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CIAT Report 1982

Centro Internacional de Agricultura Tropical
Apartado Aéreo 6713
Cali, Colombia

June 1982

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CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The government of Colombia provides support as host country for CIAT and furnishes a 522-hectare site near Cali for CIAT's headquarters. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT a 184-hectare substation in Quilichao and a 73-hectare substation near Popayan. CIAT also co-manages with the Instituto Colombiano Agropecuario (ICA) the 22,000-hectare Carimagua Research Center in the Eastern Plains of Colombia and carries out collaborative work on several of ICA's experimental stations in Colombia; similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR).

Foreword

CIAT's principal achievements in agricultural technology development and transfer for the year 1981 are highlighted in this **CIAT Report.** Progress attained is related within the larger context of the mission of CIAT and the general strategies pursued by our four commodity research programs. All four, plus training and the seed unit, are, we feel, well on their way to accomplishing their goals, the major one being collaboration with national and international agencies to increase the quantity and quality of selected staple foods in Latin America and the Caribbean.

The technology development efforts of the Bean Program has in some countries already reached its fourth and most advanced stage: horizontal transfer of new bean technology developed by one country, as has been done by Guatemala and Honduras, to other Central American countries. The first stage resulted in a build-up of the world germplasm collection in various bean-production regions through the international bean nurseries. Today, these materials are grown on more than 40,000 ha in 15 countries. In the second stage, improved CIAT-developed lines were named, multiplied, and released by several collaborating countries: four countries have already named new varieties from these lines and six more are gearing up for extensive seed multiplication schemes. At least three national programs have already reached the third stage, in which new varieties are produced at the national level from early-generation materials provided by CIAT. Today, the Bean Program has available improved materials for a majority of the 16 basic bean grain types produced in the tropics. In addition, sources of resistance to most bean diseases and insect pests have been identified and are being incorporated into commercially acceptable varieties.

Earlier, our Cassava Program showed that improved, low-input cultural practices can double traditional yields of 10 to 11 t/ha. Recent data suggest that traditional yields can be tripled if these agronomic practices are coupled with newly developed hybrids. On a larger scale, these early expectations have been applied commercially and have demonstrated that CIAT technology works. Today, much of our attention is focused on alternative uses for cassava in processed form, due to the high perishability of fresh cassava and limited potential for expansion of the fresh market. A pilot project conducted in northern Colombia, in which the CIAT Cassava Program participates, has illustrated that, if a steady supply of cassava is assured (in this case a farmers' cooperative producing dried cassava chips for animal feed), the marketing of even large cassava supplies at good prices is possible. We have great hopes that, with our new production technology and with new cassava markets, many a tropical country will find compelling economic reasons to greatly expand cassava production, thereby reducing costly imports of food and feed and increasing small-farmer income.

Our Rice Program has continued in its remarkable ability to provide a diverse set of promising rice lines to national programs for naming as new varieties or for use in national breeding programs. Today, some 80 percent of all planted irrigated rice in Latin America are high-yielding varieties that originated from CIAT's rice-improvement effort—a strictly regional endeavor for the Western Hemisphere working in close collaboration with IRRI. It is largely due to these new varieties that Latin American and Caribbean rice production has been able to keep up with the continually increasing demand. Today, most encouraging results are being achieved by our rice team in their search to find better and more stable resistance to rice blast disease, the most serious rice-production problem in Latin America. The year 1981 was also the first year of our relatively modest breeding effort for support of upland rice culture. The constraints to increased production for the various types of upland-production systems have already been qualitatively defined, and promising parental materials have been identified.

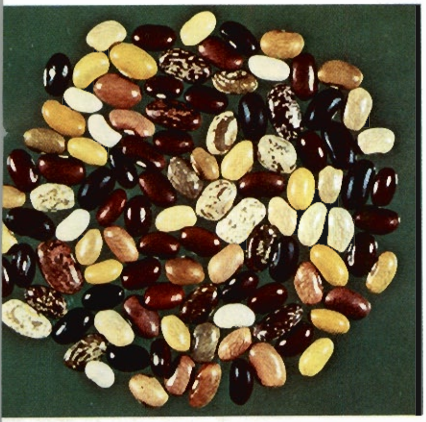
The bold strategy of our Tropical Pastures Program — developing productive and economically viable low-input pasture technology for the acid, infertile soils of the Latin America tropics—is now being confirmed. This technology will be the key component for the ecologically sound productivity of one of the last remaining great agricultural frontiers of the world. After 4 years of continuous evaluation, the most advanced grass/legume associations continue to look exceedingly promising, from both

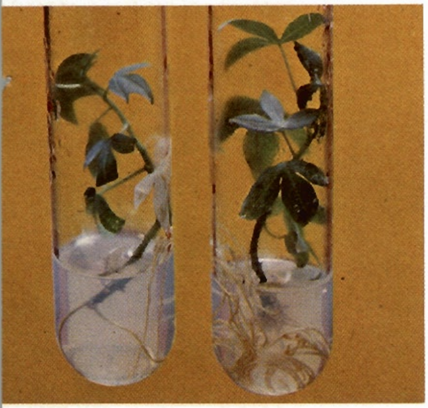
agronomic and economic viewpoints. In addition, increasing numbers of other promising legume and grass accessions are being identified and put through the rigorous evaluation sequence. We are confident that the new pasture-production technology resulting from our collaborative efforts with national programs will combine with the extraordinary ability and willingness of the livestock-production sector to accept improved technology, leading to a powerful momentum for increased sources of beef and milk, both of which are staple foods for low-income consumers in the region.

The collaboration we receive from our partners on the national level continues to be the most outstanding feature of our work. Through the years, the national programs and CIAT have continually explored ways and means for more effective and efficient cooperation, which has led to a clear definition of responsibilities for both the international and the national levels, thus assuring a high degree of complementarity. It is most gratifying to receive solid and decisive aid from our collaborators in national programs at every critical stage of our work, which assures total continuity between the efforts of both parties.

May I take this opportunity to express our sincere thanks for the financial and technical assistance we receive from the donor community and from collaborating research and development institutions. With their continued strong support, we can look into the future with great confidence that we can continue to carry out our essential role within the larger context of the overall effort to increase production in the tropics.

John L. Nickel
Director General





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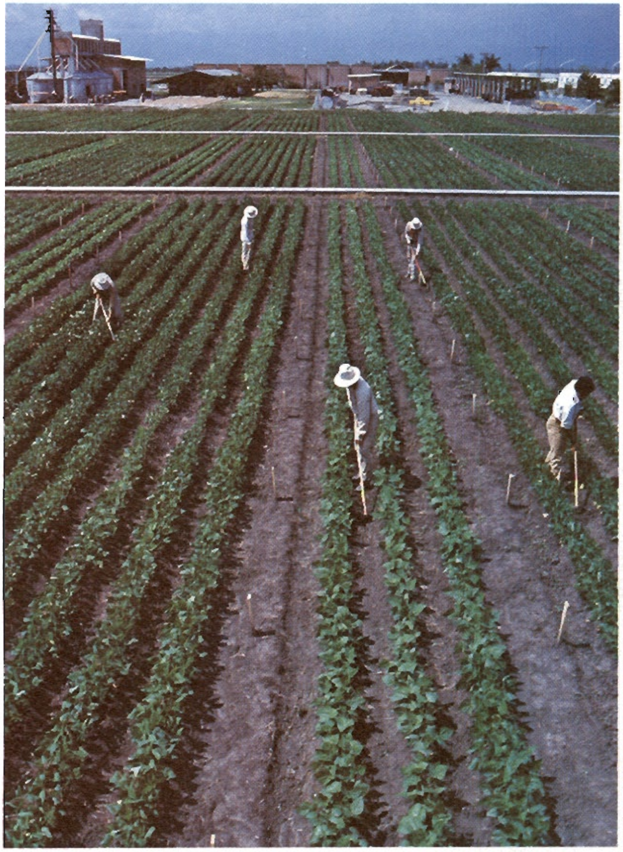


Bean Program

THE OBJECTIVE of the CIAT Bean Program is to develop production technologies that permit increased yields and improved yield stability over time. Reflecting CIAT's concern for resource-efficient production technology and the intensification of the small-farm sector, the Bean Program emphasizes technologies based on improved germplasm that combine:

- resistance or tolerance to the principal diseases, pests, and soil and climatic constraints;
- efficiency in the use of applied inputs;
- improved plant architecture and yield potential.

As part of its germplasm development work, the Bean Program collaborates closely with national bean programs in the development of viable bean-production technologies that meet regional or national requirements in terms of the farmers' cropping systems, the predominant agronomic production constraints, and consumer requirements. Training is the principal means by which the Bean Program provides assistance to the efforts of national bean programs to develop further and, ultimately, to become self-sufficient in bean research and development work at the national level.

Formed in 1973 with six senior scientists, by 1981 the Bean Program consisted of 15 scientists at the senior staff level. In 1981 the Program continued to make important advances in both technology development and international collaboration.

SUMMARY OF ACHIEVEMENTS

An integrated germplasm development and evaluation scheme has passed its formative years and has become fully operational. In breeding, notable progress was achieved in 1981 in the development of improved characters. Among diseases, this includes improved resistance/tolerance to bean common mosaic virus (BCMV), bean golden mosaic virus (BGMV), rust, anthracnose, angular leaf spot, and common bacterial blight (CBB). Among insect pests, important advances were made in breeding bean lines resistant to leafhoppers and the *Apion* pod weevil. For the first time, in 1981 promising sources of resistance to the most damaging and therefore economically important storage insects—the *Zabrotes*—were identified. Breeding successes also extended to improved nitrogen-fixation technology for beans: through the recombination of promising donor materials, markedly higher levels of atmospheric nitrogen fixation were achieved. In the area of breeding for improved architecture, several new plant types were developed and are now in preliminary testing schemes to determine their usefulness in improving yield, yield stability, and mechanisms for disease and insect pest avoidance. Beyond

Inoculation for screening of bean varieties against resistance to various diseases, in this case BCMV (left), *enables development of improved bean production technology. Thus, even this small bean producer in Latin America* (right) *will profit.*

improvement work for single traits, further advances were made in conferring desired combinations of improved characters onto the multitude of different seed types required by national programs. Already, improved bush and climbing bean materials are available for the majority of seed types required in the various production regions.

Improved bean lines are now available for many different production regions.

With the incorporation of resistance to bean common mosaic virus—the most widespread and serious seed-transmitted disease problem affecting current bean production in Latin America—into all materials leaving CIAT for further testing, and the availability of improved materials representative of a wide range of required seed types, the process of selecting from advanced breeding lines is being decentralized to collaborating national bean programs. In 1981, national programs in Latin America selected more than 20 lines from advanced-generation materials and entered these lines into seed multiplication and/or farm-level testing schemes. At the same time, 18 countries in Latin America and Africa requested more than 7000 germplasm accessions from CIAT for further testing and/or for use in their own breeding programs. These developments attest to the fact that a strong, viable international bean development effort is jointly underway.

Thus, the initial impact on bean production, which CIAT has achieved through the wide dissemination of available, non-CIAT improved commercial cultivars, can be expected to be redoubled in the near future through the wide cultivation of newly improved materials emanating from the cooperative breeding efforts between CIAT and national programs.

Collection and Screening of Germplasm

Germplasm Collection

The basis for all bean improvement work is the *Phaseolus* germplasm bank at CIAT. Through donations from collaborating institutions, and through collection expeditions to Brazil and Peru (in collaboration with and funded by the International Board for Plant Genetic Resources, IBPGR, with headquarters in Rome, Italy), the CIAT collection increased in 1981 by some 2000 new accessions, reaching a total of over 32,000. The composition of this collection is shown in Table 1.

Table 1. **Collection of *Phaseolus* beans in CIAT germplasm bank, through December 1981.**

	Accessions (no.)	
Species	**Cultivated forms**	**Wild forms**
Cultivated species		
P. vulgaris	28,117	332
P. lunatus	2,221	62
P. coccineus subsp. *coccineus*	707	
P. coccineus subsp. *polyanthus*	317	
P. coccineus		58
P. acutifolius	89	59
Noncultivated (wild) species		
P. anisotrichus		25
P. metcalfei		11
P. ritensis		8
P. filiformis		10
P. wrightii		4
P. microcarpus		9
P. pedicellatus		6
P. polystachyus		8
P. galactoides		1
P. parvulus		1
Total	31,451	594

Germplasm Screening

With the evaluation of an additional 4000 accessions of *P. vulgaris* in 1981, the total number of accessions that has undergone morphoagronomic evaluation now stands around 15,000. All data about the introduction, maintenance, evaluation, and distribution for each of the four cultivated species are organized in computer files and are made available to all researchers on the national level. In addition to the basic evaluation and documentation work performed on all entries of the germplasm bank, the various bean-breeding projects systematically screen the accessions for parental sources of specific characters or for commercial grain types.

15,000 P. vulgaris *accessions—half the germplasm bank—have undergone morphoagronomic evaluations.*

Bush beans. Some 5000 newly released accessions from the germplasm bank were evaluated in hill plots at Popayan and Obonuco. In addition, selections from 5000 accessions previously evaluated in hill plots underwent further evaluations in 1981 in single-row plots at Palmira, Popayan, La Selva, and Obonuco. Table 2 lists the specific characters for which the bush bean germplasm is evaluated, and the number of lines now available as parents for crosses in the breeding program.

Table 2. **Number of bush bean lines available at CIAT with resistance or tolerance to various characters for use as potential parents in CIAT's improvement program, through December 1981.**

Character	Lines (no.)
Biological stress	
Diseases	
Bean common mosaic virus (recessive gene resistance)	5
Bean golden mosaic virus	30
Rust	40
Anthracnose	180
Angular leaf spot	70
Powdery mildew	21
Common bacterial blight	23
Halo blight	14
Web blight	30
Insects	
Leafhopper (*Empoasca*)	64
Bean pod weevil (*Apion*)	29
Storage insects (*Zabrotes*)	5
Edaphic stress	
Nitrogen fixation	12
Soil phosphorus	16
Climatic stress	
Temperature	10
Drought	17
Architecture and yield	15
Early maturity	6
Total	587

Collaborative Research in Bean Genetics

CIAT depends on a number of research agencies and universities around the globe for resources to resolve highly specific applied agricultural research problems. For example, the Bean Program seeks the specialized knowledge, skills, and equipment from several projects for assistance in its search for resistance to the most important bean diseases and for achitectural variability.

One need is to incorporate genetic resistance to BCMV (bean common mosaic virus), a widespread seed- and aphid-transmitted disease. Normally, the Bean Program relies on a single, dominant gene (II) for resistance. While this work has proved most successful, strains of the virus exist, which, under specific environmental conditions, break this resistance. Such strains occur in important bean-producing countries such as Burundi, Chile, and Rwanda. The Institute for Horticultural Plant Breeding (IVT) in Wageningen, the Netherlands, has developed two temperate bean lines resistant to all existing races of BCMV. This resistance is controlled by the presence of several recessive genes. The current IVT/CIAT joint venture is to introduce these recessive genes into tropically adapted and commercially acceptable germplasm. IVT assumes responsibility for the extensive and highly specialized testing program in which the presence or absence of such recessive genes is detected in lines provided by CIAT. Already, the resistance encountered in these IVT lines of the small, white-seeded type, has been successfully incorporated into tropically adapted lines of various seed types at CIAT, including some commercially acceptable in Brazil and Chile.

Another need is to provide interspecific hybridization for CIAT bean lines by transferring sources of genetic resistance and architectural traits from related *Phaseolus* species to *P. vulgaris*. Crosses between *Phaseolus* species present unique problems in fertility restoration that require unique skills. Scientists at the University of Gembloux, Belgium, specialize in taxonomy of the *Phaseolus* genus. Their joint task with CIAT is to identify the desirable crosses, perform the actual crossing, and restore fertility in the resulting hybrids. Work is carried out at both CIAT headquarters and at Gembloux. Once fertility is restored, the selection among progenies is then continued by CIAT and national programs under tropical conditions. At this time, tolerance to such bean diseases as anthracnose, ascochyta leafspot, bacterial blight, and bean golden mosaic virus, as well as incorporation of various flowering characteristics, are in the delicate and time-consuming process of being genetically transferred into the common bean.

Such intensive, long-term, collaborative research efforts between CIAT and national and international agencies help the Bean Program execute its responsibility in genetic improvement.

UNIVERSITY OF GEMBLOUX

Climbing beans. All climbing bean materials are evaluated and selected for intercropping with maize. In addition to resistance and tolerance to priority diseases (such as *Ascochyta*, powdery mildew, anthracnose, and angular leaf spot), evaluation criteria include the competitiveness of the climbers relative to the maize and their ability to produce well at densities lower than those used for bush beans in monoculture. In 1981, some 800 accessions of climbing beans were evaluated in Palmira, 500 in La Selva, and 300 in Obonuco. In each site, the most promising materials were selected for further testing and for use as parents in the hybridization program.

In 1981, one of the objectives in germplasm evaluation was to identify materials that could overcome the narrow adaptation to temperature observed with earlier evaluated materials, particularly between the testing locations at La Selva and Obonuco (mean temperatures of 17 and 13°C, respectively). To date, two outstanding varieties have been identified for wide temperature adaptation. These are E 1034 and E 1056, both from the Ecuadorian collection in CIAT's germplasm bank.

Germplasm Improvement

Specific characters of germplasm are improved and recombined according to the needs of specific bean-producing regions.

Different bean-growing regions produce beans with a great variation in such factors as growth habit and the color, size, and shape of the seed. This variation reflects both producer and consumer preferences as well as differences in agroclimatic conditions and cropping systems. In addition, while most disease and pest problems are common across many production regions, great variation is found in their relative order of economic importance. Screening and evaluation of germplasm for each of these factors generally require specific methodologies and climatic conditions that are often incompatible with other artificially created epiphytotic conditions. This is one important circumstance that restricts the number of limiting factors that can be managed at a given time in a single breeding nursery to two to three. Thus, in order to identify desirable genetic variation and utilize it in improvement activities, the bean germplasm-improvement program follows a two-part strategy consisting of (1) specific character improvement and (2) recombination of desirable characters according to production regions and preferred grain types.

Specific Character Improvement

The character-improvement process is a continuous search for better sources of a desirable trait across all growth habits and grain types. Each of some 20 agronomic characters playing an important role in solving major production problems is handled in a separate breeding project. Emphasis is on maximizing the expression of the character, the character's stability, and its adaptive range. In addition to their use in CIAT breeding projects, all sources of desirable traits are made available to interested bean researchers, either through international nurseries or upon individual request. Following is a summary of progress achieved in the most important breeding projects for character improvement.

Under field conditions, bean varieties have both small (top) *and large* (bottom) *rust pustule types under natural, inoculated, and protected conditions. Yield differences between chemically protected and rust-inoculated plots ranged from 47 to 77% and from 0 to 25% for varieties of the large-pustule and small-pustule types, respectively. Similarly, yield differences between chemically protected and natural plots (not inoculated with rust) ranged from 43 to 74% for varieties with large pustules and from 0 to 19% for those with small.*

Bean common mosaic virus (BCMV). As reported before, the Program has made it a policy that all lines leaving CIAT, and all lines entering the Bean Team Nursery (see Figure 7 for definition), must be resistant to BCMV (bean common mosaic virus). Normally, progeny of F_2 selections are inoculated with a mix of different strains of the virus to detect and eliminate susceptible materials. During the year, some 5500 individual bush bean lines and some 2200 climbing bean lines were inoculated with a mixture of the Florida and the New York 15 BCMV strains and evaluated for resistance.

In the past, it has been observed that selected materials, such as the large- and medium-sized, yellow- and red-mottled bean types—which are of considerable importance in the Andean region—escaped BCMV detection, as they remained without symptoms, even when infected, after inoculation with mosaic-inducing BCMV strains. As a countermeasure, a method was developed whereby these materials are inoculated with a necrosis-inducing strain (BCMV NL3) of the virus, which makes it possible to check for the presence or absence of the dominant necrosis (I) gene that confers resistance to systemic mosaic. As a result, for the first time, the Program has identified medium- and large-sized, red-mottled bean lines with confirmed BCMV resistance. This leaves the large, yellow Canario grain type as the only one that is still lacking BCMV resistance.

In collaboration with the Institute for Horticultural Plant Breeding (IVT) in Wageningen, the Netherlands, a breeding project is underway for the incorporation of recessive genes for resistance to necrosis-inducing strains of BCMV into commercial bean types that already have dominant resistance to mosaic-inducing strains of the virus. The first group of backcrosses made in 1980 incorporated the recessive genes into bean lines adapted to the tropics. In 1981, backcrosses were performed to improve these lines for grain types and adaptation. Materials with recessive genes are needed for countries such as Chile and Burundi where necrotic BCMV strains are widespread.

Bean golden mosaic virus (BGMV). Black grain types continued to show higher levels of resistance to BGMV (bean golden mosaic virus) than other color types. For the black types, the program emphasizes multiple-factor breeding, with special attention given to combined resistance to BGMV, the *Empoasca* leafhopper, and common bacterial blight. Efforts related to non-black types are focused on increased levels of BGMV resistance within each color group; advances in 1981 were especially evident in small Pompadour and small, red-grain types.

Among the 191 materials tested, the 1981 regional BGMV nursery planted in Central America identified two CIAT breeding lines, A 171 and A 174, as showing good intermediate levels of resistance under high disease pressure. Neither of the two unrelated lines has parentage with known BGMV resistance. This finding indicates that within tropically adapted *P. vulgaris*, there are probably still more as-yet-unidentified sources of resistance to the pathogen. In the regional BGMV nursery referred to above, and in various breeding nurseries, a distinct location-by-variety interaction for BGMV was suspected, pointing to a possible pathogenic variation in the virus.

In the search for new resistance sources, 144 lines of wild forms of *P. vulgaris* were screened. Six of these accessions showed high levels of tolerance and are now being crossed to locally adapted materials. Also, several selections from interspecific crosses between resistant accessions of *P. coccineus* and *P. vulgaris* appear to have high levels of resistance but need further evaluation.

Rust. Bean rust, caused by *Uromyces phaseoli*, is a major bean disease problem throughout Latin America and other bean-growing regions of the world. Due to the marked pathogenic variation, few cultivars are resistant over a wide range of locations or over long periods of time. The bean germplasm improvement-program seeks to identify mechanisms of rust resistance that are stable in space and time. Results obtained from the 1979-80 International Bean Rust Nursery (IBRN), conducted in 22 sites in 10 countries, show that several CIAT bean lines are available that are either resistant or show an intermediate reaction to the different rust populations existing in Latin America and other bean-growing areas of the world (Figure 1). These materials are undergoing further testing, and selected ones are used as sources for rust resistance. In the meantime, crosses made from up to four rust-resistant parents are undergoing evaluation in Palmira under high levels of rust inoculation.

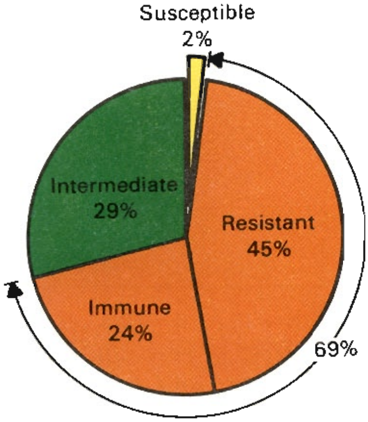


Figure 1. *The 1979-80 international Bean Rust Nursery was evaluated in 1981 in 22 sites in 10 countries. The 10 best CIAT lines were immune or resistant to rust in 69% of the testing sites, compared to only 9% of the check.*

Anthracnose. In the period 1978-81, more than 13,000 bean germplasm bank accessions were evaluated for their resistance to anthracnose, caused by *Colletotrichum lindemuthianum*. In the 1980-81 period, progenies of the most promising selections were planted and inoculated in Popayan. Resistant accessions were also evaluated in the greenhouse for resistance to a wide range of different races and isolates of the anthracnose fungus. Twenty-seven accessions were identified as resistant or showing an intermediate reaction to all known races from Europe, and to other virulent isolates from Colombia and other parts of Latin America. Among these are the following five CIAT bean lines: BAT 44, BAT 841, V 7917, V 7918, and V 7920. This group of 27 accessions is representative of a wide range of grain sizes and grain colors, including black.

In 1978-81, over 13,000 bean accessions were evaluated for resistance to anthracnose.

In a continuing effort to combine as many sources of resistance to anthracnose as possible, 15 experimental lines involving six different sources have been developed from crosses made in 1978. Also, 34 additional crosses among 35 parental sources of resistance were made. An international bean anthracnose nursery is being organized to be distributed in 1982 in the major bean-growing areas of the world.

Angular leaf spot. Although not as advanced as the improvement project for anthracnose, the angular leaf spot project—after field and greenhouse evaluations with Popayan isolates of the pathogen, *Isariopsis griseola,* plus glasshouse evaluations for anthracnose resistance—now has available some 15 accessions classified as "resistant" or "intermediate" to the Popayan isolates, and with good resistance or tolerance to various isolates of the anthracnose pathogen. The usefulness of these sources of angular leaf spot resistance cannot be determined until additional evaluation data is available from other locations and with additional isolates from other bean-growing areas of the world.

For the first time, sources of resistance to Zabrotes *and* Acanthoscelides *have been identified in wild forms.*

The segregating populations of crosses made in 1979 and 1980 to combine sources of resistance to angular leaf spot, halo blight, and powdery mildew are being evaluated in Popayan and Obonuco.

Common bacterial blight (CBB). The Program continues its efforts to develop CBB-resistant (common bacterial blight) materials in bean types and grain colors with commercial acceptance in regions where this pathogen is an important production constraint. The very promising sources of resistance identified in 1980 have now entered the crossing program; progress achieved with progenies of these sources will be reported next year. In 1981, some 100 early generation and advanced breeding lines, previously rated as resistant to the CBB pathogen, *Xanthomonas phaseoli,* were evaluated for foliar resistance. Among the 27 lines found to be resistant or intermediate were both small, red brilliant and black opaque-seeded breeding lines—color groups that previously had proved difficult to accept resistance transfers.

In the search for higher levels of CBB resistance, 19 F_2 populations from interspecific crosses between *P. vulgaris-* and *Xanthomonas*-resistant accessions of *P. coccineus* were evaluated. Several highly resistant selections were identified or confirmed.


Screenhouse evaluation for bruchid oviposition resistance. Each sleeve contains a bean pod and a pair of adult insects.

Leafhopper. As reported in prior years, the achievement of increased levels of resistance to the leafhopper (*Empoasca kraemeri*) has proved to be a difficult process. In 1981, more than 5300 materials from various nurseries were evaluated, but less than 1 percent of these were rated as resistant. The best accessions were utilized as parents in the recurrent selection program. With the completion of the fourth cycle of intermating in this breeding program, progress observed in earlier cycles of recurrent selection to increase levels of resistance was reconfirmed. Promising selections are representative of a good range of seed colors. A special effort has now been initiated to select for large-seeded types, which have proved to be especially difficult to improve for *Empoasca* resistance.

Pod weevil. Damage from the pod weevil, *Apion godmani,* is of considerable economic importance in bean-production areas of

Central America. In 1981, the *Apion* breeding project registered significant progress in that a series of highly resistant breeding lines were identified (Figure 2). These lines were identified through an international *Apion* nursery, with distribution to El Salvador, Guatemala, Honduras, Mexico, and Nicaragua. In this nursery of 40 entries, a total of 28 lines were classified as resistant. One of these lines, APN 65, was released in Honduras as a new variety under the name Copan.

Storage insects. After evaluating more than 6000 germplasm bank accessions for resistance to the Mexican bean weevil (*Zabrotes subfaciatus*), and more than 1000 accessions to the common bean weevil (*Acanthoscelides obtectus*), in the period 1975 to 1981, the conclusion was reached that resistance levels in cultivated materials are too low to be of economic relevance. In 1981, however, evaluations of 206 semi-cultivated bean accessions collected earlier in Mexico showed some of these lines to be highly resistant to both the Mexican and the common bean weevil. This resistance was found to be expressed in greatly reduced numbers of progenies of the weevils combined with retarded development and reduced progeny dry weight (Table 3). The most promising of the resistant lines have been entered into the crossing program in an attempt to transfer the resistant genes into commercial materials. Should this prove successful, an important advance in the fight against storage insects—a primary cause for the widely observed collapse of the price of beans immediately after harvesting—will be registered.

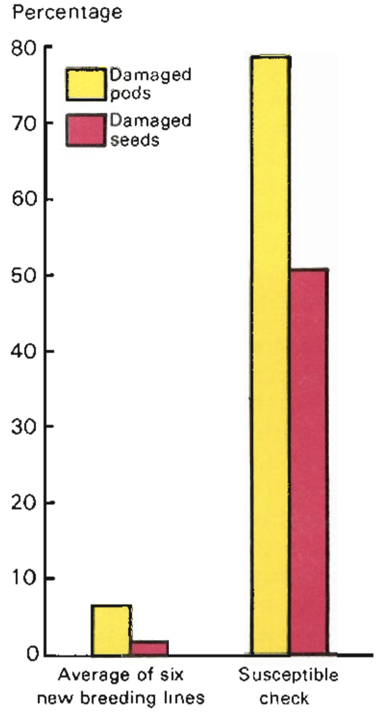


Figure 2. *Several bean lines have been identified for resistance to the pod weevil through the international* Apion *nursery. The percentages of damaged seeds and pods from the weevil were reduced by 72 and 42%, respectively, in the new breeding lines now available through collaboration with national programs.*

Table 3. **Resistance of the best-performing cultivated bean accessions, of 206 collected in Mexico, 1981, and a susceptible check to the Mexican bean weevil** *(Zabrotes subfaciatus).*

Accession	Average adults emerged (no.)[a]	Average length of development cycle (days)	Average adult dry weight (mg)
G10019	7	38	8
G12952	9	67	7
G12880	39	33	10
Diacol Calima (susceptible check)	306	31	16

a. Average of adults in five replications of 50 seeds each.

Nitrogen fixation. Results after three cycles of intermating and selecting for enhanced N_2 fixation in bush bean cultivars are most encouraging. The 114 lines of the third cycle of glasshouse selection and field evaluation fixed an average of 50 percent more N_2 than their original progenitors, which were selected for their high fixing ability. The best five of these lines fixed fully 100 percent more than the original parents (Figure 3). As these highly promising materials do not fulfill all agronomic requirements, further crosses are made to introduce this variability from other improvement projects into this recurrent selection scheme for enhanced N_2 fixation.

Plant architecture. In the search for improved yields, yield stability, and mechanisms for disease avoidance, a number of new plant-architecture traits have been developed for further testing. One particularly promising characteristic is a plant with short-spaced but numerous internodes that promises to improve yield potential especially of determinate bean types (Figure 4). Also of much promise is a bean type with a strong stem and upright branching, but with a high number of pods (Figure 5). Such erectness prevents the pods from soil contact, thus increasing seed quality and decreasing disease incidence. Characteristics such as short internodes and suppressed branching are being combined with other architectural traits such as small pods, stiff stems, small foliage, lanceolate leaf, and others to study their effect on yield potential. As most of these architectural traits are available only for small-seeded lines adapted to warmer climates, increasing attention is given to transferring these traits into medium- and large-seeded varieties and into varieties adapted to cooler production environments in the tropics.

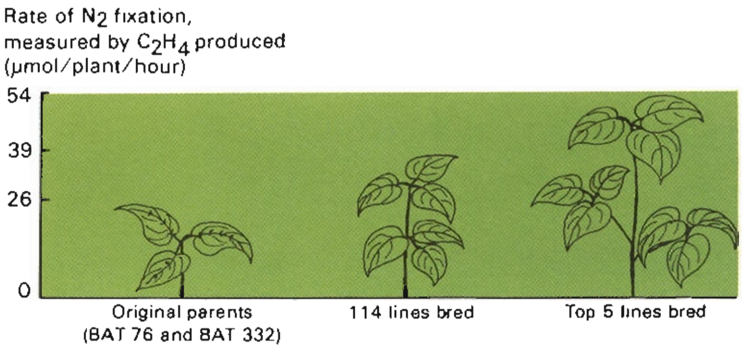


Figure 3. *New bush bean cultivars have been bred at CIAT for enhanced nitrogen fixation. Results after three cycles of recurrent selection show N_2–fixation increases of up to 100% in progenies over the original parents.*

Figure 4. *As part of its efforts to improve the architecture of bean plants, CIAT has developed this plant type, Line A 132, with short-spaced and numerous internodes, which is expected to improve yield potential in bush beans.*

Figure 5. *Another CIAT bean type, Line A 57, was developed with a strong stem, upright branching, and a high number of pods, which are expected to improve seed quality and reduce disease incidence.*

Combination of Desired Characteristics

The most promising sources of resistance and desired agronomic characters are selectively and cumulatively transferred into agronomically suitable materials with commercial bean types. In this process of recombination, some degree of individual character expressions often has to be sacrificed. As information accumulates on the value of the progenies, some parents are more widely used, while others are discarded. Using the criteria of growth habit, climatic adaptation, seed size, and grain coat color, the Bean Program has grouped the major commercial bean types into 16 basic bean groups (Figure 6). All of these groups are included in the improvement activities of the CIAT Bean Program.

In 1981, the bush-breeding projects made some 1250 crosses for the recombination of multiple characters and produced a total of 681 new experimental lines for the various production regions in Latin America and the Caribbean. All of these lines are now

BASIC BEAN GROUPS	GROWTH HABIT	CLIMATIC ADAPTATION	SEED SIZE	GRAIN COAT COLOR
1	Bush	Tropical – Warm	Small	Black
2	Bush	Tropical – Warm	Small	Red
3	Bush	Tropical – Warm	Medium	Red*
4	Bush	Tropical – Moderate	Large	Red* Pink* Purple*
5	Bush	Temperate	Small	White
6	Bush	Temperate	Small	Cream* Purple Brown Black
7	Bush	Temperate	Medium	White
8	Bush	Temperate	Medium	Cream* Pink* Brown* Pinto
9	Bush	Temperate	Large	White
10	Bush	Temperate	Large	Cream Yellow Gray Brown
11	Climbing	Tropical – Warm	Small	Black
12	Climbing	Tropical – Warm	Small	Red
13	Climbing	Tropical – Moderate	Medium and Large	Red*
14	Climbing	Tropical – Moderate	Medium and Large	White* Cream* Yellow* Brown*
15	Climbing	Temperate	Small	Black
16	Climbing	Temperate	Small	White Cream*

* Includes solid, mottled, striped, or speckled types.

Figure 6. *There are 16 basic commercial bean groups included in the CIAT breeding-improvement activities. Bush and climbing beans are developed and evaluated for adaptation to tropical and temperate climates and for seed size and grain coat color, as required for consumer preference in the various production regions.*

Table 4. **Bush and climbing lines submitted for VEF nursery evaluation in 1981.**

Basic bean group	Grain characteristic		Production region for consumption	Lines (no.)
	Color[a]	Size		
Bush beans				
1	Black	Small	Mexico, Brazil	160
2	Red	Small	Central America	190
2	Red	Medium	Caribbean	71
4	Red	Large	Andean Zone	46
5	White	Small	Peru, Ecuador	51
6	Cream	Small	Brazil	205
7	White	Medium	Peru, Chile	12
8	Pink	Medium	Mexico	70
9	White	Large	Argentina	10
10	Yellow	Large	Chile, Ecuador, Peru	59
Climbing beans				
11	Black	Small	Guatemala (highlands)	21
12	Red	Small	Central America	69
13	Red	Large	Andean Sierra	79
14	Cream	Large	Andean Sierra	25
15	Black	Small	Central America	18
16	White	Small	Peru, Ecuador	23
			Total	430

a. Includes solid, mottled, striped, or speckled types.

undergoing further evaluations. In the climbing bean project, some 270 crosses were made to transfer desirable characters into the various commercial grain types. Progeny of these crosses were planted and evaluated with maize under high BCMV and anthracnose pressure. A total of some 1400 progenies were evaluated in CIAT-Palmira, 2000 in Popayan, 1000 in La Selva, and 300 in Obonuco. Some 430 of the most promising selections were advanced to the first stage of nursery trials, the VEF, for testing for disease resistance.

In summary, 1981 saw the development of promising lines in all 16 basic bean groups (Table 4). All of these lines are BCMV resistant, and most have improved plant types. The most notable advances in improving specific grain types were registered for the Andean zone, the Caribbean (the Pompadour type), Central America (small, red types) and Brazil (Carioca and Mulatinho types).

Progeny Evaluation

The Bean Program uses a three-stage progeny evaluation program (Figure 7). The first stage, the Bean Team Nursery (VEF), is a uniform, multidisciplinary evaluation for adaptation and priority disease and insect resistance. Some 1000 lines are entered into this nursery each year. Selected materials (about 300 lines per year) are advanced to the second evaluation stage, the Preliminary Yield Trials (EP). In the EP, lines undergo a nearly complete evaluation including resistance to minor diseases and pests, quality factors, and N_2 fixation. The best materials selected from the EP trials (about 100 lines per year) are included in the International Bean Yield and Adaptation Nursery (IBYAN).

Bean Team Nursery (VEF)

The 1981 Bean Team Nursery (VEF) contained 1110 entries, of which 661 were improved bush beans and 235 were improved climbers; the remaining 194 either were germplasm bank accessions or came from national programs. Materials from all 16 basic bean groups were represented. The group with the smallest number of entries (i.e., large white bush beans for Argentina) contained 10 lines, while the group with the largest number of entries (i.e., small cream and brown grains for Brazil) registered 205 lines. All materials entering the VEF were resistant to BCMV; 43 percent of the bush bean entries and 47 percent of the climbers showed a resistant or intermediate reaction to rust. The frequency of anthracnose resistance in the 1981 VEF has greatly increased

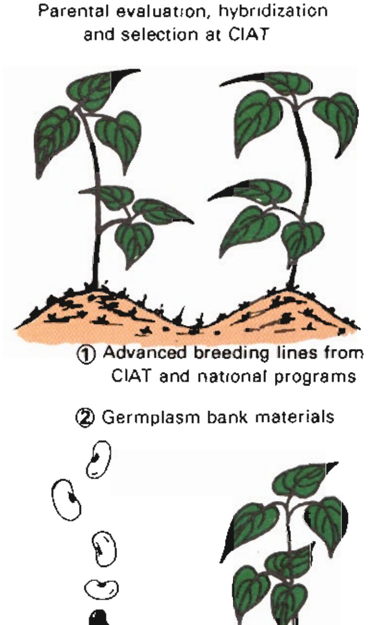
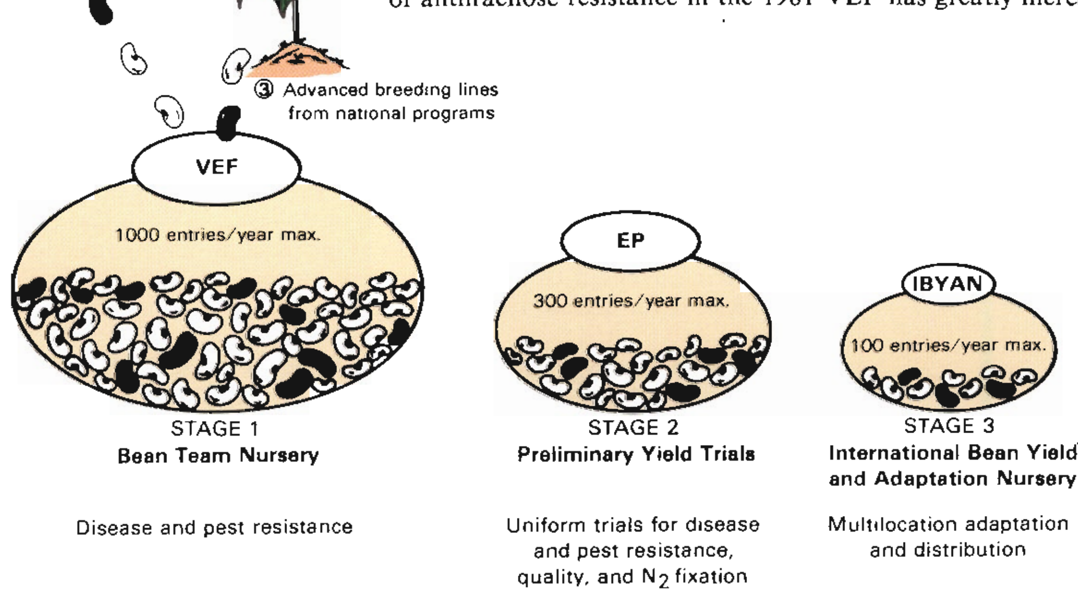



Figure 7. *As reported previously, the CIAT Bean Program uses a three-phase nursery and testing program for the development and distribution of improved bean materials. Original entries into this evaluation scheme are from both CIAT and national programs.*

over previous years, with over half the entries showing resistance to this important bean disease (Figure 8). Anthracnose-resistant lines were identified in all 16 basic bean groups.

Preliminary Yield Trials (EP)

The Preliminary Yield Trials (EP) scheme is the first evaluation for yielding ability of newly improved lines. These trials are conducted both at CIAT-Palmira and CIAT-Popayan, under high-and low-input conditions at each location. In 1981, seven sets of the EP were also planted in locations outside Colombia.

The 1981 Preliminary Yield Trials consisted of 191 lines, selected from over 500 entries evaluated in the 1980 VEF. Bush beans were represented by 135 lines and climbers by 56 lines. Except for the large- and medium-sized white grains, all basic bean types were represented. The steady progress in the long-term CIAT improvement effort is evidenced by the fact that, in the large majority of basic bean groups tested, selected breeding lines managed to outyield their respective checks, both under chemically protected and unprotected conditions, in the two principal testing sites.

Among bush beans, a series of highly promising breeding lines were identified in each of the eight basic bean groups for which advanced breeding lines were available. Figure 9 shows that, in the case of the CIAT-Palmira testing site, the average of the most promising new materials in each of the basic bean groups tested is nearly always higher than the average of the check varieties, both under protected and unprotected conditions.

Due to the relatively late start-up of CIAT improvement efforts in climbing beans, the CIAT breeding lines for basic bean groups for climbers are not as advanced as those for bush beans. Nevertheless, outstanding lines in each of the six basic bean groups for climbers are present in the 1981 EP. In five of the six climber groups, the top yielder was an improved line.

A high percentage of the Preliminary Yield Trial entries showed resistant or intermediate reactions to one or a combination of the following diseases: common bacterial blight, rust, anthracnose, *Ascochyta*, angular leaf spot, root rot complex, and web blight (Figure 10). An intermediate reaction to *Empoasca kraemeri* was observed in 11 (6%) of the entries.

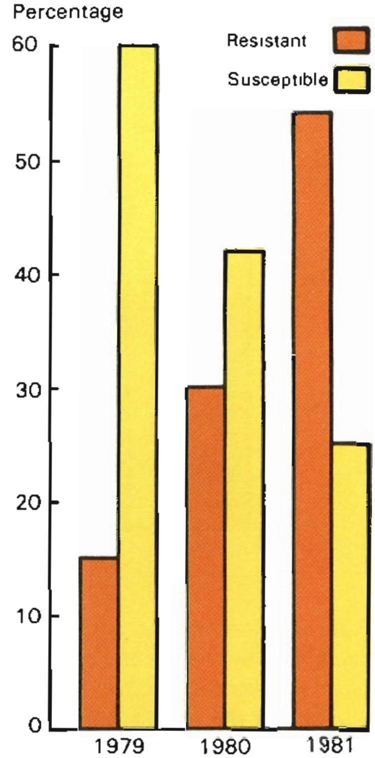


Figure 8. *Resistance to anthracnose in the VEF nursery trials has more than tripled in the last 3 years. In the 1981 nursery, over 59% of the new lines were classified resistant. All lines entered into the VEF are already BCMV resistant. (Intermediate reactions are excluded in this graph.)*

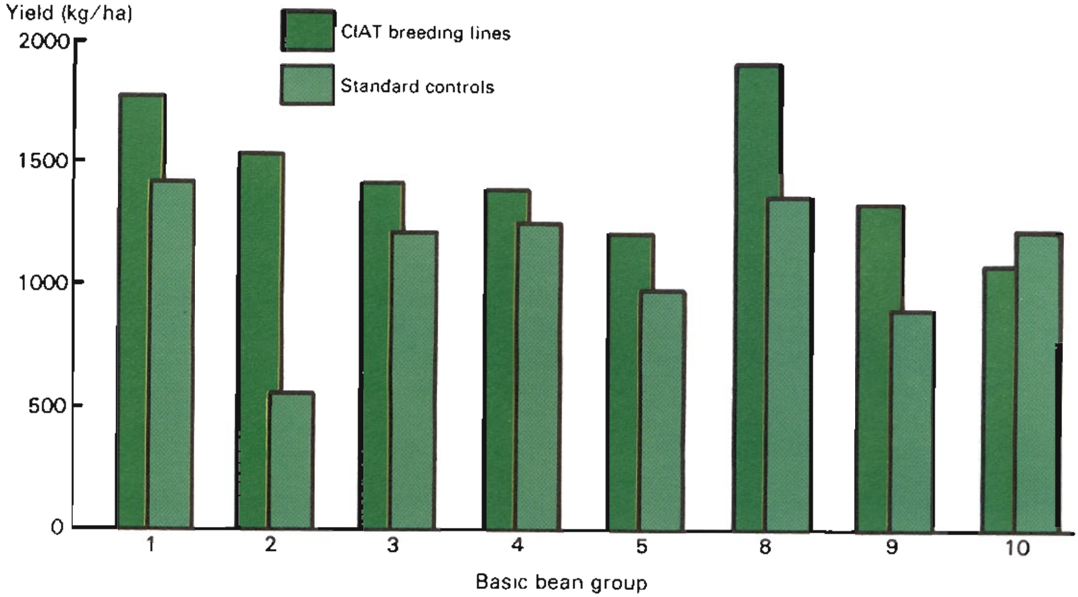


Figure 9. *Continued progress in developing improved bean materials in all basic bean groups is evidenced by the results of the 1981 Preliminary Trials at CIAT-Palmira. In seven groups (of a total of eight groups tested), the average of the 10 best new CIAT breeding lines was well beyond the average of the best-available standard control varieties, under both chemically protected and unprotected conditions.*

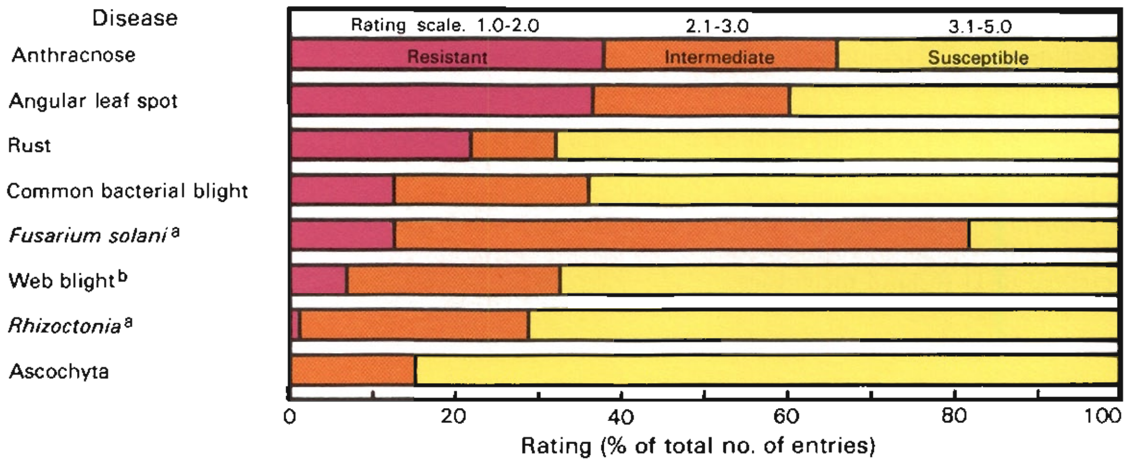


Figure 10. *The 1981 EP demonstrated improved resistance in the field to most of the primary bean diseases (each disease tested in about 191 entries).*

a. Results of experiment conducted under greenhouse conditions.

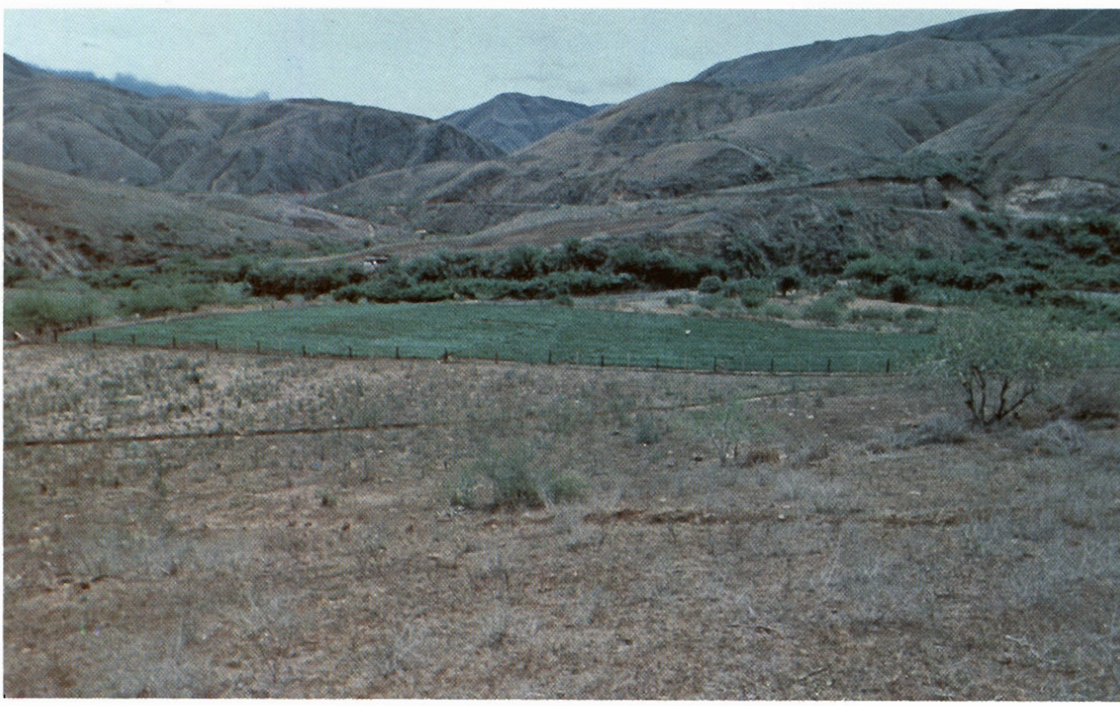
b. Evaluated in two sites in Costa Rica.

International Bean Yield and Adaptation Nursery (IBYAN)

All sources of desirable traits are made available to interested bean researchers, either through international nurseries or upon individual request.

The International Bean Yield and Adaptation Nursery (IBYAN) was started in 1976 as a bush bean trial in which all seed colors were evaluated in one nursery. Since 1977, black and colored entries of bush beans have been evaluated in separate nurseries. Climbing bean trials were added in 1978, with climbing materials separated into three color groups: black, red, and others. In 1980, the IBYAN was increased to seven different nurseries by dividing bush bean trials into four groups —black, red, white, and cream colored— allowing each national program to receive material of grain types of its interest. By the end of 1981, some 1200 IBYAN trials had been shipped worldwide (Table 5); in 1981 alone, some 300 trials were sent out.

The seven nurseries in the 1981 IBYAN trials contained a total of 46 bush bean and 30 climbing bean lines. All entries were selected from the 1980 Preliminary Yield Trials. The results of each year's IBYAN are published in separate reports available for consecutive years from the CIAT Distribution Office. The present report only includes results from the IBYAN trials planted by the Bean Program in Colombia in the second semester of 1980 and the first semester of 1981.



Bean seed for shipment in international nurseries is multiplied in an arid valley near Cali, Colombia, an area free of bean production and bean diseases. Quarantine officers from the Colombian Institute for Agriculture periodically inspect the plots as a requisite for issuing phytosanitary certificates.

Table 5. **Distribution of IBYAN trials by geographic zones.**

Region	1976	1977	1978		1979		1980		1981		
	Bush	Bush	Bush	Climbing	Bush	Climbing	Bush	Climbing	Bush	Climbing	Total
Latin America and the Caribbean	69	80	136	37	141	59	143	50	180	64	959
North America, Europe, Australia	8	9	5	0	2	0	6	0	8	0	38
Asia	9	14	0	3	1	0	17	10	26	11	91
Africa	4	5	9	2	12	5	25	8	27	9	106
Total	90	108	150	42	156	64	191	68	241	84	1194

Bush beans. At CIAT-Palmira and CIAT-Popayan, trials were planted for black-, red-, white-, and cream-seeded bean types. Used as international checks were Jamapa and Porrillo Sintético for blacks; Diacol Calima for reds; Ex-Rico for whites; and Carioca for cream-seeded materials. In addition, the best-available local varieties were used as local checks. In all cases, the international and local checks were outyielded by selected new breeding lines and by elite checks (elite checks are outstanding lines from previous IBYAN trials). Yield rankings under chemically protected and unprotected conditions were again found to be very similar.

Climbing beans. All IBYAN trials with climbing beans are designed for planting in association or relay with maize. The trials with black-seeded materials showed most breeding lines outyielding local checks. The best varieties at any one of the locations (i.e., CIAT-Palmira and CIAT-Popayan) proved to be poor performers at the other testing site, indicating a specific environmental adaptation of the materials. In the trials with red-seeded materials, the genotype-by-location interaction was less pronounced. Again, the highest yielders proved to be new breeding lines. Finally, in the trials with large-seeded materials (materials preferred in the cool highland areas of the Andean zone and in Mexico), all but one of nine breeding lines outyielded the local checks.

Climbing beans are evaluated and selected for intercropping with maize.

Dissemination of Improved Bean Materials

The evaluation scheme for bean materials, as presented in Figure 7, allows for a free flow of genetic materials from national programs to CIAT, and vice versa. In the initial phases of this evaluation scheme (1976-1977), the materials passing through it were selections from the germplasm bank and established varieties from throughout Latin America. Since 1978, the representation of new breeding lines has steadily increased. By 1981, for example, more than 80% of the bush bean entries in the IBYAN trials were improved lines from the Bean Program.

The Program supplies breeding materials to collaborating national programs at whatever stage of development the respective national programs wish to make use of the new materials. This stage varies in accordance with the type of production constraints that particular national programs are confronting, as well as the human and physical resources available at the national level. For some countries, CIAT provides breeding lines that can be used immediately as varieties. For others, early generations of segregating populations—most often from crosses made specifically to meet the needs of given national programs — best suit the requirements of national programs.

Over the years, then, the Bean Program has been involved in the distribution of three types of bean materials through its scheme of development and evaluation of germplasm: (1) varieties and germplasm bank entries obtained from national programs; (2) advanced breeding lines resulting from the improvement efforts of the Bean Program; and (3) advanced lines developed by national programs often developed from early-generation breeding lines from CIAT.

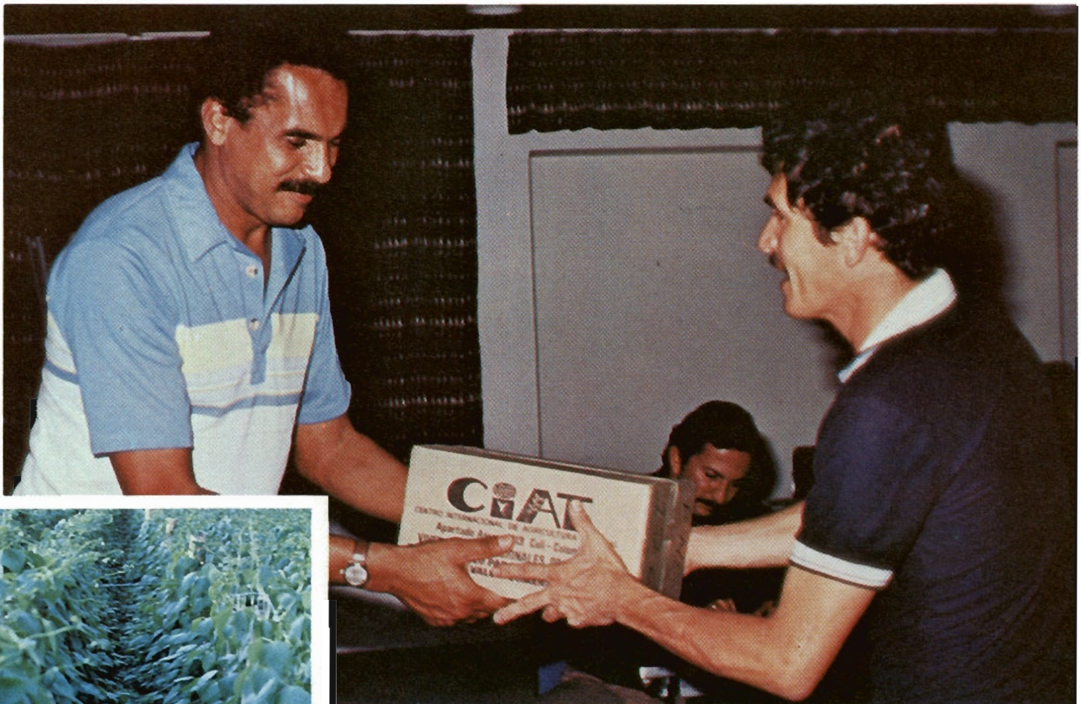
By 1981, more than 80% of the bush bean entries in the IBYAN trials were improved lines from the Bean Program.

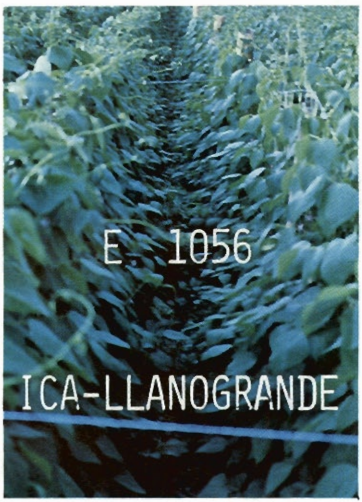
CIAT disseminated materials already existing in national programs. Of the roughly 400 entries included in the IBYAN trials from their inception in 1976 to 1981, 151 were varieties and germplasm accessions obtained from national programs. As shown in Table 6, by 1981 some 15 countries in Latin America had released bean varieties selected from such entries. It is estimated that these varieties are now planted on some 40,000 hectares outside their country of origin. This same dissemination process is also starting to become evident in eastern Africa; for example, Burundi has selected the variety Diacol-Calima from a nursery assembled by CIAT and is already making extensive commercial use of it.

Table 6. **Germplasm entries in CIAT bank, received from national programs and adopted as new varieties in other countries, as of December 1981.**

Variety	Source	Adopted by[a]
Brasil 2	Brazil	Ecuador (INIAP—Bayito)
Pirata 2	Brazil	Peru
Diacol Calima	Colombia	Burundi, Gabon
ICA Palmar	Colombia	Peru
ICA Pijao	Colombia	Bolivia, Costa Rica, Cuba, Honduras, Guatemala (Suchitan), Nicaragua
ICA Tui	Colombia	Costa Rica
ICA-10103	Colombia	Costa Rica (Talamanca)
G 1753	Costa Rica	Argentina
E 1056	Ecuador	Colombia, Ecuador
Porrillo Sintético	El Salvador	Cuba, Peru, Costa Rica
Apetito	Mexico	Peru
G 2333	Mexico	Peru
Puebla 444	Mexico	Peru
Línea 78-0327	United States	Peru
Redkloud	United States	Chile, Peru, Belize
Ex-Rico 23	(unknown)	Canada

a Names in parentheses are variety names adopted by that country.





At the end of in-country courses on bean production, participants receive a package with seed of various newly released varieties to plant (right) *as a demonstration trial rather than the certificate usually awarded. These CIAT lines (such as E 1056) are multiplied for in-country advanced testing and frequently given variety names (such as ICA-Llanogrande)* (inset).

In addition, dissemination of CIAT breeding lines took place. Whereas in the 1977 IBYAN trials only two of 35 entries were CIAT breeding lines, by 1981 there were 63 of 75 entries from CIAT breeding lines. By late 1981, Bolivia, Costa Rica, El Salvador, and Nicaragua had named as new varieties selections from such breeding lines. Figure 11 provides a summary of the CIAT breeding lines that are now undergoing seed multiplication in various Latin American countries.

Varieties developed by national programs based on CIAT crosses were also released. In close collaboration with CIAT, the national programs in Guatemala and Honduras already have developed their own varieties based on early-generation lines from CIAT crosses. The varieties developed by Guatemala are ICTA Quetzal, ICTA Jutiapan, and ICTA Tamazulapa; varieties developed in Honduras are Acacia 4 and Copan. With the active collaboration of the Bean Program's regional project in Central America, these lines are distributed and tested throughout the region. For example, the variety ICTA Quetzal has already been adopted in Cuba; ICTA Jutiapan has been adopted in Nicaragua; and Acacia has been introduced into Costa Rica.

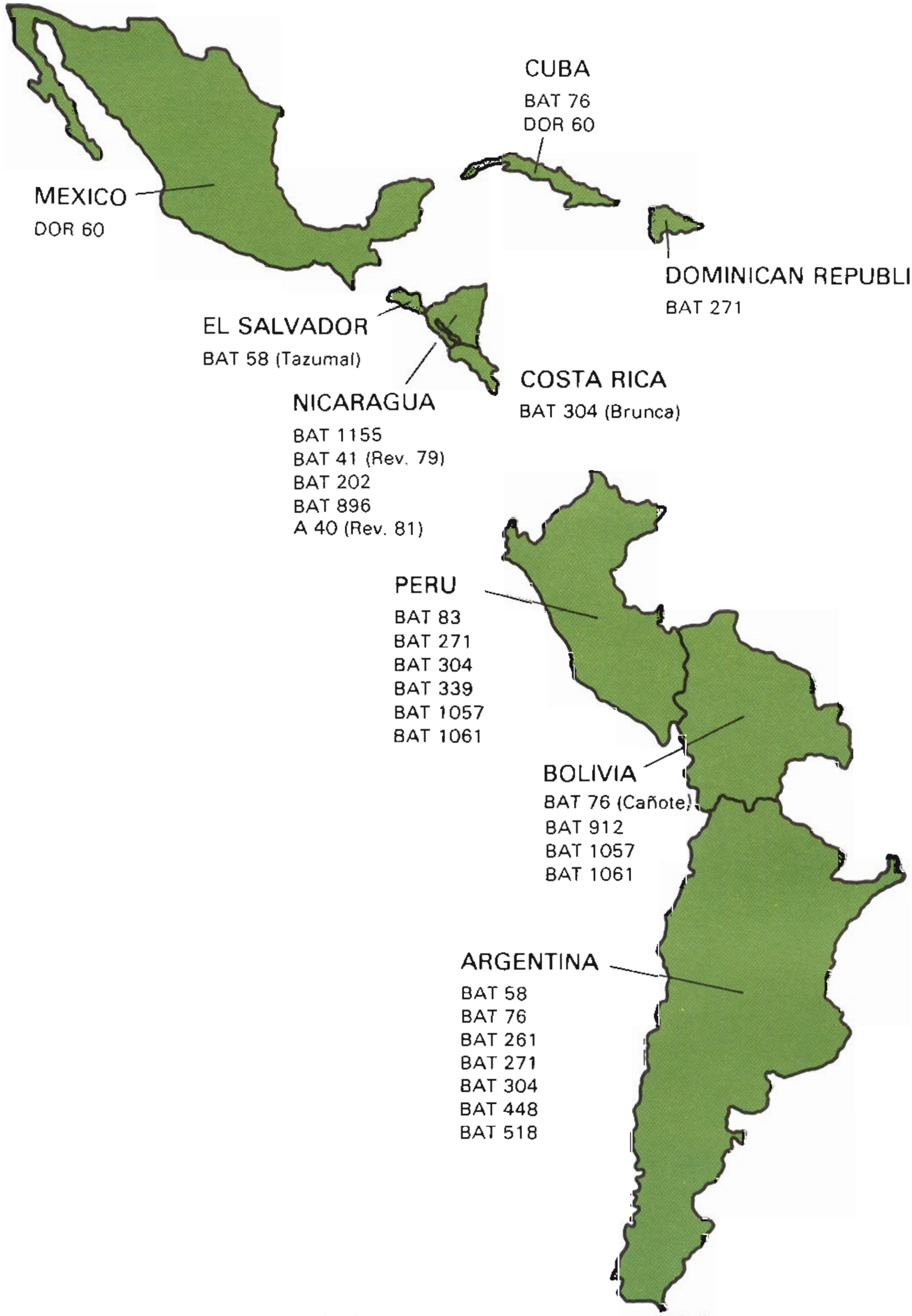


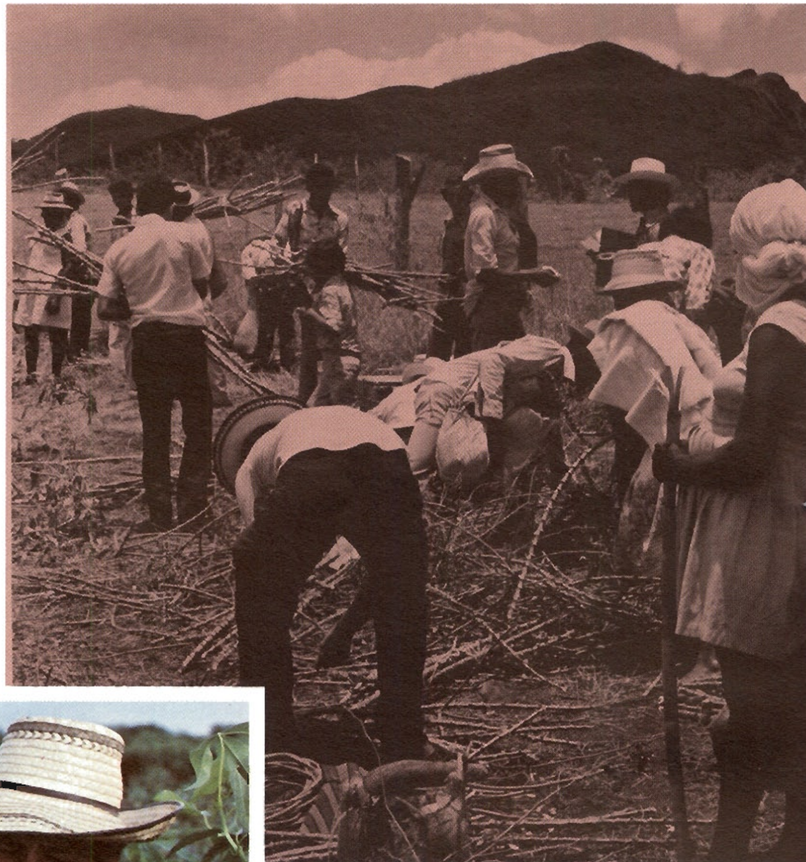
Figure 11. *CIAT bean lines, including named varieties, being multiplied for commercial use in various Latin American countries, as of December 1981.*

Growing Momentum of the International Bean Network

National programs in Latin America are increasing their capacities to independently and collaboratively engage in bean-development work.

Through the training of more than 500 bean workers, the organization of periodic workshops, and the development of the collaborative, international bean development and evaluation scheme, the Bean Program has been able to set in motion a thoroughly international bean research and development effort. Throughout Latin America, national programs are steadily progressing toward increased levels of capacities to independently and collaboratively engage in bean development work. The interactive technology-development process between the national and international levels has now attained the point where new, improved materials are undergoing seed multiplication and are beginning to reach the multitude of bean farmers in many Latin American countries. Against this backdrop, the Bean Program increasingly looks toward major bean-production areas outside the Western Hemisphere. Preliminary work along this new frontier for the Bean Program indicates that the technology base established for the Latin American context is likely to provide a strong starting point for bean-development work in such important bean-production regions as eastern and central Africa and the Middle East.

Multiplication of certified seed of variety Revolucion 81 (CIAT Line A 40) in Nicaragua. This line meets the consumer preferences in the area, is high yielding, has wide adaptation, and is resistant to both bean common mosaic virus and rust.



Cassava Program

CASSAVA IS the principal root crop and a major calorie staple in the rural lowland tropics. The plant's high carbohydrate production potential per unit of land or labor and its adaptation to more marginal agricultural conditions combine with an exceptional versatility for alternative markets: cassava can be eaten as a fresh vegetable; it can be processed into a variety of forms for human consumption; it can be used as an animal feed or in the manufacture of feed concentrates; it can serve for the production of alcohol as a fuel substitute for gasoline; and, in the form of starch, it has numerous industrial uses.

Today, world cassava production of close to 120 million tons is divided among Latin America (26%), Asia (36%), and Africa (38%). Some two-thirds of this production is consumed as human food, either in fresh or in processed form.

Traditionally, cassava has been produced by small farmers under minimal-input conditions. Yields have been low, with the world fresh root yield an average of around 9 t/ha. For centuries, farmers have selected cassava clones across a wide range of agroclimatic conditions. As a consequence, most traditional clones are well adapted to the environmental conditions and biotic problems in the zone in which they are grown when traditional management practices are used; however, the narrow germplasm base in the respective production zones has restricted the germplasm-development process. Few improved varieties have reached farmers from the few existing breeding and selection programs for cassava. Yet yields of more than 60 t/ha under experimental conditions suggest the high potential for raising farm productivity through the further development and increased use of higher yielding varieties that produce stable yields under stress conditions.

The selection of improved cassava varieties follows a systematic procedure of parental selection, hybridization, and progeny evaluation through a number of generations. "Germplasm flow" and "information flow" are inextricably linked in a two-way interchange between the national research programs and CIAT.

Superior genotypes are available for a majority of the various edapho-climatic ecosystems in which the Program works.

The high perishability of cassava makes handling difficult after harvest. Frequently, increased production is limited by the lack of nearby markets of processing plants transforming cassava into a more stable product. Farmers are often reluctant to increase production because of uncertain outlets, and entrepreneurs are not willing to invest in processing plants because of uncertain supplies. Thus, to increase cassava production, production and utilization must be integrated and effective marketing systems established.

The Cassava Program seeks to satisfy the need for food and feed carbohydrates by converting cassava from a traditional rural staple to a major, multi-use carbohydrate source. In addition, the Program is developing germplasm and management systems to improve the utilization of cassava for direct human consumption.

SUMMARY OF ACHIEVEMENTS

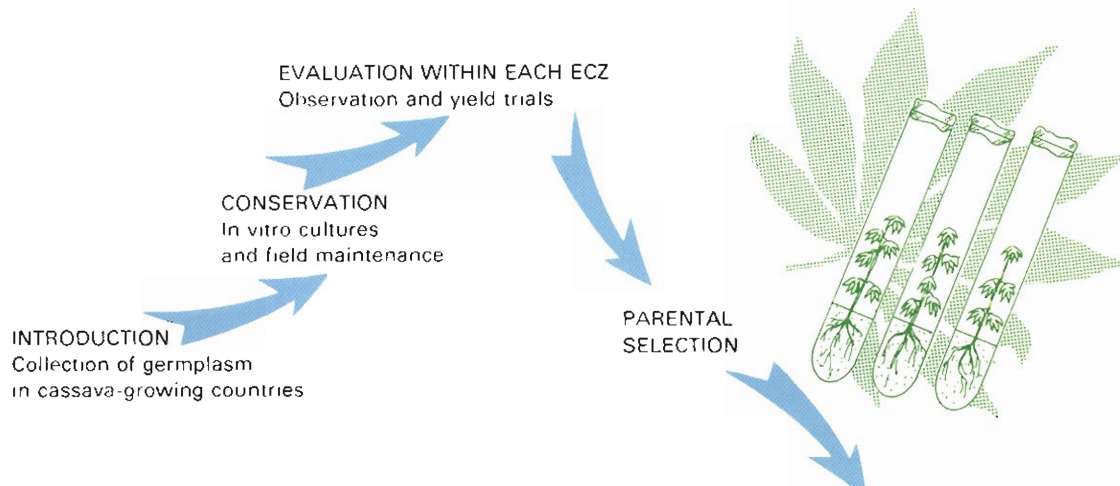
Analyses of long-term data obtained in farm-level trials confirmed that the improved, low-input management practices developed by the Cassava Program can double traditional yields of 10 tons of fresh roots/ha. If, in addition, new selections or hybrids are used, stable yields of 30/ha can be obtained.

Research factors that may leand to the further improvement of management practices continued to be assigned high priority in the Program. A long-term fertility trial has confirmed the importance of potassium application with consecutive plantings of cassava. Also, the importance of a mycorrhizal association for normal growth of cassava in soils with low phosphorus availability was established. Studies of this association point to the likelihood that inoculation with highly efficient mycorrhizal strains will have significant effects on yield increases and will enable cheap, low-grade sources of phosphorus to be used effectively. The search for improved methods of cultural control of cassava insect pests was further boosted by the identification of a series of potentially useful natural enemies of economically important cassava pests.

Progress in the long-term cassava-improvement efforts is evidenced by the fact that yields of local cultivars in the various testing sites stayed constant, whereas average yields of the CIAT genotypes have increased progressively and significantly. Superior CIAT genotypes are available for a majority of the various edapho-climatic ecosystems in which the Program works. These genotypes are already in the hands of collaborating national institutions where they are used for further testing for eventual release, or are included in national hybridization programs. Today, the Program is well on its way to producing genotypes with high yield potential, high root dry-matter content, and good eating quality. The very short shelf life of cassava remains a problem for the fresh market.

Table 1 **Edapho-climatic zones for cassava production and their main characteristics.**

Edapho-climatic zone (ECZ) no.	General description	Mean temperature (°C)	Dry season duration (mo.)	Ankal rainfall (mm)	Representative areas	Sites in Colombia for germplasm evaluation and technology testing
1	Lowland tropics with long dry season; low to moderate rainfall, high year-round temperature	Above 25	3-5	700-2000 (unimodal distribution)	N. coast of Colombia, N Venezuela, N.E. Brazil, S India, Thailand	Caribia, Media Luna, Fonseca, Nataima, Rionegro
2	Lowland tropics with moderate to high rainfall, savanna vegetation on infertile, acid soils; moderate to long dry season; season; low relative humidity during dry season.	Above 25	3-6	2000 (unimodal distribution)	Llanos of Colombia and Venezuela, Cerrados of Brazil.	Carimagua
3	Lowland tropics with no pronounced dry seasons, high rainfall, constant high relative humidity.	Above 25	Absent or very short	2500 (unimodal distribution)	Amazon basins of Brazil, Colombia, Ecuador, Peru, rainforests of Africa and Asia	Florencia
4	Medium-altitude tropics, moderate dry season and temperature	21-24	3-4	1000-2000 (bimodal distribution)	Medium-altitude (800-1500 m) areas of Andes, parts of Philippines, India, Indonesia, Vietnam, Africa.	Caicedonia, CIAT-Palmira, CIAT-Quilichao
5	Cool highland areas; moderate to high rainfall.	17-20	Variable	2000	Andean region (1600-2200 m)	Popayan
6	Sub-tropical areas; cool winters; fluctuating day lengths	Min 0	Variable	Variable (unimodal distribution)	N. Mexico, Cuba, S. Florida, S Brazil, Paraguay, N. Argentina Taiwan, S. China	None



The Cassava Program realizes that, at least in the Latin American context, cassava processing is the key to relieving current marketing constraints of cassava and to entering markets with substantial growth potential. A significant part of the work of the Cassava Program is already devoted to developing technologies to allow for cassava's exploitation of such growth industries as the animal feed and the composite flour markets.

Germplasm Development

Cassava varietal improvement at CIAT considers the diversity of edapho-climatic conditions under which cassava can be grown and for which a broad base of improved germplasm is required. In its varietal development efforts, the Program seeks to exploit the cassava plant's general adaptation to marginal conditions of rainfall and soil fertility. This concern has resulted in a minimal-input approach, whereby emphasis is given to the plant's inherent ability to resist or tolerate stress factors rather than to modify the environment to remove stresses. Varietal development thus requires a precise tailoring of genotypes to differences in the environment.

The cassava-growing regions have been tentatively classified into six edapho-climatic zones (ECZ), each characterized by soil and climatic conditions, which, to a large degree, also determine insect and disease complexes potentially important as production constraints. Colombia —the host country of CIAT—provides regions with characteristics of five of the six zones (excluding ECZ 6) as testing sites for varietal research, which is highly decentralized to take account of the necessity for ecosystem-specific germplasm. The six cassava edapho-climatic zones where most cassava is produced and the representative Colombian research sites are in Table 1. An overview of the germplasm development process is presented in Figure 1.

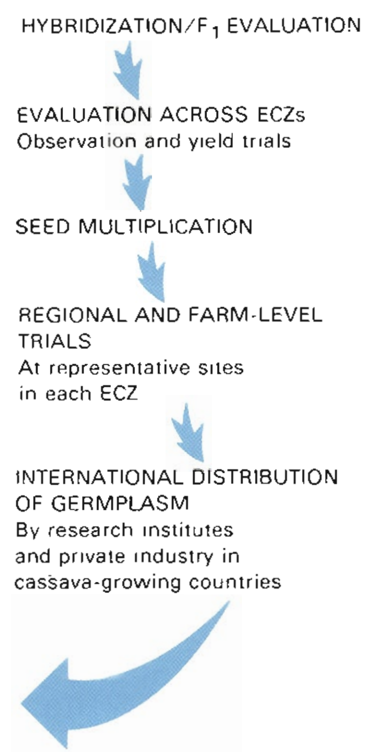


Figure 1. *The cassava germplasm flow begins and continues with the national programs. All germplasm is evaluated within and across the five edapho-climatic zones represented at various CIAT sites in Colombia.*

Germplasm Collection

The CIAT cassava germplasm bank now contains more than 2600 accessions collected from 13 Latin American and two Asian countries. Since 1980, in order to minimize the risk of introducing diseases and pests, all new additions to the cassava germplasm bank have been in the form of meristem tip cultures or true seeds. *In vitro* culture technologies, partially developed by CIAT for cassava, have permitted large-scale introductions of vegetative material from countries from which importation previously was prohibited, most notably Brazil.

Wild species of cassava *(Manihot)* have been introduced, but maintenance and reproduction have been difficult. Nevertheless, *M. glaziovii, M. dichotoma,* and *M. caerulescens*, among other wild species, have been maintained by the Program for several years. Because most wild *Manihot* species are difficult to germinate from true seed, embryo-culture techniques, which have proven successful for *M. esculenta* seed, are now being tested on wild species. Highest priority in any collection of wild species that might result, as well as for cultivated species, would be assigned to those areas of genetic diversity with no systematic collection as yet—i.e., Brazil, Paraguay, and areas of Mexico and Central America.

Germplasm Conservation

Due to a high degree of heterozygosity, cassava clones must be propagated vegetatively if their peculiar gene combinations are to be maintained. At present, this requires continuous field collections with periodic renewal by vegetative propagation. Annual replanting of the entire germplasm bank is required, with all accessions grown in two different fields on the CIAT-Palmira station. Six to ten plants per accession are maintained; this is adequate for both secure maintenance and provision of small amounts of planting materials for evaluation.

Following research in the tissue-culture laboratory at CIAT, conservation of vegetative material in the form of plantlets *in vitro* has become feasible. Techniques for long-term *in vitro* conservation are now well developed. These techniques require that plantlets are transferred to a new medium approximately once every 2 years. The entire germplasm collection is gradually being moved to *in vitro* storage. However, until long-term *in vitro* methods are shown to be completely reliable, or until a duplicate collection in another center is created, field maintenance will be continued.

Since all cassava clones are hetereozygous, sexual seed cannot duplicate the genotype of the parent clone. Nevertheless, seeds can serve as a gene pool that is representative of the parent clones. Seeds from open pollination of germplasm accessions are maintained in cold storage as a genetic reserve that could be called upon in the event of unforeseen losses in the vegetatively maintained collection. Seed is also a convenient means of distributing a wide range of genetic variability to other research programs.

The cassava germplasm bank now contains more than 2600 accessions collected from 13 Latin American and two Asian countries.

Germplasm Bank Evaluation

Evaluation of germplasm accessions for adaptation, resistance to diseases and insects, yield, and root quality is in progress in distinct sites in Colombia that have physical characteristics and pest complexes of five of the major edapho-climatic zones in which cassava is grown. Except for the CIAT-Palmira station, the sites are moderate- to high-stress areas where a broad range of adaptation, resistance, and yield factors can be measured. In all sites, evaluation begins with a single row per accession, which is compared with check varieties interspersed throughout the trial. During the growing season, data are taken on disease and insect attacks, general vigor, branching habit, and other morphological traits. At harvest, root yield and root quality traits are considered. Promising accessions are passed to a preliminary trial with commercial plant spacing, small plots, and no replication. Selected lines then pass to a replicated yield trial with plots of 25 to 30 plants and two to three replications; yield trials are repeated over several years to assess temporal stability. Those accessions showing most promise continue through additional evaluation stages to identify the best adapted and most stable genotypes. Evaluation of the germplasm bank has been nearly completed in two high-priority testing sites, i.e., CIAT-Palmira and Carimagua.

Nearly all accessions in CIAT's cassava germplasm bank are, or have been, cultivated varieties. Although yields are normally stable, they are low and can be increased through genetic improvement and improved cultural practices.

Table 2. **Combination of characters required for cassava germplasm by edapho-climatic zone in Colombia.**

Target area	Principal breeding objectives for each area	Level of expression[a]	Accessions (no.)
North Coast (ECZ 1)	Root yield plant (kg/plant)	≥3.5	1007
	+ Harvest index	≥0.5	432
	+ Root dry matter (%)	≥ 35	313
	+ *Mononychellus* mite damage[b]	≤ 2	57
	+ Thrips damage[b]	≤ 2	42
Carimagua (ECZ 2)	Bacteriosis damage	≤ 3	55
	+ Superelongation damage[b]		21
	+ *Mononychellus* mite damage[b]	≤ 3	6
	+ *Vatiga* damage[b]	≤ 3	4
Popayan (ECZ 5)	*Phoma* damage[b]	≤ 2	17
	+ *Oligonychus* damage	≤ 2	10

a. Data from Palmira. root yield, harvest index, root dry matter, mite and insect ratings. Data from Carimagua bacteriosis and superelongation ratings Data from Popayan: *Phoma* ratings

b. Disease, mite, and insect ratings on a 1 to 5 scale, where, 1 = very low damage; 5 = very high damage.

Results to date indicate that many germplasm accessions—nearly all of which are cultivated varieties—are adapted to the areas where they evolved; in general, however, yield potential of existing accessions is low. Also, the frequency of accessions having high resistance to any given disease or insect pest is generally low, and those having combined high resistance to all disease and insect problems of a region are very low. Table 2 gives examples of frequencies of accessions with combinations of traits required for three different areas. Another general observation is that although cassava as a species is well adapted over a wide range of conditions, the adaptation of any given germplasm accession seems to be limited. A final generalization that can be made, based on data presently available, is that there are many germplasm accessions with desirable characteristics that have not previously been used in the breeding programs; there is still much variability to be exploited in breeding. Hence, the Cassava Program's emphasis is on creating new, improved genotypes through hybridization and selection.

Development of Elite Lines

Germplasm evaluation serves as a means of parental selection. In general, parents are selected based on overall performance in a given edapho-climatic zone, with the intent of pyramiding genes for high levels of resistance to diseases and insects, drought tolerance, and root quality. While, originally, the germplasm bank was the sole source of all parental material, hybrid lines are increasingly being incorporated into the hybridization process. Thus, the parental base is continually improved.

The status of varietal improvement as engaged in by the Cassava Program is assessed in terms of yield potential, yield stability, and root quality in the following sections.

Yields of more than 60 t/ha with higher than 35% dry-matter content are now frequently obtained in experimental plots.

Yield potential. In a high-yielding environment with medium- to high-fertility soils in the medium-altitude tropics (as represented by CIAT-Palmira), a steady upward trend in yields has been registered from 1973 through 1981 (Figure 2). For all entries in replicated yield trials, the average yield has reached approximately 40 t/ha/year, which is some 60% above the average yield of unselected germplasm accessions in the 1973-74 trials. Yields of more than 60 t/ha with higher than 35% dry-matter content are now frequently obtained.

In the hot lowland tropics with a pronounced dry season (as represented by the north coast of Colombia), a similar trend is occurring; today, the average yield of selected F_1 lines is significantly higher than that of local cultivars. Yields of more than 40 t/ha/year with dry-matter contents of more than 30% are readily obtained.

Under difficult environments, the extremely low-fertility soils in tropical savannas, as represented by conditions at the Carimagua research site, yield potential is also on the upward trend. After intensive selection over the years for resistance to cassava bacterial blight (CBB) and general environmental adaptation, the yield level

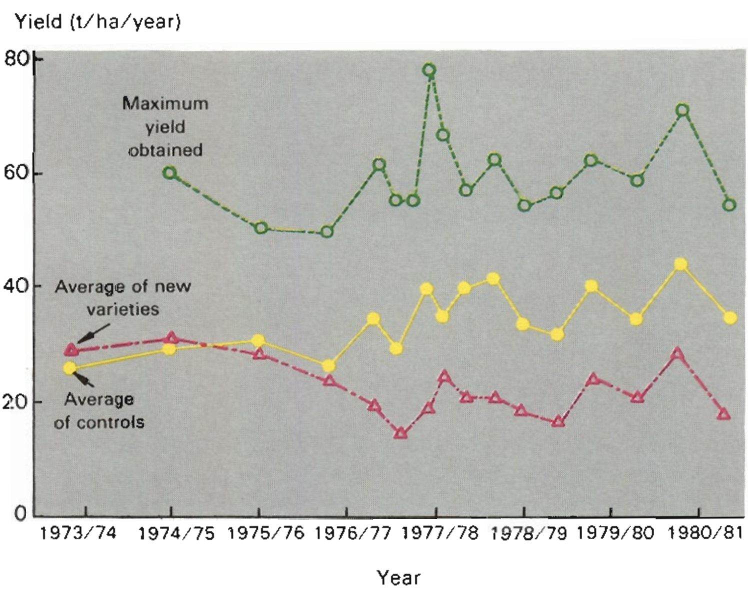


Figure 2. *An upward trend in yield potential in selected cassava accessions was evident in replicated trials in a high-yielding environment (represented by Palmira) from 1973 to 1981.*

of F_1 lines has reached an average of 18 to 20 t/ha/year. The long-term improvement at Carimagua is clearly evident when the average yields of F_1 lines is expressed as a percentage of local cultivars (Figure 3).

Yield stability. Much emphasis is often placed on yield potential. Generally, the more intense the management of an agricultural system, the less variable are the growth conditions so that yields tend to be more stable and closer to their potential. For example, high stable yields can be expected when variations in availability of water, fertility, and disease and pest incidence are minimized by irrigation, fertilizers, and pesticides; however, cassava is normally grown under low-level management and is subject to the uncertainty of natural rainfall patterns, variation in soil fertility, and attack by diseases and pests throughout its long growth cycle. The farmer is interested in obtaining stability over time (temporal stability); he is not generally concerned about stability of yield across regions (spatial stability), although he may be interested in stability across different production systems (system stability). An institute such as CIAT, however, is interested in spatial stability as the technology developed must be applicable over large areas if a reasonable return on investment in research is to be obtained.

A. Temporal stability. Data obtained from regional trials show a high correlation between yield of the same genotypes across years in different sites, suggesting that the same genotypes that are superior in one year will maintain that advantage over time, even though absolute yield levels may fluctuate from year to year.

A major cause of temporal instability is the slow build-up of disease and pest pressures, which can directly decrease yields and also quality of planting material with time; available data in cassava suggest that the best planting stakes come from locally grown genotypes which are well-adapted to prevailing environmental conditions and with good resistance to diseases and

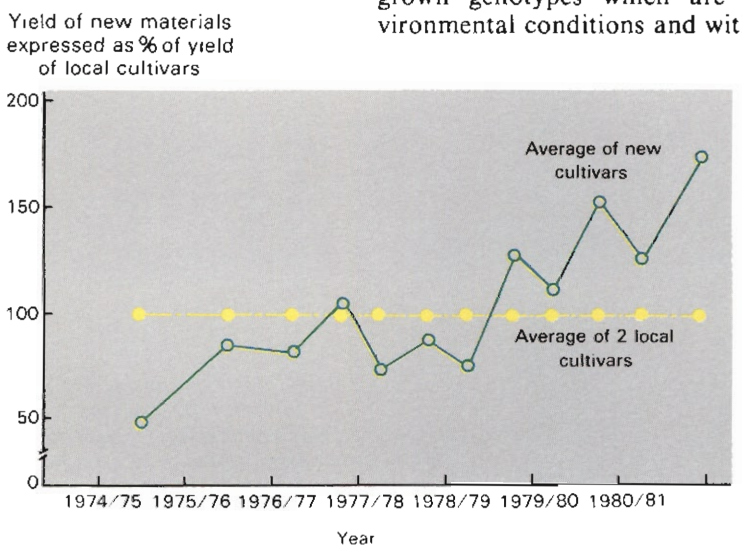


Figure 3. *Long-term improvement in yield potential in selected cassava accessions was evident even in an extremely difficult, low-fertility environment (represented by Carimagua) from 1973 to 1981.*

pests in the local environment. A major cause of temporal instability is the degeneration of planting material caused by a build-up of virus or virus-like agents, and this is being intensely investigated at present. Temporal instability is also caused by the breakdown of genetic disease resistance. The major defense mechanism of cassava for CBB and superelongation disease is slow disease development, which is inherited quantitatively. Although this mechanism does not necessarily imply that the resistance will not eventually break down, such a development is unlikely. There are reasons to believe that it is possible to find similar resistance mechanisms to other important diseases and insects, indicating that a breakdown of genetic resistance as a factor that will reduce stability is not likely to constitute a major problem in cassava.

B. Spatial stability. There is obviously a tremendous genotype-by-environment interaction, and it cannot be expected that the same genotype will perform well in all ecological regions. Available data clearly show that different genotypes are required for colder regions; however, they also indicate that broad adaptability may exist in the warmer, lower-altitude areas as a small number of clones do well in several regions. This view is supported by the stable yields of M Col 1684, M Col 1468, and M Mex 59 over a very wide range of edapho-climatic zones and the remarkably stable yield of CM 507-37 and stable starch content of CM 523-7 in the last cycle of the Regional Trials. While it is true that some broadly adapted clones exist, most clones do not possess this broad adaptability and, up to now, none have performed well in all six edapho-climatic zones.

The intensity and composition of the disease and insect complex associated with cassava is dependent on the climatic and soil conditions of an area with rather specific complexes for each edapho-climatic zone (Table 3). However, within the broad classification of each of these zones, the complexes tend to be similar. Thus in the CIAT program the objective is not to breed for macrospatial stability—that is, spatial stability across different edapho-climatic zones—but rather to breed for microspatial stability—that is, spatial stability within each edapho-climatic zone. Nevertheless, when macrospatial stability is encountered, it is obviously useful (Figure 4).

Microspatial stability—that is yield stability within a major edapho-climatic zone—however, is essential to the sucess of breeding efforts. The generally high correlations between yields of different clones in different sites within ECZ 1 suggest that microspatial stability can readily be obtained.

C. System stability. Major factors in system stability are fertility levels and farm-management practices. While fertility levels can readily be modified by the use of chemical fertilizers, such fertilizers may be expensive and will probably not be used to the extent that all differences in fertility effects on yield and quality are eliminated. Hence, it is desirable to have genotypes and attendant technology that are relatively stable over different fertility levels.

Temporal stability in the high-stress Carimagua environment depends upon high and stable resistance to CBB, anthracnose, and superelongation diseases. Evaluation over several seasons without artificial pest or disease control is an effective means of identifying stable lines.

Table 3. **Negative biotic factors affecting cassava production identified and evaluated in five different edapho-climatic zones in Colombia, during 1981 (third cycle).**

Biotic factor	Rating[a] in:				
	Caribia (ECZ 1)	Media Luna (ECZ 1)	Carimagua (ECZ 2)	Palmira (ECZ 4)	Popayan (ECZ 5)
Diseases					
Bacterial blight	2	1	2	0	0
Superelongation disease	0	1	3	0	0
Concentric-ring leaf spot	0	0	0	0	2
Anthracnose	3	1	3	1	2
Brown leaf spot	3	2	2	2	2
Blight leaf spot	2	1	1	2	0
White leaf spot	3	2	1	0	1
Bacterial stem rot	1	1	1	1	0
Cassava ash	1	1	0	2	2
Mosaics	2	3	0	3	2
Frog skin disease	3	0	0	3	0
Root smallpox	2	1	0	2	0
Root rots	2	1	1	1	0
Choanephora	3	2	3	0	0
Insects					
Cassava hornworm	1	1	1	1	1
Whiteflies	1	2	1	1	1
Thrips	1	1	1	3	1
Lace bugs	1	1	2	1	0
Shoot flies	2	0	1	1	0
Fruit flies	1	0	1	1	0
Chrysomelids	0	0	0	2	0
Gall midges	1	1	2	0	0
Termites	0	1	1	0	0
Stemborers	0	0	2	0	0
Leaf-cutting ants	1	1	2	0	0
Scales	0	0	1	0	2
Mites					
Mononychellus	1	1	1	2	1
Tetranychus	0	0	0	1	0
Olegonychus	2	2	1	3	3

a. Ratings. 0 = not present during this cycle; 1-3 = slight to high damage.

Some 700 accessions from the germplasm bank were evaluated for reaction to low phosphorus in CIAT-Quilichao; 250 of these same accessions, selected for their high levels of resistance to cassava bacterial blight (CBB), anthracnose, and superelongation, were also evaluated in Carimagua for low phosphorus and for acid soil tolerance. A direct comparison between the phosphorus-adaptation scores obtained in Carimagua with those for the same cultivars in Quilichao showed a weak correlation, indicating that tolerance to climatic and biotic factors in the ecosystem is of greater importance than tolerance to low soil phosphorus. Thus, it may be more appropriate to speak of "adaptation" (rather than "tolerance") to low soil phosphorus, as this term more aptly

Physiological deterioration is positively correlated with root dry-matter content. Thus, presently available information suggests that a combination of high root dry-matter content with low root perishability is difficult (if not impossible) to achieve through breeding.

Total HCN content in the roots is negatively correlated with root dry-matter content, physiological deterioration, and microbial root deterioration. Thus, the higher the HCN content of roots, the lower the root dry-matter content and root perishability. This correlation has been observed through various sets of genotypes and planting years. However, individual cases of low correlations have been observed, thus making it possible to select genotypes that deviate from the general correlation. This information allows the Program to visualize genotypes with high root dry matter content, low HCN, good eating quality, but short shelf life as a typical cassava type for the fresh market.

Table 5. **Most promising cassava hybrids combining high yields with good eating quality, by edapho-climatic zone, 1981.**

Genotype	Date of cross (year)	Fresh root yield (t/ha)	Root dry-matter content (%)
Caribia (ECZ 1)			
Newest selections			
CM 586-1	1975	45	36
CM 652-10	1976	40	33
CM 922-2	1977	42	35
CM 976-15	1977	52	33
Local cultivars			
Manteca		17	32
Venezolana		13	36
Carimagua (ECZ 2)			
Newest selections			
CM 621-214	1975	26	32
CM 840-31	1976	19	33
CM 946-2	1977	28	31
CM 13335-4	1977	27	38
Local cultivars			
Llanera		11	31
M Col 638		14	29
Palmira (ECZ 4)			
Newest selections			
CM 883-1	1977	65	37
CM 981-8	1977	54	42
CM 1006-5	1977	64	34
CM 1016-31	1977	59	39
Local cultivars			
Llanera		28	32
M Col 22		36	38

Integration of Production and Market Development for Cassava in Latin America

In Latin America, where cassava has remained outside the process of technology development that has occurred in most other food crops, particularly the cereal grains, a peculiar vicious circle exists. Farmers will not adopt new technology for the crop without access to more stable markets, and industry will not invest in cassava processing without the guarantee of lower farm prices and a steady crop supply. This situation is reflected in the operational hypothesis of CIAT's Cassava Program: that cassava production is limited as much by marketing constraints and restricted demand as by constraints on productivity and farmer profitability. To deal with this situation and to help national organizations break this cycle, the Cassava Program is developing integrated cassava projects that work simultaneously on increasing production, investing in processing capacity, and developing new market channels.

Such integration is an urgent need in several cassava-producing areas, such as the north coast of Colombia, where the traditional cassava markets are as fresh food and for industrial starch. During the last few years, all attempts to obtain any substantial increase in cassava production for the region has led to a market saturation and disastrously low prices for farmers. One of the many alternative uses of cassava is as animal feed, however, and CIAT is helping the small farmer enter the rapidly expanding animal-feed market.

In 1980, a collaborative venture between CIAT and the Colombian Integrated Rural Development Program (DRI) was initiated as the first pilot project to simultaneously introduce improved production and new processing technology to small-scale farmers. The focus is to develop the market for dried cassava chips in the poultry and swine animal-feed industry in Colombia. CIAT scientists work only in an advisory capacity; administration is handled by the existing, national organization, DRI, with funding from CIDA, the Canadian International Development Agency.

Preliminary results to date suggest that, with current prices for cassava at the farmgate and for feedgrains at the mill, the investment in processing plants is economically feasible. This access to the animal feed market will allow small farmers to increase their incomes with the adoption of improved production technology. Once the expansion of the cassava chip market reaches a sufficient momentum, more economy-wide benefits, including reduced food prices, an improved balance of payments, and increased employment opportunities, are expected.

In its first 2 years, the project completed the experimental and demonstration phase. A single chipping and drying plant was established by a 20-member cassava farmer association. An operational scheme for the plant was developed, based on local conditions, and the preliminary economic feasibility of the plant was evaluated. The project is currently moving into a replication and integration phase. On-farm trials of new production technology are being planned, and the best means for integrating the production system with the processing system are being analyzed. Additional plants are now being established with other farmer associations, both in the same zone and in neighboring departments.

At the same time, an overall economic survey of cassava production and markets in the Colombian north coast is being conducted to plan the basis for further expansion and replication of the plants and production technology throughout the region. A primary gain within the project has been the organization of such technology to integrate the many small producers of cassava into an agroindustrial operation. The experience gained also suggests that it might be possible to undertake similar projects in other Latin American countries.

Such regionally-based, integrated projects are considered by CIAT to be the prime means of technology reaching the farm level. These projects will continue in the next several years and are central to overcoming the principal constraints to expanding cassava production in Latin America.

Development of Management Practices

The development of new varieties with improved characteristics will not resolve all the problems associated with increasing productivity. It is necessary to develop management practices appropriate for the new germplasm. These fall in the following basic categories.

Soil and Plant Nutrition

An important objective of the Cassava Program is to identify inexpensive sources of nutrients and to develop efficient ways to apply fertilizers to the improved germplasm specifically selected to perform well at low fertility levels.

Long-term fertility trial. A long-term fertility trial established in CIAT-Quilichao in 1977 completed its third consecutive planting of cassava in 1981. While during the first planting the cassava crop responded mainly to the application of phosphorus, during the two subsequent plantings there was a much greater response to the annual application of potassium, due to the relatively large removal of potassium in each cassava root harvest, this element becomes more limiting with time. As shown in Figure 6, with consecutive plantings of cassava, fertilizer application is required to obtain good yields.

Mycorrhizal association. In the recent past, it has been amply demonstrated thad a mycorrhizal association is essential for normal growth of cassava in soils with low phosphorus availability. In 1981, this association was studied in more detail to determine the factors influencing mycorrhizal infection, to identify inexpensive and effective methods and sources for inoculation, and to examine the effect of mycorrhiza under field conditions.

Trials conducted in 1981 showed that plants inoculated with mycorrhiza absorbed phosphorus more effectively than did noninoculated plants. The low level of observed host specificity and the fact that both the soil and the roots of mycorrhizal plants can be used as inoculum indicate that the choice of an appropriate source of inoculalum depends mainly on convenience. Also, it was found that regardless of length of inoculum storage (i.e., up to 3 weeks) and quantity of inoculum used, all methods of inoculation were effective in increasing production and phosphorus absorption.

While an inoculation response in nonsterilized soils under field conditions has not yet been demonstrated, it is expected that in soils with low or inefficient native populations of mycorrhiza, inoculation with highly efficient mycorrhizal strains will have a significant effect on yield increases and will enable cheap, low-grade sources of phosphorus to be used effectively. Even if

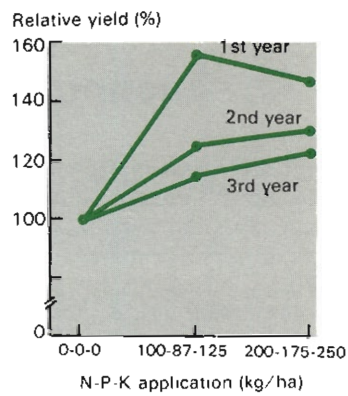


Figure 6. *The residual effect of various levels of fertilizer application shows, for all treatments in Quilichao, a decrease in yield in the second and third years, pointing to the need for fertilizer application with each consecutive planting of cassava.*

inoculation under field conditions should prove to be ineffective or impractical, the mere finding that mycorrhiza play a crucial role in phosphorus absorption in low phosphorus soils is likely to lead to the development of management practices that maximize the beneficial effect of the native mycorrhizal population.

Plant Protection

Control of diseases and pests can be obtained not only by use of host plant resistance but also by management practices. Frog skin disease, for example, is spread from region to region by use of infected cuttings. It was found that clean cuttings can be obtained by thermotherapy of infected plants from which clean meristems can be obtained. These can later be multiplied for distribution to farmers.

For international germplasm exchange, sexual seeds are extensively used and are a relatively safe form of moving germplasm. However, cassava bacterial blight (CBB) can be disseminated via infected seeds. Dry heating of infected seeds (60°C for 14 days) not only tends to break dormancy but also eliminates CBB.

The mealy bug (*Phenacoccus herreni*) causes severe damage and yield losses in parts of Latin America. At present, levels of varietal resistance are not sufficient to adequately contain a severe outbreak of the pest; however, a number of potentially useful natural enemies were identified and will now be evaluated to see if they can be effectively used for control.

Technology Testing

Testing new cassava technology is a continuous process that includes both (1) regional trials in selected sites representing each of the edapho-climatic zones and (2) on-farm evaluations to observe crop performance in the context of realistic resource and marketing constraints on the production level. The results of technology evaluation are continuously fed back into the technology design process.

Regional Trials

The seventh testing cycle for promising CIAT selections under improved, low-input technology was completed in 1981. Included in this cycle were nine trial sites in Colombia. The average dry-root yield of the new materials was 8.6 t/ha per year—which is nearly three times the national average of some 3 t/ha per year (Table 6). The average yield of the best local cultivars was 6.5 t/ha per year. These data reconfirm earlier obtained information that by adopting simple, improved cultural practices a doubling of yields with existing cultivars is possible.




The mealybug species Phenacoccus herreni *is causing severe damage* (right) *to cassava in the Americas. Numerous natural enemies have been identified and are being investigated for their effectiveness in controlling mealybug populations.* Ocyptamus stenogaster (top, far left) *and* Chrysopa *sp.* (bottom, far left) *are successful predators of eggs and larvae;* Kalodiplosis coccidarum (left) *is an efficient predator of the eggs.*

Table 6. **Yield of promising ICA-CIAT cassava varieties and hybrids at nine edapho-climatic locations in Colombia during 1980-1981 regional trials.**

	Dry-root yield (t/ha)									
Category[a]	**Media Luna (ECZ 1)**	**Rio-negro (ECZ 1)**	**Nataima (ECZ 1)**	**Carimagua (ECZ 2)**	**San Martin (ECZ 2)**	**Chigorodo (ECZ 3)**	**Florencia (ECZ 3)**	**Palmira (ECZ 4)**	**Caicedona (ECZ 4)**	**Average yield**[b] **(t/ha)**
Highest yielding hybrid or variety in each site[c]	12.3	13.8	13.2	9.0	9.6	12.9	9.8	14.6	21.3	12.9
Average of hybrids or varieties tested at each site	7.6	8.8	9.7	6.0	6.3	8.0	6.8	10.3	15.4	8.6
Best local variety in each site[d]	5.6	6.3	9.4	2.1	4.6	6.0	6.4	5.2	13.4	6.5

a. Number of varieties tested at each site ranged from 13 to 23. One local variety was tested at each site.

b. Colombian national average dry-root yield is approximately 3 t/ha with traditional technology (equivalent to approximately 11 t/ha fresh root yield).

c. Highest yielders for Media Luna, M Col 1684, for Rionegro, CM 507 37; for Nataima, CM 507 37; for Carimagua, CM 523 7, for San Martín, M Mex 59, for Chigorodo, CMC 40 (M Col 1468); for Florencia, CM 507 37; for Palmira, CM 489 1; for Caicedonia, ICA HMC 1.

d. Best local varieties. for Media Luna, Secundina, for Rionegro, Venezolana; for Nataima, Venezolana; for Carimagua, Llanera, for San Martín, Tempranera, for Chigorodo, Patepaba; for Florencia, Caqueteña; for Palmira, M Col 113; for Caicedonia, Chiroza-Gallinaza.

The average yield of selected lines evaluated in all sites was 9.3 t/ha per year. This finding suggests that yield improvement of more than 200% may be expected by adopting improved management practices and an improved CIAT selection.

As is shown in Table 6, the average yield of CIAT selections was higher than the yield of the respective best local cultivars in all trial sites. Since these trial sites represent edapho-climatic zones 1 (Media Luna, Rionegro, Nataima), 2 (Carimagua), 3 (Florencia), and 4 (CIAT-Palmira, Caicedonia), it is clear that current CIAT technology—which includes selected hybrid lines and proven older selections—covers a very wide range of geographic areas at altitudes up to 1300 masl. (Presently available CIAT-bred genotypes are not as useful in the highland tropics and the rain forest areas; however, efforts are underway to develop improved materials for them.).

The average yield of the best-performing CIAT selection in each location is 12.9 t/ha per year; this is approximately four times the national average and suggests that by further selecting among CIAT lines in each location, up to 400% of national average yields can be obtained in a broad range of environmental conditions without the use of irrigation, heavy fertilizer application, and dependence on chemical control of diseases and insect pests (Figure 7).

During the 7 years of regional trials in sites below 1300 masl, the average yield of local cultivars in all locations stayed about constant while the average yield of all CIAT genotypes increased slightly but steadily, and the best CIAT genotype (i.e., average of the best-performing CIAT genotypes in each location) increased

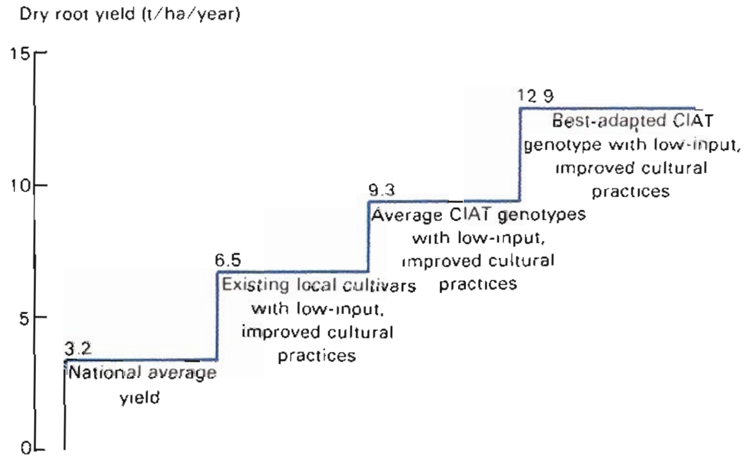
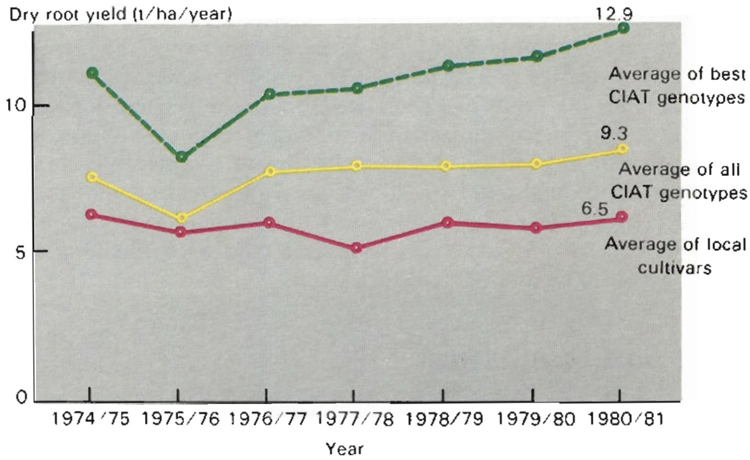


Figure 7. *Stepwise improvement from traditional varieties to the best-adapted CIAT genotype provides up to a 400% increase in cassava yield. (Calculated from regional trials 1980/81, in nine locations, see Table 6.).*



significantly (Figure 8). This reflects the cumulative advances achieved by the overall selection strategy of the Cassava Program. The germplasm accessions and hybrid lines that have been identified as promising in the various evaluation sites are being sent to interested national programs in the form of tissue culture. Also, these genotypes are frequently used in the hybridization programs, both at CIAT and elsewhere.

Figure 8. *In 7 years of regional trials at nine experimental locations in Colombia (see Table 6), the average yields of the best CIAT genotype increased steadily while the average of local cultivars remained constant.*

Perhaps the most successful way of obtaining clones for each particular region is for national programs to select their own hybrids. This process is in progress in several countries. In Thailand hybrid seeds from crosses made at CIAT by Thailand scientists in cooperation with the CIAT program have given excellent results when selected under Thailand conditions. Regional trials in Thailand, for instance, show the superiority of Huay Pong 5, a CIAT hybrid (CM 305-13T), selected at the Huay Pong experiment station. The control line Rayong 1 is grown on more than 1 million ha (Figure 9).

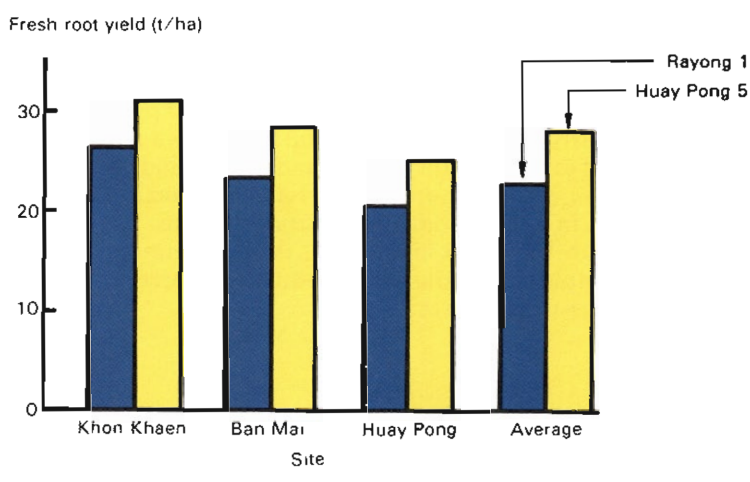


Figure 9. *A hybrid CIAT cassava line, **Huay** Pong 5, developed in Thailand, outyielded the best local cultivar at all sites. (Source: C. Tiraporn).*

Research results are normally very different from those that can be obtained by small farmers. A comparison between the regional trials and on-farm evaluation trials shows that in cassava, with the simple technology that has been developed, there need not be an important gap between scientist-managed regional trials and farmer-managed plots, even when the farmer is considered to use rather poor management practices. The high fresh weight yields obtained by farmers in this extremely poor soil and very dry area clearly demonstrate cassava's potential role as a basic calorie source from marginal agricultural areas.

On-Farm Evaluation

A principal objective of the Program's farm-level trials is to understand the determinants of the productivity of traditional cassava cropping systems. A dominant hypothesis is that yields do not vary on the basis of differing levels of inputs, but, rather, on the basis of various management factors (such as soil fertility management, erosion control, stake management, time of harvest), most of which do not require purchased inputs but are influenced by such farming-system factors as labor and land constraints and such market-system factors as seasonal output prices, access to markets, and prevalent wage rates.

In 1981, the farm-level trials conducted in the north coast of Colombia and in Mondomo (a region some 80 kilometers south of Cali) focused on the interaction between productivity and planting/harvesting time. Results showed that cassava yields vary markedly with time of planting and particularly with time of harvesting. In general, cassava was observed to be harvested earlier than what may be considered optimum due to prevalent farming- and marketing-system constraints. To the extent that alternative markets and small-scale processing units are developed, there will be scope for substantial efficiency gains through better linkages between cassava production and processing systems.

The farm-level trials were also successful in shedding light on the issue of market segregation through varieties with differential yield and quality characteristics. In general, varieties suitable for the fresh market should have a dry-matter content of at least 33%, and their cyanide content should be less than 200 ppm. The on-farm trials clearly demonstrated that soil fertility is a most critical determinant of cassava quality. These and similar findings provide an explanation why high-quality cassava production is often concentrated in high-productivity zones. Thus, if cassava production for the fresh market is to be maintained while expanding output for industrial production, three alternative strategies suggest themselves:

The farm-level trials seek to understand the determinants of productivity of traditional cassava cropping systems. The end strategy may well be specialized production for the fresh market in prime-land areas and for the industrial market in marginal areas.

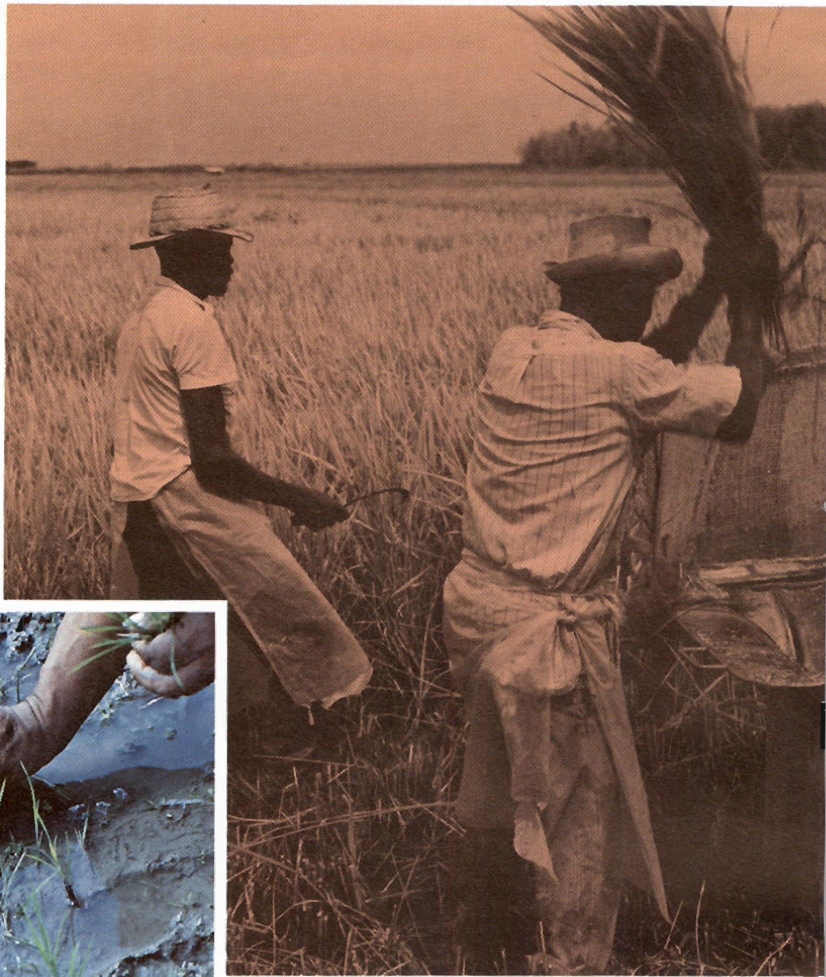
- Development of dual-purpose varieties with the requisite quality characteristics when produced under marginal conditions;
- Improved technology for local varieties produced under marginal conditions, and concentration of breeding efforts on higher yields for the industrial market;
- Specialization of production for the fresh market in prime-land areas and for the industrial market in marginal areas.

The strategy selected will depend on conditions in particular countries; but the still-preliminary results from the farm-level trials conducted in 1981 suggest that strategy (2) or (3) will be most logical in the short run. It is important to note that selection for industrial markets and for the fresh or processed food markets are not mutually exclusive. The quality restrictions for food are more rigorous than those for industry, and, hence, lines from the same breeding program may be selected for industrial use but rejected for food use.

An Epilogue

New technology must reach the farmer level, and more attention must be paid to improve particular production practices.

While cassava's high carbohydrate production potential per unit of land or labor, and its adaptation to more marginal agricultural conditions make the crop a basic rural staple, the high perishability after harvest and its high bulk-to-value ratio reduce cassava advantages over grains with their relatively low marketing costs. Thus, in Latin American economies, where the rate of urbanization is very high, the future demand for fresh cassava is uncertain. Processing will be the key to relieving the marketing constraints and to entering markets with a substantial growth potential. However, for cassava to become competitive in the principal growth markets—especially the animal-feed market and the composite-flour market—will require substantially lower farm-level prices. Given the generally low yields in Latin America, improved production technologies will be necessary to reduce costs sufficiently to profitably supply these markets. Cassava's exploitation of these new markets will allow tropical Latin American countries to reduce the very large imports of feedgrains (and possibly wheat) at minimal cost to the economy in that cassava expansion will utilize unexploited land and absorb part of the pool of unemployed laborers. However, any possible expansion of the cassava area and increase in productivity for industrial purposes (mainly animal feed) will not be feasible if (1) new, improved technology does not reach the farmer level and if (2) drying, processing, utilization, and commercialization does not receive increased attention all over the cassava world, particularly in Latin America.



Rice Program

Page

THE CIAT Rice Program—physically the smallest of the four commodity research efforts—assumes regional responsibility for the Western Hemisphere. The Program collaborates closely with the global rice research effort of the International Rice Research Institute (IRRI), headquartered in the Philippines. From the very beginning of CIAT, excellent collaboration between the CIAT Rice Program and the Colombian Institute of Agriculture (ICA) has enabled rapid progress in adapting the new high-yielding rice varieties to the agronomic and consumer preference conditions in Latin America. These cooperative efforts have resulted in some 35 dwarf varieties released by national programs in the region. The improved new varieties are now annually grown on about 1.5 million ha in both irrigated and highly and moderately favored upland systems. In conjunction with improved cultural practices, use of the new varieties has made it possible to obtain an average of 1 to 2 tons more rice per ha and has provided the means for nearly all Latin American countries to reach self-sufficiency in rice supply.

Use of the new rice varieties for irrigated conditions has resulted in an average of 1 to 2 tons more rice per ha and has provided the means for nearly all Latin American countries to reach self-sufficiency in rice supply.

One objective of the Rice Program is to develop germplasm-based technology designed to overcome the principal constraints to increased production of irrigated rice. Recently, another component was added: the development of new germplasm-based technology for the region's more favored upland rice ecosystems. The principal research strategy to reach this objective is varietal improvement to produce rice lines with higher yield potential, better tolerance to adverse environmental factors, and improved resistance to diseases. Great importance is given to strengthening of national rice research programs through training, consultative visits, and support within the active rice network, which has been growing in the last 15 years.

Improved rice lines are passed to collaborating national programs through international nurseries of promising materials. Countries evaluate and select from these nurseries the most promising materials for direct seed multiplication and distribution to rice producers or for use as parental materials in their own national breeding programs (Figure 1).

SUMMARY OF ACHIEVEMENTS

The CIAT Rice Program continued to support the efforts of national rice programs by making available to them a multitude of promising genetic materials, which meet the particular agronomic needs and consumer preferences of the countries involved. These materials are pre-selected by CIAT from throughout the rice-growing world as well as from the CIAT rice-improvement program. In consultation with CIAT's collaborators at the national level, the nursery system by which national programs receive new materials was further streamlined to assure that new promising materials are tailormade to the needs of given countries.

Much of the rice-improvement work continued to be directed at finding more durable resistance to rice blast disease, the major rice-production problem throughout the region. Initially, the Rice Program set its attention on one particularly promising new, highly tolerant line: 5738. This line has already been launched as a new variety by several collaborating countries.

The year 1981 saw the initiation of a modest rice-improvement effort in support of upland culture. Given that close to half the rice produced in Latin America is grown under upland conditions and yields in this sector have remained stagnant, even modest advances are likely to have an important impact on the rice-production scene in Latin America. At this time, the biological constraints to upland rice production have been charted, the research priorities have been set, and promising parental materials have been identified.

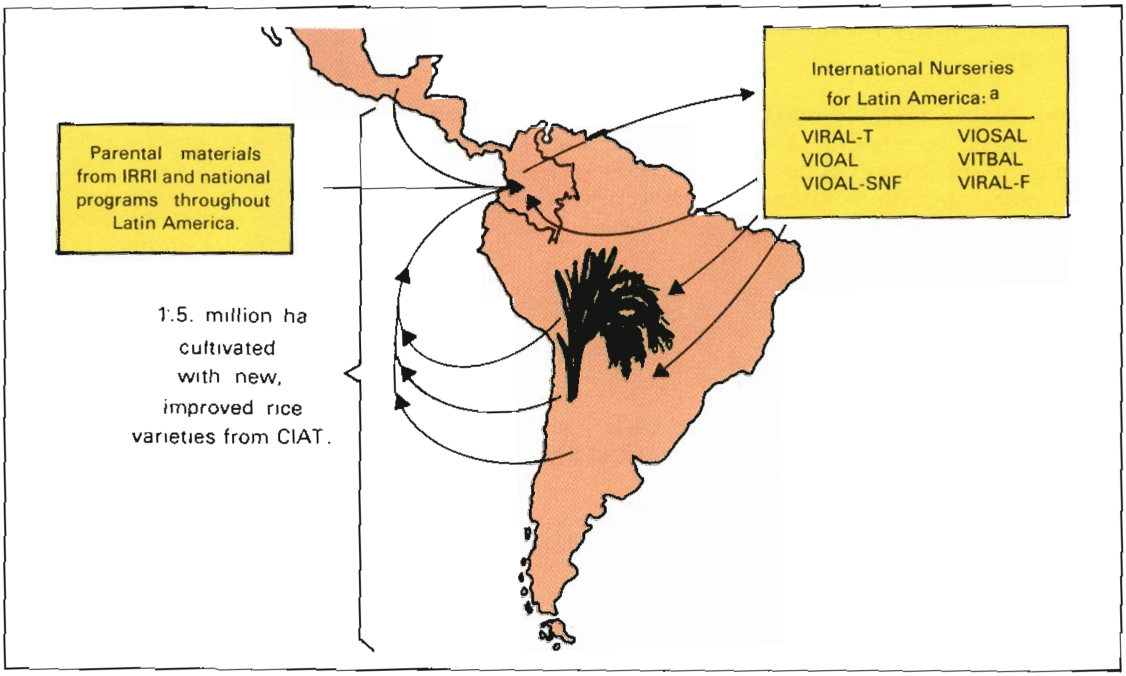


Figure 1. *CIAT's Rice Program receives germplasm from Latin American countries and from Asian countries (the latter through IRRI) and evaluates and breeds materials for use in the Latin American international nurseries. Countries select seed from these nurseries, multiply, breed, and distribute within their own boundaries. Today, 1.5 million ha of land are cultivated with new, improved varieties from CIAT.*

a. VIRAL-T: Medium-duration varieties
VIOAL: Early, medium, and late-maturity varieties (irrigated or favored upland)
VIOAL-SNF: Unfavored upland varieties
VIOSAL: Adapted to salinity and alkalinity } germplasm from IRRI
VITBAL. Adapted to low temperatures } germplasm from IRRI
VIRAL-F: Adapted to semi-deep water } germplasm from IRRI

Rice Improvement

Irrigated Rice

In 1981, breeding efforts for irrigated rice continued to center on achieving yield and production stability through the development of improved varieties that combine good grain quality and resistance or tolerance to the major common biological constraints. The rice blast disease caused by *Pyricularia oryzae*, the "hoja blanca" virus disease, and the planthopper *Sogatodes oryzicola* are the principal problems in Latin American countries. Other damaging diseases are leaf scald caused by *Rhynchosporium oryzae* and sheath blight caused by *Thanetephorus cucumeris*.

Following is a status report on rice-improvement projects in progress. Aspects related to breeding for disease resistance reflect the interdisciplinary work of the Program's efforts in breeding and pathology.

The Rice Program is developing germplasm-based technology designed to overcome the principal constraints to increased production of irrigated rice.

Rice blast. Durable resistance to rice blast disease has continued to be elusive. Diverse genetic strategies such as pyramiding of major genes, concentration of slow-blasting components, and combination of vertical genes with slow-blasting characters are used to exploit the possibilities of obtaining durable resistance.

Table 1. **Promising sources of rice blast resistance entered from various countries into the CIAT germplasm bank in 1981 for further testing.**

Cultivar	Country of origin	Affected by: Leaf blast (%)[a]	Affected by: Panicle blast[b]
Ram Tulasi	India	0	0
W.R.C. No. 4		2	0
Sornavari	India	0.4	0
NP-97	India	1.6	0.3
El Golper	U.S.A.	0	0.1
Huan-Sen-Goo	China	0	0.2
DL 12	Bangladesh	0	0.3
Thava Lakkanan	India	0	8.2
Ram Tulasi (Sel)	India	0	9.5
Intan	Indonesia	0.1	15.4

a. Leaf area affected evaluated 60 days after planting.
b. Panicle blast severity: 0 = no disease; 100 = maximum disease.

To broaden and diversify sources of resistance to rice blast disease, the Rice Program continually searches for new potential donors of blast resistance. In 1981, the materials listed in Table 1 were identified as promising sources pending further tests to confirm their resistance.

A. Pyramiding of major genes. As highlighted in earlier reports, after extensive testing of 12 promising pyramided lines, four of these lines (5738, 5685, 5709, and 5715) were selected for further evaluation. By the end of 1981, various countries—including Colombia—were recommending release of one of these lines, 5738, as a new variety. This particular line has markedly better resistance to blast, better grain quality, and earlier maturity than CICA 8—the latter a most successful commercial standard released in 1978 by the CIAT/ICA collaborative rice research effort.

An additional 16 new, advanced pyramided lines were evaluated in replicated yield trials at two different sites at CIAT-Palmira and at the ICA La Libertad station in Meta (Colombia) where environmental conditions favor screening against the rice blast disease. Seven of these new lines yielded equally well as CICA 8. These seven advanced lines are now being purified for further testing in regional trials.

Some 73 advanced breeding lines resulted from a breeding project that sought to combine two sources with resistance to blast (i.e., Line 4440 and CICA 7) and were evaluated in 1981 in yield trials at CIAT-Palmira. Based on yield potential, grain type and

Table 2. **Yield and grain quality performances of eight advanced rice breeding lines selected for regional trials in Colombia and IRTP network trials in Latin America. All the lines are resistant to lodging, rice blast, and *Sogatodes*.**

Line no.	Parents[a]	Yield (t/ha)	Grain quality: White belly occurrence[b]	Milling performance (%): Whole grain	Milling performance (%): Total
11377	4440 // Bg 90-2 / CICA 7	8.5	0.2	60	67
11373	4440 // Bg 90-2 / CICA 7	8.4	0.4	55	64
11292	4440 // Bg 90-2 / CICA 7	8.3	0.8	54	70
11589	4440 // Bg 90-2 / Tetep	8.2	0.6	54	65
11295	4440 // Bg 90-2 / CICA 7	8.0	0.8	59	69
11587	4440 // Bg 90-2 / Tetep	8.0	1.0	54	67
11219	CICA 4 // Bg 90-2 / Tetep	8.0	0.8	54	70
7677	4440 // Bg 90-2 / CICA 7	7.9	1.2	60	70
CICA 8 (Control)		8.2	1.0	53	64
Metica 1 (Control)		7.0	0.8	56	64

a Cross of Bg 90-2 with second parent; then F_1 generation crossed twice with 4440 or CICA 4.

b As measured on a scale of 0 (= grain without chalky kernel) to 5 (= grain with kernel completely chalky) evaluated at ICA-La Libertad, Meta, Colombia, where climatic conditions favor White Belly incidence quality, and resistance to lodging, blast, and the *Sogatodes* plant hopper, 20 lines were selected to be issued for regional trials as well as in the network of the International Rice Testing Program (IRTP) for Latin America. The seven top yielders of these 20 lines all surpassed 8 t/ha at CIAT (Table 2).

B. Combination of slow-blasting characters. Slow-blasting characters include such attributes as relatively long latent periods from inoculation to infection and from infection to sporulation, fewer and smaller lesions, and reduced sporulation—all of which are considered to constitute rate-reducing, or horizontal, resistance to rice blast disease. Progenies resulting from an on-going breeding project in which slow-blasting components are transferred to adapted, susceptible varieties now have reached the F_4 and F_5 generations; the evaluation continues.

C. Combination of major genes with slow-blasting components. The combination of vertical resistance (i.e., major genes) with slow-blasting components (i.e., minor genes) is believed to provide increased stability of the resistance mechanism to blast. A breeding project that uses the Surinam variety Camponi as a source for slow-blasting characteristics and a natural mutant of line K8 from Sri Lanka as a source of vertical resistance is now in the F_5 generation. Most of the more than 900 selections were characterized by good plant type, long grain, and stiff straw.

One of the breeding strategies in the fight against rice blast disease (inset, left) *is the pyramiding of major genes to include disease resistance. One of these lines, CIAT 5738, has already been released as a new variety in various countries.*

D. Backcrossing for concentration of slow-blasting components. Breakdowns of varietal resistance to rice blast disease often have been attributed to the failure of varieties to capture the entire complement of genetic factors for resistance from their respective parental sources. Many of the sources for slow-blasting characters are from tall, upland types. While backcrossing to tall donors is an adequate safeguard against genetic dilution, it runs the risk of leading to an unproductive plant type. Efforts to transfer an adequate load of the genetic complement of the tall donor sources through single backcrosses are underway. A project that involves four donor varieties as recurrent parents was complemented by another that involves two different resistance sources (i.e., single crosses between a dwarf and a tall donor top-crossed to a second, different donor). In 1981, 24 backcrosses involving three Surinam varieties and one Brazilian variety as recurrent parents were planted and harvested to be advanced to the B_1F_1 generation. And F_1 populations from 21 crosses top-crossed to a second parental source were planted and harvested to be advanced to the F_2 generation.

Breeding for early-maturing rice resulted in 20 lines advanced to regional trials in Brazil, Colombia, Panama, and Venezuela.

Earliness. Several important rice-producing zones in Brazil, Colombia, Panama, and Venezuela need early-maturing rice varieties (105-115 days) to reduce irrigation costs, facilitate multiple cropping, and evade the negative effects of spells of cold weather. From a total of some 60 advanced breeding lines derived from a breeding project for earliness, over 20 lines were selected in 1981 to be advanced to regional trials. The selected lines are characterized by excellent grain quality and plant type and by resistance to blast, "hoja blanca," and *Sogatodes*. Further testing of these lines should identify substitutes for IR 22, although it remains popular because it has excellent grain quality, is susceptible to "hoja blanca" virus, is moderately susceptible to the *Sogatodes* planthopper, and lacks early vigor, a trait essential for competition against weeds.

Mutation breeding. Most of the donor parents of broad-spectrum (i.e., horizontal) resistance to rice blast disease are of a tall, undesirable plant type with poor straw strength, thus rendering them unsuitable as recurrent parents for backcrossing. Dwarfing such tall donors through irradiation should eliminate their limitations as recurrent parents. Through a collaborative mutation breeding project with the International Atomic Energy Commission in Vienna, 83 dwarfs were selected from the lines Tetep, Tadukan, Moroberekan, OS-6, IAC-25, and Tapuripa. Their stature varies from typical dwarf to intermediate type. The selected dwarfs, together with their parents, are undergoing evaluation for blast resistance. During 1981, an additional 112 dwarf mutants from MI-48, Colombia 1, PI-184675, Carreon, Bahagia, and a deep-water rice variety, were selected and evaluated.

Upland Rice

More than 70% of the total land area devoted to rice production in Latin America is sown to upland rice. While some four-fifths of the total upland area in Latin America is in Brazil, important upland rice-growing areas also occur in Mexico, Central America, Bolivia, Colombia, Ecuador, and Venezuela. Average yields of upland rice, at 1.4 t/ha, are very low.

Recognizing the importance of upland rice in the region and the potential contribution of concerted research on upland rice culture, CIAT expanded its rice-improvement program to include this sector. An upland rice breeder was added to the Rice Program in early 1981, and other disciplines will be added as financing permits.

Upland rice-production systems. Upland rice in Latin America represents a broad continuum of ecosystems, ranging from very low to moderately high levels of productivity. Although these ecosystems are difficult to separate, CIAT has decided to use the following working definitions of upland production systems to delineate different yield constraints, potential productivity, breeding objectives, priorities and economic profitability:

- subsistence;
- moderately to highly favored, mechanized; and
- unfavored, mechanized.

A. Subsistence upland rice. This production system is located in remote areas and at the agricultural frontier. No mechanization and no purchased inputs are utilized. Major constraints are total dependence on family labor which limits farm size, necessitates wide plant spacing, demands the use of native varieties, and prohibits use of purchased inputs. CIAT does not stress research for this production system at this time because it is estimated that research on this system could only result in a minor contribution to rice production.

B. Moderately to highly favored upland rice. Highly favored upland rice is confined to relatively flat areas with good rainfall distribution of over 2000 mm during a 6- to 8-month period. Soils are normally alluvial, slightly to moderately acid, and well drained. Major yield constraints are grassy weeds, blast, leaf scald, and lodging for some varieties. Modern dwarf varieties are doing well in this production system.

Moderately favored upland rice is found in Central America and large areas in sub-Amazonia Brazil; it has a shorter wet season, less rainfall, and short dry period during the rainy season. In some areas, soils are somewhat less fertile than in highly favored upland rice areas. Dwarf varieties are suitable for the areas in Central America; in Brazil where drought stress and mineral deficiencies are more severe, the use of tall varieties is predominant. Blast, leaf scald, mineral deficiencies, and grassy weeds are major constraints to rice production in this production system.

Favored upland rice is grown on fertile, alluvial, and deep soils in Central America. Rice varieties with roots that can penetrate to lower soil depths are desired because they take advantage of available soil moisture and readily withstand dry spells.

Increased production in the small-farmer sector in upland rice will provide a large increase in total rice production in Latin America.

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

The CIAT breeding objectives for highly favored upland conditions are somewhat similar to those for irrigated conditions, viz.: to obtain high yield potential in plants with intermediate plant height, good early vigor, and intermediate tillering ability, tolerance to major insect pests and diseases, long and heavy grains, intermediate amylose content, good eating and milling quality, and 115- to 125-day maturity.

A moderately favored upland rice-production system that is of immediate interest to CIAT is the one found in the high-rainfall, acid savannas of Colombia and Venezuela. The primary breeding objectives for this system are to achieve a moderate yield potential of 2 to 3 t/ha; stable yields (with particular attention to tolerance to blast, aluminum toxicity, phosphorus deficiency, leaf scald, and *Sogatodes*); intermediate plant height, tillering ability, and deep root systems; and good eating and milling quality.

C. Unfavored mechanized upland rice. This production system, which is found in the Cerrados (central Brazil), is characterized by infertile soils, irregular and low rainfall, low planting densities, and low average yields (about 1 t/ha). Drought stress and blast disease are aggravated by problems associated with highly acid soils characterized by aluminum toxicity and/or phosphorus and zinc deficiencies. CIAT has no immediate plans to engage in research on this production system.

Latin American Rice Production

Rice is a staple food throughout Latin America and the Caribbean. In the 1979-80 growing season, the area produced some 15 million tons, which corresponds to approximately 30 kg of polished rice per capita. Net regional imports remain insignificant.

The giant of the region's rice-producing countries is Brazil, which accounts for 57% of total production. Four countries of the Andean region—Colombia, Ecuador, Peru, and Venezuela—contribute 22% to the total regional production. Thus, these five countries account for four-fifths of the total regional rice production.

The area planted to rice covers 7.6 million ha, with 5.5 million devoted to upland rice and 2.1 million grown under irrigated conditions. However, since the average productivity of upland rice does not exceed 1.4 t/ha, the contribution of the upland rice sector to total rice production is only 52%. Yields in the irrigated sector vary from 2.1 t/ha to 5.4 t/ha, with an average of 3.5 t/ha.

Improved, high-yielding varieties are grown on approximately 80% of the irrigated rice land area, and have been the principal factor in raising the productivity of the irrigated rice sector in the region. The upland rice sector—where high-yielding varieties are but marginally suitable—is still largely cultivated with traditional varieties.

For the region as whole, per capita consumption of rice has been relatively stable over the last 15 years, although increases were registered in Bolivia, Colombia, the Dominican Republic, Guatemala, Haiti, Paraguay, and Uruguay. In recent years, population and income growth in the area has generated an increase of 3.5% for rice demand each year. To keep pace with demand, the area planted to rice has been increasing at the rate of approximately 2.4%; together with increased productivity, this has assured an annual production growth rate of 3.3%. However, the relative contributions to increased rice production from increases both in land area and productivity have been highly variable and country-specific.

Using conservative parameters, it is estimated that by the year 2000 the demand for rice in the region will reach 30 million tons per year. Based on an analysis of current production trends and their implications for the future, as well as an assessment of the contribution of further technological development during the remainder of this century, and assuming that new production technology and government policies in support of favored upland rice will bring about a significant shift in the relative importance of this type of upland rice, the CIAT Rice Program has concluded that the region can stay relatively self-sufficient in rice production throughout the period under consideration (*see* table).

Current (1979—80) and projected (year 2000) indicators of rice production in Latin America and the Caribbean.

	Area (million ha)		Yields (t/ha)		Production (million ton)	
Production system	1980	2000	1980	2000	1980	2000
Irrigated	2.1	2.3	3.5	5.0	7.3	11.5
Rainfed	0.6	0.6	2.6	3.0	1.6	1.8
Upland						
Favored	1.3	2.6	2.1	3.0	2.7	7.8
Unfavored	3.6	5.8	1.0	1.0	3.6	5.8
Total	7.6	10.0	2.0	2.1	15.2	26.9

Evaluation of segregating materials. Over the last few years, the ICA/CIAT cooperative rice-breeding program has made a large number of crosses involving upland varieties for the development of materials that will be suited to upland and irrigated cultures. Some of the upland varieties used were IRAT 8, IRAT 13, Line 63-83, Moroberekan, OS-6, Azucena, IAC 23, and IAC 25. Progenies of these crosses were evaluated in Meta under upland conditions and high disease pressure (i.e., neck blast, leaf scald, and *Helminthosporium*). In 1981, 42 F_4 populations were evaluated, and over 700 single plant selections were made from 27 of these populations. These plant selections are to be planted in 1982 in three-row plots and evaluated for grain quality, resistance to *Sogatodes* and blast, and plant characters. In addition, a large number of early-generation populations were planted and mass-selected for advancement to higher generations.

At the same time, some 150 advanced breeding lines from the breeding project for irrigated rice were evaluated in replicated trials under favored upland conditions. Based on disease incidence, grain quality, plant type, and vigor, 32 lines were identified as being promising.

Development of Improved Management Practices

Preliminary indications are that significantly less sulfur-coated urea than other forms of nitrogen fertilizers is needed to achieve the same yields.

Sources of nitrogen and forms of application. In most soils used for rice production in Latin America, there is a marked response in rice yields to the application of nitrogen fertilizers. But the high cost of such fertilizers calls for identification of more efficient sources and application methods. Results from experiments conducted in 1981 with different forms of urea (i.e., prilled, forestry grade, supergranular, sulfur-coated) and ammonium sulfate show distinct advantages of the sulfur-coated form of urea in irrigated rice-production systems when the complete dosage of nitrogen is applied at planting. When one-third of the nitrogen fertilization was applied at planting and two-thirds when panicle growth was initiated, all sources of nitrogen proved equally effective. However, there are preliminary indications that with this application method, significantly less urea of the sulfur-coated type is needed to achieve the same yields as with other forms of nitrogen fertilizers.

Nutritional requirements and response to nitrogen application. A series of experiments was conducted to establish nutritional requirements and response to nitrogen application of four varieties (CICA 4, CICA 8, Metica 1, and Metica 2) and of four promising lines (5738, 5685, 5715, and 5709). The order of requirement for the major and minor elements of the materials tested was silicon, nitrogen, potassium, calcium, phosphorus, magnesium and sulfur, iron, manganese, zinc, boron, and copper.

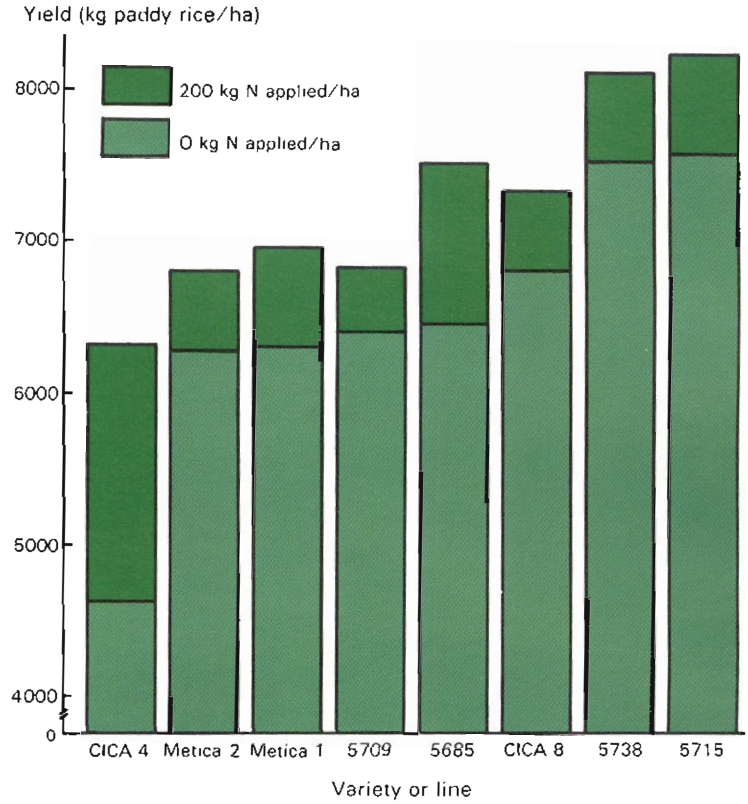


Figure 2. *Several CIAT rice lines showed relatively high yields without nitrogen fertilizer; others showed variable response rates to applied nitrogen. The Rice Program is searching for varieties to combine high yields without N applications and acceptable response to applied N.*

A comparison of yields with and without the application of 200 kg/ha of nitrogen (Figure 2) showed relatively high yields without any application of nitrogen fertilizers. Variable response rates for each additional kg/ha of nitrogen applied ranged from 2.13 kg of rice (Line 5709) to 8.44 (CICA 4).

Upland rice in soils with high levels of aluminum. Two traditional varieties adapted to upland acid soils (Monolaya, a tall Colombian variety, and IAC 25, a tall Brazilian variety) were compared with two modern rice varieties adapted to irrigated acid soils (CICA 8 and Metica 1). Monolaya and IAC 25 were shown to be vastly superior in terms of root development and drought tolerance when grown under acid-soil upland conditions (Figure 3); thus, they were identified as promising candidates for a crossing program directed toward a production system in acid soils with high levels of aluminum, low levels of phosphorus and calcium, and minimum-tillage management conditions.

Varieties and planting methods in saline soils. Certain soils in rice-growing areas have high contents of sodium and calcium salts, making them inadequate for agricultural use. With rice, however, crops may be economically produced when these salts are being leached. An experiment was conducted with the objetive of comparing yields of six rice varieties when grown in sodium-saline soils. In addition, we considered the best planting method, compared direct planting with pregerminated seed, and determined three ages for transplanting. The date for transplanting was chosen to avoid high saline content in the soils during the plant's first stages of development, when it is most susceptible. Before transplanting, the plantlets were kept in a normal soil seed bed.

It was determined that transplanting rice in its later-development growth stage is an adequate method for using saline soils for rice production while these soils are being desalinated. It was also found that some varieties are more tolerant to salinity than others. All varieties tested (except Pokkali) yielded best when transplanted at 45 days **(Figure 4).**

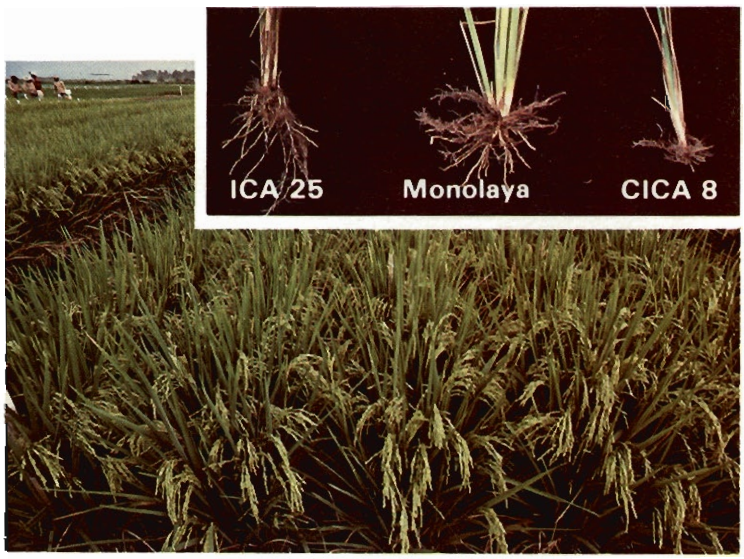


Figure 3. *Varieties adapted to acid, upland rice soils (Monolaya and IAC 25) were superior to varieties adapted to irrigated soils (CICA 8 and Metica 1) in terms of root development. These varieties were recommended for crossbreeding for use in upland soils.*

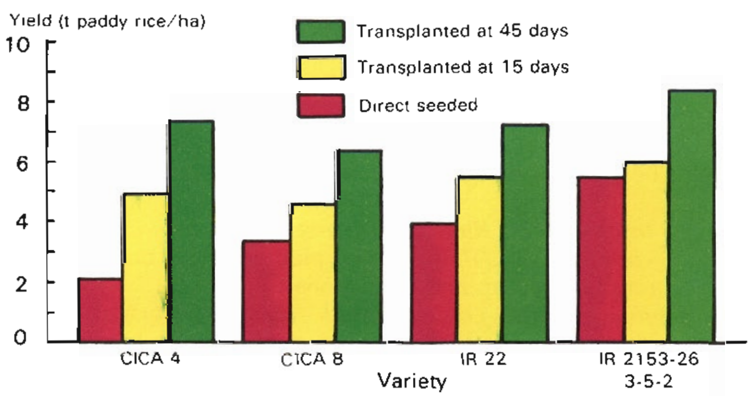


Figure 4. *Transplanting rice at 45 days of age gave higher yields on saline soils than earlier transplanting or direct seeding.*

International Rice-Testing Program for Latin America

This program forms part of the worldwide International Rice Testing Program (IRTP) coordinated by IRRI. In 1980, CIAT received a total of some 1600 entries from IRRI for evaluation, selection, and distribution. These nurseries were rated at CIAT-Palmira in early 1981 for *Sogatodes* resistance, grain quality, plant type, and lodging. A total of 358 promising entries were selected for inclusion in the 1981 IRTP nurseries for Latin America. Added to these selections were 264 promising lines from previously distributed nurseries and 67 entries from the CIAT/ICA breeding program.

These promising materials were assembled in 14 nurseries (8 yield nurseries and 6 observational nurseries), and 297 sets of these nurseries were distributed to cooperators in 24 countries in Latin America and the Caribbean.

Collaborators at the national level value the IRTP nurseries as a means to obtain new, promising lines that have been pre-screened and assembled in packages to meet the particular needs of given rice-production environments. As shown in Table 3, a total of 19 countries have selected a relatively large number of lines from the 1980 IRTP nurseries for Latin America for further yield trials or for use in their hybridization programs.

During an IRTP workshop held at CIAT in August 1981, a total of 39 delegates from 18 collaborating countries analyzed the progress of IRTP activities in the region during the last 5 years. Conclusions reached included:

- While materials from Asia have good genetic variability and high yield potential, their use in Latin America is restricted to limited ecological areas, thus necessitating stricter criteria for the selection of potentially useful materials for the region.
- The CIAT Rice Program already has available many advanced materials to meet most of the needs of national programs in the region.
- Many national programs have progressed to the point where they have available materials that can be shared with other national programs via the IRTP network.

It was agreed that starting in 1982, the IRTP for Latin America should be composed of the following nurseries.

- *International Rice Yield Nursery with medium-duration varieties* (VIRAL-T)—to be planted under both irrigated and favored upland conditions.
- *International Observational Nursery* (VIOAL)—to include promising entries of early, medium, and late maturity; resistance to principal diseases of the region; and

Table 3. **Number of rice lines selected from the 1980 IRTP nurseries for Latin America for in-country yield trials or hybridization programs.**

Country	Entries (no.) selected for: Yield trials	Hybridization
Argentina	2	0
Bolivia	3	0
Brazil	7	24
Chile	0	5
Colombia	0	38
Costa Rica	44	0
Dominican Republic	13	0
Ecuador	19	0
El Salvador	4	0
Guatemala	9	0
Haiti	10	0
Honduras	50	0
Jamaica	24	0
Mexico	5	4
Nicaragua	2	0
Panama	6	6
Peru	7	2
Uruguay	0	8
Venezuela	46	12
Total	251	109

tolerance to acid soils. The nursery can be planted on irrigated land or under favored upland conditions.

- *International Observational Nursery for unfavored upland ecosystems* (VIOAL-SNF)—to include materials from Asia, Africa, Brazil, and other regions, as well as some CIAT materials.
- *Specific Nurseries*—to include nurseries for low-temperature (VITBAL), salinity/alkalinity (VIOSAL), and semi-deep water (VIRAL-F) conditions.



Tropical Pastures Program

SOME 850 million hectares, or 42%, of the land area in the tropical Americas, are acid, infertile soils (Oxisols and Ultisols)—nearly one-third of which is comprised of savannas. It is for these large and as-yet-underutilized land resources that the CIAT Tropical Pastures Program is developing pasture-production technology. The goal is increased cattle production, with the further expectation that the resulting infrastructural development will provide the basis for opening these land resources to agriculture in general. At the same time, this increased production is expected to contribute to the availability of proteins in the diets of people in tropical American countries where both high- and low- income families spend a large and significant portion of their food budget on beef and milk products.

Stocking rates and animal productivity in the acid, infertile soil regions of the tropical Americas have traditionally been low. The current average stocking rate in the savannas is 0.12 animals/ha; and animal productivity, even on the best-managed native savanna, is only about 95 kg of liveweight gain/animal/year. The constraint to increased production is the lack of high-yielding pastures that are adapted to the harsh soil, climatic, and biotic conditions and which can provide animals with a year-round balanced diet of energy and protein.

The aim is to develop low-cost, low-input pasture technology adapted to ecological conditions and prevalent farming systems in various regions.

Recognizing that nutrition is the key to improved beef production in the savannas, the Tropical Pastures Program concentrates its efforts on the development of low-cost, low-input pasture technology adapted to ecological conditions and compatible with prevalent farming operations in the different regions. The Program pursues this objective by:

- selecting pasture germplasm adapted to the soil and environmental constraints and tolerant to prevailing pests and diseases;
- assembling the germplasm materials into persistent and productive legume-based pastures;
- integrating improved pasture technology into biologically and economically efficient animal-production systems.

As described in earlier reports, the Tropical Pastures Program, using such parameters as climate, land slope, and soils, has classified the acid, infertile soil regions of tropical America into five distinct ecosystems:

- well-drained, isohyperthermic savannas, as represented by the "Llanos";
- well-drained, isothermic savannas, as represented by the "Cerrados";
- poorly drained savannas;
- semi-evergreen seasonal forests;
- tropical rainforests.

This classification system serves as the basis for the research design to improve production technologies. Because of the marked interactions between pasture, germplasm and ecosystem, tropical pasture development is being generated considering the characteristics of each ecosystem. To date, the Program has focused primarily on the well-drained savannas and maintains research teams in each of the two ecosystems representing the savannas: in the "Llanos" ecosystem, at the Carimagua Research Center--a station jointly managed by CIAT and ICA; and in the "Cerrados" ecosystem, at the Agricultural Research Center for the Cerrados (CPAC)— a research station of the Brazilian Institute for Agricultural Research (EMBRAPA) near Brasilia. In the remaining three ecosystems, and within the International Tropical Pasture Evaluation Network, national programs and the CIAT Tropical Pastures Program maintain an extensive system of regional trials for the evaluation of pasture germplasm.

In accordance with the three sequential sets of activities through which the Program pursues its objective, the Tropical Pastures Program is organized into three interdisciplinary research units:

- germplasm evaluation;
- pasture-management evaluation;
- pasture evaluation in farm systems.

The germplasm unit focuses its attention on the selection, characterization, and development of legumes and grasses adapted to the environmental and prevalent pest conditions. The pasture-evaluation unit assembles various combinations of legumes and grasses and tests them under alternative management

Tropical pasture research emphasizes improved pasture technologies for five distinct ecosystems, which constitute the largest agricultural frontier in Tropical America. This is a view of a type of Llanos, called "Serrania."

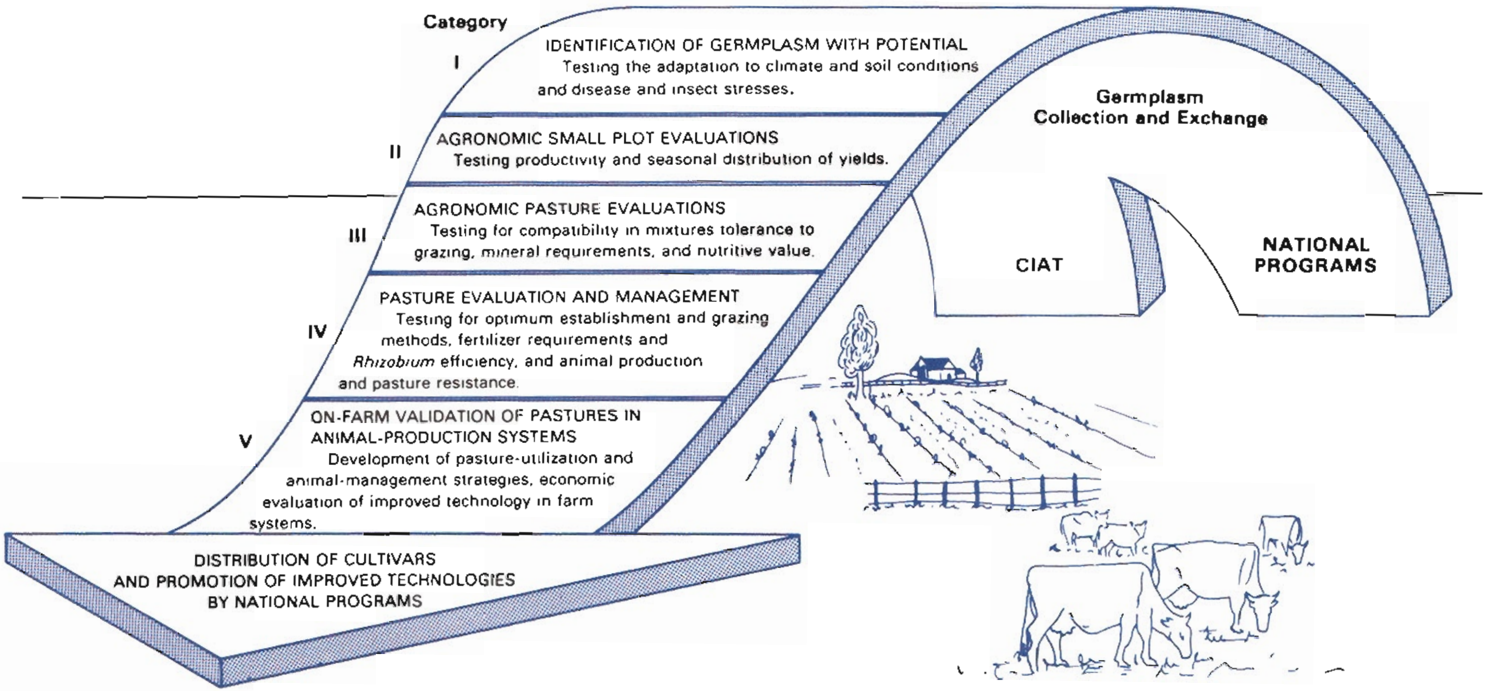


Figure 1. *Phases of selection, evaluation, development, and distribution of tropical pasture germplasm at CIAT and in the national programs. The number of germplasm accessions passing the multitude of tests is progressively reduced.*

practices. The farm-systems unit analyzes prevailing cattle-production systems and defines the improved pasture components needed to correct critical production constraints in a given farm system; it also evaluates the expected impact of alternative technologies on the productivity of the system. Such information is continually being used as the basis for all technology development activities of the Program.

After germplasm has been collected and undergone initial evaluation and seed multiplication, materials are sent to each ecosystem for screening for climate and soil adaptation, as well as for tests on disease and pest tolerance. Promising accessions are then selected for pasture establishment and pasture-management trials and for evaluation in grazing trials. The most promising pastures then enter evaluations in actual production systems.

In its hierarchy of germplasm evaluation phases (Figure 1), the Program recognizes five categories:

I—Identification of germplasm with potential
II—Agronomic evaluation on small plots
III—Agronomic pasture evaluation
IV—Pasture evaluation and management
V—Pasture evaluation in production systems

The number of germplasm accessions passing the multitude of tests in the sequential evaluation phases is progressively reduced from about 1000 in Category I to 5 in Category V.

SUMMARY OF ACHIEVEMENTS

The intensive germplasm-evaluation work carried out by the Tropical Pastures Program in 1981 has allowed for continued advancement of a relatively large number of accessions to higher categories. In 1981, no fewer than 41 accessions (i.e., 24 accessions in Carimagua and 21 accessions in Brasilia) passed the very strict tests to be promoted to a category involving evaluation under grazing (i.e., Categories III, IV, and V). Table 1 presents a status report of the germplasm accessions currently in categories III, IV, and V, for both the isohyperthermic and the isothermic, well-drained savannas.

41 accessions passed strict tests in 1981 and were sent on for evaluation under grazing.

In the isothermic, well-drained savannas (Cerrados), 1981 was the first time that any legumes reached Category IV status (i.e., evaluation of management alternatives in large grazing trials). The isohyperthermic, well-drained savannas (Llanos) have several grass and legume accessions in Categories IV and V.

After the national research institutions in Colombia and Brazil released the grass *Andropogon gayanus* CIAT 621 in their respective countries, FONAIAP, the National Agricultural Research Institution in Venezuela, began the process of releasing this accession for the Venezuelan Llanos. By the end of 1981,

Table 1. **Promising pasture germplasm undergoing advanced evaluation for the well-drained savanna ecosystems, as of December 1981.**

Isohyperthermic, well-drained savannas (Llanos)		
Category	**Species**	**Entries (no.)**
Legumes		
V	*Desmodium ovalifolium*	1
	Pueraria phaseoloides	1
	Stylosanthes capitata	6
IV	*Centrosema brasilianum*	1
	C. macrocarpum	1
	Stylosanthes capitata	2
	S. macrocephala	1
III	*Centrosema* sp.	1
	C. arenarium	1
	C. macrocarpum	1
	Codariocalyx gyroides	1
	Desmodium canum	1
	D. ovalifolium	2
	Stylosanthes capitata	2
	S. guianensis "tardio"	4
	S. leiocarpa	1
	S. macrocephala	1
	Zornia sp.	1
	Z. brasiliensis	2
	Z. latifolia	1
Grasses		
V	*Brachiaria humidicola*	1
IV	*Brachiaria dictyoneura*	1
III	*Andropogon gayanus*	4
	Brachiaria brizantha	3

Isothermic, well-drained savannas (Cerrados)		
Category	**Species**	**Entries (no.)**
Legumes		
V	None	
IV	*Stylosanthes capitata*	2
	S. macrocephala	1
	S. guianensis "tardío"	1
III	*Centrosema* sp	1
	C. brasiliensis	1
	C macrocarpum	5
	Stylosanthes capitata	2
	S. macrocephala	5
	S. guianensis "tardío"	7
	Zornia sp.	1
	Z. brasiliensis	1
Grasses		
V	None	
IV	None	
III	*Brachiaria brizantha*	2
	Panicum maximum	3

CIAT was in the process of producing 1500 kg of basic seed of *A. gayanus* to support FONAIAP in this endeavor.

At the end of 1981, ICA, the national Agricultural Research Institute of Colombia, was considering adoption and promotion of ICA/CIAT-developed technology involving the use of *Pueraria phaseoloides* as a companion legume for *A. gayanus* and *Brachiaria decumbens*. Several other legumes are now in the final evaluation stage, and national programs are interested in their commercial release. Such release of legumes will constitute a major step toward overcoming the critical constraint to forage quality for animal production in the savannas of tropical Latin America.

Germplasm Evaluation

Germplasm Collection

Most of the germplasm materials in CIAT's tropical pastures collection are accessions of wild, undomesticated species. Many of the species are unknown from an agronomic point of view; some are even new from a taxonomical point of view. With the addition of 1500 accessions in 1981, the germplasm collection has increased to 8635 entries (Figure 2). As in previous years, a large majority of the new materials (a total of 1175 accessions in 1981) was obtained during collection trips through areas that are representative of, or at least related to, the ecosystems in the Program's interest. In its efforts to broaden the genetic base of African grasses, the Program obtained an important collection of some 100 accessions of *Brachiaria* spp. and of *Andropogon gayanus* from the Commonwealth Scientific and Industrial Research Organization (CSIRO), in Australia. In the area of legumes, a valuable collection was received from the Brazilian National Center for Genetic Resources (CENARGEN/EMBRAPA). Today, some 1000 accessions from the CIAT germplasm bank belong to "key species"— i.e., species within which highly promising lines for one or more ecosystems have already been identified.

A list of species considered promising is shown in Table 2. With respect to forest ecosystems, observations are still underway, and the classification must be considered tentative. It is interesting to note that although the Tropical Pastures Program is not necessarily seeking species adapted across the ecosystems of the Program's interest, some of the species listed in Table 2, notably *A. gayanus, B. decumbens, Centrosema macrocarpum* and *Stylosanthes guianensis* "tardio", show a remarkably wide range of adaptability, a fact that could possibly contribute to a relatively early and marked impact of the Program's germplasm technology.

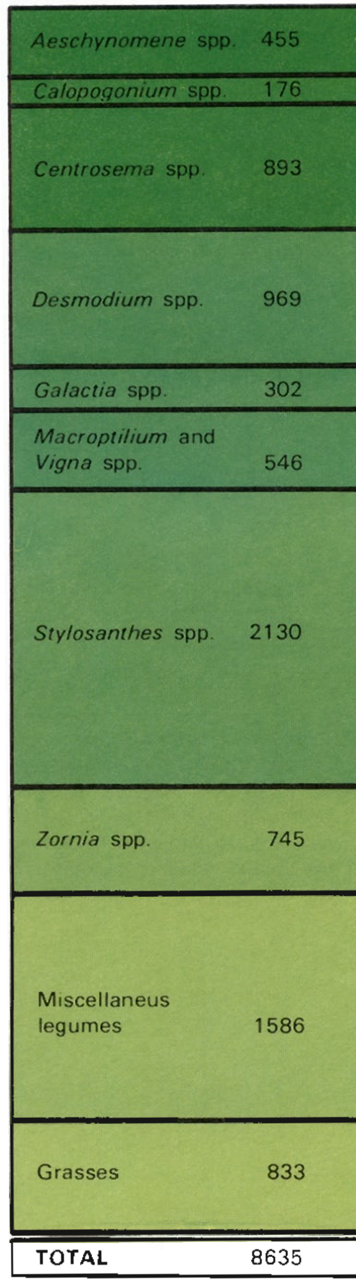


Figure 2. *Total collection of germplasm of tropical pasture species, as of November 1981. About 1500 accessions were added in 1981.*

Table 2 **Key species of pastures identified for the well-drained savanna and tropical forest ecosystems, as of December 1981.**

Species	Promising for: Well-drained savannas Isohyperthermic[a]	Isothermic[b]	Tropical forests[c]
Andropogon gayanus	yes	yes	(yes)
Brachiaria decumbens	yes	yes	(yes)
B. dictyoneura	yes	?	?
B. humidicola	yes	no	(yes)
Centrosema brasilianum	yes	yes	(no)
C. macrocarpum	yes	yes	(yes)
Desmodium ovalifolium	yes	no	(yes)
Pueraria phaseoloides	yes	no	(yes)
Stylosanthes guianensis "tardio"	yes	yes	(yes)
S. capitata	yes	yes	(no)
S. macrocephala	yes	yes	?
S. guianensis (common)	no	no	(yes)
Zornia brasiliensis	yes	yes	?

a Represented by the Llanos.
b Represented by the Cerrados
c. Includes both tropical semi-evergreen seasonal forest and tropical rainforest
Parentheses indicate estimate is from original trials and only a preliminary assessment of promise; a question mark indicates there is no information yet as to performance in this ecosystem.

Evaluation of Germplasm in Ecosytems

During 1981, almost 2000 new accessions of forage germplasm were under observation in CIAT-Quilichao for plant description, initial seed increase, and preliminary evaluation with regard to adaptation and productivity on the very acid and infertile Quilichao-Ultisol, as well as for resistance to pests and diseases. As a result, several hundred accessions with outstanding performance, especially material of key species, were given priority to enter the germplasm flow to the principal testing sites, where evaluation of both grasses and legumes is ecosystem-based.

These ecosystem-based trials are conducted at two major sites—Carimagua for the Llanos and Brasilia for the Cerrados. Further tests are made in two types of Regional Trials, A and B, through the International Tropical Pasture Evaluation Network and in collaboration with national agencies.

Table 4. **Root yield of traditional cultivars and selected F lines, with and without fertilizer application, in Carimagua; planted October 1980.**

Genotype		Fresh root yield (kg/ha) Without fertilizer application[a]	With fertilizer application[b]
Traditional cultivars			
Llanera		3.5	5.6
M Col 638		4.5	15.3
M Col 1684		3.1	6.9
	Average	3.7	9.3
Newer selections			
CM 430-37		10.8	26.4
CM 523-7		12.5	19.4
CM 723-3		8.7	21.2
CM 946-2		9.7	22.9
CM 996-6		6.9	27.4
	Average	9.7	23.4

a. 500 kg/ha of dolomitic lime was applied.

b. The same as above, plus 750 kg/ha of 10-20-20 (N, P_2O_5, K_2O, respectively in %).

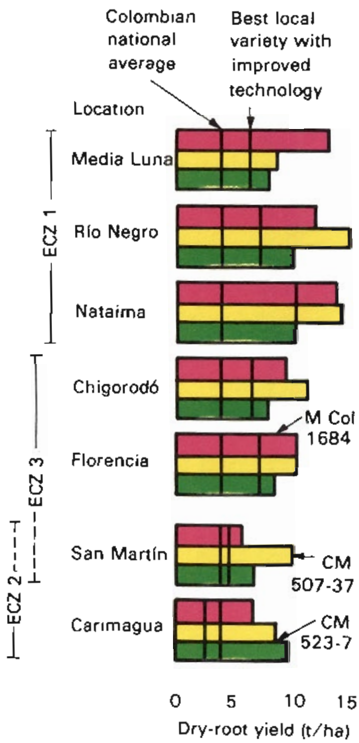


Figure 4. *Average yields of dry roots of several improved cassava clones over a wide range of growing conditions illustrate their macrospatial stability across three different edapho-climatic zones.*

reflects the fact that tolerance to low soil phosphorus implies a high degree of adaptability to the ecosystem. The Carimagua results also showed that the adaptation scores for high acidity were generally higher than those for low soil phosphorus, suggesting that lack of phosphorus is a greater limiting factor than lack of lime. However, those varieties with good adaptation to low soil phosphorus generally were also adapted to high acidity. This is due to the fact that high levels of aluminum partially block the uptake of phosphorus; hence, those varieties with greatest efficiency in phosphorus uptake are also most tolerant to acid soils.

Some 60 hybrid lines were also included in the evaluations. On the average, these lines had much higher adaptation scores than the germplasm accessions. The highest scores for both adaptation to low phosphorus and high acidity were obtained with CM 523-7, a line which was also among the highest yielders in the Regional Trial and Preliminary Yield Trial in Carimagua.

In Carimagua, without fertilizer application, the yields of both hybrid and traditional cultivars were much lower than in fertilized plots (Table 4). However, the superiority of selected hybrids over traditional cultivars was maintained even at low fertility, suggesting that yield superiority of carefully selected cassava genotypes can be maintained over a wide range of fertility levels.

Some 40% of the world's cassava is grown in intercropping systems. Cassava genotypes that yield well when intercropped with short-season grain legumes also yield well in monoculture,

The program seeks technologies appropriate for multiple uses of the cassava end-products, particularly for fresh human consumption, or dried and processed for either human or animal diets.

even though the starch content of the intercropped cassava is generally less than that of the monocrop.

Differences in weed control can cause important differences in yield, particularly in less vigorous cassava varieties, which tend to have higher yield potential. Thus, in a trial conducted in the north coast of Colombia, the variety M Mex 59 showed stable but low yields over a wide range of weed-control management techniques, whereas the variety M Col 22 only yielded well with good weed control. This situation also holds true with respect to such factors as disease and pest resistance and suggests that, in some cases, stability can only be obtained as a trade-off with yield potential. Nevertheless, results from technology-validation trials suggest that stable yields can be obtained over a range of different management systems (Figure 5).

Root quality. Eating quality is a subjective matter; nevertheless, good eating quality is loosely related to a high starch or dry-matter content. In recent years, increased importance has been assigned to the selection for higher root dry-matter content. Many new selections combine high fresh yield with high dry-matter content. Table 5 shows results of some of the best selections available in Caribia (north coast of Colombia), Carimagua, and CIAT-Palmira.

One of the major problems of cassava is its extremely short shelf life. As reported in earlier years, two phases of root deterioration after harvest have been identified. Physiological deterioration occurs 1 to 6 days after harvest, and microbial deterioration follows afterward.

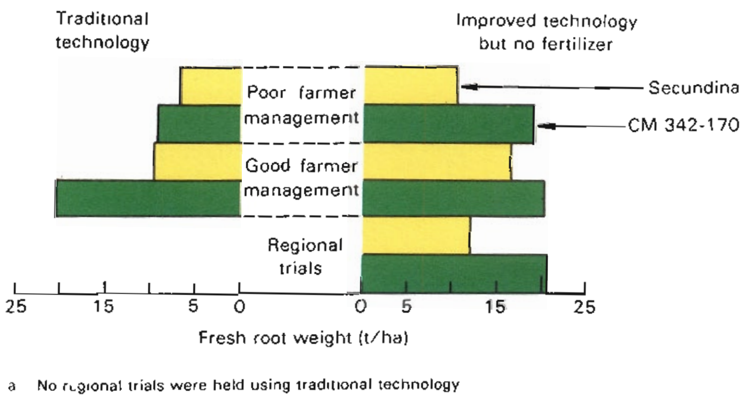


Figure 5. *A comparison of regional trials and on-farm validation trials illustrates the similarity of response that can be obtained from cassava when minimally improved technology (stake selection, stake treatment, land preparation, and weed control) is used (Media Luna, May 1981).*

Well-drained, isohyperthermic savannas. The principal research site representing the ecoystem of the well-drained, isohyperthermic savannas (Llanos) is Carimagua, in the eastern plains of Colombia. The work at this research station is supported by an additional series of regional trials spread throughout the ecosystem. There were 70 accessions of the various genera of grass germplasm and 1109 of legume germplasm undergoing evaluation in Categories I, II, and III during 1981.

A. Evaluation of grasses. After the release of *Andropogon gayanus* CIAT 621 in 1980 by ICA as cultivar Carimagua I, the search for additional, well-adapted, and highly productive grasses has continued unabated. *A. gayanus* continues to be of high interest; the search for material that is superior to the CIAT 621 accession continues by means of a thorough evaluation of the entire *A. gayanus* collection, as well as by attempts to genetically improve the CIAT 621 population of this cross-pollinating species.

Another genus of considerable importance to the Program is *Brachiaria,* primarily because it includes aggressive, mat-forming species which can be considered ideal companion grasses for the highly promising legume *Desmodium ovalifolium,* which is also aggressive and mat-forming. In 1981, the species *B. dictyoneura* was added to the Program's list of key species for the well-drained, isohyperthermic savannas. Morphologically, it is very similar to *B. humidicola* (which has already reached Category V, the highest category of the Program's evaluation scheme), but it is characterized by a high seed-production potential, compared to the low potential in *B. humidicola,* which limits the wider use of the latter in the Llanos ecosystem. An additional advantage of *B. dictyoneura* over *B. humidicola* is its less-prostrate growth habit during the establishment phase, which is conducive to the better establishment of a companion legume. As with *B. humidicola, B. dictyoneura* was observed to combine well with *D. ovalifolium.* Contrary to *B. decumbens,* which across the ecosystems is very susceptible to the spittlebug, the major pest of grasses in the tropics, *B. humidicola* and *B. dictyoneura* are spittlebug-tolerant. Even though the latter two grasses can become severely infested with the pest, they have the capacity to recover, possibly because of their high rates and amount of shoot growth. Among other *Brachiaria* species, *B. brizantha* CIAT 664 is also showing promise and now is under evaluation in mixtures with *D. ovalifolium.*

The grass/legume association with the aggressive species Brachiaria humidicola *and* Desmodium ovalifolium *represents a highly compatible mix and holds great promise for increased animal production in the Llanos ecosystem and possibly the humid tropics.*

B. Evaluation of legumes. Good drought resistance and high nutritive values observed in several *Centrosema* species make the genus extremely valuable in this ecosystem. In most species, however, susceptibility to foliage diseases seems to be the main limiting factor, pointing out the necessity for examining additional accessions for disease resistance. A species of particular value in this respect is *C. macrocarpum,* of which accession CIAT 5062 is being used as a parental line in a promising hybridization program with *C. pubescens.*

Desmodium ovalifolium has already been defined as a key species for the well-drained, isohyperthermic savannas. Due to its relatively long period of vegetative growth and its high water requirements, it has not been classified as a key species for the Cerrados ecosystem. Accession CIAT 350 has already advanced to Category V status; it is a nearly ideal companion for the mat-forming *Brachiaria* grasses. In 1981, a number of early flowering accessions with high seed-production potential were identified. As Table 3 shows, these new materials not only produce good dry-matter yields in comparison with the late-flowering control CIAT 350, but also show very good regeneration from seeds and produce considerable seed yields.

The main limiting factor of the *Stylosanthes* genus is its susceptibility to anthracnose. Figure 3 shows the superiority of *S. capitata*, *S. guianensis* "tardio", and *S. macrocephala* over the common types of *S. guianensis* in terms of anthracnose resistance, not only at Carimagua but also at Brasilia. These data also point to marked location-by-species interaction, suggesting the importance of conducting multilocational screening experiments with *Stylosanthes* and the need to identify materials with broad adaptability.

Of more than 40 accessions of *S. guianensis* "tardio" evaluated in Carimagua, five showed good dry-matter yields and high disease tolerance. However, none of these accessions produced sufficient seed for self-regeneration. In an attempt to combine the anthracnose resistance of the "tardio" types with a series of positive agronomic attributes (including high seed-production potential) of the common types of *S. guianensis*, crosses between these two types were made and are under evaluation.

Routine evaluations of new germplasm of *S. capitata* continues. Also continuing is the selection process within *S. capitata* hybrid populations produced in 1978. *S. macrocephala* continues to show good promise, primarily because of its rusticity, which includes

Table 3. **Performance of accessions of *Desmodium ovalifolium* (grown in association with *Brachiaria humidicola* at Carimagua), under grazing, 1981.**

CIAT accession no.[a]	Seed yield (kg/ha)	Regeneration (no. of seedlings /m²)	Dry-matter yield (t/ha)	Amount of legume in mixture (%)
3666	109.1	9.8	9.0	65
3780	15.2	18.5	7.2	59
3784	152.6	53.3	7.8	59
3793	48.9	40.1	8.2	62
Control[b]				
350	0.8	2.9	10.6	71

a. All lines are early flowering.
b. Control line is late flowering.

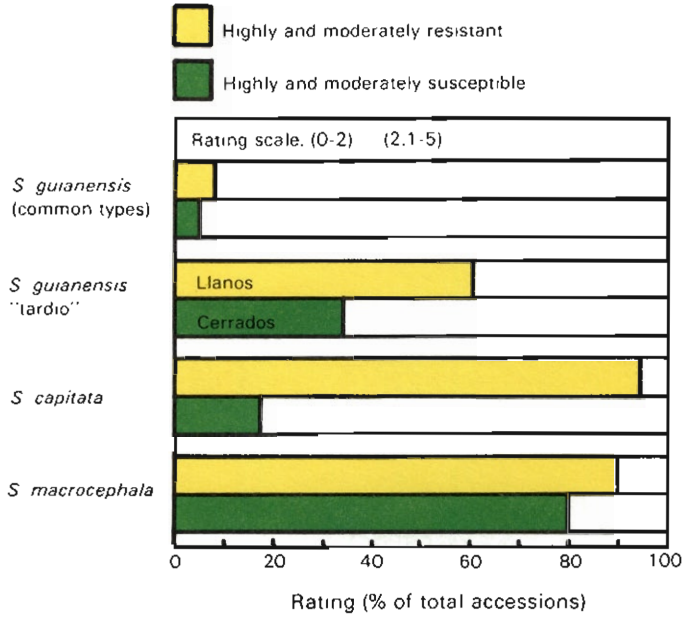


Figure 3. *CIAT-improved species of* Stylosanthes *are rated more resistant to anthracnose in the two savanna ecosystems, represented by Carimagua (Llanos) and CPAC/Brasilia (Cerrados).* S. macrocephala *is highly resistant across both environments.*

Brachiaria dictyoneura *has high seed-production potential and a less-prostrate growth habit; it is also tolerant to spittlebug.*

anthracnose resistance. Considerable variability in vigor and flowering time has been observed. The search for and identification of more vigorous, late-flowering ecotypes continues.

Most of the accessions of *S. capitata* and *S. macrocephala* and many of the *S. guianensis* "tardio" materials show a high degree of resistance to the major *Stylosanthes* pest, the stemborer *Caloptilia* sp.

The two-leaflet species of the *Zornia* genus, such as *Z. latifolia,* gave disappointing results because of serious disease problems. A highlight in 1981 was the observation that the four-leaflet species, e.g., *Z. brasiliensis* and *Z. myriadena,* possess a high degree of disease resistance. Such resistance appears to be inherent in the four-leaflet *Zornia* species. Nutrient contents of both species are exceptionally high.

Well-drained, isothermic savannas. The principal research site for the well-drained isothermic savannas (Cerrados) ecosystem is at CPAC in Brasilia, Brazil. As in the case of the ecosystem represented by the Colombian Llanos, the work performed in Brasilia is supported by a regional-trial network in the Cerrado-type environment, which adds the dimension of evaluations across different sites in the same ecosystem. In these regional trials, germplasm productivity is measured during the period of minimum and maximum precipitation.

The strategic use of legumes, such as Pueraria phaseoloides *(Kudzu), in the form of legume banks in native savanna or pastures with improved grasses, is proving to be a sound and economically most attractive management practice.*

In 1981, a total of 123 accessions of five grass genera and 345 accessions of two legume genera were under preliminary evaluation in Brasilia.

A. Evaluation of grasses. The potential of *Panicum maximum* for Cerrado areas with dark-red latosols was confirmed; three accessions (CIAT 6141, CIAT 6116, and CIAT 6124) yielded more than 7000 kg/ha of dry matter in their second year of establishment, versus less than 3000 kg/ha of the control. Regarding other grass species, *Brachiaria brizantha* CIAT 6016 and CIAT 6021, as well as *Brachiaria* sp. CIAT 6058, produced markedly more dry matter than the commercial control cultivar. None of the tested accessions of *Andropogon gayanus* was found to be superior to the control cultivar, CIAT 621, which was released under the name "Planaltina" in Brazil in October 1980.

B. Evaluation of legumes. Five accessions of *Centrosema* were selected in 1981 for advanced testing: *C. macrocarpum* CIAT 5274, 5276; *C. brasilianum* CIAT 5234; and *Centrosema* sp. CIAT 5118. Thus far, no pest or disease problems have been noted.

Four years of observations indicate that for the Cerrados ecosystem, the key species of *Stylosanthes* are *S. capitata, S. guianensis* "tardio", and *S. macrocephala.* From plantings in the last 3 years, three accessions of *S. capitata,* eight of *S. guinensis* "tardio", and five of *S. macrocephala* were selected for advanced evaluation under grazing (Category III). All are characterized by high resistance to anthracnose.

Five accessions of *Zornia*, predominantly *Z. brasiliensis*, significantly outyielded the control *Z. latifolia* CIAT 728 and were selected for evaluation in Category III. These accessions were found to be free of symptoms of the insect-virus-fungus complex and *Sphaceloma* scab, which attack germplasm of two-leaflet *Zornia* species.

Regional trials. Through "Regional Trials A," a relatively large number (100 to 120) of germplasm accessions undergo evaluation for adaptation and survival. In 1981, Regional Trials A were conducted at 13 sites representing each ecosystem —five sites in Brazil, three in Colombia, one in Nicaragua, one in Peru, and two in Venezuela. Results of the regional trials in the well-drained savannas largely corroborated the results obtained at the respective principal research sites.

A large number of potentially promising legumes were also identified for the tropical forest ecosystems (i.e., semi-evergreen seasonal forest and tropical rainforest). Particularly remarkable were the productivity and anthracnose resistance of two of the common types of *S. guianensis* (CIAT 136 and 184), as well as of some "tardio" types of this species. Also, *D. ovalifolium* 350 showed very good performance. Among the grasses, *A. gayanus* CIAT 621 was outyielded only by two accessions of the same species, namely CIAT 6053 and 6054. At the same time, accessions of the genus *Brachiaria* performed exceedingly well, particularly *B. humidicola;* this grass is spreading rapidly in the humid tropics, especially in Brazil where it is known as "Quicuio da Amazonia," a term used to compare it with the temperate Kikuyu grass, *Pennisetum clandestinum*.

Evaluation of pasture germplasm is accomplished within an extensive system of regional trials.

In the next type of regional trials, "Regional Trials B," the Network evaluates seasonal productivity of promising materials emerging from the major screening sites at Carimagua and Brasilia, as well as from Regional Trials A. In 1981, 36 Regional Trials B had been established in four ecosystems in 14 countries. Results from four Regional Trials B in the well-drained, isohyperthermic savanna ecosystem (the Colombian Llanos) confirm that *S. capitata* and *D. ovalifolium*, as well as *A. gayanus* and *B. decumbens*, are the most promising legume and grass species, respectively. Results from 11 Regional Trials B in the forest ecosystems indicate that these same two grasses, *A. gayanus* and *B. decumbens*, are the most productive. Among legumes, *D. ovalifolium* emerged as a most promising species also for the forest ecosystems; furthermore, two common forms of *S. guianensis* (CIAT 136 and 184) were among the three best legumes identified. These same two materials did not survive in the savanna conditions due to the prevailing anthracnose pressure.

Effect of Fertilization on Tropical Pastures and Animal Nutrition

One of the most promising legumes in CIAT's Tropical Pastures germplasm collection is *Desmodium ovalifolium*. It is well adapted to the acid, infertile soils of almost all ecosystems in tropical South America, has no major insect and disease problems,. produces considerable amounts of biomass, and combines well with grasses, even with the most aggressive ones. It was found, however, that this legume was not being accepted by grazing cattle. CIAT researchers determined that this lack of palatability most probably was associated with the high contents of tannins in *D. ovalifolium*

Differences in acceptability between grazed *D. ovalifolium* pastures in Carimagua and Quilichao suggested that there might be a relation between tannin level in the plant, consumption of this species by animals, and soil fertility. Results obtained from subsequent fertilization experiments in Carimagua clearly demonstated that small amounts of magnesium and sulfur added to the fertilizer mixture of phosphorus, calcium, and potassium significantly increased forage production, forage quality, and animal acceptance of *D. ovalifolium*. There were increased protein, sulfur, and phosphorus, and reduced tannin contents in the legume fertilized with the more complete fertilizer mixture.

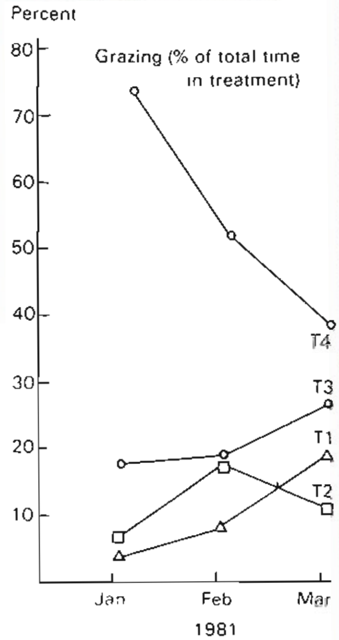
Follow-up research reveled that these increases could be attributed to one key element: sulfur. It was established that maintenance fertilization of 20 to 30 kg/ha of sulfur is sufficient to assure continued high productivity, quality, and animal acceptance of *D. ovalifolium*.

Thus, *Desmodium ovalifolium* remains one of the most promising legumes in the ranks of the Tropical Pastures Program. And the use of fertilization as an interesting tool to improve legume consumption by grazing animals has been identified.

Effect of fertilizer treatment on quality of *D. ovalifolium* 350 under grazing (Carimagua).

	Fertilizer treatment[a]			
Element measured on leaf tissue (%)	**T1 (control)**	**T2 (+P+Ca)**	**T3 (+P+Ca+K)**	**T4 (+P+Ca+K+Mg+S)**
Calechin equivalents (Vanillin, HCl)	37.5 ^{b}	37 0 ^{b}	34.1 ^{b,c}	28.7 ^{c}
Nitrogen	1 99 ^{b}	2.01 ^{b}	2.09 ^{b}	2.59
Nitrogen soluble pepsin (48 hr)	39.5 ^{b}	39 8 ^{d}	43.4 ^{c}	49 4 ^{d}
S	.094 ^{b}	.102 ^{b}	.121 ^{c}	.145 ^{d}
P	.118 ^{b}	133 ^{b,c}	130 ^{b,c}	.140 ^{c}

a TI fertilizer applied at establishment May 1978 (105 kg P_2O_5, 259 kg Ca, 52 kg K_2O, 11 kg Mg, and 22 kg S/ha), T2, T3, T4 fertilizer applied August, 1980 (60 kg P_2O_5, 117 kg Ca, 44 kg K_2O, 22 kg Mg, and 44 kg S/ha Means in the same row with different letters are significantly different (P <0 5)



Time animals spent grazing, D. ovalifolium 350 under various fertilizer treatments, (see footnote a, table), in Carimagua.

Pasture-Management Evaluation

The pasture-management evaluation activity of the Tropical Pastures Program serves as a bridge from the germplasm evaluation unit to the activities devoted to pasture evaluation in production systems. It receives promising accessions from the germplasm evaluation unit and assembles them in alternative grass/legume combinations; at the same time, it develops associated pasture-establishment and management practices. Pasture technology is developed within the agroeconomic guidelines established by the pasture-evaluation in farm systems unit and is designed to achieve superior and stable pasture productivity in terms of animal liveweight gains. In 1981, management technology evaluation focused on the following practices.

Soil/Plant Interactions

Evaluation of *Rhizobium*. One of the principal advantages of legume-based pastures is their relative self-sufficiency in nitrogen, which is fixed from the atmosphere and made available to the pasture system by the legume/*Rhizobium* symbiosis. To enhance this nitrogen-fixing ability, the Program seeks to identify *Rhizobium* strains that form the best possible symbiosis with the legumes and to develop effective, low-cost inoculation techniques.

In the past, while inoculation with selected *Rhizobium* strains was shown to be effective during the establishment stage, only modest long-term effects could be observed. Research carried out in 1981 indicates that an important factor in the selection process of *Rhizobium* strains is whether screening is done in disturbed or in undisturbed soils. It was found that in disturbed soil (i.e., growing of inoculated legumes in pots), organic matter is mineralized more repidly than in undisturbed soil (i.e., growing of inoculated legumes in undisturbed cores extracted from the ground). Hence, if screening is done in pots with the soil disturbed and with an attendant release of considerable amounts of mineralized organic matter, the effect of inoculation is diminished, which, in turn, diminishes the effectiveness of the screening process. It is hoped that with the initiation of large-scale screening for effective *Rhizobium* strains in cores of undisturbed soil, truly superior strains can be identified, which, when inoculated in the respective legumes, will have an important long-term effect in terms of nitrogen made available to the pasture system.

In 1981, key legume species were inoculated with a range of *Rhizobium* strains in cores of undisturbed Carimagua soil in order to identify the most effective strains for further evaluation. Strains with superior nitrogen fixation and tolerance to low pH and high aluminum saturation are being selected for further testing.

Response of inoculation by Centrosema macrocarpum *in pots (disturbed soil) was lower than in cylinders (undisturbed soil). The latter treatment is suggested for selection of strains.*

Nutrient requirements. The Program's efforts to develop pasture technology that requires minimum fertilizer input translates into a strategy that emphasizes identifying pasture species and ecotypes tolerant to the major soil constraints (aluminum and mangenese toxicities) and low native soil fertility (macro-, secondary, and micronutrient deficiencies, except nitrogen).

The large variation in the reaction of different species and ecotypes to adverse soil conditions is illustrated in Table 4. Selected results are shown from an experiment testing the differential tolerance of several materials to high levels of soil manganese. Among grasses, differential tolerance was more evident at the species level. Particularly noteworthy is the fact that most tolerant accessions had a higher dry-matter production rate at high than at low manganese stress, thus pointing to the beneficial effect of manganese in tolerant species.

The development of low-input technology for managing low native soil fertility centers around increasing fertilization efficiency. The strategy includes both (1) identifying and correcting soil-nutrient deficiencies and (2) growing pasture species and ecotypes that are efficient users of fertilizer inputs.

Well-managed grass/legume associations have vigorous root systems and are highly efficient at capturing soil nutrients.

In an effort to determine the external nutrient requirements for establishment of various tropical pasture grasses and legumes in the isohyperthermic, well-drained savannas, a series of field experiments was carried out in 1981. Requirements for both macro- and micronutrients were studied. Table 5 presents the external requirements of phosphorus, potassium, calcium, and magnesium for selected promising grasses and legumes. The low levels of these elements required for establishment are a reflection of the outstanding edaphic adaptation of most of the germplasm with which the Program is working.

The effects of P fertilization and lime applications were studied on pasture establishment in the Brazilian Cerrados using the two representative soils of the region. Lime application (1 ton/ha) was found to be beneficial in both a red-yellow Latosol and a dark-red Latosol at low levels of P fertilization (26 kg P/ha) when using triple superphosphate and Yoorin thermophosphate rock. These results suggest that P fertilizer efficiency can be enhanced by applying 1 ton lime/ha when low P fertilizer levels are used but not when high P levels are employed. The relative costs of lime and phosphorus sources will determine the practical fertilizer recommendations.

Nutrient recycling in pastures. A sampling in a Kudzu *(Pueraria phaseoloides)/Andropogon gayanus* pasture in the Colombian Llanos at the end of the 1981 dry season showed an accumulation of over 4 tons/ha of leaf litter (dry-weight basis) with a nitrogen concentration of over 2%, the equivalent of 80 kg of nitrogen/ha. How is it possible that a pasture producing around 400 kg of liveweight gains per year/ha naturally maintains such high levels of a key nutrient? Long-term observations by the

Table 4. **Dry-matter production and differential tolerance of several tropical forage species to manganese.**

Species	CIAT accession no.	Dry-matter yield (t/ha): Low soil Mn (10 ppm)[a]	Dry-matter yield (t/ha): High soil Mn (86 ppm)	Relative index (high Mn/low Mn)[b]
Grasses				
Andropogon gayanus	6054	3.40	4.06	1.19
	6200	6.07	4.39	0.72
Brachiaria decumbens	606	5.52	6.69	1.21
	6132	3.14	1.28	0.40
B humidicola	675	2.66	2.63	0.98
	679	5.73	2.78	0.48
Legumes				
Calopogonium mucunoides	7367	2.27	2.41	1.06
	9161	2.79	1.68	0.60
Centrosema sp.	5118	1.26	1.95	1.54
	Common	2.47	1.89	0.76
Stylosanthes capitata	1405	1.93	2.59	1.34
	1097	3.23	3.32	1.02
S. guianensis	136	4.82	6.21	1.29
	184	5.39	5.80	1.07

a Low soil Mn = 0-20 ppm; levels above 50 ppm are considered toxic for tropical pastures.

b. A relative index of less than 0 5 implies that the species is susceptible to Mn toxicity.

Table 5. **Nutrient requirements for the establishment of various tropical pasture grasses and legumes in Carimagua, representing the isohyperthermic, well-drained savannas.**

Species	CIAT accession no.	External requirements (kg/ha)[a]: P	K	Ca	Mg
Grasses					
Andropogon gayanus	621	20	20	100	12
Brachiaria humidicola	679	10	10	50	6
B. decumbens	606	20	20	100	12
B. brizantha	665	20	20	100	12
Panicum maximum	604	40	25	250	15
Legumes					
Centrosema macrocarpum	5065	11	10	100	12
C pubescens	5063	20	20	400	12
Codariocalyx gyroides	3001	35	30	100	20
Desmodium ovalifolium	350	20	20	100	12
Pueraria phaseoloides	9900	20	20	100	20
Stylosanthes capitata	1315	20	20	50	12

a. Critical levels of nutrients in the soil solution, associated with 80% of maximum yields obtained at 8 weeks of plant growth

Program point to a very effective recycling mechanism that is operational under conditions of well-managed pasture-production systems.

Most of the pasture contains carbon, hydrogen, oxygen, and nitrogen. The carbon, hydrogen, and oxygen come from the air and water; the nitrogen is provided by the *Rhizobium* bacteria via the legumes. The export of mineral nutrients from the pasture is very low. For example, 400 kg of liveweight production per year/ha will remove only 3 kg of phosphorus, 0.8 kg of potassium, and 5.2 kg of calcium from the pasture. There is very little leaching loss of nutrients in spite of the porous nature of the soil and the heavy rainfall that characterizes the savannas; this is due to the vigorous root systems of grasses and legumes in well-managed associations, which allow for a complete exploitation of the soil volume to a considerable depth. Thus, as long as the pasture is well-managed and growing vigorously, it is highly efficient at capturing the nutrients that return to the soil and at recycling them for the forage-production system.

The export of mineral nutrients from the pasture is very low.

Savanna replacement. The year 1981 was the second year of a large-scale series of experiments in Carimagua assessing the feasibility of replacing native savanna with introduced species through strip seeding. This experiment draws on establishment and maintenance concepts derived from research in spatial distribution, low-density seeding, tillage methods, and fertilization practices. After successful establishment of the initial strips, which cover 20% of the total area, the pastures were grazed lightly during the dry season and fully stocked at the onset of the rainy season. The stocking rate was one animal/ha of total area, or five animals/ha of seeded area. The strategy in this experiment is to let the aggressive legumes *Desmodium ovalifolium* and Kudzu *(Pueraria phaseoloides)* invade the savanna areas between the planted strips, and to increase the fertilized area adjacent to the planted strips by 20% per year so that at the end of 4 years the entire area will be fertilized and colonized by the planted species. Even under grazing, both *D. ovalifolium* and Kudzu have spread rapidly into the native savanna (Figure 4). Due to the presence of the legume in the diet, the consumption of native grass species was observed to be greatly increased, with animals even aggressively consuming savanna that had not been burned for 18 months. Animal performance varied with the association: gains during the 5-month observational period ranged from 200 g/animal/day (*A. gayanus* in association with *D. ovalifolium)* to 400 g/animal/day *(B. humidicola* in association with *P. phaseoloides).*

An analysis of the effects of strip width showed that narrow strips of 50 cm with 2 meters of native savanna between the planted strips is the best alternative for quick savanna replacement. Both *D. ovalifolium* and Kudzu had completely covered the entire area in 18 months when planted in this manner.

The possibility of managing native savanna with grazing rather than with fire has important implications for potential productivity of savannas. Presently, the savanna is grazed for 3 to 4 months after burning and then is left for the next 12 to 15 months to accumulate fuel to assure good burn. Hence, the effective stocking rate on native savanna is three to four times higher than the apparent stocking rate since any particular area is unused for 75 to 80% of the time. The Tropical Pastures Program now looks at the strip-seeding experiment with a view to other alternatives, such as planting 10 to 20% of the area with introduced species, not as the initial phase for replacement of all the savanna but strictly as a supplement to it.

Seedling vigor in *Stylosanthes capitata*. The lack of persistance of *S. capitata* in association with *A. gayanus* is a major limitation for that species. Studies conducted in 1981 indicate that one of the principal causes for this lack of persistance is competition by the grass for nutrients, leaving the new legume seedling inadequately supplied for normal development. Work carried out by ICA scientists at Carimagua points to the possibility that *S. capitata* may be compatible with *Melinis minutiflora*, a grass that is much less aggressive and competitive than *A. gayanus* and, therefore, should impose less stress on the *S. capitata* seedlings.

Planted strip width (m)	Average advance from original strip (m) Association of	
	Brachiaria humidicola x *Desmodium ovalifolium*	*Andropogon gayanus* x *Pueraria phaseoloides*
5	1.7	2.9
2.5	2.8	2.8
0.5	1.0	2.0

Figure 4. *Effect of associated species and strip width on the invasion of native savanna by two legumes in a savanna replacement trial. (Planted May 1980; grazing initiated April 1981; measurements taken November 1981.)*

During the year, large volumes of seed were multiplied to provide a critical supply for germplasm and pasture evaluation. Basic seed is required to initiate commercial seed production. In addition, seed availability is a major determinant of farmers' access to and use of new pastures and their potential.

Pasture Quality

In 1981, a new section was added to the Tropical Pastures Program to focus on identification and characterization of germplasm quality factors and to relate them to nutrition of the grazing animal. Accessions have been undergoing such evaluation for the past several years, but the new section contributes to an increased emphasis on quality factors in pastures.

Results in 1981 showed that, in grasses, there is no difference in digestibility and intake between *B. humidicola* and *B. dictyoneura*. In legumes, *Zornia* sp. were found to have very high nutritive values, so that, provided they are palatable enough, they could be recommended as a forage in early weaning programs.

A study of selective grazing on *A. gayanus*/ *S. capitata* and *A. gayanus*/ *Pueraria phaseoloides* mixtures was completed in Carimagua after two dry seasons and one rainy season. It was shown that the proportion of *S. capitata* in the forage declined considerably with time as a consequence of mother plants dying and seedlings lacking vigor; in contrast, *P. phaseoloides* remained relatively stable over time in the association. In the dry season, legume selection was higher than in the rainy season, and animal preferences were for *S. capitata* inflorescences and *P. phaseoloides* leaves. The presence of a legume in the sward contributed to an increase in protein in the leaves of *A. gayanus* and to an adequate protein level in the diet during the dry season. Thus, in the dry season, animals gained weight when grazing on grass/legume mixtures, whereas animals lost weight when grazing only straight grass.

Pasture Utilization

The Program's activities in pasture productivity and management are designed to determine animal-productivity potential of promising germplasm in grazing trials and to identify management practices to assure persistence and stability of pasture components.

Pure-stand grass pastures. After concluding the evaluation in pure stands of *B. decumbens* and *A. gayanus,* in 1981 only the evaluation of *B. humidicola* in pure stands continued. Under Carimagua conditions, the productivity of *B. humidicola* is lower than that of the other two. During the wet season and with a stocking rate of 3.4 animals/ha, weight gains reached 215 g/animal/day. During the second part of the rainy season, a significant improvement of animal performance was achieved after a maintenance fertilization of 22, 11, and 22 kg/ha of potassium, magnesium, and sulfur, respectively, which resulted in greater leaf growth at all stocking rates, but the effect was not sufficient to sustain animal productivity over the whole season.

Legume protein bank. To provide high-quality forage during the dry season or during critical animal growth stages, it might be advantageous to establish legumes—particularly those that are aggressive and tolerant to heavy seasonal grazing—in strips or blocks within grass paddocks. This protein-bank concept is being evaluated in a long-term experiment with *P. phaseoloides.* Table 6 shows the results of the same planted pasture in the third year of this experiment in which the legume is established in specific blocks within savanna surroundings. In 1981, animal productivity at the low stocking rate reached 122 kg liveweight gain per animal for the entire year, which compares favorably with normally observed gains in animals on well-managed native savannas. At the high stocking rate, it was necessary to restrict access to the legume bank to allow the legume to recover after heavy grazing during the dry season and for recovery after maintenance fertilization, thus causing an important drop in productivity during the wet season and thus in total annual liveweight gain.

In a parallel experiment, the protein bank was established in strips and blocks within areas planted to *B. decumbens.* After 3 years of observation, animal performance in the protein-bank treatments planted in strips was better than in the grass-alone treatment, pointing to the good quality of *B. decumbens,* especially in the rainy season.

The legume protein-bank concept is being evaluated using Pueraria phaseoloides *in blocks within grass paddocks.*

Grass/legume associations. Evaluation of the association of *A. gayanus* with *P. phaseoloides, S. capitata,* and *Z. latifolia* was continued in its third year. In 1981, animal performance was similar to or better than that in Year 2, both with respect to dry- and wet-season results (Table 7), despite the fact that both absolute yield and relative proportion of the legumes in the association diminished significantly. Results indicate that grazing animals are able to obtain legumes for their diet even at very low levels of availability during the dry season.

Table 6. **Seasonal liveweight gain of steers grazing savanna supplemented with *Pueraria phaseoloides* in blocks (0.2 ha/animal) in Carimagua during the third year of the experiment (1981).**

Stocking rate (animal/ha)	Liveweight gain (kg)					
	Dry season (111 days)		Wet season (255 days)[a]		Total (366 days)	
	Per animal /day	Per animal /season	Per animal /day	Per animal /season	Per animal /year	Per ha /year
0.25	.117	14	.423	108	122	31
0.50	.096	10	.215	55	65	32

a. Access to the bank was restricted for 186 days in the rainy season to allow recovery of the legume after maintenance fertilization

Table 7. **Seasonal liveweight gains of steers grazing *Andropogon gayanus*/legume associations in Carimagua, 1981 and 1980 (years 3 and 2 of experiment).**

Associated legume	Stocking rate[a] (animal/ha)	Liveweight gain (kg)					
		Dry season		Wet season		Total	
		Per animal /day	Per animal /season	Per animal /day	Per animal /season	Per animal /year	Per ha /year
1981 (dry season = 96 days; wet season = 269 days; total = 365 days)							
Stylosanthes capitata (1919 + 1315)	1.0/1.8	.166	16	.684	184	200	349
Zornia latifolia	1.0/1.0	.135	13	.420	113	126	126
Pueraria phaseoloides[b]	1.0/1.8	.531	51	.520	140	191	310
1980 (dry season = 118 days; wet season = 248 days; total = 366 days)							
Stylosanthes capitata (1919 + 1315)	1.0/1.8	.167	20	.609	150	170	238
Zornia latifolia	1.0/1.4	.021	2	.744	185	184	223
Pueraria phaseoloides	1.0/1.8	.208	25	.667	165	190	322

a. Dry/wet season, respectively.
b. Rested for 71 days in 1980.

After various years of continuous evaluation, the grass/ legume association Andropogon gayanus/ Stylosanthes capitata *continues to be exceedingly promising. Annual liveweight gains of cattle grazing this association in the Colombian Llanos is around 200 kg/animal.*

Evaluation of a highly promising association, *B. humidicola* with *D. ovalifolium*—established in 1980—started in 1981. Previous experiments with *D. ovalifolium* in Carimagua indicated the need for a very aggressive companion grass for this legume and for management practices that would encourage legume consumption to maintain a proper balance between the pasture components for better animal performance. Preliminary animal-performance data—liveweight gains averaging more than 500 g/animal/day—are most encouraging.

A summary look at the last 10 years of evaluation work on animal liveweight gains that can be obtained in the savannas under various pasture systems reveals the data presented in Figure 5. In essence, these data confirm the Program's fundamental precept that improved pasture technology holds the key to substantial increases in animal performance in the acid, infertile soil areas of Latin America.

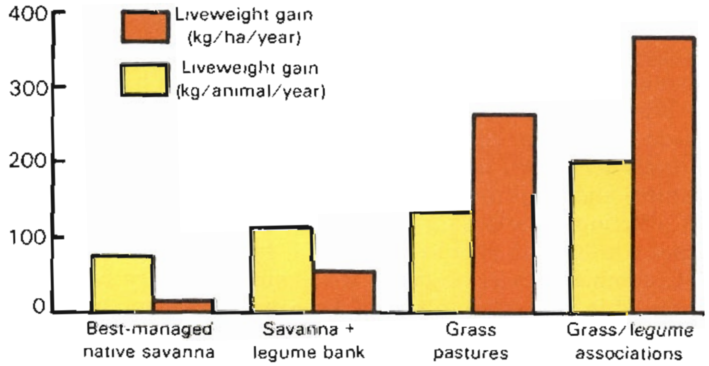


Figure 5. *Summary of 10 years of data on animal performance using various pasture systems, in Carimagua 1971-1981.*

Pasture Evaluation in Farm Systems

The set of research activities included in the third stage, pasture evaluation in farm systems, is assigned a threefold purpose within the Tropical Pastures Program. First, the objective is to survey and diagnose prevailing cattle-production systems and identify critical biological and economic constraints for efficient animal production; second, to integrate improved pastures, animal management strategies, and health schemes into relevant production systems; and third, to evaluate the potential impact of adoption of technology on beef and milk production and on benefits to be accrued by consumers and producers.

Monitoring Prevailing Farm Systems

A large-scale project known as the Economic and Technical Studies of Systems (ETES), initiated in 1977, is designed to identify and describe existing cattle-production systems in the savanna areas of tropical America. This project is carried out in collaboration with the Institute for Animal Production, University of Berlin, West Germany; the German Agency for Technical Cooperation (GTZ); the Agricultural Research Center for the Cerrados (CPAC/EMBRAPA) in Planaltina, Brazil; and the Agricultural Research Center of the North Eastern Plains (CIARNO/FONAIAP) in Maturin, Venezuela.

The ETES Project in Colombia was completed in 1980, and a final report is being prepared. The collection of technical and economic information for the ETES Project in Brazil has been concluded; these data are now undergoing final analyses. The Brazil project concentrated on seven farms in the state of Goias and five farms in Mato Grosso. Average weaning rates (i.e., more than 60%) in Brazil were substantially higher than those observed in the eastern plains of Colombia. These superior rates are attributed to the availability of better forage resources, better management, and smaller farm size—all of which probably also account for slightly higher animal weight gains of beef grazing in the Brazilian setting. In addition, fewer lowlands and a longer dry season in the Brazilian Cerrados than in the Colombian Llanos partially accounted for the relatively high adoption of introduced pastures and crop-rotation schemes by farmers.

Collection of field data from 13 farms in the ETES Project in Venezuela came to an end in late 1981. In contrast to the findings in Colombia, it was observed that extensive dairy ranching is practiced in the eastern plains of Venezuela; some one-third of all cows surveyed in 1981 were being milked.

A second phase of the ETES Project is designed to assess the effect of introducing a technology package based on improved,

Through the international pasture evaluation network, national programs are testing promising pasture grasses and legumes for adaptation to specific agroecological conditions. Here, an aspect of a regional trial in Porto Velho (Amazonia), Brazil.

legume-based pasture, mineral supplementation, restricted mating, and systematic weaning. In Colombia, such a follow-up study is being carried out on seven farms, which also were included in Phase I of the ETES Project. Sown pastures are mostly associations of *B. decumbens* with *D. ovalifolium* and *A. gayanus* with *S. capitata*. Most pastures were established in 1980-81. The study entails the taking of complete records of pasture utilization and animal performance. Collection of data will begin in 1982.

Integrating Cattle-Production Strategies

A long-term experiment at the Cerrado Center is underway to study the effect of the strategic use of improved pastures and of early weaning and different mating seasons on cow fertility. An interaction between the use of improved pastures and weaning age has clearly been shown; early weaning leads to a 25% higher calving rate when associated with the use of improved pastures during the restricted mating season.

Weight performance of calves born in this experiment was recorded from birth onward. At 1 year of age, calves weaned at 3 months of age were considerably lighter than those weaned at 5 months. Nevertheless, these differences became negligable at ages beyond 18 months. These results confirm the existence of marked compensatory growth in animals with access to improved tropical grasses.

Strategic use of small areas of sown pastures is assessed for supplementing savanna-based breeding herds.

A major line of research in pasture evaluation in farm systems centers on assessing seasonal, strategic use of small areas of sown pastures for the supplementation of savanna-based breeding herds. In the recent past, this research was conducted at the Carimagua Station in the form of a breeding-herd-systems management experiment, which was initiated in 1977 and terminated in late 1981. Sown pastures were mostly based on *B. decumbens*. Results suggest that, in terms of weight of weaned calves/cow/year, highest performance is achieved when continuous mating is used. The data show that the differences between treatments are mainly due to reproductive performance and much less to improved weight gains of the calves. Under well-managed native savanna conditions, some 25% of lactating cows were observed to re-conceive. However, when legumes were present, the percentage of lactating cows that were re-conceiving rose up to 64%. Even though the statistical analyses of these experiments have not yet been completed, it can be concluded that the availability of legumes plays a major role in improved calving rates.

Clinical photosensitization is a syndrome frequently observed in young cattle grazing on *Brachiaria decumbens*. Research has led to the development of a technique that measures the level of specific hepatic enzymes to diagnose subclinical cases. Using this technique, a close association was shown to exist between underaverage weight-gain performance of animals and the presence of subclinical photosensitization. Thus, the economic importance of this syndrome may be larger than previously expected. On the other hand, there is some evidence that photosensitization may also be related to very low levels of zinc in *B. decumbens* forage. This hypothesis is presently being tested.

Economic Implications of the Use of Improved Pastures

As the Program's technology-development efforts result in increasing numbers of germplasm materials as candidates for eventual release by national institutions, there is a concurrent increase in the need to provide information to potential adopters of the merits and drawbacks of the different technologies. To this end, the Program has engaged in an exercise to compare broad groups of improved pasture technologies, including alternative uses of forage, under the conditions of the Colombian Llanos. Using empirically derived values for such parameters as pasture-establishment costs and other investments necessary for alternative beef-production systems, a preliminary analysis based on a linear-programming model indicated (a) that the relative advantage of alternative beef-production technologies in the savannas is highly dependent on the relative price of grazing land per animal unit; (b) that investments per animal unit are relatively stable across all pasture-production technologies analyzed; (c) that, given present price structures, production alternatives based on the exclusive use of improved pastures promise only a relatively low profitability, but that the strategic use of improved pastures to solve specific production bottlenecks (viz., weaning of calves or fattening of cull-cows), provides a most attractive option from an economic point of view; and (d) that dual-purpose systems (i.e., beef and milk production) based on improved pasture technology provide an additional promising economic proposition, particularly for smaller farms.

Illustrative of the economic advantages of new pasture technology is an analysis of fattening systems on improved pastures in the Colombian Llanos. In this exercise—which was built on the availability of the results of grazing trials conducted over a period of 3 years—the internal rates of return were predicted for 6 and 12 years at constant prices for a 300-ha model farm. The value of the land was not included, assuming the producer to be the owner of the land and wishing to identify the best pasture alternative for fattening purposes. For this analysis, it was also assumed that the fattening process is initiated in the dry season with low stocking rates, but that the stocking rate is increased in the wet season by adding steers of 250-kg initial liveweight. All steers were assumed to be sent to market at the end of the rainy season. In the evaluation of different technology alternatives, fertilization regimes as recommended by CIAT were inferred. The performance of *B. decumbens* (i.e., grass alone) was used as a basis for the comparison among alternatives (pure *B. decumbens* is already in relatively widespread use).

As shown in Figure 6, the associations (1) *A. gayanus* with *S. capitata* and (2) *B. decumbens* with strips of *P. phaseoloides* and the use of (3) native savanna with strips of *P. phaseoloides* all present internal rates of return that are substantially superior to that of *B. decumbens* alone.

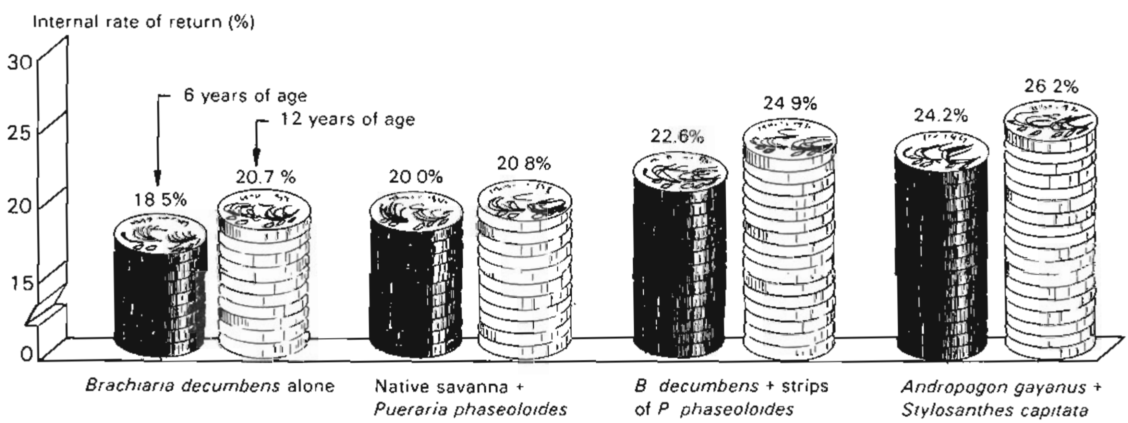


Figure 6. *Estimated profitability of fattening operations with various improved pasture-production technologies under experimental conditions, in the Llanos of Colombia, as represented by Carimagua.*

Seed Unit

THE SEED Unit was established in early 1979, initially as a 5-year project with financial support from the Swiss Development Cooperation. Its primary purposes are to provide seed-technology input to the commodity programs of the Center through advising and assisting in the production of basic seed and to play a catalytic role in getting seed of promising varieties and hybrids into the hands of agencies at the national level for multiplication. Since most of the countries in Latin America have recently stepped-up efforts to develop seed programs and have expressed a desire to receive more technical assistance from the international level, the Seed Unit places heavy emphasis on the provision of technical collaboration and seed-technology training as means to help strengthen seed activities at the national level. As the latter task requires the Seed Unit to provide technical assistance within a wide range of seed-related concerns, the Unit, by necessity, must tackle issues that go beyond the strictly commodity-based approach of the rest of CIAT.

Seed Production and Supply

Seed production at CIAT is carried out by the Station Operations Unit and by the Seed Unit. While the former assumes a major responsibility for growing the seed crop, the Seed Unit is in charge of quality control, drying, conditioning, storing, and dispatching the seed. All requests for seed are reviewed with the individual commodity programs concerned.

In 1981, seeds of promising materials of beans, rice, and tropical pastures were multiplied and distributed. In addition, inbred lines of publicly available maize materials were maintained and were supplied upon request. Promising sorghum lines for use in sorghum hybrid development and multiplication programs were received from ICRISAT and a few countries and are being maintained for further distribution on request. Two *Stylosanthes* lines were multiplied at the request of Peru. figure 1 summarizes the types and quantities of seed produced and delivered by the Seed Unit in 1981.

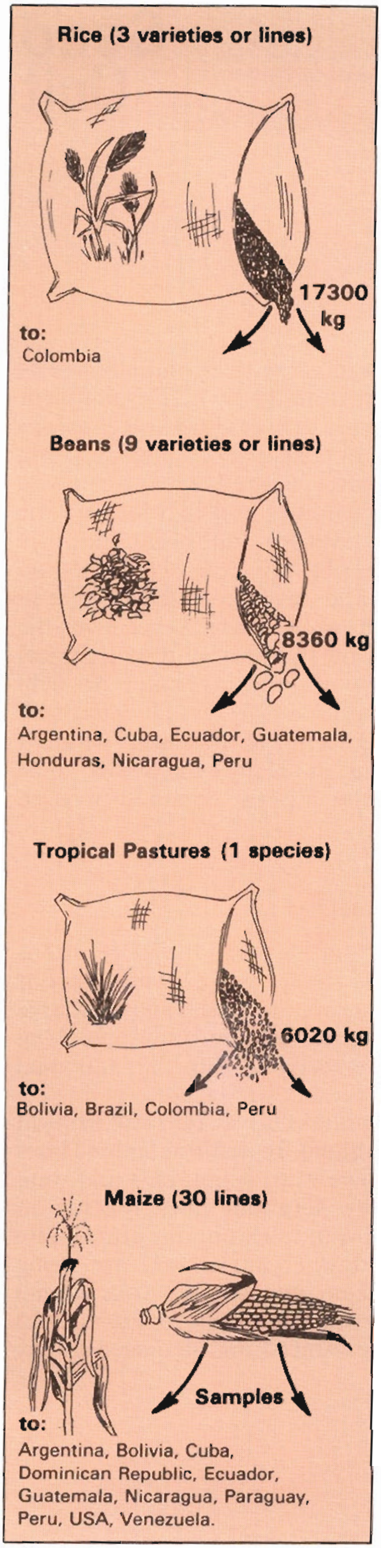


Figure 1. *In 1981, the Seed Unit distributed seed to various countries throughout the Western Hemisphere for in-country multiplication and commercial production. The figure shows the total number of lines or varieties of each species and the total quantity of seed supplied.*

Training and Workshops

The Unit offered two courses in 1981: a basic, 8-week course on seed production and technology for 30 participants from 14 countries in the Latin American region; and an advanced course in seed-quality assurance and control offered to 31 participants from 13 Latin American countries. Assistance to in-country courses and training acitivities at CIAT for the bean and rice programs were also provided.

A total of 42 leaders of national seed programs and a few representatives from seed associations and seed enterprises participated in the Seed Unit-sponsored workshop on "Program Strategies, Plans and Implementation" held at CIAT in January 1981. And 82 participants, primarily from seed enterprises and seed associations, took part in a related workshop on "Seed Enterprise Management and Marketing" held at CIAT in May 1981. Both workshops were designed to develop guidelines on seed program industry development.

Technical Collaboration

In 1981, the Seed Unit completed a review of the status of national seed programs in Latin America to determine its future direction in seed support. Only one country was found to have a highly satisfactory development of its program; five other countries were considered to be satisfactorily developing effective seed programs; 15 countries have programs that are less advanced and need considerable further attention and development; one of the 22 countries surveyed scarcely has an operational seed program. Assistance to each country will be provided in accordance with the stage of development.

A "Seed Liaison Committee" was formed with representation from Central America, CIMMYT, ICRISAT, CIP, the University of Costa Rica, and Mississippi State University to help achieve closer cooperation in seed-program development in Latin America.

The Seed Unit also provided leadership to the Central American technical subcommittees on beans, rice, sorghum, and maize.

Varietal descriptions and guidelines for production of these crops were completed during the 1981 meeting of the Central American Cooperative Program for the Improvement of Food Crops held in the Dominican Republic, and a special seed group was established to deal with research papers and seed-related matters.

To stimulate further development of seed programs on the national level, and to provide technical assistance, the small staff of the Seed Unit continued in 1981 its intensive schedule of visits to seed activities throughout the region. These travels—which included 13 countries in 1981—provide follow-up on former training participants, contribute to the development of seed-program strategies, and help in solving production and quality problems.

Network Development

After only 3 years of operation, the CIAT Seed Unit has demonstrated that its endeavors in support of seed-program developments in Latin America are filling an important vacuum in the dissemination and use of improved agricultural technology. Its very active presence has much contributed to drawing attention to the importance of improving national seed programs, and its extensive training efforts are contributing to the steady development of a personnel base in seed-production technology on the national level. A newsletter, "Semillas para América Latina," was started in 1981 and is published quarterly to assit in network cooperation. A most important recent phenomenon is the emergence of a regional network of seed professionals, many of whom are helping in Seed Unit activities. It is expected that this network—which is furthered and nurtured by the CIAT Seed Unit to the extent possible—will ultimately be able to create a momentum in favor of regionwide seed cooperation and mechanisms for the horizontal interchange of improved seed stock.

During 1981, construction of the Seed Unit facilities at CIAT were completed (right) *and the first basic seed was bagged for distribution* (left).


SEMILLERO

Scientific Training

CIAT is a center for both research and training. The training component is considered the foundation for the further development of technology transfer channels among the national and international levels. At the same time, training is the principal means by which CIAT collaborates with national programs in building up in-country capabilities for cooperative and independent agricultural research. Beyond that, CIAT is keenly aware that the international commodity research networks in the Latin American region, which have been created to support CIAT-mandated commodities, are in no small measure the direct result of the Center's extensive and persistant training efforts.

Training is offered by CIAT on a postgraduate basis in the following forms:

- Intensive courses on research for production related to CIAT commodities;
- Individualized internships that allow the training participant to specialize in a given aspect in any of the four CIAT commodities;
- Thesis internships for M.S. and Ph.D. students.

In 1981, a total of 229 professionals received training at CIAT (Table 1). The length of internships ranged from 1 to 12 months, with an average of close to 4 months.

A total of 69 of the training participants in 1981 were financed by CIAT. The remainder—except for three participants paying their own way—were financially supported by their employing institutions or by third-party institutions.

In 1981, as a reflection of CIAT's primary concern for close working relationships with collaborating institutions in Latin America and the Caribbean, as well as for reasons of sheer proximity, fully 92% of all training participants came from this region. The number of representatives from each country was as shown in Figure 1.

Some three-fourths of the training participants in 1981 received commodity-based, nondegree-related training. Most of these individuals participated in one of the seven intensive short-courses (of 4- to 12-week duration) offered by CIAT in the year. As has become common practice in the last few years, about one-third of the course participants entered individualized internships for 3 to 4 months upon completing short-course participation.

Table 1. **Professionals trained at CIAT in 1981, by training category in each commodity and support unit.**

Program or unit	Trainees (no.) Visiting research associates	Research scholars	Postgraduate research interns	Special trainees	Short course participants	Program subtotals
Commodity programs						
Beans	8	11	24		9	52
Cassava	6	3	13	14	10	46
Rice		2	17	1	6	26
Tropical pastures	7	7	22	3	5	44
Total commodity programs	21	23	76	18	30	168
Support units and others						
Audiotutorials			2	1		3
Seed production and technology		1	3		52	56
Station operation management			1			1
Total support units and others	1	1	6	1	52	61
Total 1981	22	24	82	19	82	229

Table 2 **Sponsored and cosponsored conference events held at CIAT during 1981.**

Title	Participants (no.)
Seminar on Research Strategies and Agricultural Policies CIAT/CIMMYT/Kettering), 14-16 January	39
Workshop on Seed Strategy, Planning and Management, 19-23 January	39
8th Meeting of the Latin American Society for Plant Physiology and XIII Meeting of the Colombian Society for Weed Control and Plant Physiology (COMALFI), 28-30 January	160
Workshop on Biological Nitrogen Fixation Technology (CIAT/NifTAL/ICRISAT), 9-13 March	155
Workshop on Nitrogen Cycling (SCOPE/UNDP), 16-21 March	55
Consultation Seminar on Research and Training Strategies at CIAT, 7-9 April	30
3rd Workshop on International Bean Yields Adaptation Nurseries, 22-24 April	58
Workshop on Seed Enterprise Management and Marketing, 18-22 May	97
4th Conference of International Rice Testing Program for Latin America, 10-13 August	49
5th International Conference of Plant Bacteriologists, 17-21 August	110
Workshop for U.S.A. Bean Breeders, 23-26 November	17
Total	809

The total number of professionals having received training at CIAT since the 1970s now has surpassed 2000. Naturally, there has been some attrition of CIAT-trained professionals in collaborating national institutions. Nevertheless, it is felt that a critical mass of trained scientists is available and that, in the future, increasing emphasis can be placed on relatively long-term, especially degree-related, CIAT training to assist national institutions in their efforts to further upgrade the scientific level of their personnel. It is in this context that CIAT provided thesis-research opportunities to 23 students working toward their master's degrees in 1981. In addition, 15 students conducted Ph.D. thesis research at CIAT; most of the Ph.D. students, however, came from developed countries where they pursue their academic studies with collaborating universities.

Assistance to in-country training courses again increased in 1981 as part of CIAT's efforts to help national research development institutions train extension leaders in the use of new varieties and cultural practices. CIAT professionals help national institutions and conduct the courses and also provide relevant training materials for the courses. CIAT assistance to in-country courses is designed to be catalytic in nature in that direct assistance is only provided until the respective national institutions are in a position to continue the course series on their own. In 1981, in-country bean courses were assisted in Colombia, Chile, Cuba, Guatemala, Nicaragua, and Peru; rice-production courses were supported in Honduras and Panama, and a cassava-production course was assisted in Colombia.

Eleven conferences —including workshops, seminars, and meetings— were held or cosponsored by CIAT in 1981 (Table 2) to help in the exchange of knowledge and agreement of strategies in CIAT's commodity-research networks. Other noncommodity-specific conferences reviewed the state of the art in specific research fields.

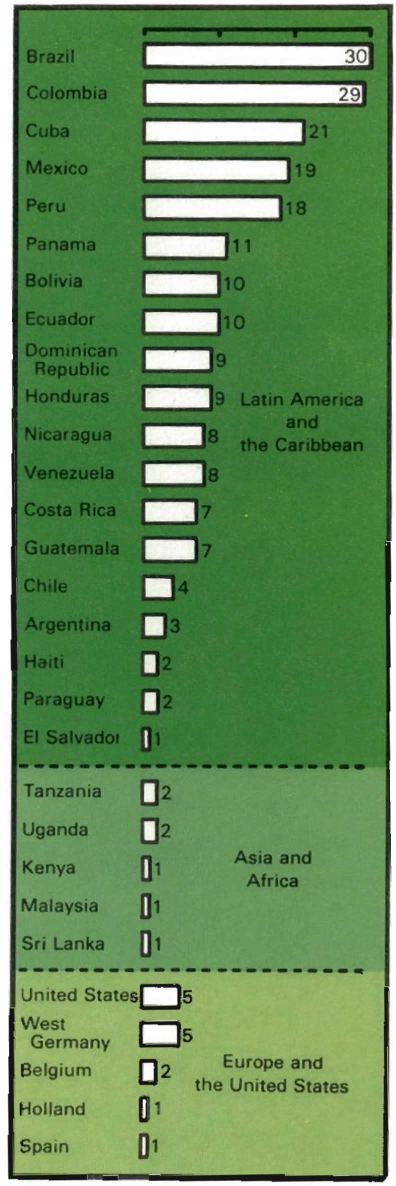


Figure 1. *Professionals trained at CIAT in 1981, by country of origin.*

Financial Statements

Price Waterhouse & Co.

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

March 8, 1982

REPORT OF INDEPENDENT ACCOUNTANTS

To the Board of Trustees of

Centro Internacional de Agricultura
Tropical (CIAT)

In our opinion, the accompanying balance sheets and the related statements of revenue and expenditures and unexpended funds present fairly the financial position of Centro Internacional de Agricultura Tropical (CIAT) at December 31, 1981 and 1980 and the results of its operations for the years then ended, in conformity with generally accepted accounting principles consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our examination for the year ended December 31, 1981 also encompassed the schedule of comparison of approved budget and actual expenditures which is presented as supplementary information, and, in our opinion, this schedule presents fairly the information shown therein.

Price Waterhouse

Notes to Financial Statements

NOTE 1—ACCOUNTING POLICIES

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

Inventories

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

Fixed assets

Fixed assets are recorded at cost.

Depreciation

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

NOTE 2—FOREIGN EXCHANGE

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

	P/$1	
Peso balances included in current assets and current liabilities	59.07	Year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	54.49	Average monthly rate of exchange applicable to sales of dollars

NOTE 3—OPERATIONS

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

BALANCE SHEET

(Expressed in thousands of U.S. dollars)

ASSETS	December 31 1981	December 31 1980
CURRENT ASSETS		
Cash	1,484	1,471
Accounts receivable		
Donors	273	201
Employees	275	172
Others	1,268	1,372
	1,816	1,745
Inventories	1,335	1,290*
Prepaid expenses	69	5
Total current assets	4,704	4,511
FIXED ASSETS		
Equipment	3,682	3,357
Aeroplane	676	676
Vehicles	1,993	1,441*
Vehicles (replacements) in transit	523	840
Furnishings and office equipment	1,286	1,247
Buildings	6,929	6,415
Other	201	218
Total fixed assets	15,290	14,194
Total assets	19,994	18,705

LIABILITIES AND FUND BALANCES	December 31 1981	December 31 1980
CURRENT LIABILITIES		
Bank overdrafts	44	73
Accounts payable	2,371	2,601
Total current liabilities	2,415	2,674
GRANTS RECEIVED IN ADVANCE	407	305
FUND BALANCES		
Invested in fixed assets	15,290	14,194*
Unexpended funds (deficit)		
Core		
Unrestricted	(100)	
Working fund	603	860
Capital grants	265	198*
Special projects		
Donors	1,217	641
Other	(103)	(167)
	1,882	1,532
Total fund balances	17,172	15,726
Total liabilities and fund balances	19,994	18,705

**Reclassified for comparative purposes.*

The notes on page 104 are an integral part of the financial statements.

STATEMENT OF REVENUE AND EXPENDITURES AND UNEXPENDED FUNDS

(Expressed in thousands of U.S. dollars)

	December 31	
	1981	1980
Revenue		
Core		
Operating grants		
Unrestricted	9,283	14,122
Restricted	6,358	
Working fund grant		96
Capital grants	678	551
Total Core	16,319	14,769
Special projects	2,732	1,977
Earned income	540	582
Total revenue	19,591	17,328
Expenditures		
core programs		
Crop research	5,554	4,950
Land resources research	3,949	3,563
International cooperation	2,165	2,317
Administration expenses	1,343	1,181
General operating costs	3,200	2,350
Total Core programs	16,211	14,361
Special projects	1,934	1,773
Fixed assets	1,096	1,763*
Total expenditures	19,241	17,897
Excess of revenue over expenditures		
Operating grants	(100)	(7)
Working fund	70	446
Capital grants	(418)	(1,212)*
Special projects	798	204*
	350	(569)
Transfers between funds		
From working fund	(327)	(560)
From special projects	(158)	
To capital grants	485	560
	350	(569)
Unexpended funds at beginning of year	1,532	2,101*
Unexpended funds at end of year (see balance sheet)	1,882	1,532

**Reclassified for comparative purposes.*

The notes on page 104 are an integral part of the financial statements.

SUPPLEMENTARY INFORMATION: COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES

(Expressed in thousands of U.S. dollars)

	Core unrestricted		Restricted core		Capital	
	Approved budget	Actual	Approved budget	Actual	Budget	Actual
Crops research						
Office of the Director	83	59	241	190		
Beans	1,226	1,117	619	505		
Cassava	1,089	1,022	602	691		
Rice	330	330	294	270		
Genetic resources	50	50	276	245		
Research services	148	129	214	177		
Station operations	301	298	436	472		
	3,227	3,005	2,682	2,550		
Land resources research						
Office of the Director	71	54	200	171		
Tropical pastures	990	990	1,875	1,692		
Carimagua	250	239	281	280		
Data services	228	232	254	293		
	1,539	1,515	2,610	2,436		
International cooperation						
Office of the Director			183	135		
Training and conferences	544	544	354	240		
Communication support	330	330	624	484		
Documentation services	220	220	307	212		
	1,094	1,094	1,468	1,071		
Administration						
Board of Trustees	9	10	43	48		
Office of the Director General	46	31	217	159		
Controller	80	70	374	358		
Executive officer	116	110	546	556		
	251	221	1,180	1,121		

—Continued

Supplementary Information - *Continued*

General operating expenses						
Physical plant	199	179	927	912		
Motor pool	148	165	694	849		
General expenses	162	179	762	914		
	509	523	2,383	2,675		
Other —Contingency	30		138			
Total Core	6,650	6,358	10,461	9,853		
Capital						
Fixed assets					976	1,096
Analysis of variances						
Underfunding		292		708		
Deficit carried forward				(100)		
Transferred from special projects funds						(158)
Transferred from working fund						(327)
Surplus transferred to unexpended funds						365
		292		608		(120)

Senior and Professional Staff

OFFICE OF THE DIRECTOR GENERAL

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

Assistants
Cecilia Acosta, Administrative Assistant

ADMINISTRATION

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

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

Associates
Camilo Alvarez, M S., Administrative Associate

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

Food and Housing

General Administrative Services staff
Eduardo Fonseca, Head

Human Resources

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

Assistants
Germán Arias, Abog., Attorney, Personnel Office

Maintenance Services

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

Assistants
Mario Cadena, Electrical Section
Marvin Heenan, Head, Motor Pool

Supplies

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

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

CONTROLLER'S OFFICE

Senior staff
Andrew V Urquhart, F.C.A., Certified Accountant, Controller

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

Assistants
* Gregorio Bedoya, C.P., Treasurer (stationed in Carimagua)
Alexis Corrales, Treasurer (stationed in Carimagua)
Jaime Cumba, Budget Assistant
* Mauricio Lozano, M.B.A., Assistant Controller
César Moreno, C.P., Accountant
Marino Rengifo, Cashier

CROPS RESEARCH

Senior staff
Douglas R. Laing, Ph.D., Director

BEAN PROGRAM

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

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

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

Postdoctoral fellows
Michael Dessert, Ph.D., Plant Breeding

*Left during 1981.
**On sabbatical leave

Visiting research associates

- * Robin Buruchara, M.S., Plant Pathology
- Julia Kornegay, M.S., Breeding
- * Deborah Mulindwa, M.S., Breeding Pathology
- * Theresa Sengooba, M.S., Virology

Research associates

- José Ariel Gutiérrez, M.S., Plant Breeding
- Carlos Jiménez, M.S., Plant Breeding
- Nohra R. de Londôño, Ing. Agr., Economics
- Jorge Ortega, M.S., Agronomy

Research assistants

- * Alfredo Acosta, Ing. Agr., Entomology
- Bernardo Alzate, Ing. Agr., Agronomy
- * Carlos Bohórquez, Ing. Agr., Agronomy
- Horacio Carmen, Ing. Agr., Plant Pathology
- Mauricio Castaño, Ing. Agr., Virology
- Jesús A. Castillo, Ing. Agr., Physiology
- Fernando Correa, Ing. Agr., Plant Pathology
- Aurora Duque, Ing. Agr., Microbiology
- Myriam C. Duque, Lic. Mat., Economics
- Oscar Erazo, Ing. Agr., Agronomy
- Diego Fonseca, Ing. Agr., Physiology
- Jorge E. García, Ing. Agr., Entomology
- * Luis Hernández, Ing. Agr., Plant Breeding
- Oscar Herrera, Ing. Agr., Economics
- Carlos Mantilla, Ing. Agr., Entomology
- Nelson Martínez, Ing. Agr., Agronomy
- Gustavo Montes de Oca, Ing. Agr., Agronomy
- Gerardo Tejada, Ing. Agr., Agronomy
- * Silvio Viteri, Ing. Agr., Microbiology
- * Hugo Zapata, Ing. Agr., Agronomy

CASSAVA PROGRAM

Senior staff

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

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

Visiting scientists

Mabrouk El-Sharkawy, Ph.D., Plant Physiology

Visiting specialists

Ewald Sieverding, Ph.D., Soil and Plant Nutrition

Postdoctoral fellows

Upali Jayasinghe, Ph.D., Virology

Visiting research associates

- * Zainol Abd Azis, M.S., Physiology
- * Benhard Lohr, M.S., Entomology
- Jan Margaret Salick, M.S., Entomology

*Left during 1981.

* Hendrick Veltkamp, M.S., Physiology
* Robert Zeigler, M.S., Plant Pathology

Research associates
Alvaro Amaya, M.S., Germplasm
Rafael Orlando Díaz, M.S., Economics
Rafael Alberto Laberry, M.S., Plant Pathology
Benjamín Pinedo, M.S., Plant Pathology
Jorge Santos, M.S., Utilization
Octavio Vargas, M.S., Entomology

Research assistants
Bernardo Arias, Ing. Agr., Entomology
Eitel Adolfo Burckhardt, Lic. Biol., Soils
Luis Fernando Cadavid, Ing. Agr., Soils
Fernando Calle, Ing. Agr., Soils (stationed in Carimagua)
Ernesto Celis, Ing. Agr., Agronomy
Carolina Correa, Lic. Econ., Economics
Julián Hernández, Ing. Agr., Soils (stationed in Carimagua)
Julio Eduardo Holguín, Ing. Agr., Physiology
Diego Izquierdo, Lic. Econ., Economics
Gustavo Jaramillo, Ing. Agr., Agronomy
Lucy Kadoch, Lic. Biol., Physiology
Javier López, Ing. Agr., Cultural Practices
Pedro Millán, Ing. Agr., Germplasm
Germán E. Parra, Ing. Agr., Physiology
Edgar Salazar, Ing. Agr., Soils (stationed in Carimagua)
Mauricio Valdivieso, Zoot., Utilization
* Ana Milena Varela, Lic. Biol., Entomology
Ana Cecilia Velasco, Clin. Lab., Plant Pathology

RICE PROGRAM

Senior staff
Joaquín González, M.S., Agronomist, Coordinator

Sang-Won Ahn, Ph.D., Plant Pathologist, Plant Pathology
Peter R. Jennings, Ph.D., Plant Breeder, Plant Breeding
César Martínez, Ph.D., Plant Breeder, Plant Breeding
Manuel Rosero, PhD., Plant Breeder, IRRI Liaison Scientist
Hector Weeraratne, Ph.D., Plant Breeder, Plant Breeding

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

Research associates
Marco Perdomo, Ing. Agr., Agronomy

Research assistants
Luis Eduardo Berrio, Ing. Agr., International Trials
Luis Eduardo Dussán, Ing. Agr., Plant Breeding
Yolanda Cadavid de Galvis, Ing. Agr., Agronomy
Jenny Gaona, Ing. Agr., International Trials
Luis Ernesto García, Ing. Agr., Plant Breeding
Luis Octavio Molina, Ing. Agr., Plant Breeding
Eliseo Nossa, Ing. Agr., Plant Breeding
Miguel Eduardo Rubiano, Ing. Agr., Plant Pathology
Edgar Tulande, Ing. Agr., Plant Pathology

*Left during 1981.

RESEARCH SUPPORT

Genetic Resources

Senior staff
* Leonard S. P. Song, Ph.D., Germplasm Specialist, Head
William M. Roca, Ph.D., Physiologist, Head

Visiting research associates
* Paul Gepts, Ir. Agr., Germplasm (Beans)
Thierry Vanderborght, Ir. Agr., Germplasm (Beans)

Research associates
Germán Alvarez, M.S., Germplasm (Forage)
Rigoberto Hidalgo, M.S., Germplasm (Beans)

Research assistants
Javier Narváez, Ing. Agr., Physiology
Jorge Alberto Rodríguez, Ing. Agr., Physiology
Hember Rubiano, Ing. Agr., Germplasm (Beans)
Hugo H. Zapata, Ing. Agr., Germplasm (Beans)

Laboratory Services

Senior staff
* Robert Luse, Ph.D., Biochemist, Head

Research associates
Octavio Mosquera, M.S., Analytical Services

Research assistants
* María Eugenia Cantera, Lic. Quim., Nutrition
Charles McBrown, Tec. Elec., Intruments Maintenance
Roberto Segovia, Ing. Agr., Greenhouses/Landscaping

Experimental Stations Operations

Senior staff
Alfonso Díaz-Durán, P.E., Agricultural Engineer, Superintendent

Research assistants
Xavier Carbonell, M.S., Palmira Station
Xavier Castillo, Ing. Agric., Palmira Station
Ramiro Narváez, Ing. Agric., Head, Quilichao Substation
Carlos Otero, Ing. Agr., Palmira Station
Rómulo Pérez, Ing. Agric., Head, Popayan Substation

LAND RESOURCES RESEARCH

Senior staff
Gustavo A. Nores, Ph.D., Director

Associates
Uriel Gutiérrez, M.S., Associate Administrator

TROPICAL PASTURES PROGRAM

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

Eduardo Aycardi, Ph.D., Animal Health Specialist, Animal Health
Rosemary Bradley, Ph.D., Soil Microbiologist, Microbiology
Mario Calderón, Ph.D., Entomologist, Plant Entomology

*Left during 1981.

Walter Couto, Ph.D., Soil Scientist, Pasture Development (stationed in Brasilia, Brazil)

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

Bela Grof, Ph.D., Forage Agronomist, Agronomy (stationed in Carimagua)

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

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

John W. Miles, Ph.D., Plant Breeder, Forage Breeding/Agronomy

C. Patrick Moore, Ph.D., Animal Scientist, Cattle Production Systems (stationed in Brasilia, Brazil)

Esteban A. Pizarro, Ph.D., Agronomist, Agronomy/Regional Trials

José G. Salinas, Ph.D., Soil/Plant Nutritionist, Soil and Plant Nutrition

Rainer Schultze-Kraft, Dr. agr., Agronomist, Germplasm Collection and Evaluation

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

Luis E. Tergas, Ph.D., Agronomist, Pasture Productivity and Management

Derrick Thomas, Ph.D., Forage Agronomist, Agronomy (stationed in Brasilia, Brazil)

Raúl R. Vera, Ph.D., Nutritionist, Cattle Production Systems

Visiting scientists

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

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

* Nobuyoshi Maeno, Ph.D., Pasture Productivity and Management

* Robert Reid, Ph.D., Plant Introduction

* A. Sheldon Whitney, Ph.D., Soil and Plant Nutrition

Visiting specialists

* Rolf Minhorst, Dr. agr., ETES Project (stationed in Brasilia, Brazil)

Cristoph Plessow, Dipl. Ing. Agr., ETES Project (stationed in Maturin, Venezuela)

Postdoctoral fellows

Pedro J. Argel, Ph.D., Seed Production

*L. Antonio Carrillo, Dr. agr., Economics, ETES Project

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

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

Ruprecht Schellenberg, Dr. agr., Animal Science/Economics (stationed in Panama)

Carlos Seré, Dr. agr., Economics/ETES Project

Visiting research associates

* Elke Boehnert, M.S., Pasture Quality and Nutrition

Gerhard Keller-Grein, M.S., Germplasm

Martin Schneichel, M.S., ETES Project (stationed in Puerto Gaitán, Colombia)

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

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

Research associates

Miguel Angel Ayarza, M.S., Soil Microbiology

Edgard Burbano, M.S., Seed Production (stationed in Carimagua)

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

Rodolfo Estrada, M.S., Economics

Rubén Darío Estrada, M.S., Economics

Libardo Rivas, M.S., Economics

* Fabio Nelson Zuluaga, M.S., Animal Health (stationed in Carimagua)

Research assistants

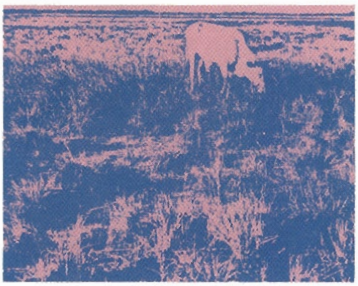
Amparo de Alvarez, Ing. Agr., Plant Pathology

Guillermo Arango, Lic. Biol., Entomology

Hernando Ayala, D.V.M.Z., Cattle Production Systems (stationed in Carimagua)

*Left during 1981.

**On sabbatical leave.



Gustavo Benavides, Ing. Agr., Germplasm
Gerfried Carlos Buch, Ing. Agr., Agronomy (stationed in Carimagua)
Raúl Botero, D.V.M.Z., Cattle Production Systems (stationed in Carimagua)
Arnulfo Carabaly, Ing. Agr., Agronomy, Regional Trials
* Rubén Darío Cabrales, Zoot., Cattle Production Systems (stationed in Carimagua)
Javier Asdrúbal Cano, Lic. Econ., Administrative Assistant to the Coordinator
Manuel Coronado, Ing. Agr., Legume Improvement
Martha Lucía Escandón, Ing. Agr., Forage Breeding/Agronomy
Carlos Escobar, Ing. Agr., Soil and Plant Nutrition
Luis H. Franco, Ing. Agr., Pasture Development (stationed in Carimagua)
Manuel Arturo Franco, Ing. Mec., Systems Analyst, Office of the Coordinator
Duván García, Ing. Agr., Seed Production
Obed García, D.V.M., Animal Health
Hernán Giraldo, Ing. Agr., Agronomy
Ramón Gualdrón, Ing. Agr., Soil and Plant Nutrition
Francisco J. Henao, D.V.M.Z., Animal Health (stationed in Carimagua)
Phanor Hoyos, Zoot., Pasture Quality and Nutrition
Carlos Humberto Molano, Ing. Agr., Forage Breeding/Agronomy
Dazier Mosquera, Ing. Agr., Soil Microbiology (stationed in Carimagua)
Gloria Navas, Ing. Agr., Pasture Development (stationed in Carimagua)
Edgar Quintero, Ing. Agr., Plant Pathology/Entomology (stationed in Carimagua)
Fabiola de Ramírez, Lic. Bact., Soil Microbiology
Raimundo Realpe, Ing. Agr., Agronomy (stationed in Carimagua)
Bernardo Rivera, D.V.M., Animal Health
Manuel Sánchez, Ing. Agr., Seed Production
* José Ignacio Sanz, Ing. Agr., Soil and Plant Nutrition
Celina Torres, Ing. Agr., Plant Pathology
* Gustago Urrea, Ing. Agr., Plant Pathology
Fernán Alberto Varela, Ing. Agr., Entomology
Jaime Velásquez, Zoot., Pasture Productivity and Management (stationed in Carimagua)
Bernardo Velosa, Ing. Agr., Forage Breeding/Legume Improvement (stationed in Carimagua)

SPECIAL STUDIES

IFDC/CIAT Phosphorus Project

Senior staff
Larry L. Hammond, Ph.D., Soil Chemist, Head

Jacqueline A. Ashby, Ph.D., Sociologist, Sociology
Luis Alfredo León, Ph.D., Soil Chemist, Soil Chemistry

Visiting research associates
David J. Harris, M.S., Soils, IFDC/Benchmark Soils Project

Research assistants
Germán Montes de Oca, Ing. Agr., Agronomy
Carlos Arturo Quirós, Ing. Agr., Agronomy
Luis Guillermo Restrepo, Ing. Agr., Agronomy (stationed in Carimagua)

*Left during 1981.
**On sabbatical leave.

RESEARCH SUPPORT

Data Services

Senior staff
Leslie C. Chapas, Dipl. Math. Stat., Biometrician, Head

Visiting scientists
* Thomas T. Cochrane, Ph.D., Land Resources Evaluation
Peter Jones, Ph.D., Agroecological Studies

General Administrative Services staff
María Cristina Amézquita de Quiñones, Dipl. Math. Stat., Head, Biometrics

Visiting research associates
* Luis Fernando Sánchez, Ing. Agr., Land Resources Evaluation

Research associates
James Harbey García, M.S., Biometrics
José Eduardo Granados, M.S., Biometrics
Gloria Quintero, Ing. San., Computing
* Jorge Augusto Porras, Ing. Quim., Computing

Research assistants
María del Rosario Henao, Ing. Sist., Computing
Camilo Jordán, Computing
Oscar L. Quevedo, Ing. Sist., Computing
Julián E. Rengifo, Ing. Sist., Computing
Alfredo Rojas, Biometrics
José Alfredo Saldarriaga, Ing. Sist., Biometrics

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Associates
Jorge Peña, M.S., Administrative Associate

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Audiotutorials

Associates
Cornelio Trujillo, M.S., Supervisor
María Lucía de Posada, M.S., Editorial Services

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Fernando Fernández, Ing. Agr., Production
Cilia Fuentes de Piedrahita, Ing. Agr., Production
Héctor Fabio Ospina, Ing. Agr., Production
Carlos Alberto Valencia, Ing. Agr., Production

Graphic Arts and Production

General Administrative Services staff
Walter Correa, Ph.D., Chemist, Head

*Left during 1981.

Associates
Alvaro Cuéllar, Photography
Carlos Rojas, Graphic Design

Assistants
Didier González, Graphic Design
Carlos Vargas, Graphic Design

Publications

Senior staff
Susana Amaya, Ph.D., Editor/Writer, Editorial Services

Visiting editors
* Matilde de la Cruz, Editorial Services
Paul Gwin, M.S., Editorial Services

Associates
Ana Lucia de Román, Ing. Agr., Editorial Services
Francisco Motta, M.S., Editorial Services

Assistants
María Lida Cabal, Editorial Services

Public Information

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

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Senior staff
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Associates
* Alejandro Jiménez, Ing. Agr., Documentation Center
Jorge López, Bibliographic Services

Assistants
Fabiola Amariles, Lic. Educ., Agricultural Economics Documentation
Stella Gómez, Lic. Bibl., Reference Services
Carlos P. González, Ing. Agr., Bean Documentation
Francy González, Ing. Agr., Cassava Documentation
Mariano Mejía, Lic. Educ., Tropical Pastures Documentation
Lynn Menéndez, Translations
Piedad Montaño, Adquisitions
Hernán Poveda, Lic. Bibl., Technical Processing (Serials)
Himilce Serna, Lic. Bibl., Technical Processing (Books)

*Left during 1981.

TRAINING AND CONFERENCES

Senior staff
Fernando Fernández, Ph.D., Soil Scientist, Coordinator

General Administrative Services staff
David Evans, Administrator, Conferences

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

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

Associates
Carlos Dominguez, M.S., Cassava
Carlos Flor, M.S., Beans
Elias Garcia, Ing. Agr., Rice
Marceliano López, M.S., Beans
Alberto Ramirez, M.S. Tropical Pastures
Jesús Reyes, M S., Cassava
Eugenio Tascón, Ing. Agr., In-country Training/Rice

Assistants
Carlos Suárez, B.S., Orientation

SEED UNIT

Senior staff
Johnson E. Douglas, M.S., Seed Specialist, Head

Federico Poey, PhD., Seed Specialist, Seed Production

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

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

CIMMYT/CIAT ANDEAN REGION MAIZE PROJECT

Senior staff
Gonzalo Granados, Ph.D , Entomologist, Head

James Barnett, Ph D., Plant Breeder, Andean Regional Services

Research assistants
Edgar Castro, Ing. Agr., Breeding

CIAT Report 1982

Fritz Kramer, Text
Cynthia L. Garver, Design, Managing Editor
Susana Amaya, Editor, Spanish Edition
Alexandra Walter, Assistant Editor, English and Spanish Editions; Figure Design
Alejandro Jiménez, Translator (English to Spanish)
Walter Correa, Head, Graphic Arts and Production
Beatriz Davis de Vallejo, Word Processing
Yolanda de González, Head, Typesetting
Addiana Loaiza, Typesetting
Mariella Quebrada, Typesetting
Carlos Rojas, Head, Graphic Arts
Camilo Oliveros, Graphic Arts
Oscar Idárraga, Graphic Arts
Alvaro Cuéllar, Head, Photography
Diego Parra, Photography
Ancizar Chamorro, Photomechanics