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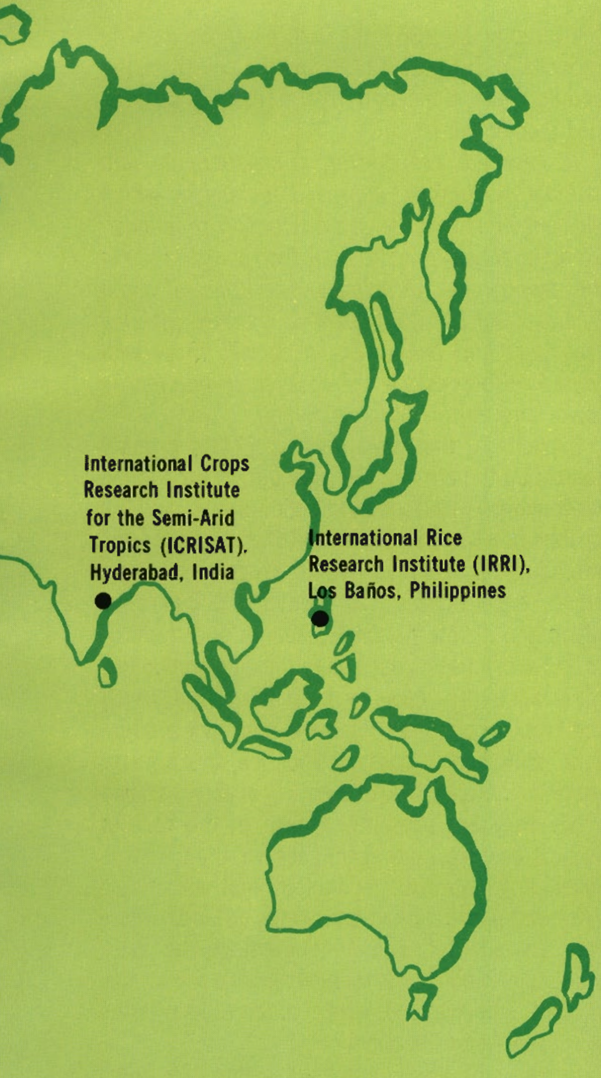
CIAT REPORT 1980

Centro Internacional de Agricultura Tropical
Apartado Aéreo 6713
Cali, Colombia

Contents

International Research in Agriculture

CGIAR



The Consultative Group for International Agricultural Research (CGIAR) was formed in 1971 to provide a mechanism for mobilizing broad-based financial support for international agricultural research and development. Although four international centers had already been formed and were being supported, creation of the CGIAR signified the desire of donor agencies to continue long-term support of agricultural development utilizing a system of high-level analyses of needs and achievements.

Acting on the advice of its Technical Advisory Committee — a panel of top-level scientists which broadly oversees the technical programs of the centers — the CGIAR is able to assure financial donors that their resources are being utilized to achieve maximum research and development benefits. The soundness of this administrative system is evidenced by the fact that donor membership in the CGIAR has grown from 15 in 1972 (contributing about US$20 million) to 30 donors in 1979 (providing about US$100 million). CIAT is one of 12 international agricultural research centers or center-related entities receiving support from the CGIAR.

Each center or other organization in the system is autonomous, usually with its own board of trustees or other governing body. Each develops its own budget, consistent with its objectives and the overall framework goals of the CGIAR system. Individual center budgets are submitted annually for the International Centers' Week, during which each center presents a short review of its program and accomplishments before the body of CGIAR donors and other representatives. Funds are provided for each center's budget, 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.

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

CIAT - An Overview

Chartered in late 1967, the Centro Internacional de Agricultura Tropical (CIAT) was the fourth of the world's international agricultural research centers. CIAT's objective is:

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

Explicit in this statement is CIAT's primary dedication to help improve agricultural production in a region — the tropics of Latin America and the Caribbean. Over its years of development CIAT has attempted to mold its overall program into one which best utilizes the Center's comparative advantage in international research and training. To this end, it has focused on four food commodities important in the region — dry beans, cassava, rice and tropical pastures (for beef and milk production). With beans, cassava and rice, the primary goal is to increase the productivity of each on lands where they are presently grown. In the case of tropical pastures and again cassava, the Center is developing improved technology that will enable increased production of both crops on lands where they are adapted and can potentially be more productive. Such lands include millions of hectares of acid, infertile soils where other crop species cannot be grown economically.

Because of the interactions within the international centers network, each center has clearly defined zones of responsibilities. Therefore, while CIAT is fully responsible for the international development and improvement of four commodities within the tropics of the Western Hemisphere, it also works in other regions. Among

CIAT's Donors during 1980

CIAT receives funds for annual operations from the members of the Consultative Group for International Agricultural Research (CGIAR). During 1980 CGIAR members contributing to the Center's Core program are: the governments of Australia, Belgium, Canada, Germany, Japan, the Netherlands, Norway, Switzerland, the United Kingdom, and the United States; The Rockefeller Foundation and The Ford Foundation; and the Commission of the European Communities, the Inter-American Development Bank, the International Bank for Reconstruction and Development, and the International Fund for Agricultural Development.

Funding for various Special Projects and other non-Core activities is being provided by the governments of the Netherlands, Switzerland and the United States; and by The Kresge Foundation, The Rockefeller Foundation, the International Development Research Centre (Canada), and the United Nations Development Programme.

the centers, CIAT has worldwide responsibility for work with *Phaseolus* beans, and responsibility in all regions except Africa for improvement of cassava. Rice improvement activities are restricted to Latin America but still depend somewhat upon technical cooperation with the International Rice Research Institute, especially for the interchange of germplasm material. While not a part of CIAT's basic program, the Center also furnishes a base location for maize improvement activities in the Andean region, in cooperation with the Centro Internacional de Mejoramiento de Maíz y Trigo, in Mexico.

CIAT's headquarters is a 522-hectare farm located between Cali and Palmira, in southwest Colombia. Here scientists are backed by a full complement of support activities and, depending on the commodity, are able to conduct preliminary field research as well as laboratory, screenhouse and glasshouse evaluations. The Center also leases for a nominal rent from the Colombian Fundación para la Educación Superior (FES) a 188-hectare farm (CIAT-Quilichao) 50 kilometers south of Cali. There preliminary evaluations are done for crop adaptation to poorer soils. In the Eastern Plains (the Llanos) of Colombia, at Carimagua, CIAT co-manages, with the Instituto Colombiano Agropecuario (ICA), a large ranch where extensive work is done with tropical pastures and cattle, and with cassava.

CIAT also maintains cooperative agreements with other national and regional institutions to help carry out regional and international testing activities at many locations. In some cases, these agreements help support out-posted staff members who conduct research or manage outreach networks.

Board of Trustees

Foreword

The physical product of an international agricultural research center like CIAT is improved germplasm, complemented by associated improved management practices. Virtually everything we do as a group of scientists relates in some way to producing, evaluating and distributing genetic material that will perform better than anything before.

The critical food situation facing the world dictates that we work urgently. In our earlier years as an international center we responded to this sense of urgency by directing our efforts to evaluating, selecting and distributing germplasm that had been developed by others. These materials included commercial cultivars and advanced breeding lines. Many of these have been found superior to local materials in locations other than those for which they were developed. The early distribution of such germplasm selections has thus already provided various national programs with useful cultivars while the time-consuming processes of hybridization and selection are going on. Now CIAT is at the point that increasing amounts of our own products are being distributed as the results of our interdisciplinary breeding efforts have reached advanced stages of development and testing.


Beans

The movement of germplasm can be compared to flows occurring in a pipeline. Materials that include existing cultivars, advanced materials from national programs, and CIAT's own advanced lines, enter at various inlets and flow forward through a complex series of testing networks. These networks depend heavily upon the full cooperation of collaborators at regional, national and local levels. A few of these materials finally leave the pipeline at the outlets of our customers — the national programs which will work to see that the new varieties are adapted to local conditions and adopted by farmers.

It is easy to fill up the pipeline. The vast amount of germplasm existing today from all sources and emerging from hybridization activities could insure the pipes are always full. Our pipeline, however, has a unique design with a number of "check valves" that permit only the better materials to flow through. In fact, as materials move through the line towards the customer, they must be refined continuously. The highlights of our work in 1979 largely reflect these methods of refinement we are incorporating to assure that germplasm materials under our responsibility move efficiently and rapidly to our customers. They show that very promising material is indeed flowing from the CIAT pipeline to the conduits of national programs. Equally exciting are the many further improvements advancing through earlier stages in the pipeline.


Tropical Pastures

As is evident in the reports of our four commodity programs, we still depend heavily upon existing cultivars of the various species. They are the sources for each and every favorable character we seek to isolate and incorporate into improved materials. Isolating these characters in order to make efficient use of them has always been an important goal. This year, several screening methodologies were modified and improved to help our scientists be sure they are selecting the most valuable materials for use as parents and rejecting useless material most efficiently.

Whether we are working with existing germplasm or new materials, to perform to their potential these cultivars and lines must be adapted to local conditions and growing practices. Our programs are aware of this requirement and are working to understand the complex environmental relationships existing in their respective target areas. While we do not expect to produce a great amount of new materials specifically adapted to each of the myriad of local conditions throughout our zone of influence, we do need to understand how various local factors of the environments are going to affect performances of materials emerging from our programs.

A great deal of the progress we report results from our strong collaboration with counterpart workers in Latin America and the Caribbean, in Asia, and other parts of the world. We can provide many nursery sets to agricultural workers, but this action is of no use to us or others unless we receive complete, accurate data from local performance evaluations. It is, therefore, satisfying to note the immense value of the fine collaboration we are receiving at the various control points along the pipeline. Our investments in providing training to hundreds of professionals in past years is now paying great dividends as our scientists are able to work closely and productively with these former trainees. More importantly perhaps, we are observing the excellent work going on to meet local needs within respective countries.

Our accomplishments in 1979 resulted from carefully chosen mixtures of both narrow- and broad-based projects. The fact that our programs have been able to sharply define their respective goals, establish priorities, develop the proper strategies for reaching them and move new technology well along their pipelines clearly demonstrates our evolution as a Center.

Last year we mentioned our maturity will be measured "by the quantity and, ultimately, the degree to which the new technologies are included in the adaptative/validative research endeavors by our national program clients and are finally adopted by their farmers". We believe results this year show we are making significant progress towards the first part and that the second will soon follow.

I take this opportunity to congratulate my colleagues at CIAT and our colleagues in national programs for the very real progress summarized in this report — and to thank our donors whose generosity and concern have made this possible.

John L. Nickel
Director General


Cassava


Rice

Grain legumes are traditionally important sources of protein in many parts of the world, and especially in developing areas. The United Nations Food and Agriculture Organization (FAO) has estimated annual world bean production at 12.4 million tons, during 1975-77. Latin America, producing 4.7 million tons or 38 percent of the total, is the most important zone. Eastern Africa is the next most important zone, producing 0.8 million tons annually. While these total world production data include various edible legumes, in both Latin America and Eastern Africa the edible legumes produced are almost wholly dry beans *(Phaseolus vulgaris)*.

In Latin America, where CIAT has up to now concentrated its efforts in *Phaseolus* improvement, dry bean production has lagged substantially behind the average population growth rate of 2.8 percent. Despite the rapid increase in imports in several countries of the region, per capita consumption of beans has declined from 16.8 to 13.5 kg/year, over the region. Although production has increased slightly each year during the past 15 years, increases have been through expansion of the area planted. Over the entire region average yields have decreased and now are below 600 kg/ha. This represents a large gap between actual and potential yields.

Bean Program

INTRODUCTION

The objective of the CIAT Bean Program is to produce, in collaboration with national programs, technology to improve bean productivity. The Program seeks to accomplish its objectives by developing improved genotypes which incorporate resistance or tolerance to several important stress factors; through developing better agronomic practices compatible with both the improved genotypes and the various systems of cultivation practiced by bean farmers; by training personnel from national programs; and, through international cooperation to develop strong bean research networks in Latin America and Eastern Africa.

During 1979, the Bean Program made significant advances in each of these four areas. Most improved lines which entered international testing this year carried resistance to major pest problems, including the high-priority diseases bean common mosaic virus (BCMV), rust, common bacterial blight, angular leaf spot, anthracnose, and the leafhopper insect. Improvements were made in screening for reactions to important stress factors, and management schemes were adjusted to enable more efficient evaluations of the Program's nurseries. Methodologies were clarified for the breeding and early generation evaluation of climbing beans. The movement of advanced, promising breeding lines and commercial cultivars among countries of the region increased during the year.

In agronomic studies, nitrogen fixation was achieved under rather high temperatures in the field. Materials were identified that showed tolerance to moderately acid soils and low levels of soil phosphorus. Experiments at the farm level confirmed that certain low-cost technological components are profitable and can significantly increase bean yields.

Training activities were strong in the Program during 1979. While training was mainly offered to professionals from Latin America, the first trainees from Eastern Africa also worked in CIAT this year.

Two CIAT conferences-workshops — on bean diseases and bean breeding strategies — brought together scientists from national programs in Latin America and elsewhere. Publication of a newsletter for Latin American bean workers was initiated and several other reports were issued to help provide timely and useful information.

SCREENING OF GERMPLASM FOR DESIRED TRAITS

In 1979, the Genetic Resources Unit added more than 5000 new germplasm accessions of *Phaseolus* species to CIAT's holdings of this genus. The number of accessions in the bank now totals almost 27,000 of which 24,000 are *Phaseolus vulgaris*.

Basic to the accomplishment of the Bean Program's goals of producing and distributing improved germplasm is the identification and utilization of variability in parent materials for specific breeding projects. Therefore, as part of the management of this collection, scientists in the Genetic Resources Unit and the Bean Program are systematically evaluating all accessions for 32 basic characters. This will permit promising materials to be selected and utilized either by Bean Program scientists at CIAT or by bean workers elsewhere.

Evaluations of the first 10,000 accessions of *P. vulgaris* were completed during the year. The materials were planted in various locations in Colombia to observe their adaptation over a range of environments and their reactions against various stress factors.

Resistance to Diseases

Bean common mosaic virus (BCMV) is one of the most widespread disease problems in Latin America. Screening of the 10,000 accessions was done in the screenhouse (inoculations) and in the field at CIAT-Palmira and Popayan this year. Only 8.7 percent of the materials were uniformly resistant and 13.8 percent showed variable reactions. These latter accessions will be screened

Table 1. **Climatic data for CIAT bean research locations mentioned in this report.**

Location (Colombian departamento)	Altitude (masl)	Mean temp. (°C)	Mean rainfall (mm/year)
Principal			
CIAT-Palmira (Valle del Cauca)	1000	23.7	1000
Popayan (Cauca)	1850	17.9	1600
Secondary			
CIAT-Quilichao (Cauca)	1052	24.8	1845
Huila (4 areas) (Huila)	900-1300	17.0-23.0	1100-1500
La Selva (Antioquia)	2200	18.0	1500
Obonuco (Nariño)	2710	13.0	575
Restrepo (Valle del Cauca)	1500	19.9	1000
Santa Fe (Antioquia)	400	26.7	1120

[1] In cooperation with the Secretary of Agriculture, Cauca

[2] In cooperation with the Instituto Colombiano Agropecuario (ICA)

against specific strains of BCMV to eliminate additional susceptible and segregating materials.

Results from four years of testing a group of promising materials in the International Bean Rust Nursery (IBRN) showed that while all entries were susceptible at one or more locations during one or more years, several entries were widely resistant to many of the rust race complexes present throughout Latin America and other parts of the world. This year, more than 30 sets of the 1979-80 IBRN were dispatched.

Figure 1 shows the location-specific and time-specific variability for 41 standard monitoring entries in the IBRN. These contrasting locations and seasons form a complementary germplasm testing network capable of demonstrating which entries have wide or intermediate resistance to the pathogenic variability in rust populations present in these areas.

At Popayan, the 10,000 germplasm entries received multiple inoculations with anthracnose and angular leaf spot. About 300 materials were selected as promising for local adaptation and resistance to one or both of the diseases. These will be evaluated more intensively in coming seasons.

Approximately 1000 advanced breeding lines, all resistant to BCMV, were inoculated and evaluated as seedlings in the screenhouse for reaction to common bacterial blight. About 5 percent showed resistant or intermediate reactions. In addition, 1500 breeding lines were tested in the glasshouse against halo blight with about the same percentage showing resistant reactions to Colombian isolates of the pathogen. Resistant selections from both groups will be retested to confirm their reactions.

Resistance to Insects

Another 4000 materials were evaluated this year for resistance to leafhopper (*Empoasca kraemeri*) with about 5 percent showing high levels of tolerance. Special emphasis is directed toward selecting red-seeded materials, since little resistance has been identified in germplasm bank accessions of this seed color.

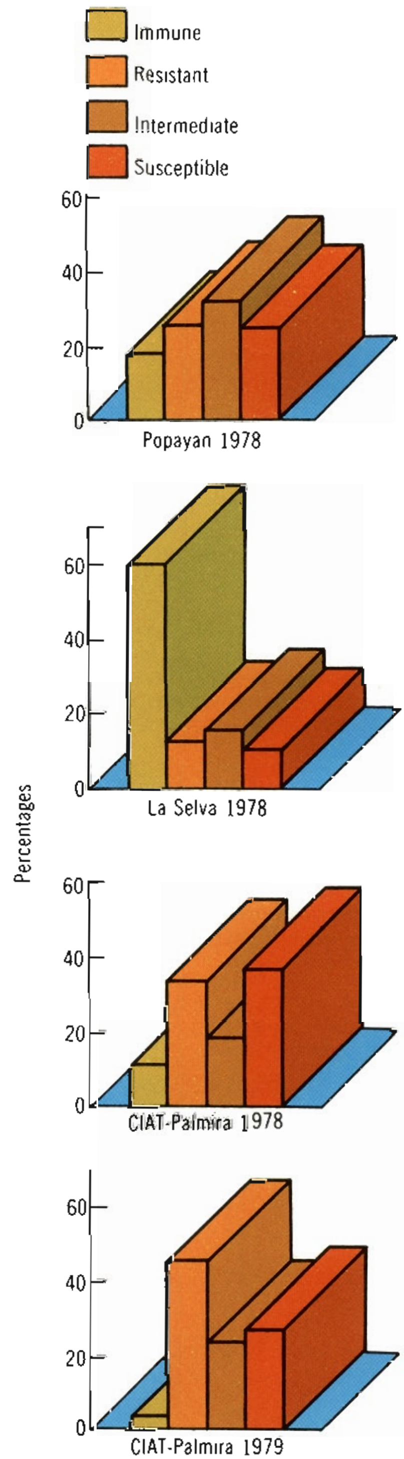


Figure 1.
Pathogenic variability displayed by bean rust populations which infected International Bean Rust Nursery (IBRN) monitoring entries in various locations in Colombia.

Figure 2.
This field at Popayan contains 10,000 bean accessions (each hill of a few plants includes one accession) that are being evaluated simultaneously for reaction to angular leaf spot and anthracnose.

Figure 3.
The acid, infertile soil at the CIAT-Quilichao substation makes this an ideal location to screen bean materials for adaptation to poor soil conditions, in this case, for their reactions to low levels of phosphorus.

Figure 4
A few materials, such as this accession from Brazil that Agronomist Michael Thung holds, tolerate moderately acid soils and low phosphorus levels.

An International *Empoasca* Nursery was assembled and sent to seven Central American and Caribbean countries. The nursery includes 54 materials selected for tolerance or resistance under high levels of infestation in CIAT fields.

Tolerance to Moderately Acid Soils

In many Latin American areas bean production is being forced onto marginal fertility land. Problems on many of these lands include low available phosphorus, and soil acidity with attendant high levels of aluminum and manganese. While the Bean Program is not specifically developing materials adapted to acid, infertile tropical soils, it is identifying genotypes that perform well under moderately acid conditions.

This year the screening system was modified so actual yield under these stress factors can be used to show tolerance to poor soil conditions. Of the cultivars tested, some from Brazil were identified as the highest yielders under low phosphorus levels and moderate soil acidity. Some of these have already been used in crosses for resistance to anthracnose and improved architecture.

Plant Architecture

Among the 10,000 germplasm accessions screened at four locations in Colombia, various promising materials were selected for their small leaves, short internodes and small pods. Each of these characters is being evaluated for its potential in improving yields.

Tolerance of Drought Stress

Results of two years of testing in CIAT-Palmira revealed 15 germplasm materials and hybrid selections that performed favorably under conditions of drought stress. Eight more materials performed differently between seasons but also appeared to possess tolerance.

Adaptation to Extreme Temperatures

Very few bush bean varieties were adapted either to a mean growing temperature of 14°C (Obonuco location) or to 28°C (Santa Fe location), and none was adapted to both locations. A few materials have been identified that are suitable as parental sources to improve adaptation to extreme temperatures. Results of climbing bean evaluations for temperature adaptations are reported under Climbing Bean Improvement.

Figure 5.
A new technique for inoculating with common bacterial blight has proven very rapid and effective for evaluating large numbers of materials. Second-trifoliate leaves are nicked with two razor blades while in contact with a sponge saturated with blight spores.

Figure 6.
After 10 to 14 days, good infections of bacterial blight are clearly evident in susceptible bean materials.

BREEDING AND EVALUATION OF IMPROVED MATERIALS

The major part of the Bean Program's work to improve *P. vulgaris* germplasm is centered around breeding projects designed to upgrade and combine specific characters in the species. Promising materials emerging from these projects enter a four-level screening process summarized in Figure 7. In addition to breeding lines from CIAT projects, promising materials from national programs or germplasm bank accessions may also be included in these evaluations.

Progress in Major Breeding Projects

Table 2 shows the number of crosses made in 1979 for the various breeding projects in the Bean Program. Activities in some of the specific projects are discussed in the following paragraphs.

Table 2. **Numbers of crosses made in 1979 in various CIAT bean breeding projects.**

Breeding project	No. of crosses
Resistance to:	
Angular leaf spot	43
Anthracnose	170
Apion	21
Bean common mosaic virus (BCMV) (backrosses, multiple genes)	244
Bean golden mosaic virus (BGMV)	418
Common bacterial blight	76
Empoasca	117
Rust	19
Multiple factors	63
Tolerance to:	
Drought	0
Extreme temperatures	6
Low soil phosphorus	61
Architecture and yield	198
Climbing beans (including BCMV, common bacterial blight, *Empoasca* and rust resistances)	193
Maturity ranges	11
National cultivar upgrading	111
Nitrogen fixation	239
Other	75
Total	2065

Bean Common Mosaic Virus (BCMV)

The objective of this project is to incorporate the dominant *I*-gene resistance for BCMV into commercial cultivars now susceptible to this important seed-transmitted virus and to protect the *I* gene from necrosis-inducing strains of BCMV. Collaborators at the Plant Breeding Institute, in the Netherlands, have identified F_3 families with combinations of multiple recessive resistance genes. Several backcrosses will be required to incorporate this multiple gene resistance into materials having favorable agronomic backgrounds.

Rust

As a result of multilocational testing, including IBRN results, many new sources of resistance to rust were included in the crossing block to help secure the frequency and stability of resistance to this high-priority disease. Currently, most crosses made in the Program have at least one rust-resistant parent. Some of the new sources include different types of resistance and inheritance studies of this variability have been initiated.

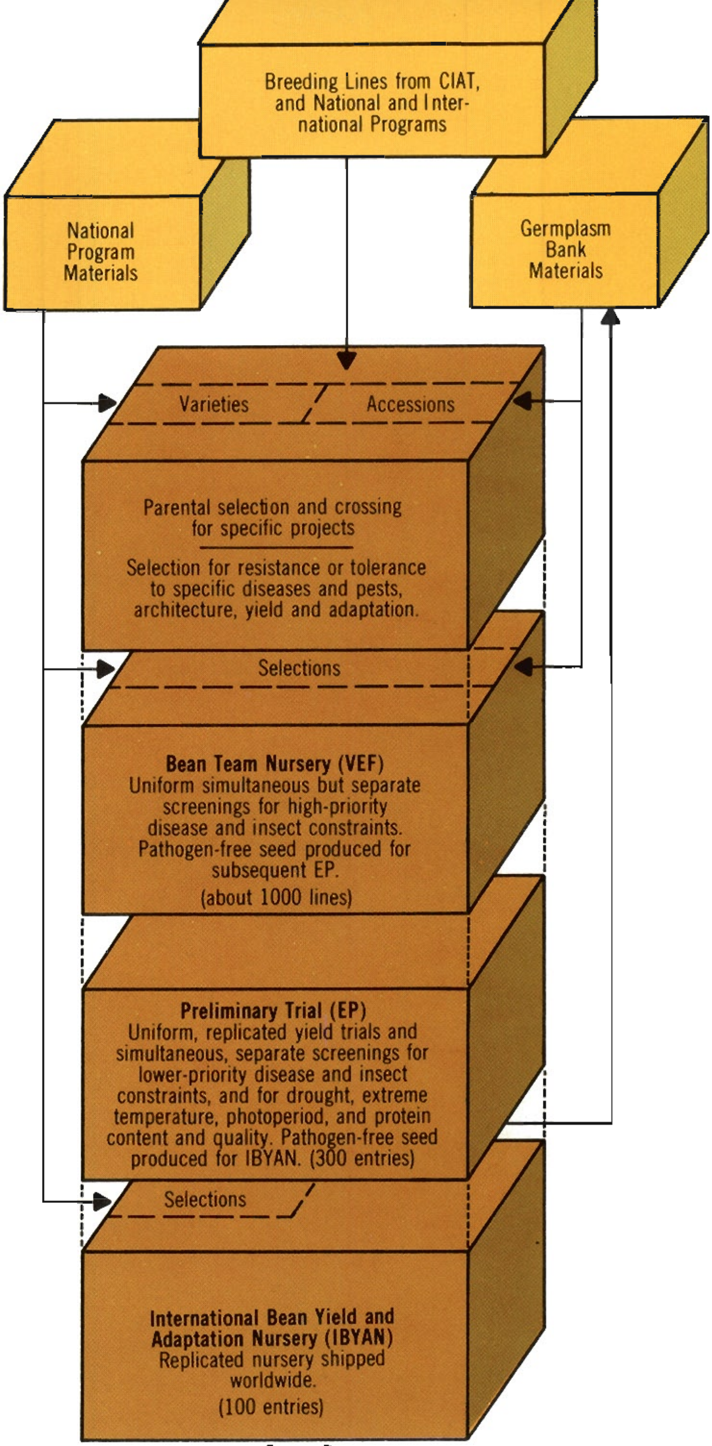


Figure 7.
The CIAT Bean Program utilizes this stepwise scheme to produce and test its improved germplasm. Not shown on the diagram is the Bean Information System (SIFRI) where results of all crossing and evaluation are documented and readily available for retrieval from computer files.

Figure 8
Bean Program Coordinator Aart van Schoonhoven (left) discusses results of this screening with Steven Beebe, Postdoctoral Fellow in Plant Pathology.

Bean Golden Mosaic Virus (BGMV)

A total of 418 crosses were made in 1979 for BGMV resistance utilizing a much higher proportion of non-black seeded parents than used previously. A uniform international trial of 145 hybrid lines bred for BGMV resistance was distributed.

Common Bacterial Blight

Disappointing results from the 1978 Bean Team Nursery (VEF) showed the need to intensify the program for incorporating resistance to common bacterial blight into new improved germplasm. Additional crosses were evaluated by a new screening technique that emphasizes lesion size as the main determinant of infection degree. This screening provided an encouraging increase in materials observed to be highly resistant or resistant.

Anthracnose

Utilizing more than two dozen new resistance sources, 170 crosses were made with selected cultivars from several countries in the region. Resistance sources included several materials of desirable grain type.

Bean Pod Weevil

New crosses were made for resistance to *Apion godmani* using promising selections from El Salvador. Ninety families from previous crosses with *Apion*-resistant parents were distributed in mid-1979 for evaluation in Central America.

Nitrogen Fixation

During the year two cycles were completed to develop populations with increased nitrogen fixing capacity. In the second cycle of crossing, some promising materials from the VEF and the Preliminary Trials (EP) were introduced. All materials in these crosses carry resistance to BCMV. A total of 140 F_3 lines derived from promising single plant selections made in the glasshouse in the first cycle are being evaluated in the field at CIAT-Quilichao for nitrogen fixing capacity, adaptation and yield.

Improvement of Climbing Beans

The climbing bean improvement project involves the evaluation and selection of outstanding materials from the germplasm bank as well as hybridization to produce new materials. Because this project is relatively new, some emphasis has been on defining optimum methodologies for breeding and evaluation. This is necessary because climbing beans are mainly selected for their adaptation to the small farm systems of relay and associated cropping with maize.

Breeding Methodologies. The relay planting system, in which beans are planted in maize when the latter has reached physiological maturity, is important in Central America and areas of South America. Competition effects are practically nonexistent and yield potentials of both crops are higher than in associated plantings.

In trials at CIAT-Palmira, climbing beans behaved quite differently in monoculture and relay, indicating that varieties should be selected and hybrids developed for the particular cropping system to be used. Large differences were again observed in the incidence of insect pests, especially *Empoasca* and the tropical mite. Much lower levels of attack were observed in relay planting than in monoculture or association.

Evaluations in three low-temperature sites showed location-specific adaptation with a sharp break between the highest altitude location (Obonuco, 2710 m, 12.7°C) and the intermediate site (La Selva, 2100 m, 17.0°C). For this reason, breeding of climbing beans for colder areas will be done as a separate project.

Trials were also done to compare bean and maize yields in intercropping (in rows) and mixed cropping (in hill plots) to verify if the latter system can be used for early generation screening for bean yields. Although yields of both crops were higher when intercropped, in the farmers' traditional system of mixed cropping, these yields were almost equalled when beans were planted at 8 plants/m^2, indicating this system is valid for screening trials.

Figure 9.
Climbing beans are a traditional crop for the small farmer. Because they are most often grown in association with other crops like maize, breeders pay special attention to their performance under conditions of competition.

Figure 10.
Anthracnose is one of the most widespread and serious bean diseases, and is one of the high-priority problems for CIAT's Bean Program.

Some effects of competition were also studied. Resistance to lodging was the most important maize characteristic observed to influence its suitability for associated cropping. Competition of climbing bean varieties on the maize was determined mainly by their effects on maize lodging. The growth habits of beans, in turn, affected maize lodging with the most vigorous beans (type IVb) tending to pull down the maize.

Varietal Improvement. The complete collection of climbing beans (1950 accessions) was evaluated during the year in Popayan, La Selva and Obonuco. All accessions were planted in hills, in monoculture relay and direct association with maize.

La Selva was an excellent location to evaluate in the field for resistance to anthracnose. Several promising new sources of resistance were selected and subsequent screening in the glasshouse at CIAT-Palmira showed them to be resistant to several races of the pathogen.

Two accessions selected for yield potential in relay cropping and for resistance to anthracnose are now being tested in on-farm trials in Antioquia, Colombia.

Breeding. The climbing bean breeding program is aimed at combining high yield potential with resistance to major diseases and insects, especially anthracnose, BCMV and *Empoasca*. After early generation evaluations in individual breeding projects, advanced selections are entered in the Bean Program VEF. Several families were selected in early generations for their acceptable yields in association with maize and are being evaluated more intensively for reactions to the priority disease and pest problems.

Widely grown and commercially acceptable cultivars are being backcrossed to simultaneously introduce resistance to anthracnose and BCMV. Selections of uniform, double-resistant lines of Cargamanto, the first cultivar used in this project, will be available for on-farm testing by late 1980.

Figure 11.
Appearing as one huge field, these climbing beans planted in relay actually are on fields of only a few hectares owned by many small-scale farmers. The better farmers in this region of Antioquia, Colombia produce 1 t/ha or more on their lands.

Figure 12.
Two CIAT Bean Program trainees on a study trip to Antioquia, Colombia observe the region's common method for drying the harvest.

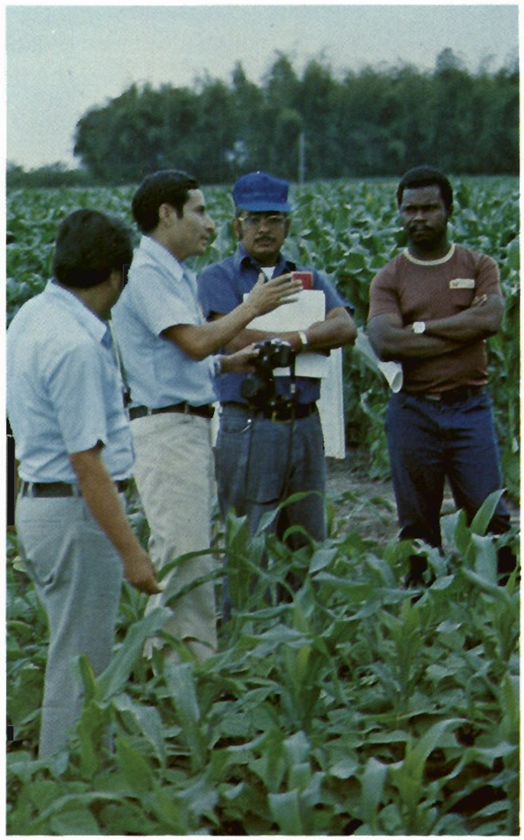


Figure 13.
Four participants in the Bean Breeding Workshop discuss breeding strategies while visiting the climbing bean evaluation fields at CIAT-Palmira.

UNIFORM TRIALS OF PROMISING AND IMPROVED MATERIALS

Germplasm accessions showing valuable traits and promising breeding lines that have passed early generation evaluations may be selected as CIAT entries in the Bean Program's formal evaluation system (Fig. 7). Promising selections from national breeding programs are also sought as entries. All materials entering these uniform evaluations must be resistant to BCMV.

Bean Team Nursery (VEF)

The VEF is the first uniform screening nursery. The 1979 VEF contained a much lower number of entries (594 compared to 1464 the previous year) due largely to more stringent requirements for entry, especially BCMV resistance. Most disciplines in the Program improved their evaluation criteria for materials entering this nursery.

Levels of resistance recorded for the important diseases evaluated in the VEF included: rust (7 percent of the materials); angular leaf spot (0.5 percent); anthracnose (15 percent); and white spot (6 percent). No materials were observed resistant to *Empoasca* or common bacterial blight.

Among the important considerations that will determine ultimate adoption of cultivars by farmers are grain color and size of new materials. The 1979 VEF showed good color variability with only 22 percent of the entries black-seeded. Forty-five percent of the entries were of the more desirable medium and large seed size.

Figure 14.
An outstanding example of a new CIAT bush breeding line bred for improved architecture, especially an upright growth habit.

Preliminary Trial (EP)

The EP is the second level of uniform testing of promising and improved materials and includes the first replicated yield screening. It is a closed nursery with all entries selected from the previous VEF. The 1979 EP consisted of 180 selections from the 1978 VEF. Yields were obtained from replicated plots planted at CIAT-Palmira and Popayan. Additional evaluations are made for disease reactions and adaptation at these and other locations.

In yield trials at CIAT, six black-seeded entries and eight non-black seeded entries outyielded the respective international checks. In Popayan, 27 black-seeded and 47 non-black seeded materials surpassed yields of checks. These results demonstrate the significant improvement in yield made during recent years, especially for non-black materials. Yields within groups are summarized in Table 3.

In addition to yield, the EP nursery is evaluated for several other factors including tolerance to drought. Seventeen entries showed relatively high levels of tolerance to moderate drought stress. Six materials showed yield reductions of less than 10 percent and four of these still yielded more than 2200 kg/ha under moderate stress.

Resistances to the diseases rust, angular leaf spot, anthracnose, southern blight, halo blight and gray and white leaf spots, and to *Empoasca* were found in materials of several grain colors and plant types. Twenty non-black and 35 black-seeded entries were resistant to three or more priority problems and one entry showed resistance to seven. Few materials were resistant to web blight and the tropical mite, and none was resistant to BGMV, common bacterial blight or Ascochyta leaf spot.

Table 3. **Summary of yields of 1979 CIAT Bean Program Preliminary Trial (EP) entries.**

	All test entries	Inter-national checks	Outyielding best international check	1979 IBYAN selections
	Yield (kg/ha)			
Black-seeded:				
CIAT-Palmira	2764 (105)[1]	2964[2]	3232 (6)	3003 (15)
Popayan	2796 (105)	2868	3282 (27)	2838 (15)
Non-black seeded:				
CIAT-Palmira	2497 (75)	2496	2918 (8)	2686 (25)
Popayan	2779 (75)	2352	3147 (47)	2695 (25)

1 Values in parentheses are numbers of materials

2 Three commercial cultivars of each color group were common checks

EP materials were also tested for protein content with none of the entries having less than 23 percent protein while nine showed levels above 30 percent. Cooking times were also determined for the EP entries with the range being from 25 to 80 minutes.

International Bean Yield and Adaptation Nursery (IBYAN)

The IBYAN is the third test in the sequence of uniform trials and the first intended for broad-scale international evaluations. As of the second semester of 1979, all materials evaluated in the IBYAN are selected from the previous EP according to the Program's germplasm development scheme. Figure 16 shows how compositions of the IBYANs have changed over four years with the 1979 sets consisting almost entirely of new breeding lines. Through the end of 1979, 120 sets of the current nurseries (two for bush beans and three for climbing beans) had been distributed, almost all in Latin America.

Results from the 1978 IBYANs, for bush beans only and divided according to grain color, showed

Figure 15.
The first International Bean Yield and Adaptation Nursery (IBYAN) for climbing beans was distributed in 1979. This IBYAN for red-seeded climbers in Costa Rica is being evaluated by Agronomist/Breeder Jeremy Davis.

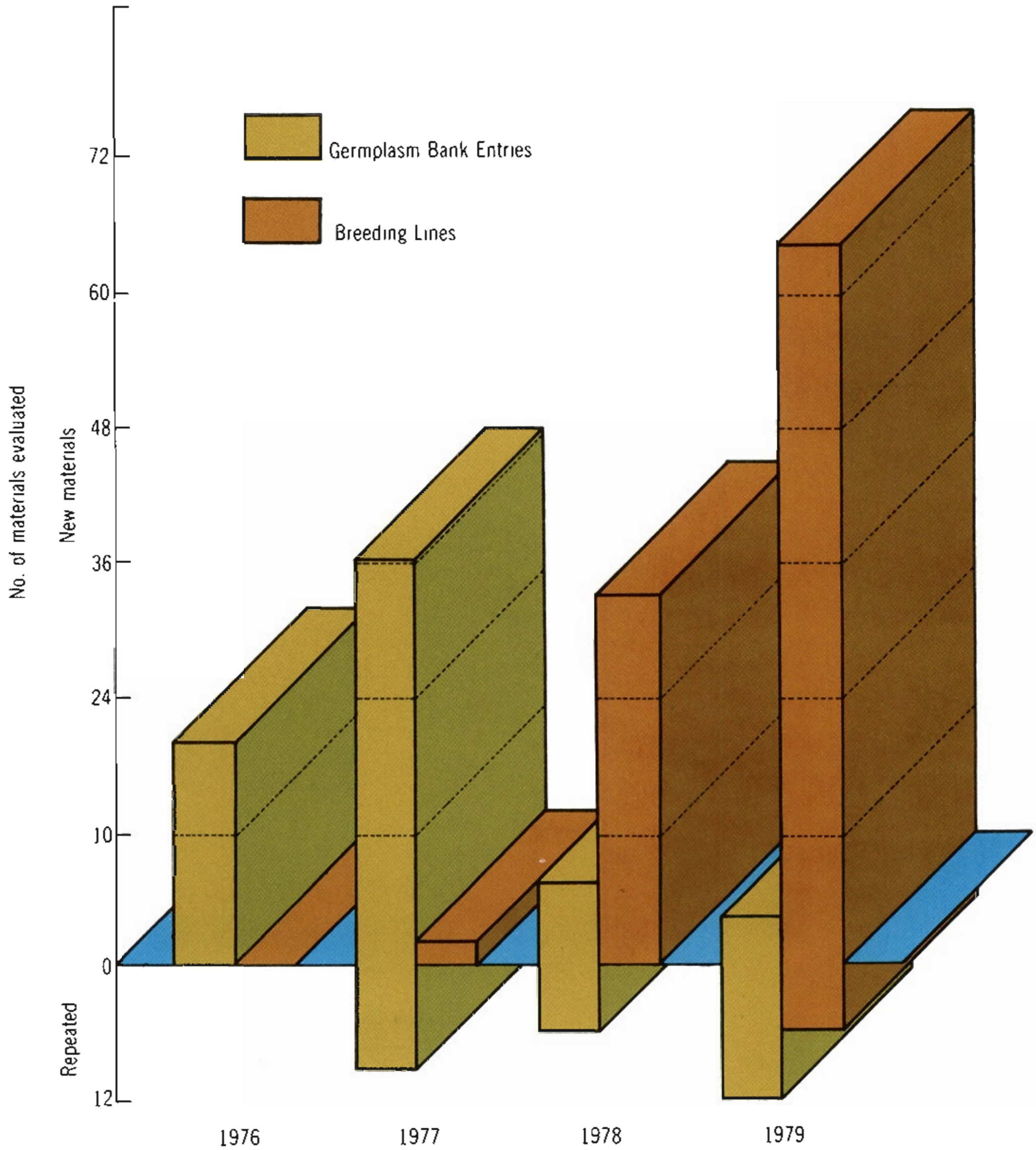


Figure 16.
Four years of development of CIAT's International Bean Yield and Adaptation Nursery (IBYAN) program have shifted nursery compositions from germplasm bank accessions to almost entirely breeding lines.

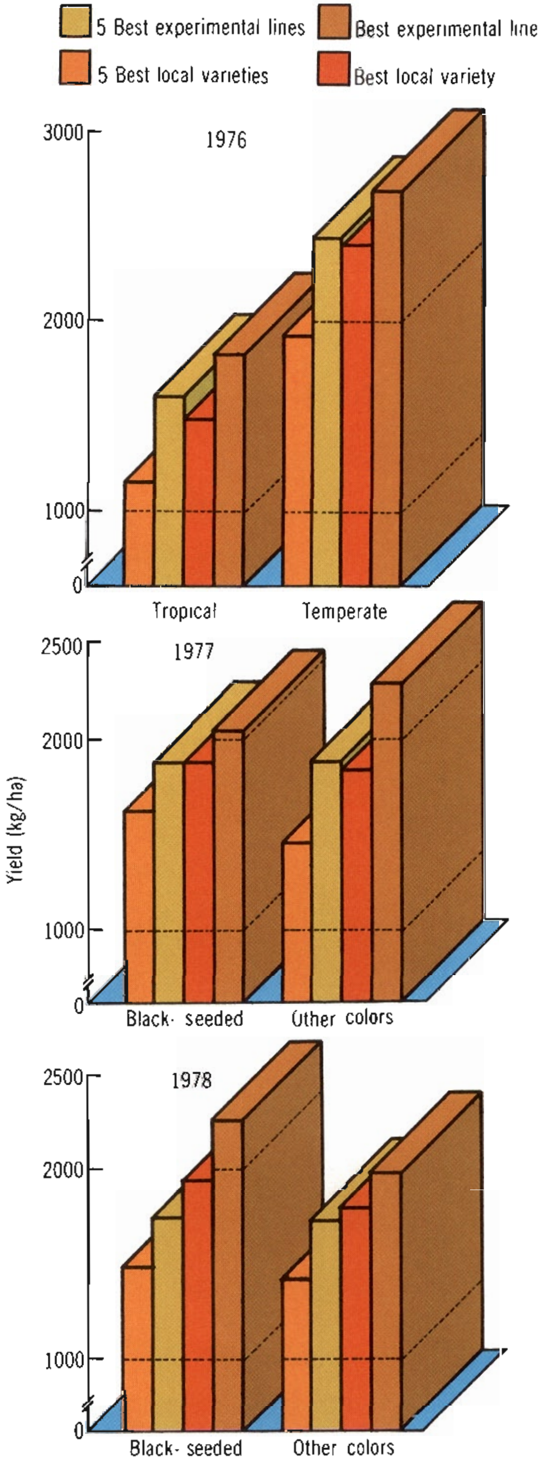


Figure 17.
Results of International Bean Yield and Adaptation Nursery (IBYAN) trials show that many high-yielding, well-adapted materials are available to national bean programs.

that at almost all testing sites improved germplasm performed better than the local checks. In the case of non-black seeded materials, although they may have outyielded local varieties, most entries still lacked the desired characteristics of commercially acceptable grain size and color. Figure 17 summarizes results of three years of IBYAN testing according to averages for the best local and test materials.

Selection of Materials for Local On-farm Trials or Release

Twenty-one promising materials, including cultivars from the germplasm bank and CIAT's own breeding lines, were selected by several national programs this year for on-farm adaptation trials or pre-release multiplication.

Among these materials are three hybrids being released in Guatemala after development from early generation lines furnished by CIAT. All carry resistance to BGMV. Also, three other lines developed in Honduras from crosses made in CIAT are being considered for release there. In Cuba, the variety ICA-Pijao is being extensively multiplied for release, and in Ecuador, the variety Brazil 2 was released under the name INIAP-Bayito. Most materials were selected from international nurseries sent to these countries.

DEVELOPMENT AND TESTING OF AGRONOMIC PRACTICES

Symbiotic Fixation of Nitrogen

Last year it was reported that high temperatures might not act as adversely as previously thought in inhibiting nitrogen fixation in the bean/*Rhizobium* association. In field tests this year at CIAT-Quilichao (mean temperature 24°C and low soil nitrogen) several *Rhizobium phaseoli* strains were effective in fixing nitrogen. Three strains provided bean yields above the production of the high-nitrogen control (100 kg of N/ha).

To evaluate the performance of *R. phaseoli* strains at different locations in the Americas, an International Bean Inoculation Trial was distributed in 1979. The trial, sent to cooperators in eight countries, consisted of 10 strains plus appropriate nitrogen controls.

On-farm Testing of New Technology

On-farm tests of improved agronomic practices were conducted in three areas of Colombia — Antioquia, Huila and Restrepo. These farm trials are designed to assess the profitability of the practices and their adaptability to existing farmer production systems, and to identify any factors which might affect the introduction or performance of the new technology.

Improved agronomy involving low input use in Huila and moderately high input use in Restrepo and Antioquia was profitable and could be easily adopted by profit-maximizing farmers. Higher bean densities and better weed control proved to be important low-cost inputs. Significant yield gains were achieved by substituting a more effective fungicide (Benlate) to protect against anthracnose where this disease was a problem. On farms in Huila where low fertility was a problem, a minimum application rate of complete fertilizer was also effective in increasing yields.

Figure 18.
(Left) Seed multiplication of a new line tolerant to bean golden mosaic virus (BGMV) under high disease pressure in Guatemala.

Figure 19.
A local variety susceptible to bean golden mosaic virus (BGMV) growing in the same field shown in Figure 18.

Experiences with "clean" (pathogen-free) seed have demonstrated that varieties must have genetic resistance to BCMV, which is so highly transmissible and prevalent in most bean-producing regions.

SPECIAL AGROCLIMATIC STUDY OF BEAN PROGRAM TARGET AREA

The objective of this study is to provide the Bean Program with an integrated data management and analysis system for the target area, including climatic, edaphic and cropping system data. Data from approximately 2700 meteorological stations have been processed and microregions are being defined. Verification of growing season temperature ranges using more refined data sets agreed closely with estimates made last year. While production within temperature regimes was slightly broader than estimated, some 80 percent of the beans in the target area are produced between the mean growing temperature extremes of 17.5° and 25°C. This range is adequately covered by CIAT's principal screening sites at Popayan and Palmira.

A cluster analysis was performed to classify the major climatic systems in which beans are grown. The major variables include maximum, minimum and mean temperatures during the flowering period, and the mean daily balance of precipitation and evapotranspiration for the vegetative, flowering and reproductive periods. The systems are summarized in Figure 21.

From this summary, a considerable proportion of the target area appears subject to some drought stress from flowering onwards, emphasizing the need to continue screening for tolerance to drought stress.

CIAT's on-farm testing sites for improved bean technology, in Antioquia and Huila, are found under conditions in systems A and E, which account for almost 60 percent of the target area production figures.

Figure 20.
Agricultural Economist John Sanders evaluates the performance of climbing beans in on-farm trials to test improved agronomic techniques.

INTERNATIONAL COOPERATION

International Cooperation was an important part of the Bean Program's activities during 1979. In association with the CIAT Training Office, the Program provided training for 138 professionals including 66 who attended two one-month short courses in bean production. Almost all of the trainees will continue to work in national programs of the region, further strengthening the bean research network operations in Latin America.

The Program made plans to begin development of a bean improvement network in Eastern Africa. Four trainees (one from Tanzania and three from Kenya) worked at CIAT this year. One of the first steps in this new activity will be a conference to explore the problems and potentials of beans in that region. It will be held in March 1980, in Malawi.

The Program's regional coordinator for Central America and the Caribbean continued to provide strong support between CIAT and the national

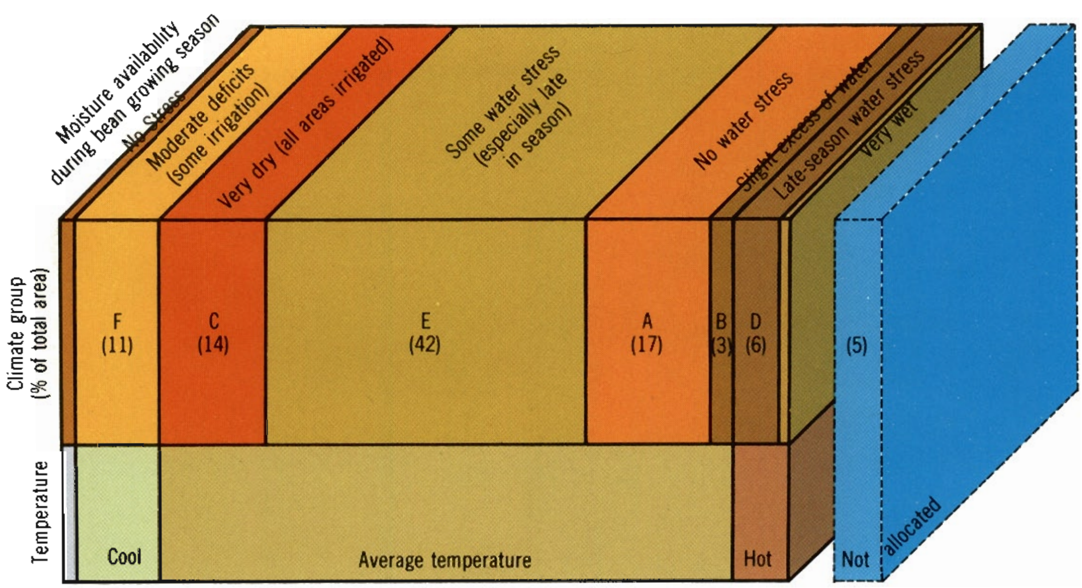


Figure 21.
The major climatic systems in which beans are grown in Latin America, based on moisture availability and mean temperatures during bean growing seasons.

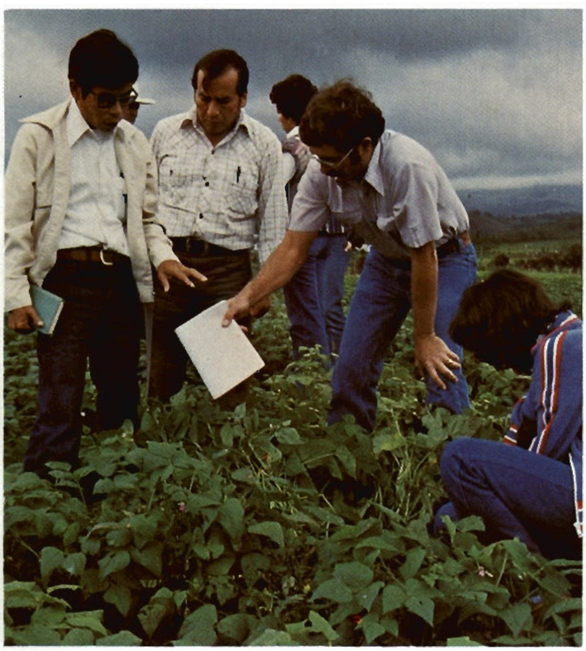
programs, assisting in germplasm movement within the area, overseeing the distribution and evaluation of CIAT's own international nurseries, and helping to identify candidates for training. As part of a special project in Peru, an outreach agronomist was stationed there with the responsibility for strengthening collaboration and complementary research between CIAT and Peruvian bean programs.

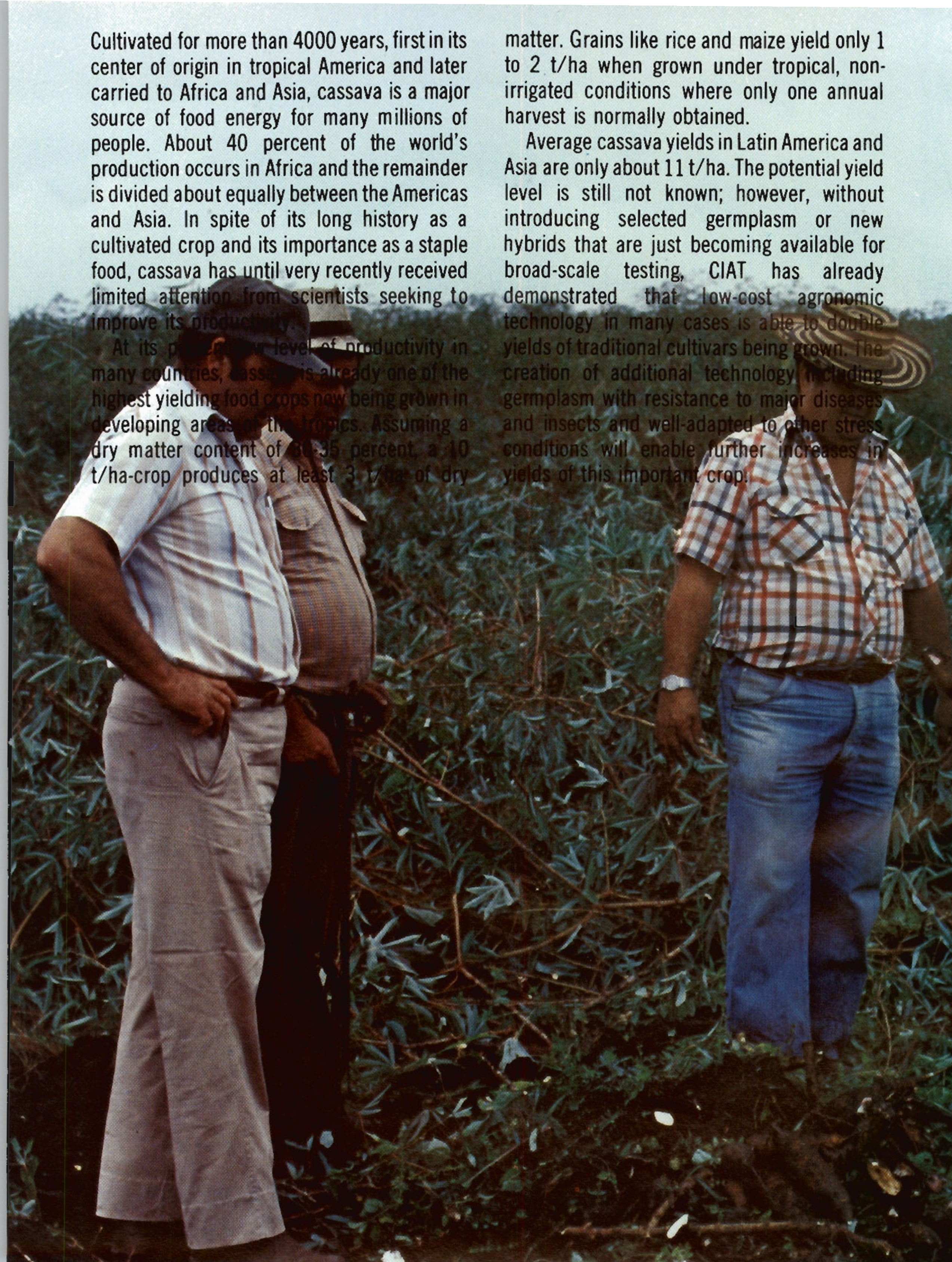
Two workshops were sponsored by the Bean Program, in November 1979. The first, on the diseases anthracnose, angular leaf spot and common bacterial blight, had 40 participants. One week later a workshop on bean varietal breeding was held for 11 scientists. The majority of the participants were from national programs in Latin America. The meetings provided opportunities to interchange ideas on needs of the various programs and to discuss and evaluate strategies which the CIAT Bean Program is following.

Figure 22.
Participants at the Bean Disease Workshop at CIAT visited this large evaluation field at Popayan.

Figure 23.
Pathologist Howard Schwartz points out interesting disease reactions to Kazuhiro Yoshii, CIAT Pathologist stationed in Guatemala, and Felix Camarena, of Peru.

Figure 24.
Jose Galindo, a Cornell University graduate student working in Costa Rica, and Cornell Pathologist George Abawi discuss disease symptoms on this plant.





Cultivated for more than 4000 years, first in its center of origin in tropical America and later carried to Africa and Asia, cassava is a major source of food energy for many millions of people. About 40 percent of the world's production occurs in Africa and the remainder is divided about equally between the Americas and Asia. In spite of its long history as a cultivated crop and its importance as a staple food, cassava has until very recently received limited attention from scientists seeking to improve its productivity.

At its present low level of productivity in many countries, cassava is already one of the highest yielding food crops now being grown in developing areas of the tropics. Assuming a dry matter content of 30-35 percent, a 10 t/ha-crop produces at least 3 t/ha of dry matter. Grains like rice and maize yield only 1 to 2 t/ha when grown under tropical, non-irrigated conditions where only one annual harvest is normally obtained.

Average cassava yields in Latin America and Asia are only about 11 t/ha. The potential yield level is still not known; however, without introducing selected germplasm or new hybrids that are just becoming available for broad-scale testing, CIAT has already demonstrated that low-cost agronomic technology in many cases is able to double yields of traditional cultivars being grown. The creation of additional technology including germplasm with resistance to major diseases and insects and well-adapted to other stress conditions will enable further increases in yields of this important crop.

Cassava Program

INTRODUCTION

Scientists in CIAT's Cassava Program this year continued to acquire knowledge about basic functioning of the cassava plant during its growing cycle. Important results were obtained about development of root dry matter and two of the major diseases—cassava bacterial blight and superelongation. A major study was begun to understand the water stress relations of the crop. In fertility studies, additional information was obtained on cassava's performance on marginal agricultural lands, especially the acid, infertile soil regions.

On a broader scale, a study of the interaction of the cassava plant and various ecosystems is providing a basis for better definition of technology development needs in the Program's target areas. The development of germplasm pools to increase gene frequencies for particular priority systems was initiated as a means to eventually make available to national programs genotypes with adaptability to the broad spectrum of climatic, biotic and edaphic conditions.

Hybrid lines from the varietal improvement section continued to perform very well in their second year of regional testing over a range of environmental conditions. In addition to this new germplasm, other components of technology are also being developed. These include effective chemical and cultural methods of weed control and intercropping systems for marginal soil areas.

The development and testing of a meristem tissue culture method for cassava was largely accomplished this year. This technique can be used for propagating new materials, eradicating some diseases, conserving germplasm in a very small and disease-free environment, and, very importantly, increasing the exchange of cassava vegetative material between CIAT and its client national programs.

Due largely to the Program's efforts in training of national program personnel and providing other international cooperation assistance, a Latin

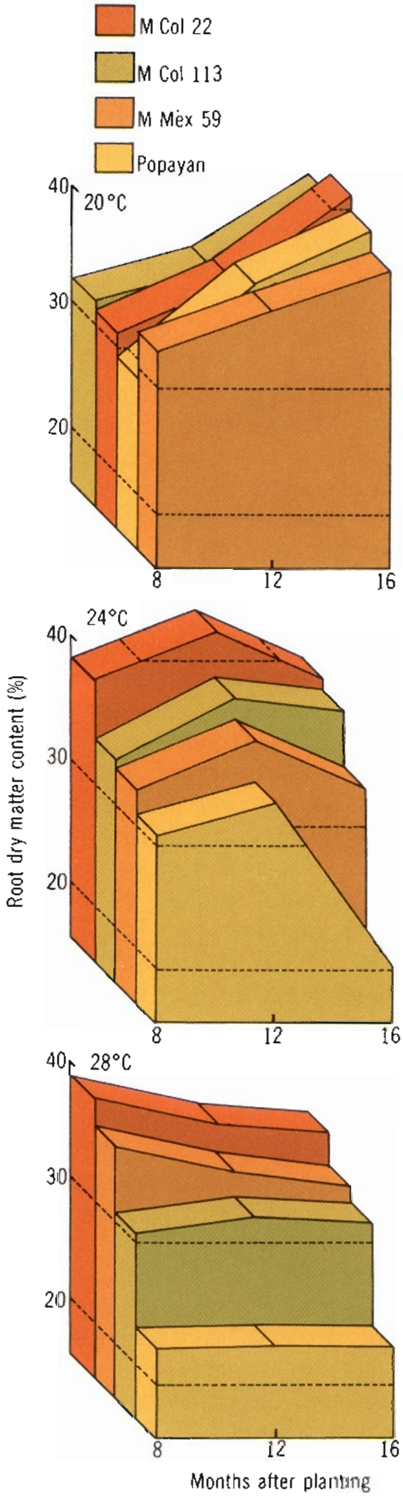


Figure 1.
Changes over time of root dry matter content of four cassava varieties grown in three temperature regimes.

American network for international testing of germplasm has expanded rapidly in the past two years. In Asia, a network is also being formed and germplasm materials were distributed this year for the first international trials.

With continued training, improved technology evaluation systems, improved germplasm exchange with the newly developed meristem techniques, and greatly expanding interest in tropical countries in the economic potential of cassava, the Program is now placing major emphasis on strengthening of national programs and extending cassava technology to them.

BASIC STUDIES OF STRESSES AFFECTING CASSAVA

Physiological Stresses

Only in recent years have researchers made concerted efforts to understand how the cassava plant functions during growth and how various stress factors ultimately affect the cassava crop. Compared to many other cultivated crops, the growing season for cassava is much longer — at least eight months and frequently twice that long — depending on the cultivars and environment. During this long period the plant is subjected to seasonal changes in moisture availability, temperature, and buildups of diseases and insects. Among the important areas of work in the Cassava Program this year were those directed to understanding how environmental factors affect growth of the cassava plant.

Root Dry Matter Content

The percentage of dry matter (starch content) in the harvested root is an important criterion of quality, both for human consumption and for processing uses. While root dry matter content varies between varieties, it has also been observed to vary for the same variety between sites.

Observations from studies of factors that influence final dry matter content of roots have suggested four relationships: (a) varietal differences in dry matter are greater at higher temperatures; (b) root dry matter content increases with plant age and then declines; (c) in the same variety maximum dry matter content is reached earlier when temperatures are higher; and, (d) stresses (water stress, low fertility or weed competition) that reduce carbohydrate supply to the roots during the bulking or root filling period will reduce dry matter content. Figure 1 shows how dry matter content of four cultivars varied over time at different temperatures.

Water Stress

In most areas where cassava is produced the crop experiences one or two dry seasons during its growing cycle. Research was begun this year to study the cassava plant's response to water stress. A preliminary trial with 50 clones showed large differences in yield reductions when moisture was withheld from four to seven months after the cassava was planted.

When the early- and late-bulking clones M Col 22 and M Mex 59, respectively, were grown in the field, they demonstrated a highly developed capacity to maintain their internal water status within a rather close range despite a rapidly deteriorating water supply. This response is achieved by a reduction in the production and expansion of leaves, morphological and physiological modifications to the stomatal system and the capacity of the fibrous root system to explore the soil deeply. This research will continue in order to fully understand plant activity during periods of water stress.

Figure 2.
Workers measure light penetration into the canopy of cassava cultivar M Col 22 growing under water stress at CIAT-Quilichao.

Figure 3.
This plant of cultivar M Col 22 has had rainfall excluded from its root system for 10 weeks. Leaf production is reduced and newer leaves that are formed are not expanding to normal size.

Biological Stresses

Resistance to Mites

Mites are among the most important pests of cassava with at least one species usually present wherever cassava is grown. Laboratory studies were done this year to learn which types of resistance mechanisms are present in the plant.

Figure 4.
After extensive screenings for mite resistance in the greenhouse and at two field locations, 43 cassava accessions have been selected that are promising for their resistance to this pest.

Against the *Mononychellus tanajoa* mite both non-preference and antibiotic mechanisms were evident. With *Tetranychus urticae,* both feeding and ovipositional preferences were observed with susceptible cultivars. There were no significant differences among resistant cultivars in preferences for feeding or oviposition. Fecundity of the females was also less on resistant cultivars than on susceptible materials.

Development of Diseases

Cassava Bacterial Blight. Disease severity of cassava bacterial blight (CBB) was studied under controlled conditions and shown to be affected by the pattern of day/night temperatures; steady changes in the temperatures reduced disease severity while fluctuating ones increased it.

Epidemiological studies in Carimagua and Caribia (see Table 1, p. 42) during 1978 and 1979 indicated that duration, quantity and distribution of rainfall were important factors on development of epidemics. Climatic changes during different growing seasons appeared to cause different patterns of epidemic development and severity.

Superelongation. Basic work was done this year in cooperation with pathologists at Cornell University (U.S.A.) to study the mechanism of action of superelongation disease (*Sphaceloma manihoticola*). The fungus was found to produce a plant growth regulator *in vitro,* identified as a gibberellic acid (GA_4). This is the first time these compounds have been known to be produced by fungal species other than *Gibberella fujikurol.*

Interactions between Cassava and Different Ecosystems

The differential reactions of cassava cultivars to different ecosystems are being investigated by planting local or regional and introduced genotypes in five ecosystems and evaluating important production parameters. Five interactions have been observed up to now.

(1) Several unrecorded biotic problems (diseases, insects and mites) have been identified on

genotypes introduced into each ecosystem, and their importance has been evaluated according to damage induced on susceptible cultivars. Similarly, incidence and severity of biotic problems appear related to ecological characteristics of a given region. Identification and evaluation of the potential importance of these problems is better performed on introduced cultivars than on the regionally adapted ones.

(2) Resistance to primary negative production factors (NPFs) of a given ecosystem is much higher in cultivars from ecosystems similar to the test one than in those from ecosystems with a different set of NPFs. This is clearly shown in Figure 5, in comparisons of cultivar performance in the very different ecosystems of Carimagua and Popayan. The presence of strong cultivar/ecosystem interactions, at least among ecosystems with different sets on NPFs is strongly indicated.

(3) Mean reactions of groups of (a) native cultivars, (b) cultivars from the most dissimilar ecosystem, and (c) cultivars from the other three ecosystems showed that native cultivars of each ecosystem were most resistant to the NPFs in that ecosystem (Fig. 6).

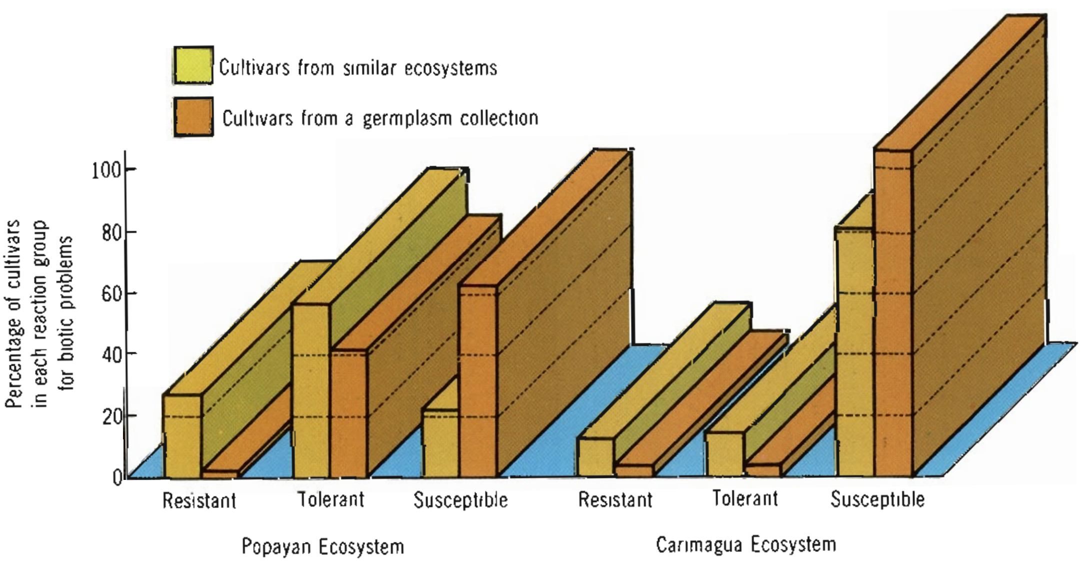


Figure 5.
General reactions of cassava cultivars to biotic production problems in two very different ecosystems.

(4) Results also indicate that, at least for diseases and pests, material selected in ecosystems with severe biotic problems could behave well in other ecosystems with similar but moderate problems. However, if the edaphic and climatic problems are dissimilar, behavior of selected materials may not be as expected. Material selected from ecosystems with moderate biotic problems may be severely affected by the biotic problems of ecosystems with more severe NPFs or even moderate but different biotic NPFs.

(5) The germination, production and yield from planting stakes of cultivars susceptible to NPFs present in each of four ecosystems were reduced when replanted in the same ecosystem. However, they were not even slightly reduced when stakes were taken from resistant cultivars grown in the same ecosystem. This may indicate that the quality of the planting material produced by a given cultivar is related to the biotic and abiotic (climatic, edaphic, etc.) pressures on the cultivar during its growing cycle and the genetic capacity of such cultivars to overcome these pressures.

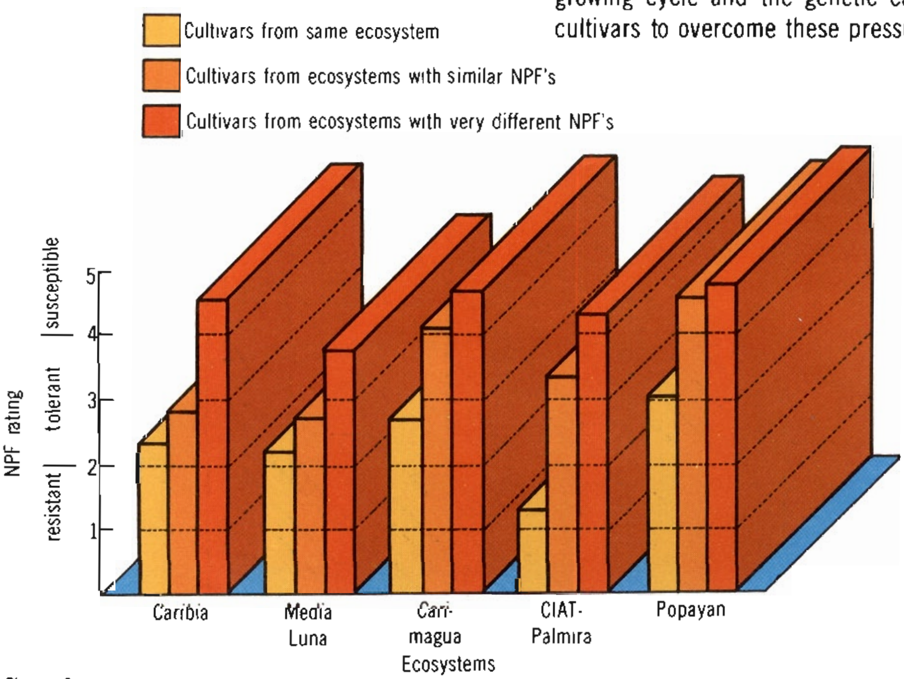


Figure 6.
Mean reaction of 25 cassava cultivars, collected or selected in five different ecosystems and all planted in each ecosystem, to the negative production factors (NPFs) present in each ecosystem.

GERMPLASM DEVELOPMENT

Preliminary observations from the above study of genotype/ecosystem interactions and previous results from regional trials and other experiments on adaptation demonstrate that single cultivars appear to have clear limits of adaptability. Accordingly, this year the Cassava Program began to assemble regionally adapted materials for major production systems associated with specific ecosystems defined mainly by climatic regimes (except for the acid, infertile savannas). Major characteristics of the identified ecosystems are shown in Table 1.

Germplasm Evaluation

Nearly all cassava germplasm accessions have been evaluated at CIAT-Palmira in preliminary trials for yield, root form and quality, plant growth habit and other traits. Materials will continue to be evaluated in this manner.

Then, emphasis will be placed on cultivar performance in four moderate- to high-stress environments representing combinations of several major stress factors encountered in a large percentage of the world's present and potential cassava growing areas. In these trials, various disciplines in the Program will evaluate the materials. The primary objective is to identify genotypes with moderate to high tolerance or resistance to a combination of all NPFs, rather than seeking narrow, individual traits by specific disciplines. Final yield will be emphasized as the integrating measure of tolerance to all stress factors and yield potential.

Carimagua

Primary NPFs at this location are low pH, low phosphorus, CBB, anthracnose and superelongation. One hundred-three accessions were selected on the basis of root yields, harvest index and disease reactions.

Popayan

Selection in this location will be mainly for adaptation to low temperatures, anthracnose and

Figure 7.
Two cultivars planted in Carimagua demonstrate sharp differences in adaptation to local ecosystem conditions.

Figure 8.
Planted in Popayan, the same two cultivars shown in Figure 7 have now reversed their adaptative reactions.

Table 1. **Cassava production ecosystems and their main characteristics.**

Eco-system	General description and representative areas	Mean temperature	Dry season duration	Annual rainfall
1	Lowland tropics with long dry season; low to moderate annual rainfall; high year-round temperature. (Media Luna, Caribia, Nataima and The Guajira, Colombia; Southern India; Northeastern Brazil; Northern Venezuela; and Thailand)	above 25°C	3-4 mo	700-200 mm (Unimodal distribution)
2	Lowland tropics with moderate to high rainfall; savanna vegetation on infertile, acid soils; moderate to long dry season; low relative humidity during dry season. (Llanos of Colombia (Carimagua); Llanos of Venezuela; Cerrado of Brazil)	above 25°C	3-6 mo	above 1200 mm (Unimodal distribution)
3	Lowland tropics with no pronounced dry seasons; high rainfall; constant high relative humidity. (Florencia, Quibdo and Leticia, Colombia; Amazon Basins of Brazil, Ecuador and Peru; rainforests of Africa and Asia)	above 25°C	absent or very short	above 2000 mm
4	Medium-altitude tropics; moderate dry season and temperature. (CIAT-Palmira and CIAT-Quilichao, Colombia; Costa Rica; Bolivia; Brazil; the Philippines; Africa; India; Indonesia; Viet Nam)	21°-24°C	4 mo	1000-2000 mm (Bimodal distribution)
5	Cool highland areas; moderate to high rainfall (Popayan, Colombia; Andean region; East Africa)	17°-20°C	—	above 2000 mm
6	Sub-tropical areas; cool winters; fluctuating daylengths. (Mexico (Culiacan); Southern Brazil; Cuba; Paraguay; Northern Argentina; Taiwan; Southern China)	Min. 0°C	—	above 1000 mm

Phoma leaf spot. Three accessions and two CIAT hybrids were selected this year as promising for adaptation in this ecosystem.

North Coast of Colombia

Important factors limiting cassava production in this region include drought, mites and Cercospora leaf spot. At Media Luna, 392 accessions were planted and 101 selected for more extensive evaluations.

Development of Broad-Based Gene Pools for Cassava

This year development of three germplasm pools was initiated to broaden the genetic base of cassava materials for ecosystems represented at Carimagua, Popayan and the North Coast. All sites are considered high-stress environments and include combinations of stress factors that occur over extensive areas where cassava is produced. A few cycles of selection and recombination will be required to develop well-adapted populations for each area, after which emphasis can be directed to improving yield and quality. The final objective will be to develop these adapted gene pools so that breeders in national programs can do final selecting for specific climatic and agronomic conditions in each country.

VARIETAL IMPROVEMENT OF CASSAVA

During 1979, hybridizations, F_1 seedling selections, observational yield trials and replicated yield trials were continued at CIAT-Palmira, Caribia and Carimagua.

Trials at CIAT-Palmira

At CIAT, 46 lines (about 25 percent of all entries) yielded more than 50t/ha/year with the maximum yield 82.2 t/ha/year. Root dry matter content was generally high with all entries averaging 33.5 percent.

Trials at Caribia

At this location on the North Coast of Colombia several hybrid lines yielded more than 50 t/ha/year. Line CM 323-403, the highest yielder at 66.4 t/ha, was harvested only nine months after planting.

Low dry matter content of roots is a general characteristic of materials harvested at Caribia. When harvested at eight months, all genotypes yielded an average of 27.3 t/ha and had an average dry matter content of 32.2 percent. When the same materials were harvested at 12 months, the yield average was 35.9 t/ha but dry matter decreased to 28 percent. These results are similar to those reported in the physiological studies and suggest that, for high temperature climates, early harvesting may provide more acceptable levels of dry matter.

Trials at Carimagua

In this location where NPFs are numerous and severe, root yields are always much lower than at either CIAT-Palmira or Caribia. In yield trials planted in May 1978, five lines outyielded the best local cultivar (M Col 638) with the best line yielding 18 t/ha/year. In a trial planted in October, about one-half the lines outyielded M Col 638. Eight materials, including the best germplasm accession M Col 1684, yielded more than 25 t/ha/year.

Although CBB and superelongation are very severe disease stresses at Carimagua, disease reaction comparisons between materials from CIAT's original germplasm population planted there in 1974 and new materials selected in that site for resistance against the two diseases show substantial progress has been made in developing resistant materials (Fig. 10).

Figure 9.
CIAT hybrid CM 523-7 combines disease resistance with high dry matter content (37-38 percent). It has yielded 28 t/ha of fresh roots at Carimagua but does not perform well in other locations.

Classification of Promising Lines

Six to ten hybrid lines each year pass to multiplication and advanced agronomic testing in regional trials. Four primary groups have been identified among these lines.

(1) Lines with stable performance. Although yields vary, lines in this group have shown good yield stability across different locations.

(2) Lines with resistance to CBB and superelongation. One such line is CM 523-7, which was first in yield trials at Carimagua (15 t/ha/year in the May planting and 28 t/ha/year in the October planting). In addition, it has a very high dry matter content (37 and 38 percent at Carimagua and 39 percent at CIAT). Other genotypes now having good adaptation to conditions at Carimagua generally show low dry matter content.

(3) Lines with high yield under good conditions. These materials include those with very high yields (more than 60 t/ha/year at CIAT and more than 40 t/ha/year at Caribia). However, existing lines are highly susceptible to CBB and superelongation so their use is restricted to areas where these diseases are absent.

(4) Lines adapted to hot, lowland climates. Among these are line CM 323-403 which has yielded 48 and 52 t/ha/year and 66 t/ha in nine months, over three seasons in Caribia.

Breeding Methodology for Resistance to CBB and Superelongation

Studies were done during the past two years at Carimagua to help define the genetic basis for resistance to CBB and superelongation. For both diseases results showed that the stages of disease initiation and disease development were controlled by independent genetic systems. This indicates that field resistance is continuous for the two diseases and also that highly resistant lines can be produced and selected from crosses between moderately resistant parents.

Data from another trial indicated that present resistances to CBB and superelongation diseases are expected to be of a durable nature. Results of yet another experiment showed that selection for high resistance to these two diseases can be done without sacrificing high yield.

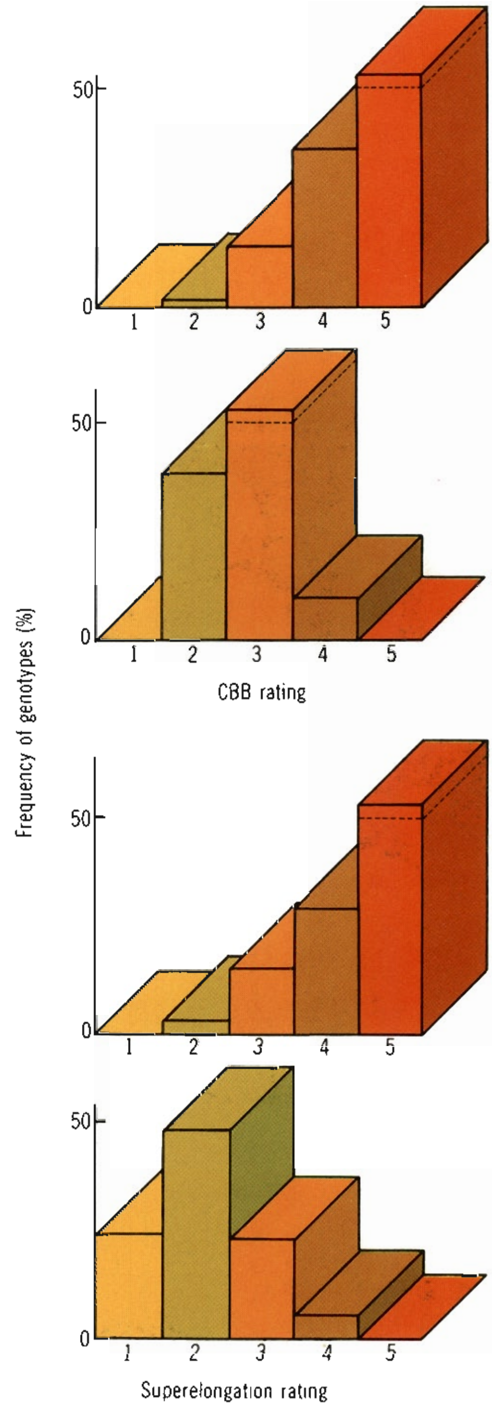


Figure 10.
Changes in disease rections after five years of selection in Carimagua. The upper sets of columns for each disease are for cassava germplasm accessions tested in 1974-75; lower columns are for CIAT hybrid populations tested and selected in 1979.

Figure 11.
A cassava plant severely affected by a mosaic disease ...

Figure 12
... and the same cultivar after meristem tissue culturing to eradicate the virus-type disease.

CASSAVA TISSUE CULTURE

In close cooperation with the Cassava Program, CIAT's Genetic Resources Unit is adapting meristem tissue culturing techniques to cassava. Tissue culturing will provide four very important contributions to Cassava Program scientists for developing and disseminating new technology: (a) a new technique for propagating cassava; (b) a means of eradicating some diseases; (c) a convenient method of conserving cassava genetic resources; and, (d) a safe means of international transfer of cassava vegetative materials.

Propagation

A simple procedure was devised for producing single-rooted plantlets in test tubes. It permits quick rooting, irrespective of the cassava variety, and also prevents callus formation at the shoot/root transition zone which would adversely affect subsequent potting of the new shoot. A technique was also developed for producing multiple shoots from a single culture. The shoot-forming capacity of present cultures provided a harvest of 10-20 stem tips weekly for eight or nine weeks before shoot production begins to decline. Work is being done to increase the capacity of these cultures.

Disease Eradication

One of the more promising applications for tissue culturing is in disease eradication. Sprouts from cassava plants infected with the frog-skin disease received a heat treatment and then very small meristem tips were cultured in the usual manner. After planting the cultured plantlets in the field and selecting from them during two cycles, over 90 percent of the heat-treated, cultured plants remained free of disease symptoms. Similar success was achieved with mosaic-type diseases, suggesting that if necessary, populations affected by viral types of diseases can be treated, cultured and eventually converted into healthy planting materials.

Germplasm Conservation

Work continued to adjust culture media and other operating procedures so that plantlets can be stored for long periods in test tubes. Through the end of 1979, cassava meristem cultures have been maintained for up to 18 months without replenishing the nutrient media. Eventually, CIAT's cassava germplasm bank will be converted into meristem culture form for long-term storage.

International Exchange of Germplasm

Meristem culture combined with heat treatments provides an efficient means to eradicate virus-like diseases, and other contaminating organisms (insects, mites, fungi and bacteria) should also be absent in aseptic cultures. Hence, the international exchange of cassava germplasm as disease-free meristem cultures would greatly reduce the risks of disseminating diseases and pests.

A simple procedure was developed this year in collaboration with the Brazilian Germplasm Center (CENARGEN), to exchange cassava germplasm in the form of meristem cultures. Three shipments were sent to Brazil and one shipment sent from Brazil to CIAT, as the first steps in wider-scale international exchange of germplasm.

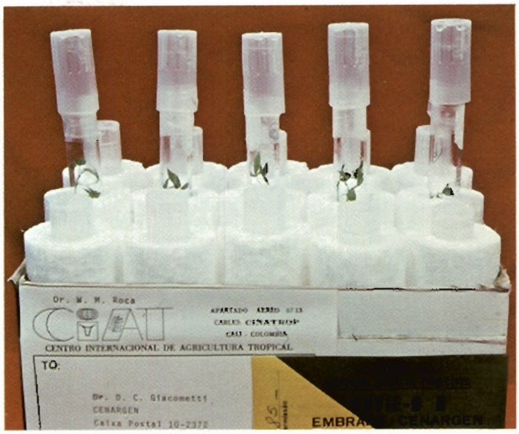


Figure 13.
Single meristem tissue cultured plantlets ready for shipping to Brazil.

Figure 14.
Meristem tissue cultured cassava cultivars arriving in CIAT are first grown out in a quarantine greenhouse to confirm that they are free of diseases.

CROP PROTECTION

Insect Control

An important continuing project for economical cassava crop protection programs has involved studies of biological control of insect pests. During 1979 techniques were developed for maintaining small permanent colonies of the following beneficial insects: *Trichogramma* spp.; *Telenomus* sp.; *Anagyrus* sp.; two species of *Podisus;* four species of Reduviidae; *Kalodiplosis coccidarum* and Carabid *Calosoma* sp. Foundation stocks of these beneficial insects, plus instructions for their rearing and release, are now available to national programs.

Studies in the Program have shown that these and other beneficial insects attack various life stages of many important cassava pests including the cassava hornworm, mealybugs and mites.

Disease Control

Xanthomonas manihotis, the causal agent of CBB, was found to have an epiphitic survival phase on weeds growing in infected cassava plantations at Carimagua. This implies that disease control might be achieved by crop rotation and fallowing of infected fields if good weed control is also practiced

X. manihotis was also detected in cassava seed embryos and pollen collected from infected plantations. Because plant quarantine regulations are generally less strict for true seed than for vegetative materials, care must be taken to assure that seeds are collected only from disease-free plantings.

Weed Control

Weed control is the major single cost factor in cassava production. To help producers with this problem, the Cassava Program this year continued to study effective chemical and cultural control methods.

Figure 15.
Although larvae of the cassava hornworm are very serious pests, CIAT has developed effective biological methods to control them in the field.

Chemical Control of Weeds

Evaluations continued with the promising pre-emergent herbicide oxyfluorfen. At CIAT-Palmira, oxyfluorfen applied at 0.5 kg a.i./ha in combination with alachlor (1.4 kg a.i./ha) provided good weed control and this combination was also cheaper than oxyfluorfen applied at twice that rate. The same combination gave good results under high weed pressure at Caribia, including significant growth reduction of purple nutsedge (*Cyperus rotundus*) during the first five weeks after application.

Cultural Control of Weeds

Cultural control methods that provide the cassava with a competitive advantage over weeds are being sought to assist small producers. Several mulches were tested at CIAT-Palmira and Carimagua for their effectiveness in controlling weeds. In both locations, cassava yields were highest when maize stalks were used for mulching. Other effective materials were sugarcane leaves and straw of *Hyparrhenia rufa* and *Stylosanthes*.

At CIAT-Palmira, the green cover established with *Desmodium heterophyllum* and intercropped field beans also provided good long-term weed control. Although cassava yields were reduced about 20 percent, the additional production of dry beans offset the yield decrease in terms of total value of the crops.

AGRONOMIC EVALUATIONS

Storage of Planting Materials

Cassava planting often follows annual rainfall cycles causing considerable intervals between harvesting and subsequent planting. During these times, stored planting material is exposed to physical damage, dehydration and disease and insect attacks. Program scientists, therefore, have been seeking cheap, satisfactory methods of conserving planting materials in the field.

Chemical treatment (3000 ppm each of BCM and captan) and storage as 1-m long stakes, either in a dry room or standing in the open air under shade,

Figure 16.
Pruning cassava plant stems three weeks before harvest helps prevent root deterioration. The root on the left was not treated and has only been harvested three days; roots on the right have been stored for 60 days after harvesting from pruned plants.

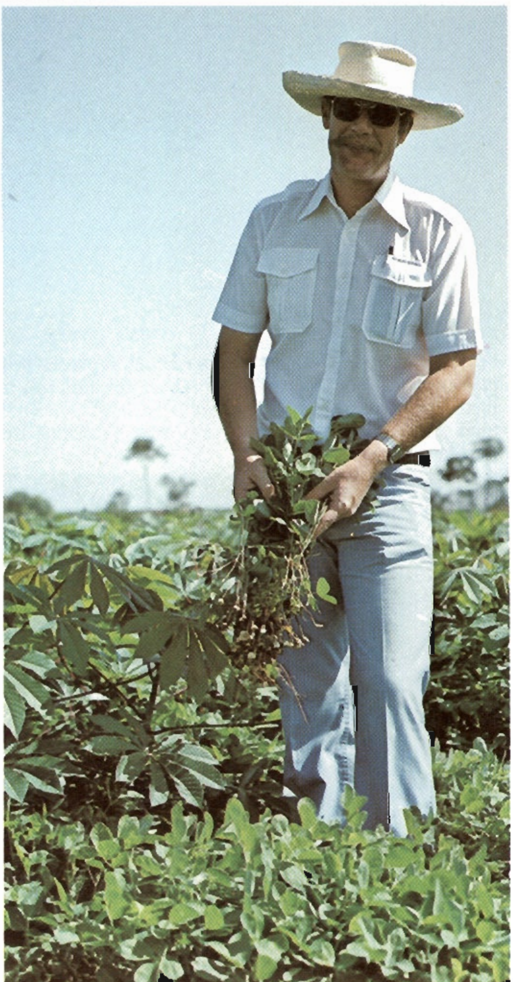
confirmed that planting materials can be preserved and good germination secured for several months. As storage time increased, storage conditions became more critical.

Multiple Cropping

Several legume species were screened on the low fertility soil at CIAT-Quilichao and at the medium- and high-fertility sites at Caribia and CIAT-Palmira, respectively. Cowpea (*Vigna unguiculata*) was the only grain legume with good productivity at CIAT-Quilichao and considerable adaptation to conditions at the other two locations. A local variety of peanut (*Arachis hypogea*) was also well-adapted at CIAT-Quilichao and had the adequate growth habit that should make it a favorable intercrop with cassava. Mungbeans were adapted to the better fertility at Caribia and CIAT-Palmira.

Spatial arrangements were studied with both cowpea and peanut to find the planting pattern that minimizes competition with cassava. Grain yields of both legumes were highest in a pattern of three rows between two rows of cassava spaced 1.8 m apart. Outside rows of legumes were 0.55 m from the cassava with 0.35 m spacing between rows of legumes. Cassava yields were highest when two rows of legumes were planted 0.7 m from cassava rows spaced 1.8 m apart.

Figure 17.
Trials by Agronomist Dietrich Leihner have shown peanuts to be one crop that associates well with cassava on acid, infertile soils.



Soil Fertility Experiments

Cassava Response on Highly Acid Soils

The adaptation of cassava to highly acid soils was confirmed in tests at CIAT-Quilichao. Average yields of 30 cultivars grown on unlimed plots (pH 4.0 and 77 percent aluminum saturation) were 90 percent of those from plots limed at the rate of 6 t/ha.

Cassava Responses to Phosphorus and Potassium

The cultivar Llanera has an external phosphorus requirement of 0.01-0.02 ppm in soil solution, much lower than other major crops. Yields were, however, unusually low in all phosphorus trials due to a marked reduction in harvest index. At CIAT-Quilichao, Llanera responded mainly to applications of phosphorus with little response to potassium and no response to nitrogen. In Carimagua, potassium applications did not significantly affect fresh root yields but significantly increased dry matter content up to the level of 200 kg K_2O/ha applied.

Cassava appears to depend heavily on an effective mycorrhizal association for phosphorus uptake in soils low in this element. Root inoculation with mycorrhiza significantly increased plant growth and uptake of phosphorus, both in soils and in nutrient solution.

Regional Yield Trials in Colombia

Eight regional trials were harvested in Colombia during 1979 completing the fifth consecutive testing cycle. Locations covered a wide range of altitudes, temperatures, rainfall and edaphic conditions. Technology used was based on low inputs, principally simple agronomic practices along with improved germplasm.

At seven of the eight locations at CIAT a germplasm selection or hybrid outyielded local cultivars. At five sites, cultivar M Col 1684 yielded the highest, and it averaged 33.1 t/ha across all seven sites where it was grown. This cultivar has given consistently high yields under little or moderate stress conditions. The Brazilian cultivar CMC 40 ranked second this year, averaging 27.9 t/ha in seven locations. It has already been selected for commercial production in several Latin American countries.

On-farm Trials of Improved Technology

Improved agronomic practices are being evaluated on small farms at Media Luna, on the North Coast of Colombia. The four technology components being tested are: increased plant populations (from about

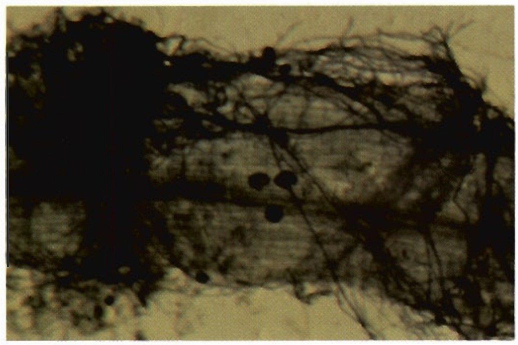


Figure 18.
Cassava grows very slowly in the sterilized soil on the left but when the same soil is inoculated with mycorrhiza, plant growth is vigorous, total dry matter increases up to three-fold and phosphorus uptake increases up to seven-fold.

Figure 19.
Through the microscope, the extensive network of mycorrhizal hyphae that extend the root system's nutrient-absorbing capacity is very evident.

Figure 20.
On-farm trials of cassava technology are confirming that simple agronomic practices can significantly increase yields of farmer's traditional varieties.

6250 plants/ha under traditional systems up to 10,000); stake selections and treatment; fertilizer; and different germplasm (two selections exhibiting wide adaptability in four years of CIAT regional trials).

Stake selection and treatment plus increased densities raised yields of the local cultivar from 7.1 to 12.1 t/ha; the local cultivar also showed a higher starch content than the other two cultivars. Yields between the three cultivars did not differ significantly, and except for the least vigorous one, M Col 22, there were no significant responses to fertilizer applications.

INTERNATIONAL COOPERATION

Latin America

The Cassava Program's outreach strategy varies among countries based on two principal factors: the potential for cassava in the country — according to both production and marketing potentials — and the current level of development of each national program. Four categories of countries have been defined: (1) those with strong national cassava research programs linked to well-developed extension programs; (2) countries with capable research programs but which are not linked to well-defined production and market objectives; (3) countries with no or only limited programs but with a need and interest in increasing cassava production; and, (4) countries with deficits in production of calories and which have not shown interest in increasing cassava production or do not have a well-defined cassava program, although the countries do have the potential to produce cassava.

The Cassava Program's strategies for assisting these countries vary. For countries in the first category, CIAT assists by identifying the local factors limiting production and defining the appropriate research strategy. Technology can be transferred at this level; it commonly consists of improved agronomic practices of general applicability and new genetic material recommended for specific conditions. The Program works with Category 2 countries by helping them evaluate national and introduced cultivars to determine their production potential. Economists might also assist in analyzing the possible economic benefits of increasing cassava production. Countries in the third group can best be helped by training their technicians to evaluate germplasm and other technology generated at CIAT and by assisting them in collecting local base data for use in future planning. Work with countries in Category 4 consists of making them aware of the potential of cassava by establishing and evaluating international trials in cooperation with local researchers and by collecting data on cultural and agronomic practices and making this information available to national planners.

Training

As development needs are defined, training of national program personnel in Latin America is the primary means the Program uses to help establish strong cooperative links in the various countries. During 1979, an intensive course in cassava production was held for 39 agronomists from 11 countries. Another 32 professionals from the region also received training during the year.

Germplasm Distribution

Distribution of promising germplasm materials has been another major link with cooperators in the network. Vegetative material of 13 germplasm cultivars and 12 hybrids was sent to 25 national agencies in 17 countries. These shipments were in addition to meristem tissue cultures sent to Brazil by the Genetic Resources Unit. Future exchanges using this technique are expected to increase rapidly.

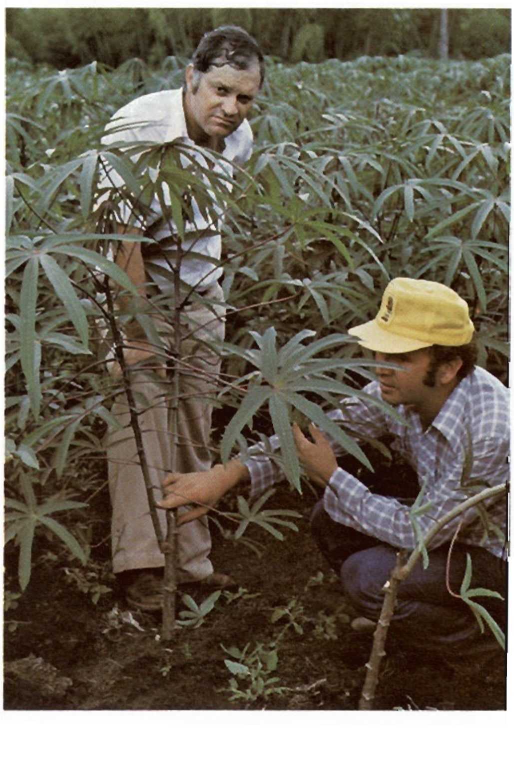
International Yield Trials

The International Yield Trial network has expanded considerably with tests harvested in eight countries this year. International trials began only three years ago.

While the best CIAT materials in international trials yielded an average of 10 t/ha more than local

Figure 21.
Training activities are the Cassava Program's primary means for building and maintaining strong cassava improvement networks.

Figure 22.
CIAT Agronomist Julio Toro and Samuel Garcia, of the Colombian National Federation of Coffee Growers, observe the excellent growth of this vertically planted stake. Stake selection, proper length (20 cm) and vertical planting help assure good cassava yields.



cultivars, the average for local cultivars of almost 30 t/ha was very high, indicating that countries presently have materials capable of significantly increasing production if the simple, inexpensive technology is used as recommended.

Asia

Of the six cassava-producing countries accounting for 70 percent of the world's cassava, three (Indonesia, India, and Thailand) are in Asia. Average yields in the region are 10 t/ha. However, the yield potential in the region is estimated to be more than 20 t/ha, using new technology based on improved varieties and the simple, low-input cultivation and phytosanitary practices developed at CIAT and adapted locally. Interest in cassava production has been increasing and national research programs continue to be established. CIAT has stationed an outreach specialist in the Philippines to assist in developing and introducing new cassava production technology in Asian countries.

Training

Seven cassava workers from five Asian countries participated in a four-week course on tissue culture techniques, at CIAT. This training will enable an accelerated effort in germplasm exchange between CIAT and Asia and among the countries in the Asian network.

Three short courses on rapid propagation techniques of cassava were organized in the Philippines. A total of 45 technicians attended the courses.

Germplasm Distribution

One of the important limiting factors in increased cassava production in Asia is the narrow genetic base of existing cultivars. Last year efforts were begun to introduce new germplasm in the region.

Seven cultivars and eight CIAT hybrids were propagated in quarantine in the Philippines after shipment from CIAT. Stakes of nine of these materials were distributed for evaluation in India, Indonesia and Sri Lanka. Twelve of the materials

are also being evaluated at two locations in the Philippines. Ten other CIAT hybrids, transferred to Asia as true seed, are being propagated and evaluated for possible distribution.

Figure 23.
Cassava producers in the Caicedonia region of Colombia have adopted many of the low-cost agronomic techniques that provide higher yields. Better growers here produce up to 40 t/ha (about four times the national average) by vertically planting selected, treated stakes on ridges and by keeping fields free of weeds.

Rice is a commodity which is of increasing importance in Latin America and the Caribbean. Rice provides about one-third of the total calories consumed in the region. Recently, per capita consumption has been increasing, from an apparent 41 kg/year in 1973-75 to 45 kg/year in 1975-76. The region as a whole is a net importer. Between 1963 and 1977, production increased about 3.4 percent per annum with two-thirds of this increase coming from expansion of area planted. Increased production, however, has varied from country to country and according to the production system. Nine of 24 countries, for example increased their production at least 4 percent per annum during the period.

In Latin America and the Caribbean rice is produced under two systems of cultivation — upland and irrigated. Fifty-one percent of the rice in the region is produced as irrigated, on only 28 percent of the area cultivated. Average yields for irrigated rice are 3.4 ton/ha compared to 1.3 ton/ha for upland. Because irrigated rice is the overwhelmingly predominant system of cultivation in most of the world, technology developed by the international centers' system up to recently has been directed mainly to this type of cultivation. Primary constraints in irrigated cultivation are the biological problems of diseases and pests. Because upland cultivation requires very different technology to overcome different problems, increasing attention will be given to working with this system of cultivation as resources permit.

Rice Program

INTRODUCTION

The Rice Program in 1979 continued to direct its activities towards producing and transferring technology to help overcome biological and agronomic constraints on rice production in Latin America and the Caribbean.

In varietal improvement activities, advanced breeding lines carrying genes pyramided against the rice blast disease entered wide-scale testing. A program was also initiated to produce multi-purpose crosses whose progeny will be available in the F_2 generation to national breeding programs. Early screening and selection for local environmental stresses will help accelerate germplasm movement to these client programs.

A plant pathology section was established in the Rice Program this year and comprehensive screening techniques to detect tolerance or resistance to rice blast were set up. Agronomic studies concentrated on alleviating the major production constraints of insect pests and weeds through chemical controls.

The International Rice Testing Program for Latin America (IRTP) continued to evaluate, assemble and distribute germplasm nurseries in the region. It also sponsored a major conference for cooperators and provided in-country assistance with establishing and evaluating the various nurseries.

VARIETAL IMPROVEMENT

The primary objective of the varietal improvement program in rice is to combine resistance or tolerance to major biological production constraints in order to stabilize yields and reduce any gap between actual and potential yields.

Figure 1.
Development of materials with good yield potential and tolerance or resistance to major production constraints is the overall breeding objective of the Rice Program. Breeder Hector Weeraratne here observes some of the promising new progenies.

Resistance to Rice Blast

The rice blast disease (caused by *Pyricularia oryzae*) continues to be the most destructive and widespread common production constraint in Latin America. Achievement of stable resistance to rice blast is being attempted utilizing the breeding techniques of pyramiding major resistance genes, development of multilines, and concentration of minor genes for resistance.

This year 11 advanced breeding lines pyramided against rice blast entered extensive regional trials at 11 sites in Colombia. The International Rice Testing Program for Latin America (IRTP) also distributed these lines in a special nursery to other countries for identification of wide adaptability and broad-spectrum resistance. In addition to their resistance to blast, the lines are of short to intermediate plant type, resistant to the plant hopper (*Sogatodes*), have good tolerance to leaf scald, and have good grain quality and high milling recovery.

Other Breeding Projects

Backcrossing has been done with the variety Bg 90-2 to combine its high yield, wide adaptability, excellent plant type and very good early vigor with rice blast resistance and improved grain quality from other sources. Several progenies that combine blast resistance, improved grain quality and the Bg 90-2 plant type were selected and advanced to preliminary yield trials.

A new breeding project was initiated this year to produce segregating populations for diverse systems of cultivation in Latin America. Parental sources have been selected and the crossing combinations planned to provide for dwarf and intermediate stature, tolerance to water stress, adaptability for upland, rainfed and irrigated cultures, good grain quality, resistance to blast (through combining major and minor genes) and resistance to leaf scald. F_2 seed of the multi-purpose crosses will be supplied to all Latin American countries interested in upland or rainfed rice, to facilitate early screening and detection of desirable stress-tolerant segregates through their exposure to environmental stresses specific to each country.

Five high-yielding advanced lines were selected from segregating populations brought from Sri Lanka and are being used as donors for yield in the varietal improvement program. Two of the lines were identified as tolerant to sheath blight and leaf scald. Another is being extensively crossed to utilize its excellent early vigor, high tillering capacity and good plant type.

More than one hundred introductions from the International Institute for Tropical Agriculture (IITA) and the International Rice Research Institute (IRRI) were evaluated as sources of good parental material for diversification of the genetic base used in the varietal improvement program.

Twelve of the intermediate type African lines combining early vigor, profuse tillering and stiff straw were selected. Ten of the lines from IRRI were selected for combinations of very stiff straw strength, very profuse tillering and typical dwarf stature.

Breeding Methodologies

Mutation Breeding

Broad-spectrum resistance to rice blast has only been identified up to now in poorly yielding rice types that are tall, weak-strawed and highly prone

Figure 2.
Rice Pathologist Sang-Won Ahn (nearest on left) explains the procedure he uses to evaluate seedlings for reactions to rice blast in this nursery bed.

to lodging. Dwarfing of these broad-spectrum, tall donor parents through induced mutations is being attempted, to render them suitable for use as recurrent parents. Fourteen varieties have been irradiated at the laboratories of the International Atomic Energy Commission (Vienna) and have been planted for evaluation.

Inducement of Male Sterility

Ready availability of male sterile stock would greatly facilitate recurrent selection projects for concentration of desired genes. Up to 73 percent male sterility has been obtained by treating the CICA 8 variety twice during the booting stage with Ethrel (2-chloroethylephosphonic acid).

PLANT PATHOLOGY

Evaluation for Resistance to Rice Blast Disease

With the creation of a pathology section in the Rice Program this year a comprehensive screening procedure was developed for resistance or tolerance to rice blast. Materials which show high resistance to the disease in the blast nursery pass into more intensive tests under inoculation and into multilocational trials at various locations in Colombia. This year about 38 percent of almost 700 breeding lines and accessions from other sources showed a highly resistant reaction in this nursery.

Several resistance mechanisms such as lower infection efficiency, longer incubation periods, small size of lesions and low production of spores have been observed to contribute to slow progress of the disease. Materials showing this slow blasting reaction during initial evaluations pass into a separate set of screenings. Twenty plants, from among 500 being evaluated, showed this character and will be evaluated further.

In spite of constantly maintaining a favorable microclimate in the blast nursery, several entries showed remarkable recovery from severe reactions to blast while others continued to have the same or more severe reactions. Very few studies have been

Figure 3.
This seedling bed, identical to the one in Figure 2, is utilized to check for slow-blasting reactions. Only the susceptible spreader rows for the disease have been planted here; materials to be evaluated will be interplanted soon in the bare spaces.

done on this recovery mechanism of resistance although the character may contribute a great deal to lowering the rate of infection. Studies will be done to better understand this type of reaction.

Variability of the Rice Blast Pathogen in Latin America

Analysis of data from the 1978 International Rice Blast Nursery for Latin America (VIPAL) confirmed that the blast pathogen varies from one location to another. Moreover, the kind and frequency of races of *P. oryzae* are known to change continuously even at the same location. Some entries in the 1978 VIPAL have been selected for use as temporary race differentials. Continuous monitoring of these materials will provide information on the change of races in each testing site.

Eyespot Disease

A leaf disease that has caused considerable damage on the variety CICA 7 in two provinces of Panama and on CICA 6 near CIAT-Palmira was identified as eyespot, caused by the fungus *Drechslera gigantea* (Heald & Wolf) Ito. Symptoms have been observed in these locations for some five years and closely resemble the symptoms of rice brown spot (*Helminthosporium oryzae*). This eyespot has been known to occur on several grass species and on banana, but has never been reported on rice. Studies will be continued to monitor its development and importance on rice.

AGRONOMY

Studies of Insect Pests

The dipterous insect *Hydrellia* sp. is becoming an important pest in some areas of Latin America. It proliferates rapidly under conditions of rice flooding and thus is much more serious in areas cultivated under irrigation.

Figure 4.
This eyespot disease, caused by *Drechslera gigantea* (Heald & Wolf) Ito., has been identified this year in rice fields in Colombia and Panama.

This year several insecticides were evaluated for their effectiveness in controlling *Hydrellia*. Differences between effectiveness of the compounds were not significant and all provided acceptable control. Very good control is also provided by draining fields and allowing the soil surface to dry. This treatment should not continue for more than five days, to prevent both damage to the young plants and weed growth.

A stem borer, *Rupela albinella* Cramer, was studied to determine its economic importance in reducing yields, the effects of agronomic practices such as transplanting density and nitrogen fertilization on *Rupela* populations and damage, any varietal preferences of the insect and possibilities for biological control.

Average damage to stems of variety CICA 8 was 44 percent and to IR 22, 28 percent. Insect populations were lower in both varieties when they were transplanted at 20 x 20 cm distances, compared to 30 x 30 cm. Varying the levels of

Table 1. **Yields of paddy rice and quantity of weeds from plots treated with several granular herbicides.**

Treatments	Application rate (kg a.i./ha)	Rice yield (t/ha)	Weed dry matter (g/m²)
Hand weeding	-	8.73 a[1]	2.0
butachlor + 2,4-D	0.75 + 0.5	8.37 ab	3.3
oxyfluorfen + 2,4-D	0.2 + 0.5	8.28 ab	4.0
bifenox	2.5	8.13 abc	4.0
2,4-D	0.5	8.09 abc	11.3
butachlor	1.0	8.09 abc	25.0
bifenox + 2,4-D	2.0 + 0.5	7.95 abcd	2.0
bifenox	3.0	7.85 abcd	2.3
2,4,5-T	0.8	7.84 abcd	20.0
tiobencarbo	1.0	7.48 bcd	7.6
2,4-D	0.8	7.40 bcd	27.3
tiobencarbo + 2,4-D	0.75 + 0.5	7.31 bcd	10.6
oxyfluorfen	0.3	7.08 cd	13.3
Unweeded control	-	6.92 d	30.3

[1] Values followed by the same letter are not significantly different at the 0.05 level.

nitrogen applied did not affect insect incidence. Levels of parasitism by *Strabotes abdominalis obscurus* Zwart and *Trathala* sp. varied between 64 and 71 percent with no differences for varieties, densities or fertilization rates.

Weed Control

Granulated herbicides provide the small farmer with an attractive option to hand weeding of rice. Not only does he usually have hand labor available to apply these herbicides, but also no special equipment is required for their application.

Several granular compounds were applied alone or in combinations four days after rice transplanting. Fields were flooded one day before and kept irrigated until 10 days before harvesting. Results, in terms of rice yields, are shown in Table 1. A regression analysis showed that every 1 kg of weeds (dry matter) reduced rice yields about 3 kg/ha.

INTERNATIONAL COOPERATION

International Rice Testing Program for Latin America

The activities of the International Rice Testing Program for Latin America in 1979 were oriented to helping national programs increase rice production and productivity by providing improved germplasm to help overcome a range of constraints.

1977 Nurseries

Final results of nurseries distributed in 1977 and tested through last year indicated that every one of the entries in yield nurseries was selected by one or more national programs for further yield trials or regional tests.

In Cuba, line IR 1529-430-3, introduced from IRRI and included in the Upland Yield Nursery for Latin America (VIRAL-S, 1977), was released to farmers under the name IR 1529. The same line is in regional trials and seed multiplication in Santa Cruz, Bolivia, as Saavedra V-5.

Figure 5.
The widely distributed aquatic fern *Azolla* sp. is being studied as a potential source of nitrogen in rice paddies. It is the only member of the order Pteridofita (fam. Salvinacea) that lives in symbiosis with the biofungus *Anabaena azollae* Strans. In association, *A. azollae* is able to fix nitrogen from the atmosphere. This symbiosis will be studied in more detail to determine its effect on rice production.

Figure 6.
The continuous production system for rice is based on seeding or transplanting a certain area of the total field every 15 days. The system is usable on farms of all sizes. It permits higher yields, better use of equipment and labor, as well as of water and the soil. More than two complete crops are easily possible if water is available year-round. This demonstration field at CIAT-Palmira shows plots (0.1 ha) on the left planted with pre-germinated seed and plots (0.12 ha) on the right that were transplanted.

Table 2. **Nurseries distributed in 1979 in the International Rice Testing Program for Latin America (IRTP).**

Nursery[1]	Number of entries	Number of sets	Yield range[2] (t/ha)
VIRAL-P	23	39	4.3-6.7
VIRAL-T	23	28	3.6-8.5
VIRAL-Tar	19	9	5.9-7.9
VIRAL-S	24	30	4.8-8.9
VERAL	14	22	4.7-7.0
VIOAL	97	14	4.1-9.1
VIOAL-S	52	25	3.9-8.7
VIOAL-R	61	18	4.3-8.3
VIPAL	120	31	-
VIAVAL	16	12	5.5-8.9
VIOSAL	10	8	4.7-8.6
VITBAL	23	10	2.9-8.1
VIRAL-F	15	8	4.6-8.1
Total	497	254	

1 VIRAL-P International Rice Yield Nursery-Early
VIRAL-T International Rice Yield Nursery-Medium
VIRAL-Tar International Rice Yield Nursery-Late
VIRAL-S International Rice Yield Nursery-Upland
VERAL International Specific Rice Yield Nursery
VIOAL International Rice Observational Nursery
VIOAL-S International Rice Observational Nursery-Upland
VIOAL-R International Rice Observational Nursery-Leaf Scald
VIPAL International Rice Blast Nursery
VIAVAL International Rice Sheath Blight Nursery
VIOSAL International Rice Salinity and Alkalinity Observational Nursery
VITBAL International Rice Low Temperature Nursery
VIRAL-F International Rice Yield Nursery-Deep Water

2 Yield range in two seasons at CIAT under irrigated/transplanted conditions.

1978 Nurseries

Among germplasm of yield nurseries distributed in 1978 and harvested this year, several entries had good yield potential under both irrigated and favored upland conditions (Table 2).

Similarly, several lines of the 1978 observational nurseries (VIOAL and VIPAL) had good performance and resistance to leaf and neck blast infection. Germplasm of the VIPAL-1978 with resistance to rice blast was re-entered in the VIPAL-1979 for further testing. The entries of VIOAL-1978 will be evaluated for yield in 1980 nurseries.

1979 Nurseries

The 1978 nurseries from IRRI were planted this year at CIAT-Palmira and evaluated under field conditions for plant type, maturity, lodging resistance and yielding ability, and under laboratory conditions for *Sogatodes* resistance and grain quality. Only those entries combining desirable traits were included in the various nurseries distributed in 1979 (Table 3).

Twelve 1979 IRRI nurseries were planted at CIAT-Palmira in July and August for evaluation, selection and seed increase. This germplasm will be evaluated in the laboratory for *Sogatodes* resistance and grain quality and selected materials included in the 1980 IRTP nurseries.

IRTP Monitoring Tour

A monitoring tour to northern South America was made to visit rice research activities of national programs and to evaluate germplasm of IRTP nurseries in Colombia, Ecuador, Guyana, Surinam and Venezuela. A complete report on rice culture, research activities and the constraints limiting production in these five countries was published in English and Spanish. Individual visits were made in Belize, Colombia, El Salvador, Guatemala and Panama. From these visits, valuable information was obtained on performance of IRTP nurseries. Among germplasm of various nurseries, varietal resistance was observed for the acid soils problems of Belize, Colombia and El Salvador.

IRTP Conference

A Third Conference of the IRTP for Latin America was held this year with a Rice Blast Workshop as the central discussion topic. Fifty-nine rice scientists of national programs and 14 scientists of other national and international institutions participated in the conference at CIAT, from May 30-June 2. Current operational procedures for the Latin American IRTP were revised and new nurseries for specific constraints in the region were established.

Table 3. **Average yield and days to flowering of the best five entries in each of the three International Rice Yield Nurseries for Latin America in 1978.**

Designation	Origin	Yield (t/ha)		Days to flowering
		Average	Range	
International Rice Yield Nursery-Upland (VIRAL-S)[1]				
1. IR 1529-430-3	IRRI	4.9	2.6- 8.6	93
2. CICA 8	ICA-CIAT	4.7	1.8- 7.5	99
3. CR 261-7039-236	India	4.6	2.1- 7.9	95
4. IET 6047	India	4.5	2.2- 8.4	97
5. CR 46-15/IR24[2]	Philippines	4.3	1.8- 6.7	90
International Rice Yield Nursery-Medium Maturing (VIRAL-T)[2]				
1. Bg 375-1	Sri Lanka	6.2	3.5-10.5	97
2. CICA 8	ICA-CIAT	6.0	1.3- 9.2	103
3. B541b-Kn-91-3-4	Indonesia	5.9	2.0- 9.9	96
4. B541b-Kn-22-7-2	Indonesia	5.8	1.5- 9.6	97
5. IR 4422-98-3-6-1	IRRI	5.6	2.1-10.2	104
International Rice Sheath Blight Nursery (VIAVAL)[3]				
1. B189c-Kn-45-1-3	Indonesia	6.4	4.1- 9.9	100
2. BW-196	Sri Lanka	6.3	3.2- 9.3	111
3. IR 4422-98-3-6	IRRI	6.2	3.0-10.1	106
4. IR 2796-44-2	IRRI	6.2	3.8- 8.6	107
5. Chianung Sen Yu 19	Taiwan	5.9	2.8- 8.3	101

1 Planted in 22 locations, 17 under favored upland and 5 under unfavored upland conditions.
2 Planted in 18 locations, 12 under irrigated and 6 under favored upland conditions.
3 Planted in 8 locations, 6 under irrigated and 2 under favored upland conditions. All entries were tolerant to sheath blight disease.

Figure 7.
A typical rainfed rice farm on the plains of the Guayas River in Ecuador was one of many locations visited on the 1979 Monitoring Tour of the International Rice Testing Program (IRTP).

Data on rice area, production, yields, varieties cultivated, and limiting constraints were up-dated. A report of the conference was published in English and Spanish.

The discussion on rice blast emphasized the need for research on techniques to induce leaf and neck blast infection under field conditions for segregating populations and methodologies for identifying stable resistant segregates, especially for neck infection. Identification of stable resistant donors was also encouraged.

Seed Distribution

Another activity of the IRTP is related to seed distribution of promising lines or varieties requested by institutions of several countries. In 1979, 656.4 kg of seed of 22 varieties were dispatched to eight countries.

Training

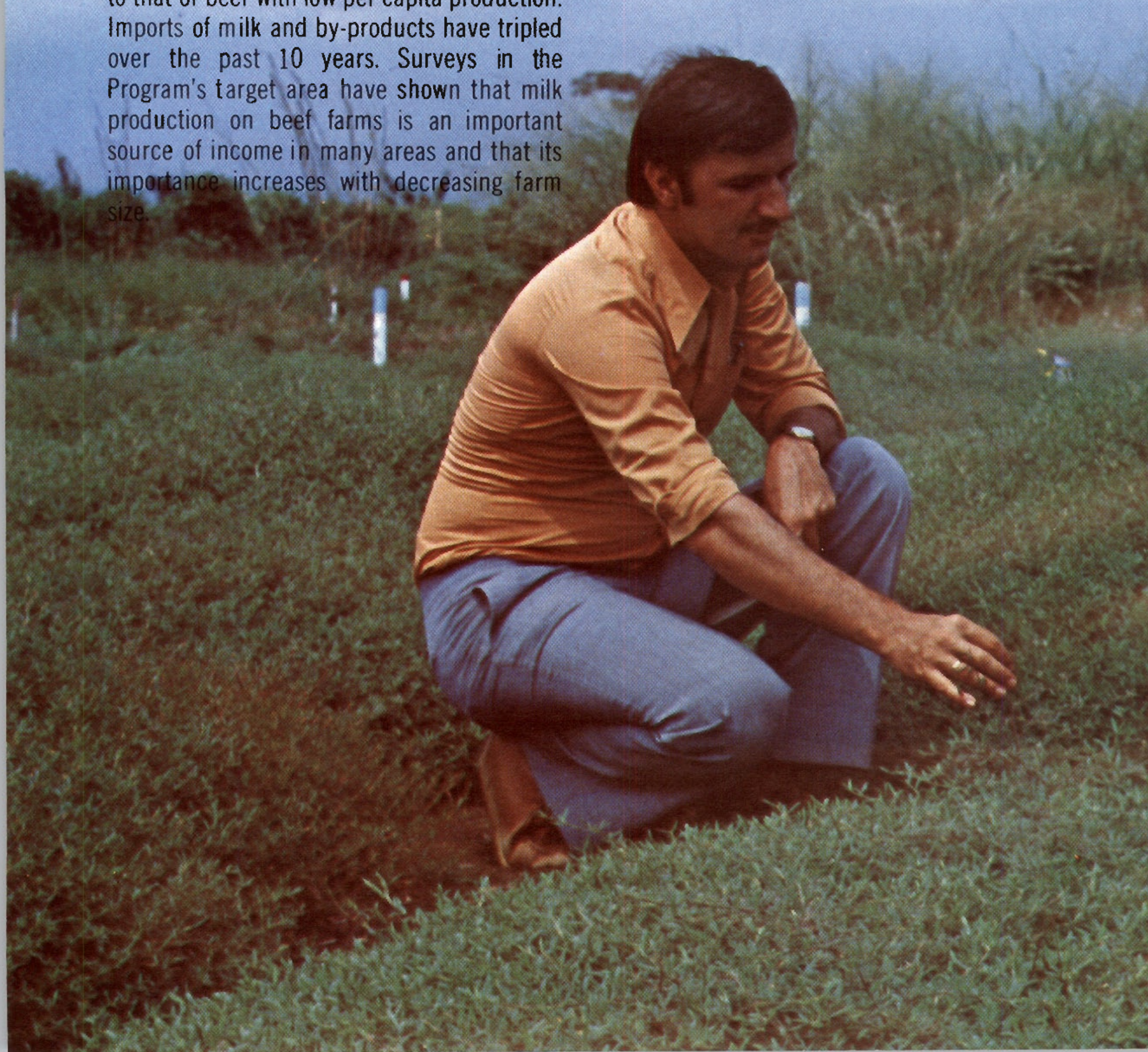
The Rice Program provided formalized training to 52 professionals during 1979. Ten trainees from six countries of the region participated in a six-month rice production course and another 34 persons from 13 countries attended a one-month intensive course. Eight professionals trained in various other subject-matter areas in the Program.

Figure 8.
Before germplasm nurseries are distributed throughout the region in the International Rice Testing Program for Latin America (IRTP), each is grown at CIAT-Palmira for observation and seed multiplication.

Figure 9.
The III Conference of the International Rice Testing Program for Latin America (IRTP), held at CIAT-Palmira in mid-1979, was attended by 73 rice scientists, most of them from national programs in the region.

Beef is one of the staple foods of Latin American urban and rural poor, and one of the principal reasons why protein malnutrition is less acute in tropical America than in Africa or Asia. During the past 15 years the annual growth in demand for beef in tropical America (5.6 percent) has exceeded production increases (3.6 percent). This gap is resulting in real price increases which will cause a decrease in beef consumption by families of the lower 25 percent income strata who presently spend from 8 to 16 percent of their total budgets to buy beef. The situation with milk production trends in the region is similar to that of beef with low per capita production. Imports of milk and by-products have tripled over the past 10 years. Surveys in the Program's target area have shown that milk production on beef farms is an important source of income in many areas and that its importance increases with decreasing farm size.

In the face of the growing demand for low-cost beef and other animal products, it would seem that one solution would be to develop new technology for land best suited to grazing. Pressure will continue to increase for crop production on more fertile lands; however, about one-half (850 million hectares) of the American tropics have soils of such low fertility that crop production on them is not economical. These tropical savannas and jungles could support a thriving beef industry, if the proper forage species and low-cost associated pasture and cattle management systems were developed and introduced.



Tropical Pastures Program

INTRODUCTION

The poor nutritional status of grazing animals has been identified as the principal factor limiting animal production on savanna and jungle soils in tropical America. Research at CIAT has, therefore, been directed towards developing more productive and nutritional pastures. To reflect this emphasis in its activities, in 1979 the name of the Beef Program was changed to the Tropical Pastures Program.

The Program's central objective remains the same as before, namely, to remove the main constraints to increased beef (and milk) production on the acid, infertile soils of the American tropics by developing low-cost pasture technology for the various ecosystems comprising these infertile soil areas. This new technology includes adapted germplasm of both grasses and legumes, and the management practices for establishing and maintaining the improved pasture systems.

Accomplishment of this objective would produce four principal contributions to increasing production of basic foods in the lesser developed countries of the region.

1. Increased production of beef, a staple commodity among the low-income groups of tropical Latin America.

2. Increased production of by-products from beef farming on acid soils, such as milk and its products which are commodities in large deficit in the region.

3. The conservation and improvement of acid soils in fragile ecosystems.

4. A basis for expanding the agricultural frontier in tropical America in economically and ecologically viable forms, while at the same time releasing for crop production more fertile land presently used for cattle production.

CLASSIFICATION OF MAJOR ECOSYSTEMS

One of the Program's underlying objectives in recent years has been to clearly define the ecosystems in its target area, particularly in terms of climates and soils. Based on detailed surveys and data analyses, this year the target area was classified into five major ecosystems by stratifying Total Wet Season Potential Evapotranspiration (TWPE). This parameter has provided a rational quantitative means that: (a) explains the existing vegetation coverage on the basis of available energy for plant growth during the growing season; and, (b) enables the anticipation of the major expected differences in pasture growth and animal performance. Locations of the ecosystems are shown in Figure 2. Their major distinguishing features may be summarized as follow.

1. Tropical savanna (with TWPE of 910-1060 mm), well-drained and hyperthermic (mean temperature during the rainy season greater than 23.5°C). This ecosystem is represented by the Llanos of Colombia, Venezuela, Guyana and Surinam, and by the savannas of Roraima and Macapá, in Brazil.

2. Tropical savanna (with TWPE of 910-1060 mm), well-drained and thermic (mean temperature during the rainy season less than 23.5°C). The primary area is the Brazilian Cerrado.

Figure 1.
Tropical savanna pastures of improved forage species will contribute in several ways to increasing production of basic foods in the target area of the Tropical Pastures Program.

3. Tropical savanna, poorly drained. Representative areas include the Beni of Bolivia, the Pantanal in Brazil, the Casanare region in Colombia, and Apure region in Venezuela. TWPE figures may vary.

4. Tropical semi-evergreen, seasonal forest (TWPE 1060-1300 mm).

5. Tropical rainforest (TWPE greater than 1300 mm).

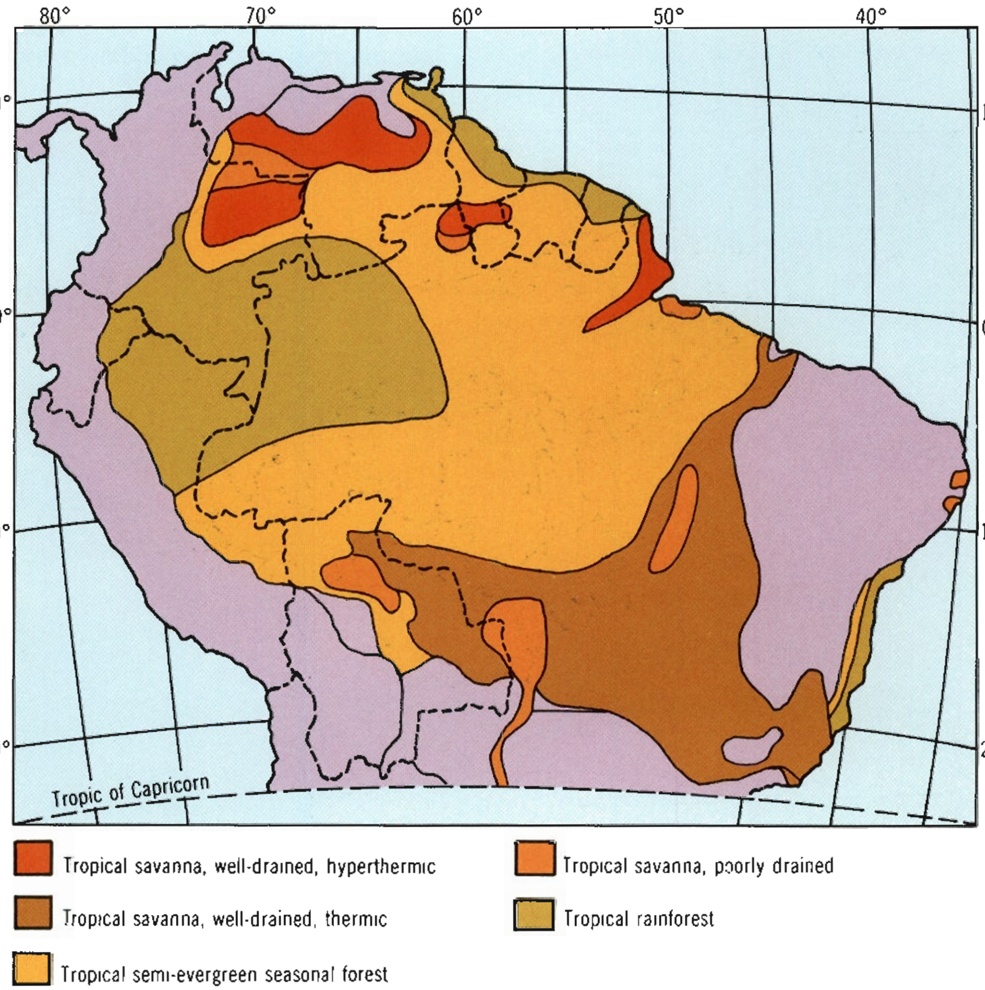


Figure 2
Boundaries of ecosystems defined for the target area of the CIAT Tropical Pastures Program.

GERMPLASM DEVELOPMENT

Evaluation Scheme

Of the five ecosystems, the most is known about germplasm performance in the well-drained, hyperthermic savanna, from the Program's work at the Carimagua research station, in cooperation with the Instituto Colombiano Agropecuario (ICA). About two years ago work also began in the thermic savannas. This ecosystem is well-represented by the Cerrado Research Center (CPAC), at Brasilia, of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA). Preliminary information on germplasm performance is also received from a limited set of

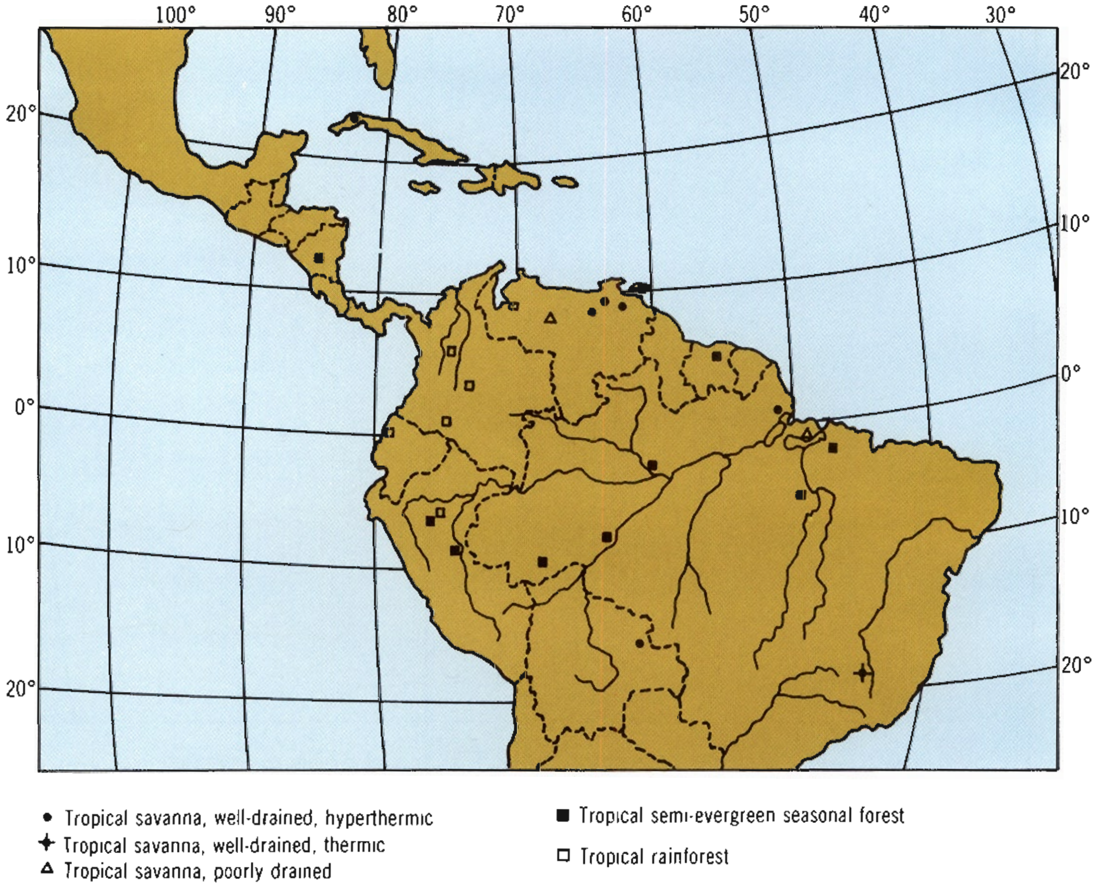


Figure 3.
Distribution of existing regional trials of the CIAT Tropical Pastures Program, located according to ecosystems.

regional trials whose geographical distribution is shown in Figure 3.

Preliminary results of these evaluations showed that germplasm accessions performed differently in the different ecosystems. Accordingly, as of 1979, the Program's germplasm classification scheme was changed from a single list of promising materials to lists by categories for each ecosystem. A list of promising germplasm is available for Carimagua; a list for Brasilia is based on preliminary results.

Figure 5 shows the overall evaluation scheme in the Tropical Pastures Program. After characterization and multiplication of germplasm in CIAT-Quilichao, material showing adaptation to the acid, infertile Ultisol conditions there are placed in follow-up trials in the various ecosystems. This occurs either through the Program's own research activities in Carimagua and Brasilia or through the network of regional trials.

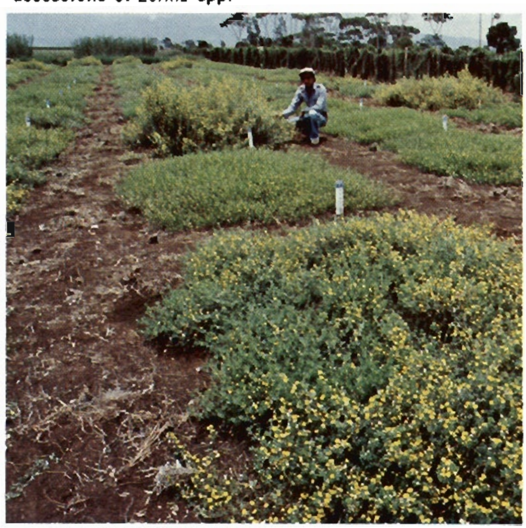
Target area surveys had shown that conditions at CIAT-Quilichao are not representative of any particular one of the five ecosystems. On the other hand, due to a series of features common to all ecosystems, (particularly the presence of acid soil with a high aluminum saturation), this site is very suitable for plant introduction and seed production work.

Plant Introduction

During 1979, an additional 765 germplasm accessions were added to the Program's collection, bringing total holdings to 5475 accessions. Collection trips this year were directed specifically to increasing germplasm of several genera and species having well-identified potentials. One trip was made to collect *Zornia* and *Centrosema* germplasm native to the Colombian Llanos. Another trip to Thailand concentrated on the collection of the native species *Desmodium ovalifolium* and *Desmodium heterocarpon*.

Characterization of new introductions at CIAT-Quilichao showed 41 accessions (11 percent of those tested) of several genera and species performing well during and after at least 12 months

Figure 4.
The CIAT-Quilichao station offers an excellent site for early evaluation of germplasm introductions such as these accessions of *Zornia* spp.



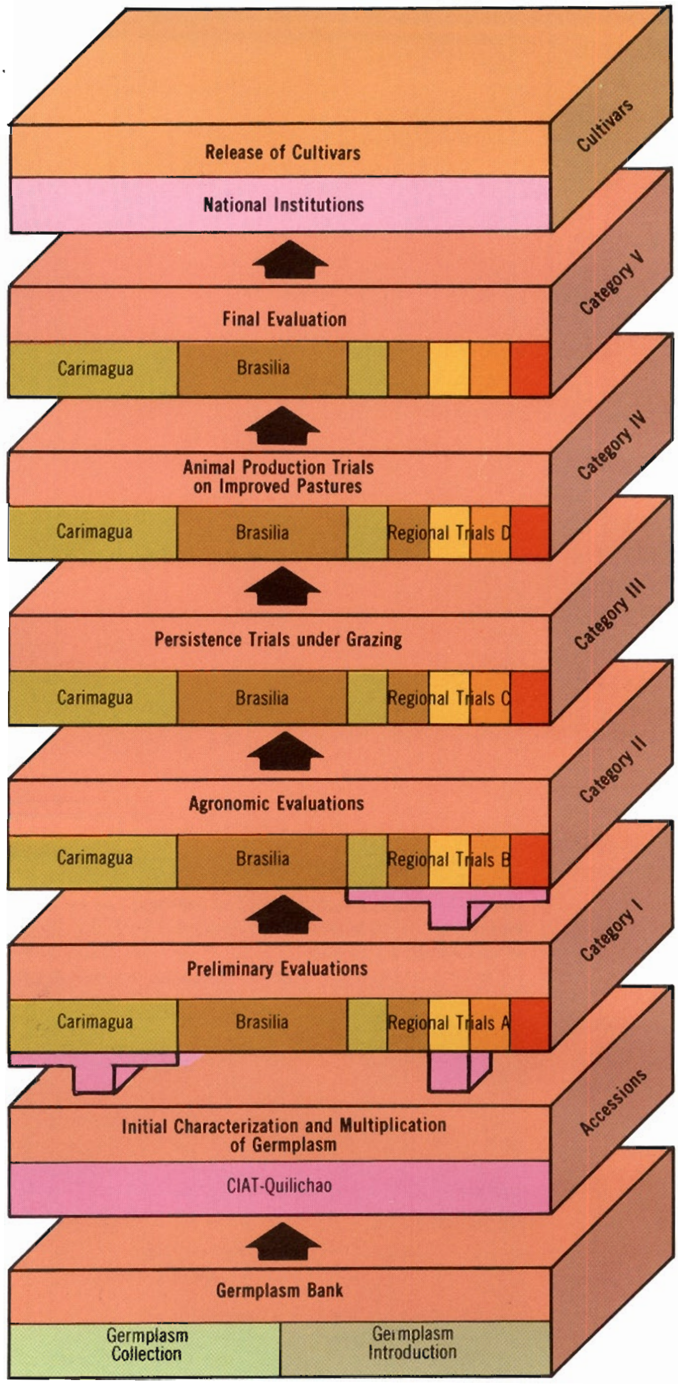


Figure 5.
Overall germplasm evaluation scheme of the CIAT Tropical Pastures Program.

of observations at that site. These materials were selected for priority evaluation in Carimagua and Brasilia. Furthermore, good potential was observed in several legume species that up to now are not well-known agronomically. These include *Centrosema brasilianum, Centrosema macrocarpum, Zornia brasiliensis* and *Zornia myriadena.*

Seed Production

During 1979 in CIAT-Quilichao, 9 ha with 33 legume and two grass accessions were under seed production. In addition, at CIAT-Palmira 15 ha with four legume and two grass accessions were grown. A total of 4.5 t of seed was produced, one-third of it legumes and two-thirds grass, mainly *Andropogon gayanus.*

An indirect method of measuring purity, as defined by the International definition, was developed for use with seed of *A. gayanus.* The test provides a precise purity estimation in only one-quarter of the time normally required for the conventional method.

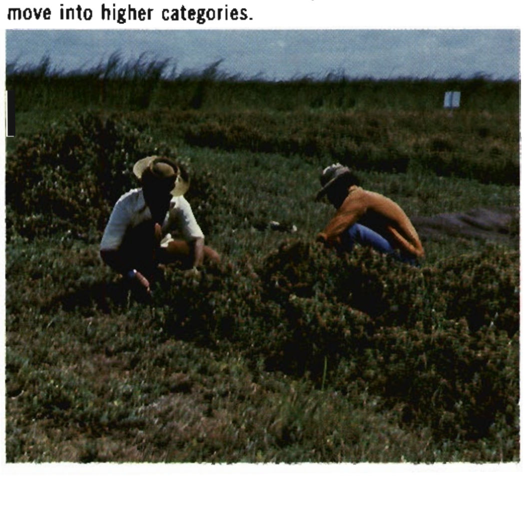
RESEARCH ON CONSTRAINTS TO PASTURE PRODUCTIVITY

Tolerance to High Levels of Aluminum Saturation

High aluminum saturation in the soil is a major constraint to plant growth in the Program's target area. However, preliminary data from target area surveys indicate considerable differences between ecosystems, and within these, between sub-ecosystems. To rapidly assess the potential of germplasm under different aluminum saturation levels, a simple test was adapted this year to screen the large number of forage germplasm accessions entering the Program's collection.

The technique utilizes a 0.2 percent solution of hematoxilin, which has a high affinity for aluminum, as a staining agent for plant tissue. The test is simple, fast, permits high-volume screening, and is quite accurate as confirmed by checking against controls of known tolerance to aluminum.

Figure 6.
Seed production, shown here at CIAT-Quilichao is a critical part of the Tropical Pastures Program's germplasm evaluation scheme. Sufficient seed must be produced as accessions move into higher categories.



The test allows the grouping of forage germplasm into highly susceptible, susceptible and tolerant accessions.

Diseases

A survey of diseases affecting forage species at 20 sites in the target area was completed this year (Table 1). Twenty-two pathogens were identified affecting legumes and grasses. False-smut, Rhynchosporium leaf spot and Sphaceloma scab were detected as new diseases identified on forages and for which additional studies are needed.

Table 1. **Distribution of forage diseases in the target area ecosystems of the CIAT Tropical Pastures Program.**

Forage disease	Tropical savanna, well-drained, thermic	Tropical savanna, well-drained, hyperthermic	Tropical semi-evergreen seasonal forest	Tropical rainforest	CIAT-Quilichao
Anthracnose*[2]	+	+	+	+	+
Cercospora leaf spot (A)[3]*		+	+	+	+
Cercospora leaf spot (B)[3]		+	+	+	+
Root-knot nematode*					+
Blight*				+	
Sphaceloma scab*				+	+
Smut-*(Ustilago)**	+	+		+	
Smut-*(Urocystis)*					
Camptomeris leaf spot*				+	+
Rust-*(Uromyces)*		+	+		+
Rust-*(Puccinia)*					
False rust*	+				
Rhizoctonia solani		+		+	
Rhynchosporium leaf spot*				+	
Drechslera leaf spot		+		+	
Little leaf virus		+		+	+
Ergot	+				
Gibberella inflorescence blight	+				
Botrytis inflorescence blight				+	
Black mold	+				
Powdery mildew	+				+
Slime mold					+

1 The poorly drained tropical savanna ecosystem is not included as little information is available on diseases in that system.

2 Diseases with asterisks are considered important in the target area.

3 (A), on *Panicum maximum;* (B), on *Centrosema* spp.

An important finding was that apparently different diseases and, most probably, different pathogenic races exist in the various ecosystems of the target area. Anthracnose is the only disease found in all ecosystems studied to date. Cercospora leaf spots and smut (*Ustilago* sp.) are present in three ecosystems, whereas other diseases have limited distribution.

Although these results are preliminary, they do suggest that screening for disease resistance should be decentralized to expose forage accessions to as many potential pathogens as possible. Moreover, this would help ensure that germplasm is evaluated in areas of high disease incidence, preferably the center of diversity of the species, and under favorable conditions of disease attack.

Insects

Similarly, a survey of insects affecting forage species at a series of locations over the target area's ecosystems was conducted. Preliminary results indicate that in the various ecosystems, plants are affected by the same orders of insects, but important differences were observed between ecosystems, on the genus and species levels.

An important finding of the same survey was the rather even distribution of beneficial insects throughout the target area. This suggests that biological control might be an important component of future integrated pest control programs in tropical pastures.

Seed Production

One of the constraints to future pasture development is the eventual availability of commercial seed. One prerequisite is that production areas be located within appropriate geographical regions which consistently favor both high yields and quality of seed of a number of species. As part of a long-term assessment of regional seed production potentials within the target area, field experiments were established at seven locations within or

Figure 7.
Anthracnose is one of the most serious diseases of legumes in the Tropical Pastures Program's target area.

Figure 8.
Pathologist Jillian Lenné observes disease damage in this *Stylosanthes* material.

adjacent to the two major savanna ecosystems. These trials, with an average of nine legumes and three grasses, were established in cooperation with local institutional collaborators.

Pasture Establishment

Additional information was obtained this year on low-tillage pasture establishment methods for introducing improved, adapted species into native savanna. In trials with four grass and three legume species planted in association at the low density of 1000 hills/ha, several species successfully invaded and established in native savanna. The potentials of the various species are summarized in Table 2. Successful establishment in these trials was achieved at minimum fertilizer, seed and land preparation costs.

Table 2. **Introduction of improved forage species into native savanna, at Carimagua.**

Treatment of native savanna	Species	Capable of: in-vading	Capable of: dis-placing
Burn only	*Desmodium ovalifolium*	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria radicans	Yes	No
Chemical control	*Desmodium ovalifolium*	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria humidicola	Yes	Yes
	Brachiaria radicans	Yes	No
Tine tillage to 12 cm	*Desmodium ovalifolium*	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria humidicola	Yes	Yes
	Brachiaria decumbens	Yes	Yes
	Andropogon gayanus	Yes	Yes
	Brachiaria radicans	Yes	No
Complete seedbed preparation	*Desmodium ovalifolium*	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria radicans	Yes	Yes
	Brachiaria decumbens	Yes	Yes
	Andropogon gayanus	Yes	Yes
	Brachiaria radicans	Yes	No

Figure 9.
The Tropical Pastures Program has had success in introducing improved forages into this type of native savanna at Carimagua.

EVALUATION OF EXISTING BEEF PRODUCTION SYSTEMS

The Beef Production Systems Evaluation Project (ETES) is directed to analyzing beef farming operations in the two well-drained savanna ecosystems in Colombia and Venezuela and in Brazil. The project's first phase involves surveying selected farms in each region to define the prevailing technology and factors limiting beef production. The second phase will involve introducing certain improved technology components onto selected farms. Presently, only the first phase has been completed on the 16 sample farms in the Colombian Llanos.

Production on Hyperthermic Savannas in Colombia

Results from the Colombian farms showed that production levels, both per animal unit and per hectare, are low. Farm production per animal unit (A.U.) ranged from 34 to 129 kg/A.U./year; the second best farm produced only 71 kg/A.U./year.

Figure 10.
Control of native savanna with tine tillage provides a good establishment base for improved forages.

Similarly, annual animal production rates ranged from 3 to 34 kg/ha; again, the second best farm only produced 17 kg/ha. Conception rates over two years averaged only 50 percent and abortion rates, which averaged about 14 percent, ranged as high as 42 percent.

Poor animal nutrition, shown in previous studies to be the primary limiting factor on production in the Llanos, was confirmed as the important factor in these farm surveys. The lack of good, year-round forage on the low-fertility, higher savanna areas was especially critical. These areas, which are most affected by the severe dry seasons in this ecosystem, represent two-thirds of the total pasture on the farms surveyed. The low, wetter savannas are generally more fertile; farms with larger proportions of these savannas showed better production than farms with little low savanna areas.

Common management practices employed in more advanced cattle production systems were either not applied at all, or applied only at levels of doubtful impact. Improved management, particularly adequate mineral supplementation, would provide some production increases. However, the poor growth rate of stock and, most likely, the low fertility of breeding stock, can only be improved measurably by overall better nutrition.

Very preliminary evidence from an experiment being done in Carimagua provides some indication of expected benefits from improved nutrition and management. The experimental objectives are to study the strategic use of improved pastures and the length of the mating season on breeding herd productivity.

Cows with access to improved pastures for three to five months in the late dry and/or early rainy seasons had higher calving rates than cows grazing only native savanna. Shortening the mating period from four to three months also did not reduce the calving rate of cows with access to improved pastures, but calving rates of cows grazing only savanna decreased when mating periods were shortened.

EVALUATION OF PROMISING GERMPLASM IN ECOSYSTEMS OF THE TARGET AREA

Hyperthermic Savannas

Program scientists have worked in this ecosystem of the well-drained savannas for several years, at Carimagua. Observations and results of germplasm performance are based on extensive evaluations of adaptation to this environment, including the soil type (Oxisol) at the station.

Promising Germplasm

Grasses. Within this ecosystem, the Category V grass *Andropogon gayanus* continued its outstanding performance as a highly productive forage grass. Important characteristics include: (a) good growth and dry matter production in acid, infertile soils with minimum fertilizer inputs; (b) tolerance to drought stress, burning and high levels of soil aluminum saturation; (c) low phosphorus requirements; (d) tolerance to insects and diseases; (e) seed production ability; (f) compatibility with legumes; (g) adaptability to low-cost pasture establishment systems; (h) acceptability by animals; and, (i) high animal production levels, particularly when grown in association with legumes.

Table 3 shows the results of at least three years of grazing trials for pure grass pastures of *A. gayanus* and *Brachiaria decumbens.* The high carrying capacity and, therefore, high animal

Figure 11.
Andropogon gayanus and *Zornia latifolia* **provide one of the most promising improved forage mixtures for the hyperthermic savanna ecosystem.**

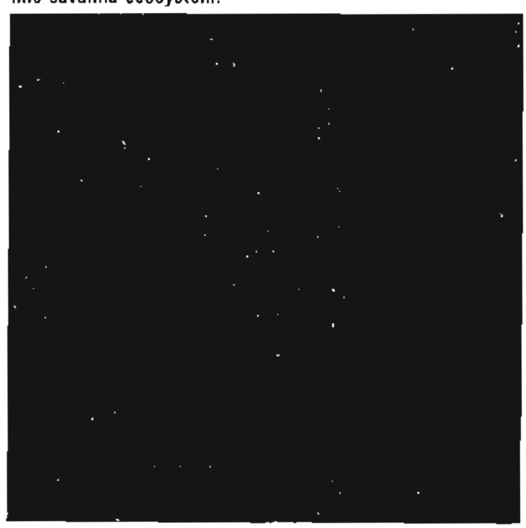


Table 3. **Summary of results of animal productivity on pure grass and legume/grass pastures, at Carimagua.**

Pasture species	Pasture productivity			
	Dry season	Wet season	Total year	
	(g/animal/day)		(kg/animal)	(kg/ha)
Grasses (3 years or more data):				
Best managed savanna	-167	449	90	22
Melinis minutiflora	-445	508	97	43
Brachiaria decumbens	-50	506	118	147
Andropogon gayanus	-97	567	128	457
Mixtures (10 months data):				
Andropogon gayanus + *Desmodium ovalifolium*	-21	606	120	128
Andropogon gayanus + *Stylosanthes capitata*	500	673	223	308
Andropogon gayanus + *Zornia latifolia*	317	836	245	399
Andropogon gayanus + *Pueraria phaseoloides*	371	732	225	373

production per unit area of a well-established *A. gayanus* pasture is evident. While its nutritive value is not very high, its apparent tolerance to diseases and insects makes it a very promising alternative to the widely established Category IV grass *B. decumbens*, which is susceptible to the spittlebug. Only preliminary results from grazing trials are available for *Brachiaria humidicola*, another Category IV grass.

Experience in the Program with the cross-pollinating *A. gayanus* has, up to now however, been almost exclusively with accession CIAT 621. This ecotype is very variable for plant type, leafiness, time of flowering and other characters. A range of other accessions has been assembled from different sources so their characteristics can be compared with those of CIAT 621. A recurrent selection program is being developed with initial selection for later, leafier types which flower and produce seed during a more restricted period.

Legumes. Germplasm of *Stylosanthes capitata*, *Zornia* spp. and *Desmodium ovalifolium* continued to perform well at Carimagua. This assessment is based on the adaptation of these species to the acid, infertile Oxisol conditions, their persistence, and their productivities —including animal performance— in the dry as well as the rainy seasons. *S. capitata* accessions continued to show resistance to anthracnose and stemborer in this environment. Most accessions of *Z. latifolia* were severely affected by the scab fungus, *Sphaceloma* sp., but resistant ecotypes within this and other *Zornia* species have been identified.

The high productivity, aggressiveness and nitrogen-fixing capacity of *D. ovalifolium* was confirmed for the Carimagua ecosystem. This species has also demonstrated its compatibility with aggressive grasses such as *B. decumbens* and *B. humidicola*. Animal performance was, however, substantially reduced by the low intake of the legume when grown in a sward with a low proportion of grass. Thus, more variability in terms of palatability is being sought in this species.

First year results of animal performance of grazing these legumes, and the control *Pueraria phaseoloides*, all in association with *A. gayanus*, are summarized in Table 3. The very substantial effect of the legumes on animal liveweight gains is evident.

Figure 12.
Pueraria phaseoloides and *Andropogon gayanus* **have provided very good liveweight gains over the entire year at Carimagua.**

With the exception of the association with *D. ovalifolium*, the legume/grass associations appear to have a productive potential of about 360 to 420 kg/ha/year, if a reasonable voluntary intake of the legume and availability of the grass can be maintained. Satisfactory balances of the legumes and grasses have been observed up to now, except for *D. ovalifolium*. Due to its poor palatability and aggressive growth habit, it tends to dominate most grasses and does not appear to be suitable for continuous grazing in this ecosystem.

Thermic Savannas

Collaborative work with EMBRAPA at its Brasilia center became fully operational during 1979. Germplasm evaluations at this location are being done at two sites within CPAC, on two different soils —a Red-Yellow Latosol and Dark-Red Latosol. Both are representative of the great majority of soils in the well-drained, thermic savanna ecosystem.

Promising Germplasm

Preliminary results after the first year of evaluation indicate that the most promising genus is *Stylosanthes*. Moreover, trials have confirmed the good potential observed under Cerrado conditions for a distinctive group of *Stylosanthes guianensis* ecotypes originating in Brazil and Venezuela. These ecotypes "tardío" are late-flowering, fine-stemmed, and have a very viscous pubescence, narrow leaflets and a particular flower-head structure. The outstanding characteristic of these materials is their resistance to anthracnose.

Other legume species selected for follow-up evaluations include *S. capitata, S. scabra, S. viscosa* and *Desmodium (= Codariocalyx) gyroides*. Two other species of which commercial cultivars are available in Brazil, *Galactia striata* and *Calopogonium mucunoides*, also warrant further evaluations.

Species like *Z. latifolia, D. ovalifolium* and *P. phaseoloides*, while very promising in the hyperthermic savanna ecosystem at Carimagua, have proven to be much less adapted to the thermic savannas.

Figure 13.
Stylosanthes capitata is one of the most promising legume accessions selected for continued evaluations in the thermic savanna ecosystem at Brasilia.

The two grass species *A. gayanus* and *B. decumbens*, both well-adapted in Carimagua, are also very promising for the thermic ecosystem at Brasilia.

Overall Germplasm Status

As of the end of 1979, the Tropical Pastures Program showed three groups of germplasm which can be related to ecosystems of its target area. The adaptation of species in these groups is summarized in Table 4.

Materials in the most advanced group, for the well-drained, hyperthermic savannas, have demonstrated their agronomic promise as well as their potential as components of legume/grass pastures through limited grazing trials at Carimagua. For the well-drained, thermic savannas, another group exists after limited agronomic trials in Brasilia. Finally, preliminary information from the first regional trials at a series of sites in humid areas of Bolivia, Brazil, Colombia, Peru and Venezuela, indicates that *B. decumbens*, *D. ovalifolium* and *P.*

Table 4. **Summary of most promising germplasm in various ecosystems of the CIAT Tropical Pastures Program target area.**

	Tropical savannas, well-drained		Tropical forests[3]
	Hyperthermic[1]	Thermic[2]	
Andropogon gayanus	Yes	Yes	(No?)
Brachiaria decumbens	Yes	Yes	Yes
Stylosanthes capitata	Yes	Yes	No
Stylosanthes guianensis[4]	Yes[5]	Yes	?
Desmodium gyroides	Yes[5]	Yes	?
Desmodium ovalifolium	Yes	No	Yes
Zornia latifolia	Yes	No	?
Pueraria phaseoloides	Yes	No	Yes
Stylosanthes scabra	No	Yes	?
Stylosanthes viscosa	No	Yes	?
Galactia striata	No	Yes	?
Calopogonium mucunoides	No	Yes	?

1 Represented by Carimagua
2 Represented by the Cerrado Center
3 Based on preliminary information from regional trials
4 Late-flowering, fine-stemmed ecotypes with viscous pubescences
5 Very promising agronomically but has not been under grazing

phaseoloides are well-adapted to tropical forest ecosystems. The performance of *A. gayanus* under humid conditions seems to be considerably lower than under savanna conditions.

INTERNATIONAL COOPERATION

Regional Trials Network

As the Program directs its activities to specific ecosystems of its target area, a well-designed network for regional evaluations of promising germplasm becomes critical. A workshop to plan the operation of the network was held at CIAT in October 1979; 91 scientists and collaborators from 40 institutions in 14 countries participated.

The workshop emphasized differences between procedures for the major ecosystems and defined the standardized methodologies for germplasm evaluations. A set of analytical methods and procedures for soil and plant materials was also agreed upon and a handbook was developed. These standards are particularly important because movements of soil and plant materials between countries are restricted.

An experimental sequence for germplasm evaluation in the network was also developed and approved. Presently, evaluations will be done at two levels and methodologies for two additional levels will be defined later.

In the first level (A), germplasm survival to main factors (climate, soil, diseases and insects) of the major ecosystems will be evaluated with a large number of entries (more than 100) tested in a few sites. A reduced number of entries will pass to level B in each ecosystem for sub-ecosystem testing for dry matter production during periods of maximum and minimum rainfall. Grazing trials will be incorporated in the other two levels.

Figure 14.
Evaluations of forage accessions in regional networks will play an important role in the Tropical Pastures Program's activities.

Training

In order to help develop research and extension capacities in local institutions of its target area and to assist in forming a strong regional collaborative network, the Program continued its efforts in training during 1979. A total of 62 professionals were trained during the year. Twenty-four of these persons from nine countries attended the 20-week Second Course on Research on Tropical Pasture Production and Utilization, in the first semester. Seven postdoctoral fellows participated in major research projects of the Program, ten visiting research associates conducted research for the PhD, and eight research scholars worked in research projects for their MS degrees. Thirteen others worked as postgraduate research interns and special trainees.

STUDY OF DISTRIBUTION OF BENEFITS FROM INCREASED BEEF PRODUCTION

Results of surveys in several urban areas of Latin America have confirmed that consumers at all income levels would benefit from increased beef production. The largest net impact would be on protein intake among protein-deficient groups, that is, those with lowest incomes.

Family surveys were conducted in 12 cities of Latin America. Families were classified into income quartiles based on per capita expenditures.

In the lowest income strata of the seven cities analyzed this year, an average of 16.5 percent of the food budget was for beef. Income elasticities of demand in this income group ranged from 0.8 to 1.28, reflecting a high consumer preference for beef. Elasticities were lower in the higher income groups.

Family expenditures for milk and dairy products were studied since these items are important by-products of beef herds in many regions of the target area. Generally, 7 to 18.6 percent of the food budget was spent for milk products. Although these expenditures were smaller than for beef, still not less than 3.4 and as much as 12.2 percent of family incomes were spent on milk products.

These results show that new technology to increase beef and milk products in Latin America will provide large absolute benefits to all consumers. Also, consumer benefits from increased supplies will be distributed less regressively than is current income.

Training and Conferences

Figure 1.
Among CIAT's training activities in 1979 was a special eight-week course on meristem tissue culture of cassava. Here a few of the seven participants from five Asian countries observe cassava plants which have been produced from tissue cultures.

TRAINING

Improved technology was mentioned in the Foreword to this CIAT Report as the primary product of an international agricultural research center. A parallel product is trained scientific manpower. Professionals in CIAT's client national institutions must acquire the skills to enable them to test and adapt CIAT's primary product under local conditions and transfer it to the ultimate users. Through training, CIAT helps meet the objective of institutionally transferring improved production technology, at the same time that young professionals are prepared for careers in commodity-based cooperative and independent research and agricultural development endeavors in their home institutions.

Since 1976, much effort has been placed on achieving a "critical mass" of research workers in each commodity. Short intensive courses of four to six weeks are utilized for this purpose. Once a critical mass has been achieved, longer-term training is justified to help solidify and strengthen national research programs. Medium-term internships and MS thesis research are the means for accomplishing this objective. Thesis research opportunities for PhD candidates are also offered.

The Training Office is responsible for the overall coordination of training activities to assure: (a) continuity of the various training efforts across commodities; (b) efficiency of administration; (c) adherence to Center-wide training standards; (d) effective sharing of training resources; and, (e) integration of relatively independent training efforts into overall CIAT outreach strategies.

All of the Center's training is commodity-based and decentralized with each research program or unit providing its assigned training participants with relevant training experiences. Training activities during 1979 in CIAT's four commodity programs and the Seed Unit are briefly described in the respective sections of this report.

Table 1 shows the total number of professionals trained at CIAT in 1979, by training category. Total trainees increased to 402 (32 percent over 1978)

Table 1. **Professionals trained in CIAT during 1979, by training category.**

	Number of trainees and (months), by category							
	Postdoctoral Fellows	Visiting Research Associates	Research Scholars	Postgraduate Research Interns	Postgraduate Production Interns	Special Trainees	Short Course Participants	Total
Major Programs:								
Beans	5 (45)	15 (100)	10 (74)	39 (106)		3 (10)	66 (67)	138 (402)
Cassava	3 (31)	8 (70)	3 (26)	11 (51)		10 (20)	46 (46)	81 (243)
Rice	—	1 (6)	1 (4)	3 (14)	10 (58)	3 (5)	34 (34)	52 (121)
Tropical Pastures[1]	7 (51)	10 (79)	8 (54)	9 (42)	24 (102)	4 (5)	—	62 (333)
Other Units:								
Data Services	—	—	—	1 (10)	—	—	—	1 (10)
Seed Production	—	—	1 (5)	—	—	—	37 (37)	38 (42)
Documentation Services	—	—	—	—	—	—	18 (34)	18 (34)
Station Operations	—	—	—	4 (19)	—	—	—	4 (19)
Communication Support	—	—	—	4 (6)	—	4 (13)	—	8 (19)
Total, 1979	15 (127)	34 (255)	23 (163)	71 (248)	34 (160)	24 (53)	201 (218)	402 (1223)
Total, 1978	5 (25)	6 (26)	9 (74)	49 (218)	52 (267)	12 (48)	171 (188)	304 (846)

1 Beef Program before 1979.

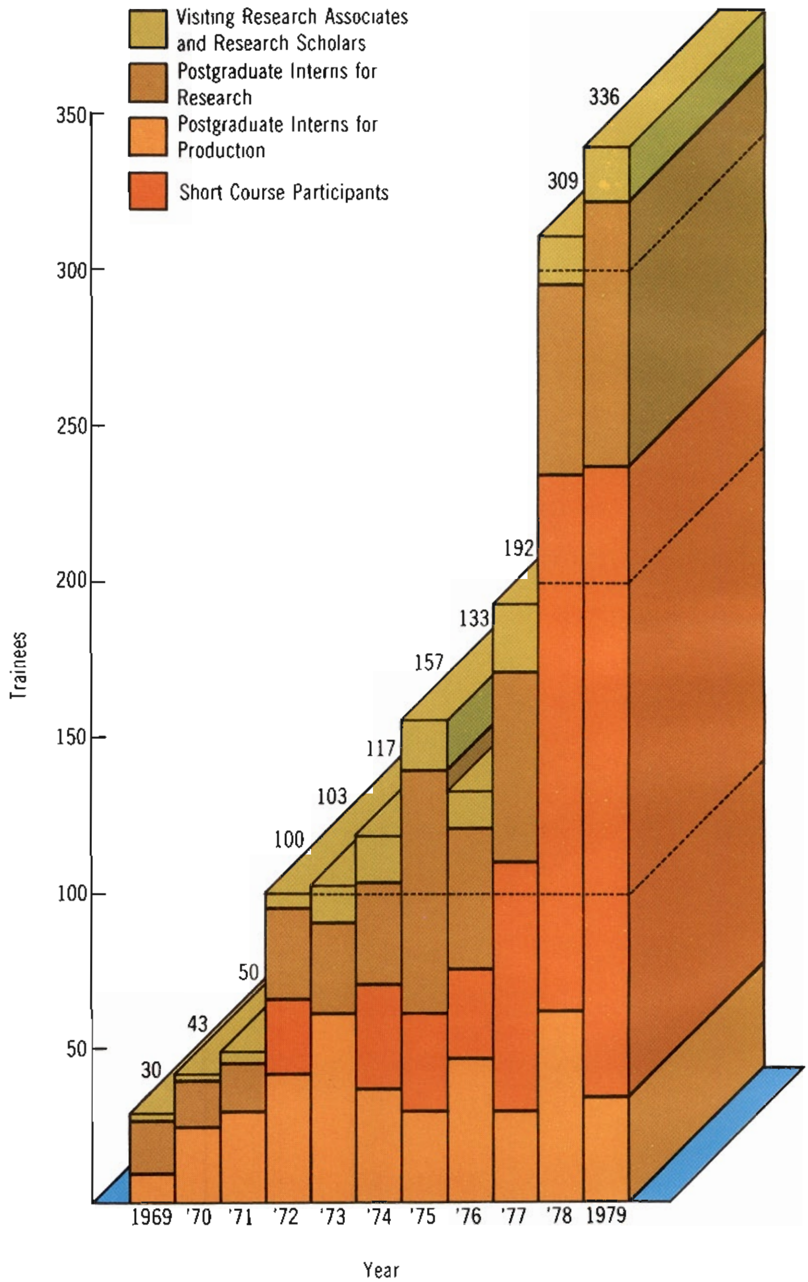


Figure 1.

Number of training participants who have completed training at CIAT from 1969 to 1979.

with 337 of these completing training during the year. About one-half of the participants were enrolled in research discipline training. As of the end of 1979, CIAT has trained almost 1600 professionals during 11 years of training activities (Fig. 2).

Training participants in 1979 came from 23 countries of the Latin American and Caribbean region and from 15 other countries including 7 where CIAT commodity programs now operate or plan to operate projects. Ninety-one percent of all trainees came from target area countries of the various commodity programs.

Thirty-one entities provided funding for training during the year. Special project funds from the United Nations Development Programme (UNDP) sponsored slightly more than one-half of the trainees. About one-half the training funds in 1979 came from CIAT's Core budget and supported one-quarter of the total trainees.

As part of a special UNDP-funded project, CIAT provided assistance in organizing intensive courses onrice, in Honduras, and on rice and cassava, in the Dominican Republic. Assistance for in-country training in beans, maize, farming systems and seed production was provided in El Salvador, with Inter-American Development Bank (IDB) funding to the Centro Nacional de Tecnología Agrícola (CENTA). UNDP funding at CIAT and IDB resources in Honduras helped support a bean production course in that country. CIAT's Bean and Cassava Programs also assisted the Instituto Colombiano Agropecuario (ICA) with local courses in Colombia.

CONFERENCES

CIAT utilizes conference activities including meetings, seminars, workshops and symposia to assist in integrating and operating commodity research networks and for exchanging information on new scientific developments.

Eight conferences were sponsored or co-sponsored by CIAT in 1979 (Table 2). Approximately 400 persons participated in these meetings. Another 20 conferences of other organizations were hosted by the Center.

Table 2. **CIAT-sponsored or co-sponsored conferences in 1979.**

Conference	No. of participants
Workshop on Pre-release Testing of Agricultural Technology (19-21 Mar.)	40
Seminar on Advances in Research at CIAT (14-16 May)	50
III Conf. of International Rice Testing Program for Latin America (IRTP) (30, 31 May)	60
Workshop on *Pyricularia* in Rice (1, 2 June)	65
Workshop on Regional Trials Network for Adaptation of Tropical Forage Species (1-4 Oct.)	130
Meeting on Communication/Information Strategies in Support of International Cooperation Strategies (CIP/CIMMYT/CIAT) (8, 9 Nov.)	12
Workshop on Anthracnose, Angular Leaf Spot and Common Bacterial Blight in Beans (12-14 Nov.)	40
Workshop on Bean Varietal Breeding (19-23 Nov.)	12

Seed Unit

The Seed Unit at CIAT is a new support unit formally created in late 1978 as a special project funded by the government of Switzerland. The Unit has the following objectives.

1. To train governmental and private institutional personnel primarily from Latin American and Caribbean countries in various aspects and at different levels of seed industry and program development and seed technology.
2. To extend technical collaboration to countries in the region to meet a wide range of needs. The end goal is to expand the production of high-quality seed of improved varieties with emphasis on, but not restricted to, the commodities with which CIAT works.
3. To conduct research in seed technology, primarily in collaboration with CIAT commodity programs and relevant to problems of the region.
4. To provide a single seed multiplication and distribution capability which can: (a) cooperate with CIAT commodity programs in multiplying, drying, processing, storing and distributing advanced experimental material and Breeder and Basic Seed to collaborating countries for farmer trials and further multiplication; (b) relate closely to training activities in order to make training as relevant and practical as possible; and, (c) assist in propagating and introducing seed in the region for commodities of other international agricultural research centers.

In addition to its overall planning activities during 1979, the Unit directed special emphasis to training and technical collaboration.

Figure 1.
William Boyd, of Mississippi State University (U.S.A.), works with trainees in the 1979 course in seed technology at CIAT.

TRAINING

Training will be an important part of the Seed Unit's program as it matures. This year, a five-week intensive course for 36 professionals was conducted at CIAT, in cooperation with Mississippi State University (U.S.A.). The Unit also cooperated in seed technology portions of courses in the Rice and Bean Programs. To assist in future training efforts, the Seed Unit and the Communication Support Unit worked during the year on developing five audiotutorial units for seed technology training.

TECHNICAL COLLABORATION

Renewed interest in the improvement of seed programs in the region and a series of constructive recommendations resulted from the meeting on Interregional Cooperation for the Improvement of Seed Programs in Central America and Panama. The meeting was sponsored by the CIAT Seed Unit, the Instituto Interamericano de Ciencias Agrícolas (IICA), and the Regional Office for Central America and Panama (ROCAP) of the United States Agency for International Development (AID). The Unit also assisted in the first National Seed Symposium, in Colombia.

In other activities, technical backstopping was provided to a professional working in a seed quality and training in El Salvador. As part of the development for good backgrounds on seed programs in the region, in preparation for further technical collaboration, several countries were visited and profiles developed for countries in Central America and the Andean Pact group. Discussions were held with the Andean Pact office, Lima, Peru, concerning their efforts to harmonize rules and regulations that can facilitate seed movement and to strengthen training programs within the five Andean Pact countries.

Figure 2.
Trainees observe legume seed production plots at CIAT-Quilichao as part of their practical experience in seed technology.

Personnel

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Senior staff
John L. Nickel, PhD, Director General

Other professional staff
Cecilia Acosta, Administrative Assistant

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GENERAL SERVICES ADMINISTRATION

Senior staff
Jesús Antonio Cuéllar, MBA, Executive Administrator

Other professional staff
Camilo Alvarez, MS, Administrative Associate
Edgard Vallejo, Adm. Emp., Travel Office Assistant

Carimagua Station
Rubén Darío Estrada, MS, Acting Station Superintendent

Government Relations (Bogotá)
Ricardo Castañeda, Administrative Assistant

Human Resources
General Administrative Services staff
Germán Vargas, MS, Head
* Carlos R. Viana, BS, Head

Other professional staff
Edgar Echeverri, Lawyer, Personnel Officer

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General Administrative Services staff
* Alessandro Ferran, Superintendent

Other professional staff
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Marvin Heenan, Assistant Superintendent (Motor Pool)
Francisco Jaramillo, Assistant Superintendent (Mechanical Shops)

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General Administrative Services staff
Eduardo Fonseca, Head

Supplies
General Administrative Services staff
Fernando Posada, MS, Head

Other professional staff
Percy de Castro, Administrative Assistant
Marino López, Administrative Assistant
Diego Mejía, Administrative Assistant

FINANCIAL ADMINISTRATION

Senior staff
Andrew V. Urquhart, FCA, Controller

General Administrative Services staff
Joffre A. Guerrero, Assistant Controller
Mauricio Lozano, MBA, Assistant Controller

Other professional staff
Gregorio Bedoya, CP, Accountant (stationed in Carimagua, Colombia)
Alonso Cardona, CP, Cashier
Alexis Corrales, Budget Assistant
Jaime Cumba, Internal Auditor
Yolanda Fernández, Accountant
César Moreno, CP, Accountant
* Hernando Navia, CP, Internal Auditor
* Rafael Petti, Contract Assistant

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* Left during 1979.

LAND RESOURCES RESEARCH DIVISION

OFFICE OF THE DIRECTOR FOR LAND RESOURCES RESEARCH

Senior staff

Gustavo A. Nores, PhD, Director for Land Resources Research

Other professional staff

Uriel Gutiérrez, MS, Administrative Associate

TROPICAL PASTURES PROGRAM

Senior staff

Gustavo A Nores, PhD, Economist (Acting Coordinator)
* Pedro A. Sánchez, PhD, Soil Scientist (Coordinator)
Eduardo Aycardi, PhD, Animal Health Specialist
Mario Calderón, PhD, Entomologist
Walter Couto, PhD, Soil Scientist, Pasture Development (stationed in Brasilia, Brazil)
John E. Ferguson, PhD, Agronomist, Seed Production
Bela Grof, PhD, Forage Agronomist, (stationed in Carimagua, Colombia)
* Jake Halliday, PhD, Soil Microbiologist
* C Allan Jones, PhD, Grass Agronomist
Ingo Kleinheisterkamp, DAgr, Animal Scientist, Pasture Utilization
Jillian M. Lenné, PhD, Plant Pathologist
C. Patrick Moore, PhD, Animal Scientist, Cattle Production Systems (stationed in Brasilia, Brazil)
* Osvaldo Paladines, PhD, Animal Scientist, Pasture Utilization
José G. Salinas, PhD, Soil/Plant Nutritionist
Rainer Schultze-Kraft, DAgr, Legume Agronomist, Germplasm Evaluation
James M. Spain, PhD, Soil Scientist, Pasture Development (stationed in Carimagua, Colombia)
Luis E. Tergas, PhD, Agronomist, Technology Transfer/Training
José M. Toledo, PhD, Soil/Plant Nutritionist, Forage Agronomy/Regional Trials
Derrick Thomas, PhD, Forage Agronomist (stationed in Brasilia, Brazil)

Visiting scientists

E. Mark Hutton, DAgr, Breeder, Plant Improvement
Nobuyoshi Maeno, PhD, Legume Agronomist, Forage Agronomy

Postdoctoral fellows

Antonio Carrillo, PhD, ETES Project
Carlos Lascano, PhD, Pasture Utilization
John W Miles, PhD, Grass Improvement
Eugenia de Rubinstein, PhD, Economics
James E. Sumberg, PhD, Legume Improvement

Visiting specialists

* Peter Kammer, MS, ETES Project (stationed in Maturin, Venezuela)
Rolf Minhorst, MS, ETES Project (stationed in Brasilia, Brazil)
Cristoph Plessow, MS, ETES Project (stationed in Maturin, Venezuela)

Research associates

Edgar Burbano, MS, Seed Production
Carlos Castilla, MS, Pasture Development (stationed in Carimagua, Colombia)
Rubén Darío Estrada, MS, Economics
Clemencia Gómez, MS, Training/Technology Transfer
Alberto Ramírez, MS, Forage Agronomy/Regional Trials
Libardo Rivas, MS, Economics
Fabio Nelson Zuluaga, MS, Animal Health

Visiting research associates

Elke Bohnert, MS, Pasture Utilization
* Fabio Calvo, Ing. Agr., Pasture Development
* Guido Delgadillo, MS, Soil/Plant Nutrition
Jorge Luis Díaz, MS, Pasture Utilization
* William F Gómez, DVM, Pasture Utilization
Hendrik Jansen, MS, Legume Agronomy
* Joel Levine, MS, Economics
* Frank Müller, MS, Legume Agronomy (stationed in Carimagua, Colombia)

* Left during 1979

Research assistants
Amparo de Alvarez, Ing. Agr., Plant Pathology
* Edgard Belalcázar, Ing. Agr., Soil Microbiology
Javier Belalcázar, Ing. Agr., Plànt Introduction
* Francisco Bonilla, Ing. Agr., Seed Production
Gerfried Carlos Buch, Ing. Agr., Forage Agronomy (stationed in Carimagua, Colombia)
Raúl Botero, DVM, Cattle Production Systems (stationed in Carimagua, Colombia)
Arnulfo Carabaly, Ing. Agr., Forage Agronomy
Manuel Coronado, Ing. Agr., Plant Improvement
* Misael Cortés, DVM, Animal Health
Patricia Chacón, Biologist, Entomology
Martha Lucía Escandón, Ing. Agr., Plant Improvement
* Luis E. Forero, Biologist, Plant Introduction
Luis H. Franco, Ing. Agr., Pasture Development (stationed in Carimagua, Colombia)
Duván García, Ing. Agr., Seed Production
Obed García, DVM, Animal Health (stationed in Carimagua, Colombia)
Hernán Giraldo, Ing. Agr., Germplasm Evaluation
Ramón Gualdrón, Ing. Agr., Soil/Plant Nutrition (stationed in Carimagua, Colombia)
* Fabio Gutiérrez, Ing. Agr., Soil Microbiology
Silvio Guzmán, DVM, Technology Transfer/Training
Phanor Hoyos, Zoot., Pasture Utilization (stationed in Carimagua, Colombia)
Carlos Humberto Molano, Ing. Agr., Plant Improvement (stationed in Carimagua, Colombia)
Rodrigo F. Mutis, Zoot., Cattle Production Systems (stationed in Carimagua, Colombia)
Bernardo Rivera, DVM, Animal Health
Manuel Sánchez, Ing. Agr., Seed Production
Roberto Sánchez, Ing. Agr., Biometrics
José Ignacio Sanz, Ing. Agr., Soil/Plant Nutrition
Celina Torres, Ing. Agr., Plant Pathology
Luis Miguel Uribe, Zoot., Pasture Utilization
Gustavo Adolfo Urrea, Ing. Agr., Technology Transfer/Regional Trials
Fernán Alberto Varela, Ing. Agr., Entomology (stationed in Carimagua, Colombia)
Bernardo Velosa, Ing. Agr., Plant Improvement

SPECIAL STUDIES

IFDC PHOSPHORUS PROJECT

Senior staff
William E. Fenster, PhD, Soil Fertility Specialist (Project Leader)
Luis A. León, PhD, Soil Chemist

Research assistants
* Luis A. Duque, Ing Agr., Soil Chemistry
Henry Llanos, Ing. Agr., Soil Chemistry
Germán Montes, Ing. Agr., Soil Chemistry (stationed in Carimagua, Colombia)

LAND RESOURCES EVALUATION

Visiting scientist
Thomas T. Cochrane, PhD, Land Resources Specialist

Visiting research associate
Luis Fernando Sánchez, MS, Land Resources

Grain Legume Project

Research assistant
Guillermo Giraldo, Ing. Agr.

RESEARCH SUPPORT

DATA SERVICES

Senior staff
* Gastón Mendoza, PhD, Statistician (Head)

Statistical Services

Research associate
María Cristina Amézquita de Quiñónez, Dip. Est. Mat. (Section Head)

Research assistants
James Arbey García, Ing. Agr.
Jaime Eduardo Muñoz, Ing. Agr.
* Juan Ospina, Ing. Agr.
José Alfredo Saldarriaga, Ing. Sist.
** Roberto Sánchez, Ing. Agr.

---
* Left during 1979.
** Assigned to the Tropical Pastures Program

Computer Services

Research associate
Jorge Augusto Porras, Ing Quím. (Section Head)

Research assistants
* Adolfo Gordillo, Ing. Eléct.
Gerardo Ignacio Hurtado, Ing. Agr.
* Hugo Toro, Ing. Ind.
Raúl Samudio

Meteorological Stations

Research assistant
Delmar Peña, Meteorologista

SWINE UNIT

Senior staff
Julián Buitrago, PhD, Nutritionist (Head)
Guillermo Gómez, PhD, Nutritionist/Biochemist (on sabbatical leave)

Research associate
Jorge Santos, MS, Nutrition

Research assistants
Luis Enrique Beltrán, DVM, Animal Health
Mauricio Valdivieso, Zootecnista, Animal Management

CROPS RESEARCH DIVISION

OFFICE OF THE DIRECTOR FOR CROPS RESEARCH

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Douglas R. Laing, PhD, Director for Crops Research

Other professional staff
José Fernández de Soto, Ing. Agri., Administrative Assistant

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Senior staff
Anthony C. Bellotti, PhD, Entomologist (Coordinator)
Abelardo Castro, PhD, Agronomist
James H. Cock, PhD, Physiologist (on sabbatical leave)
Clair Hershey, PhD, Plant Breeder
Reinhardt Howeler, PhD, Soil Scientist
Kazuo Kawano, PhD, Plant Breeder
Dietrich Leihner, DAgr, Agronomist
J. Carlos Lozano, PhD, Plant Pathologist
John K. Lynam, PhD, Agricultural Economist
Romeo R. Obordo, PhD, Regional Coordinator for Asia (stationed at SEARCA, Los Baños, the Philippines)
Julio César Toro, PhD, Agronomist

Visiting scientists
David Connor, PhD, Plant Physiologist
* Yoshiki Umemura, MS, Plant Pathologist

Postdoctoral fellow
Bodo Hegewald, PhD, Cassava Intercropping

Visiting specialist
Jesús Antonio Reyes, MS, Entomology

Research associates
Alvaro Amaya, MS, Breeding
Rafael Orlando Diaz, MS, Economics
** Carlos Dominguez, MS, Training
Benjamín Pineda, MS, Plant Pathology
Octavio Vargas, MS, Entomology

Visiting research associates
* David Byrne, MS, Entomology
* Fritz Elango, MS, Plant Pathology
Rafael Laberry, MS, Plant Pathology
Bernhard Lohr, MS, Entomology
* Peter Jan Strobosch, MS, Rural Sociology
Hendrick Jan Veltkamp, MS, Plant Physiology
Christopher Wheatly, MS, Plant Pathology

Research assistants
Bernardo Arias, Ing. Agr., Entomology
Eitel Adolfo Burckhardt, Biologist, Soils
Luis Fernando Cadavid, Ing. Agr., Soils
Fernando Calle, Ing. Agr., Soils (stationed in Carimagua, Colombia)
* Darío Cárdenas, Econ., Economics

* Left during 1979
** Assigned to Training and Conferences.

Ernesto Celis, Ing. Agr., Agronomy
Carolina Correa, Econ., Economics
Julio Eduardo Holguín, Ing. Agr., Agronomy (stationed in ICA-Caribia, Colombia)
Diego Izquierdo, Econ., Economics
Gustavo Jaramillo, Ing. Agr., Agronomy
Javier López, Ing. Agr., Cultural Practices
Sara Mejía, Ing. Agr., Plant Physiology
Pedro Millán, Ing. Agr., Germplasm
Germán E. Parra, Ing. Agr., Plant Physiology
Edgar Salazar, Ing. Agr., Soils (stationed in Carimagua, Colombia)
Ana Milena Varela, Biologist, Entomology
Ana Cecilia Velasco, Med. Tech., Plant Pathology

BEAN PROGRAM

Senior staff
Aart van Schoonhoven, PhD, Entomologist (Coordinator)
Jeremy H.C. Davis, PhD, Breeder/Agronomist
Guillermo G. Gálvez, PhD, Regional Coordinator for Central America (stationed in San José, Costa Rica)
Peter H. Graham, PhD, Microbiologist
Francisco J. Morales, PhD, Virologist
Silvio H. Orozco, MS, Plant Breeder (attached to ICTA, Guatemala)
John H. Sanders, PhD, Agricultural Economist
Federico Scheuch, MS, Agronomist (stationed in Lima, Perú)
Howard F. Schwartz, PhD, Plant Pathologist
Shree P. Singh, PhD, Plant Breeder
Steven Ray Temple, PhD, Plant Breeder
Michael D.T. Thung, PhD, Agronomist
Oswaldo Voysest, PhD, Agronomist
Kazuhiro Yoshii, PhD, Plant Pathologist (attached to ICTA, Guatemala)

Postdoctoral fellows
Stephen Beebe, PhD, Breeding
César Cardona, PhD, Entomology
Peter Jones, PhD, Plant Physiology
Paul Kretchmer, PhD, Plant Physiology/Climatology

Research associates
** Carlos Flor, MS, Training
José Ariel Gutiérrez, MS, Breeding
* Eduardo Translateur, MS, Agronomy

Visiting research associates
Gustavo Arcia, MS, Economics
Susana García, Ing. Agr., Agronomy
Upali Jayasinghe, BS, Plant Pathology
Mary Katherman, MS, Plant Pathology
Julia Kornegay, MS, Breeding
* Jeffrey W. White, MS, Plant Physiology

Research assistants
Alfredo Acosta, Ing. Agr., Entomology
Bernardo Alzate, Ing. Agr., Agronomy
Carlos Bohórquez, Ing. Agr., Agronomy
Horacio Carmen, Ing. Agr., Breeding
Mauricio Castaño, Ing. Agr., Plant Pathology
Fernando Correa, Ing. Agr., Plant Pathology
Aurora Duque Maya, Ing. Agr., Microbiology
Oscar Eraso, Ing. Agr., Agronomy
Jaime García, Adm. Agri., Seeds
Jorge García, Ing. Agr., Entomology
Ranulfo González, Biologist, Entomology
Luis Hernández, Ing. Agr., Breeding
Oscar Herrera, Ing. Agr., Economics
Nohra R. de Londoño, Ing. Agr., Economics
Nelson Martínez, Ing. Agr., Agronomy
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Pedro Pineda, Ing. Agr., Plant Pathology
* Luz H. Ramírez, Ing. Agr., Entomology
* José Restrepo, Ing. Agr., Plant Physiology
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Gerardo Tejada, Ing. Agr., Agronomy
* Luis Gonzaga Vergara, Ing. Agr., Breeding
Silvio Vitery, Ing. Agr., Microbiology
Silvio Zuluaga, Ing. Agr., Plant Physiology

RICE PROGRAM

Senior staff
Joaquín González, MS, Agronomist (Coordinator)
Sang-Won Ahn, PhD, Plant Pathologist
Peter R. Jennings, PhD, Regional Coordinator for Central America (stationed in San José, Costa Rica)
Manuel Rosero, PhD, IRRI Liaison Scientist
Hector Weeraratne, PhD, Plant Breeder

Research associates
** Elías García, Ing. Agr., Training
Marco Perdomo, Ing. Agr., Agronomy

Visiting research associates
Luis E. Dussán, Ing. Agr., Agricultural Economics
William Zimmerman, Botanist, Agronomy

* Left during 1979
** Assigned to Training and Conferences

Research assistants
Gustavo Benavides, Ing. Agr., International Trials
Luis E. Berrío, Ing Agr., International Trials
Yolanda Cadavid, Ing. Agr., Agronomy
Luis García, Ing. Agr., Plant Breeding
* Camilo Jaramillo, Ing. Agr., International Trials
Luis Octavio Molina, Ing. Agr., Plant Breeding
Miguel E. Rubiano, Ing. Agr., Pathology
Edgar Tulande, Ing. Agr., Pathology

RESEARCH SUPPORT

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Research associate
Octavio Mosquera, MS, Analytical Services

Research assistants
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Charles McBrown, BS, Instrument Maintenance
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Research associates
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Rigoberto Hidalgo, MS, Germplasm

Visiting research associates
* Daniel Debouck, Ir. Agr., Germplasm
Paul Gepts, Ir. Agr., Germplasm
Thierry Vanderborght, Ir. Agr., Germplasm
Judith M. Lyman, MS, Germplasm

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Gustavo Montes de Oca, Ing. Agr., Germplasm
Hember Rubiano, Ing. Agr., Germplasm
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Alfonso Díaz-Durán, MS, PE, Experimental Farms Superintendent

Research assistants
Xavier Carbonell, Ing. Agri
* Ricardo Cruz, Ing. Agri.
Ramiro Narváez, Ing. Agri., (CIAT-Quilichao Substation Assistant Farm Superintendent)
Carlos Otero, Ing. Agr.

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OFFICE OF THE DIRECTOR FOR INTERNATIONAL COOPERATION

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Alexander Grobman, PhD, Director for International Cooperation

TRAINING AND CONFERENCES

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Fernando Fernández, PhD (Coordinator)

Training Office

General Administrative Services staff
Alfredo Caldas, MS, Admissions Administrator

* Left during 1979

Training associates
Carlos Domínguez, MS (Cassava)
Carlos Flor, MS (Beans)
Elías Garcia, Ing. Agr. (Rice)
Marceliano López, MS (assigned to CENTA, El Salvador)
Luis Alberto Ramirez, MS (Tropical Pastures)
Eugenio Tascon, Ing. Agr. (In-country Training, Rice)

Training assistants
Silvio Guzmán, DVM (Tropical Pastures)
Carlos Suárez, BS

Conferences

General Administrative Services staff
David Evans, Conference Administrator

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Fritz Kramer, PhD, Communication Scientist (Head)

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Charles E. Bower, BSJ, Editor
* Mario Gutiérrez, Ing. Agr., Editor

Associate
Francisco Motta, MS, Editorial

Assistants
Alejandro Jiménez, Ing. Agr., Editorial
Dorothy Muller de Posada, BA, Editorial
Alexandra Walter, Translations/Editorial

Training Materials

Research associate
Cornelio Trujillo, MS

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Maria Lucía de Posada, MS, Editorial
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Luis Fernando Ceballos, Ing. Agr., Production
Cilia Fuentes de Piedrahita, Ing. Agr., Production
Héctor Fabio Ospina, Ing. Agr., Production

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Walter Correa, PhD, Graphic Arts (Section Head)

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* Manfred Hirsh, Photographer

Assistants
Didier González, Graphic Designer
Carlos Rojas, Graphic Designer
* Fanny Rodriguez, Graphic Designer
Carlos Vargas, Graphic Designer

Public Information Office

Associate
Fernando Mora, BA, AHA, (Section Head)

Assistant
Jorge Enrique Paz, Ing. Agr.

DOCUMENTATION SERVICES

Senior staff
Fernando Monge, PhD, Communication Scientist (Head)

Library and Documentation
Visiting specialist
Trudy Brekelbaum, MA, Editor

Associate
Hernán Poveda, BA

Assistants
Fabiola Amariles, Documentalist
Roberto Añez, Ing. Agr., Documentalist
Stella Gómez, BA
Francy González, Ing. Agr., Documentalist
* Marilú O. de Hensel, BA, Documentalist
* Sonia Laverde, BA, Public Services (Section Head)
Jorge López S., Documentalist
Piedad Montaño, Acquisitions (Section Head)
Himilce Serna, BA, Technical Services (Section Head)
Julia Emma Zúñiga, Ing. Agr., Documentalist

* Left during 1979

SEED UNIT

Senior staff
Johnson Douglas, MS, Seed Specialist (Head)

Research associate
Joseph Cortés, Ing. Agri., Drying and Processing

COLLABORATIVE PROJECTS

CIMMYT/CIAT ANDEAN REGION MAIZE PROJECT

Senior staff
Gonzalo Granados, PhD, Entomologist (Head)
James Barnett, PhD, Plant Breeder

Research assistant
Edgar Castro, Ing. Agr.

ICTA/CIAT PROJECT

Senior staff
* Robert K. Waugh, PhD, Associate Director
* Roland E. Harwood, BS, Coordinator of Experiment Station Operations

(This project was completed in 1979 according to schedule.)

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* Left during 1979