among others) to the improvement list of this group of germplasm. Nevertheless, germplasm developed in Latin America has shown impressive performance

Small farmers in the tropics will reap the benefits of technology developed by the Bean Program in conjunction with national research organizations.

in Africa. The variety Diacol Calima, for instance, was developed by ICA, Colombia, and is now being grown commercially in Burundi.

Argentina, North Africa, and Middle East. Large, white dry beans are grown in Argentina and in selected countries in North Africa and the Middle East. These beans are largely grown in monoculture. In Argentina, the crop suffers from BCMV, BClMV, anthracnose, angular leafspot, common bacterial blight, and other diseases. In African and Middle Eastern countries, serious production problems can be caused by bean yellow mosaic virus (BYMV), the beanfly, drought, root rots, and low soil phosphorus.

At CIAT, breeding of large white beans was initiated in 1980. BCMV-resistant lines with medium to large seeds were rapidly developed, several of which will be tested in Argentina in 1983. Some of these are superior to Alubia in agronomic performance and carry resistance to anthracnose, BCMV, and BClMV (Figure 7). Also in 1983, several hundred F_4 and F_5 families from the second cycle of crosses will be evaluated in both Argentina and Colombia.

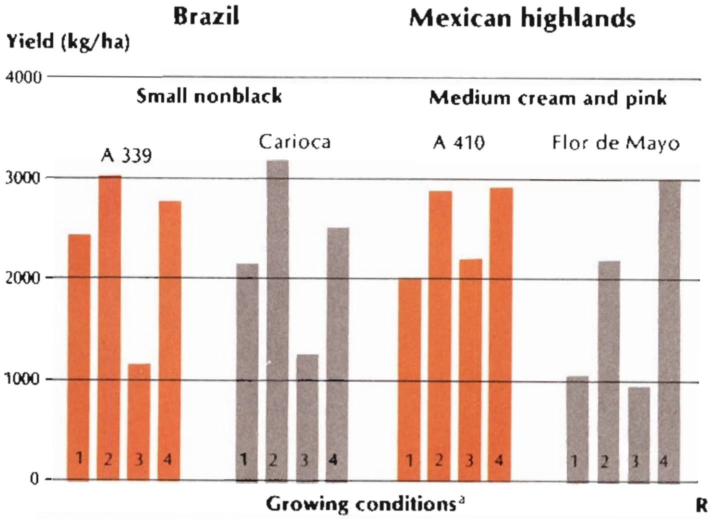
A crossing program for Middle Eastern and North African problems is not scheduled to begin until the end of 1983 or early in 1984, following a seminar in May 1983 on the potentials and current production-limiting factors of beans in that region.

Brazil. Brazil, the world's largest producer and consumer of dry beans, is among those countries that have received highest attention from the CIAT Bean Program. Among other colors, small-seeded black, cream, beige, and pink bush bean varieties of indeterminate growth habits (Types II and III) predominate in Brazilian bean production. These are the types that possess highest yield potential among all bean types suitable for monoculture.

Brazil has had a long history of bean improvement. As a result, high-yielding varieties resistant to BCMV of most grain types—except pink and purple—have been available for many years and occupy over 50% of the total hectarage in the country. Today, frequent droughts in the northeast and the continuously increasing incidence of BGMV and angular leafspot in the south-central part of the country are among the most important bean problems.

While improvement of pink- (Rosinha) and purple- (Roxo) seeded varieties was initiated only recently, high-yielding Mulatinho (cream) and Carioca (cream-mottled) lines resistant to anthracnose, BCMV, rust, and drought have been available in Brazil for testing (Figure 8). The outposting of a member of the CIAT Bean Program at the National Research Center for Rice and Beans (CNPAF) in Goiânia facilitates the evaluation of a backlog of experimental lines developed thus far. The new lines may need improvement for BGMV resistance.

Chile, and coastal Ecuador, Peru, and Mexico. Bush bean varieties of medium-to-large seeds of white, yellow, and beige colors predominate in this region. Small-seeded black and white varieties are also important. Chile also grows some cream-mottled and pinto types for local consumption. While there is some varietal and climatic similarity, production problems vary



CIAT line	International check	CIAT line	International check	Reaction to:[b]
R	R	R	S	BCMV
R	S	S	S	Rust
R	I	R	S	Anthracnose
I	S	S	S	Angular leafspot
S	S	I	S	Common bacterial blight
I	S	I	S	*Empoasca*

a. 1 and 2 = trials conducted at Palmira with low and high levels of inputs, respectively, 3 and 4 = trials conducted at Popayan with low and high levels of inputs, respectively

b. R = resistant, I = intermediately resistant, S = susceptible

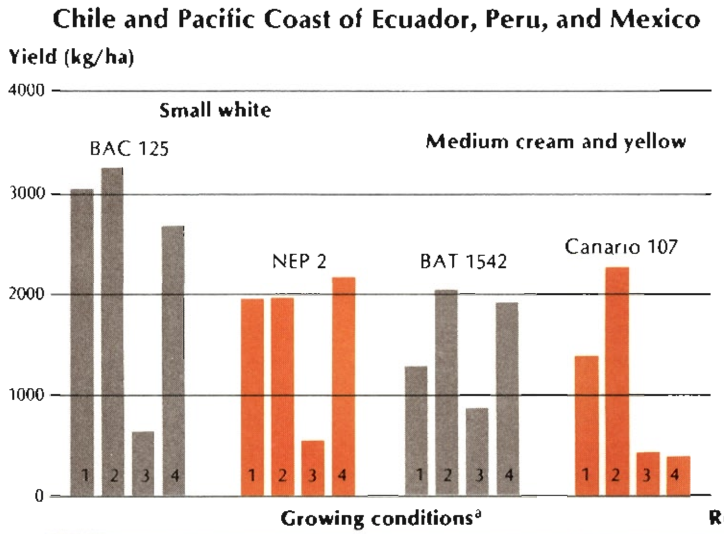
Figure 8. Small nonblack and medium cream and pink bean types bred for growing conditions found in Brazil and the Mexican highlands were compared to international checks in the 1982 EP.

with the regions. For example, in Chile, BYMV is a serious problem, whereas in coastal Peru, rust and drought are the principal production-limiting factors.

Experimental lines resistant to the type strain of BCMV of small white and medium-cream and beige grain colors with good yield potential have been developed in a relatively short time (Figure 9). An intensive effort is being made to improve their desired grain characteristics and to combine resistance to BYMV and necrosis-inducing strains of BCMV. The latter is being pursued in collaboration with the Institute of Horticultural Plant Breeding (IVT), in the Netherlands.

Mexican highlands. Bean production in the Mexican highlands is often subject to inadequate and erratic rainfall. Also, soils are relatively marginal, and farmers make but very limited use of chemical inputs. As a result, bean production/ha in the region is one of the lowest in the world. Varieties used are largely semi-climbing and climbing, medium-sized beans of cream, beige, and pink colors, either solid colored or with spots, stripes, or speckles.

The National Institute for Agricultural Research in Mexico (INIA) initiated improvement of climbing beans in 1978. At CIAT, improvement of bush bean varieties for the Mexican highlands started in 1979 and that for climbing beans in 1982. While new varieties have already been developed by INIA and have been released, most of the area planted is



	BAC 125 (CIAT line)	NEP 2 (International check)	BAT 1542 (CIAT line)	Canario 107 (International check)	Reaction to:[b]
	R	R	R	S	BCMV
	S	S	I	S	Rust
	R	S	R	S	Anthracnose
	I	S	R	S	Angular leafspot
		S	S	S	Common bacterial blight
	S	S	I	S	*Empoasca*

a 1 and 2 = trials conducted at Palmira with low and high levels of inputs, respectively; 3 and 4 = trials conducted at Popayan with low and high levels of inputs, respectively.

b R = resistant, I = intermediately resistant, S = susceptible.

Figure 9. In its search for resistance to the major pests and diseases attacking beans, CIAT and national programs have developed various lines whose yields are equal to or greater than those of the susceptible international checks. The figure illustrates the case for the small white and medium cream and yellow bean types bred for Chile and Pacific Coast areas.

still in indigenous varieties, all of which are highly susceptible to the prevalent diseases and insect pests.

Resistance to BCMV has been incorporated into the bush bean experimental lines of all Mexican grain colors. While several of these also carry resistance to anthracnose and are among the highest yielding of all lines tested in the 1982 EP (*see* Figure 8), their evaluation in Mexico began only in 1981. Encouraging is the fact that through intensive breeding efforts, which have included crosses with donor parents of black, cream, beige, and other grain color types, a high frequency of the preferred Flor de Mayo and Rosita (pink) grain types was achieved.

International Network Activities

Underlying all international cooperation activities of CIAT is the goal to strengthen the research capability of national programs to enable them to increasingly carry out many aspects of technology development (which today are handled by CIAT) at the national level, and to become full-fledged members in the international network to which they contribute materials and information for use in all regions

Effective working relationships with national

National and international programs collaborate in technology generation and transfer through the bean network.

research and development institutions are a fundamental prerequisite for CIAT's technology development efforts to bear fruit. The Bean Program is advanced in the effort to decentralize—in the adjusting of its collaborative activities according to that country's particular needs and wishes.

Ten years ago at the start of the Bean Program's involvement in Latin America and the Caribbean, it was found that national programs and CIAT needed to collaborate along three fronts in support of increasing bean production:

1. Development of improved production technology applicable and relevant to the conditions of the bean producer;
2. Development of institutional and human resources at the national level to strengthen the research capacity of national programs;
3. Integration of international and national research and development efforts through an international bean network.

With the gradual development of national programs, the direction of the germplasm flow itself has started to change. Through 1980, the principal germplasm flow was from CIAT to national programs; starting in 1981, however, several countries reached a stage in which they had developed their own improved bean lines, now sent through the international bean network to other countries, thus initiating horizontal transfer of bean technology.

Development of Relevant Bean Production Technology

To meet the needs and help fulfill the aspirations of collaborating national bean programs, the CIAT Bean Program has chosen the following strategies designed to allow the Program to stay in tune with developments at the national level.

First of all, bean production zones have been defined and production-limiting constraints localized. The three major bean production areas—Latin America and the Caribbean, Eastern Africa and, in the future, West Asia/North Africa—have distinct bean breeding activities headquartered at CIAT in collaboration with the various national organizations.

Then, to define the research needs of each bean production area, the Bean Program has engaged in a series of in-depth analyses of the location-specific potential problems. A major ingredient in these analyses is a set of formal working sessions with bean workers from the region, at which both the problem context and future research strategies are discussed. The basic workshop that ushered in CIAT's involvement in Latin America was held at CIAT headquarters from 26 Feb. to 1 March, 1973; the workshop that predated CIAT's involvement in Eastern Africa took place in Lilongwe, Malawi, on 9–14 March, 1980; and the workshop for CIAT's involvement in West Asia/North Africa is planned for Aleppo, Syria, on 21–23 May, 1983.

To ensure national input into research, each member of the senior staff of the Bean Program is assigned one or more countries as a link between CIAT and that country for coordination of collaborative activities and continuity in working relationships. In addition, in 1978, all staff was posted at CIAT: at the end of 1983, however, the Bean Program had senior staff personnel outposted in Brazil (1), Central America (3), and Peru (1) and was exploring means to station a team of scientists in Eastern Africa. Moreover, through CIAT-sponsored conferences, seminars, and workshops, the Bean Program provides international forums for joint analysis of given problems or challenges and mutual agreement on appropriate and coordinated research strategies.

These and other forms of consultation with national collaborators provide the Bean Program with information that has a direct and immediate effect on the Program's technology design and international cooperation activities.

Through on-farm trials, researchers evaluate the economic feasibility of the technology developed.

Manpower Development and Institution Building

For purposes of manpower development, traditionally CIAT has invested heavily in commodity-based, postgraduate training of professionals in national programs. As early as 1977, it had become apparent that to build up a "critical mass" of trained personnel, it was necessary to organize short, intensive courses to increase the awareness about availability of new production technology. By the early 1980s, the short courses as a means to handle large numbers of training participants had come to a successful conclusion, and emphasis could be shifted to longer term, individual research internships.

Production-oriented training was then shifted to the national level. In 1982, CIAT assisted in seven in-country courses in bean production in five countries. Short courses continue to be organized at CIAT, but they increasingly serve as an introductory phase for national research scientists before entering individualized, discipline-based internships.

Network Development

Establishment and maintenance of an international bean research network is the basis for the interchange of materials and information both among national programs and between CIAT and national programs.

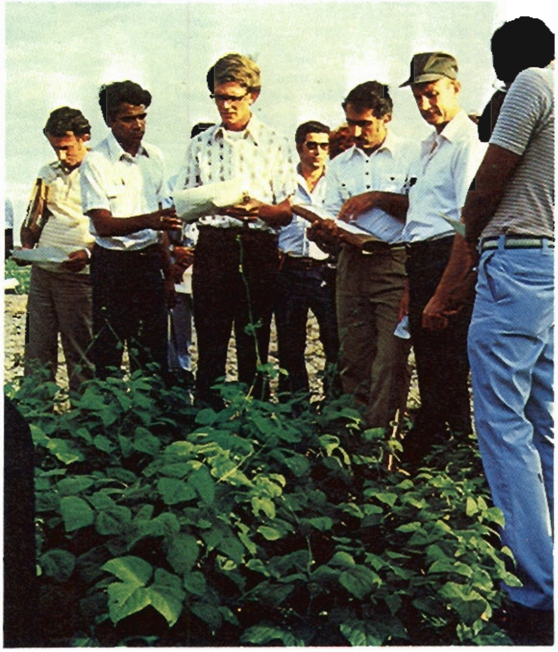
In 1976, the network of uniform testing was initiated with the first IBYAN; by 1982, a total of 10 more specialized IBYAN's, organized by grain type and growth habit, were distributed. The EP and VEF nurseries were introduced in 1978 as a two-part, general observational nursery. Today, the Program also has, among others, the IBRN (International Bean Rust Nursery), VIM (International Webblight Nursery), IBAN (International Anthracnose Nursery), and IERN (International *Empoasca* Resistance Nursery). In addition, there are two enrivonmental stress screening nurseries, the International Drought Nursery and the International High Temperature Nursery.

The preferred mode of conducting research on regionally important production-limiting factors is through collaborative projects with national programs. Through the bean network, such cooperative projects have included the search for resistance to the bean pod weevil and to BGMV, conducted in cooperation with ICTA in Guatemala; the search for webblight resistance, conducted in cooperation with the research arm

Table 4. Lines and varieties distributed by CIAT which have passed the experimental phase in various countries.

Country	Promising lines	Varieties or lines in seed multiplication	Established commercial varieties
Argentina	EMP 84	DOR 41	ICTA Quetzal
	A 493	BAT 76	
		BAT 448	
Bolivia		ICA Pijao	
		BAT 76	
		Carioca Sel-1 (Carioca)	
Brazil		Milionario 1732 (BAT 64)	
		Rico 1735 (BAT 65)	
Burundi		Diacol Calima	
Chile		78-03-74	Redkloud
Colombia	BAT 1297	ICA-Llanogrande (E 1056)	
	BAT 1296		
Costa Rica	Huetar (Mex 80 x BAT 202)	Brunca (BAT 304)	Talamanca (ICA COL 10103)
	Chorotega (Mex 80 x BAT 724)		ICA Pijao
	Corobici (Mex 80 x ICA Pijao)		Porrillo Sintético
Cuba	Hatuey 1 (Line 23/24)		ICA Pijao
	Hatuey 2 (BAT 202)		
	Tomeguin 1 (DOR 15 or EMP 84)		
Ecuador	INIAP Imbayas (E 1056)	INIAP Bayito (Brazil 2)	
	INIAP Saraguro (E 1486)		
	INIAP Puellaro (L 24)		
	INIAP Pimanpiro (E 101)		
El Salvador	Tazumal (BAT 58)		
Guatemala			Suchitan (ICA Pijao)
			ICTA Quetzal
			ICTA Tamazulapa
			ICTA Jutiapan
Honduras	Copan (Mex 80 x BAT 724)		Acacias 4
	Ilama (BAT 1217)		
	Yojoa (BAT 1192)		
Mexico		Negro Huasteco 81 (D 145)	
Nicaragua			Revolución 79 (BAT 41)
Panama	ICA Palmar		
Peru	Gloriabamba (G 2829)		
Republic of South Africa			Cordoba (BAT 317)
Trinidad & Tobago	BAT 21		
	BAT 22		
	BAT 23		
	Brazil 2 (Bico de Ouro)		

Working together, scientists and professionals trained at CIAT are creating a network for bean research and technology transfer.



of the Ministry of Agriculture in Costa Rica; the development of tolerance to low phosphorus levels, conducted in cooperation with CNPAF (National Center of Rice and Bean Research) in Goiânia, Brazil; and development of resistance to BClMV, conducted in cooperation with EEAOC (Agroindustrial Experimental Station Obispo Colombres) and INTA (National Institute of Agricultural Technology) in Argentina.

In addition, the Bean Program facilitates the exchange of information among members of the international bean network throughout Latin America, the Caribbean, and Africa with packaged technical information, a complete abstracting/documentation service, and a quarterly *Bean Newsletter*, which reaches 850 bean researchers worldwide The *Abstracts Journal* in beans has a subscription base of 550.

By 1982, the Bean Program's persistent efforts in technology development and international collaboration had already provided a series of tangible results. More than 420 CIAT-trained bean professionals were staffing national bean programs; a full-fledged international bean network in which some 47 national institutions and 382 individuals in Latin America and the Caribbean actively participated was growing; and the momentum in support of bean improvement for increased bean production was in place. Already, 9 African bean scientists have been trained.

Most important, the majority of collaborating national institutions already had available improved bean germplasm to pass on to bean producers. Table 4 presents a summary of improved germplasm as it was available to collaborating countries at the end of 1982, subdivided into the categories of "promising lines," "lines in seed multiplication," and "established commercial varieties." Materials shown in this table are either commercial varieties that found their international distribution through the CIAT-coordinated international evaluation schemes, selections from the CIAT germplasm bank, and lines developed by CIAT or lines developed by collaborating national programs based on CIAT-provided parental or segregating materials.

Estimates indicate that at the end of 1982, such improved varieties were already planted on at least 200,000 hectares in Latin America and the Caribbean and Africa, where, through improved yield stability and higher yield, they already make a significant contribution to increased bean production. Granted, on a relative scale this acreage devoted to improved bean varieties is still modest, and, due to year-to-year fluctuations in bean production, no definitive changes in bean production trends can be demonstrated on the basis of these developments. Nevertheless, as Table 4 shows, many materials are still waiting in the wings: the dissemination of improved materials has begun and will surely be followed by the release of many more materials, which will put an indelible mark on bean production in the tropics.

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PROGRAM CASSAVA

PROGRAMA DE YUCA

World cassava production is estimated at around 130 million metric tons, cultivated on some 14 million hectares. Most of this is produced by small farmers who cultivate marginal soils. About one-fifth of the total cassava production is in the tropics and subtropics of the Americas, two-fifths are in Asia, and the remainder is in Africa (Figure 1) Of the total production, some two-thirds are used for human consumption—half as fresh cassava, the other half after some form of processing.

Cassava is among the most inexpensive sources of food calories. Since the crucial nutritional deficiency in low-income countries is calories, cassava plays a particularly important role in the nutrition of the poor. It is estimated that cassava provides from 200 to 1000 calories per day for more than 700 million people in developing countries

One important potential growth market for cassava is in the area of cassava flour as a substitute for part of the wheat flour in products such as bread, pastas, and biscuits. Thus, cassava could partially replace expensive wheat imports. Although cassava is relatively low in protein, it can contribute to augmenting protein availability when used as the energy component in animal feed. Because of the availability of large areas of unused marginal lands which cannot support other crops but could produce cassava, the use of cassava as an animal feed could vastly reduce the competition between feed grains for the concentrate industry on the one hand, and the human food sector on the other, for calorie sources

The problems facing the cassava crop differ depending on the desired end use. In the market for fresh cassava, the major problem is crop perishability, which is the prime reason why, in many areas, the producer only receives a very small percentage of the final price paid by the urban consumer. In the use of cassava as a dried product—either for human food or animal feed—the principal problem is low productivity. Present average yields of only slightly more than 10 t/ha are well below the potential due to the use of inefficient agronomic practices, the lack of varieties that are responsive to improved management practices, and damage caused by diseases and insects. A further problem in the production of dried cassava products is the lack of efficient natural drying techniques, especially in those areas of the tropics where humidity is rarely low.

The market potential for dried cassava products is very large if the roots can be produced at low costs and if they can be effectively dried. The emergence of new production and processing technology has the potential to make cassava highly competitive in a wide range of new markets.

The aim of the Cassava Program is to increase production and utilization of cassava, with particular emphasis on Latin America and Asia. The Program's specific research objectives are to:

- Develop germplasm and cultural practices based on low input levels and responsive to improved management to increase cassava productivity in areas where cassava is presently grown;
- Develop germplasm and cultural practices based on medium-input levels to increase cassava production in the acid, infertile soils of the lowland tropics;
- Develop systems to reduce perishability of cassava and allow more efficient use of cassava for direct and indirect human consumption.

In pursuing these objectives, the Program is guided by the consideration that improved production technology must be low-cost so that the final product can be kept at a low price level. This leads directly to the development of technology based on improved germplasm that overcomes many of the constraints on production.

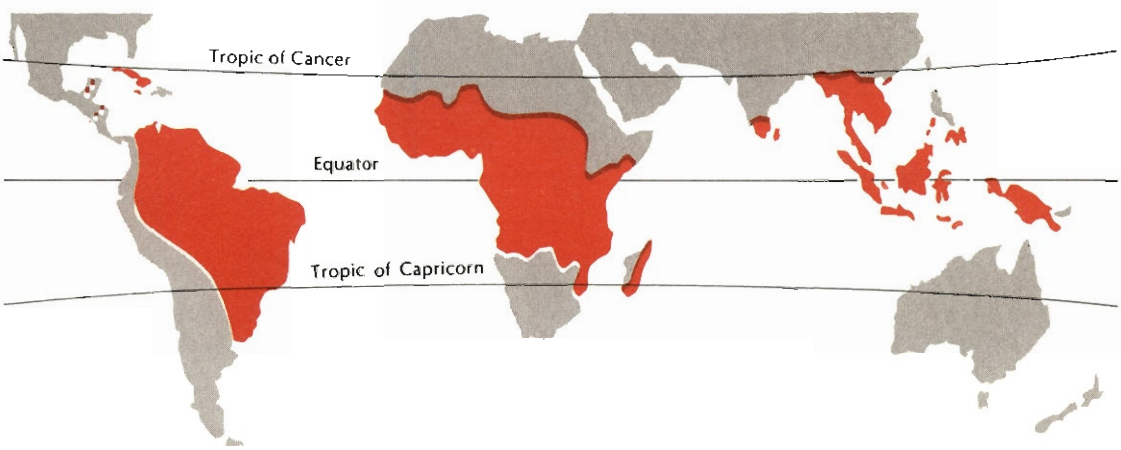


Figure 1. Major cassava production areas of the world.

Other constraints can be minimized by the use of improved management, including agronomic practices, biological control of insect pests, phytosanitary control of diseases, and efficient techniques for fertilizer use.

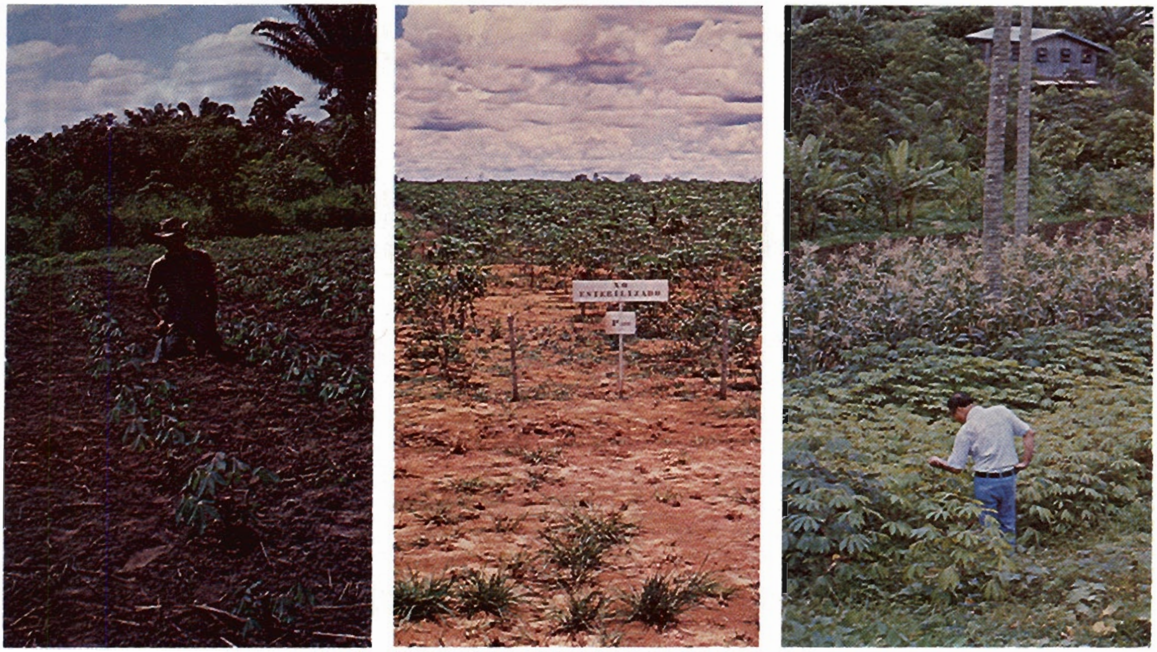
Cassava is grown in six major edaphoclimatic zones Germplasm accessions are tested in the different zones, and elite materials are used in the crossing program that directs specific populations to each of them. For countries with well-established breeding programs, the Cassava Program provides sexual seed from crosses known to be suitable for their conditions. For countries that do not have the capacity to recive segregating populations, CIAT provides, through meristem tissue culture, selected lines that have performed well under similar conditions. For the most important zones, the Program also develops improved management practices that are tested together with the advanced lines in a regional trials network. Based on these trials, technology packages are recommended for validation in on-farm trials.

It is expected that 40% of the total world cassava production will be in Asia in the coming years. In order to satisfy the specific requirements of germplasm for Asia and to develop agronomic practices that are appropriate to the varied cropping systems prevalent on this continent—and also to assist in the strengthening of Asian national cassava programs—CIAT is in the process of establishing a regional program in Asia.

Summary of Achievements

The CIAT Cassava Program germplasm bank in 1982 consisted of over 3000 accessions from different regions of the Americas and Asia, and a number of superior lines were selected as parents for crossing. Thousands of hybrids have now been evaluated in the principal ecosystems for cassava production in the tropics including the hot lowland areas with a pronounced dry season; the acid, infertile savannas; and the cooler highland areas. Several of these hybrids have shown high, stable yields of good-quality roots when produced under simple, improved management systems. Furthermore, these new hybrids have maintained their yield advantage over local clones even under very low fertility conditions and poor management.

Results from both on-farm trials and regional trials suggest that the yields of local clones can be doubled if traditional management practices are changed for simple, improved practices (e.g., stake



Casssava production systems are developed for the lowland tropics with a pronounced dry season (ECZ 1, left); the lowland, acid soil savannas (ECZ 2, middle); and the hot, humid, lowland tropics (ECZ 3, right).

selection and treatment, timely weed control, and planting on ridges in areas of high rainfall). When these practices are combined with improved clones, a further large production boost is achieved. Recent data from on-farm trials in the Piedmont region of Colombia have shown that yields of more than 30 t/ha can be obtained when this new technology is combined with selected hybrids. (In a survey from the early 1970s, yields were less than 8 t/ha in this region.) These data point to the reality that new, high-yielding technology is fully accessible to the cassava farmer.

Cuba has extensively applied the CIAT-developed package and has greatly increased productivity: in a mere 5 years, national cassava production has doubled. In Colombia, the new high-yielding technology is seen to be at least partially responsible for a 40% increase of the average national yield over the last 6 years.

Collaborating national cassava programs are now receiving from CIAT clones suitable for areas in the hot lowland tropics with a pronounced dry season. These clones possess high yield potential, moderate disease and pest resistance, moderate-to-high starch content, and a high degree of yield stability. For the acid soil savannas, national programs are also receiving clones with the required very high levels of disease and pest resistance, which nevertheless yield moderately high.

In collaboration with national agencies in Colombia, CIAT has developed prototypes of small-scale drying industries that provide markets for increased cassava production, thus permitting the small farmers on these marginal soils to capture the increased production potential of improved cassava technology. Colombia and Mexico are now in the process of setting up a series of cassava production/drying industries based on this model. In this context, Mexico has officially released two CIAT-selected clones with the appropriate technological package. Progress along similar lines is being made in other countries in the Americas (e.g., Brazil, the Dominican Republic, Haiti, and Panama).

The Cassava Program has recently increased its activities in Asia, placing a regional cooperation scientist in the region. Thousands of hybrid seeds have been sent to Asia over the past few years, and these are now in advanced stages of selection in various national programs.

The emphasis is on (1) breeding clones adapted to specific zones and (2) ensuring that clones are broadly adapted within zones.

Germplasm Improvement for Edaphoclimatic Zones

In the early years of the CIAT Cassava Program, a principal breeding objective was to develop cultivars with *wide adaptability*, i.e., cultivars that would be successful across all principal selection sites. Accordingly, in the regional trials network, most clones were planted in all sites. Emphasis later shifted toward selection for *yield stability* under moderate to high stress conditions, and new selection sites were added where low soil fertility, drought stress, and mite attacks are principal constraints to productivity. By the end of the 1970s, a great deal of information had been accumulated on the effects of various factors on varietal adaptation and genotype-by-environment interactions. Based on this information, the Cassava Program divided cassava-growing regions into six edaphoclimatic zones (ECZ) (Table 1). This subdivision is based principally on differences in mean temperature, rainfall distribution, photoperiod, and soil characteristics. These physical factors largely determine the pest and disease complexes which are potentially or actually important (Table 2). The six zones were selected by carefully balancing the number of separate breeding projects that could be managed by CIAT with the number of resistance and adaptation factors that could realistically be combined in a single genotype.

With the definition of edaphoclimatic zones, the germplasm improvement process is now highly decentralized. Because each zone requires the attainment of different breeding objectives, the emphasis on breeding for broad adaptability *across* zones has now given way to breeding for adaptability across the existing variability *within* zones. Concurrently, the regional trials network has moved toward the selective placement of clones in particular sites, based on their performance in the earlier stages of selection. CIAT-managed international cassava trials are nonexistent. Rather, CIAT passes on to collaborating countries germplasm that is matched to the edaphoclimatic and pest conditions of given cassava production regions for their own trials and evaluations.

Collection/Introduction

As the Cassava Program attempts to combine a wider range of traits into new varieties, the need for increasing the diversity of the germplasm base makes itself felt. Many of the desired adaptation, resistance, and quality characteristics exist in only low frequencies in landrace varieties. The availability of relevant parental material can save the breeder many years of time required for recombining traits, and selecting the desired genotypes. In view of this, collection of existing clones continues to be a high priority of the Program.

The International Board for Plant Genetic Resources (IBPGR) has made cassava a priority crop for further collection and conservation. Under a collaborative IBPGR/CIAT arrangement, germplasm collections were made in 1982 in Mexico and Peru, and a series of additional collection tours are planned for the near future. At the same time, the Program continued its efforts to introduce national program germplasm into the CIAT collection by meristem culture. With the introduction of some 350 new accessions from Brazil in recent years, the CIAT collection now stands at over 3000 clones. These accessions have been maintained at CIAT-Palmira in the field, but they are now gradually being transferred into *in vitro* cultures for storage. In this process, rooted

Table 1. Edaphoclimatic zones for cassava production and their main characteristics.

Edaphoclimatic zone (ECZ) no.	General description	Representative areas	Sites in Colombia for germplasm evaluation and technology testing	Major yield constraints
1	Lowland tropics with long dry season, low to moderate annual rainfall, high year-round temperature	Northeastern Brazil, north coast of Colombia, northern Venezuela, Thailand, southern India, sub-Sahelian Africa	Caribia, Fonseca, Media Luna, Nataima, Rionegro	Drought, mites, thrips, mealybugs, termites, bacteriosis, root rots, viruses
2	Acid soil savannas with moderate to long dry season, low relative humidity during dry season	Llanos of Colombia and Venezuela, Cerrados of Brazil, savanna of southern Mexico	Carimagua	Low soil fertility, drought, bacteriosis, superelongation, anthracnose, *Cercospora* leafspot, mites, mealybugs, lace bugs
3	Lowland tropics with no pronounced dry season, high rainfall, constant high relative humidity	Amazon basins of Brazil, Colombia, Ecuador, and Perú; rainforests of Africa and Asia	Chigorodó, Florencia	Low soil fertility
4	Medium-altitude (800-1500 m) tropics with moderate dry season and temperature	Medium-altitude areas of Andean Zone, Bolivia, Brazil, Costa Rica, Indonesia, Philippines, Vietnam, India, Africa	Caicedonia, CIAT-Palmira, CIAT-Quilichao	Thrips, mites, mealybugs, bacterioris, mycoplasma, anthracnose, root rots, and viruses
5	Cool, tropical highland (1600-2200 m) areas with mean temperatures of approx. 17-20°C	Highlands of Andean zone and tropical Africa	Popayán	Low temperature, *Phoma* leafspot, anthracnose, mites
6	Subtropical areas, with cool winters and fluctuating daylengths	Southern Brazil, Paraguay, northern Argentina, Cuba, northern Mexico, southern China, Taiwan	None	Low winter temperature, bacteriosis, superelongation, anthracnose

Table 2. Importance and control of various physical and biological environmental factors on cassava production in the six edaphoclimatic zones.

Environmental factor	Degree of stress effect in each edaphoclimatic zone[a] 1	2	3	4	5	6	Capability of managing stress[b]: Through breeding	Other than by genotype[c]
Physical environment[d]								
Photoperiod	L	L	L	L	L	H	2	0
Relative ambient humidity	H	H	L	M	L	L	2	0
Soil acidity	L	H	M	L	M	M	2	2
Soil phosphorus	M	H	M	M	M	M	2	2
Soil water	H	H	L	L	L	L	2	1
Temperature	N	N	N	L	H	H	2	0
Biological environment								
Anthracnose	H	H	M	M	M	H	2	1
Bacterial blight	M	H	L	M	L	H	3	1
Cercospora leafspots	M	M	M	M	L	M	3	1
Phoma leafspot	N	N	N	L	H	M	3	1
Root rots	L	L	M	H	M	H	1	2
Superelongation disease	M	H	M	M	L	H	3	1
Green cassava mite	H	H	L	M	L	L	3	2
Hornworm	M	M	M	M	L	M	1	3
Lace bug	M	H	L	M	L	L	2	1
Mealybug	H	H	M	M	L	L	2	2
Red spider mite	H	M	L	M	L	L	2	2
Scale insects	M	M	M	M	M	M	1	3
Shootfly	M	L	M	M	L	M	1	2
Thrips	H	H	L	H	L	L	3	1
Whitefly	M	M	M	M	L	L	2	2
Weeds	H	H	H	H	H	H	1	3

a. N = none; L = low, M = medium, H = high.
b. 0 = zero or near zero, 1 = low, 2 = moderate, 3 = high.
c. For example, by changing environment or by modifying agronomic practices.
d. Stress effects for physical factors resulting from long photoperiod, low relative humidity, high soil acidity, low soil phosphorus, low soil water availability, and low temperature.

node cutting segments, obtained from meristem-grown plantlets, are used as storage explants.

Germplasm Evaluation

In 1982, some 700 clones underwent evaluation in different ECZs, and some 8–15 clones were selected as potentially promising for each zone, as well as others with useful individual traits. Evaluation of the accessions in the germplasm bank permits the identification of clones that can be directly recommended as new varieties and of clones that can contribute desired genes for the hybridization program. All germplasm accessions are first evaluated in single row trials, and those that appear promising in each zone continue through a standard stepwise evaluation and selection procedure.

The experience to date shows that only a small number of germplasm accessions combine the requisite traits for a given zone and can be directly recommended as new cultivars. However, those that meet basic criteria (such as resistance to diseases and pests, high yield potential, and good root quality) can be used in crosses to produce superior progeny for immediate selection.

Many germplasm accessions have individual desirable traits, but they may be deficient in other aspects. These clones, when used in hybridization, have little chance of directly producing superior progeny. However, to broaden the germplasm base for genetic improvement, the Cassava Program uses such accessions to produce improved hybrids to, on the one hand, act as a bridge between germplasm accessions, and on the other, provide the most advanced hybrids available in the Program. The first generation of these "bridge hybrids" is now at the preliminary yield stage in various edaphoclimatic zones. The generally good performance of these populations provides evidence of the efficacy of this approach.

Thus, while only a few germplasm accessions that have so far been evaluated meet the criteria for direct recommendation as new cultivars, the on-going germplasm bank evaluation serves the fundamental function of identifying parental materials.

Progeny Evaluation and Hybrid Selection

The germplasm development process leads to distinct but interrelated end products: unselected F_1 seed and "finished" varieties.

F_1 populations are sent to those national programs with the interest and the capacity to evaluate and select from segregating populations. Since the F_1 generation is the only seed-propagated generation, it represents the only stage at which large numbers of genotypes can be readily moved across international boundaries. The distribution of segregating populations allows national programs to take full advantage of gains made in CIAT through selected parental material, at the same time as it enables national programs to select lines adapted to local conditions from the large numbers of genotypes contained in segregating populations.

The definition of a "finished" variety is necessarily arbitrary, since the genotype is already fixed by vegetative propagation at the F_1 stage. The Program defines a finished variety as a clone that has advanced through the final stages of selection by CIAT in Colombia, after having undergone evaluation over several years and locations in replicated yield trials. At this stage, clones are ready to enter regional trials in Colombia and internationally. Phytosanitary considerations have made it imperative that CIAT send cassava vegetative material internationally only through *in vitro* culture.

While parent selection is based on the performance of germplasm accessions in the various edaphoclimatic zones, hybridization and initial selection is done at CIAT-Palmira. In 1982, some 63,000 F_1 seeds were obtained, of which more than 20,000 were used in the selection program, and close to 40,000 were distributed to national programs in Brazil, China, Malaysia, Mexico, the Philippines, and Thailand.

Currently, the Cassava Program assigns highest priority to the warmer ECZs. Considerable interchange of material selected for any one of these three (I, II, III) zones occurs among the source populations. On the other hand, physiological studies have uncovered a significant effect of photoperiod and low temperatures (below 20°C) on yield, which indicates it is necessary to have distinct gene pools for both the highland (V) and subtropical (VI) zones. Within the warmer, ECZs, the Cassava Program assigns particular importance to zone I, which represents a major cassava-growing region of the world, and zone II, which offers a large number of adverse cassava-growing factors and represents an ideal testing ground for "finished lines" of promising cassava materials (Figure 2).

In edaphoclimatic zone I, the lowland, long dry-season zone with evaluation sites in the

Major emphasis is placed on selecting progenies tolerant to endemic disease and pest problems.

Colombian north coast, trials are being conducted without recourse to fertilizer and pesticide application or irrigation. Two cycles were evaluated in 1982 (Figure 3). The results show that the new hybrids combine high dry-matter content with greatly improved yielding ability. The challenge now is to further improve these clones, particularly in terms of insect and mite resistance.

For edaphoclimatic zone II, the evaluation site is at Carimagua in the Eastern Plains of Colombia. Soils are poor—with low pH, low available phosphorus, and high exchangeable aluminum. Trials are conducted with the application of modest levels of lime, nitrogen, phosphorus, potassium, and zinc. Disease and pest pressures from cassava bacterial blight (CBB), superelongation disease, anthracnose (during the wet season), and mealybug, lacebug, thrips, and mites (during the dry season) are very high. However, diseases and pests are not artificially controlled. Hence, experimentation at the Carimagua research site constitutes evaluation under very difficult growing conditions.

In 1982 both selected hybrid clones and germplasm accessions planted at the beginning of the rainy season yielded reasonably high; the later planting was heavily attacked by mealybugs, and

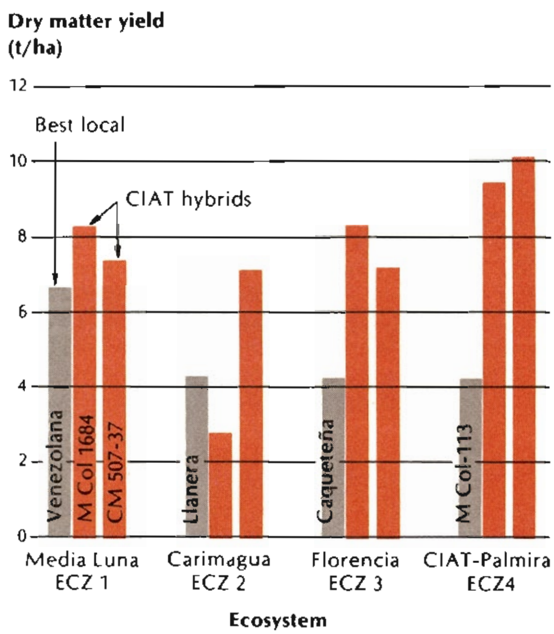


Figure 2. CIAT hybrids selected under the adverse conditions of Carimagua tend to perform very well under less stressful conditions, and perform better than the best local variety at each site even with stressful conditions.

Decentralized selection of hybrids assures local adaptability.

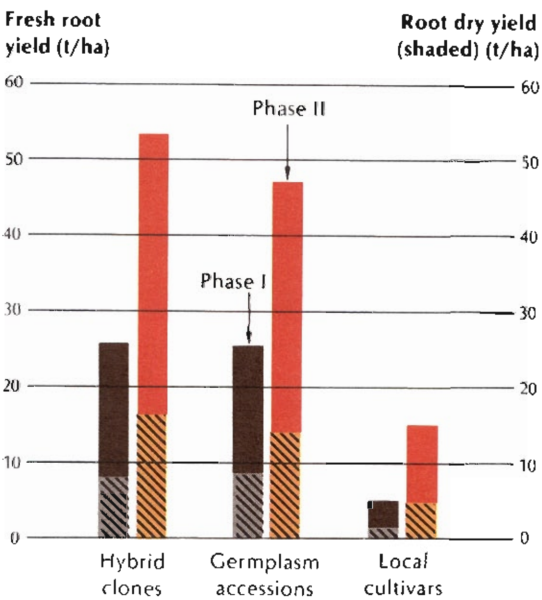


Figure 3. Comparison of 1982 average yields of various hybrid clones, germplasm accessions, and local cultivars grown on trials at Caribia (ECZ 1). The first harvest (Phase I) came from a poor soil and an unfavorable rainfall pattern; the second (Phase II) from a good soil spot and a favorable rainfall pattern, thus representing a highly productive growth cycle. Many hybrid clones resulted in high fresh and dry root yields.

yields were more modest. This is an important change from previous years when susceptibility to CBB, superelongation disease, and anthracnose always caused lower yields in the earlier planting. The newer clones are more tolerant to these diseases and enter the dry season with more foliage and therefore get attacked by insects. Selected hybrid clones gave good yield and had high root dry-matter content in both trials.

Both high bacteriosis and superelongation-disease resistance are now common in many high-yielding hybrids. Combining these with mite, mealybug, and lacebug resistance is a challenge that may require new germplasm sources and several selection cycles.

While some high-yielding hybrid selections in both ECZ I and II have the identical source population, there also exist such widely adapted clones as M Col 1468, M Col 1684, and CM 507-37, which constitute outstanding parental materials. Decentralized selection, however, may be needed to assure a high frequency of clones with local adaptability. One potential danger for "final" selection is excessive narrowing of the germplasm base; another is extreme location-specific adaptation. At CIAT, the first problem is counteracted by continuous integration of new, promising parental materials into the hybridization program; the second is obviated by frequent use of widely adapted clones as parental material.

Plant Protection to Improve Crop Productivity

Before the 1970s, cassava was commonly described as a rustic crop, resistant to most pests and diseases, and particularly well suited to regions with poor soils and prolonged drought. As more systematic information about cassava has become available, however, it has become increasingly clear that this description refers only to a locally adapted crop. That is, local cultivars are often remarkably tolerant to the diseases and pests occurring in their native surroundings, when they are grown under traditional management systems. When they are grown in other sites, or with different management, these same cultivars are frequently susceptible to


Host plant resistance is complemented by biological control. Resistance to the cassava hornworm (left) *has not been found, but several predators, including the* Polistes *wasp* (right), *and parasites can be used for effective natural pest control.*

diseases, pests, weeds, and other adverse factors dominant there.

Both the presence and severity of cassava pests (diseases, insects, and mites, for example) are influenced by specific climatic and edaphic characteristics. From 1979 to 1982, it was observed that those diseases which initially (i.e., 1978–1980) caused severe damage in particular sites representative of various ecosystems—e.g., anthracnose in ECZ I and II, CBB in ECZ II, concentric ring leafspot and anthracnose in ECZ V—were moderate in later years (1980–1982). This indicated that disease problems reach a certain biological balance with existing clones, which could be due to the gradual elimination of susceptible genotypes with a consequent decrease in the inoculum potential of the causal agents. Those diseases detected after the first year of evaluation and which could have been introduced to the ecosystem (e.g., frog skin disease and root rot caused by *Diplodia manihotis*) were observed to increase in severity, and, in the last cycle of observation, were reaching epidemic proportions.

The pest and disease complex documented in Table 2 applies to the Americas, the center of origin of cassava. As cassava was exported, first to Africa and then to Asia, some of its pests and diseases were also disseminated. The number of pests of economic importance is less in Africa and Asia than in the Americas. While the varieties originally exported from the Americas carried at least some resistance to the diseases and pests introduced with them, and thus allowed the farmers to select for clones tolerant to the introduced pests, most of the resistance to diseases and pests not present in the new environment was lost in the selection process.

African mosaic disease is an exception. This endemic disease, transmitted by whiteflies (*Bemisia tabaci*), has not been reported in the Americas, but has spread throughout the cassava-growing area of Africa. Because resistance genes for this disease were not found in clones of African or American origin, IITA (International Institute of Tropical Agriculture) has improved resistance by incorporating them from *Manihot glaziovii*, a species of American origin.

Recently, two introduced pests have started to cause massive losses in Africa. The cassava mealybug and the green spider mite have spread

Table 3. Level of resistance[a] to various production constraints of CIAT lines and hybrids adapted to the different edaphoclimatic zones.

Edapho-climatic zone/ clone	Diseases						
	Bacterioris	Super-elongation	*Phoma* leafspot	Anthracnose Lowland	Anthracnose Highland	*Cercospora* leafspot	Preharvest root rot
ECZ 1							
M Col 22	1	2	2	4	1	3	4
M Bra 12	2	1	3	5	5	2	4
M Ven 25	3	2	—[b]	3	—	—	—
CM 681-2	2	1	—	—	—	—	—
ECZ 2							
M Per 245	5	3	—	4	—	4	—
M Ven 77	5	5	2	5	4	1	5
CM 523-7	5	4	3	4	3	2	1
CM 1585-13	5	5	—	5	—	5	—
ECZ 3							
M Col 1684	3	3	1	3	2	3	4
CM 507-37	4	4	—	3	—	3	—
ECZ 4							
CM 91-3	4	2	—	3	—	4	—
CM 489-1	1	1	—	—	—	—	—
CM 849-1	3	5	—	—	—	—	—
ECZ 5							
M Col 1522	2	2	5	1	4	4	4
M Col 2059	—	—	5	3	5	3	4
ECZ 6							
M Col 1468	4	3	3	4	3	4	1
M Cub 74	2	4	—	—	—	—	—

a. 1 = very low, 2 = low, 3 = intermediate, 4 = high, 5 = very high.
b. Tests have not been conducted for this specific constraint.

rapidly throughout Africa, after being introduced, probably during the 1960s, on infected planting material. These pests have thrived in large areas of susceptible cassava varieties, in the absence of natural enemies, and under optimal environmental conditions. In the Americas, with relatively tolerant cassava varieties and with natural enemies, these two pests, although widespread, do not normally cause severe damage or yield reduction.

At present, a concerted effort is being made by IITA (which, within the Center system, has regional responsibility, for cassava in Africa), the Commonwealth Institute of Biological Control, Trinidad, and the CIAT Cassava Program to identify biological control agents in the Americas, rear them, verify that they are free of hyperparasites, and then introduce them to Africa. It is possible that the biological control agents will only give partial control; nevertheless, their importance is undoubted especially during the interim period before resistant varieties are produced and host plant resistance and biological control can be combined.

Host Plant Resistance

With a long crop cycle such as cassava's (6–24 mo), it is not possible to base crop protection on continued applications of pesticides. Other methods of control must be developed around host plant resistance. The resistance normally

Insects and mites						Soil problems	
Thrips	*Mononychellus* mite	*Oligonychus* mite	Mealybug	Lace bug	Whitefly	Soil acidity	Low phosphorus
4	2	2	3	3	1	2	3
5	4	1	1	3	4	2	2
2	3	2	1	3	—	—	4
4	—	—	2	—	—	—	—
1	4	—	3	3	—	5	4
2	2	2	2	2	—	5	4
3	—	—	1	—	—	4	5
4	—	—	—	—	—	2	4
1	1	4	—	2	5	4	3
1	—	—	2	—	—	2	4
3	2	—	1	—	—	3	4
2	2	—	1	2	—	—	—
4	—	—	—	—	—	—	—
4	4	4	—	4	—	—	—
—	—	—	—	—	—	—	—
1	1	3	1	2	1	5	3
4	—	—	2	—	—	—	—

found in cassava is controlled by many genes (poligenic), which lowers the probability of development of new races or biotypes of the pest population.

Incorporation of host plant resistance is the basis of an integrated control program for cassava, and it forms a fundamental part of the cassava varietal improvement program at CIAT. Table 3 lists the principal cassava pests, diseases, and soil constraints for which host plant resistance has been identified. These sources are now being used for development of resistant hybrids.

But adequate host plant resistance is sometimes difficult to achieve. In this case, it can be combined with biological control and improved agronomic management practices for adequate integrated disease and pest control. Research in these areas is described in the following sections.

Biological Control

Host plant resistance is particularly efective when used in conjunction with biological control. Reduced pest populations, due to resistant cassava varieties, increase the efficiency of biological control. Natural enemies of cassava pests are abundant: more than 140 have been identified, and nearly 40 of these have been studied at CIAT. Special emphasis has been given to the biological control of the cassava hornworm, mealybugs, and mites.

The compatibility of breeding for resistance and using natural biological control has been demonstrated in studies with mites. Mite populations on resistant varieties are considerably lower than populations on susceptible varieties; mite predators thus have a better opportunity to

Integrated pest control combines biological control and improved agronomic practices with host plant resistance.

reduce mite populations before they reach economic injury levels. More than 30 mite predators have been identified in cassava. Current studies center on the effectiveness of *Phytoseiidae* mite predators, which appear to be especially effective against low populations of phytophagus mites.

Recently, considerably more attention has been given to biological control of mealybugs; two species, *Phenococcus herreni* and *P. manihoti*, are causing considerable cassava damage, especially to crops in the Americas and Africa, respectively. There are a large number of natural enemies of mealybugs: approximately 30 parasites and predators have been identified at CIAT-Palmira or Carimagua, and nearly 70 have been identified in the Americas. A systematic field collection of mealybugs during 1981 revealed that *Ocyptamus stenagastus* was the most dominant predator, accounting for 68% of the total natural enemies, and *Anagyrus* was the most dominant parasite. Studies during 1982 revealed that *Acerophaga coccois* was the predominant natural enemy, comprising up to 92% of the parasites observed. This parasite appeared to be reducing mealybug populations in the fields observed. *Ocyptamus* was, once again, the dominant predator observed, but, in addition, high populations of the dipteran predator *Kalodiplosis coccidarum* were collected during systematic sampling of mealybug populations. This predator was released in CIAT fields 3 years ago and is a very efficient predator of mealybug eggs. The combination of host plant resistance and biological control thus also offers considerable promise in the control of cassava mealybugs.

One of the most spectacular pests of cassava is the cassava hornworm (*Erinnyis ello*), which can completely defoliate large cassava plantations. A single larva can consume 1100 cm² of cassava foliage during its 15-day larval cycle. Although the adult female has been shown to exhibit some ovipositional preference, the most promising means of pest control is through efficient use of its numerous natural enemies in an integrated pest-control program. Approximately 40 natural enemies have been identified, consisting of parasites, predators, and pathogens, and the egg, larval, and pupal stages of the pest are all susceptible to natural enemies. Current studies are centering on dipteran parasites, which appear to be especially effective against low populations of the hornworm. There are numerous larval predators, with the paper wasp, *Polistes* sp., one of the most important.

In 1982, a virus disease of the hornworm was studied. A granulosis virus was recovered from infested hornworm larvae and was tested by reinfesting leaves in the laboratory. One hundred percent of healthy hornworm larvae feeding on these leaves died with virus symptoms. Field applications of the virus to cassava foliage have also resulted in high mortality rates.

Improved Agronomic Practices

Several agronomic management practices also assist in combating disease and pest problems, as well as protecting plants from weeds and improving plant quality. A summary of current research in several such fronts follows.

Soil fertility. Cassava is remarkably well adapted, physiologically, to acid, infertile soils; yield reduction at low fertility levels is less than in most crops. Under acid, infertile soil conditions, however, disease and pest attacks are extremely severe. Few data exist on the interaction between diseases and soil fertility conditions, such as pH and nutrient status. For the development of clones that grow particularly well at low fertility levels in acid soils, however, this interaction should be borne in mind. Research studies are now being initiated in this area.

Technology developed can readily be used by small farmers to obtain high yields and increased income even under extremely poor agricultural conditions.

Land preparation. Cassava will not tolerate very wet soil conditions. If the soil becomes waterlogged, cassava growth is reduced and root rot becomes a severe problem. Some varietal resistance to root rot is known to exist; however, problems may be reduced in clones that are susceptible by planting on ridges. Furthermore, when root rot problems are severe, rotation with cereal crops is an effective control measure.

Planting date. Anthracnose, CBB, and superelongation disease are all severe problems in the Colombian Llanos. When susceptible clones are planted early in the wet season, the disease pressure builds up rapidly, and the crop can be completely destroyed. If these same clones are planted shortly before the dry season, however, pressure is reduced, and they still provide some yield. In this manner, in the absence of highly resistant materials, diseases can be managed by changing the planting date. As new, highly resistant lines become available, the farmer will gain more flexibility in his planting date. This flexibility, however, can also bring certain dangers. If consecutive plantings are made in neighboring plots, the later plantings are likely to suffer from increasing severity of pest attack due to a build-up of inoculum potential. Furthermore, whereas diseases tend to be more severe in the wet season, insect pests are more of a problem in the dry season. Hence, management to reduce diseases may augment the insect problems.

Mixed cropping. Disease and pest epidemics are normally favored by genetic uniformity and are reduced by growing mixtures of cultivars or crops. In traditional cassava-growing areas in the Americas, farmers not only mix cassava with other crops but also grow a mixture of cassava cultivars. With the development of new, improved varieties, it is probable that farmers will shift to only one or two varieties rather than a mixture, unless several improved varieties are available. The probability of severe epidemics of diseases and pests can also be reduced by incorporating good levels of resistance into new clones.

As cassava production expands, farmers tend to replace mixed cropping with monoculture using only one variety. In the "Campo Cerrado" of Brazil, for instance, cassava production, in the Curvelo area expanded very rapidly to provide raw material for an alcohol production plant. Initial yields were about 20 t/ha on small plots. With the massive expansion of monoculture cassava, yields declined drastically to 3–6 t/ha on many plantations due to disease and pest epidemics. Only now, nearly a decade later, are yields approaching the initial levels with the introduction of more disease-resistant lines and integrated pest management programs.

Table 4. Yield, percentage yield reduction, and number of cuttings per plant in the native clone "Secundina" in relation to cutting source and type of selection.[a]

Treatment	Cutting source	Yield (t/ha) Fresh root weight	Yield (t/ha) Starch	Yield reduction (%)	Number of cuttings per plant/quality Good	Number of cuttings per plant/quality Poor
1	From meristem culture	24 a	8 a	0	6 a	3 ab
2	From farms without symptoms of mosaic; selected cuttings[b]	20 b	6 b	18	4 bc	5 ab
3	From farms with mosaic; selected cuttings[b]	15 c	5 c	39	3 bcd	4 b
4	From farms regardless of mosaic symptoms and without selection of cuttings	7 d	2 d	70	3 bcd	4 a

a. Values followed by the same letter are not significantly different from Duncan's multiple range test ($P = 0.05$).
b. Visually selected for good quality.

Plant debris. The cassava stems left in the field after harvesting can germinate and act as foci of infection or infestation for the succeeding crop. Roots left in the field can also act as foci of infection for root rots. Wherever possible, roots and stems should be removed from the field or otherwise destroyed.

Planting material. Systematic production of quality planting material is still the exception among cassava growers, although the poor quality of planting stock is a frequent cause of low yields.

An evaluation of the planting material production capacity of different cassava genotypes showed that the erect-growing, late-branching cultivars produce the most good-quality stakes per plant. These types are also frequently those with the highest root yield potential. When a cassava crop is primarily managed for stake production, high planting densities of 20,000 to 40,000 plants/ha can significantly increase stake production per unit area.

Because soil fertility influences topgrowth in cassava, it thus affects stake production. In 1982 trials, good natural soil fertility or moderate applied fertilizer levels on poor soils proved to be sufficient for a well-balanced topgrowth and a high proportion of stem material suitable for stake production; high fertilizer levels upset this balance, however, leading to much foliage and many immature stems from which only a limited number of quality stakes can be obtained. With some information available on the effect of mother-plant nutrition on stake production, further studies are needed to assess the plant nutrition carry-over effect with stakes into the subsequent crop.

Other trials in the north coast of Colombia have shown that cuttings obtained from virus-free plants, obtained by meristem culture from plants that have undergone thermotherapy, can greatly increase yields. It may not be practicable for farmers to employ such sophisticated techniques, but these trials did show that they may visually select farms and plants from which to take cuttings so they may reduce virus levels and thus substantially improve yields (Table 4)

Weed control. Because cassava is slow to establish, good weed control is essential. This can be achieved by hand weeding, mechanical means, or chemical control. Cassava is frequently planted at the beginning of the wet season when farmers have a shortage of labor; under these circumstances, chemical control may be advantageous, and several effective products are available in the tropics. Traditional vigorous varieties, although they have low yield potential, also compete well with weeds; however, higher yielding types may require better weed control to show their potential superiority.

Much of the world's cassava is intercropped. When cassava is grown with short-season grain legumes, the rapid early growth of the latter tend to supress weeds. In one trial with cassava and beans (*Phaseolus vulgaris*), and in the absence of any other control measure, the total weight of weeds 135 days after planting was reduced by 67% due to the intercrop. This effect can be enhanced using pre-emergent herbicides that are selective for both cassava and beans.

Effect of Soil and Plant Nutrition on Crop Growth

Cassava and Long-term Soil Fertility

To study the effect of continuous cassava production on soil fertility and yield, a long-term fertility trial was established in 1977 at CIAT-Quilichao. With the completion of its fourth cycle in 1982, the trial is continuing. Thus far it was observed that applications of high levels of phosphorus in the absence of adequate applications of potassium initially resulted in high yields, which, however, soon converted to very low yields due to the depletion of soil potassium. While the soils at the trial site originally were low in phosphorus but relatively high in potassium, after 4 years of continuous cassava production it was determined that potassium fertilization is most crucial for sustained high yields of cassava roots. While yields without fertilizers were still around 20 t/ha, the treatment with an annual application/ha of 100 kg of nitrogen, 87 kg of phosphorus, and 125 kg of potassium resulted in the very high yield of 66 t/ha in the acid, low-fertility soils of CIAT-Quilichao. Although this fertilizer level implies a cost of about US$250/ha, the value of the yield increase obtained is around

Table 5. Effect of fallow state and fertilizer application on cassava root yield (t/ha).

	Site 1		Site 2		Site 3	
	Short fallow	Long fallow	Short fallow	Long fallow	Short fallow	Long fallow
No fertilizer applied						
Local cultivar	9	14	6	16	6	22
CIAT-introduced variety	13	17	12	30	7	14
Intermediate use of fertilizer[a]						
Local cultivar	12	15	7	17	19	23
CIAT-introduced variety	12[b]	22	20	33	18	16

a. 50-50-50 N-P-K in Site 1, 50-100-100 in Site 2, and 50-50-100 in Site 3. Fertilizer level determined by soil fertility needs.
b. Root rot substantially reduced yield in these plots.

Poor quality of planting stock is a frequent cause of low yields. Simple techniques such as using erect-growing cultivars, can markedly improve both the quantity and quality of planting stakes.

US$5000 at present fertilizer and cassava prices, thus pointing to the fact that fertilization of cassava can be highly economic.

Cassava-Mycorrhiza Association

The importance of an effective association of cassava with mycorrhizal fungi in soils with low levels of phosphorus has earlier been amply demonstrated. In 1982, research on the factors that determine the effectiveness of the association were continued, both in greenhouse and field experiments. Major emphasis was placed on the collection, identification, purification, and multiplication of efficient new strains collected in various parts of Colombia. Some of the most efficient strains were found to be previously undescribed species. The recently named species, *Glomus manihotis*, originally collected in CIAT-Quilichao, was found to be among the most efficient strains in a range of soils.

While responses to mycorrhizal inoculation have been quite dramatic in greenhouse trials, in the field they were smaller and often not significant. In four trials in Quilichao, only nonsignificant responses to inoculation were registered. Soil sterilization, however, decreased yields to less than 50% because of the initial elimination of the native mycorrhizal population, even though plants had later recuperated due to re-infection from unsterilized subsoil and borders. This indicates the importance of mycorrhiza for phosphorus nutrition of cassava and the high efficiency of the native population in Quilichao. However, similar trials in Carimagua, where the native strains are less efficient, produced significant yield responses to inoculation with *Glomus manihotis*, as well as with selected other strains, even in unsterilized soil. In unsterilized soil, inoculation increased yields up to 37%, whereas in the sterilized soil, the increase was 200%. Highest yields were obtained in the sterilized soil with inoculated plants. Comparing roots of different plant species as sources of inoculum, it was found that inoculation with infected roots of cassava produced the best responses, increasing yields 64%.

In a trial on phosphorus sources and levels, greatest responses to inoculation were obtained with the application of 100 kg/ha of phosphorus, but at either higher or lower levels, the inoculation response was nonsignificant. Inoculated plants with phosphorus applications of 50 kg/ha produced the same yield as non-inoculated plants with 100 kg/ha, indicating that in phosphorus-deficient soils with a low or inefficient mycorrhizal population, inoculation seems to be a promising alternative to high fertilizer applications.

Fallow vs. Fertilizer Use

Available data on cassava production systems in Latin America suggest that only rarely do farmers use fertilizer on cassava. Cassava farmers tend to operate relatively small-scale holdings, but this in itself does not appear to be the reason for the lack of fertilizer use. Small-scale farmers growing such crops as beans, potatoes, and tomatoes do apply fertilizers, and even cassava farmers use fertilizer with their other crops but seldom with cassava.

Rapid postharvest deterioration is a major constraint for efficient cassava utilization. Low-cost treatment and packaging of cassava fresh roots can greatly increase their shelf life.

Previous on-farm research results and the more detailed surveys of cassava production suggest that farmers use either a fallow or crop rotation system to maintain soil fertility levels and yields. In 1982, the Cassava Program's on-farm research set as its objectives to evaluate the role of fallow in traditional cassava production systems, to determine whether the higher yield potential of improved varieties could be maintained in such systems, and to test whether fertilizer could replace fallow in cassava production systems. The trial design involves a cross-section stratification of farmers on the basis of fallow state. The trials were carried out in four locations, and will be repeated in 3 more cycles. The 1982 planting was the first cycle, so these results are preliminary.

Although there were differences between regions, certain general patterns of yield response did arise in the first year of the evaluation (Table 5). First, a chemical soil analysis showed the soils to be universally infertile, with levels of soil phosphorus and potassium falling below accepted critical limits. Moreover, there was no significant difference in soil analyses between fallow states, with the short-term fallow often having slightly higher levels than the long-term fallow periods. Second, at zero fertilizer application, the longer-term fallow plots consistently gave a higher yield (on average, over 100%) than the short-term fallow. Third, there was a general but not universal pattern for a substantital response to fertilizer on the short-term fallow and a lack of a profitable response on the longer-term fallow plots. Finally, there was a general but not universal tendency for the fertilized plot under short-term fallow to produce a lower yield than the long-term fallow plot without fertilizer. Generally, the maximum yield in the long-term fallow plots was higher than the maximum yield in the short-term fallow plots.

These first-year results suggest reasons why farmers can produce cassava without using fertilizer. Fallow provides an effective means of maintaining yields, given an adequate supply of low-cost land. However, since most cassava farmers operate quite small holdings, an effective fallowing system is often constrained by land availability. As shown by the trials, a degrading fallow results in a large sacrifice in yields. On the other hand, the yield patterns also suggest that one fertilizer application cannot substitute for fallow. Data from long-term fertility trials (see above) suggest that only continued year-after-year applications of fertilizer can build up soil fertility and organic matter levels in the soil comparable to those obtained in long-term fallow. This result possibly ties in with the fact that chemical soil analysis does not give an indication of other important factors, such as good soil structure, microbial activity, and nutrients tied up in decomposing plant material. Soil fertility management will play a crucial part in increasing and maintaining cassava yields. However, the above results suggest that chemical fertilizer will be only one component of a more integrated soil fertility management strategy and that such a strategy will have a longer time horizon than a single crop year.

Improving Cassava Utilization

Extension of Shelf Life

Cassava's very high carbohydrate production potential per unit of land or labor, and its ability to produce well under marginal agricultural conditions, make this crop a basic rural staple throughout the tropics and subtropics of the world. However, its high post-harvest perishability significantly reduces the advantages of cassava for human consumption over grains with their relatively low marketing costs.

Deterioration is both physiological and microbial. Previous work at both the Tropical Products Institute (which collaborates with CIAT in the development of post-harvest technology for cassava) and at CIAT showed that the post-harvest accumulation of a phenolic compound, scopoletin (a coumarin), is implicated in the development of the blue-black tissue discoloration characteristic of physiological deterioration. Varietal differences in physiological deterioration have been observed, with roots resistant to such deterioration accumulating less scopoletin content than susceptible roots. A quick assay for scopoletin has been developed and is now being used in screening for resistance to deterioration.

While resistance to physiological deterioration can be obtained through appropriate selection of undamaged roots, post-harvest curing (high relative humidity and temperature conditions which promote wound healing), and careful harvesting and transportation, medium-term storage can only be achieved through the control of secondary, or microbial, deterioration, which normally commences 5 to 7 days after harvest.

Any storage system must have low cost and low labor requirements if adoption by farmers and wholesalers is to be achieved. Previous work had demonstrated that boxes filled with sawdust are successful, but a more practical solution that would permit easy transport was desired. Hence, work based on plastic bags (initially started in 1977) was continued. Laboratory experiments were conducted in which roots were treated with potassium sorbate, a low-cost antimicrobial agent with minimal residue problems, and stored in polyethylene bags for curing. Without any pre-treatment, substantial fungal and bacterial growth was observed after only 7–10 days of storage, whereas no microbial growth was observed in roots treated with potassium sorbate, even after 2 weeks of storage. Subsequent large-scale experiments using perforated bags to reduce the amount of free water formed inside the closed-bag system permitted root storage for up to 2 weeks without the necessity of sorbate treatment, indicating that perforations in the bags permit a balance between the high humidity needed to obtain good curing conditions and the requirement that there not be any excess free water that would encourage microbial activity.

As Animal Feed

In many cassava-producing countries, the future demand for the fresh market is uncertain, and increased processing will be required to relieve the marketing constraints and to allow cassava to enter markets with a substantital growth potential. A particularly promising growth market is animal feed. The Cassava Program has continued its poultry and swine feeding trials to determine least-cost diets containing cassava meal as a substitute of feed cereal grains, notably sorghum. This work has led to the following conclusions:

- Whole roots of cassava varieties with high cyanide content can be safely used in broiler feeds if properly processed.
Sun-drying of whole root chips is a highly efficient processing method to reduce cyanide content to harmless levels for animal feeding.

Improved cassava drying systems are now being used commercially to produce chips for incorporation in poultry rations. Initial results suggest that the introduction of these new drying techniques could revolutionize production and marketing of cassava in the Americas.

- The satisfactory results obtained with broilers fed diets containing 30% of cassava meal with experimentally produced high levels of 300 ppm of cyanide suggest that the limit for hydrocyanic acid set by the European Economic Community (100 ppm) could be reevaluated.
- The combination of three protein sources (soybean, fish, and cottonseed meal) in balanced diets containing 20% cassava meal produces better broiler performance than that obtained with fewer protein sources. Palatability aspects of the protein sources are important considerations in obtaining optimum nutritional value of cassava meal.
- For the feeding of growing pigs and lactating sows and their litters, cassava-based diets (i.e., 30–40% of the diets consisting of cassava meal produced from whole roots of varieties containing high levels of cyanide) led to similar or identical results as sorghum-based diets.

With the price of cassava meal fixed at 80% of the price of sorghum, diets based on cassava meal wre invariably found to produce economic results similar to or slightly better than those obtained with sorghum-based diets. By using cassava in feed rations, many countries could reduce their large imports of feedgrains—at minimal cost to the economy in that cassava expansion will use unexploited, marginal land and absorb part of the pool of unemployed laborers. In Colombia, for example, balanced feed production for broilers and pigs amounts to approximately 500,000 tons per year. The inclusion of 20% cassava meal in balanced feeds for these animals would require a total of 100,000 tons of dried cassava chips, which could readily be produced in areas such as the Atlantic Coast where CIAT, in collaboration with Colombian national institutions, has demonstrated through a series of prototype operations, the economic feasibility of small farmers collectively producing and processing cassava for the animal feed market.

CIAT has recently increased its research and collaboration in Asia, which produces 40% of the world's cassava for a multitude of uses.

International Cooperation Activities

The production and utilization technology being developed at CIAT must be transferred to the national agencies where it is tested, modified, and adapted to specific local conditions before adoption by farmers. In the case of utilization technology and agronomic practices, the adoption and testing phase can be relatively rapidly carried out, however, in the case of development of new germplasm, the process is much slower and requires a continued effort over several years.

In 1982, with the cooperation of national agencies and two other international centers involved with root crops, IITA and CIP, a combined effort was made to review and improve the process of germplasm exchange and testing. In three workshops—held in Asia, Latin America, and Africa—national programs presented data on progress made in germplasm testing and evaluation. The latest techniques to minimize risks of introducing pests and diseases with imported germplasm were presented to quarantine officials from the various agencies attending, and guidelines were laid down for the safe interchange of material in the future. The risks involved in germplasm exchange were carefully weighed against the potential benefits of utilization of the new high-yielding varieties now available. With the help of UNDP, which financed all three workshops, the proceedings of the workshop in Latin America have been published to serve as the basis for future germplasm exchange and testing.

In addition, breeders and agronomists from various countries in the Americas were invited to CIAT to review their experiences with germplasm improvement over the last few years. The published proceedings of this workshop clearly show the slow but continuous development of new germplasm.

Latin American Germplasm Release

In Cuba, clone CMC 40 introduced from CIAT in the mid-1970s is now grown on 250 ha, and projections suggest that it will occupy 15% of the total area in 1985. At the same time, the national program, with 11 professionals trained at CIAT, has developed its own clones, CEMSA 5-28 and

The development of new cassava germplasm requires a long-term commitment by national and international agencies.

CEMSA 74-725, which together are expected to occupy a further 20% of the total acreage. The rapid increase in area planted with new varieties in Cuba has only been possible because of the existence of rapid propagation systems, developed at CIAT and modified in Cuba. As one Cuban technician reported, ". . . the help of CIAT has generated a new technology known as the Colombian System that has completely revolutionized cassava production in the country."

The Mexican national cassava program was initiated in 1977 with the objective of replacing imported sorghum and maize in balanced diets. However, as early as 1970 CIAT had collaborated with the Instituto Nacional de Investigaciones Agrícolas (INIA), in the collection of germplasm throughout south and southeast Mexico. One of these early collections, M Mex 59, and another introduction from the CIAT collection, M Pan 51, have now been released in Mexico. The latter variety has shown particularly good disease resistance.

In 1978, 1500 seeds from 14 crosses were sent to an ex-CIAT student working at Tarapoto in the jungle of Peru. Of these 1500 hybrids, a small number with high yield potential and starch content were selected and are now being further evaluated. In Ecuador, starting in 1975, most material was sent in the form of stakes rather than sexual seeds. Several of the introductions that performed well have been given to farmers.

The first materials introduced to Haiti from CIAT were in 1976. CMC 40 introduced in that year has now been released as Madames Jaques, and several other clones and hybrids are being multiplied for possible future release.

Cassava in Asia

In Asia, a similar pattern of selection of materials over the years is occurring. The first sexual seed was sent to Asia in 1975. In Thailand two of the selections from the original batch of only 800 seeds are now being tested on farmers' fields as Huey Pong 4 and Huey Pong 5. One of these lines is likely to be released in the near future.

Similar results have been obtained in Malaysia where several hybrids introduced in the mid-seventies are now in the final stages of testing before release. In the Philippines, although no CIAT clones have been officially released, several of these are being grown commercially on a small scale.

All the reports on germplasm movement in the Americas and in Asia point to a steady inexorable process of germplasm evaluation leading eventually to use by the farmers. Often varieties are not officially released but farmers get hold of them and use them. This is particularly notable in Colombia where many farmers are using materials obtained from the regional trials even though they have never been officially released. It is also interesting to note that there is a delay of about 8 years from introduction of new clones or sexual seed before they reach farmers. Hence farmers are now beginning to receive materials developed in the mid- to late seventies and over the next few years will be receiving the newer improved lines developed in the 1980s.

Manpower Development

In addition to the three workshops on germplasm, in which 35 professionals participated, two intensive courses were held in 1982. A 4-week course on cassava tissue culture demonstrated both laboratory work and rapid multiplication methods for certified seed production. In a short course in biological control, some lectures were attended by more than 150 people.

In-country training on cassava production was held, with CIAT assistance, in Brazil, Colombia, the Dominican Republic, and Haiti.

To date, since 1970, a total of 410 professionals in cassava have completed training at CIAT.

Formal contacts at workshop and training sessions are complemented by informal meetings during travel. These network linkages are maintained, then, through publications and documentation services, and regular correspondence.

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Rice Program

Programa de Arroz

Rice is one of the most widely cultivated crops in Latin America, with approximately 8 2 million ha of land planted at present (Figure 1). Currently, total production in the area is estimated to be over 15 million t/year, and per capita rice consumption is estimated to range from 9 kg/capita in Mexico to 26 in Venezuela, 57 in Colombia, and 79 in Brazil

In the past 15 years, Latin American rice production has increased at an annual rate of 2.8%, equal to the population growth rate. In general, one-third of the increase in production can be attributed to increases in yield Nevertheless, importation of rice to Latin America has also increased from about 385,000 tons in the period 1963–1965 to some 470,000 tons today. To help the area become self-sufficient in rice production, therefore, expansion into the extensive region still unplanted, with favorable topography, adequate temperatures throughout the year, and sufficient moisture year round, may be needed.

Thus, the primary objective of the CIAT Rice Program continues to be to increase production and crop yields, and to improve rice quality, to meet consumer demand for this staple food. The two basic strategies are to:

- Develop improved rice germplasm with a high yield capacity and superior quality, resistant to the most limiting production problems and well adapted to the soil and environmental conditions;
- Determine the agronomic practices appropriate to conditions in various regions.

The Program closely collaborates with IRRI (International Rice Research Institute), whenever possible, adapting its plant materials and technologies to specific needs of the region. In addition, CIAT is hosting an IRRI/CIAT liaison scientist who manages the well-established Latin American sector of the International Rice Testing Network (IRTP)

For several years, CIAT emphasized lowland, irrigated rice in its research. Beginning in 1981, the Rice Program expanded to include the more favored types of upland rice in Latin America.

In the region, upland rice now occupies a major portion (72%) of the total rice area, while irrigated rice represents about 20% of the area and half the production It is projected that production of favored upland rice will rise to almost 14 million tons by the year 2000 (Figure 2). Rainfed lowland rice, in the Asian definition, covers less than 7% of the Latin American rice area. The bulk of upland rice is found in Brazil; also in Central America, most (87%) rice production is from upland rice Mexico recently adopted a policy of shifting from irrigated rice to upland production in the humid southeast, and upland rice culture occupies significant areas in Bolivia, Colombia, Ecuador, and Venezuela.

All this activity and interest in upland rice requires development of a more appropriate technology and improved varieties better suited to the diverse growing conditions.

CIAT's approach is to continue its work on three rice-growing ecosystems—irrigated; moderately favored upland; and favored upland areas In 1982, FEDEARROZ, the Colombian National Rice Federation, contributed 30 ha of land to CIAT, creating a facility in Colombia for favored upland rice research in Latin America.

The general research procedure includes breeding for stable resistance to the various diseases and pests; testing of improved lines from CIAT, IRRI, and national programs through the international rice-testing nurseries (IRTP) for Latin America; and seed multiplication and production, which is handled directly by national programs.

Linkage of rice researchers throughout the region is emphasized, both through the IRTP and manpower development

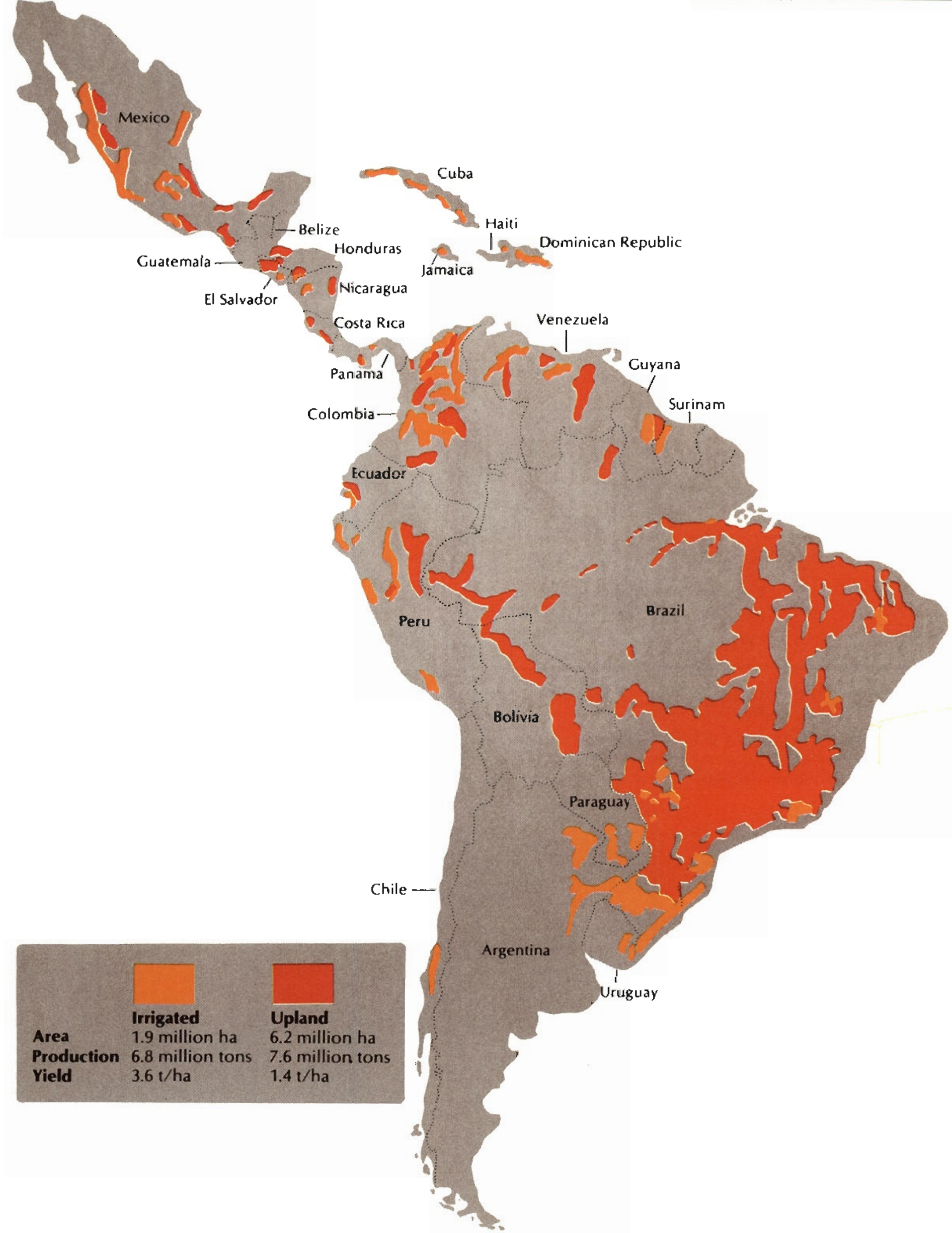


Figure 1. Distribution of the rice crop in Latin America, 1980.

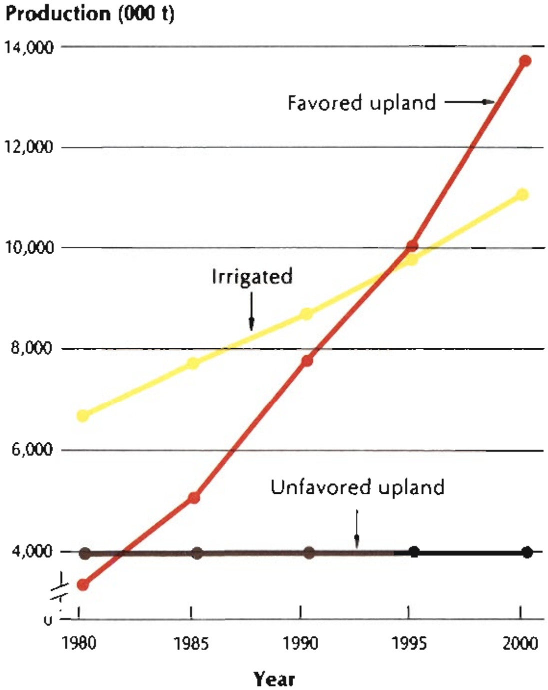


Figure 2. Projected estimates of rice production in the three main production systems in tropical Latin America for the period 1980 to 2000. Predictions are based on past trends in area expansion, relative profitability, land availability, and other factors.

CIAT's intensive effort to develop improved rice varieties for both irrigated and upland conditions serves rice production in Latin America and the Caribbean.

High priority is given to breeding for resistance to both the plant hopper and the hoja blanca virus.

Summary of Achievements

Over the years, the Rice Program has been most successful in adapting the new high-yielding rice technology to the irrigated and favored upland production systems throughout Latin America. More than 50 dwarf varieties based on lines developed by CIAT's Rice Program have been released by 15 national programs in the region, and these varieties now are grown on about 1.7 million ha (or 81%) of the irrigated rice area. In some cases, there has been an adoption of new improved varieties at the level of up to 100% (Table 1).

In general, yields in the irrigated sector have increased 1.2 tons/ha to an average of 4.0 tons/ha in all of Latin America. This is a 43% increase over average yield estimated in the absence of research programs and brings Latin America third in rice productivity after southern Europe and the United States. In conjunction with improved cultural practices, the use of these improved varieties has provided the means for nearly all Latin American countries to reach self-sufficiency in rice supply.

Much of the improvement work in irrigated rice continues to be directed at finding more durable resistance to the rice blast disease, the major rice production problem throughout the region. Several lines are in advanced stages of evaluation; these combine acceptable levels of resistance to blast with resistance to hoja blanca disease and the *Sogatodes* leafhopper (the vector of the hoja blanca virus) and are characterized by very good grain quality.

With the impact on irrigated rice clearly defined, CIAT is now able to move more strongly into research on upland rice in Latin America. Some work has already been done in testing irrigated varieties for use in upland areas. By 1982, promising parental material for use in the upland rice breeding effort had been tested in various upland sites, and advanced generations of progenies resulting from crosses involving promising parents are now undergoing extensive evaluation.

Irrigated Rice Production Systems

Irrigated rice is found on the Pacific Coast of Mexico and in Nicaragua, and in the Caribbean countries, most rice is cultivated under irrigated conditions: in Cuba, the Dominican Republic, and Haiti irrigated rice predominates over upland, and in Guayana and Surinam it constitutes 80% of the total. In the Andean countries—in Colombia, Ecuador, Peru, and Venezuela—both rice production systems are found. Irrigated rice is also produced in temperate Argentina, southern Brazil, Chile, Paraguay, and Uruguay.

For this area, CIAT's goals are to find stable resistance to the rice blast disease and locate new sources of resistance to sheath blight, leaf scald, and grain discoloration. A high priority is being given to breeding for resistance to both the plant hopper *Sogatodes oryzicola* and the hoja blanca virus. The possibilities for further yield increases are being explored through the use of many widely adapted, high-yielding parents in the breeding program. A major aim is to produce new varieties that increase average yields and reduce the cost per ton of food produced.

Table 1. Contribution of improved varieties (I.V.) to the production of rice under irrigated conditions in Latin America, 1980-1981.

Country	(1) Irrigated rice area[a] (000 ha)	(2) Area planted with I.V.[a] (000 ha)	(3) (2 ÷ 1 x 100) Area planted with I.V.[a] (%)	(4) 1982 yield (t/ha) Actual[a]	(5) 1982 yield (t/ha) Estimated[b] without I.V.	(6) (4 ÷ 5 x 2) Estimated increase in production due to area planted with I.V.[c] (000 t)	(7) (1 x 5) Estimated total production without I.V.[d] (000 t)	(8) (6 ÷ 7 x 100) Estimated increase in production due to I.V.[e] (%)
Originally planted with other varieties								
Brazil	780	538	69	3.8	3.0	430	2340	18
Colombia[f]	328	328	100	5 0	2.5	820	820	100
Costa Rica	2	2	100	5.0	3 3	3	6	50
Cuba	151	151	100	3.0	2.2	121	332	36
Ecuador	66	66	100	4.1	2.6	99	172	57
El Salvador	3	3	100	4.2	3.4	2	10	20
Haití	32	32	100	5.4	3.0	77	96	80
Mexico	74	73	98	4.2	3.4	58	251	23
Nicaragua	23	23	100	3.4	2.5	21	58	36
Panama	2	2	100	3.5	2.6	2	5	40
Peru	72	45	62	5.0	4.0	45	288	16
Dominican Republic	99	34	34	3.0	2.8	7	277	3
Surinam	36	36	100	4.2	3 0	43	108	40
Uruguay	62	60	96	5.0	4 0	60	248	24
Venezuela	125	113	90	4 0	2.5	170	312	55
Originally planted with I.V.								
Argentina	100	72	72	3.0	3.0	0	300	0
Belize	4	4	100	2.5	2.5	0	10	0
Chile	41	41	100	2.3	2.3	0	94	0
Guyana	86	68	79	3.0	3.0	0	252	0
Honduras	1	1	100	3.0	3.0	0	3	0
Jamaica	2	1	65	2.8	2.8	0	6	
Paraguay	21	11	50	2.1	2.1	0	44	0
Total[g]	2110	1704	81	4.0	2.8	1958	5920	33

a. Information collected through the IRTP network. The basic publications consulted were IRTP's *Third Conference Report* CIAT/IRRI, 1979, and *Fourth Conference Report* CIAT/IRRI, 1981.

b. Yield calculated as the average of the period 1968-1970 if improved varieties had not been planted.

c. Calculated as the difference between current yield and estimated yield in the absence of improved varieties, multiplied by the area planted with I.V.'s.

d. Calculated as total irrigated rice area, multiplied by estimated yield in the absence of improved varieties.

e. Calculated as production due to yield increases in area with improved varieties, divided by estimated total production in absence of improved varieties, multiplied by 100.

f. Colombia irrigated rice area includes mechanized upland rice, a very favorable upland rice system.

g. Percentage and yield averages are weighted by area.

Although rice is produced commercially, many small farmers still cultivate the crop for their own consumption, as is the case with this farmer in the north coast of Colombia.

Breeding Varieties for Disease Resistance

Apart from weeds, the three major biological constraints to irrigated rice production are the rice blast disease, caused by *Pyricularia oryzae*, the hoja blanca virus disease, and the plant hopper *Sogatodes oryzicola*. Grain discoloration caused by a complex of pathogens affects the market value of the crop and is particularly severe in acid, infertile soils. Leaf scald caused by *Rhynchosporium oryzae* affects rice both under irrigated and upland culture. In addition to foliar damage, *R. oryzae* has been identified as one of the pathogens causing grain discoloration, as well. In Central America and some locations in Colombia, sheath blight caused by *Thanatephorus cucumeris* damages rice.

CIAT's rice breeding efforts are geared to preventing outbreaks of these diseases.

Evaluation for resistance. A new relative evaluation system (RES) for assessing resistance to rice blast and scald was developed and applied by the Rice Program in 1982. Using this system, 392 lines or cultivars were tested for resistance to various diseases.

The RES (Table 2) is based on the comparison of plots or plants with a standard entry (Table 3) rather than quantification of the amount of disease in each entry. Conventional disease evaluation requires a visual estimation of disease severity, indicating both incidence and intensity, to assign a scale rating. But such visual quantification under field conditions is difficult and tedious. The RES, on the other hand, is simple and rapid and can be done by inexperienced observers. The key is to retain a mental image of the disease intensity in the standard entry.

Hoja blanca disease. An increased incidence of the hoja blanca virus disease was reported in several countries, including Colombia, since 1981. Resistance to the vector, formerly considered a reasonable safeguard against the virus, has failed to provide protection during this time. Severe incidence of hoja blanca has been observed among varieties resistant to the vector. Hence, the Rice Program is vigorously pursuing a breeding objective of combining resistance to both the vector and the virus.

Since 1981, crosses have been made and 64 advanced breeding lines for medium-maturity duration were derived and tested in yield trials in Villavicencio, Colombia. Under natural infection, incidence of hoja blanca was severe. Of the 64 lines, 34 (53%) were field resistant to the virus. These lines, however, were susceptible in other countries where virus levels were higher. Sources of true resistance, functional in all locations, were identified and are being used in expanding the genetic base of the Program

Rice blast disease. Rice blast disease is a major constraint throughout Latin America for irrigated rice production, and is a major aspect of the Rice Program and the IRTP. Breeding tactics include pyramiding of major genes, incorporation of slow-blasting characteristics, and the development of composite varieties.

Continuous effort is being made to broaden the genetic basis of resistance to rice blast. Based on nursery reactions in repeated trials and panicle blast reaction under field conditions, additional resistance sources were identified or confirmed in 1982, and many cultivars from the Ivory Coast were found to be resistant. Their type of resistance remains to be confirmed, although the majority are believed to have the slow-blasting type of resistance. In a leaf blast nursery

Table 2. Procedure to define grade of disease intensity using the relative evaluation system (RES).

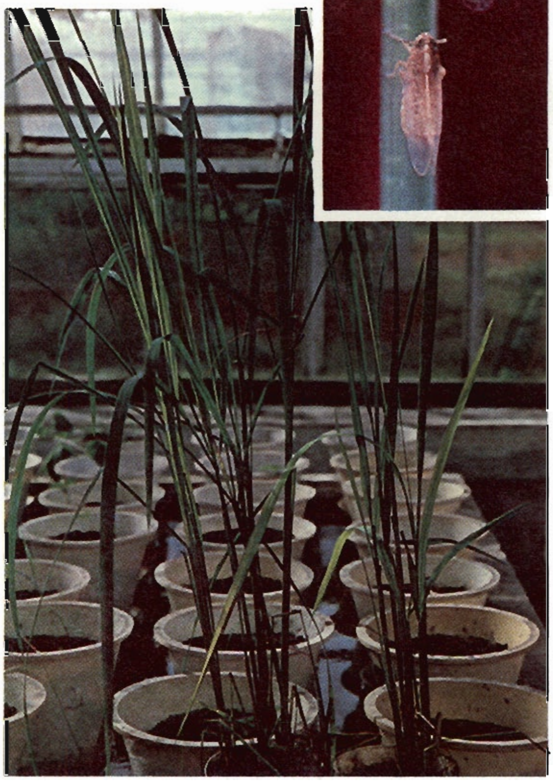
Step	Procedure
Identify the Standard Entry	
1	Carefully observe all the entries to identify one with a maximum level of infection and assign grade 9. This entry is called the Standard Entry at the time of evaluation and may vary from evaluation to evaluation.
2	Describe the plant's growth stage. disease incidence or severity, and presence of other diseases. if any, in the Standard Entry.
3	Form a mental image of the Standard Entry, and indicate this as grade 9
Evaluate individual entries	
4	Evaluate individual entries by comparing their relative level of infection with that of the adjacent entries. Use the scale from 0 to 9 (see Table 3).
5	Repeat the procedure, but do not refer to the first evaluation. Compare both evaluations. If there are large discrepancies, evaluate the plot a third time
Quantify the data	
6	To quantify the damage, randomly select entries for each grade using a pictorial index.
7	Compute the value for each grade using either arithmetic average or regression analysis between grades and values.
8	Transform all the grades into quantitative terms.

Table 3. Scale for relative evaluation system (RES).

Grade[a]	Description
0	Careful observation of all plants reveals no infected plants or leaves
1	Rapid observation does not detect infected leaves or plants, but careful observation detects a few infected leaves or plants.
3	Rapid observation detects a few infected plants or leaves.
5	Distribution of infected plants or leaves is uniform.
7	A high level of infection; but clearly less than the Standard Entry.
9	Maximum level of infection, at the time of evaluation defined by Standard Entry.

a Intergrades 2, 4, 6, and 8 can be used when the infection level of the Standard Entry is extremely high.

A sudden and serious resurgence of the hoja blanca virus was observed in previously resistant fields in the Colombian Llanos, confirming the cyclical nature of the disease. To prevent more widespread outbreaks, CIAT is working both on biological control through parasitism of the Sogatodes vector and on breeding for crop resistance to both the insect and the virus.



evaluation in 1982, 94% of the irrigated breeding lines and 96% of the upland accessions were rated as resistant or moderately resistant to the disease

Pyramided line 5738 was earlier found highly resistant to rice blast, and in 1982 was named Oryzica 1 by ICA. In Panama and Guatemala, the same line is under seed multiplication and will shortly be recommended for extensive cultivation.

Combination of slow-blasting components. Longer latent periods, fewer and restricted lesions, and reduced sporulation are believed to be the main components of slow blasting, or the rate-reducing (horizontal), type of resistance to rice blast disease. Over 1200 F_6 progenies originating from the horizontal resistance breeding project were planted in pedigree rows at the Villavicencio station. Almost all the parental sources for slow blasting have been found to be tall, upland types characterized by very poor combining ability. In addition, all the tall parental sources were found to be highly susceptible to hoja blanca.

In this trial, over 90% of the rows succumbed to hoja blanca. A large number of lines were also found to be severely affected by leaf scald and grain spotting. Of these 1200 lines, 46 progenies were selected to be advanced to yield trials.

Over 900 selections made from combinations of vertical genes and slow-blasting components were evaluated at CIAT-Palmira, and the promising lines advanced to F_6 progenies. Because many of the parents involved were susceptible to hoja blanca, over 95% of the progenies were affected by the virus. Approximately 30 progenies were identified as promising, resulting from the following crosses:

- Camponi//2940/3224
- 5745//Camponi/K8
- 5738//IR 262/Costa Rica
- 5738//63-83/Ceysvoni

The selected progenies were characterized by good grain types, plant type, and lodging resistance; they were advanced to yield trials.

Improvement of CICA 8. CICA 8 has gained wide popularity and farmer acceptance because of its wide adaptability and high yields. Its blast resistance has broken down under upland conditions, however, and it has succumbed to the hoja blanca virus. A project was initiated to incorporate additional genes for blast resistance from Colombia 1 and S.M.L. 56/7

CICA 8 was backcrossed three times to each variety, and a total of 116 BC_3F_5 progenies were planted for testing. Under reasonably good blast pressure, 24 lines from the two backcross programs were identified as blast-resistant.

Recognizing the importance of upland rice in Latin America and the potential contribution of concerted research, CIAT expanded its rice-improvement program to include the upland rice sector.

Top 5430, a Panama line derived from CIAT-supplied F_2 material from the cross IR 22//IR 930-147-8/Colombia 1 has been named and is under seed multiplication in Panama The new line is characterized by good grain quality, but it is moderately susceptible to leaf scald and sheath blight.

Weed Control

One of the priorities for agronomic management of irrigated rice is control of weeds, especially the Cyperaceae and Gramineae. This problem has been attacked by testing the results of combining two postemergent herbicides. In 1982, studies were continued on the effects of applications of oxyfluorfen and propanil; treatments and results are shown in Table 4.

Both herbicides have a low phythotoxic effect, and they do not interfere with rice yield. Costs are also low, because of the low doses applied Highest rice yields were obtained when propanil, in doses of 3 6 kg active ingredient (AI)/ha, was sprinkled after sowing and watering the rice, followed by the application 3 days later of oxyfluorfen, in doses of 0.15 or 0.10 kg AI/ha, mixed with urea.

New Rice Varieties Released

Eight new varieties were released for the irrigated rice sector in 1981 and 1982.

In Brazil, variety IAC 1278 was selected from the 1979 IRTP and in 1982 it was released to growers CICA 8 was released by EPAMIG under the commercial name INCA 4440. In El Salvador and in Venezuela, varieties originally crossed at CIAT in 1972 and 1975 were released with the names of Centa A 2, Centa A 3, and Araure 1. In Guatemala,

Table 4. Effect on rice yields of various pre- and postemergent herbicides.

Treatment	Dose (kg AI/ha)	Period of application[a]	Toxicity[b]	Yield[c] (kg/ha)
Propanil + oxyfluorfen/urea	3.6 + 0.15	Post + post	3	6141 a
Propanil + oxyfluorfen/urea	3.6 + 0.10	Post + post	3	5977 a
Oxyfluorfen + oxyfluorfen/urea	0.28 + 0.2	Pre + post	6	5792 ab
Propanil	3.6	Post	3	5329 abc
Oxyfluorfen + propanil	0.2 + 3.6	Pre + post	6	4800 bc
Oxyfluorfen	0.28	Pre	5	4623 bc
Control			1	2900 d

a. Pre = preemergent; Post = postemergent.
b. Degree of toxicity to the rice plant; scale = 1–9, where 1 = all plants healthy and 9 = all plants dead.
c. Yields followed by the same letter are not significantly different (Duncan).

ICTA named and released the variety Tempisque, which resulted from the same cross as Centa A 2.

INIA in Mexico has recommended Cárdenas A 80, which originated in Thailand, for the lowland dry zones and irrigated areas in the state of Tabasco.

In Panama, variety Tocumen 5430 was released by the University of Panama rice program.

Upland Rice Production Systems

Upland rice yield constraints differ quantitatively and qualitatively from those of irrigated rice. Essentially all soils increase in fertility when flooded. This does not occur in upland rice, which suffers a number of mineral deficiencies or toxicities. These are most severe in the moderately favored and unfavored upland ecosystems. Upland rice grown on strongly acid soils is negatively affected by aluminum toxicity and deficiency of calcium and phosphorus. Additionally, the relatively low water-holding capacity in the root zone of upland soils creates drought stress, which is most severe in areas of low rainfall. Drought and soil infertility interact to predispose rice to attacks by fungal pathogens. Thus, upland rice yields are constrained by soil problems, drought and diseases, and their interactions. Additionally, there are several agronomic stresses including difficulty of stand establishment, weed competition, and the ineffectiveness of herbicides during drought stress.

Plant types developed for irrigated conditions are not necessarily suitable for favored upland culture, therefore. Moreover, all the additional stresses make the rice plant less tolerant to attacks from pests and diseases.

Figure 3 shows the Program's projected breeding emphasis for upland rice varietal improvement in the 1980s.

Because upland rice is grown under various systems in Latin America, each with distinct production constraints, testing sites for upland rice include the following ecosystems: highly favored upland (Santa Rosa, Colombia); favored in terms of rainfall, but unfavored in terms of soil quality (La Libertad, Colombia); and moderately

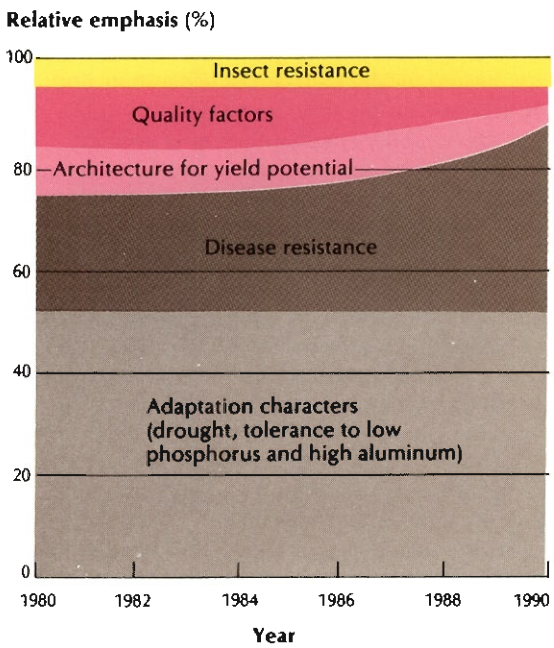


Figure 3. The Rice Program's varietal improvement efforts on upland rice will emphasize five major areas of research during the 1980s.

CIAT works in close cooperation with the Colombian Agricultural Institute (ICA) in the evaluation and release of improved varieties to farmers in Colombia. ICA's rice program facilities located in Palmira are used to evaluate blast resistance of lines and varieties of ICA/CIAT's cooperative program.

favored (Río Hato, Panama). Tall rice phenotypes are desired for the La Libertad ecosystem, and dwarf types for the other two.

Each site differs in organic matter content, soil pH, fertility, texture, water-holding capacity, total rainfall, and rain distribution. Aluminum is particularly high in La Libertad. Disease pressure is high in all sites but is more severe in Santa Rosa and La Libertad. Total rainfall is over 2500 mm/year and well distributed in Santa Rosa and La Libertad, whereas it is much lower (approximately 1400 mm) and erratic in Rio Hato. These three sites represent the favored to moderately favored upland rice environments in Latin America in terms of precipitation. Rio Hato is most representative of the upland conditions prevailing in Central America.

CIAT's upland rice program is also working on a potentially important production system that combines excellent rainfall with strongly acid, infertile soils. This environment is found in the vast savanna regions of Colombia and Venezuela and in the jungle areas of Peru and northern Brazil. Existing varieties in these areas are tall land races that tolerate aluminum toxicity, phosphorus deficiency, and fungal disease at low input levels.

Breeding for Disease and Pest Resistance

One of the constraints to upland rice production are several pathogens and pests, which are not as widespread as rice blast but cause losses in specific areas. These include *Rhynchosporium* (leaf scald), *Helminthosporium* (brown leaf spot), grain discoloration, hoja blanca virus disease, and the plant hopper *Sogatodes oryzicola*.

Breeding for favored upland rice is conducted on moderately fertile, alluvial upland soils, without supplemental irrigation, to expose populations to upland soil stresses. Fungal disease pressures on segregating materials and advanced lines are induced using appropriate designs. Parents for crosses are carefully selected among desirable lowland varieties and crosses to upland varieties from the Americas, Africa, and Asia. Currently, there are about 640 entries in CIAT's upland germplasm bank.

The F_1 generation is grown at CIAT headquarters; from the F_2 onward, evaluation and selection are done under upland conditions in at least four different sites. Alluvial soils in Villavicencio, Colombia, are used to select material for favored upland environments with two crops a year. An Oxisol site in Villavicencio is used to select materials for the highly infertile, acid soils; selections made there are sent to Yurimaguas, Peru, for planting and evaluation and then brought back to La Libertad, Colombia, for another evaluation. Penonome, Panama, is another site for selection and evaluation. Some of the lines coming from this project should be useful in some parts of northern Brazil, in addition to the vast savannas of Colombia and Venezuela and some acid areas in Bolivia and Peru. A collaborative research project has been signed between IDIAP (Panamanian Agricultural Research Institute) and CIAT, which allows the Program to use Rio Hato as a selection site for the moderately favored environments found in Central America. Some national programs, including those in Costa Rica and Guatemala, already have the capability of handling early segregating materials and are receiving some F_2 populations.

Selections showing high promise are turned over to the IRTP program for evaluation throughout Latin America. The IRRI representative at CIAT helps the CIAT upland breeder select the most appropriate materials for the IRTP.

Irrigated Materials for Upland Conditions

The excellent collaboration between the rice program at CIAT and ICA has resulted in more than 50 dwarf cultivars released by national programs in the region. These cultivars have impacted upland rice production in specific countries, but they were an unexpected spinoff from breeding under irrigated conditions. These cultivars have high yield potential in these conditions where blast and weeds are the most important yield constraints.

Disease pressure is severe at the Santa Rosa substation, and of a total of 196 F_2, F_3, and F_4 segregating populations, only 38% were selected in 1982. The disease susceptibility was not unexpected, however, because most of these populations came from crosses designed for the irrigated breeding program. This confirms the need for higher levels of disease resistance under upland conditions, and that these must come from a broader array of upland parents. All of the promising F_2 lines were bred from one African or Surinam parent noted for disease tolerance under upland conditions. Only 9 populations from the F_4 evaluations were selected; these included promising crosses between 5782//Camponi/IAC 25 and 5738//Camponi/IAC 25. IAC 25 is an upland variety from Brazil, and Camponi is from Surinam.

A total of 49 advanced lines (F_6, F_7) from the irrigated breeding program were evaluated in two replicated yield trials in Santa Rosa. CICA 7, CICA 8, and Metica 1 were used as control varieties. All lines outyielded CICA 7 and CICA 8 and showed a good level of resistance to blast (Table 5). Except for line 18467, however, all were severely affected by leaf scald. These lines will be distributed through the IRTP nurseries for further evaluations in multilocational trials in several countries.

Grain discoloration. Grain discoloration damage caused by seed-borne pathogens varies from small brown spots to complete blackening of the glumes. The problem frequently extends to the endosperm and even the embryo, thus reducing seed germination and the grade of rice. Kernels that are spotted severely break in the milling process. In very susceptible varieties, most of the affected florets are unfilled. Thus, grain discoloration significantly reduces yields.

The principal causal agent differs from area to area in tropical rice production. In Nigeria, the most common fungus isolated from discolored seed is *Sarocladium attenuatam*; in the Philippines it is *Trichoconis* sp., and in Colombia the most common pathogen is *Helminthosporium*

Table 5. Some agronomic characteristics of promising rice breeding lines for favored upland areas (Santa Rosa experiment station, Meta, Colombia, 1982).

Line no.	Days to heading[a] (no.)	Height (cm)	Disease rating: Rice blast[b] Leaf	Rice blast[b] Neck	Leaf scald[d]	Grain discoloration[b]	Hoja blanca[c]	Shattering[c]	Yield (kg/ha) 1981	Yield (kg/ha) 1982
5959	104	97	2 (3)	1	8	3	MR	MR	3646	4790
14643	99	91	2 (3)	1	8	2	R	MR	4160	4353
14682	103	89	2 (3)	1	7	2	R	MS	4229	4793
14697	100	93	1 (2)	1	7	2	R	MS	5056	4711
14819	97	89	1 (2)	4	8	7	R	MR	5010	4549
14918	100	80	1 (2)	3	7	5	R	MS	4852	4596
18453	105	91	1, 2 (3)	2	8	8	R	MS	3271	4752
18458	105	93	2, 3	1	7	6	R	MS	-[d]	4167
18467	97	89	2, 3	5	2	4	R	MR	-[d]	5500
Controls										
CICA 8	106	79	5	9	3	6	S	MR	3313	2308
CICA 7	98	91	2, 3	2	9	2	R	MS	3983	3536
Metica 1	98	102	2, 3	2	2	6	R	MR	3700	4263

a Recorded when 50% of the field has reached the heading stage.
b Relative evaluation scale (see Table 3 in this section). Numbers in parentheses indicate higher grades of damage were found in a few plants
c. R = resistant. MR = moderately resistant; MS = moderately susceptible; S = susceptible.
d Not evaluated during 1981

(Bipolaris) oryzae. The disease is associated with differing complexes of rainy weather, high relative humidity, upland conditions, infertile soils, and the hoja blanca virus. Hence, grain discoloration is a complex problem determined by the interaction of plant-pathogen and environment.

In 1982 evaluations, except for line 14757, none of the breeding lines was free of grain discoloration under upland conditions. Under irrigated conditions, of 94 cultivars evaluated, only 9 entries, advanced lines, were resistant.

Determining Improved Agronomic Practices

For pest control. *Elasmopalpus lignosellus*, *Blissus leucopterus*, and *Phyllophaga* spp. are widespread but sporadic insects found in upland rice. Damage by the first two is appreciable when the crop is subjected to prolonged drought stress during the early growth stages. They generally do not cause yield reductions in higher rainfall ecosystems. *Phyllophaga* (white grubs) cause losses in rice fields rich in organic matter, particularly in converted pasture areas. The *Sogatodes* plant hopper is most serious in areas of high relative humidity and moderately high rainfall, and is thus a particular problem in favored upland rice ecosystems in Colombia, Venezuela, and Central America.

For disease control. The fungal diseases are limiting factors in upland rice production. One ecological factor is critical: prior drought stress preconditions plants toward susceptibility, and the longer the stress period, the greater is the degree of leaf disease. Another critical factor is the soil. Crops on some soils appear particularly disease prone, while crops on other soils have a remarkable absence of infection under similar climatic conditions. The highly acid soils, Oxisols and Ultisols, that predominate in the savannas of South America, favor the development of leaf blast and other fungal diseases and appear to contribute to stronger disease epidemics.

Some irrigated cultivars have high yield potential in upland areas where rice blast disease and weeds are the most important yield constraints.

For weed control. The major difficulty for controlling weeds in upland rice is related to the prevailing soil moisture conditions. Excessive moisture, when weeds are most sensitive to herbicides, makes entry into fields with ground equipment very difficult. The resulting delay in application requires heavier herbicide dosages and results in less effective weed control.

Uniform trial testing in the IRTP in 1982 demonstrated that best results (effective weed control and highest yields) were obtained with application of low doses of oxadiazon as a preemergent (at 1.12 kg active ingredient/ha) and either propanil (at 3.24 kg AI/ha) or bentocarbo (at 4.0 kg AI/ha) as a postemergent. Manual weeding, without using herbicides, gave higher yields than the herbicide treatments alone, but because of high labor costs, the yield increase does not compensate for the input costs.

For soils with high levels of aluminum. The savanna soils of the Llanos Orientales of Colombia are representative of extensive areas of Latin America and have the potential to produce rice with little energy and low costs; the Rice Program is investigating economic and profitable

Improved rice lines are passed to collaborating national programs through international nurseries of promising materials. Countries evaluate and select from these nurseries materials for direct seed multiplication and distribution.

forms of producing upland rice in these areas to provide an inexpensive food source of good quality.

The principal problems these soils have are their high content of aluminum, low levels of phosphorus, and low acidity. The Rice Program is searching for varieties that have resistance to the region. Varieties have been found that are adapted to this region, including TOX 1011-4-1 and 1011-4-2, as well as the Brazilian varieties IAC 164 and 165, IAC 544, and Perola.

International Network Activities

Transfer of new technology is based on cooperation with national agencies through training, germplasm exchange, technical advice, and information sharing via publications.

For the past 10 years, Central American national rice programs have received a great deal of advanced breeding material from CIAT and IRRI through the IRTP (the International Rice Testing Program). This has proved to be an effective linkage of the various research groups since 1977.

IRTP for Latin America

In 1982, the IRTP for Latin America reorganized the distribution of improved germplasm according to the needs of the national programs. At present, two nurseries are emphasized: a large observation nursery for international evaluation in irrigated, favored upland, and unfavored upland ecosystems; and a smaller yield nursery directed toward the irrigated and favored upland systems. The bulk of the entries in these two nurseries are advanced lines from CIAT breeding programs, and some materials provided by IRRI/CIAT, which are thoroughly screened for suitability under Latin American conditions.

Table 6 indicates the cycles of duration and yields of the best materials in three nurseries,

Table 6. International Rice Yield Nursery (VIRAL) evaluations of rice varieties selected for favored upland areas in Latin America (distributed in 1981).

Nursery and variety	Origin	Days to heading (no.)	Yield (t/ha)
VIRAL *(planted in 9 sites)*			
P 1397-4-9M-3-3M-3	CIAT/ICA	97	4.5
P 1266-3-6M-1-1B	CIAT/ICA	87	4.2
IR 11248-13-2-3	IRRI	92	4.1
P 1363-5-13M-3-1B	CIAT/ICA	97	4.0
P 1377-1-15M-1-2M-3	CIAT/ICA	97	4.0
CICA 8 (control)	Colombia	98	4.5
CICA 4 (control)	Colombia	91	3.8
CICA 7 (control)	Colombia	93	4.4
VIRAL-P *(early maturing, planted in 9 sites)*			
IET 4094 (CR 156-5021-207)	India	89	4.9
Suweon 298	Korea	80	4.4
B 2360-6-7-1-4	Indonesia	101	4.2
MTU 3419	India	100	4.2
IR 13540-56-3-2-1	IRRI	97	4.1
CICA 7 (control)	Colombia	95	4.3
IR 50 (control)	Philippines	76	3.9
VIRAL-T *(medium-maturing, planted in 7 sites)*			
P 1381-1-8M-2-4M-5	CIAT/ICA	98	5.8
P 1332-3-8M-1-1B	CIAT/ICA	102	5.6
PAU 41-306-2-2-PR 406	India	91	5.6
P 1369-4-16M-1-2M-4	CIAT/ICA	96	5.6
IR 4422-98-3-6-1	IRRI	99	5.4
CICA 8 (control)	Colombia	98	5.5
CICA 4 (control)	Colombia	90	4.2
VIRAL-S *(upland varieties, planted in 13 sites)*			
IET 4094 (CR 156-5021-207)	India	88	4.4
P 1377-1-15M-1-2M-3	CIAT/ICA	98	4.3
TOX 728-2	Nigeria	94	4.3
B 733 C-167-3-2	Indonesia	91	4.2
P 1381-1-8M-2-1B	CIAT/ICA	99	4.1
CICA (control)	Colombia	99	4.2
IR 43 (control)	Philippines	94	4.4

The best locally adapted breeding lines are included in a Central American Upland Nursery, designed to evaluate parental material for superior upland cultivars for this region.

which are also resistant or tolerant to the principal diseases

Four other nurseries are provided to a limited number of national programs. These are sets of materials for low temperature tolerance, salinity, floating rice, and rice resistant to hoja blanca disease.

CIAT also provides additional segregating populations and advanced lines to all interested national programs.

New Upland Nursery

Each Central American national rice program decided in 1978 to select their best locally adapted breeding lines to be included in a special upland nursery called VICA (Central American Upland Nursery). This nursery was made up of 60 lines, of which 32 were named by Costa Rica, 16 by Panama, six by Honduras, four by Guatemala, and two by Nicaragua. After several plantings and evaluations under upland conditions in these countries, the number of lines was reduced to 14 in 1981. This nursery probably contains good parental material for the development of superior upland cultivars for the region. These lines have high yield potential and resistance to blast and leaf scald under favored upland conditions but are somewhat affected by these diseases in less-favored environments.

Materials developed elsewhere have been particularly important in providing sources of germplasm for particular characteristics. In this respect, cultivars developed by the Cereal Program at IITA have proved outstanding as potential parental sources for acid soil tolerance in studies at CIAT for the less-favored areas of acid soils in the Colombian Llanos. Some IRAT (Tropical Agronomic Research Institute, France) materials are excellent sources of resistance to dirty panicles and blast. The various sources of West African materials from IRAT and IITA have also proved useful in Brazilian research at CNPAF (National Research Center for Rice and Beans), Goiânia.

A network of researchers and of research collaboration is developing in upland rice, parallel to and associated with the already well-developed regional research collaboration activities in the irrigated sector.

The quarterly *Rice Newsletter*, published in Spanish, reaches an audience of 850.

Manpower Development

Most of the national Latin American rice programs are restrained from expanding their programs due to lack of trained personnel. CIAT's objective is to train a few individuals from each country in rice breeding and production. On completing their training, they will become key professionals for transferring technology as well as for strengthening their respective national programs.

The training strategy is also integrated with research and outreach. Production courses provide training on practical aspects according to the Program objectives.

Analysis of research personnel in upland rice by discipline with each national research program indicates that, in the 24 countries listed, only 179 professional scientists are doing rice research. This in an inadequate number, given the projected future importance of rice in human diets in the region and the range of problems remaining to be resolved through research in all rice systems.

Half the total number of regional rice researchers, however, are already working in the upland sector. This ratio is an encouraging indication that governments are efficiently allocating limited available resources. Many countries in the region are not gaining full benefit from the new rice technologies due to inadequate adaptive research capacity. In general, the in-service training opportunities offered by the international centers have been fundamental in the development of national research efforts; further training will be necessary, however, to fill the gaps and provide for staff turnover.

To date, CIAT has trained more than 219 rice researchers from 23 countries in the areas of agronomy, breeding, pathology, and production. Thus, an effective regional network of collaborators now exists for the continuing interchange and evaluation of technology and information. The Rice Program has continued to emphasize regional activities, including the IRTP, monitoring tours, production courses within countries, and biannual conferences for rice researchers. These activities have greatly contributed to the further strengthening of the Latin American rice network.

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Grass legume pastures selected for their adaptation to acid, low-fertility soils are an alternative solution to the nutritional problems of the vast agricultural frontier of tropical America.

Beef is a staple food throughout tropical Latin America. Consumption ranges between 4 and 36 kg per capita/year, representing between 16 and 70% of the total meat consumption. It is important in the diets of all income groups, and even the lowest income strata spend between 10 and 23% of the total food bill on beef At the same time, demand for beef products is increasing at a rate of 5.3% per year, whereas the production growth rate is a mere 2.2%.

Today, cattle and milk production systems are mostly concentrated in fertile areas where land costs are high and pasture production is in direct competition with crop production. At the same time, however, more than 40% (850 million ha) of the tropical Americas consists of acid, infertile soil regions where, due to the harsh ecobiological conditions (soils, climate, pest and disease incidence), agricultural production is scant or nonexistent. These immense land masses, however, hold promise for conversion into productive regions for beef and milk products and possibly other commodities. Such use will liberate the scarce but more favorable agricultural lands for the intensive production of high-value crops.

The Tropical Pastures Program of CIAT concentrates its resources on precisely these acid, infertile soil regions. The objective of the program is to develop, in collaboration with national programs, improved, low-input pasture technology to increase beef and milk production, conserve and improve the soil resources of tropical ecosystems, and provide a basis for an economically and ecologically sound utilization of underexploited land resources.

It is practically impossible to significantly adjust the chemical soil properties of the target area to make it more amenable to cultivation of conventional pasture species. Thus, the Program's general approach is to identify and further develop grass and legume species that are adapted to the prevailing conditions and which assure high performance in animal production systems. A basic tenet is to develop legume-based pastures, in which the grass component provides energy and roughage for the grazing animals' diet and the legume component provides nitrogen to the biological system, as well as high-quality protein to the animals' diet that is of critical importance especially in the long dry seasons.

The Program is organized into three interrelated research units: (1) Germplasm Evaluation, which includes the sections of germplasm introduction, agronomy, regional trials, plant pathology, entomology, and plant breeding; (2) Pasture Evaluation, including soil-plant nutrition, soil microbiology, pasture development, pasture quality and nutrition, and pasture evaluation/management; and (3) Pasture Evaluation in Production Systems, which is composed of seed production, cattle production systems, and economics. These three units collaborate in moving new germplasm accessions from their introduction and characterization to screening for use in the various ecosystems; developing alternative pasture production systems; and evaluating new pasture production technologies in farming systems. While the number of germplasm accessions that enter the germplasm development phase can be measured in the thousands, only very few, highly promising grasses and legumes succeed in being selected for their further evaluations and assembly into pasture technologies.

Although the target area of the program has one common denominator—the acid, infertile soils (mostly Oxisols and Ultisols)—it is made up of five distinct ecosystems whose unique set of climatic characteristics require that pasture germplasm be developed separately for each ecosystem. The five ecosystems are:

- Well-drained, isohyperthermic savannas, represented by the Eastern Plains, or "Llanos," in Venezuela and Colombia;

- Well-drained, isothermic savannas, represented by the "Cerrados" of Brazil;
- Poorly drained savannas;
- Semi-evergreen seasonal forests;
- Tropical rainforests.

To date, the Program has placed its emphasis on the two savanna ecosystems, as represented by the Llanos and the Cerrados, which comprise more than 300 million ha of land. Research for the Llanos ecosystem is conducted in the Carimagua station in the Llanos of Colombia. This station is jointly administered with ICA, the Colombian Agricultural Research Institute. Research for the Cerrados ecosystem is conducted in collaboration with the Brazilian Agricultural Research Center for the Cerrados region (CPAC), a station of the Brazilian Agricultural Research System (EMBRAPA). The direct research efforts in these two ecosystems are supported by the International Network for the Evaluation of Tropical Pastures, conducted in collaboration with national institutions, to evaluate promising germplasm in sites that represent subecosystems in both the Llanos and the Cerrados (Figure 1). The network also extends into the additional ecosystems (poorly drained savannas, seasonal forests, and rainforests). This allows the program, in collaboration with national organizations, to evaluate the adaptation and productivity of germplasm throughout the area of interest.

Summary of Achievements

The intensive germplasm evaluation work by the Tropical Pastures Program has allowed continued advancement of a relatively large number of accessions to higher categories of evaluation. By the end of 1982, some 80 legume accessions and 15 grass accessions had passed the strict tests to be promoted to a category involving evaluation under grazing.

In the "Llanos" ecosystem, liveweight gains with associations of *Brachiaria decumbens/Pueraria phaseoloides*, *Andropogon gayanus/Stylosanthes capitata*, and *A. gayanus/P. phaseoloides* showed more than two-fold increases in gains/animal, and more than fifteen-fold increases in gains/ha over the best-managed native savanna. An economic analysis of fattening with improved pastures showed the following internal rates of return: *B. decumbens*, 20%, *B. decumbens/P. phaseoloides* (in strips), 25%; *A. gayanus/S. capitata*, 26%; native savanna plus banks of *P. phaseoloides*, 22%.

Figure 1. Geographical distribution in Latin America of the International Network for the Evaluation of Tropical Pastures.

Pasture germplasm is assembled from a wide range of conditions throughout tropical America, Southeast Asia, and Africa.

In the "Cerrados" ecosystem, promising species identified thus far are *Centrosema macrocarpum*, *S. capitata*, *S. guianensis* "tardio," *S. macrocephala*, and a yet unidentified *Zornia* species.

Regional trial results from the tropical forest environment have shown that a large number of grass and legume species originally selected for their adaptability to acid, infertile soil conditions in the Llanos and Cerrados environments are also very well adapted to the conditions of the humid tropics.

After the national research institutions in Brazil and Colombia successfully released the grass *A. gayanus* CIAT 621 in their respective countries, Panama, Peru, and Venezuela also followed suit. In Colombia, ICA has officially passed on to the seed production sector a blend of five accessions of *S. capitata* under the name of "Capica." In Brazil, CPAC is in the process of releasing *S. macrocephala* CIAT 1582 under the name of "Bandeirante," and *S. guianensis* "tardio" CIAT 2243 under the name of "Pioneiro." This initiation of the release process of legumes constitutes a major step toward overcoming the critical constraint to forage quality for animal production in the savannas of tropical America.

Germplasm Base for Pasture Improvement

The Tropical Pastures Program seeks to exploit the natural variability of germplasm to identify grass and legume species adapted to the various ecosystems in the region. Germplasm is assembled from a wide range of conditions throughout the acid, infertile soil regions of tropical America, Southeast Asia, and Africa. With the addition of 1150 tropical pastures entries in 1982, the CIAT collection has now reached 8946 legume accessions and 839 grass accessions (Table 1).

Based on data collected to date, the Program has classified a series of species as "key species," which, based on their promise, are receiving special attention within the germplasm development work and whose germplasm base is being expanded. For example, given the importance of *Desmodium* and *Pueraria* species, the Tropical Pastures Program, in collaboration with IBPGR (International Board for Plant Genetic Resources), organized a collection trip in 1982 to Southeast Asia where these legumes are native. This particular trip yielded 176 new accessions of

Table 1. Status of germplasm collection of tropical pasture accessions at CIAT.

Genus	Accessions (no.)
Legumes	
Stylosanthes	2303
Desmodium	1211
Zornia	758
Aeschynomene	486
Centrosema	939
Macroptilium/Vigna/Phaseolus	739
Calopogonium	183
Galactia	336
Pueraria	119
Miscellaneous legumes	1872
	8946
Grasses	
Andropogon	65
Brachiaria	196
Panicum	378
Miscellaneous grasses	200
	839
Total	9785

Desmodium (40% of them *D. ovalifolium*), 57 accessions of *Pueraria*, and numerous additional legume species

More than 500 accessions of six key legume species were characterized and subjected to a preliminary evaluation in 1982. Particularly encouraging results were obtained with selected accessions of *S. capitata*, *S. guianensis* "tardio," *S. macrocephala*, and *C. macrocarpum*. At the same time, the preliminary evaluation of some 350 "new entries" was concluded. In this group, which involved accessions from six genera, particularly promising species were identified in *S. viscosa* and *Dioclea guyanensis*.

During the year, some 1500 seed samples of priority materials were entered into the systematic germplasm evaluation scheme of the program. Selected accessions were also passed on to collaborators in national programs

Technology Development for the Llanos Ecosystem

The well-drained isohyperthermic savannas of tropical Latin America comprise an area of approximately 110 million hectares. Mean temperatures are above 25°C. The average length of the rainy season is approximately 6 to 8 months, with a rainfall of between 1000 and 2000 mm. The soils are predominantly Oxisols and Ultisols.

Pasture research in this region has been directed toward the identification of superior genotypes of key species of legumes and grasses. At present, the key legume species have been determined to be *C. brasilianum*, *C. macrocarpum*, and two additional *Centrosema* species not yet described, *Desmodium ovalifolium*, *S. capitata*, *S. guianensis* "tardio," *S. macrocephala*, and *Zornia* spp. Among grasses, the key species are *Andropogon gayanus* and several *Brachiaria* spp. Accessions of all these species were observed to have a wide range of variability and adaptive characteristics.

In 1982, 428 new accessions of promising species—both key and other selected species—were introduced and evaluated for adaptation. At the same time, several hundred promising accessions from earlier adaptation evaluations were evaluated in small plots for productivity and seasonal distribution of yields.

Evaluation under Grazing

A considerable range of forage species were established in a set of small-plot grazing experiments designed to assess the compatibility of accessions in mixtures, tolerance to grazing, plant mineral requirements, and nutritive value. The legume content of the 18 grass/legume associations ranged from 3 to 90% after the first season of grazing by two animals/ha (Figure 2). The most appropriate ratios are those in which a balance in consumption is achieved between the grass and the legume (treatments 5–9).

Stylosanthes capitata CIAT 1441 and *S. macrocephala* CIAT 1643 were observed to combine well with native grasses. The association of *S. guianensis* "tardio" CIAT 1283 with *A. gayanus* became strongly legume dominant due to the low palatability of the legume; this particular accession of *Stylosanthes* succumbed to anthracnose during the wet season. Two free-seeding accessions of *D. ovalifolium* produced good mixes with *A. gayanus*, molasses grass (*Melinis minutiflora*), and native savanna.

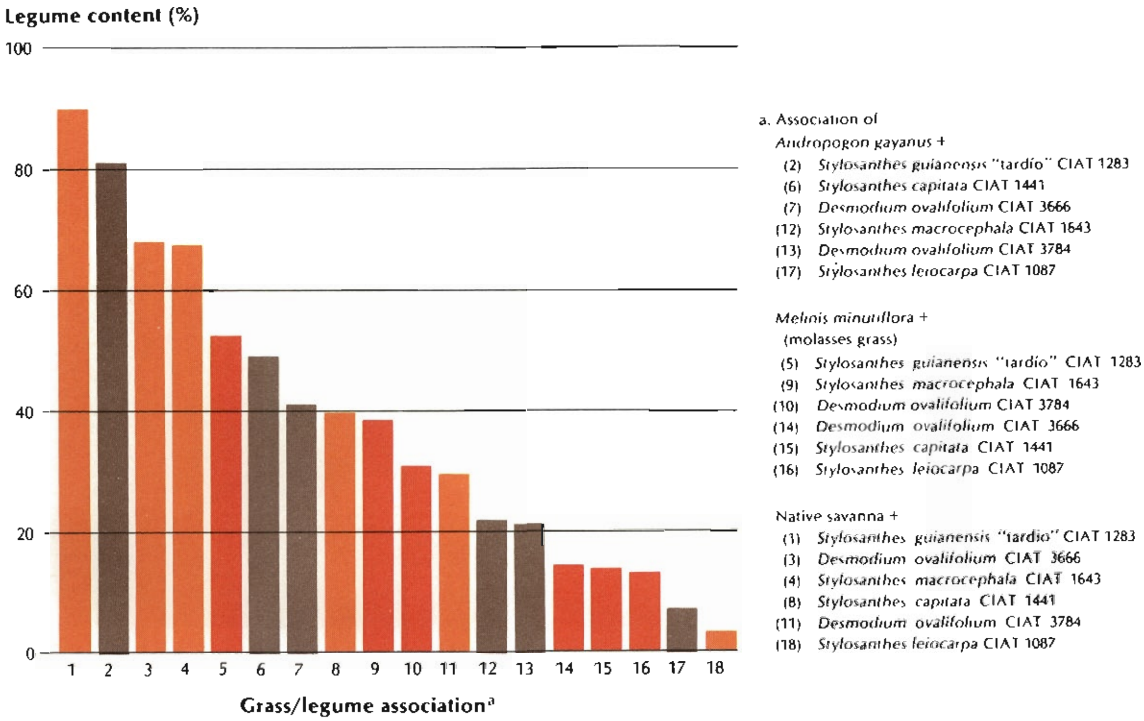


Figure 2. Legume content found in 18 grass/legume associations at the end of the first season under grazing (two animals/ha), in Carimagua, Llanos Orientales (Colombia).

Testing of Advanced Lines under Grazing

At a yet higher level of evaluation, advanced lines are agronomically tested under rotational grazing on small plots, with stocking rates of 2 to 2.5 animal units/ha during the 8 months of the wet season and 1.6 during the dry season. The following data were found in 1982 testings.

Both *Brachiaria decumbens* and *B. humidicola* have attained major economic importance in the lowlands of tropical America. Both grasses are well adapted to Oxisols. In the 1982 evaluations, *B. humidicola* showed a higher yield potential in and better tolerance to both wet and dry conditions. To date, spittlebug has not been a major problem in this species in the Llanos. *Brachiaria* remains one of the most promising grasses available.

Sixteen accessions of *Centrosema* spp. were compared in mixture with *A. gayanus*. All species were readily accepted by grazing animals with no evidence of preferential grazing. The free-seeding habit of *C. brasilianum* had a distinct advantage in aiding plant replacement. At the same time, the stoloniferous growth habit of both yet undescribed *Centrosema* species was observed to be a useful trait under heavy grazing conditions. Susceptibility of *Centrosema* spp. to leaf diseases and insect attacks remains a major selection objective.

The legume *Desmodium ovalifolium* is well suited to compete with aggressive stoloniferous grasses. It was tested in association with *B. humidicola* CIAT 679, *B. decumbens* cv. Basilisk, and *A. gayanus* CIAT 621. Dry-matter yields for the three associations were 17, 14, and 9 t/ha per year, respectively. *D. ovalifolium* proved its ability to compete well with *B. humidicola*—the most productive of the three grasses—and these two species were observed to form a highly compatible association.

During 1982, *D. ovalifolium* CIAT 350 was badly attacked by a new genus of stem gall nematode (*Pterotylenchus cecidogenus*); however, several other accessions of this legume show evidence of resistance to this nematode. Further research is needed to fully explore the range of variations to

Crossing between ecotypes of Stylosanthes guianensis *"tardío" by "common" is a project to obtain material resistant to anthracnose and with good production of forage and seed.*

correct some inherent deficiencies in *Desmodium*, including low palatability, high tannin content, and susceptibility to nematodes.

Ten ecotypes of the highly promising legume *Stylosanthes capitata* were evaluated in association with *A. gayanus*. Ecotypes flowering at mid-season showed a rapid decline in the second year after establishment; however, four early-flowering, free-seeding ecotypes persisted and yielded significantly higher under grazing than did mid-season lines. This is attributed to the larger amounts of seed produced by the early flowering accessions over a longer period of time.

Pest and Disease Problems

Results from evaluations at Carimagua and regional trial sites within the well-drained isohyperthermic savanna ecosystem showed the presence of several plant diseases affecting pasture species in this ecosystem.

Although six different diseases have been recorded on *Centrosema* spp. in the well-drained isohyperthermic savannas, generally there is only one major disease per species. For instance, Rhizoctonia foliar blight is the most important disease of *C. brasilianum*, whereas Cercospora leafspot is the most damaging disease of *C. pubescens*. *C. macrocarpum* remains relatively disease free. Among insect pests, chrysomelids continue to be the principal problems of *Centrosema* spp.

In *Desmodium* spp., the most important disease is stem gall nematode, which was only detected in Carimagua in 1982. A systematic effort is underway to identify resistant accessions.

On *Stylosanthes* spp., in the Llanos, anthracnose continues to be the most important problem. Of the more than 500 accessions of *S. guianensis* "common" evaluated thus far in Carimagua, only one accession has been able to survive anthracnose attacks for more than 2 years. On the other hand, of some 80 accessions of *S. guianensis* "tardío" evaluated in various experiments, 10 have shown moderate to high levels of resistance to anthracnose. This species is also relatively resistant to the stemborer. In *S. capitata*, anthracnose is a secondary disease in the Llanos, and *S. macrocephala* continues to show high levels of anthracnose resistance.

Pasture Establishment

A large-scale spatial distribution trial established in 1978 with the association of *B. decumbens* and *P. phaseoloides* has been increasingly hampered by a heavy spittlebug infestation. With declining grass production, the legume has suffered from heavy grazing pressure, thus forcing the suspension of the grazing of the trial (after almost 4 years) to allow for recovery of the grass and to devise a management system that will reduce the effects of spittlebug and improve the production and balance of the species.

A minimum-tillage trial for pasture establishment with low-density seedings was designed to evaluate the possibility of reducing the need for mechanical or chemical control of vegetation This trial is part of the Program's efforts to develop pasture establishment systems that require little or no machinery, designed for the small holder of the savanna regions. In Carimagua, successful establishment of *A. gayanus*, *B. humidicola*, *D. ovalifolium*, and *P. phaseoloides* has been achieved with only manual preparation of the planting site and no use of mechanical vegetation control Naturally, establishment has been much slower than in other trials where some form of tillage has been used for seedbed preparation and vegetation control.

Savanna Replacement

A savanna replacement trials was established in 1980. Four legume/grass associations were planted in strips of 0.5-, 2.5-, and 5-m width, with intervening savanna strips of 2, 10, and 20 m, so that 20% of the total area was tilled, fertilized, and planted.

Associations were formed with the grasses *A. gayanus* and *B. humidicola* and the legumes *D. ovalifolium* and *P. phaseoloides*. Due to initial low availability and higher palatability, *A. gayanus* practically disappeared; thus, the treatments in which it was included are now legume/savanna associations. Under grazing, both legumes rapidly spread into the native savanna. All treatments have succeeded in covering at least 60% of the total area, more so with *P. phaseoloides* than with *D. ovalifolium*. A high legume intake was measured in all treatments and, as a result, protein in the diet was not limiting, even in the dry season. Animals were induced to better use the native savanna vegetation,. and, as a consequence, high animal gains were recorded year-long. The stocking rate is 1.5 animals/ha. Fertilizer applications are made on 60% of the area in and along the planted strips. Based on the experience with this trial thus far, an additional series of trials is now being undertaken to test the feasibility of strip planting of only legumes as a supplement to the native savanna.

Voluntary Intake Studies

One of the most productive asssociations in Carimagua has been *A. gayanus* with *P. phaseoloides*. The balance between the grass and the legume in this association is very sensitive to the pasture management utilized and is markedly different in the two growing seasons. Under continuous grazing, toward the end of the rainy season the legume will dominate the association. This imbalance—in which the legume makes up two-thirds of the pasture—was found to lead to a corresponding imbalance in energy and protein intake of the grazing animals Whereas the protein content of the diet was found to be very high, energy and overall dry-matter intake were low, and the corresponding daily animal liveweight gains were depressed. In general, these data suggest that excessive availability of *P. phaseoloides* in association with *A. gayanus* can have negative effects on liveweight

gains due to an energy deficiency in the diet These findings point to the need for the identification of pasture management practices that will increase the availability of the grass on offer for grazing during selected periods of the year

Pasture Management and Productivity

The most promising pasture species and grass/legume associations are advanced by the Tropical Pastures Program to a level of evaluation where they can be tested for optimum establishment and grazing methods, fertilizer requirements, animal productivity, and pasture persistence. Currently, three different pasture systems are being evaluated: grasses in single stands, legumes to serve as a protein bank, and grass/legume associations.

Grasses in single stands. After the successful conclusion of the evaluation in pure stands of *B. decumbens* and *A. gavanus*, only the evaluation in pure stands of *B. humidicola* continued. The productivity of this grass under Carimagua conditions is significantly lower than that of the two grasses evaluated earlier. After the pasture was left to recuperate during the dry season in 1981, accumulated dry matter was removed, and a maintenance fertilization was applied, the liveweight gains obtained in 1982 proved to be disappointing. With a stocking rate of 3.4 animals/ha, gain per animal during the rainy season was only 215 grams/day; during the dry season, however, an average loss of 62 grams/day per animal was registered. The low productivity of this grass in pure stands can be explained by the very low voluntary intake, which is related to the low levels of crude protein contained in *B. humidicola* throughout the year. These results point out the need for a legume compatible with the very aggressive *B. humidicola*.

Legume protein banks. The strategic use of legume banks continues to be a highly promising alternative to supplement the nutrition available in grass pastures. Results from 4 years (1979–1982) of an experiment in Carimagua are now available While grazing on native savanna, each animal had available 2000 m² of *P. phaseoloides* in a legume bank. Access to the bank was controlled during the first 3 years of the experiment, but was unrestricted in 1982. In this long-term experiment, pastures are grazed continuously, and one-third of the savanna is burned at the beginning and end of each dry season.

Average annual liveweight gains were 118

The association of Brachiaria humidicola *and* Pueraria phaseoloides *in close mixture, such as in strip planting, gives high yields in liveweight gain, both per animal and per hectare.*

kg/animal with a stocking rate of 0.25 animals/ha, and 101 kg/animal with a stocking rate of 0.50 animals/ha. These results suggest that supplementary use of banks of *P. phaseoloides* with native savanna can increase weight gain per animal by approximately 30% over those obtained with best-managed native savanna treatments.

In a related experiment, *P. phaseoloides* was used to supplement an improved grass in pure stand, *B. decumbens*. The legume was established either in blocks or in strips, covering 30% of the area. Stocking rates were 1.25 and 2.00 animals/ha during the dry and wet seasons, respectively. Over 4 years, average annual liveweight gains were 183 kg/animal when the legume was established in strips, and 157 kg/animal with the legume established in blocks. Nonsupplemented *B. decumbens* pastures produced average liveweight gains of 145 kg/animal. However, during the dry season, weight gains in the legume block treatment were significantly higher than in the unsupplemented *Brachiaria*. These data indicate that, in the short run, the productivity of *B. decumbens* can be enhanced from 8 to 26% when supplemented with blocks or strips of *P. phaseoloides*, principally on the strength of the legume to enhance the nutritional quality of the animals' forage intake during the extended dry seasons.

From the Program's work with legume banks to date, it is evident that the most significant results can be obtained when low value grasses (such as native savanna) are supplemented with legumes of high nutritional value.

Grass/legume associations. The year 1982 was also the fourth year of a long-term experiment to evaluate various promising legumes grown in association with *A. gayanus* CIAT 621. The legumes evaluated include *Zornia latifolia* CIAT 728, a mixture of *S. capitata* CIAT 1019 and 1315, *S. capitata* CIAT 1405, and *P. phaseoloides* CIAT 9900. Figure 3 shows the annual liveweight gains registered for each of the years 1979–1982.

These long-term results indicate that the productivity of *A. gayanus*—an outstanding grass that produces relatively high liveweight gains even in pure stand—can be enhanced by 40–60% when grown in association with appropriate legumes. These associations require a maintenance

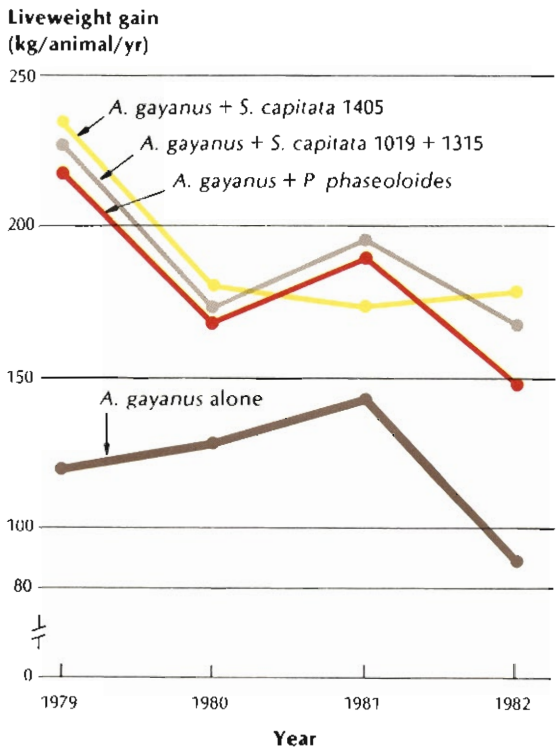


Figure 3. Animal liveweight gains with the gramineae Andropogon gayanus *have been outstanding; however, the association of this grass with legumes enhances its productivity by 40–60%. (Stocking rates used in the experiment were one animal/ha during the dry season and two animals/ha during the rainy season.)*

Table 2. Profitability of fattening operations with various pasture production technologies estimated for the Llanos piedmont and the inner Llanos regions of Colombia.

Pasture production system	Internal rate of return (%)[a]			
	Piedmont (Puerto López)[b]		Llanos (Carimagua)	
	6-year persistence	12-year persistence	6-year persistence	12-year persistence
Brachiaria decumbens alone	22.6	24.6	18.5	20.7
B. decumbens + blocks of *Pueraria phaseoloides*	20.8	23.1	16.8	19.2
B. decumbens + strips of *P phaseoloides*	26.8	28.9	22.6	24.9
Andropogon gayanus + *Stylosanthes capitata*	28.1	30.4	24.2	26.2
A gayanus + *P. phaseoloides*	21.0	23.8	16.9	17.8
A. gayanus + *Zornia* sp.	21.8	24.4	18.0	20.9
Native savanna + *P phaseoloides*	24.2	24.9	20.0	20.9

a. Internal rate of return for the 300 ha model without including the price of the land.

b. Sensitivity analysis of Carimagua biological parameters in close distance to the Bogota market.

fertilization after the second year of continuous grazing to assure persistence and stability of the mixture.

Economic Performance

With the availability of long-term performance results in Carimagua, an analysis of the likely profitability of new pasture production technology in the Llanos of Colombia has become possible. Using realistic productivity parameters based on actual experiences in Carimagua, internal rates of return were calculated for the production conditions in Carimagua and for the piedmont area (e.g., Puerto Lopez). In the absence of definitive data on pasture persistence, calculations were made for 6 and 12 years, respectively (Table 2). While these internal rates do not take into consideration land values, they nevertheless show very attractive returns for investments made for the use of the new technology. In Puerto Lopez, which is rather close to population centers, the projected returns are quite higher than at Carimagua, where transportation costs for inputs and outputs significantly add to the production costs

In interpreting these data, it must be considered that while this analysis only refers to cattle fattening, in the real world, fattening is only one part of the cattle production cycle. It is quite possible that in a real-world production system, the legume-based pastures would be used to facilitate reconception of lactating cows, recuperation of weak animals, increased protein intake during the prolonged dry season, and fattening of steers during the rainy season. This implies that the impact of introducing legumes may prove to be even greater than the one shown in Table 2.

Release of *S. capitata* cv. Capica

In 1982, the first legume cultivar derived from CIAT germplasm was formally released for use in the acid soil savannas of Colombia.

After a thorough evaluation of the performance and potential of *S. capitata* for use in legume banks and as the legume component in grass/legume associations, ICA released a blend of five accessions of *S. capitata* with the name "Capica." All accessions were collected between 1975 and 1977 in Brazil, with the assistance of EMBRAPA. A total of 170 kg of basic seed of Capica was produced by CIAT and supplied to ICA for

The first legume variety, *Stylosanthes capitata* cv. Capica, was released for use in the acid soil savannas of Colombia.

their distribution to commercial seed growers.

The next phase in the release process is the generation of a flow of commercial seed into the market to allow purchase by ranchers. It is envisioned that initial seed production efforts will be located in the same geographic region that will be used to plant the pastures Seed harvests will be made both from crop and pasture by-product systems. Because *S. capitata* has a relatively high seed yield potential, compared to other perennial tropical pasture legumes, the agronomic prospects for commercial production are high. The major determinant for commercial Capica seed supplies, however, will be marketing forces, reflecting the degree of adoption by cattlemen of this legume in pastures.

Technology Development for the Cerrados Ecosystem

The principal research challenge in the Cerrados (i e., the well-drained isothermic savanna ecosystem) is to identify pasture species and ecotypes that are well adapted to these acid,

Favorable combinations of legumes and grasses provide good animal nutrition. Desmodium ovalifolium *is a legume compatible with aggressive gramineae of the genera* Brachiaria (left). Stylosanthes capitata *and* Andropogon gayanus *in association* (right) *have a high potential for animal production.*

infertile soils and are also disease-free and persistent.

The primary research site for this ecosystem is at CPAC in Brasilia, Brazil At this site, germplasm is selected for two different soils: the dark-red latosol and the red-yellow latosol.

Evaluation of Legume Germplasm

Since 1978, some 700 accessions of 14 *Stylosanthes* spp and 350 accessions from 14 other legume genera have been evaluated for their phenology, dry-matter production, and tolerance to pests and diseases in the Cerrados ecosystem. Currently, six species are defined as key species for this ecosystem: *C. brasilianum, C. marcrocarpum, S. capitata, S. guianensis, S. macrocepahala, S. viscosa*, and *Z. brasiliensis*.

The agronomic evaluation of the most promising legume accessions was started in 1978–1979 Only five of the original 145 legumes sown at that time persisted for the 4 years of the experiment. These were *S. capitata* CIAT 1019, 1078, and 1097, *S. guianensis* "tardio" CIAT 2243, and *S. macrocephala* CIAT 1582

During 1981–1982, a new series of agronomic evaluations of legumes under grazing was initiated, and the methodology was adapted to allow for intermittent grazing in both the wet and dry season at two stocking rates A total of eight

The spittlebug (right) *is one of the most important entomological problems faced by grasses in the South American continent, especially in the Brazilian Cerrados* (left) *and in the Amazonian region.*

Manual harvesting of legumes on seed-production plots. Multiplication of basic seed is required for CIAT's research and for collaborating national programs.

legumes were sown with *A. gayanus* CIAT 621 cv. Planaltina. These were *S. macrocephala* CIAT 1582 and 10138 (both controls), *S. macrocephala* CIAT 2039 and 2053, *Z. latifolia* CIAT 728 (control), *Z. brasiliensis* CIAT 7485 and 8025, and *C. macrocarpum* CIAT 5065.

Evaluation of Grass Germplasm

The evaluation of five grasses initiated in 1978–1979 was terminated in 1981–1982 after four seasons. Dry-matter yields of *A. gayanus* CIAT 621 cv. Planaltina, *B. decumbens* cv. Basilisk, *Panicum maximum* cv. Guinezhinho, *B. ruziziensis*, and *B. humidicola* were 4725 kg/ha, 2954 kg/ha, 2428 kg/ha, 2262 kg/ha, and 1711 kg/ha, respectively. This again demonstrated the high productivity of the already released *Andropogon* in the Cerrados environment.

Plant Diseases and Pests

Centrosema spp. have fewer diseases and lower disease levels in the Cerrados than in the Llanos. No major diseases have been identified as yet.

Of the four diseases detected on *Stylosanthes* spp. in the Cerrados ecosystem, anthracnose is the most important, especially for *S. capitata* and *S. guianensis*. After 2 years of evaluation, 48% of the *S. guianensis* "tardio" accessions were found to have only few anthracnose symptoms, with CIAT 2243 being the most resistant accession. In contrast, CIAT 2243 is highly susceptible to anthracnose in the Llanos ecosystem.

Of five diseases detected on *Zornia* spp. in the Cerrados, the virus-fungus complex is the major one. Most accessions of two-leaflet *Zornia* spp. under evaluation were moderately to severely affected by this disease.

Research continues on improving resistance to spittlebug attack, the most important pest on grasses in the Cerrados. To date, *A. gayanus* has demonstrated resistance to the insect, whereas the susceptible variety *B. decumbens* undergoes large losses. Currently, a variety of pasture germplasm is being tested in different ecosystems in Brazil, Colombia, Ecuador, Panama, and Peru. In August 1983, cooperative research will begin between CPATU (Centro de Pesquisa Agropecuaria do Trópico Umido)/EMBRAPA, Brazil, and CIAT to integrate research efforts to solve this problem.

Pasture Development

Soil fertility is also a major constraint to legume-based pasture establishment in the Cerrados. While the amount of applied fertilizer can be reduced, some minimum level must be applied to obtain reasonable establishment and productivity. Although new genetic pasture material has been selected for its ability to grow well under conditions of low levels of phosphorus and high levels of acidity, in the Cerrados region, where commercial agriculture has introduced high levels of fertilizers, the response of forage germplasm to higher soil fertility levels must also be taken into account. (Figure 4).

The use of phosphate rock is considered an attractive option for pasture establishment, especially since abundant phosphate rock deposits have been identified in several parts of

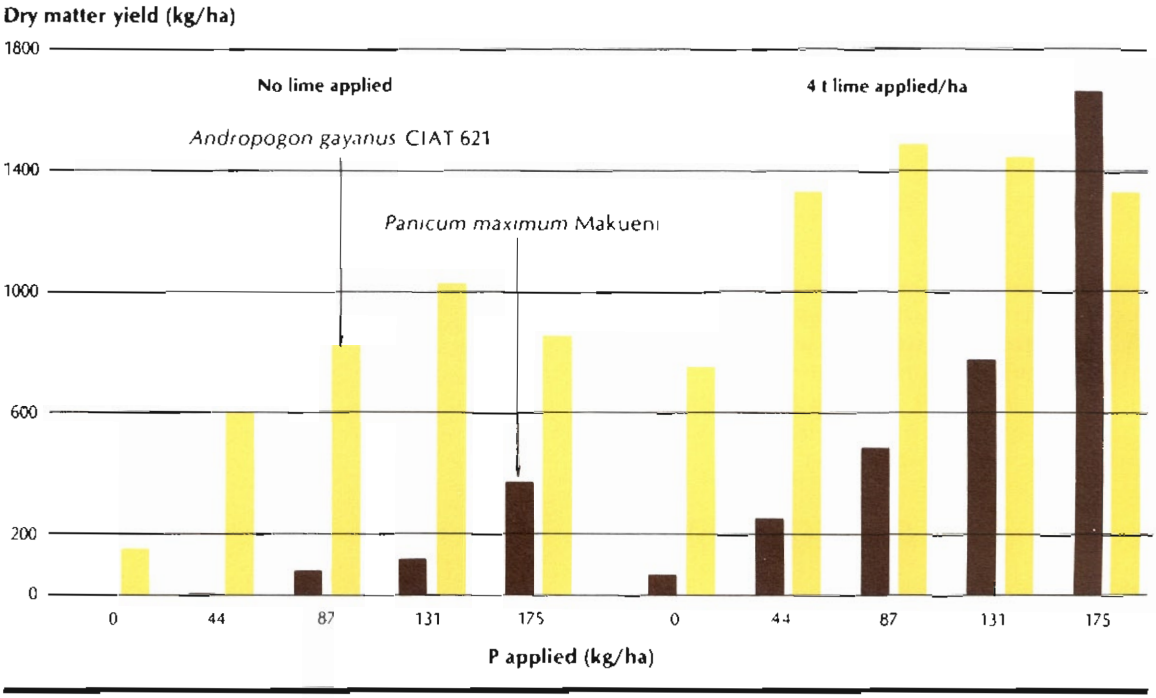


Figure 4. Response of Panicum maximum *Makueni (commercial variety) and* Andropogon gayanus *CIAT 621 to fertilization with phosphorus and lime. CIAT 621 showed significantly higher yields with and without lime applications at lower levels of applied phosphorus.*

Brazil. Results obtained with Araxa phosphate rock applied at rates of 52 and 105 of total P per kg/ha showed that this natural source compares well with equal levels of phosphorus applied as triple superphosphate, especially when no lime was added.

Experiments designed to assess the response of promising legume species to selected combinations of P levels and dolomitic lime showed that all five forage legumes tested were highly responsive to applied phosphorus, despite the fact that they were selected under low levels of applied P. Reactions to lime applications were found to be somewhat species-specific. In general, however, legumes were found to respond positively to lime applications up to 120 kg/ha. Above this level, dry-matter yield of most legume species decreased, thus pointing to the potential disadvantages involved in applying high levels of lime.

Pasture Evaluation

In 1982, the evaluation of two large-scale grazing trials with the associations *A. gayanus/S. scabra* cv. Seca and *B. ruziziensis/Calopogonium mucunoides* was continued. In both associations, as expected, the animals lost weight during the long dry season. However, due to poor health of the animals, liveweight gains during the rainy season were less than previous years, averaging only 340 grams/day.

In 1982, for the first time, four *in situ*–selected, highly promising *Stylosanthes* accessions (*S. capitata* CIAT 1019 and 1097, *S. guianensis* "tardio" CIAT 2243, and *S. macrocephala* CIAT 1582) were advanced to large-scale grazing trials. They were each sown in association with *A. gayanus*. *S. capitata* CIAT 1097 was also sown in association with *B. ruziziensis* as a control.

Fistulated animals in relative preference trials among legumes. CIAT is in the process of domesticating wild materials and evaluating their potential as new germplasm by the animals' grazing preferences.

Pasture Utilization and Herd Management

Results obtained over a period of 4 years from experiments in which the effects of the strategic use of improved pastures and early weaning on the reproductive performance of breeding cows are being evaluated. The most pronounced effects of early weaning occurred in the treatment with a 90-day mating season and the use of improved pastures. After 4 years, cows that had their calves removed at 3 months of age have an average annual calf crop of 83%, which is 26% greater than that obtained in cows that have their calves removed at 5 months (66%)

Associated Research on Pasture Improvement

Forage Breeding

The Program's research strategy is primarily based on the natural variability encountered in the multitude of genera and species available in the germplasm bank. However, when a few highly promising materials have been identified, from the thousands of accessions that enter the progressively more restrictive evaluation, it is often desirable to further improve these materials for specific traits through breeding and selection.

A second full year's data were obtained from a genetic study of *Andropogon gayanus* CIAT 621 to quantify the magnitude of genetic variability in this accession for a series of agronomic traits. Heritability estimates for most traits are sufficiently large that moderate to high rates of response to selection could be expected.

The principal aim of the *Centrosema* breeding project is to produce a type of *C. pubescens* with the capacity to grow and persist in acid Oxisols in combination with a grass under grazing with relatively low fertilizer application. In recent years, most of the breeding work in *Centrosema* has concentrated on selecting from successive populations resulting from a cross between *C. macrocarpum* CIAT 5062 and *C. pubescens* CIAT 5052. F_4 lines now available will be evaluated

In developing solutions to fertility problems, the emphasis is on low-cost alternatives to commercially available inputs.

in regional trials throughout the forest ecosystems.

The aim of breeding *Stylosanthes capitata* is to combine the best characteristics (i.e., high dry matter and seed yields, and tolerance to anthracnose, stemborer, drought, and grazing) of the parents CIAT 1019, 1078, and 1097. Results from the evaluation of the F_1 are being evaluated together with the best-seeded accessions.

In the regional trials network, the "tardio" type of *S. guianensis* has proved to have outstanding yield potential, particularly in the dry season. However, the vast majority of *S. guianensis*, both "common" and "tardio" types, failed to survive at Carimagua, where anthracnose pressure is more intense, due to a longer history of growing *S. guianensis* at this site. The accessions that have persisted at Carimagua are late flowering and low seed yielders. The breeding project for this species seeks to develop persistent genotypes with improved pest and disease resistance and seed yields. The project is directed both to the Llanos and the Cerrados ecosystem. F_2 seed of crosses made in 1981 is already available. The F_2 progenies are expected to provide an extremely wide range of genetic variation

Rhizobium and Nitrogen Technology

Last year it was reported that using disturbed soil to screen *Rhizobium* strains impairs the screening process. When the soil is disturbed, nitrogen is released by mineralization of the organic matter, thus interfering with *Rhizobium* effectiveness. The results from further strain-screening trials in 1982 confirmed that the method of undisturbed soil cores can be used to select *Rhizobium* strains that are effective in acid, infertile soils in the presence of a population of native *Rhizobium* strains. It appears that undisturbed soil cores are more appropriate for this purpose than the traditionally used sterile sand and nutrient solution where it is difficult to simulate stress conditions for plant growth and nitrogen fixation and there are no native *Rhizobium* strains to compete with the inoculated strain for nodule sites.

With the inoculation of legumes with selected strains of *Rhizobium* and with undisturbed soil cores from Carimagua, nitrogen yields in the tops of *Centrosema* spp., *D. canum*, *D. heterophyllum*, and *P. phaseoloides* were more than double the yields of their controls. Increases due to inoculation of *D. ovalifolium* were less marked;

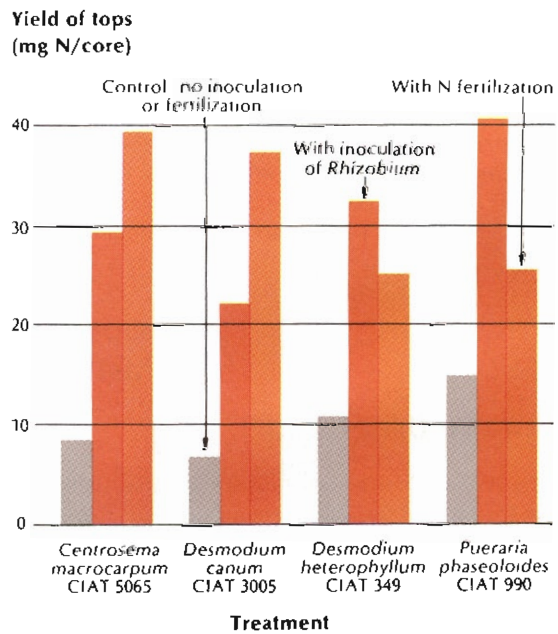
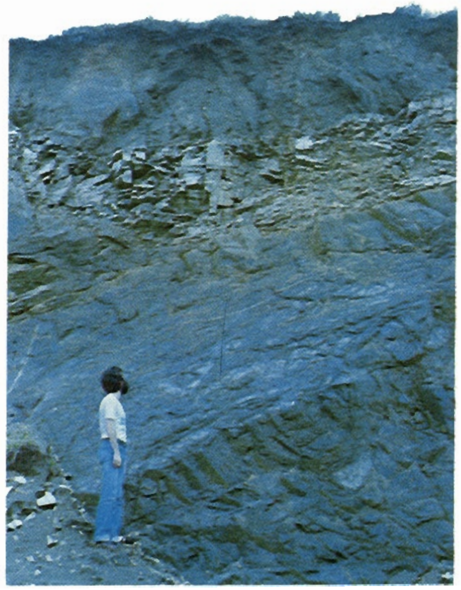


Figure 5. The inoculation of various legumes with Rhizobium *strains greatly increased their nitrogen-fixing capacity. Some accessions even fixed more nitrogen when inoculated than when N was applied as fertilizer.*



Potassium feldspars are native minerals that present an interesting alternative as fertilizer, lying within CIAT's concept of using low-cost inputs for the acid, infertile soils.

however, *D. ovalifolium's* response to nitrogen fertilization was considerable, suggesting that more *Rhizobium* strains and ecotypes of this legume should be screened (Figure 5).

Field experiments in Carimagua confirmed that strains selected in undisturbed soil cores can also function during pasture establishment in the field. However, the response to these strains is affected by soil type and tillage method

In an attempt to take advantage of soil nitrification caused by disturbance, studies conducted in 1982 indicate that native savanna contains an inactive population of nitrifying microorganisms, which may be activated by soil disturbance; however, this activity does not begin immediately—in some cases, taking over a month—but it may continue for over a year after initial disturbance. The nitrogen thus produced could provide a significant impetus for plant growth, even if the plants were legumes.

The responses to inoculation and levels of nitrogen mineralization observed suggest that there is considerable potential for managing both processes in order to increase nitrogen yield in pastures or pasture/crop combinations.

Alternative Sources of Potassium

The low-input strategy adopted by the Tropical Pastures Program implies the use of plant materials that are adapted to the soil chemical constraints, such as acidity and low soil fertility. For the establishment and maintenance of the new pasture technology, however, some minimum fertilizer must be applied. Commercially available fertilizer inputs often are inappropriate due to economic or agronomic considerations. Hence, in developing solutions to the fertility problems, the Program emphasizes low-cost alternatives to commercially available inputs.

In the case of nitrogen, emphasis is put on the use of pasture legumes, which, through atmospheric fixation, contribute nitrogen to the pasture system. In the case of phosphorus, the Program seeks to exploit the availability of large rock phosphate deposits throughout Latin America. This relatively inexpensive source of phosphorus is highly effective in the ecosystems in which the Program works as the natural acidity interacts with the rock phosphate to make the phosphate available to the plants. As mentioned in earlier *Reports*, CIAT is host to a special project activity of the International Fertilizer Development Center (IFDC), which focuses on the development of technology for the effective use of rock phosphate in the management of different crops, with special emphasis on tropical pastures.

Now, CIAT has reported that there are indications that feldspar, one of the basic constituents of igneous rock, could do for potassium fertilization what rock phosphate is doing for phosphorus fertilization. Feldspar deposits are numerous in the region. In Colombia alone, more than 20 such deposits have been identified. There is great variability in terms of the potassium content of these feldspar deposits, with a range of at least 5 to 11% of potassium.

Preliminary greenhouse experiments with different sources of feldspar showed that the agronomic effectiveness of potassium derived from feldspar can replace potassium applied in

A close interaction between graduates from national programs and scientists from the Tropical Pastures Program is essential for an effective transfer of experimental techniques and of technology.

chloride form. As the latter is a soluble fertilizer with only a limited residual affect, feldspar rock could have a long residual effect Nevertheless, considerable additional field research, especially of the long-term type, is needed to definitively confirm the potential utility of feldspar rock as a potassium source for the new pasture technology in the acid, infertile soils of Latin America.

Survey of Cattle Production Systems in the Savannas

In 1982, Phase I was concluded of the Technical and Economic Evaluatión of Cattle Production Systems (ETES), a survey of the systems in use in the savannas of Brazil, Colombia, and Venezuela. This survey was made possible through a special project funded by the German Agency for Technical Cooperation (GTZ). The study found that in all three countries surveyed, the savannas supporting cattle production are highly acid (pH of 4 to 5) and deficient in phosphorus. The aluminum saturation in the Llanos of Colombia is very high (80–90%), but it is much lower in the other regions surveyed (25–35%). This latter fact, and the well-developed infrastructure in the savanna regions of Brazil and Venezuela, are considered largely responsible for the fact that improved pastures make up 30 and 20%, respectively, of the land area in these two countries. While the composition of the herds in the three areas studied was similar, with emphasis on cow-calf operations, priorities assigned to different animal categories were found to vary from country to country. In all cases, however, it was found that, on the average, the first calf is not conceived until the cow is about 3 years old; thereafter, the reproductive life of the cow is very short. In general, animal productivity was found to be low, with average liveweight gains registering between 50 and 65 kg/animal and 12 and 32 kg/ha per year

The survey confirmed earlier indications that the low nutritional value of the forage is the primary constraint to increased cattle production in these regions. While the nutritional deficit in the savannas of Colombia and Venezuela is present at similar levels throughout the year, in the Brazilian Cerrados a particularly marked deficit occurs during the dry season

Contrary to earlier expectations, in Colombia no significant variations in biological or economic productivity of farms was found that could be ascribed to different technologies already in use. On the other hand, in Brazil and Venezuela the use of improved pastures, together with other crops, offers a viable option for the intensification of cattle production. Of particular interest in the case of these two countries was the finding that a crop-pasture rotation can significantly contribute to the improvement and maintenance of soil fertility, reduce risks, and increase the profitability of the operation

Evaluation of Improved Pastures

Phase II of ETES is designed to evaluate the effect of the introduction of improved pastures and associated production technology on farm

Many national institutions collaborate with CIAT in a series of regional evaluations of legume and grass accessions.

productivity. Seven farms in the Colombian Llanos were chosen for this evaluation; improved pastures were established in 1979. Partially available results from one representative farm indicate that, starting in late 1979 when the new pastures could gradually be used, the number of breeding cows had increased by more than 20% in April of 1982, and the average liveweight had increased from 250 to 300 kg/animal. The birth rate has increased by about 7%, with a corresponding decrease in the interval between calvings; average calf weights at weaning have increased by 20 kg/calf. A preliminary analysis of the marginal profitability of this operation suggests significantly higher returns of this alternative over the traditional operation.

A 4-year experiment on the management of breeding herds was concluded in 1982. It provided clear evidence of the importance of improved pastures in weight recuperation of lactating cows to permit successful reconception. Other long-term herd experiments with such promising associations as *A. gayanus/P. phaseoloides* and *B. humidicola/D. ovalifolium* are underway and will be reported in the near future.

Animal Health

Two major sanitary problems are associated with the intensification of animal production in the savannas of tropical America: these are the incidence of ticks and the occurrence of photosensitization.

A survey of tick counts on animals grazing sown grasses and savanna has shown that increasing stocking rates is associated with higher levels of tick infestation, but differences exist between improved grasses in the population of larvae maintained in the paddock. Thus, a tall grass such as *A. gayanus* hosts less larvae, and animals are less affected by ticks than in *B. decumbens*. It appears that preventive schemes will have to be designed, considering such factors as forage species and pasture management.

Photosensitization, a syndrome leading to severe weight loss and eventual death, occurs in animals grazing *B. decumbens*. A survey made in the piedmont region of the Llanos of Colombia showed that the disease was present in 40 of the 50 farms sampled, affecting 5% of the animal population and leading to death in 30% of the cases reported. Experiments in Quilichao gave evidence that the spores produced by the saprophytic fungus *Phitomyces chartarum* were the causative agent of the disease. It was also established that the subclinical presence of the disease can be detected by a simple blood test, and that the application of zinc as pasture fertilizer may decrease disease incidence in the animal.

International Activities

Tropical Pastures Evaluation Network

The International Network for the Evaluation of Tropical Pastures (RIEPT, *Red Internacional de Evaluación de Pastos Tropicales*) is conducted by the Tropical Pastures Program in close cooperation with national institutions. Four types of regional trials are included. Types A and B refer to agronomic trials in which germplasm materials are evaluated for their adaptation to climate, soil, pests, and diseases. The principal difference between Types A and B is that, in the former, large numbers of entries are evaluated in a few representative sites within each of the

Regional trials C and D have been established in different localities within the international tropical pastures network. Trials under grazing are being conducted in Yurimaguas, Peru, by INIPA, for instance.

ecosystems of interest, whereas, in the latter, the best selections are evaluated in as many sites as possible within each ecosystem.

Type C regional trials evaluate in small plots the persistence of selected grass/legume associations under intensive mob grazing. The objective of Type D regional trials is to evaluate the production and productivity of the two or three best pastures from Type C trials in terms of liveweight gain and milk production.

At the end of 1982, 12 Type A and 36 Type B regional trials were in place in the five ecosystems of interest to the Program. The first regional trials Types C and D are planned for testing in Brazil, Ecuador, and Panama in mid-1983.

A wealth of information on the performance of numerous germplasm accessions is already available. Information is fed into the research process as it becomes available.

In 1982 regional trials in tropical forests ecosystems, earlier indications were confirmed that many of the grass and legume accessions found to perform well in the savanna ecosystems also produce well in the tropical forest ecosystems. Particularly promising accessions identified for the tropical forests are, among grasses, *A. gayanus* CIAT 6054, 6053, and 621, and, among legumes *C. macrocarpum* CIAT 5065, *C. pubescens* CIAT 438, and *S. guianensis* CIAT 136 and 184.

Manpower Development

Mutual collaboration between national agricultural research institutions and CIAT is necessary for the validation and transfer of technology developed for tropical pastures.

During the period 1970–1982, a total of 467 professionals from 18 countries in tropical America have completed intensive training in production of tropical pastures. In 1982, 43 professionals from 12 countries participated in training at CIAT.

Most of these people continue to work with CIAT through the Tropical Pastures Evaluation Network and the Regional Trials Network.

The second meeting of the RIEPT was held in September with 52 participants; in addition, a working meeting with 25 participants was held on methodologies for germplasm evaluation. In the first meeting, the advances and results of regional trials A and B were analyzed, and in the second, methodologies for Type C regional trials were discussed.

Milking of "dual-purpose" cows is an alternative that has implications for farm economy and for nutrition of the small farmer's family.

The quarterly *Tropical Pastures Newsletter,* published in Spanish, reaches an audience of 900, and the *Abstracts Journal* is sent to 600 subscribers.

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Seed Unit

Unidad de Semillas

The Seed Unit collaborates with national enterprises to accelerate the use of good-quality seed of improved varieties.

The fourth year of operation of the Seed Unit has resulted in the highest level of activity to date. The objectives of the Unit continue to be to work within Latin America and the Caribbean to:

- Increase the number and competence of seed technologists;
- Strengthen the seed programs and seed enterprises through technical collaboration;
- Stimulate seed production in the tropics and accelerate use of the most promising varieties and hybrids;
- Help solve problems limiting seed production and distribution through research;
- Disseminate information on seed activities, advances in seed technology, and the availability of promising materials.

The Unit both supports the commodity programs of CIAT and assists in development-oriented activities to accelerate the growth of in-country seed programs and enterprises.

Increasing Competence of Seed Technologists

The Seed Unit's first priority continues to be to increase the number and competence of seed technologists by manpower development through multidisciplinary and advanced courses, in-service training, M.S. degree thesis programs, in-country training, and workshops. Since 1978, the annual number of course offerings has been progressively increasing (Figure 1).

In 1982, two basic, multidisciplinary, postgraduate courses in Seed Technology were held at CIAT, covering various aspects of seed production, conditioning, quality control at the field and laboratory level, and marketing, combined with discussions of seed program and enterprise development and management. These courses have been the basis for seed manpower development in the region since 1978. Beans, rice, tropical pastures, maize, and sorghum were the main crops for teaching purposes.

The first advanced postgraduate course in Seed Conditioning was held in 1982, with the topics of seed drying, conditioning, and storage for plant managers. The 29 participants from 13 countries dedicated some of the 4 weeks to an analysis of seven conditioning plants located in the Tolima Valley of Colombia. Their analyses were presented to the seed enterprise managers, and ultimately it is expected that the trainees will make similar applications in their own plants.

Two workshops were also conducted, focusing on priority needs for seed development. In the first, Strategies for Seed Technology Training, 49

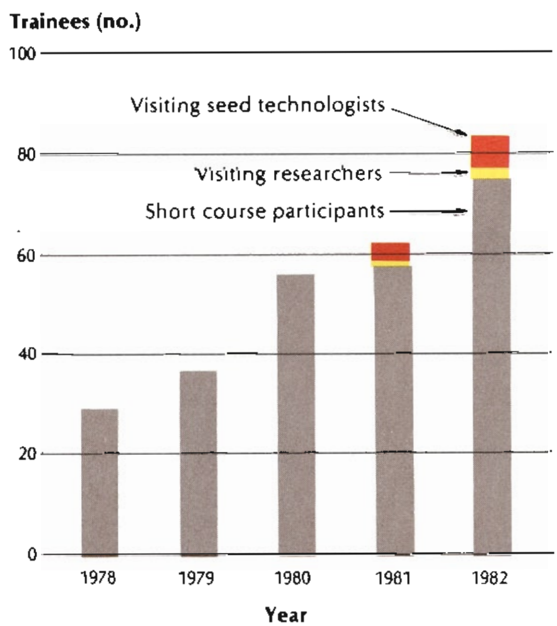

Figure 1. Number of participants who have completed training at the Seed Unit from 1978 to 1982.

Continuous purity analyses are conducted by the Seed Unit to provide national programs and commercial enterprises with seed of the best quality.

participants from universities and national training activities concentrated on identifying national needs, sharing information on training methodologies and materials, and designing modules for teaching. In the second, Improved Seed for the Small Farmers, the first of its kind, 65 participants focused on the mechanisms to help small farmers improve the quality of the seed they plant, better ways to promote improved varieties through appropriate technology and the transfer of results to the small farmer, and ways to increase use of improved seed by the small farmer. Small farmers could more effectively save their own seed of beans, rice, maize, and sorghum, and planting material of cassava and potato, and practical suggestions were offered by the participants. Increased on-farm evaluation of crop varieties was stressed as a means to help assure that materials acceptable to small farmers are introduced into regional development plans. Because of the logistical problems of reaching small farmers, the need for programs to develop seed production among selected small farmers, or groups of them, as a business was emphasized.

The Seed Unit also assisted with in-service training for the three Bean Program trainees on seed production, and two master candidates are currently completing their research at CIAT in varietal description of rice and beans, after concluding their coursework at the National University of Colombia and the Federal University of Pelotas, Brazil.

Through training, the Seed Unit collaborated with 59 national institutions and seed enterprises in 27 countries in 1982 (Table 1).

For many years, FAO and Mississippi State University have assisted in in-country training courses. Although the Seed Unit's greatest comparative advantage is in regional training at CIAT, countries are requesting varying kinds of help in their own in-country training. For example, the Seed Unit cooperated with ICA, ACOSEMILLAS, and CRESEMILLAS in Colombian courses in 1980 and 1981; in 1982, the Colombian organizations handled their own training. During 1982, the Seed Unit assisted in Seed Technology courses organized and held in Cuba and Panama. Both countries had earlier sent participants to CIAT especially to prepare them to organize their own courses. In addition, assistance was given to a regional seed testing course that was conducted in Costa Rica and cosponsored by the International Seed Testing Association and the University of Costa Rica.

It is expected that more countries will develop a total seed training plan and incorporate increased in-country training into their programs. As this happens, the Seed Unit will provide the kind of assistance desired, ranging from helping with compiling training materials to organizing and conducting a course in cooperation with national leaders. The Unit also cooperates with other international and bilateral agencies interested in seed training at the country level.

Technical Collaboration in Support of Seed Development

Technical collaboration with national programs has concentrated on personal follow-up contacts with former trainees; review of alternative policies

Table 1. National institutions and seed enterprises using the Seed Unit training in 1982.

Country	Participants (no.)	Institution/enterprise
Latin America and the Caribbean		
Argentina	2	Universidad Nacional de Córdoba; Universidad Nacional de Buenos Aires.
Belize	2	Department of Agriculture.
Bolivia	5	CIAT Bolivia, Empresa de Semillas SEFO; Instituto Boliviano de Tecnología Agropecuaria (IBTA); Ministerio de Asuntos Campesinos y Agrarios.
Brazil	12	Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA); Universidad de Pelotas; Delegación Federal de Agricultura Bahía; Cooperativa Regional Triticola; Associaçao Goiana dos Produtores de Sementes (AGROSEM). Sementes Agroceres; Coordenadoria de Assistência Técnica Integral (CATI); Máquinas Vitoria; Instituto de Zootecnia.
Colombia	12	Instituto Colombiano Agropecuario (ICA); Federación Nacional de Arroceros de Colombia (FEDEARROZ); Procesadora Agrícola Colombiana (PROACOL); Universidad del Valle; Instituto Politécnico; Universidad Nacional de Colombia.
Costa Rica	5	Consejo Nacional de Producción; Comisión Nacional de Semillas; Centro para la Investigación en Granos y Semillas (CIGRAS).
Dominican Republic	6	Secretaría de Estado de Agricultura; Productora de Semillas; Centro de Investigaciones Arroceras (CEIDA).
Ecuador	4	Compañía Mixta de Semillas, Instituto Nacional de Investigaciones Agropecuarias (INIAP): Programa Nacional de Semillas.
El Salvador	1	Instituto Salvadoreño de Investigación Agropecuaria (ISIAP).
Guatemala	2	Instituto de Ciencia y Tecnología Agrícola (ICTA), Universidad de San Carlos.
Guyana	2	Ministry of Agriculture; Guyana Rice Board
Honduras	3	Ministry of Natural Resources.
Jamaica	2	Ministry of Agriculture
México	1	Escuela de Posgraduados de Chapingo
Nicaragua	4	Empresa Procesadora de Semillas (EMPROSEM); Comité Nacional de Semillas; Universidad Nacional Autónoma.
Panamá	2	Comité Nacional de Semillas; Ministerio de Desarrollo Agropecuario (MIDA).
Paraguay	1	AGRIEX Sucursal Paraguay.
Peru	2	Ministry of Agriculture, Universidad Nacional de San Cristóbal.
Suriname	1	Ministry of Agriculture.
Trinidad and Tobago	5	Ministry of Agriculture; Caribbean Agricultural Research and Development Institute (CARDI); University of West Indies
Uruguay	1	Cooperativa Agropecuaria La Dolores.
Venezuela	2	Fondo Nacional de Investigaciones Agropecuarias (FONAIAP); Productora de Semillas Portuguesa.
Africa		
Kenya	1	National Seed Quality Control Service
Egypt	2	Crop Research Institute.
Asia		
Nepal	1	Agricultural Inputs Corporation
Turkey	1	Ministry of Agriculture.
Thailand	1	Ministry of Agriculture.

and strategies with national seed programs and seed enterprises; encouraging the development of long-term training plans with universities; and assistance to subregional groups and sister international centers. More countries are showing a high level of interest in giving their seed programs more clearly focused direction, and former trainees are also beginning to make an impact on in-country seed programs.

The subregional focus of the Unit is on Central America and the Andean Zone. Cooperation in Central America and the Technical Seed

Committee has resulted in two sets of regional guidelines, one on varietal description (published at CIAT) and one on post-harvest seed management (under development). With IICA (Inter-American Institute for Agricultural Cooperation), the regional Seed Advisory Committee is developing a plan to help meet seed training needs for Central America. The seed section of the Cooperative Centro-American Program for Improvement of Food Crops (PCCMCA) meeting in 1982 generated 25 papers and considerable participation in the seed portion of the meeting. In addition, in cooperation with the Andean Pact group, plans are being developed for joint work in various seed activities. A proposal has been drafted for collaboration with the Center for the Study and Training in Seed Technology at Pelotas, Brazil, in training, exchange of staff, and development of training materials.

The Seed Liaison Committee, composed of representation from CIGRAS (Center for Investigation in Grains and Seeds), CIMMYT, CIP, ICRISAT, IICA, Mississippi State University, and national organizations in the region, met and continued work on ways to improve collaborative efforts in seed development and training. CIMMYT sponsored three candidates in the last seed course at CIAT, and plans are being developed for Seed Unit staff members to assist in training at CIMMYT. Other kinds of cooperation are under review with other international agencies.

Seed Produced and Distributed

Seed production includes growing, drying, conditioning, storage, quality control, and distribution of seed. A rotating fund has been established to cover the expenditures and receive income for these activities, with the objective that CIAT's seed production operate on a self-financed basis. Seed growing is arranged through the Station Operations Unit at Palmira or Quilichao; on land on the CIAT farm used by the Seed Unit for training; on land utilized by a Program; or, in the case of one bean variety, with a grower outside CIAT. The seed produced and sold in 1982 is shown in Table 2. The seed not sold is stored in the warehouse and remains available for future requests. In addition, 10 ha of tropical legumes were planted at the request of the Tropical Pastures Program; crops include species of *Centrosema, Desmodium ovalifolium, Pueraria phaseoloides*, and various lines of *Stylosanthes capitata*. Also, the number of inbred lines of maize and sorghum were increased and supplies maintained to answer requests for this publically available material.

Improvements were made in the seed drying and conditioning facility, and the bag drying unit became operational in 1982. The commercial size and the laboratory unit of a friction separator constructed in 1982 are especially useful for separating both soil particles from beans and rough-coated seed from smooth-surfaced seed.

The seed testing laboratory continues to improve and offers a service to the commodity programs for seed-quality evaluations. Samples were prepared to standardize a blowing method for *Panicum maximum* and *Brachiaria decumbens*. These samples have been offered to key laboratories in Latin America and will facilitate seed purity evaluations on these species. The internal quality control work on seed produced through the Unit is managed by the head of the laboratory. A regular system of field inspections and testing of samples has been instituted.

Seed Technology Advanced through Communication

The quarterly *Seed Newsletter* was sent to a total of 1500 organizations and interested people in 1982. Through it, the Seed Unit provides seed technologists with information on its activities and developments in the region. People in

Table 2. Quantity of seed produced and distributed by the Seed Unit in 1982.

Varieties and country receiving seed	Amount produced (kg)[a]	Amount sold (kg)[b]
Beans	14,126[c]	4,146
Argentina		
BAT 58, BAT 271, BAT 304, A 211, A 231, A 235, DOR 41		
Colombia		
ICA-Llanogrande		
Costa Rica		
Chorotega, Huetar, BAT 41, BAT 76, BAT 304		
Honduras		
Copan		
Rice	108,650[d]	59,450
Colombia		
CICA 7, CICA 8, CICA 9, CICA 4, IR 22, Oryzica 1		
Pastures	3,209[e]	1,525
Venezuela		
Andropogon gayanus		
Perú		
Stylosanthes guianensis	110	83

a. Weight of seed uncleaned and with moisture
b. Seed cleaned and dried to 12% moisture
c. Includes 6,500 kg planned for Argentina.
d. Includes 24,800 kg held for ICA and 4,000 kg planned for Panama.
e. Includes 2,796 kg conditioned and 413 kg not conditioned.

individual countries have been identified to report information of interest from their area. Work has continued on audiotutorials, with three new study

With financial support from the Rockefeller Foundation, the Spanish edition of the IADS book *Successful Seed Programs: A Planning and Management Guide* was published to support seed development and training activities. A manual on *Methods for Varietal Description and Guidelines for Seed Production on Bean, Rice, Maize and Sorghum* is in production, and proceedings of the four workshops at CIAT are being published by CIAT.

Research and Development in Seed Technology Production and Distribution Problems

Theses research projects on environmental-variety interaction are now underway and will assist in defining characters to use in describing rice and bean varieties. Also, a study of the amount of mechanical damage caused at different points in the seed-conditioning operation of the Seed Unit facility has been initiated.

Many specialists and organizations both within and outside of Latin America and the Caribbean have contributed to courses, workshops, and the achievement of the Unit's objectives. Among these are ICA, Colombia; EMBRAPA, Brazil; various seed firms and Mississippi State University with assistance from USAID. Special recognition also goes to the Swiss Development Cooperation who financially supported most of these activities and made the Seed Unit a reality with its agreement to support this 5-year project starting in 1979.

Although much remains to be done, the Seed Unit is in an excellent position to cooperate with the commodity programs, national and international agencies, seed associations, and seed enterprises and to continue to play a catalytic role in accelerating the use of good seed of better varieties in the region.

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MMUNICATION TRAINING AND COMMUNICATION TRAINI

As a center for both research and training CIAT fosters a strong educational component for technology transfer to complement its technology generation and manpower development.

Scientific Training and Conferences

Manpower development through intensive group courses and individual internships remains the principal means through which CIAT collaborates with national programs to increase their capacity to conduct research in support of the commodities for which CIAT is mandated.

This postgraduate training takes the following forms:

- Intensive courses on production research for the CIAT commodities;
- Internships on a specialized aspect of any of the CIAT commodities;
- Thesis internships for M.S. and Ph.D. students.

In 1982, 237 professionals from 33 countries received training at CIAT (Table 1). The length of internships ranged from 1 to 12 months, with an average of 3.5.

Reflecting CIAT's close working relationships with collaborating institutions in Latin America and the Caribbean, as well as for reasons of proximity, fully 90% of all training participants come from this region. The number of representatives from each country is shown in Figure 1.

Some three-fourths of the training participants received commodity-based, nondegree-related training. Most of these individuals participated in one of the nine intensive short courses (of 4 to 12 weeks duration) offered by CIAT in 1982. Expanding on a practice that has proved to be very successful in the last few years, after completing their participation in the formal courses, about one-third of the students entered individualized internships with durations of 3 to 6 months.

The total number of professionals having received training at CIAT since the early 1970s now has surpassed 2300. Naturally, there has been some attrition of CIAT-trained professionals in collaborating national institutions. Nevertheless, CIAT maintains that a critical mass of trained scientists is available and that, in the future, increasing emphasis can be placed on relatively long-term (especially degree-related) CIAT training to assist national institutions in their efforts to further upgrade the scientific level of their personnel. It is in this context that CIAT provided thesis-research opportunities to 23 students working toward their master's degrees in 1982. In addition, 14 students conducted Ph.D. thesis research at CIAT; most of the Ph.D. students, however, came from developed countries where they pursue their academic studies with collaborating universities.

Concomitant with the release of new varieties in several collaborating countries, in 1982 CIAT again increased its efforts to provide assistance to in-country courses on the production of commodities in the Center's mandate. Typically, these courses are intended to help bridge the gap between research and extension and are aimed at personnel from both research and extension organizations. The courses are organized and conducted by collaborating national programs. CIAT's role is to provide organizational and technical assistance until such time that national programs are in a position to continue with the courses by themselves. In 1982, CIAT provided assistance to 14 in-country courses (eight in beans, two in rice, two in cassava, and two in seeds) in eight countries: Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Haiti, Honduras, and Nicaragua.

Twelve conferences—including workshops, seminars, and meetings—were held or

Table 1. Professionals trained at CIAT in 1982, by training category in each commodity and support unit.

	Trainees (no.)						
	Visiting research associates		Visiting researchers				
Program or unit	Ph.D. thesis	Non-thesis	M.S. thesis	Speciali-zation	Speciali-zation plus intensive course	Intensive course participants	Program subtotals
Commodity programs							
Beans	5	1	10	7	11	9	43
Cassava	3	1	2	17	11	5	39
Rice			3	1	12	3	19
Tropical Pastures	6	5	8	13	14	2	49
Total commodity programs	14	7	23	38	48	19	149
Support units and others							
Audiotutorial production				4	2	75	81
Laboratory management		1					1
Seed production and technology				4	2	75	81
Stations operation management				2			2
Total support units and others		1		10	2	75	88
Total	14	8	23	48	50	94	237

cosponsored by CIAT in 1982 to help in the exchange of knowledge and agreement of strategies in CIAT's commodity-research networks. Other noncommodity-specific conferences reviewed the state of the art in specific research fields. In addition, six major conferences were held in CIAT's facilities, sponsored by various Colombian institutions.

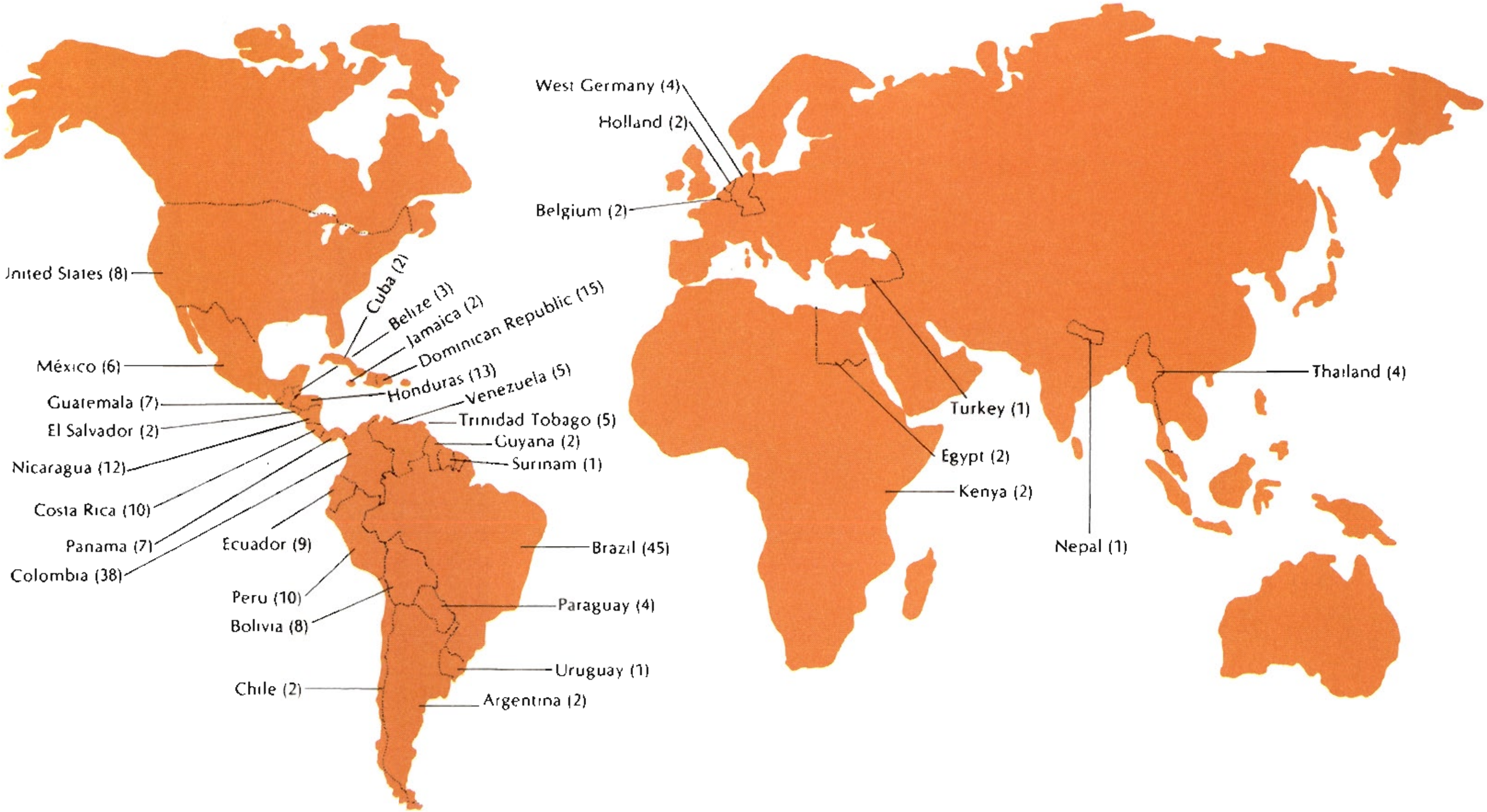
CIAT's extensive and persistant training efforts have proved to be instrumental in the successful creation and operation of the international commodity research networks in beans, cassava, rice (in Latin America), and tropical pastures. These network activities are described in detail in each of the program chapters in this report.

Communication and Information

The process of mutual interchange of information related to research also plays an integral role in technology development and transfer. CIAT's strong communication and information support component is illustrated by the large number and high quality of publications and audiovisuals/audiotutorials produced and distributed over the years and by the increasing emphasis on professional documentation services.

Publications range from quarterly newsletters that furnish up-to-date information about activities in each of CIAT's commodities and the Seed Unit; through network-based publications of research data (e.g., the IBYAN results), through manuals of guidelines for network collaborators, to monographs and books of research results. Each program also provides free of charge to network collaborators it's Annual Report. Beginning in 1982, a quarterly newsletter with broad information on all of CIAT's activities is also produced and distributed under the title of *CIAT International*.

Documentation services provide to subscribers



gure 1. *A total of 237 professionals from all over the world received training at CIAT during 1982.*

CIAT's strong educational component assists in technology transfer and complements its technology generation.

a quarterly journal of abstracts of all papers and publications for each of three commodities—beans, cassava, and tropical pastures—as well as monthly "pages of contents," with listings in several fields.

Over the last 3 years, CIAT's Audiotutorials Unit, a special project financed by the Kellogg Foundation, has gained a wide following for the quality and broad scope of the study units produced and distributed. In total, 99 audiotutorial units (consisting of a study guide, slide show with automatically pulsed cassette tape, and tapescript) have been developed at CIAT, providing trainees and others with an overall integrated picture of CIAT's research in all four commodities..

The utilization centers concept developed by this unit has resulted in nine centers in Bolivia, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Honduras, and Peru. A total of nine individuals from these centers received 27 training-months in the Audiotutorials Unit and are now capable of producing similar materials in their own national organizations.

The list of 1982 publications, documentation services, and audiotutorials follows.

Each year visiting researchers from throughout the world come to CIAT to receive training; this activity enhances decentralization and permits the establishment of collaborative networks in the four staple crops in CIAT's mandate.

CIAT 1982 Publications and Audiotutorials

Serials

	no copies	no pages
Commodity/Network Newsletters		
1. Arroz del CIAT para América Latina, nos. 5, 6, 7, 8	1200 ea.	4 ea.
2. Hojas de Frijol para América Latina, nos. 12, 13, 14, 15	900 ea.	4–6 ea.
3. Semillas para América Latina, nos. 5, 6, 7, 8, 9	1900 ea.	4 ea.
4. Yuca: Boletín Informativo, nos 10, 11	600 ea.	8–12 ea.
5. Cassava Newsletter, nos 10, 11	600 ea.	8–12 ea
6. Pastos Tropicales: Boletín Informativo, nos. 6, 7	600 ea	8–12 ea
Annual Reports (1981)		
1. Arroz	1100	104
2. Beans	1500	198
3. Cassava	1500	260
4. Pastos Tropicales	1500	302
5. Tropical Pastures	1500	304
Research Highlights		
1. CIAT International, Vol 1, Nos. 1, 2	3500 ea.	8 ea.
2. CIAT Internacional, Vol. 1, Nos. 1, 2	4500 ea.	8 ea.
3. CIAT Report 1982	3500	128
4. Informe CIAT 1982	4500	128
Abstracts (cumulative volumes)[a]		
1. Abstracts on Field Beans, Vol 6, 1981	600	276
2. Resúmenes Analíticos sobre Frijol, Vol. 6, 1981	600	294
3. Abstracts on Cassava, Vol 7, 1981	600	266
4. Resúmenes Analíticos sobre Yuca, Vol. 7, 1981	600	278
5. Resúmenes Analíticos sobre Pastos Tropicales, Vol. 3, 1981	600	266
6. Resúmenes Analíticos en Economía Agrícola Latinoamericana, Vol. 6, 1981	600	290
Journals of Abstracts[b]		
1 Abstracts on Field Beans, Vol. 7, nos. 1–3, 1982	280 ea.	av 122 ea
2 Resúmenes Analíticos sobre Frijol, Vol. 7, nos. 1–3, 1982	320 ea.	av 122 ea.
3 Abstracts on Cassava, Vol. 8 nos. 1–3, 1982	300 ea.	av. 111 ea.
4. Resumenes Analiticos sobre Yuca, Vol. 8, nos. 1–3, 1982	300 ea.	av. 111 ea.
5. Resumenes Analiticos sobre Pastos Tropicales, Vol 4, nos. 1–3, 1982	550 ea.	av 126 ea.
Pages of Contents (monthly):		
1. Agropecuaria General	488 ea	34 ea.
2. Fisiología Vegetal	306 ea.	12 ea
3. Protección de Plantas	304 ea.	18 ea
4. Suelos y Nutrición de Plantas	299 ea.	10 ea
5. Pastos Producción/Animal y Nutrición	255 ea.	20 ea.
6. Economia Agrícola/Desarrollo Rural	205 ea.	16 ea

a Yearly cumulative volumes of abstracts printed in card form ceased with these 1981 editions

b Abstracts appearing in journal form three times a year began in 1982 these replace the card forms and the annual cumulative volumes

Proceedings, Field Manuals, Technical Reports, and Monographs

		no copies	no. pages
1	Amazonia: Agriculture and Land Use Research (S. B. Hecht, ed.)	2000	428
2	Amazonia: Investigación sobre Agricultura y Uso de Tierras (S. B. Hecht, ed.)	2000	448
3.	Biological Nitrogen Fixation: Technology for Tropical Agriculture (P. Graham and S. C. Harris, eds.)	2000	726
4	Chlorotic Mottle of Beans (*Phaseolus vulgaris* L.) (W. U. Jayasinghe, ed.)	550	156
5.	Programas de Semillas: Guía de Planeación y Manejo (J. E. Douglas, ed.)	1500	358
6	Proceedings of the Fifth International Conference of Plant Pathogenic Bacteria (J. C. Lozano ed.)	2000	640
7.	Primer Taller Latinoamericano sobre Intercambio de Germoplasma de Papa y Yuca—Memorias (W. H. Roca, C. H. Hershey, and O. S. Malamud, eds.)	1000	296
8	Problemas de Campo en los Cultivos de Frijol en América Latina (C. Cardona, C. A. Flor, F. J. Morales, and M. A. Pastor-Corrales, eds.)	3000	184
9	Manual para la Evaluación Agronómica: Red Internacional de Evaluación de Pastos Tropicales (J. M. Toledo, tech. ed.)	1500	170
10.	Informe de la Cuarta Conferencia del IRTP para América Latina (M. Rosero)	200	78
11.	Report on the Fourth IRTP Conference for Latin America (M. Rosero)	200	70
12.	Yuca: Investigación, Producción y Utilización (C. Domínguez, ed.)		

Audiotutorials

		study guide (no. pp.)	slides (no.)
	Beans		
1.	La Mancha Angular del Frijol y su Control (H. F. Schwartz, F. Correa, and M. P. Corrales; produced by Héctor F. Ospina and Carlos Flor, 1982)	24	79
2.	La Mustia Hilachosa del Frijol y su Control (G. W. Gálvez, J. J. Galindo, and M. Castaño; produced by Héctor F. Ospina, Marceliano López, and Mayra Bonilla, 1982)	20	75
	Cassava		
3.	El Coquito (*Cyperus rotundus* L.): Biologia y Control (D. Leihner, J. Doll, and C. L. Fuentes de Piedrahita, produced by Cilia L. Fuentes de Piedrahita, 1982)	55	127
4.	El cultivo de Meristemas para el Saneamiento de Clones de Yuca (W. Roca and U. Jayasinghe; produced by Fernando Fernández O., 1982)	45	61
5	Intercambio Internacional de Clones de Yuca *in vitro* (W. M. Roca; produced by Fernando Fernández O., 1982)	30	72
6.	Multiplicación Acelerada de Material Genético Promisorio de Yuca (J. H. Cock, J. C. Toro, and W. M. Roca, produced by Fernando Fernández O., 1982)	25	75
	Rice		
7.	Descripción y Daño de los Insectos que Atacan al Arroz en America Latina (Y. C. de Galvis, J. Gonzalez, and J. Reyes, produced by Oscar Arregocés, 1982)	36	111
8.	Enfermedades del Arroz en América Latina y su Control (S. W. Ahn and P. R. Jennings; produced by Oscar Arregoces, 1982)	39	102
9	Fertilización Nitrogenada del Arroz (O. Arregocés and L. León; produced by Oscar Arregocés, 1982)	40	101

Tropical Pastures			
10	Cercópidos Plagas de los Pastos en América Tropical: Biologia y Control (M. Calderón, G. Arango, and F. A. Varela, produced by Carlos Valencia, 1982)	51	79
11	Descripción de las Plagas que Atacan los Pastos Tropicales y Caracteristicas de sus Daños (M. Calderón and F. A. Varela; produced by Carlos Valencia, 1982)	50	106
12	Efectividad Agronómica de las Rocas Fosfóricas (L. L. Hammond and L. A. León; produced by Oscar Arregocés, 1982)	40	80
13.	La Heterogeneidad del Suelo y los Ensayos de Uniformidad (J. A. Escobar; produced by Héctor F. Ospina, 1982)	24	76

Journal Articles and Paper Presentations

Garver, C. L. 1982. Senior staff in communication at international research centers. ACE Quarterly 65(4):43–46.

Harris, S.C. 1982. La experiencia del CIAT como centro de información especializada: consolidación e integración. Paper presented at the 13th Roundtable Meeting of the Inter-American System for Agricultural Information (AGRINTER), CIAT, Cali, Colombia.

Financial Statements

Price Waterhouse

CENTRO SEGUROS BOLIVAR
CARRERA 4 No. 12-41
APARTADO AEREO: 180
TELEFONO: 701-146
CALI - COLOMBIA

March 16, 1983

REPORT OF INDEPENDENT ACCOUNTANTS

To the Board of Trustees of

Centro Internacional de Agricultura
Tropical (CIAT)

In our opinion, the accompanying balance sheets and the related statements of revenue and expenditures and unexpended funds present fairly the financial position of Centro Internacional de Agricultura Tropical (CIAT) at December 31, 1982 and 1981 and the results of its operations for the years then ended, in conformity with generally accepted accounting principles consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our examination for the year ended December 31, 1982 also encompassed the schedules of analysis of grants and related expenditures, earned income, comparison of approved budget and actual expenditures and dates of receipt of grants for that year, which are presented as supplementary information, and, in our opinion, these schedules present fairly the information shown therein.

Price Waterhouse

BALANCE SHEET

(Expressed in thousands of U.S. dollars)

ASSETS	December 31 1982	December 31 1981
CURRENT ASSETS		
Cash	2,698	1,484
Accounts receivable		
Donors	316	273
Employees	447	275
Others	1,594	1,268
	2,357	1,816
Inventories	947	1,335
Prepaid expenses	52	69
Total current assets	6,054	4,704
FIXED ASSETS		
Equipment	4,441	3,682
Aeroplane	676	676
Vehicles	2,557	1,993
Vehicles (replacements) in transit	75	523
Furnishing and office equipment	1,364	1,286
Buildings	7,116	6,929
Others	201	201
Total fixed assets	16,430	15,290
Total assets	22,484	19,994

LIABILITIES AND FUND BALANCES	December 31 1982	December 31 1981
CURRENT LIABILITIES		
Bank overdrafts	40	44
Accounts payable	3,982	2,371
Total current liabilities	4,022	2,415
GRANTS RECEIVED IN ADVANCE	70	407
FUND BALANCES		
Invested in fixed assets	16,430	15,290
Unexpended funds (déficit)		
Core		
Unrestricted	165	(100)
Working fund	1,099	603
Capital grants		265
Special projects		
Donors	820	1,217
Others	(122)	(103)
	1,962	1,882
Total fund balances	18,392	17,172
Total liabilities and fund balances	22,484	19,994

The notes on page 110 are an integral part of the financial statements.

STATEMENT OF REVENUE AND EXPENDITURES AND UNEXPENDED FUNDS

(Expressed in thousands of U.S. dollars)

	December 31	
Revenue	1982	1981
Core		
Operating grants		
Unrestricted	10,447	9,283
Restricted	7,653	6,358
Working fund grant		
Capital grants	470	678
Total Core	18,570	16,319
Special projects	1,897	2,732
Earned income	926	540
Total revenue	21,393	19,591
Expenditures		
Core programs		
Crop research	6,311	5,554
Land resources research	4,592	3,949
International cooperation	2,374	2,165
Administration expenses	1,625	1,343
General operating costs	2,985	3,200
Total Core programs	17,887	16,211
Special projects	2,286	1,934
Fixed assets	1,140	1,096
Total expenditures	21,313	19,241
Excess of revenue over expenditures		
Operating grants	265	(100)
Working fund	244	70
Capital grants	(40)	(418)
Special projects	(389)	798
	80	350
Transfers between funds		
To (from) working funds	252	(327)
From special projects	(27)	(158)
(From) to capital grants	(225)	485
	80	350
Unexpended funds at beginning of year	1,882	1,532
Unexpended funds at end of year (see balance sheet)	1,962	1,882

The notes on page 110 are an integral part of the financial statements.

NOTES TO FINANCIAL STATEMENTS

NOTE 1 — ACCOUNTING POLICIES

The following significant accounting policies and practices of CIAT are set forth to facilitate the understanding of data presented in the financial statements.

Inventories

Inventories are stated at the lower of cost or market value, cost being determined on an average basis.

Fixed assets

Fixed assets are recorded at cost.

Depreciation

In conformity with generally accepted accounting principles applicable to nonprofit organizations, CIAT does not record depreciation of its property and equipment.

NOTE 2 — FOREIGN EXCHANGE

All foreign exchange transactions are controlled by the Colombian government and, accordingly, all foreign exchange received in Colombia must be sold through official channels. The following exchange rates were used to translate Colombian pesos (P) to U.S. dollars ($):

	P/$1	
Peso balances included in current assets and current liabilities	70.29	Year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	61.35	Average monthly rate of exchange applicable to sales of dollars

NOTE 3 — OPERATIONS

The land on which CIAT carries out its operations was ceded to CIAT under an agreement with the Colombian government which expires on July 15, 2000. The agreement may be extended thereafter by mutual consent, but if it is not, then CIAT will be obligated to relinquish its immovable assets on the land to the Colombian government.

SUPPLEMENTARY INFORMATION:
COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES FOR THE YEAR ENDED DECEMBER 31, 1982

(Expressed in thousands of U.S. dollars)

	Untestricted core		Restricted core		Capital	
	Approved budget	Actual	Approved budget	Actual	Budget	Actual
Crops research						
Office of the Director	236	224	72	80		
Beans	680	633	1,164	1,283		
Cassava	431	480	1,470	1,540		
Rice	65	110	627	643		
Genetic resources	232	257	65	55		
Research services	179	144	142	124		
Station operations	485	400	386	338		
	2,308	2,248	3,926	4,063		
Land resources research						
Office of the Director	200	194	61	77		
Tropical pastures	2,041	2,266	1,030	1,030		
Carimagua	367	237	263	248		
Data services	338	281	245	259		
	2,946	2,978	1,599	1,614		
International cooperation						
Office of the Director	165	173	6	6		
Training and conferences	377	276	501	400		
Communication support	571	537	436	433		
Documentation services	306	331	219	218		
	1,419	1,317	1,162	1,057		
Administration						
Board of Trustees	49	67	13	17		
Office of the Director General	143	176	36	47		
Controller	398	435	100	110		
Executive officer	597	617	145	156		
	1,187	1,295	294	330		

— *Continued*

Supplementary Information — *Continued*

General operating expenses						
Physical plant	1,036	1,067	267	265		
Motor pool	813	787	202	192		
General expenses	898	543	202	131		
	2,747	2,397	671	588		
Total Core	10,607	10,235	7,652	7,652		
Capital						
Fixed assets					1,036	1,140
Analysis of variances						
Underfunding		107				
Overexpenditure						(77)
Transferred from special projects funds						(27)
Surplus transferred to unexpended funds		265				
		372				(104)

Senior and Professional Staff

(as of December 1982)

OFFICE OF THE DIRECTOR GENERAL

Senior Staff
John L. Nickel, Ph.D., Dr.sc.agr. h.c., Director General

Fritz Kramer, Ph.D., Assistant to the Director General (New position beginning November 1982)

Assistants
Cecilia Acosta, Administrative Assistant

INTERNAL AUDITING

Associates
Luis Fernando Montoya, C.P.T., Internal Auditor

Assistants
Jorge Alberto Bermúdez, C.P.T., Internal Auditor
Orlando Millán, Internal Auditing

VISITORS' OFFICE

Associates
Fernando Mora, B.A., A.H.A., Head

Assistants
Rodrigo Chávez, Information Services
Jorge Enrique Paz, Ing. Agr., Information Services

FINANCE AND ADMINISTRATION

Senior staff
Andrew V. Urquhart, F.C.A., Director (New position beginning April 1982)

ADMINISTRATION

Senior staff
Jesús Antonio Cuéllar, M.B.A., Business Administrator, Executive Officer

General Administrative Services staff
José J. Cortés, Superintendent, Carimagua Station

Associates
Camilo Alvarez, M.S., Administrative Associate

Assistants
Ricardo Castañeda, Administrative Assistant, Government Relations (Bogotá)
Edgar Vallejo, Adm. Emp., Head, Travel Office

Food and Housing
General Administrative Services staff
David Evans, Head
*Eduardo Fonseca, Head

Human Resources
General Administrative Services staff
Germán Vargas, M.S., Industrial Administrator, Head

Assistants
Germán Arias, Abog., Personnel Officer

Maintenance Services
General Administrative Services staff
Germán Gutiérrez, Ing. Mec., Superintendent

Assistants
Marvin Heenan, Head, Motor Pool

Supplies
General Administrative Services staff
*Fernando Posada, M.S., Head

Assistants
*Percy de Castro, Head, Warehouse
*Marino López, Head, Imports
Diego Mejía, Head, Purchasing

FINANCE

General Administrative Services staff
Héctor Flórez, C.P.A., Assistant Controller
*Joffre E. Guerrero, Assistant Controller

Assistants
Alexis Corrales, Treasury (stationed in Carimagua)
Jaime E. Cumba, Budget
César Moreno, C.P.T., Accounting
Mario Rengifo, Cashier

*Left during 1982.

CROPS RESEARCH

Senior staff

Douglas R. Laing, Ph.D., Director

BEAN PROGRAM

Senior staff

Aart van Schoonhoven, Ph.D., Entomologist, Coordinator

Stephen Beebe, Ph.D., Plant Breeder, Central America Bean Project (stationed in Guatemala City, Guatemala)
Jeremy H. Davis, Ph.D., Plant Breeder, Plant Breeding
Guillermo E. Gálvez, Ph.D., Plant Pathologist, Regional Coordinator, Central America Bean Project (stationed in San José, Costa Rica)
*Peter H. Graham, Ph.D., Microbiologist, Microbiology
Francisco J. Morales, Ph.D., Virologist, Virology
Silvio H. Orozco, M.S., Agronomist, Central America Bean Project (stationed in Asunción Mita, Guatemala)
Douglas Pachico, Ph.D., Agricultural Economist, Economics
Marcial Pastor-Corrales, Ph.D., Plant Pathologist, Plant Pathology
Federico Scheuch, M.S., Agronomist, Peru/CIAT Bean Project (stationed in Lima, Perú)
Shree P. Singh, Ph.D., Plant Breeder, Plant Breeding
Steven R. Temple, Ph.D., Plant Breeder, Plant Breeding
Michael D. Thung, Ph.D., Agronomist, Agronomy (stationed in CNPAF, Goiânia, Brazil)
Oswaldo Voysest, Ph.D., Agronomist, Agronomy
Jonathan Woolley, Ph.D., Agronomist, Cropping Systems

Visiting scientists

*César Cardona, Ph.D., Entomology
*Ramiro de la Cruz, Ph.D., Physiology

Postdoctoral fellows

Michael Dessert, Ph.D., Plant Breeding
Guy Hallman, Ph.D., Entomology
James Nienhuis, Ph.D., Plant Breeding

Visiting research associates

Krista C. Dessert, M.S., Nutrition
*Julia Kornegay, M.S., Plant Breeding
Jeffrey Mackelroy, M.S., Plant Breeding

Research associates

José Ariel Gutiérrez, M.S., Plant Breeding
*Carlos Jiménez, M.S., Plant Breeding
Nohra R. de Londoño, Ing. Agr., Economics
Jorge Ortega, M.S., Agronomy
Jorge E. García, Ing. Agr., Entomology

Research assistants

*Bernardo Alzate, Ing. Agr., Agronomy
Jorge Beltrán, Ing. Agr., Cropping Systems
César Cajiao, Ing. Agr., Plant Breeding
*Horacio Carmen, Ing. Agr., Plant Pathology
Mauricio Castaño, Ing. Agr., Virology
Jesús A. Castillo, Ing. Agr., Physiology
*Fernando Correa, Ing. Agr., Plant Pathology
Carlos Francisco Chavarro, Ing. Agr., Coordination
Aurora Duque, Ing. Agr., Microbiology
Myriam C. Duque, Lic. Mat., Economics
Oscar Erazo, Ing. Agr., Agronomy
Diego Fonseca, Ing. Agr., Physiology
Oscar Herrera, Ing. Agr., Cropping Systems
Germán Llano, Plant Pathology
Carlos Mantilla, Ing. Agr., Entomology
Nelson Martínez, Ing. Agr., Agronomy
Carlos Aníbal Montoya, Plant Pathology
Gustavo Montes de Oca, Ing. Agr., Plant Breeding
Darío Ramírez, Ing. Agr., Plant Breeding
Gerardo Tejada, Ing. Agr., Agronomy

CASSAVA PROGRAM

Senior staff

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Anthony C. Belloti, Ph.D., Entomologist, Entomology
Guillermo G. Gómez, Ph.D., Nutritionist/Biochemist, Utilization
Clair Hershey, Ph.D., Plant Breeder, Plant Breeding
Reinhardt Howeler, Ph.D., Soil Scientist, Soil and Plant Nutrition
Kazuo Kawano, Ph.D., Plant Breeder, Plant Breeding (stationed in Rayong, Thailand)
Dietrich Leihner, Dr. agr., Agronomist, Cultural Practices
J. Carlos Lozano, Ph.D., Pathologist, Plant Pathology
John K. Lynam, Ph.D., Agricultural Economist, Economics
Julio César Toro, Ph.D., Agronomist, Agronomy

Visiting scientists
Rupert Best, Ph.D., Utilization
*Mabrouk El-Sharkawy, Ph.D., Plant Physiology
*Shinichu Sawada, Ph.D., Plant Physiology

Visiting specialists
Ewald Sieverding, Dr. agr., Soil and Plant Nutrition
Christopher Wheatley, Ph.D., Utilization

Postdoctoral fellows
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Visiting research associates
*Jan Margaret Salick, M.S., Entomology

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*Alvaro Amaya, M.S., Germplasm
Rafael Orlando Díaz, M.S., Economics
Rafael Alberto Laberry, M.S., Plant Pathology
Benjamín Pineda, M.S., Plant Pathology
*Jorge Santos, M.S., Utilization
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Luis Fernando Cadavid, Ing. Agr., Soils
Fernando Calle, Ing. Agr., Germsplasm
*Ernesto Celis, Ing. Agr., Agronomy
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*Lucy Kadoch, Lic. Biol., Physiology
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*Pedro Millán, Ing. Agr., Germplasm
Germán E. Parra, Ing. Agr., Physiology
Edgar Salazar, Ing. Agr., Cultural Practices
Mauricio Valdivieso, Zoot., Utilization
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RICE PROGRAM

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Peter R. Jennings, Ph.D., Plant Breeder, Plant Breeding (assigned by the Rockefeller Foundation)
César Martínez, Ph.D., Plant Breeder, Plant Breeding
Manuel Rosero, Ph.D., Plant Breeder, IRRI Liaison Scientist
Hector Weeraratne, Ph.D., Plant Breeder, Plant Breeding

Visiting scientists
Surapong Sarkarung, Ph.D., Plant Breeding

Postdoctoral fellows
Jairo Castaño, Ph.D., Plant Pathology
Rafael Posada, Ph.D., Economics

Research associates
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Research assistants
Luis Eduardo Berrío, Ing. Agr., International Trials
Luis Eduardo Dussán, Ing. Agr., Plant Breeding
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Eliseo Nossa, Ing. Agr., Plant Breeding
Miguel Eduardo Rubiano, Ing. Agr., Plant Pathology
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Federico Poey, Ph.D., Seed Specialist, Seed Production

Research associates
Joseph E. Cortés, Ing. Agric., Training

Research assistants
José F. Aristizábal, Ing. Agric., Seed Quality Control
José Fernández de Soto, Ing. Agric., Communication
Guillermo Giraldo, Ing. Agr., Seed Production
Napoleón Viveros, Ing. Agric., Seed Processing

GENETIC RESOURCES

Senior staff

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

Visiting research associates

*Thierry Vanderborght, Ir. agr., Germplasm (Beans)

Research associates

Germán Alvarez, M.S., Germplasm (Forages)
Rigoberto Hidalgo, M.S., Germplasm (Beans)

Research assistants

Javier Narváez, Ing. Agr., Physiology
Jorge Alberto Rodríguez, Ing. Agr., Physiology
Hember Rubiano, Ing. Agr., Germplasm (Beans)

LABORATORY SERVICES

Research associates

Octavio Mosquera, M.S., Analytical Services

Research assistants

Charles McBrown, Tec. Elec., Instruments Maintenance
Roberto Segovia, Ing. Agr., Greenhouses/Landscaping

EXPERIMENTAL STATIONS OPERATIONS

Senior staff

Alfonso Díaz-Durán, Ing. Agric., P.E., Superintendent

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Javier Carbonell, M.S., Palmira Station
Javier Castillo, Ing. Agric., Head, Popayan Substation
Ramiro Narváez, Ing. Agric., Head, Quilichao Substation
Edgar Quintero C., Ing. Agr., Palmira Station

RESOURCES RESEARCH AND INTERNATIONAL COOPERATION +

Senior staff

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*José Valle-Riestra, Ph.D., Director, International Cooperation

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Uriel Gutiérrez, M.S., Administrative Associate
*Jorge Peña, M.S., Administrative Associate

TROPICAL PASTURES PROGRAM

Senior staff

José M. Toledo, Ph.D., Pasture Agronomist, Coordinator

Eduardo Aycardi, Ph.D., D.V.M., Animal Scientist, Animal Health
Rosemary S. Bradley, Ph.D., Soil Microbiologist, Microbiology
Mario Calderón, Ph.D., Entomologist, Entomology
Walter Couto, Ph.D., Soil Scientist, Pasture Development (stationel in CPAC, Brasilia, Brazil)
John E. Ferguson, Ph.D., Agronomist, Seed Production
Bela Grof, Ph.D., Agrostologist, Legume Agronomy (stationed in Carimagua)
Carlos Lascano, Ph.D., Animal Scientist, Pasture Quality and Animal Nutrition
Jillian M. Lenné, Ph.D., Plant Pathologist, Plant Pathology
John W. Miles, Ph.D., Plant Breeder, Agronomy/Forage Breeding
C. Patrick Moore, Ph.D., Animal Scientist, Cattle Production Systems (stationed in CPAC, Brasilia, (Brazil)
Esteban A. Pizarro, Ph.D., Agronomist, Regional Trials
José G. Salinas, Ph.D., Soil/Plant Nutritionist, Soil and Plant Nutrition
Rainer Schultze-Kraft, Dr. agr., Agronomist, Germplasm
Carlos Seré, Dr. agr., Agricultural Economist, Economics
James M. Spain, Ph.D., Soil Scientist, Pasture Development (stationed in Carimagua)
Luis E. Tergas, Ph.D., Agronomist, Pasture Productivity and Management
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Raúl R. Vera, Ph.D., Animal Scientist, Cattle Production Systems

+ International Cooperation combined with Land Resources Research as of November 1982.

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Haruo Hayashi, B.S., Pasture Productivity and Management

*E. Mark Hutton, D.Sc., Legume Improvement

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*Raymond F. Cerkauskas, Ph.D., Plant Pathology (stationed in Brasilia, Brazil)

*Frank Müller, Dr. agr., Cattle Production Systems (stationed in Carimagua)

Saif ur Rehman Saif, Dr. agr., Soil Microbiology (stationed in Carimagua)

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*Gerhard Keller-Grein, Dipl. agr., Germplasm

Martin Schneichel, Dipl. agr., ETES Project (stationed in Puerto Gaitán, Colombia)

*Isabel Valencia, M.S., Pasture Development (stationed in Carimagua)

*Linus Wege, M.S., Agronomy (stationed in Carimagua)

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Edgard Burbano, M.S., Soil Microbiology

*Carlos E. Castilla, M.S., Agronomy/Regional Trials

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Rubén Darío Estrada, M.S., Economics

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Carlos Escobar, Ing. Agr., Soil and Plant Nutrition

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Fabiola de Ramírez, Lic. Bact., Soil Microbiology

Raimundo Realpe, Ing. Agr., Agronomy (stationed in Carimagua)

Bernardo Rivera, D.V.M., Animal Health (stationed in Carimagua)

Manuel Sánchez, Ing. Agr., Seed Production

Celina Torres, Ing. Agr., Plant Pathology

Fernán Alberto Varela, Ing. Agr., Entomology

*Jaime Velásquez, Zoot., Pasture Productivity and Management (stationed in Carimagua)

*Bernardo Velosa, Ing. Agr., Forage Breeding/Legume Improvement (stationed in Carimagua)

IFDC/CIAT PHOSPHORUS PROJECT

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Alfredo Rojas, Biometrics
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(New organization beginning November 1982)

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*Cilia Fuentes de Piedrahita, Ing. Agr., Production
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Ana Lucía de Román, Ing. Agr., Network Communication

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Alexandra Walter, Scientific/Technical Communication

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Carlos Rojas, Supervisor, Graphic Design

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Carlos Vargas, Graphic Design

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*Carlos P. González, Ing. Agr., Bean Documentation
Francy González, Ing. Agr., Bean Documentation
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Lynn Menéndez, Editing and Translations
Piedad Montaño, Supervisor, Acquisitions
Hernán Poveda, Lic. Bibl., Supervisor, Technical Processes
*Himilce Serna, Lic. Bibl., Technical Processes (Books)

SCIENTIFIC TRAINING AND CONFERENCES

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Postdoctoral fellows
Jairo Cano, Ph.D., Training Evaluation

General Administrative Services staff
Alfredo Caldas, M.S., Admissions Administrator

Associates
Carlos Domínguez, M.S., Cassava
Carlos Flor, M.S., Beans
Elías García, Ing. Agr., Rice
Marceliano López, M.S., Tropical Pastures
Jesús Reyes, M.S., Cassava
Eugenio Tascón, Ing. Agr., Rice/In-country Training

Assistants
Carlos Suárez, B.S., Orientation

REPRESENTATION OF COLLABORATING INSTITUTIONS IN CIAT

Andean Region Maize Project (CIMMYT)

Senior staff
Gonzalo Granados, Ph.D., Entomologist, Head
James Barnett, Ph.D., Plant Breeder, Andean Regional Services

Research assistants
Edgar Castro, Ing. Agr., Plant Breeding

Regional Sorghum Project (INTSORMIL)

Senior staff
Lynn Gourley, Ph.D., Plant Breeder, Head

Research Assistants
Manuel Coronado, Ing. Agr., Plant Breeding

CIP Regional Representation

Oscar Malamud, Ph.D., Liaison Officer, Head (stationed in Bogotá)
Jan Henfling, Ph.D., Liaison Officer (stationed in Medellín)

GTZ Regional Representation

Günther John, Dr. agr., Liaison Officer

IBPGR Regional Representation

Miguel Holle, Ph.D., IBPGR Representative for Latin America

REGIONAL AND BILATERAL PROJECTS

Agricultural Research and Extension Project, INIPA, Peru (World Bank)

Edward Pulver, Ph.D., Co-leader, Rice (stationed in Tarapoto, Perú)

CGIAR

Consultative Group for International Agricultural Research

THE CONSULTATIVE Group for International Agricultural Research (CGIAR) was formed in 1971 to provide a mechanism for mobilizing broadbased financial support for the global system of 13 international agricultural research centers and organizations. The creation of CGIAR indicated the desire of donor agencies to provide long-term support for agricultural development in the developing world. In addition, in consultation with the Technical Advisory Committee—a panel of top-level scientists who oversee the research programs of the centers — CGIAR is able to assure financial donors that their resources are being used to achieve maximum benefits.

The soundness of this system is evidenced by the fact that donor membership in CGIAR has grown from 15 in 1972, who contributed about US$20 million, to 35 in 1982, with a total contribution of about US$145 million.

Each center (of which CIAT is one, see front endpaper) or organization in the CGIAR system is autonomous, with its own Board of Trustees or other governing body. Each develops its own budget for funds provided by CGIAR, consistent with the total money pledged to be available for the coming year and the center's program in relation to the goals of the system. Each center budget is submitted annually during the center's review week, when a short overview of its programs and accomplishments is presented before the body of CGIAR donors and other representatives.

CGIAR operates informally and by consensus and provides an outstanding example of effective, flexible, and successful cooperation between the industrialized and developing worlds. Headquarter offices are furnished by the World Bank in Washington, D.C. The Bank also provides the services of a Chairman and an Executive Secretariat. The Secretariat of the Technical Advisory Committe is provided by the Food and Agriculture Organization of the United Nations in Rome.

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

- International Center for Tropical Agricultural (CIAT), Cali, Colombia: cassava, field beans, rice, and tropical pastures.
- International Center for Maize and Wheat Improvement (CIMMYT), El Bataan, Mexico: maize and wheat.
- International Potato Center (CIP), Lima, Peru: potatoes.
- International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria: farming systems, cereals, food legumes (broad bean, lentil, chickpea), and forage crops.
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India: chickpea, pigeonpea, pearl millet, sorghum, groundnut, and farming systems.
- International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima bean, soybean).
- International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya: trypanosomiasis and theileriosis of cattle.
- International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia: livestock production systems.

- International Rice Research Institute (IRRI), Los Baños, the Philippines: rice.
- International Board for Plant Genetic Resources (IBPGR), Rome, Italy: plant varieties collection and information.
- International Food Policy Research Institute (IFPRI), Washington, D.C., USA: analysis of world food problems.
- International Service for National Agricultural Research (ISNAR), The Hague, the Netherlands: research support.
- West Africa Rice Development Association (WARDA), Monrovia, Liberia: rice.

CIAT Report 1983

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