02E1-77
September 1978

Annual Report
1977

Centro Internacional de Agricultura Tropical, CIAT

Apartado Aéreo 67-13 Cali, Colombia, S. A.

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Foreword

1977 was a landmark year in the history of CIAT. It was a year of *consolidation* of previous program modifications, making possible well-defined strategies with increased staff and expanded facilities; *confirmation* of the appropriateness of these strategies through the positive results of a high level, external review; and *clarification* of philosophy and objectives of the Center. Thus, 1977 represented a transition year from building and fine-tuning research and training programs and philosophies to a new period of stability and productivity.

CIAT programs had individually been through intensive internal and external reviews during the past several years. In the Beef Program particularly, and also in the Training Activities, these resulted in major changes in direction. The uncertainties and program changes consequent to this process, resulted in a sufficient turnover in staff and delays in recruitment that the numbers of senior staff remained virtually static during 1975 and 1976, in spite of CIAT, as a young institution, still being in a planned expansion phase. This changed in 1977, with a net gain of 11 senior staff along with a rapid increase in the numbers of visiting scientists, postdoctoral fellows and support personnel. The procurement and development of the CIAT-Quilichao substation on acid, infertile soils south of Cali, and the development of a new, co-management relationship with the Instituto Colombiano Agropecuario for research on its station at Carimagua in the Colombian Llanos, greatly improved the availability of research facilities. The outposting of staff to the Colombian Llanos, Brazil, Costa Rica and the Philippines also consolidated efforts to increase off-site research and improve outreach functions.

The Technical Advisory Committee (TAC) of the CGIAR is responsible for conducting an in-depth review of each Center in the international agricultural research system every five years. The TAC Quinquennial Review of CIAT was conducted in 1977. That, together with the review by the TAC of farming systems research across centers was very supportive of the objectives, strategy and accomplishments of CIAT.

The culmination of the earlier series of reviews by the in-depth, five-year review provided an opportunity and stimulus for a restating of CIAT's objectives to better reflect the policy decisions taken by its Board of Trustees during the evolution of this Center. The new statement reads as follows:

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

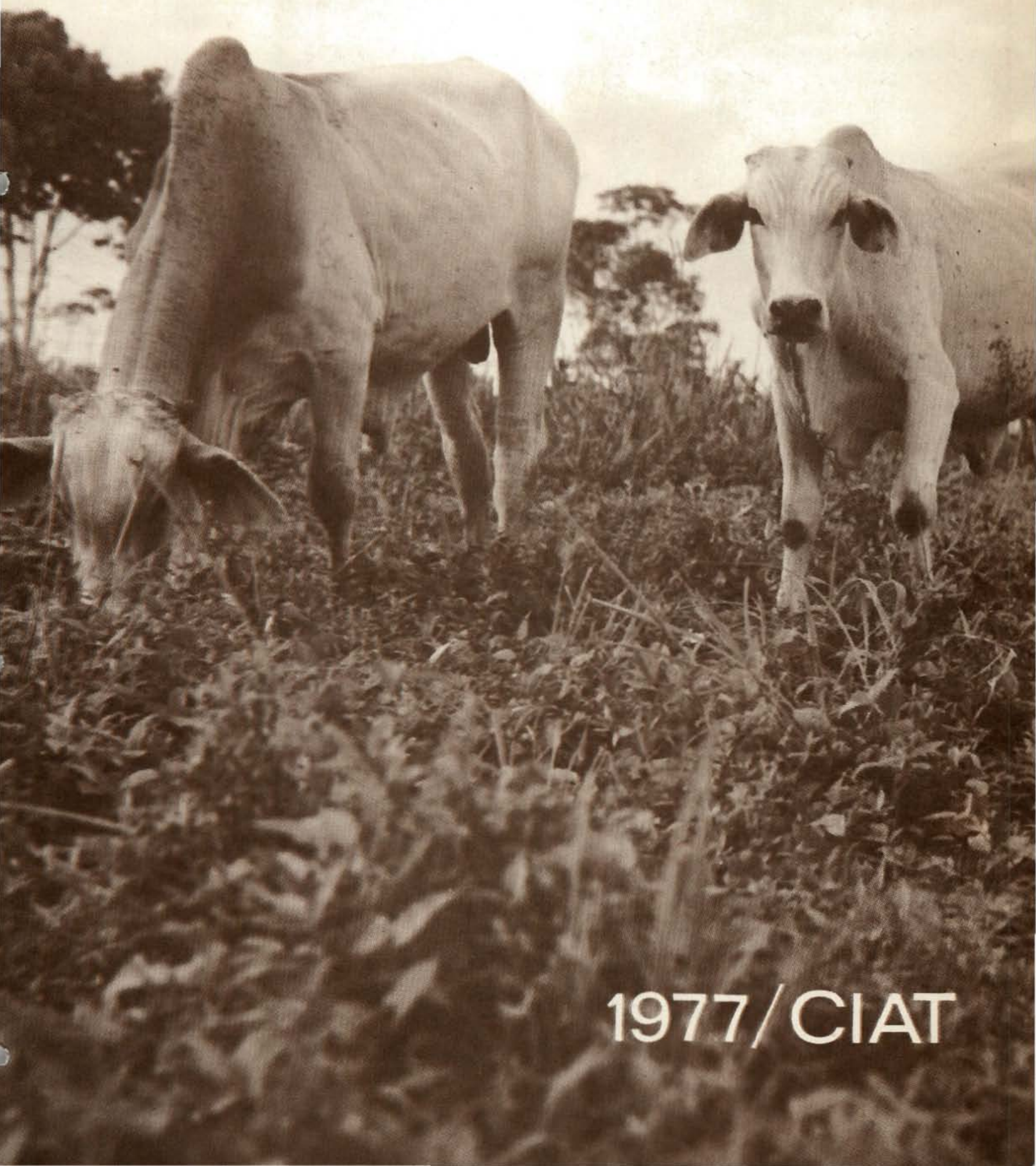
This makes clear that the product of CIAT is improved technology and identifies national research institutions as the chief clients and collaborators in the development of this technology and its local adaptation and transfer to farmers. Naming of the poor consumers and producers as special target beneficiaries greatly affects the nature of the technology being produced and transferred and makes clear that CIAT has human welfare concerns as well as production goals.

CIAT has developed programs which translate its concerns for poor consumers and producers into concrete action through appropriate commodity selection and technology design. The commodities included in CIAT's mandate insure that the low-income sector among consumers will benefit most through increased productivity resulting ,from improved technology. By adopting a philosophy stressing minimum inputs, and by close collaboration with national programs emphasizing on-farm testing, CIAT is endeavoring to insure that this technology will be valid and feasible on farms with limited resources.

The results achieved in the various programs in 1977, as summarized in this report, encourage us to believe we are making excellent progress towards achieving these objectives.

John L. Nickel
Director General

Beef program



1977/CIAT

Beef Program

The reorientation of the Beef Program was completed during the year. An interdisciplinary team was assembled for a synchronized attack at overcoming the soil-plant-animal barriers preventing increases in beef production in acid soil ecosystems. The Program impact area was defined, and a geographical study of the 850 million hectares of Oxisols and Ultisols of tropical America is in progress. A research and transfer of technology strategy was developed, and operations at three principal research stations at CIAT-Quilichao, Carimagua and Brasilia are underway. A regional testing network with locations throughout the impact area is being organized to initiate extensive testing in 1978.

The Program's objective is to develop and transfer effective low input technology for increasing beef production in acid, infertile soils of tropical America, primarily through improved, year-round pasture production, supplemented by economically-sound animal management and health practices. The following advances illustrate progress during 1977 towards attaining this objective.

The genetic base of CIAT's tropical forage germplasm collection adapted to acid soil ecosystems was doubled this year reaching a total of 3400 accessions. The number of grass and legume accessions under field evaluation in clipping or grazing trials was broadened considerably. At Carimagua, for example, the number of forage legume accessions tested under grazing, increased from six accessions of one species last year to 30 accessions of several species in 1977.

Specific selection criteria for forage legumes and grasses were established and the most promising germplasm was ranked according to its potential for cultivar release in specific ecosystems.

For the high stress savanna conditions of Carimagua, characterized by extreme acid soil infertility and devastating disease and insect attacks on legumes, several accessions of *Stylosanthes capitata, Zornia* sp. and *Desmodium ovalifolium* showed most promise among the legumes, while *Andropogon gayanus* appeared the most promising grass species. *S. guianensis* is no longer considered promising for this ecosystem because of disease or insect susceptibility and/or poor seed production potential.

For the somewhat less stressful climatic, edaphic and pest conditions at CIAT-Quilichao, *S. guianensis* 136 and 184 plus *Centrosema* hybrid 1733 appeared most promising and are at advanced stages of testing. Swards of these legumes mixed with *A. gayanus, Panicum maximum* or *Brachiaria decumbens* produced sustained liveweight gains of 561 g/steer/day at a stocking rate of 2.3 animals/ha during an unusually extended dry period which caused severe weight losses in adjacent pastures. Seed production increase of the most promising germplasm has proceeded accordingly.

CIAT's *Rhizobium* strain collection for forage legumes also doubled during 1977. Effective inoculation techniques with or without lime or rock phosphate pelleting were developed for most of the promising accessions.

Several promising legume and grass accessions were found to have extremely low requirements for phosphorus, coupled with an excellent tolerance to aluminum levels considered toxic for most cultivated plants.

Direct application of rock phosphates with low to medium reactivity typical of most Latin American deposits, performed equally as well or better than superphosphate when applied to Carimagua Oxisols growing aluminum-tolerant grass species. Considering that the cost of a kilogram of P_2O_5 as rock phosphate is one-third or one-quarter that of superphosphate, the use of these materials appears to be an important component of the emerging low-input technology.

New pasture establishment and maintenance systems featuring low-cost, space-planting techniques, and 2.5-meter wide-strip planting of grass-legume mixtures such as *Brachiaria decumbens* and *Pueraria phaseoloides* showed significant promise. Systems for conventional and nonconventional pasture establishment methods were initiated at Quilichao, Carimagua and Brasilia.

Long-term pasture utilization and herd systems studies and their economic evaluation showed that only very limited beef production levels are possible by grazing native savanna without improved, persistent pastures. Blood parameters of Zebu breeding cows grazing native savanna underscored the need for improved nutrition.

Evaluation of the Herd Systems trial, completed at Carimagua in May 1977, provided excellent information on herd performance on native savannas during four reproductive years. The most profitable improvement under such conditions was direct mineral supplementation. Salt supplementation, early weaning and the use of *Melinis minutiflora* pastures during the wet season are not profitable alternatives.

Among other improved grasses, *Hyparrhenia rufa* has failed under grazing because of its relatively high phosphorus and potassium requirements and lower tolerance to high levels of aluminum. *Brachiaria decumbens*, with modest fertilization requirements, produced annual liveweight gains of 150 to 200 kg/ha, approximately 5 to 10 times more than native savanna. Under the intense rainfall at Carimagua, these pastures are now showing severe symptoms of nitrogen deficiency, which raises questions as to how long they will remain productive.

Transfer of technology activities were integrated with research activities during the year. Training is oriented towards program objectives and operations of regional trials throughout the impact area.

Program Organization and Strategy

Beef cattle production is one of the most important agricultural enterprises in Latin America and a major source of protein for its 300 million people. The per capita beef consumption in tropical Latin America is three times higher than that of tropical Africa and about 16 times higher than Asia. At 16 kg/year, per capita consumption approaches that of Western Europe. This is probably an important reason why there is less protein malnutrition in the Latin American tropics than in tropical Africa and Asia. Studies in Cali, Colombia showed that families of all economic strata spend 10-12 percent of their total income on beef, underlying the fact that beef is a staple food in Latin America.

About two-thirds of Latin America's beef is produced in its tropical regions where 71 percent of its cattle population is found. The annual productivity per head of cattle in tropical America, however, is about one-half of the productivity in temperate South America and nearly one-fourth the productivity in the United States and Canada.

This technology gap is more acute when one considers the rapidly growing demand for low-cost beef, and the beef production potential of the vast areas of acid, infertile soils classified as Oxisols and Ultisols, presently under savanna and forest vegetation. These regions together encompass about one-half tropical America's land surface and are characterized by high annual rainfall with a dry season of varying intensity, good soil physical properties, but extremely low native soil fertility and poor infrastructure. The paramount barrier preventing beef production in these areas is inadequate year-round forage supply caused by the severe soil and water stresses.

As population pressures increase it is estimated that beef production in the fertile, high-base status soils of tropical America will be unable to compete with food crop production, while in the vast, acid infertile soil areas just the opposite occurs. In mid-1976 CIAT's Board of Trustees directed that the Program concentrate its efforts towards increasing production in these areas with primary emphasis on overcoming the nutritional gap.

A large part of 1977 was devoted to orienting the Program in this direction, developing a clear objective, a research strategy, recruiting new staff, obtaining appropriate research facilities to do the work, and formulating means for technology transfer to the national institutions.

OBJECTIVES

The **objective** of the Beef Program is to develop and transfer effective technology for increasing beef production in acid, infertiles soils of tropical America, primarily through improved year-round forage production.

The **expected result** of the Program's activities is the development of improved pasture production systems both in terms of quantity and quality, complemented by economically viable animal management and health practices. The national research and extension institutions are **the clients**, the beef producers the **users** and the **consumers** the beneficiaries. Hence the final objective is to benefit consumers through increasing production leading to lower prices of beef in tropical America, and other regions of the world with similar conditions.

The Program's orientation toward acid soil ecosystems also represents a significant effort towards the development of the 300 million hectares of infertile, acid soil savannas of Latin America, and the increasing proportion of the 550 million hectares of similar soils presently under forest vegetation which are being cleared for agricultural production. These vast areas are recognized as one of the most important underutilized land resources of the world with great potential for increasing food production at a global scale. The comparative advantage of beef cattle can serve as a major tool bringing these areas into efficient and ecologically-sound agricultural production and therefore an important factor in the overall economic development of these countries.

STRATEGY

The research and outreach strategy is illustrated in Figure 1. Through worldwide plant exploration efforts plus the new plant breeding section, a wide variety of forage grass and legume accessions is assembled, multiplied in the greenhouse or field nurseries, screened for tolerance to the main disease and insect pests as well as for aluminum toxicity and low phosphorus availability typical of the Oxisols and Ultisols of the impact area. The surviving accessions are observed in space-planted field plots for growth, vigor and other agronomic traits at the Quilichao substation. Seed of the promising ones is increased for further testing, including the inoculation needs for effective nitrogen fixation of the legumes and laboratory estimates of intake and digestibility. Clipping trials then follow, testing compatibility of grass-legume mixtures, cutting frequency, height, fertilization requirements and drought tolerance.

The most promising material is then tested in small regional screening trials conducted by collaborating national institutions throughout the impact area to provide an early estimate of adaptation to different environments. The necessary seed production technology is then developed and a second seed increase effort takes place in order to permit plantings of 5 to 10 hectares of the promising accessions. These promising lines are subjected to grazing pressure trials involving several variables such as stocking rates, grazing intervals and fertility levels, primarily to test for persistence under grazing, without making animal measurements as such. A second level of regional trials follows, testing agronomic variables and persistence under grazing throughout the impact area. All germplasm rejected through this process is given to CIAT's Genetic Resources Unit for their maintenance and possible future use.

The survey of the impact area will characterize the variability of the 850 million hectares of interest in terms of climate, soils, topography, existing pasture and beef production systems, animal health problems and the economics of the beef industry. This knowledge will increase the Program's ability to focus its technology to the most crucial aspects. Among them are the different pasture establishment and maintenance methods including oversowing native savannas, planting grass-legume mixtures either directly or preceded by annual crops, and intensively managed pastures in small irrigated areas or in the pockets of fertile soils found in some ranches. The results of these efforts and the regional trials permit the final evaluation of the potential cultivars through animal performance, measuring liveweight gains and other parameters. Foundation seed is then increased and new cultivars are then recommended for release.

Animal management trials are conducted with the promising pasture systems in order to synchronize the improved nutritional levels with the needs of different types of animals in the herd, through seasonal mating, early weaning and other herd management practices. The diseases of Zebu cattle which are likely to disappear with improved nutrition are identified as well as those diseases that are likely to increase as a consequence of higher animal density because of improved

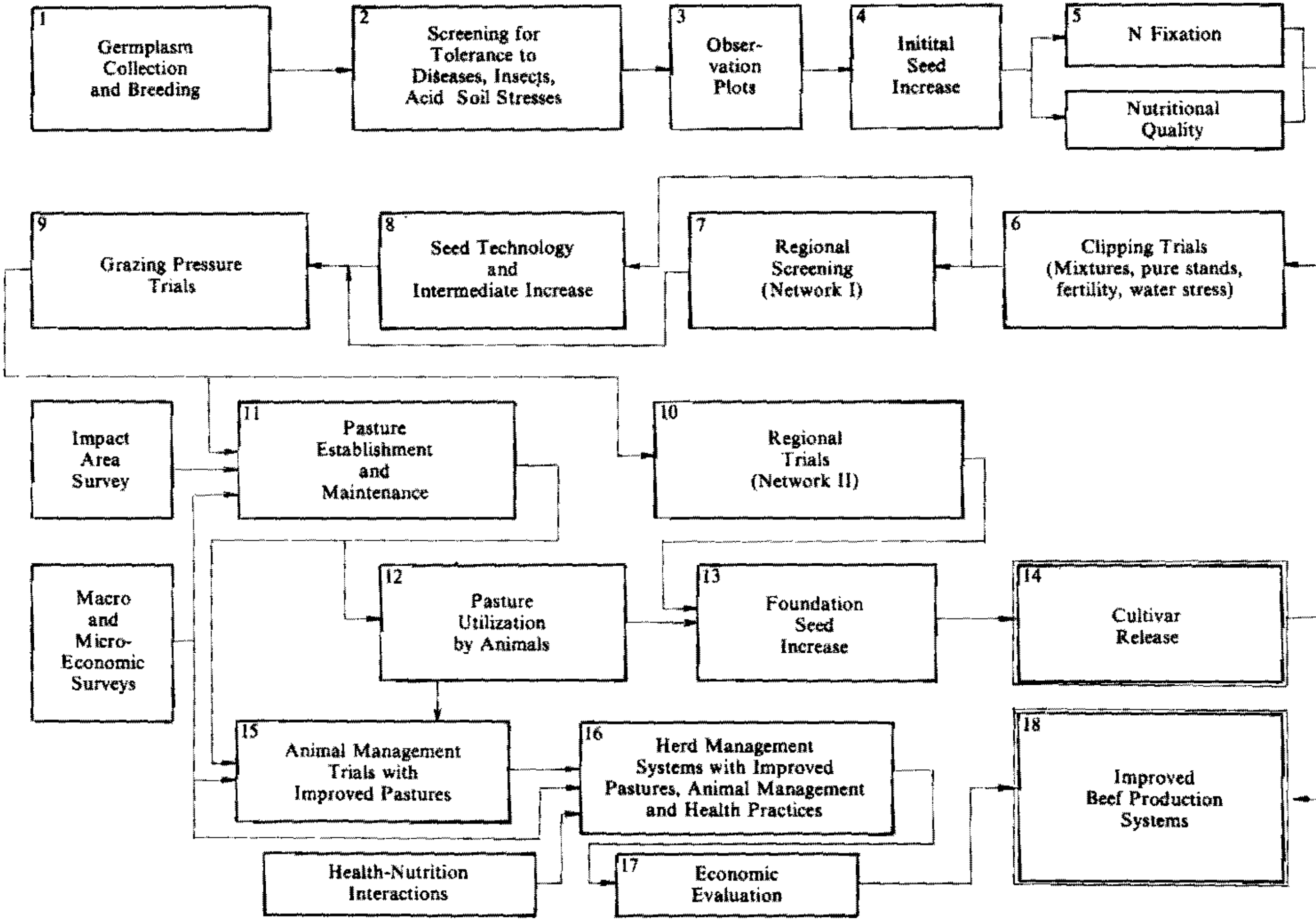


Figure 1. **Flow chart of activities and strategies in the CIAT Beef Program.**

nutrition. The control of these diseases is then attacked. A package of the new technology consisting of improved pastures, animal management and health practices is then put together to quanitify it at the herd level. After economic evaluation, improved beef production systems will be released.

The complexity of the program and the nature of the impact area dictate that research and international cooperation be totally integrated. Training of national institution personnel is linked with their role as actual or potential collaborators in regional trials and other means of technology transfer.

RESEARCH LOCATIONS

Because of the fertile, high base status soils at Palmira, most field research has to be conducted elsewhere, with the CIAT facilities serving as headquarters and for greenhouse, laboratory and library work. During 1977, arrangements were made to operate in three important field research locations suitable to the Program's objectives and providing a wide range of climatic and soil conditions.

The three locations are CIAT-Quilichao, 40 kilometers south of Cali, the Centro Nacional de Investigaciones Agropecuarias of the Instituto Colombiano Agropecuario (ICA) at Carimagua, in the Colombian Llanos and the Centro de Pesquisa Agropecuaria dos Cerrados (CPAC) of Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), 35 kilometers northeast of Brasilia, Brazil. Long-term climatic data are shown in Figure 2. The most important difference between these locations is the dry season length. At Quilichao there are two short but intense dry seasons a year, each of about two to three months duration. Carimagua has a strong four-month dry season and Brasilia, a strong six-month dry season.

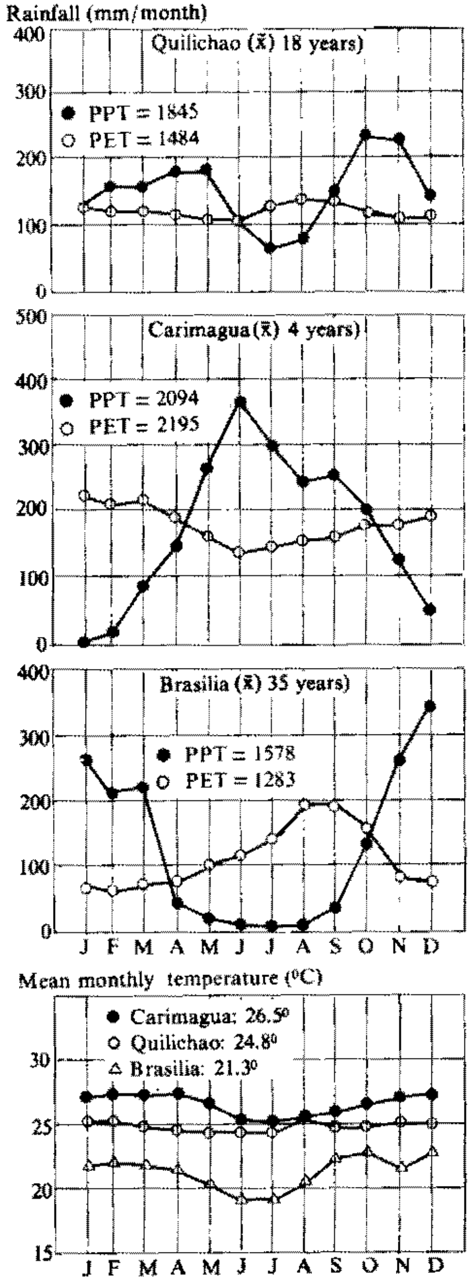


Figure 2. **Mean rainfall (PPT), potential evapotranspiration (PET) and temperature regimes at the three main stations of Beef Program research. Quilichao, Cauca, Col: Lat. 3°06'N, Long. 76°31'W; elev. 990m. Carimagua, Meta, Col.: Lat. 4°02'N, Long. 71°10'W., elev. 200 m. Brasilia, Dist. Fed., Brazil: Lat. 15°36'S., 47°42'W., elev. 1010 m.).**

The soil at Quilichao is classified as an Ultisol, while those of Carimagua and Brasilia are Oxisols. They are all acid (pH 4.1 to 4.9), high in aluminum saturation (64 to 82%), very low in available phosphorus and deficient in many of the other nutrients. Their well-granulated structure, however, provides excellent physical properties. Details on soil properties are presented in the Soil Fertility section.

In addition to climatic and edaphic properties, the three sites offer significant contrasts of pests and disease attacks on forage legumes. The incidence of anthracnose and stemborer at Carimagua is high, at Quilichao moderate to slight, while these pests are not yet important at Brasilia.

Although beef production is the principal activity in all three locations and the productivity of native pastures is low, the degree of infrastructure development also provides a range of economic possibilities. The closeness of Quilichao to the Cali metropolitan area contrasts with the fairly developed but more difficult conditions in the Cerrado near Brasilia. Both in turn are totally different from the relatively isolated Carimagua station, representative of an area with poor roads and communications infrastructure.

Many of the Program's sections have been in operation for several years and have accumulated a significant amount of data. Other sections were established this year, and are at the early stages of development.

Impact Area Survey

The Beef Program's impact area consists of 850 million hectares of acid, infertile soils of tropical America classified as Oxisols and Ultisols. A detailed breakdown of these soils in tropical America is shown in Table 1, ranking the countries in terms of the extent and importance of these soils.

Most of these areas are sparsely populated and devoted to extensive beef cattle production. In order to obtain detailed information a survey was initiated in mid-1977 to classify the land resources and provide a geographically-oriented economic synthesis to serve as the basis of the Program's transfer of technology strategy. The survey and analysis of the impact area is to be completed in two years.

The "Land Systems" approach developed by Christian and Stewart in northern Australia was the methodology adopted. For our purposes, a Land System has been defined as "an area or group of areas throughout which there is a recurring pattern of climate, landscape and soil". The environmental parameters affecting land utilization are classified in the following categorial order:

1. Climate
   - a. Radiant energy received
   - b. Temperature
   - c. Potential evapotranspiration
   - d. Water balance
   - e. Other climatic factors
2. Landscape
   - f. Land-form
   - g. Hydrology
3. Soil
   - h. Soil physical characteristics
   - i. Soil fertility characteristics

Professor George Hargreaves with his associate Mr. Karl Hancock of the Utah State University (USA) are carrying out the climatic work using data from over

Table 1. **Distribution of Oxisols and Ultisols in Latin American countries, calculated from the FAO World Soil Maps at the scale of 1:5 million.**

Country	Million hectares	Percentage of country	Importance[1]
Brazil	572.71	68	***
Colombia	67.45	57	*
Peru	56.01	44	**
Venezuela	51.64	58	***
Bolivia	39.54	57	**
Guyana	12.25	62	***
Surinam	11.43	62	***
Paraguay	9.55	24	*
Ecuador	8.61	23	*
Fr. Guayana	8.61	94	***
Mexico	4.42	2	
Panama	3.59	63	***
Honduras	3.13	29	**
Nicaragua	2.92	30	**
Cuba	2.42	21	*
Chile	1.37	2	
Argentina	1.28	0.4	
Guatemala	0.96	9	
Costa Rica	0.70	14	*
Haiti	0.52	19	*
Jamaica	0.45	41	**
Trinidad	0.42	84	***
Dominican Republic	0.42	9	
Belize	0.40	18	*
Puerto Rico	0.16	18	*
Guadalupe	0.09	47	**
Martinique	0.05	43	**
Totals:			
Latin America[2]	851.10	42	**
Tropical America	848.45	51	***
Tropical South America	828.21	59	***
Central America and Caribbean	15.80	23	*

1 *** More than 50% of the country
** More than 25% of the country
* More than 10% of the country

2 Includes the following countries where Oxisols and Ultisols are not present: Uruguay, El Salvador, Antigua, Bahamas, Barbados, Curacao ad other lesser Antilles.

1000 metereological stations in the impact area. Satellite imagery with supporting aerial and land reconnaissance is being used to define landscape patterns. A complete collection of LANDSAT imagery for the impact area was assembled. Soil fertility characteristics are being described according to the Soil Fertility Capability Classification System developed by Dr. Stanley Buol and co-workers in North Carolina.

The study will be complemented by a preliminary definition of the conditions of growth of the major grasses and legumes throughout the area, to help forage introduction. Further, an attempt will be made to locate the geographical boundaries of major cattle disease problems in cooperation with the animal health specialist.

Following the geographical delineation of Land Systems, geographical priority areas for the introduction of improved beef cattle production technology will be made according to economic considerations. This work, to be carried out by the economist, will be complemented by field studies of management practices of specific areas to help identify production systems. This latter work will come under the direction of the animal management specialist.

The survey, as it crosses national boundaries, involves the cooperation of various national agencies. In Brazil where work has started, the project is a joint venture with the Cerrado Center of EMBRAPA, with Dr. Luiz Guimaraes de Azevedo as coordinator.

At this time, the climatic studies by Dr. Hargreaves' group are proceeding normally and the organization of the literature review and cartographic aspects are under way.

In-situ checking of the preliminary interpretation of the satellite imagery of approximately 200 million hectares of land has been carried out over the major savanna regions of tropical South America, including the central-west of Brazil and a part of eastern Bolivia between latitudes 10ºS and 20ºS. This represents about 23 percent of the project area as a whole and about 60 percent of the savanna regions to be studied. Presently the preliminary satellite image interpretation is being revised according to field checks, and data compilation is under way for eventual classification and storage in a data-bank, prior to report compilation.

Some provisional findings can be highlighted:

(1) Throughout the area studied to date, approximately 40 percent of the lands classify as well-drained savannas, principally Oxisols, 25 percent as poorly drained savannas, mainly Ultisols, and the remainder as other ecological forms. Cattle production on the well-drained savannas is generally limited by a lack of dry season fodder, whereas on the poorly-drained savannas there is often a problem of wet season feeding due to flooding and a shortage of accessible non-flooded higher lands with adequate fodder.

(2) Over 85 percent of the well-drained savannas have a relatively continuous tree-shrub cover, commonly referred to as "Cerrado" in Brazil, and only a relatively small fraction would classify as open savannas. As the density of tree-shrub vegetation has a positive correlation with soil fertility, this would indicate that whilst these savannas undoubtedly classify with the low fertility soil circumstance, this circumstance is by no means as extreme as is found in the northern eastern plains area of Colombia. Further, it is common to find significant intrusions of more fertile soils, especially along the drainage patterns, in these lands.

(3) It is clear that there are vast areas in

western Brazil which might be used for more intensive cattle production, with the application of innovative, low-cost technology.

Plant Introduction

The objective of this section is to augment and broaden the genetic diversity of tropical forage germplasm with potential for the Beef Program's impact area. Activities started at the end of 1976, and during 1977 were focused on: (1) assembling of germplasm through direct collection and exchange with other institutions; (2) initial increase and maintenance of germplasm; (3) preliminary evaluation of germplasm; and (4) identification and classification of germplasm through a reference herbarium.

COLLECTION AND INTRODUCTION OF FORAGE GERMPLASM

Since the creation of the Plant Introduction Section in 1977, CIAT's tropical forage germplasm has increased significantly (Fig. 3). This increase is the result of systematic collection trips through Oxisol and Ultisol regions of the Llanos of Colombia—mainly in the departments of Meta and Vichada, the Llanos of Venezuela—in the states of Bolivar, Anzoátegui and Monagas; and in the Cerrado regions of the state of Mato Grosso in Brazil. The latter expedition was with the participation of scientists from CIAT, EMBRAPA and CSIRO (Australia).

These systematic expeditions and several occasional collection trips within Colombia contributed considerably to CIAT's forage germplasm collection, which is specialized in materials originating from regions with very acid, infertile savanna and jungle soils. Besides direct collection, germplasm was introduced through exchanges with other institutions. The major contribution was obtained from the International Development Research Centre (IDRC, Canada) University of West Indies Forage Legume Project in Belize and Antigua. Direct collections and introduction through exchange of germplasm during 1977 more than doubled CIAT's forage germplasm collection to 3400 accessions. Table 2 shows the germplasm acquisitions during 1977 for major genera and groups in the forage germplasm bank.

INITITAL GERMPLASM INCREASE AND MAINTENANCE

In most cases the amount of seed or vegetative material introduced per accession is not sufficient for any evaluation work nor for maintenance of germplasm. For this reason, much of the section's work during 1977 consisted of maintaining and increasing germplasm. In addition to 493

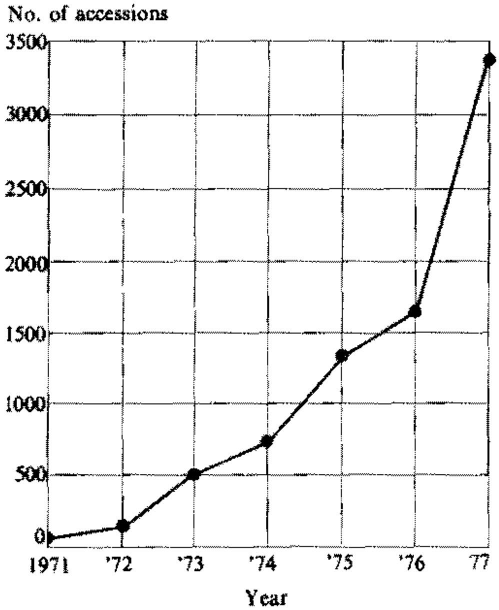


Figure 3. Development of CIAT's tropical forage germplasm collection.

Table 2. **Introductions of forage germplasm by direct collection and exchanges with other institutions during 1977.**

Genera	No. of accesions acquired by collections in:				No. of accessions acquired by exchange from:					Total accessions in CIAT Forage Germplasm Bank
					IDRC Univ. of W. Indies Forage Legume Project					
	Colombia	Venezuela	Brazil	Total	Belize	Antigua	USDA	Others	Total	
Stylosanthes	62	67	148	277	48	24	-	10	82	1021
Desmodium	125	5	114	244	61	7	-	6	74	525
Zornia	42	-	74	116	1	-	-	-	1	145
Aeschynomene	40	2	32	74	2	-	-	-	2	92
Macroptilium group[1]	60	1	32	93	32	12	-	7	51	278
Centrosema	25	5	13	43	35	4	-	3	42	232
Galactia	30	-	16	46	-	4	-	-	4	70
Arachis	-	-	6	6	-	-	42	-	42	77
Miscellaneous legumes[2]	171	4	158	333	146	13	-	12	171	806
Grasses	3	-	1	4	-	-	13	20	33	154
Total	558	84	594[3]	1236	325	64	55	58	502	3400

[1] *Macroptilium*, *Phaseolus* and *Vigna*.

[2] *Calopogonium*, *Pueraria*, *Teramnus*, *Glycine*, *Cassia*, *Rhynchosia*, *Crotalaria*, *Tephrosia*, *Eriosema*, *Clitoria*, *Indigofera*, *Leucaena* and others.

[3] Plus 41 accessions of which only vegetative material was collected and which are presently under seed increase in EMBRAPA's Centro Nacional de Pesquisa de Gado de Corte, Campo Grande, N.I.

Table 3. Forage plant germplasm acquired in 1977 that is under initial seed increase for maintenance and working collection.

Genera	No. of accessions
Stylosanthes	342
Desmodium	121
Zornia	71
Aeschynomene	50
Macroptilium group[1]	99
Centrosema	47
Galactia	31
Arachis	47
Miscellaneous legumes	170
Grasses[2]	48
Total	1026

[1] *Macroptilium*, *Phaseolus* and *Vigna*

[2] Also for preliminary evaluation, including earlier introductions

accessions from earlier introductions (1971-1976 germplasm), initial seed increase of 60 percent of the 1977 materials was initiated under screenhouse conditions at CIAT-Palmira and in the field at CIAT-Quilichao (Table 3).

Furthermore, maintenance of non-seed-producing grasses was initiated by establishing a living collection of 28 accessions in CIAT-Quilichao.

PRELIMINARY EVALUATION OF GERMPLASM

Preliminary evaluation of some of the potentially most promising 1977 legume germplasm was initiated in CIAT-Quilichao. New accessions of the *Macroptilium* group, *Zornia* spp., *Aeschynomene* spp., *Centrosema* spp. and *Stylosanthes capitata*, all of which originate from acid soil savanna regions, and of which sufficient seed was available, were established in introduction plots with 24 spaced plants each. They are being tested against the most outstanding accessions of previous collections (Table 4).

Table 4. Forage legume germplasm acquired in 1977 that is under preliminary field evaluation in CIAT-Quilichao.

Species	No. of accessions
Zornia spp.	55
Macroptilium group	31
Aeschynomene spp.	26
Centrosema spp.	14
Stylosanthes capitata	10
Total	136

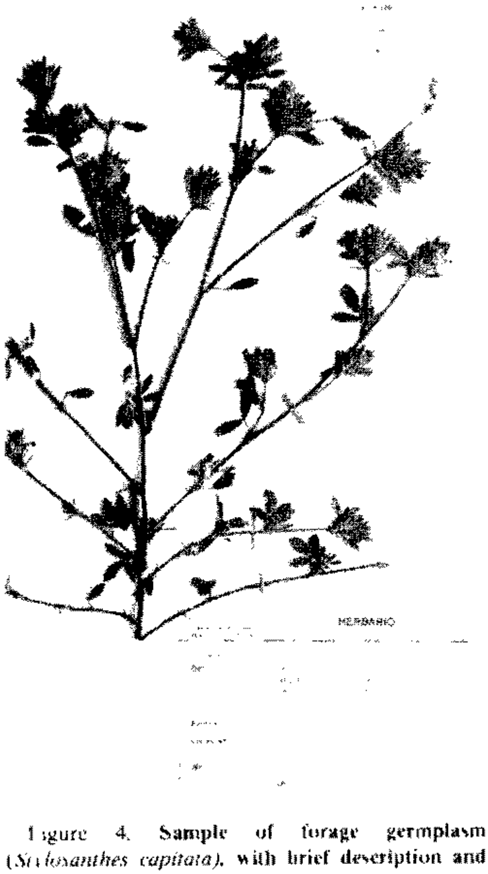


Figure 4. Sample of forage germplasm (*Stylosanthes capitata*), with brief description and collection data, in CIAT's reference herbarium.

DEVELOPMENT OF A REFERENCE HERBARIUM

In cooperation with CIAT's Genetic Resources Unit, development of a reference herbarium was initiated. Herbarium specimens (Fig. 4) of a wide range of genera, species and ecotypes will document the broad variation of tropical forage plants and enable identification and classification of new germplasm as well as of native savanna vegetation. During 1977, 208 specimens were assembled (Table 5).

Table 5. **Specimens of tropical forage plants and savanna vegetation in CIAT's reference herbarium, as of November 1, 1977.**

	No. of specimens
CIAT forage germplasm	
Gramineae	20
Leguminosae	39
Savanna vegetation	
Graminae and *Cyperaceae*	34
Leguminosae	55
Other families	60
Total	208

Forage Breeding

In the past, the Beef Program has relied entirely on the evaluation of native forage legume ecotypes obtained from CIAT-sponsored collecting expeditions or from germplasm collections available at other institutions in the attempt to identify suitable ecotypes for commercial planting in the impact area. This rationale has been sound because of the many promising, native tropical forage legume genera, species within genera and ecotypes within species that have not been adequately evaluated to assess both their direct utility in commercial production and their feasibility for consideration within a plant breeding framework. Priority emphasis is and will continue to be given to evaluating new accessions.

Therefore, the forage breeding section as presently conceived has two major funtions. First, breeders will participate in evaluating existing germplasm in close coordination with other Beef Program scientists to identify ecotypes suitable either for direct, commercial utilization or as parental types for use in crosses. Second, the section will initiate breeding investigations involving those forage legume species which have demonstrated the most general promise within the impact area as indicated by previous and continuing experiences of the Beef Program.

Inititally, the legume breeding section is placing first priority with the complex of *Stylosanthes* species, primarily *S. capitata*. Secondary priority will be given to other promising genera — *Centrosema, Desmodium, Macroptilium, Leucaena* and *Zornia*. Until recently introduced ecotypes of species of these genera have been more fully field-evaluated and/or a wider genetic base has been collected, primary emphasis will remain with *Stylosanthes*.

Specific breeding investigations have been initiated with *Stylosanthes* species, particularly with *S. capitata*. The chromosome number of this species is unknown. Initial chromosome counts made with *S. capitata*, using root-tips squashes, have been inconsistent. Some ecotypes appear to have 2n = 20 chromosomes, the same as *S. guianensis*, while others apparently are tetraploids with 2n = 40. The morphology of the chromosomes of these two species, in addition, appears to be markedly different (see Fig. 5) which could indicate dif-

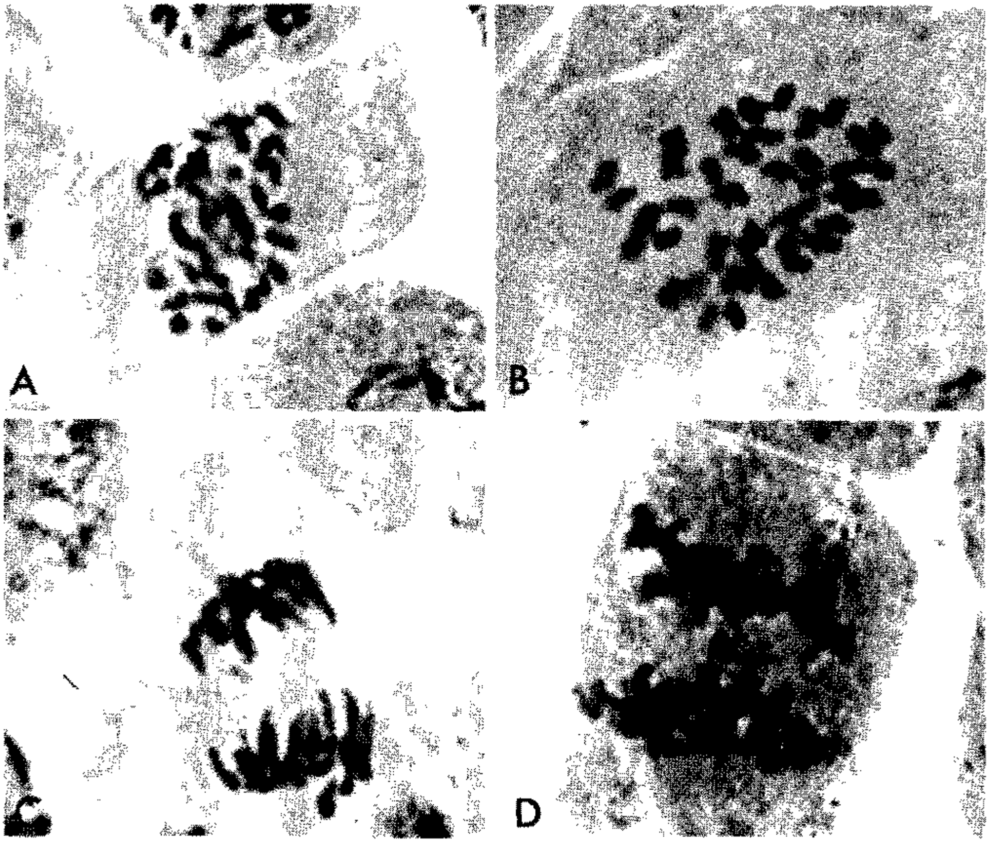


Figure 5. Somatic chromosomes of two *Stylosanthes* species. (A) *S. guianensis*, metaphase (2n = 20); (B) *S. capitata*, metaphase (2n = 40); (C) *S. guianensis*, anaphase; (D) *S. capitata*, anaphase.

ficulties in making inter-specific hybridizations between these two species.

Pure line selections are being made within ecotypes of various *Stylosanthes* species to determine both intra-ecotype as well as inter-ecotype variability for certain traits. Laboratory-greenhouse screening methods to identify resistance to *Colletotrichum gloeosporiodes* (anthracnose) are being modified to eventually handle segregating populations coming from crosses. Experiments in Carimagua, in cooperation with the entomologist, were initiated to characterize and separate the effect of anthracnose and stem borer in order to develop reliable field screening methods for identifying resistance to both problems.

Plants of ecotypes of the several *Stylosanthes* species with known valuable characteristics have been established in the greenhouse and will be used for preliminary crosses both within and between species. These plants will serve to develop the most appropriate controlled pollinization methods and the resulting hybrids will provide a small, but representative sample of segregating populations to use as a prototype for developing efficient screening procedures.

Legume Agronomy

The Program's legume agronomists are responsible for evaluating germplasm believed to be adapted to acid soil conditions through a series of steps ranging from observation plots to clipping and grazing trials. During 1977, 226 accessions of 34 species were evaluated at six locations, including the base sites at Quilichao and Carimagua. The number of accessions under grazing in Carimagua increased from 6 in 1976 to 30 in 1977.

ESTABLISHMENT OF SELECTION CRITERIA

A program Germplasm Committee was formed in mid-1977 with three functions: (1) to establish selection objectives for grasses and legumes; (2) to establish promising categories and project seed increase priorities; and (3) to classify the promising accessions according to selection criteria into promising categories.

The legume selection objectives are shown in Table 6. The criteria will be reviewed and quantified further as new information on tolerances to the various stresses become available. The criteria for general adaptation to specific ecological conditions are based on growth and vigor observations. Although adaptation to moderate and high soil fertility conditions is not part of the Program's mandate, promising accessions from the working collection are identified for possible use outside of the impact area as well as in the pockets of high fertility soils found within the impact area. The promising categories developed are shown in Table 7.

CLASSIFICATION OF LEGUME GERMPLASM

Tables 8 and 9 group 21 promising accessions into the two most advanced categories, describing their known reaction to the selection objectives. Twelve accessions of five species are listed in the most promising Category 4 and are now in grazing pressure testing at either Quilichao or Carimagua, or in both locations. This table shows that accessions of *Stylosanthes capitata*, *Zornia* sp. and *Desmodium ovalifolium* are promising under the environmental stresses at Carimagua, where tolerance to anthracnose and stem borer is of paramount importance for *Stylosanthes*. The *Centrosema* hybrids and the two *Stylosanthes guianensis* accessions are more promising for the somewhat lower stress ecosystem found at Quilichao, particularly in terms of disease and insect attacks. The many blank spaces in this table underline the need for further evaluation, particularly persistence under grazing and throughout the impact area via regional trials, before any cultivar can be recommended for release.

Table 6. Preliminary selection criteria for CIAT forage legumes.

Criteria	Symbol
Adaptation to Carimagua conditions[1]	YC
Adaptation to Quilichao conditions[1]	YQ
Adaptation to medium fertility soils	YM
Adaptation to high fertility soils	YH
Disease tolerance	D
Insect tolerance	I
Nitrogen fixation potential	N
Seed production potential	Sp
Water stress tolerance	W
Aluminum and low phosphorus tolerance	S
Nutritional quality	Q
Persistence under grazing	P
Ease of management	M
Animal productivity	A

1 Described in Figure 2 and Table 26.

Table 7. **Promising categories for CIAT forage legume accessions and implications for evaluation and seed increase.**

Promising category	Level of evaluation	Stages[1]	Seed production planning[2]
1	Initial tolerance and or small scale agronomic trials	1-4	Initial: (Up to 0.2 ha)
2	Complete agronomic trials	1-7	Primary: (Up to 5.0 ha)
3	Complete agronomic and grazing pressure trials	1-11	Secondary: (Up to 10 ha)
4	Complete agronomic and animal trials	1-17	Tertiary: (More than 10 ha)
5	Pre-cultivar release	1-14	Foundation: (More than 10 ha)

1 Refers to numbered activities in the Beef Program Flow Chart (Fig. 1)

2 Seed production sufficient to plant the indicated area.

Table 8. **CIAT forage legume accessions classified as promising Category 4 as of November 1977.**

Species	CIAT No.	Selection criteria[1] (blanks represent unknown)											
		YC	YQ	YM	YH	D	I	N	Sp	W	S	Q	P
Centrosema sp.	1733	-	+	+		+	+	+	+			-	
" "	1787	-	+	+		+	+		+			-	
" "	845	-	+	+		+	+		+			-	
Desmodium ovalifolium	350	+	+			+	+	+					
Stylosanthes capitata	1019	+	-	-	-	+	+	+	+				
"	1078	+	-	-	-	+	+	+	+				
"	1097	+	-	-	-	+	+	+	+				
"	1315	+	-	-	-	+	+		+				
"	1405	+	-	-	-	+	+		+				
Stylosanthes guianensis	136	-	+	-	-	-	-	+	+				
"	184	-	+	-	-	-	-	+	+		-		
Zornia sp.	728	+	-	-	-	+	+		+				

1 Codes are described in Table 6

Table 9. **CIAT forage legume accessions classified as promising Category 3 as of November 1977.**

Species	CIAT No.	Selection criteria[1] (blanks represent unknown) YC	YQ	YM	YH	D	I	N	Sp	W	S	Q	P
Desmodium distortum	335	-	-	+				+	+			+	-
Desmodium heterophyllum	349	-	+	+				+	+				
Desmodium sp.	336	-	-	+			+						
Glycine wightii	201	-	-	-	+				+		-		
" "	204	-	-	-	+				+		-		
Macroptilium sp.	535		+			+	+	+	+				
Pueraria phaseoloides	9900	+	-	+		+	+	+	+		+		
Stylosantes hamata	118	-	-	-	+				+				
"	147	+							+				

[1] Codes are described in Table 6.

Being a first attempt at a systematic classification of tropical legume germplasm these lists should be considered tentative and subject to change as not all the projected evaluations have been completed.

STYLOSANTHES

Anthracnose, caused by *Colletotrichum gloeosporiodes* Penz, is a highly destructive disease of *Stylosanthes* spp. The disease is endemic in South and Central America, and plant resistance is the only practical means of control. The widespread occurrence of stylo anthracnose in tropical and subtropical America and recent reports of its presence in Australia, Africa and Florida emphasize the need for disease-resistant genotypes.

Systematic screening of 850 accessions of *Stylosanthes* spp. for anthracnose resistance was initiated some three years ago. Simultaneously, the genetic diversity of the germplasm in CIAT's forage legume collection has been increased by exploring and collecting new accessions from the savanna regions of tropical America. Information and results from these investigations may be summarized as follows.

The seed-borne nature of anthracnose was explored in one accession of *S. scabra* as the subject of a special project. *C. gloeosporioides* was isolated from surface sterilized pods and seeds of *S. scabra* grown in field plots at Palmira. This isolate produced anthracnose symptoms and killed seedlings of *S. guianensis* CIAT 1198 and also affected several other species and ecotypes of *Stylosanthes.*

A high degree of resistance was found by screening a large number of *Stylosanthes* accessions. *S. capitata* Vog. displayed the best tolerance to anthracnose in glasshouse and laboratory pathogenicity tests. Results of a series of experiments are summarized in Figure 6a-f. Several accessions of *S. capitata* maintained strong resistance to anthracnose under actual field conditions at Carimagua over the past two years. Ecotypes of *S. capitata* were tolerant to a wider spectrum of physiological races of the pathogen than other species of the genus, although variation between ecotypes was indicated in this character (Table 10).

Effective nodulation after inoculation was observed on *S. capitata* in all plantings at Carimagua.

S. capitata is one of the most promising legumes for the environmental conditions of the Llanos of Colombia. Tolerance to anthracnose and stemborer attack coupled with good adaptation to low base status soils which are also high in aluminum are important agronomic characteristics of the species. Indeed, this species is rather intolerant of soils with high pH or high calcium status. When grown on a Carimagua Oxisol limed to pH 6.1 in the greenhouse, *S. capitata* showed distorted growth and symptoms of nutrient disturbances which have not been identified.

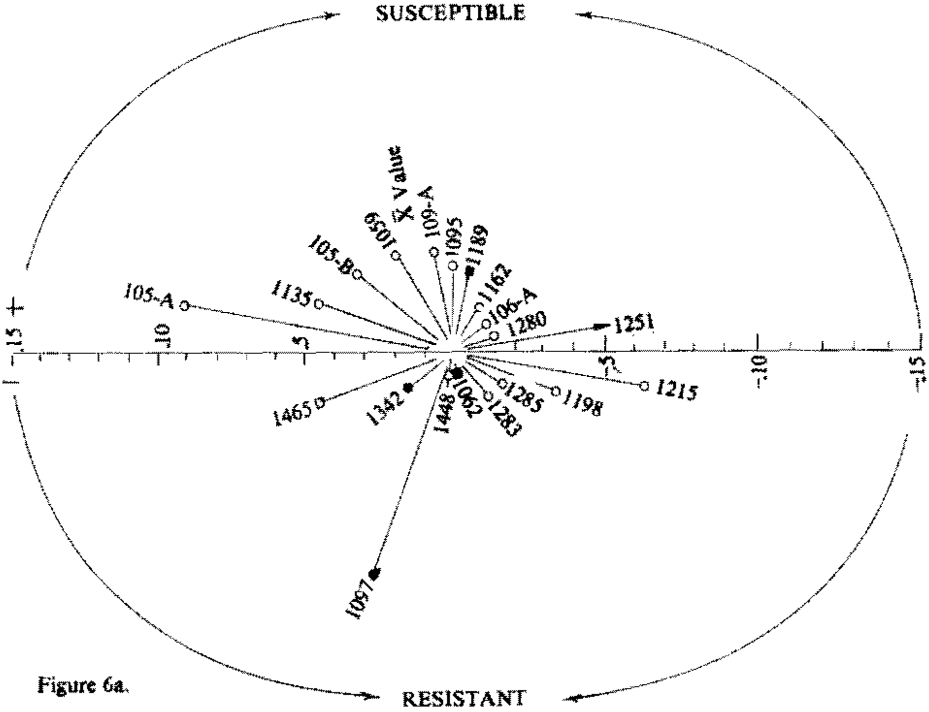


Figure 6a.

Figure 6. a-f. Disease severity indices (DSI) for *Stylosanthes* spp. and deviation (±) from mean values. Positive values represent susceptible lines of *Stylosanthes* and negative values indicate various degrees of resistance. DSI was calculated from the formula:

$$DSI = \frac{\text{Mean Disease Score of Accession - Mean Disease Score of Experiment}}{\text{Standard Deviation of Mean Score of Experiment}}$$

Disease Score = weighted means of five score classes: 1 = no infection; 2 = spots < 1 mm; 3 = 25% of leaf area infected; 4 = 50% of leaf area infected; 5 = dead plant.

○ *S. guianensis*
□ *S. guianensis* (fine-stemmed)
• *S. capitata*
△ *S. bracteata*
▲ *S. humilis*
◬ *S. viscosa*
⊙ *S. scabra*
□ *S. hamata*
◉ *S. montevidensis*
– *Stylosanthes* sp.

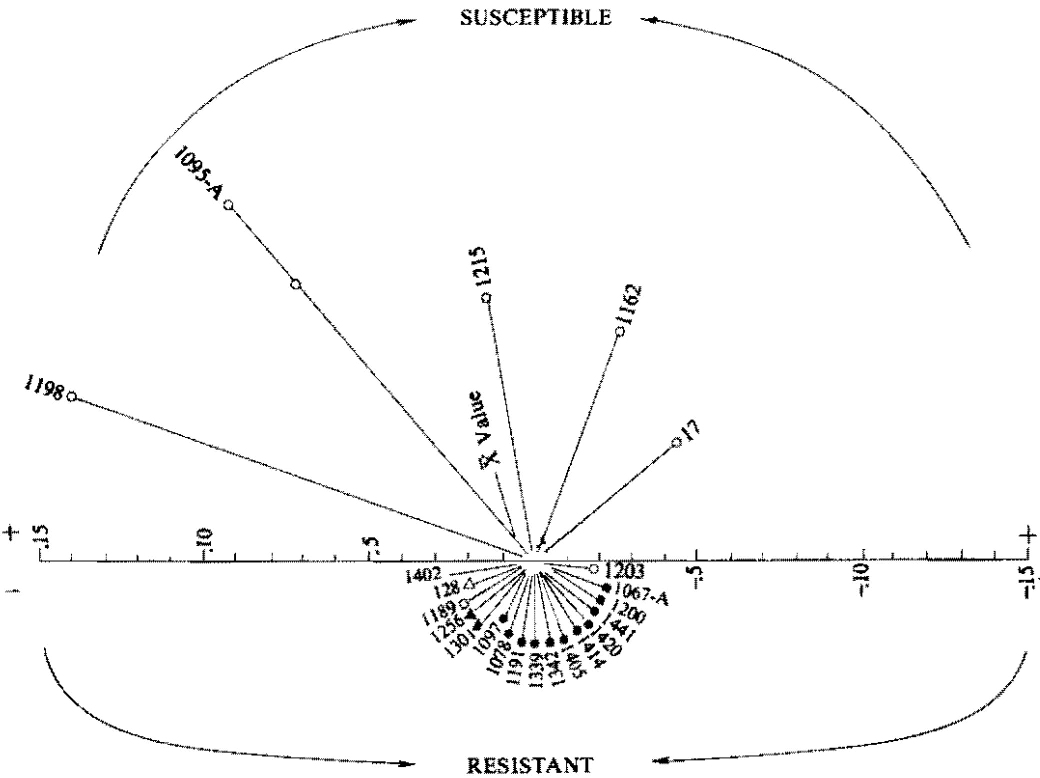


Figure 6b.

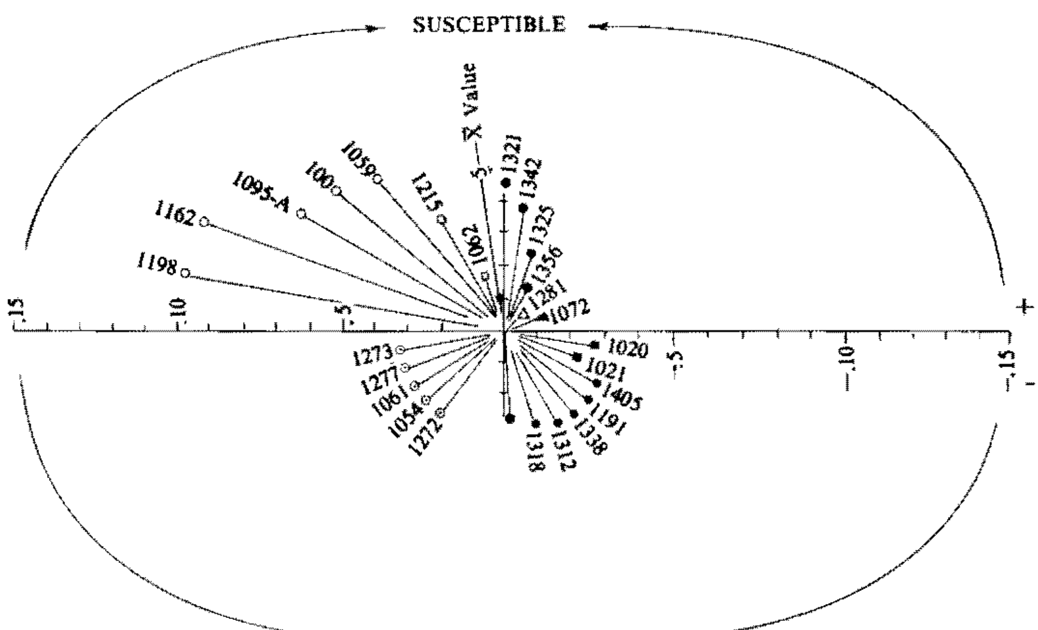


Figure 6c.

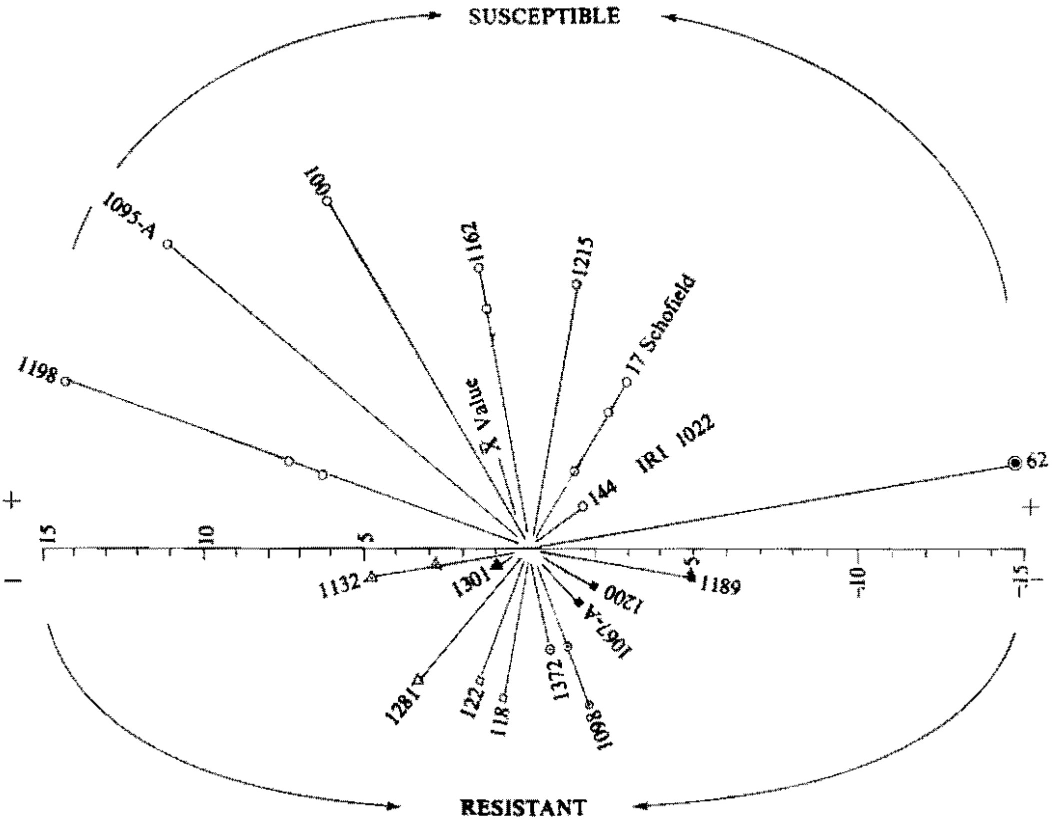


Figure 6d.

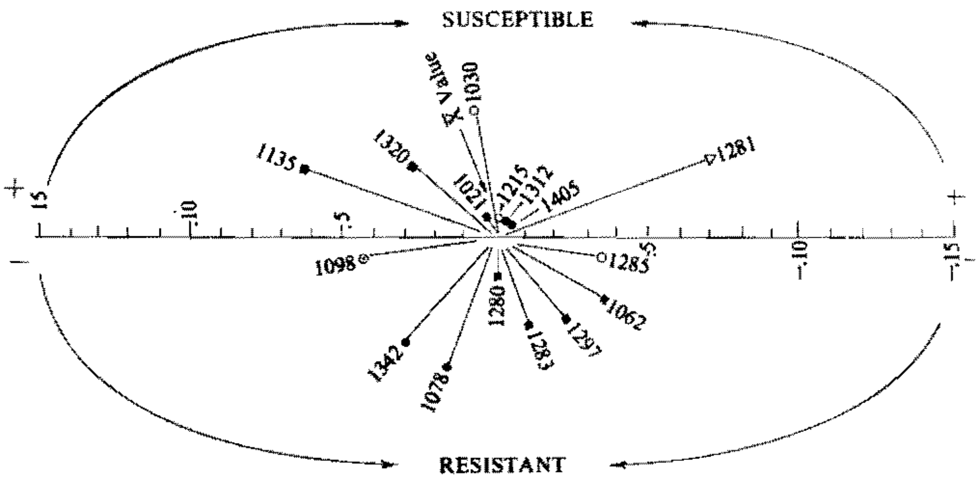


Figure 6e.

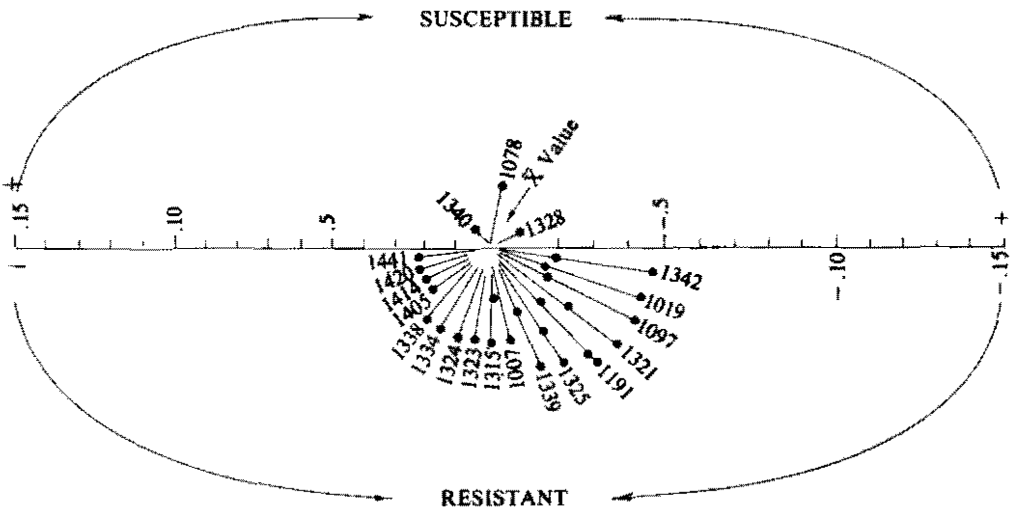


Figure 6f.

Table 10. **Reaction of *Stylosanthes* spp. to two isolates of anthracnose.**

CIAT accession No.	Species	Disease score[1]	
		Isolate I	Isolate II
1054	*Stylosanthes* sp.	2.33	5.00
1061	*S. scabra*	1.00	1.00
1062	*S. guianensis*	1.50	1.00
1078	*S. capitata*	1.00	1.33
1097	*S. capitata*	1.33	1.00
1098	*S. scabra*	1.00	1.67
1068A	*S. guianensis*	2.17	1.00
1087A	*Stylosanthes* sp.	1.00	2.83
1191A	*S. capitata*	2.00	1.33
1129	*S. guianensis*	5.00	1.00
1162	*S. guianensis*	3.00	1.00
1297	*S. guianensis*	1.50	1.33
1298	*S. capitata*	1.67	1.00
1312	*S. capitata*	1.00	1.00
1338	*S. capitata*	1.00	1.00
1379	*S. hamata*	1.00	1.67
1405	*S. capitata*	1.00	1.00
1497	*S. capitata*	1.67	2.17
1526	*Stylosanthes* sp.	1.33	1.17
1527	*S. scabra*	1.00	1.83
1538	*Stylosanthes* sp.	1.00	1.00

[1] Weighted means of five score classes: 1 = no infection; 5 = dead plant. Isolate I from *S. capitata* 1097, isolate II from *S. guianensis* [illegible].

The species is known only from Brazil and Venezuela, however, it is rather wide-ranging in the savannas of Brazil (Fig. 7). The first accession of *S. capitata* was introduced from Brazil in mid-1974. Presently, some 57 ecotypes of this species are held in CIAT's forage germplasm bank.

Ecotypes differ morphologically and considerable variation was observed in flowering date. At Quilichao, accessions from the southern limit of distribution of the species (latitude 16° - 21°S) commenced flowering in August, at least one month ahead of the accessions from the northeastern states of Brazil at latitudes 3° - 5°S (Table 11).

During late 1977 about three hectares of *S. capitata* grass mixtures have been seeded at Carimagua. Twelve accessions of stylo are included. The two companion grasses of contrasting growth habit are *Brachiaria decumbens* and *Andropogon gayanus*. Anthracnose-tolerant accessions selected from the collection will have to be exposed to a wide spectrum of strains of the fungus in several ecological regions where the disease is present to ascertain the existence of stable, horizontal resistance.

For the Quilichao site varieties of the common plant type of *S. guianensis* appear to be very well adapted. Observations and yield data over two years indicate that the fine-stemmed varieties also showed good field resistance to anthracnose and stem-borer at Quilichao. Unfortunately, most of the fine-stemmed stylo accessions are poor seed producers. Selection pressure shou'd be directed toward the fine-stemmed

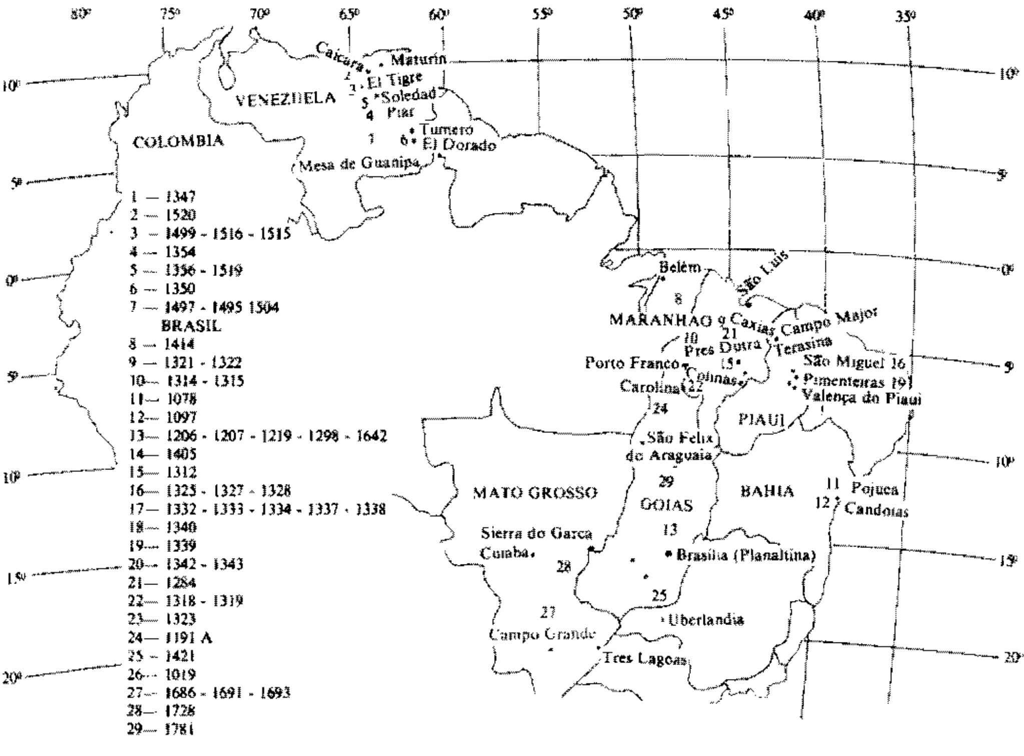


Figure 7. Collection sites of *Stylosanthes capitata* Vog. in Brazil and Venezuela.

Table 11. Yield attributes of 15 *Stylosanthes capitata* and two *S. bracteata* accessions grown as spaced plants at Quilichao.

CIAT accession No. and species		Mean of four yield cuts (g plant)	Flowering response[1]
1078	*S. capitata*	187.17 a[2]	L
1323	"	150.83 ab	MS
1342	"	146.75 ab	MS
1318	"	142.08 ab	MS
1339	"	141.42 ab	MS
1315	"	123.92 abc	MS
1324	"	121.92 abc	MS
1382	*S. bracteata*	121.24 abc	MS
1340	*S. capitata*	115.42 bc	MS
1328	"	113.17bc	MS
1325	"	106.25 bc	MS
1334	"	102.92 bc	MS
1281	*S. bracteata*	97.58 bc	MS
1333	*S. capitata*	92.50 bc	MS
1338	"	89.83 bc	MS
1375	"	80.95 bc	MS
1298	"	61.58 c	E

1 L = late flowering (November); MS = mid-season flowering (October); E = early flowering (mid-August).

2 Means followed by a different letter are significantly different at P= 0.05 by Duncan's Multiple Range Test.

ecotypes with better seed producing capacity.

At Quilichao, 10 accessions of *S. guianensis* were established during the current season to compare fine-stemmed varieties with the two high-yielding typical forms of *S. guianensis* e.g., 184 and 1175.

Two accessions of *S. guianensis*, 184 and 136, have been included in cutting and grazing experiments. The former is a local variety, native to the Quilichao region; the latter is an accession from the Llanos. Data obtained so far indicate that 184 is the higher yielding of the two accessions, in both cutting (Table 12) and grazing trials.

Since October 1975, a total of 158 *Stylosanthes* accessions have been established at El Limonar (near Quilichao) for initial observation. Some high-yielding ecotypes were identified among the accessions of the typical robust growth form of stylo. The incidence of anthracnose in the Quilichao area has been rather low during the last two exceptionally dry years and some of the promising material selected on the basis of yield data must be checked for anthracnose tolerance over one or more seasons.

CENTROSEMA

Preliminary testing of new accessions of *Centrosema* originating from Oxisol savanna regions has been done in the greenhouse. Dry matter yields of 12 accessions of *Centrosema* grown in pots containing eight kilograms of soil are presented in Table 13.

At Quilichao *Centrosema* was regularly

Table 12. **Dry matter yields, plant nitrogen and phosphorus contents of two advanced accessions of *Stylosanthes guianensis* cut at five- and nine-week intervals at Quilichao, July 1976 to July 1977.**

	CIAT 184			CIAT 136		
Cutting frequency (weeks)	Dry Matter (t/ha/year)	Protein (%)	P (%)	Dry Matter (t/ha/year)	Protein (%)	P (%)
5	15.9	16.0	0.17	13.6	17.6	0.18
9	10.9	15.0	0.17	9.7	17.8	0.17

Table 13. **Yields attributes of 12 accessions of *Centrosema* spp. grown on Llanos soil.**

CIAT accession No.	Origin	Dry Matter yield, mean of three harvests (g/plot)
495	Venezuela	4.54 a[1]
5039	Brazil	4.50 a
411	Colombia	4.27 ab
420	Venezuela	4.04 ab
400	Venezuela	4.01 ab
497	Colombia	3.97 ab
491	Brazil	3.84 abc
5008	Colombia	3.48 bcd
458	Colombia	3.29 bcd
492	Brazil	2.99 cd
Commercial	Australian	2.87 cd
5040	Colombia	2.76 d

Means followed by a different letter are significantly different (P= 0.05) by Duncan's Multiple Range test.

higher in plant nitrogen and phosphorus content than *Stylosanthes*. This observation was recorded in various grass/legume combinations under cutting and grazing (Fig. 8).

Desmodium

Desmodium ovalifolium has shown promise at both testing sites, and it was selected for further evaluation. It is being compared with *Centrosema* and *Galactia* under six- and eight-week cutting regimes at Quilichao. Establishment and early growth of this *Desmodium* is rather slow but once established it produces yields comparable to the other legume species (Table 14).

Its stoloniferous habit and apparent compatibility with *Brachiaria decumbens* make *D. ovalifolium* a fairly attractive

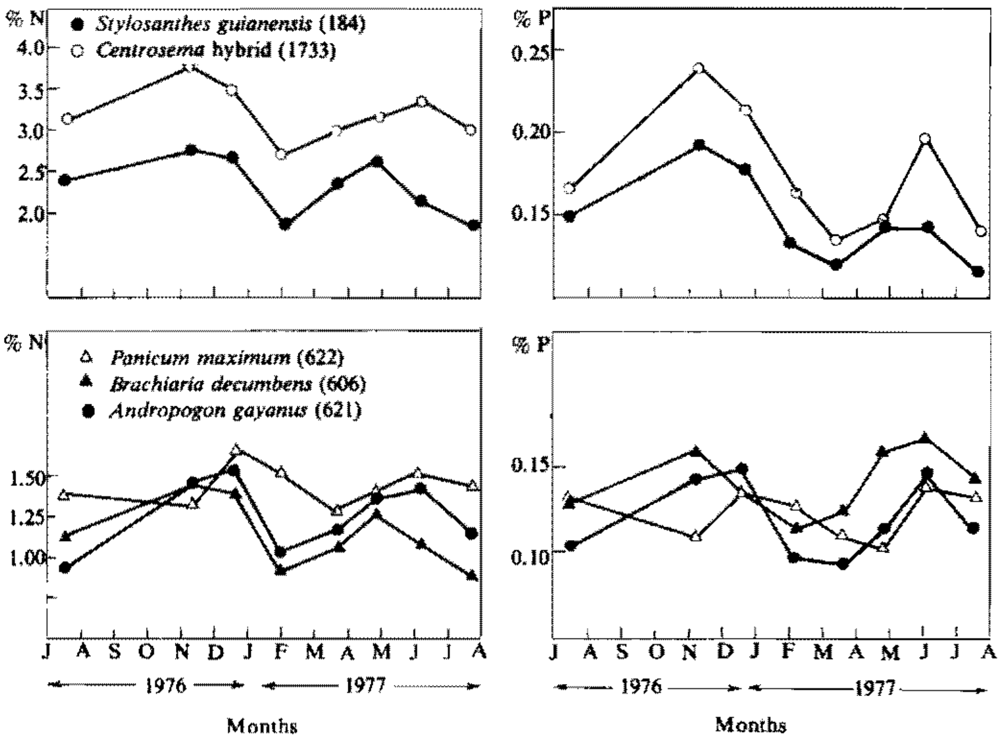


Figure 8. **Plant nitrogen and phosphorus contents of *Stylosanthes guianensis* CIAT 184, *Centrosema* CIAT 1733, *Panicum maximum* cv. Makueni, *Brachiaria decumbens* cv. Basilisk and *Andropogon gayanus* CIAT 621 all under grazing at El Limonar, (near Quilichao).**

Table 14. Dry matter yields of *Centrosema* hybrid, *Galactia striata* and *Desmodium ovalifolium* at El Limonar (near Quilichao), from March 1977 to October 1977.

Species and CIAT accession No.	Harvest				Total
	I	II	III	IV	
	(kg/ha)				
Centrosema sp. (1733)	4831 a[1]	938 cde	1692 c	1080 c	8543 a
Galactia striata (964)	3655 b	857 e	1707 c	1389 cde	7608 a
Desmodium ovalifolium (350)	3255 b	905 e	1657 cd	1166 cde	6984 a

[1] Means followed by a different letter are significantly different at P = 0.05 by Duncan's Multiple Range Test

prospect for the better Oxisols. It has been established with *Andropogon gayanus, B. decumbens* and *B. humidicola* for further evaluation under cutting and/or grazing. Following preliminary studies, promising accessions of *D. scorpiurus, D. barbatum, D. heterocarpon* and *D. canum* have been established in sward plots at Quilichao.

ZORNIA

Several introductions of this little-known forage legume show promise under Llanos conditions and at Quilichao. Four accessions have been included in yield trials seeded with *Andropogon* or *Brachiaria*. Of them only CIAT 728 appears to be perennial and the others are free-seeding annuals. The annuals regenerate well from self-sown seed early in the wet season, but provide little or no feed for the dry season. Preliminary data (Table 15) indicate that the perennial form, CIAT 728, is more productive and better adapted to the longer growing season of the Llanos as well as the Quilichao site. To date, no serious insect or disease problems have been identified in *Zornia*.

Table 15. Wet and dry season yields (two harvests) of five accessions of *Zornia* spp. at Quilichao.

CIAT accession No.	Dry Matter yield March to October, 1977 (kg/ha)
728	8168
814	4067
883	2072
802	2048
897	1496

EVALUATION IN MIXED STANDS UNDER GRAZING

The African gamba grass *(Andropogon gayanus)* continued to show good potential at Quilichao as well as at Carimagua. This introduction is being observed in the third year and it was included in cutting experiments and grazing tests, in mixtures with several legume species e.g.: *S. guianensis, Centrosema* hybrid, *Galactia striata,* and *S. capitata.*

It is well-adapted to acid soils, tolerant to drought and fire, has a rather moderate requirement for phosphorus, and is also tolerant to high aluminum levels. *Andropogon* out-yielded *Hyparrhenia rufa* under a five weekly cutting regime. It was compatible with stylo and centro under both cutting and grazing (Table 16).

Three hectares of *A. gayanus* were established at El Limonar in May, 1976, to test the reaction of various pasture species and grass/legume mixtures to grazing. In one experiment *S. guianensis* 184 and 136 were established with *B. decumbens* and *A. gayanus*. *Brachiaria* was the more productive of the two grass species. *Brachiaria* in association with stylo varieties produced 111-114 kg/ha/day of dry matter, while

Table 16. **Dry matter yields of *Andropogon gayanus* and *Hyparrhenia rufa* each with *Centrosema* or *Stylosanthes* under a five weekly cutting regime at El Limonar (near Quilichao) 1976-77.**

Mixture	Dry Matter yield (kg/ha/year)	Protein (%)	P (%)
Andropogon gayanus +	18,710	8.8	0.14
Centrosema hybrid 1733	4,005	19.8	0.19
Total	22,715		
Andropogon gayanus +	15,295	8.9	0.13
Stylosanthes guianensis 136	6,158	14.7	0.16
Total	21,453		
Hyparrhenia rufa +	13,665	7.5	0.11
Centrosema hybrid 1733	4,039	20.9	0.19
Total	17,704		
Hyparrhenia rufa +	13,710	7.7	0.11
Stylosanthes guianensis 136	9,563	16.1	0.18
Total	23,273		

Andropogon ranged from 46 - 71 kg/ha/-day. Maximum dry matter production of stylo was only 29 kg/ha/day. This yield was obtained in the *Andropogon*/stylo mixture (Fig. 9). The result of the slower growth rate of *Andropogon* was a higher legume content in the mixtures containing this grass species (Figure 10).

In another mixture containing the same two grass species with a mixture of legumes i.e. stylo + centro + *Galactia*, a better grass/legume balance was maintained during the first seven-month grazing period (Fig. 11).

In the third grazing test, five varieties of *Centrosema* were established with *A. gayanus* as the common companion grass. The four centros, including three hybrid varieties, outyelded (P = 0.05) the local ecotype of *C. pubescens* (Fig. 12)

The area has been under grazing since February, 1977. A rotational grazing system was adopted and the plots were

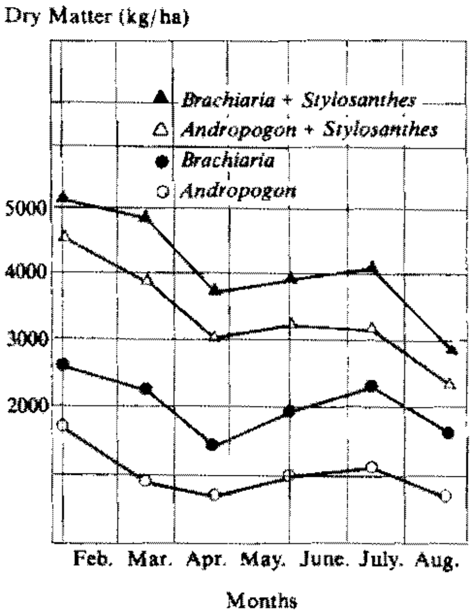


Figure 9. **Grass and legume presentation yields of *Brachiaria* and *Andropogon* alone and mixed with *Stylosanthes guianensis* (CIAT 184 & 136) at El Limonar (near Quilichao).**

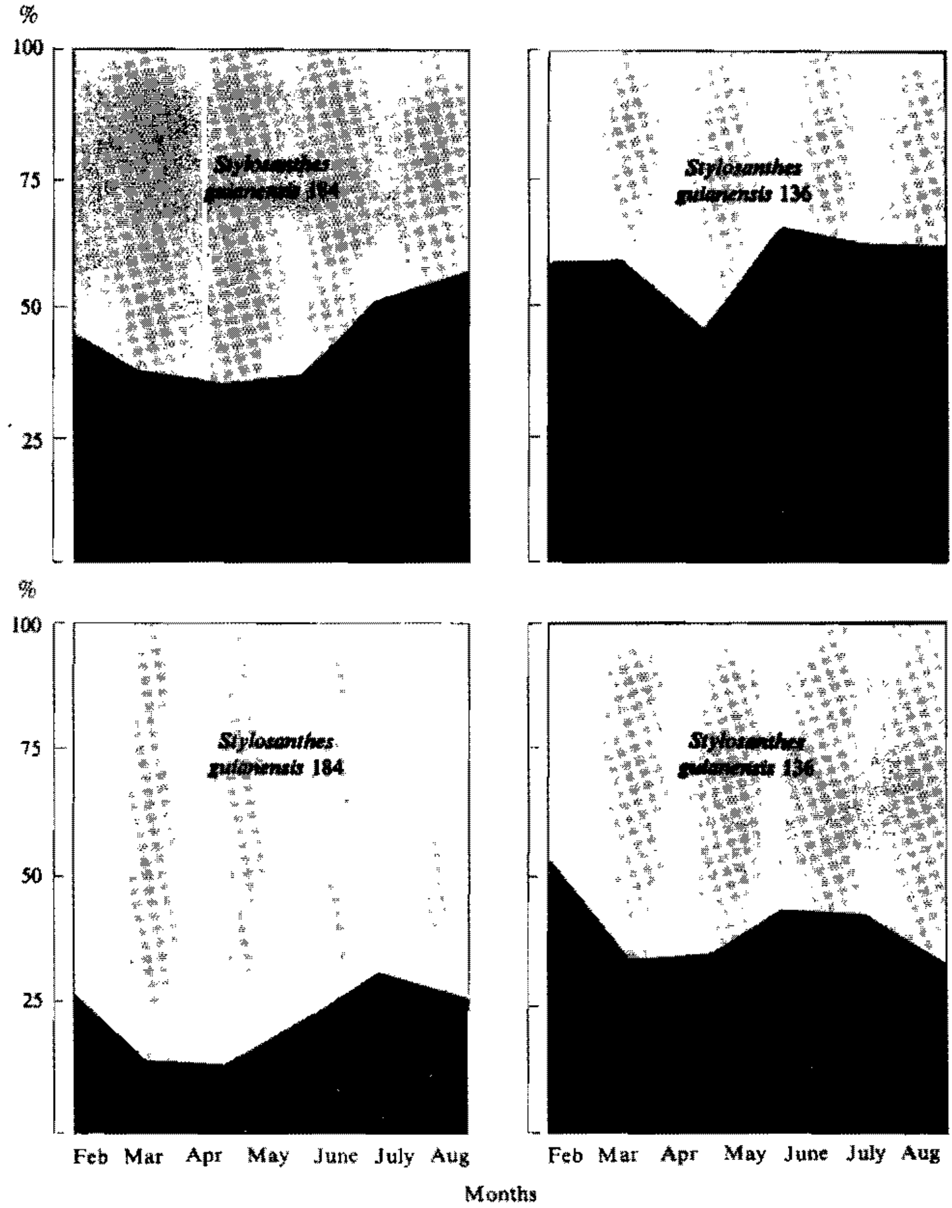


Figure 10. **Grass/legume composition of four pasture mixtures under grazing at Quilichao.**

grazed at the uniform rate of 2.3 animals/ha. The first 214-day period has been completed and in spite of the long dry season an average liveweight gain of 561 g/animal/day was obtained from Zebu steers introduced from the Colombian Llanos. These animals reached the slaughtering weight of 450 kilograms at the age of 2.5 years; in sharp contrast, animals grazing on the native *Paspalum notatum* savanna suffered severe weight losses.

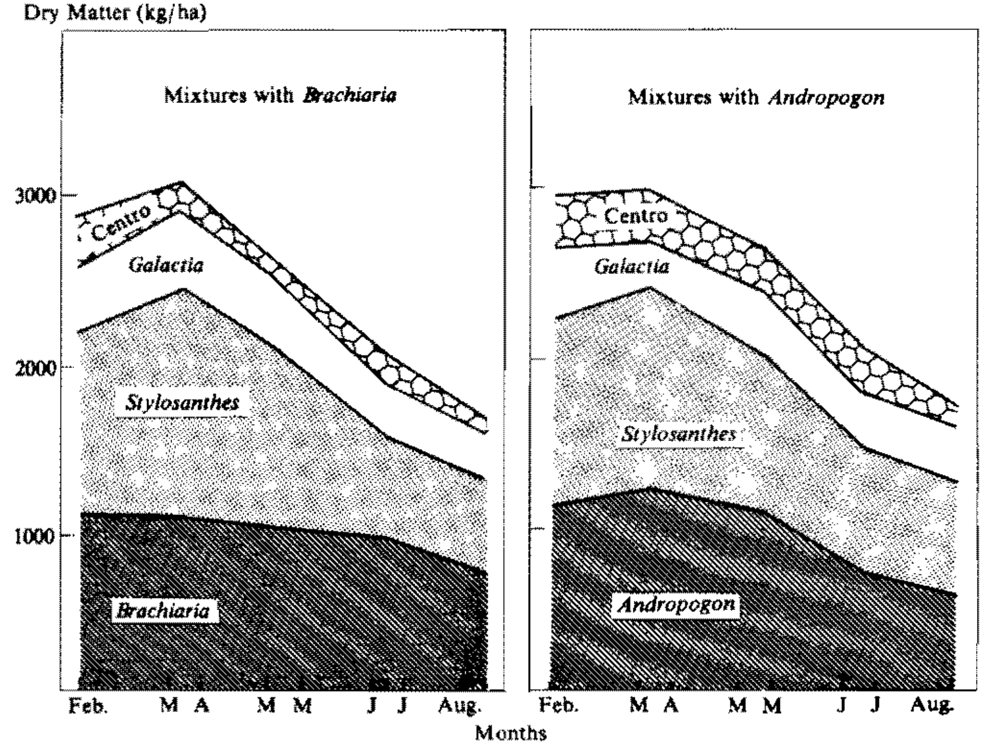


Figure 11. Dry matter yields available in two grass/legume pastures under grazing at El Limonar (near Quilichao).

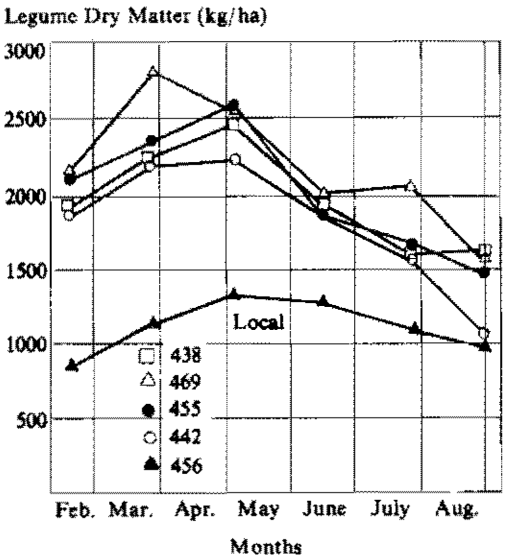


Figure 12. Dry matter available in grazed plots of five *Centrosema* varieties at El Limonar (near Quilichao).

Grass Agronomy

The newly-formed Grass Agronomy section has begun work in four areas. First, initial evaluation and characterization of accessions is being conducted at Quilichao and will be extended by regional testing to other parts of the impact area. Second, promising and well-known varieties are being studied at Quilichao and Carimagua to determine their response to drought stress, nitrogen and phosphorus requirements, tolerance to burning, and response to clipping. Third, the relative importance of competition for light and nutrients is being studied at Quilichao. Finally, mass selection for productivity, quality, and date of flowering is being conducted in *A. gayanus* (CIAT 621).

The Program's Germplasm Committee has identified the selection criteria and has determined the outstanding characteristics and research priorities for each of the most promising grass accessions (Tables 17 and 18). This list will be periodically revised to reflect changing knowledge and priorities.

Table 17. **Preliminary selection criteria for CIAT forage grasses.**

Criteria	Symbol
Adaptation to Carimagua	YC
Adaptation to Quilichao	YQ
Adaptation to medium fertility soils	YM
Disease tolerance	D
Insect tolerance	I
Water stress (drought) tolerance	W
Acid soil stress tolerance	S
Vegetative vigor	V
Flood tolerance	F
Burning tolerance	B
Seed production	Sp
Persistence under grazing	P
Nutritional quality	Q
Ease of management	M
Animal productivity	A
Compatibility with legume	C

Table 18. **CIAT forage grass accessions classified according to selection criteria, as of November 1977.**

Species	CIAT No.	Selection criteria[1] (blanks represent unknowns)											Category
		YC	YQ	YM	C	D	I	W	S	Sp	B	Q	
Andropogon gayanus	621	+	+		+	+	+	+	+		-		4
Andropogon gayanus	635								+				1
Brachiaria decumbens	6012	+	+		-	+	+	+	+	+			3
Brachiaria sp.	664								+				2
Brachiaria humidicola	6013	+	+		-				+				2
Brachiaria humidicola	679		+		-				+				2
Brachiaria ruziziensis	6019			+									1
Hemarthria altissima	603			+								+	1
Panicum maximum	622		+	+									3
Paspalum plicatulum	600								+				1

Seed Production

The objectives of the seed production section are: (1) the production of seed for the experimental needs of the Beef Program, and (2) the identification and study of the restrictions to commercial seed production within the impact area of this program. The Program's Germplasm Committee defines which genetic materials are required for experimental purposes and the seed section responds with a field production program. The strategies applied are first to identify suitable geographic regions for forage seed production and then to develop efficient production systems for particular species.

SEED INCREASE

Establishment of lots for grass seed production was continued at both Quilichao and Palmira while legumes were concentrated in the Quilichao region. Sixty-five legume accessions were increased under non-irrigated conditions at El Limonar (near Quilichao). Because of the large number of lines and small plot sizes, almost all harvesting was done manually. Most were harvested twice during the year, with the main harvest period between March-April and lighter crops in August.

The total amounts of seed produced and average annual yields are presented in Table 19. This seed provided the basis for extensive new forage evaluation studies initiated by other team members at both Carimagua and Quilichao and will provide material for regional trials. The high yield levels for the majority of legume accessions combined with low weed infestation, confirmed the utility of the Quilichao region for basic seed increase of a wide array of germplasm.

The current promising accession lists (Tables 8, 9, and 18) show the revised orientation of seed increase for the coming year. Included are 37 accessions of 23 legume species and 10 accessions of 8 grass species. Some 8.5 hectares of new lots were established at the Quilichao site during September and October and will be managed with supplemental irrigation and mechanical harvesting.

LEGUME SEED PRODUCTION TECHNOLOGY

The two most advanced *Stylosanthes guianensis* accessions (CIAT 136 and 184) showed highly contrasting phenology and yield patterns at Quilichao . CIAT 136 was harvested once, in January, and yielded 95 kg ha of pure seed. CIAT 184, however, flowered throughout the year and was harvested in January, May and August, yielding 41, 102 and 117 kg/ha respectively, for a total yield of 260 kg/ha/year. Neither accession responded to phosphorus above 45 kg P_2O_5/ha. Defoliation prior to the January harvest, while not affecting yield of CIAT 184, did increase yield of CIAT 136 at the 135 kg/ha level of P_2O_5.

Stylosanthes capitata proved to be a good seed producer as low density, hand-harvested stands produced yields averaging 266 kg/ha during the establishment year.

Seed yield of *Centrosema* sp. (CIAT 1733) was studied on a trellis support system at Quilichao, with row spacings of one, two and three meters. Yield declined with increasing spacing from 877 to 515 to 466 kg/ha, respectively. At Palmira by comparison, a two-meter trellis system yielded 90 kg/ha. In another hand-harvested varietal comparison at Quilichao, but without a support system, CIAT 1733 and common centro produced equal seed yields. The high hand-harvested seed yields of *Centrosema* spp. at Quilichao, averaging 750 kg/ha, indicate a

Table 19. **Summary of forage seed produced at CIAT from October 1976 to October 1977.**

Species	Number of accessions	Total seed produced (kg)	Average seed yield (kg/ha/year)	Type of seed
Sylosanthes				
capitata	5	41.0	266	in pod
guianensis	11	43.0	64	"
hamata	2	51.0	283	"
scabra	8	5.9	254	"
sympodialis	2	4.5	163	"
viscosa	2	0.5	45	"
Desmodium				
heterophyllum	1	15.1	302	pure
canum	4	1.2	162	"
spp.	24	5.6		"
Centrosema				
pubescens	1	17.4	650	pure
spp.	3	162.3	750	"
Macroptilium spp.	2	8.7	192	pure
Andropogon gayanus	2	350.0	120	graded
Panicum maximum	2	20.0	48	graded
Brachiaria decumbens	2	31.0	57	graded

high potential for successful mechanical harvesting in this region (Fig. 13).

Desmodium heterophyllum produced abundant seed at Quilichao during 1977. The below average rainfall (about 450 millimeters) during the second 1976 rainy season may have provided ideal conditions for successive flushes of flowering, seed maturity and accumulation of shed seed on the ground. Seed was harvested by clipping to remove all above-ground growth (which contained no seed) followed by several passes with a small suction harvester (Fig. 14). The average pure seed yield per crop was 265 kg/ha, but the average annual yield was 302 kg/ha. This is the first instance where economic seed production appears possible for this valuable species.

GRASS SEED PRODUCTION TECHNOLOGY

Andropogon gayanus CIAT 621 initiates flowering throughout the year at Palmira and Quilichao. Flowering is variable between plants and very prolonged within plants. Mature spikelets are shed progressively. As a result, optimum harvest maturity is difficult to determine and harvest efficiency is low. To date all lots have been hand-harvested with flowering stems left in the field for 3-6 days before hand threshing and natural shade drying.

Figure 13. High seed yields were obtained with *Centrosema* hybrid on trellises at Quilichao.

Figure 14. Suction harvesting of *Desmodium heterophyllum* at Quilichao.

Spikelets have been machine-threshed or hand-rubbed over wire screens then passed over a gravity table. Graded seed lots contained as much as 45 percent cariopses. Yields last year were extremely variable, ranging from 30-300 kg/ha of graded seed and reflecting the below-average rainfall. Germination of untreated pure seed has been as high as 65 percent at nine months from harvest.

Seed yield of *Brachiaria decumbens* was recorded in various crops in the Cauca Valley where the species flowers from early June until October. The earliest crop matured in late June and the majority from mid- to late July. Hand-harvested crops yielded from 15-50 kg/ha pure seed. With irrigation and nitrogen fertilizer a second crop was harvested in early September. The highest yield recorded from one such area was 68 kg/ha/yr. These modest yields reflect a low proportion of flowering tillers, poor synchronization of flowering, and inadequate nitrogen nutrition.

Plant Protection

The Plant Protection section of the Beef Program was established in July 1977, with the arrival of an entomologist. It has three objectives: (a) to conduct basic studies (taxonomy, biology, ecology, population dynamics of the main insect pests); (b) to determine economic thresholds to define priorities; and, (c) to develop an integrated control program of the pests on promising pasture legumes. The plant pathology dimension is expected to start in 1978.

STEM BORER

A survey of stem borer damage caused possibly by *Zaratha* spp. on stylo accessions together with biological and preliminary evaluation of plant resistance have been initiated, to establish the status and importance of the pest. The initial evaluation was carried out on available material at Quilichao and Carimagua. At both locations random samples of all available accessions were evaluated for stem borer damage (Tables 20 and 21). At Quilichao, all 19 accessions evaluated showed damage, but CIAT 1019, 1152, 1102, 184, 1009, 1057 and 1094 showed the lowest levels of infestation.

An average of 88 percent of infestation was recorded at Carimagua, and 84 percent at Quilichao. However, a high percentage of accessions growing at Quilichao, showed low infestation. At Carimagua, *S. guianensis* CIAT 1385 which was not planted at Quilichao, did not show any stem borer damage. This may indicate that this material could have better levels of resistance or tolerance to this insect, or that the environment and/or other factors may favor higher insect populations at Carimagua. These possibilities will be further evaluated.

To determine which part of the plant is the most attacked by the borer, evaluations were made on upper, middle and lower thirds (Table 22). Observations indicated that stem borer attacks begin at the basal part of the plant in which the females

Table 20. Preliminary evaluation of *Stylosanthes* spp. to stem borer (possibly *Zaratha* sp.) at Quilichao.

Accessions	No. of random samples	Stem borer damage
Stylosanthes guianensis		
136	3	+[1]
184	3	+
191A	3	+
1094	3	+
1098	3	+
1071	3	+
1067A	3	+
Stylosanthes capitata		
1019	3	+
1078	3	+
Stylosanthes scabra		
1064	3	+
1009	3	+
Stylosanthes viscosa		
1057	3	+
1096	3	+
Stylosanthes angustifolia		
1102	3	+
Stylosanthes sp.		
1043	3	+
1051A	3	+
1051B	3	+
1122	3	+
1152	3	+

1. Indicates stem borer damage.

Table 21. **Preliminary evaluation of *Stylosanthes* spp. to stem borer (possibly *Zaratha* sp.) at Carimagua.**

Accessions	No. of random samples	Stem borer damage
Stylosanthes guianensis		
1182	3	+[1]
1203	3	+
1285	3	+
Stylosanthes capitata		
1298	3	+
1315	3	+
1342	3	+
1191A	3	+
Stylosanthes viscosa		
1273	3	+
1059	3	+
1062	3	+
Stylosanthes sp.		
1152	3	—
1281	3	+
1051B	3	+
1385	3	—
1448	3	+
1215	3	+
1277	3	+

1 + Indicates stem borer damage, — indicates no damage.

presumably oviposit. The larvae then penetrate the stem and commence to build tunnels. Plants attacked by stem borer

Table 22. **Stem borer distribution, within *Stylosanthes* plants, at Quilichao.**

Distribution	No. of plants examined	No. of lesions	Infestation (%)
Upper third	57	8	5
Middle third	57	64	38
Lower third	57	94	57

Figure 15. ***Stylosanthes scabra* affected by the stem borer (possibly *Zaratha* sp.), showing pupation site.**

develop gall-like malformations. In these structures, which become soft and decomposed, several larvae and pupae can be found.

Last instar larvae are approximately 8.5 millimeters long and white in color. The adult is a microlepidoptera and is brown-grey in color with very long filiform antennae. (Figs. 15, 16, 17).

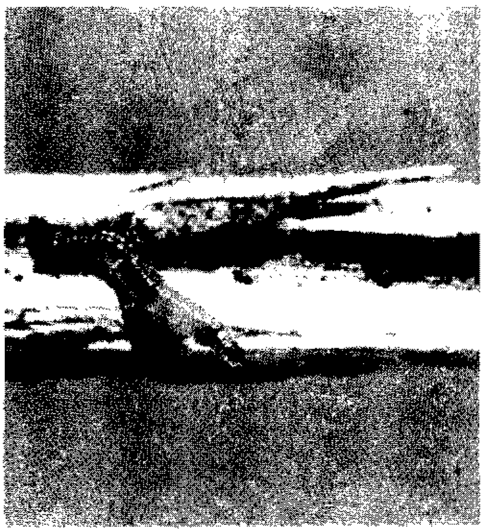


Figure 16. ***Stylosanthes capitata* showing damage caused by the stem borer larva (possibly *Zaratha* sp.).**

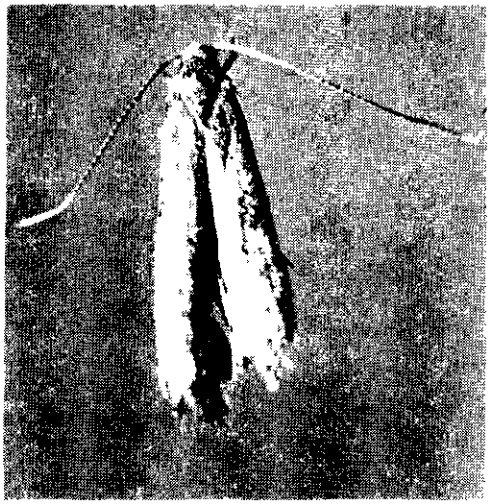


Figure 17. Stem borer adult (possibly *Zaratha* sp.).

Figure 18. *Stylosanthes guianensis* attacked by the budworm, *Stegasta bosqueella* (Chambers) Lepidoptera, Gelechiidae.

Stem Borer Parasite

Adult parasites of the order Hymenoptera were found in laboratory examinations of material collected from Quilichao. Studies of these parasites will continue.

Alternate Hosts

In Carimagua, the weed called "Escoba" *(Sida* sp.) has been observed infested with stem borers. This weed is also host to another borer, a beetle probably belonging to the family Curculionidae, which occasionally attacks stylo plants.

BUDWORM

The budworm, identified as *Stegasta bosqueella* (Chambers) Lepidoptera, Gelechiidae, is another pest of *Stylosanthes*. The eggs of *Stegasta* are white and elongated, about 0.2 millimeters long, and have a corrugated surface. The females lay their eggs on the trichomes of the external bracts of the inflorescence. One larva is usually found per bud. First instar larvae are approximately 1 millimeter long, and milky-white in color with a dark-reddish cervical plate. Last instar larvae become pinkish in color and are approximately 6 millimeters long. The adult is a microlepidoptera, 5 millimeters long, black in color with a yellow spot on the dorso and two small lateral spots on the wings (Fig. 18 and 19). Two different parasites of the budworm belonging to the order Hymenoptera have been obtained at Quilichao.

Figure 19. Adult of the budworm, *Stegasta bosqueella* (Chambers) Lepidoptera, Gelechiidae.

Soil Microbiology

The objective of the Soil Microbiology section is to maximize the benefits of biological nitrogen fixation to adapted forages in the acid, infertile soils of tropical Latin America. Although "forages" implies both grasses and legumes, priority has been given to the legume/*Rhizobium* symbiosis. The research strategy is: (1) to maintain and augment the CIAT *Rhizobium* germplasm resource; (2) to evaluate the symbiotic nitrogen fixation potential of *Rhizobium* strains with adapted legumes; and, (3) to test expression of symbiotic potential of selected strains in field situations, initially at Quilichao, Carimagua and Brasilia, and then in regional trials throughout the Beef Program's target area.

RHIZOBIUM COLLECTION

There were 1051 strains for forage legumes in the CIAT *Rhizobium* Collection as of October 31, 1977; of these, 644 were added during 1977. These have been isolated from 111 species in 50 genera. For each strain the following information is recorded and stored in an information retrieval system.

Relating to origin:

- **Genus*** from which strain was isolated.
- **Species*** from which strain was isolated.
- **Accession number*** of plant of origin (seed of the plant of origin may be conserved in the CIAT Forage Germplasm Bank).
- **Source***. If isolated and supplied by another laboratory this is acknowledged by inclusion of the original strain number. If isolated at CIAT the collector is acknowledged.
- **Country** where collected.
- **State** where collected.
- **Rainfall** (mm/year) at collection site.
- **Temperature*** (mean daily temperature (°C) during growing season).
- **Land use** at collection site.
- **pH*** of soil at collection site.

Relating to growth in pure culture:

- **Days*** to reach 2 mm colony diameter on YMA (28°C).
- **Acid*** or **alkali*** producer on YMA with bromthymol blue.
- **Comments** on colony appearance.

Relating to strain efficiency:

- **Effectiveness*** with individual plant species (and accessions).
- **Acetylene reduction** (per plant and per unit weight of nodules).

A catalogue which includes those parameters of wide interest (marked with an asterisk above) was published and is available from the Beef Program on request. A compact, sturdy kit which facilitates surface sterilization of legume root nodules and the transfer of nodule bacteria onto culture plates has been developed for use by plant explorers during prolonged collecting expeditions in remote regions. The main advantages offered over conventional collection methods based on retrieval of dessicated nodules are that the success rate with isolations from small nodules (especially from *Stylosanthes* spp.) is increased from 12 to 85 percent and that quarantine regulations prohibiting the importation of plant material and/or soil are not applicable to this system.

STRAIN SELECTION

The fives stages of strain selection are described in Table 23. The following is a summary of the trials conducted during

Table 23. **Procedure for *Rhizobium* strain selection.**

Stage	To assess	Method
I	Genetic compatibility	Inoculation of plants cultured aseptically in agar deeps of Hensen's medium in 150 x 25 mm tubes. Five replicates. Data: + or -nodulation
II	Nitrogen fixation potential	Inoculation of plants cultured in Leonard jar assemblies using washed river sand as rooting medium and Norris and Date's nutrient solution. Five replicates. Data: dry matter and N content.
III	Physical and chemical stress	Inoculation of plants cultured in pots of sterilized (methyl bromide) site soils. Five replicates. Data: dry matter and N content.
IV	Biological and climatological stress	Field trial of three best strains from III inoculated by three techniques (simple inoculation, lime pelleting and rock phosphate pelleting). Randomized complete block design (3 replicates) using 4 x 2 m plots with 1 m drainage canals around each. Data: dry matter and N content; % nodulation due to inoculant strain.
V	Range of applicability of recommendation	Regional trial of inoculation recommendation (strain and technology) compared with uninoculated and nitrogen fertilized plots. Three replicates. Data: dry matter and N content; % nodulation due to inoculant strain.

1977 (no trials were done in Stages III and V).

Stage I

Desmodium heterophyllum (CIAT 349) was nodulated by 10, and *Desmodium ovalifolium* (CIAT 350), by 35 of a total of 39 *Rhizobium* strains originally isolated from *Desmodium* species (Table 24).

Stage II

In an evaluation of 48 strains (all *Centrosema* isolates) with the *Centrosema* hybrid CIAT 1733 (*C. brasilianum* x *C. virginianum*) the commercial strain for *C. pubescens* was only partially effective, whereas several local isolates (CIAT 193, 221, 224, 227, 590, and 602) were outstanding, giving higher dry matter yields than those plants that were grown with combined nitrogen (Fig. 20). The best two strains (CIAT 583 and CIAT 584) were isolated at CIAT from dessicated nodules collected in Mexico from *C. brasilianum*, one of the parents in the cross. The black nodule strain C 101a (CIAT 49) was among the most efficient strains. Crude protein content (Kjeldahl Nx6.25) of shoots of plants with efficient symbioses averaged 20.7 percent, compared to 6 percent in non-nodulated plants, 11.3 percent in plants with nitrogen available in the media, and 12 percent in inefficient symbioses.

In a trial of 35 strains with *Desmodium distortum* (CIAT 335), the current Australian recommendation for *D. intor-*

Table 24. **Contrasting compatibility ranges of *Desmodium heterophyllum* (CIAT 349) and *Desmodium ovalifolium* (CIAT 350) with 39 *Rhizobium* strains.**

CIAT[1] Strain No.	*Desmodium heterophyllum*	*Desmodium ovalifolium*	CIAT[1] Strain No.	*Desmodium heterophyllum*	*Desmodium ovalifolium*
13	-[2]	+	296	-	+
31	+	-	297	+	+
46	-	+	298	-	+
59	-	+	299	-	+
80	+	+	304	-	+
109	+	+	310	-	-
164	-	+	329	+	+
187	-	+	353	-	+
259	-	-	359	-	+
272	-	-	388	+	+
282	-	+	507	+	+
283	-	+	512	-	+
284	-	+	529	+	+
288	+	+	533	-	+
289	-	+	571	-	+
290	-	+	572	+	+
291	-	+	573	-	+
293	-	+	592	-	+
294	-	-	595	-	+
295	-	+			

1 All strains isolates from nodules of *Desmodium* species. 2 +: Nodulated (two or more of the five replicates nodulated); -: Non-nodulated.

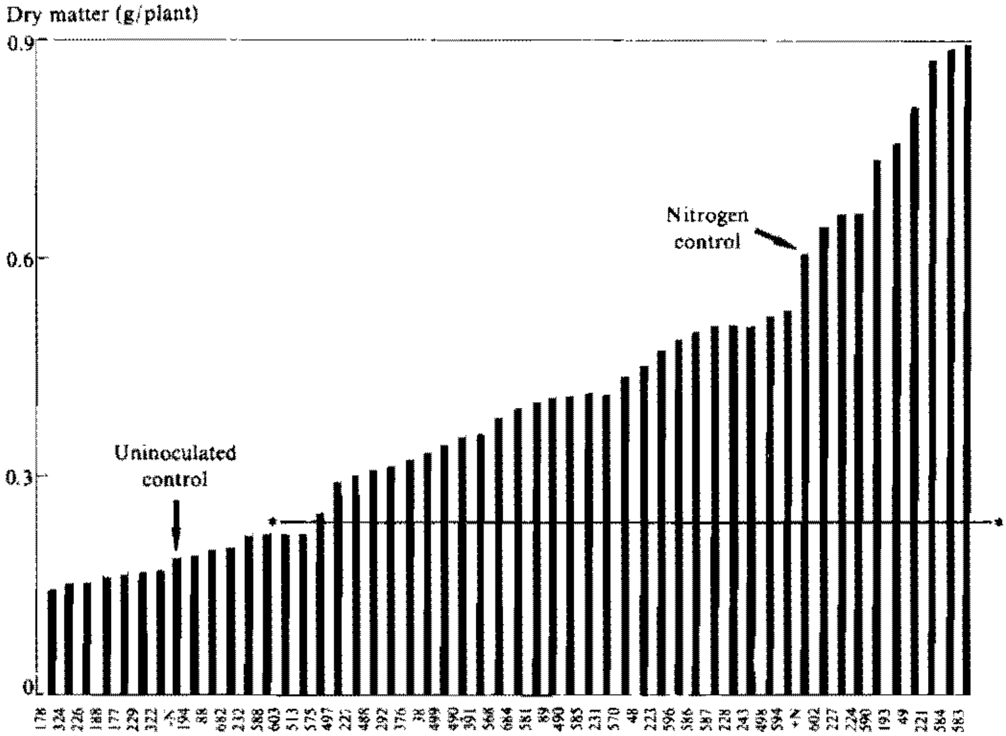


Figure 20. *Rhizobium* **strain selection for** *Centrosema* **hybrid (Stage II). (* Upper confidence limit (95%) to mean of uninoculated control.)**

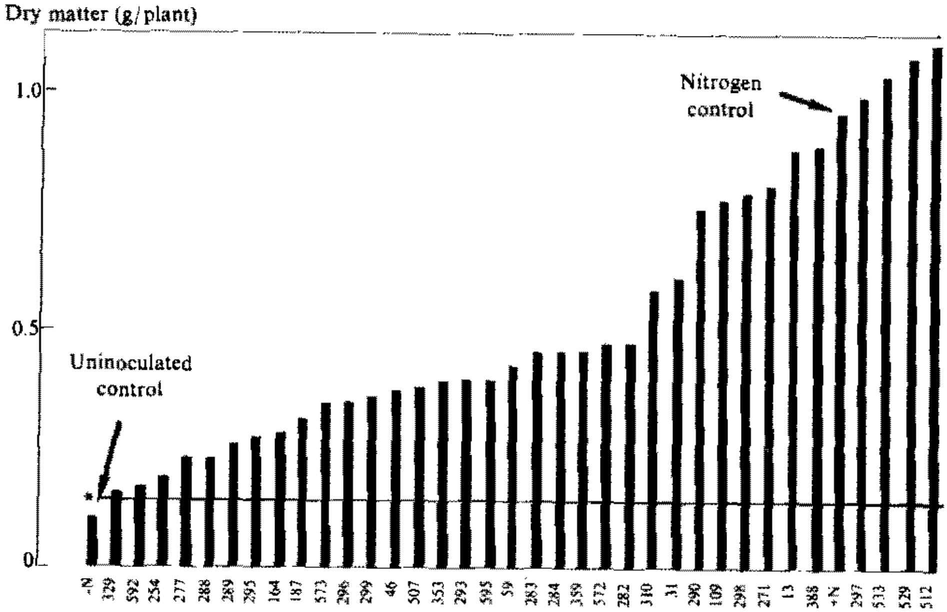


Figura 21. *Rhizobium* **strain selection for** *Desmodium distortum* **(Stage II). (* Upper confidence limit (95%) to mean of uninoculated control.)**

tum (CB 627) was ninth in efficiency order (Fig. 21). CIAT 512 and 533 gave 33 percent more dry matter than CB 627. The best strain in the test (CIAT 512) was the

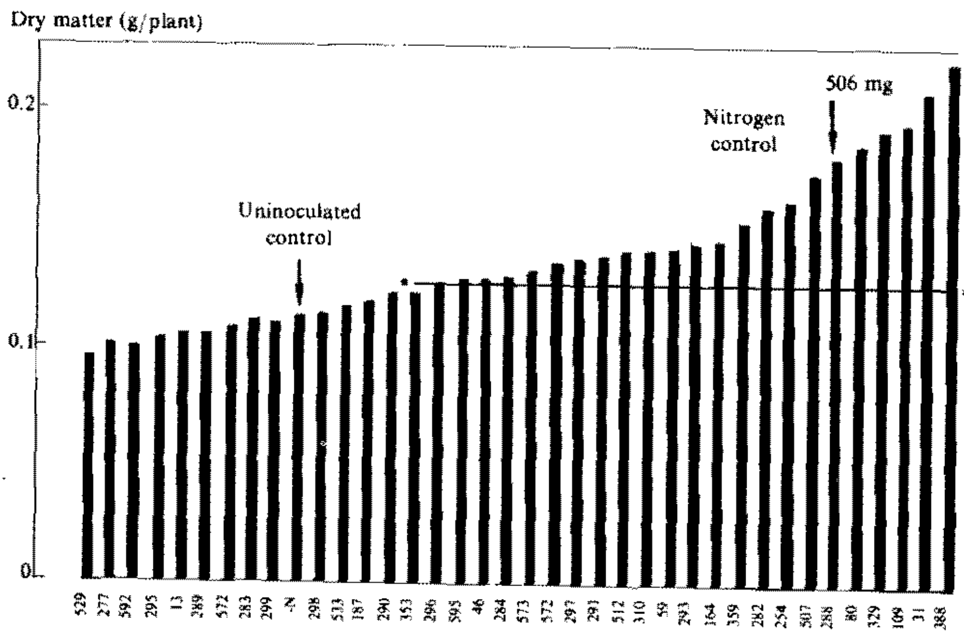


Figure 22. *Rhizobium* **strain selection for** *Desmodium heterophyllum* **(Stage II). (* Upper confidence limit (95%) to mean of uninoculated control.)**

only one originally isolated from nodules of *D. distortum*.

D. heterophyllum is known to be specific in its *Rhizobium* strain requirement. Only seven of 37 *Desmodium* isolates formed effective associations (Fig. 22). The Australian recommendation (CB 2085) for *D. heterophyllum* was efficient in this test.

Stage IV

Ten field experiments of the standardized design outlined in Table 23 were sown, six at Quilichao and four at Carimagua.

Quilichao. Inoculation of *Galactia striata* (CIAT 969) with *Rhizobium* strain CIAT 378 increased the dry matter yield 20 percent and the percentage protein of cut forage by 18 percent during establishment (Fig. 23); at the second cut, however, dry matter yield of inoculated plots was not significantly different from the uninoculated control. The *Centrosema* hybrid (CIAT 1733) responded slightly to inoculation with CIAT 590 and CIAT 594, with no consistent effect due to the inoculation method (Fig. 23). *Stylosanthes guianensis* (CIAT 136) responded to inoculation with all three strains, and rock phosphate-pelleting was consistently superior to lime-pelleting (Fig. 23). Simple inoculation, i.e. wetting seeds with an aqueous suspension of inoculant, was adequate for the strains CIAT 71 and CIAT 702 (isolates from acid soils) but not for CIAT 79 (CB 756) a wide-spectrum cowpea strain. Plots inoculated with CIAT 71 were markedly superior to all others at weekly visual assessments during the first two months of establishment but less so during the third month. By the time of the first cut (14 weeks after sowing) plots inoculated with CIAT 71 did not differ significantly from those inoculated with CIAT 79. CIAT 71 had proven much more efficient than CIAT 79 in Stage II and Stage III (CIAT Annual Report, 1976). This early advantage from inoculation with *Rhizobium* suggests its exploitation as a strategy to impart early vigor to legumes which are notoriously slow to establish in mixed pastures.

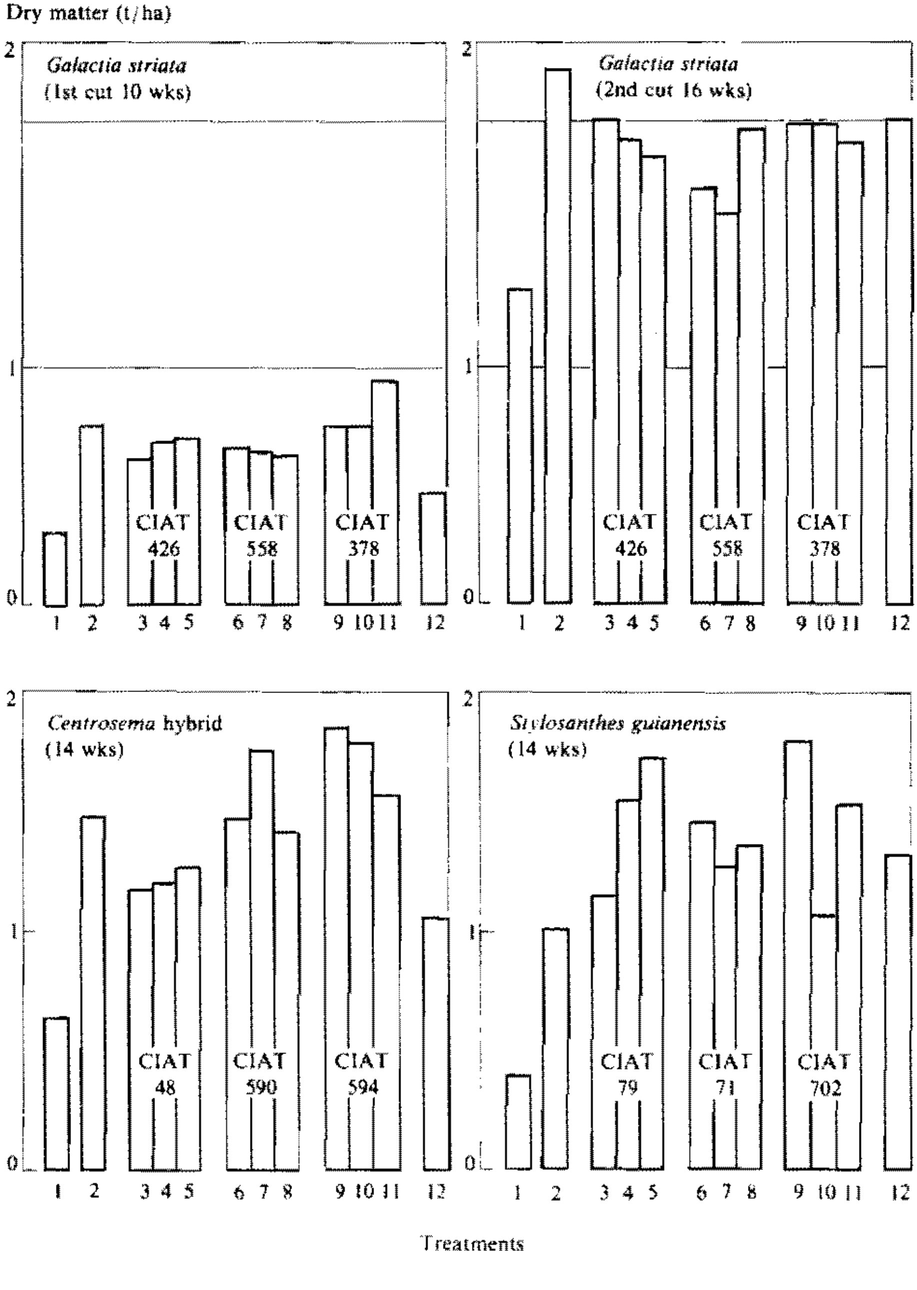
Carimagua. *Macroptilium* sp. (CIAT 535) responded to inoculation with all three *Rhizobium* strains (Fig. 24). CIAT 318 was the most effective strain and lime-pelleting was the best inoculation technology. These results contradict traditional concepts that *Macroptilium* is unresponsive to *Rhizobium* inoculation and that slow growing (tropical) rhizobia should not be lime-pelleted. Trials with *D. ovalifolium*, *S. capitata* (CIAT 1019) and *S. capitata* (CIAT 1078) are in progress.

INOCULATION RECOMMENDATIONS

An inoculation recommendation has been made for each promising legume accession under evaluation (Table 25). Although preferable that each recommendation is based on field evaluations (Stage V) it has been necesary to make tentative recommendations based on early screening stages or, in the case of accessions still pending investigation, Australian recommendations. In a few cases, tentative recommendations were made on the basis that the strain was isolated from the same species.

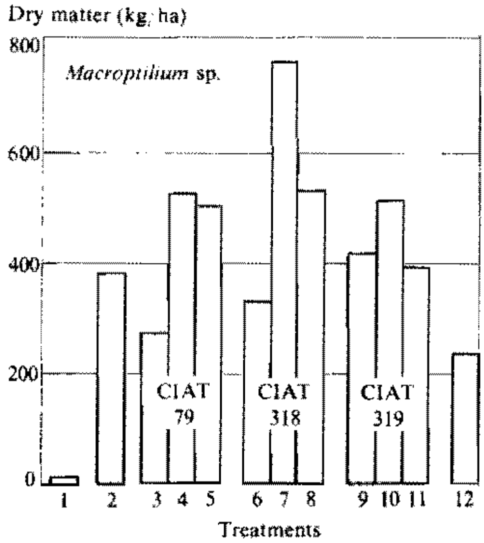
INOCULANT CARRIERS

Peat-based legume inoculant is available for all accessions for which inoculation is recommended (and also for all agriculturally important forage legumes). Finely-milled peat is widely accepted as the most satisfactory carrier for rhizobia but is not available in many countries, or is of variable and unpredictable quality. In Colombia peat from only one of nine deposits tested for use as an inoculant base exhibited satisfactory survival of rhizobia. The inconvenient location of this peat source and suspicions about quality variability within the deposit was the motive for comparative evaluation of peat with coals from three local mines.



Treatments: (1) Not fertilized, not inoculated; (2) Fertilized (no N), not inoculated; (3), (6), (9) Inoculated with aqueous suspension of *Rhizobium;* (4), (7), (10) Inoculated with *Rhizobium*, lime-pelleted; (5), (8), (11) Inoculated with *Rhizobium*, rock phosphate-pelleted; (12) Fertilized (100 kg N/ha), not inoculated.

Figure 23. ***Rhizobium*** **strain selection Stage IV (field trial, Quilichao).**



Treatments: See Figure 23.

Figure 24. *Rhizobium* **strain selection Stage IV (field trial, Carimagua).**

The survival of rhizobia in coal- and peat-based inoculants was determined by the plant dilution method. Peat afforded best survival, having 1.2 x 10^9 rhizobia/gram of inoculant after six months of storage. One of the three coals tested supported acceptable survival of rhizobia (Fig. 25) but could not be recommended as an inoculant base due to its tendency to aggregate into hard lumps during storage and to resist wetting at the time of seed inoculation.

Table 25. **Current inoculation recommendations for promising forage legumes (31 October, 1977).**

Species	CIAT No.	Strain	Technology	Basis[1]
Alysicarpus sp.	706	CIAT 503	Rock Phosphate Pellet	SS
Centrosema sp.	1733	CIAT 594	Rock Phosphate Pellet	I, II, IV
"	1787	CIAT 594	Rock Phosphate Pellet	I; II; IV
"	845	CIAT 594	Rock Phosphate Pellet	I; II; IV
Desmodium barbatum	3063	CIAT 359	Rock Phosphate Pellet	SS
" *canum*	3005	—	—	
" *distortum*	335	CIAT 512	Rock Phosphate Pellet	SS; II
" *heterocarpon*	365	—	—	
" *heterophyllum*	349	CIAT 80	Rock Phosphate Pellet	AUS; II; FB
" *leonii*	3001	—	—	
" *ovalifolium*	350	CIAT 46	Rock Phosphate Pellet	II; IV; FB
" *scorpiurus*	3022	—	—	
" sp.	336	—	—	
" sp.	3019	—	—	
Glycine wightii	201	CIAT 79	Rock Phosphate Pellet	AUS
" "	204	CIAT 79	Rock Phosphate Pellet	AUS
Macroptilium sp.	535	CIAT 318	Lime Pellet	IV
Pueraria phaseoloides	(common)	CIAT 79	Rock Phosphate Pellet	AUS
Stylosanthes capitata	1019	CIAT 71	Rock Phosphate Pellet	III; FB
" "	1078	CIAT 71	Rock Phosphate Pellet	III; FB
" "	1097	CIAT 71	Rock Phosphate Pellet	III
" "	1405	CIAT 71	Rock Phosphate Pellet	III

Basis: AUS = Australian recommendation; SS = Isolate from same species; FB = Feed Back Program use; Strain Selection Stages: I = Tube culture; II = Leonard jar; III = Pot trial; IV = Field trial; V = Regional trial.

Table 25. (continued)

Species	CIAT No.	Strain	Technology	Basis[1]
S. guianensis	64A	CIAT 71	Rock Phosphate Pellet	I, II
" "	136	CIAT 71	Rock Phosphate Pellet	I; II; III; IV; FB
" "	184	CIAT 71	Rock Phosphate Pellet	I, III
" "	1135	CIAT 111	Rock Phosphate Pellet	AUS
" "	1200	CIAT 111	Rock Phosphate Pellet	AUS
" "	1062	CIAT 111	Rock Phosphate Pellet	AUS
S. hamata	118	CIAT 71	Rock Phosphate Pellet	III
" "	147	CIAT 71	Rock Phosphate Pellet	III
S. humilis	1304	CIAT 71	Rock Phosphate Pellet	III
S. scabra	1047	CIAT 71	Rock Phosphate Pellet	III
S. sympodialis	1044	CIAT 71	Rock Phosphate Pellet	III
S. viscosa	1074-A	CIAT 71	Rock Phosphate Pellet	III
Teramnus uncinatus	508	CIAT 452	Rock Phosphate Pellet	SS
Zornia sp.	728	CIAT 103	Rock Phosphate Pellet	SS

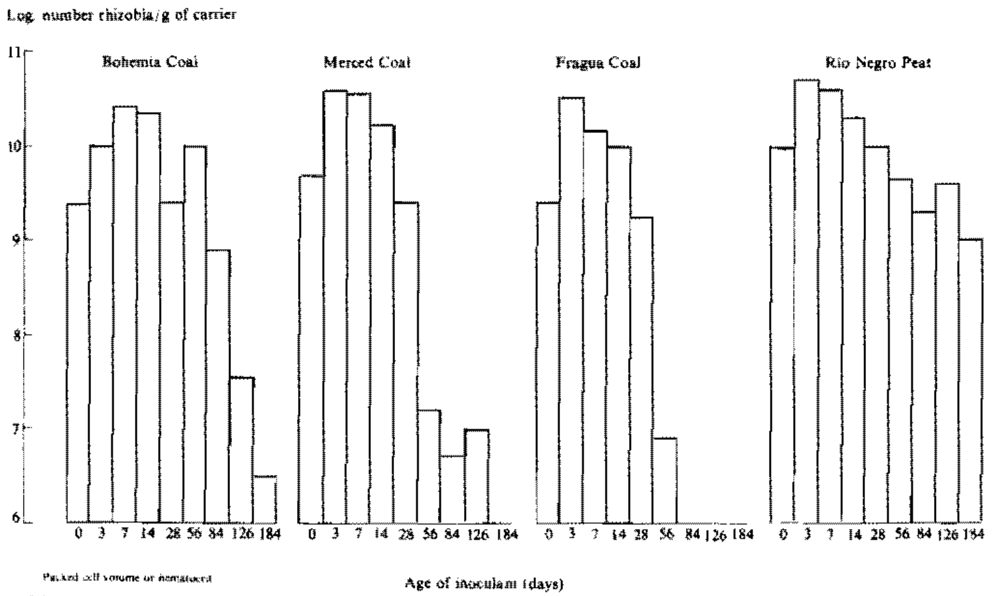


Figure 25. Survival of rhizobia in four prospective carriers.

Soil Fertility

Soil fertility research is conducted by program soil scientists with the purpose of: (1) identifying soil limitations where field research is undertaken; and, (2) to develop more efficient methods of fertilizer management. Emphasis during 1977 was on characterizing the soil properties at the new CIAT-Quilichao station, determining

Table 26. **Characteristics of the main soils at Quilichao, Carimagua and Cerrado Center Stations.**

Horizon (cm)	Clay (%)	Sand (%)	pH (H_2O)	Org. C (%)	Exchangeable cations (meq/100 g) Al	Ca	Mg	K	ECEC	Al satn (%)	Avail. P[1] (ppm)	Avail. H_2O (% vol)
CIAT-Quilichao: Ultisol (Orthoxic Palehumult, clayey, kaolinitic, isohyperthermic).												
0-20	71	4	4.1	4.1	2.7	.65	.49	.36	4.2	64	1.8	16
20-35	77	5	4.0	2.3	2.7	.31	.04	.13	3.2	83	1.1	13
35-62	64	2	4.3	1.1	3.2	.24	.02	.09	3.6	88	0.9	16
62-91	88	1	4.4	0.4	1.1	.15	.02	.06	1.4	77	0.9	9
91-150	90	1	4.4	0.3	2.0	.22	.01	.04	2.3	85	1.2	14
Carimagua: Oxisol (Typic Haplustox, clayey, kaolinitic, isohyperthermic).												
0-12	38	12	4.5	2.2	3.8	0.2	0.2	0.4	4.7	81	0.9	9
12-32	41	11	4.6	1.2	2.8	0.1	0.1	0.1	3.1	89	0.9	7
32-58	43	11	4.8	0.9	2.1	0.1	0.1	0.1	2.3	91	0.4	5
58-88	45	12	5.2	0.4	0.7	0.1	0.1	0.1	0.9	78	0.4	6
88-148	45	12	5.1	0.3	0.6	0.1	0.1	0.1	0.8	75	0.4	7
Cerrado Center: Oxisol (Typic Haplustox, fine, kaolinitic, isohyperthemic - LVE).												
0-10	45	36	4.9	1.8	1.9		0.4	.10	2.4	79	tr.	11
10-35	48	33	4.8	1.2	2.0		0.2	.05	2.2	89	tr.	11
35-70	47	35	4.9	0.9	1.6		0.2	.03	1.8	88	tr.	9
70-150	47	35	5.0	0.7	1.5		0.2	.01	1.7	88	tr.	9
150-260	42	39	4.6	0.3	0.7		0.2	.02	0.9	76	tr.	9

[1] Bray II extraction method.

the limiting soil factors at that location, and evaluating sources and methods of phosphorus application in Oxisols and Ultisols.

SOIL PROPERTIES AT THE PRINCIPAL RESEARCH SITES

Representative profiles of well-drained positions at Quilichao, Carimagua and Brasilia are shown in Table 26. All sites are very acid, with surface pH values ranging from 4.1 to 4.9, with toxic levels of aluminum saturation. They are very low in available phosphorus, exchangeable calcium, magnesium, potassium and several micronutrients. The basic cation contents of Quilichao however, are considerably higher than at Carimagua and Brasilia, but still very much within the realm of acid, infertile soils.

Because of their high clay contents and the presence of iron and aluminum oxides, the three locations have a high capacity to fix fertilizer phosphorus. The phosphorus fixation curves in Figure 26 indicate an extremely high fixation capacity —on the order of 620 to 750 ppm phosphorus for Quilichao and Brasilia, and about one-half that amount (350 ppm) for Carimagua. For comparison, the phosphorus fixation level of the Mollisol from CIAT's headquarters at Palmira is about 50 ppm of phosphorus.

A detailed soil survey of CIAT-Quilichao was contracted with the Corporación Autónoma Regional del Valle del Cauca (CVC) at the scale of 1:20,000. The soil map indicates little variability from the profile shown in Table 26 on plateau and slope positions, all of which are classified as Orthoxic Palehumults. The poorly-drained soils in lower topographic positions are also extremely acid and low in exchangeable bases, indicating that the entire landscape is base-depleted, similar to conditions at Carimagua and Brasilia. The poorly-drained soils are also Ultisols but are classified as Umbric Paleaquults.

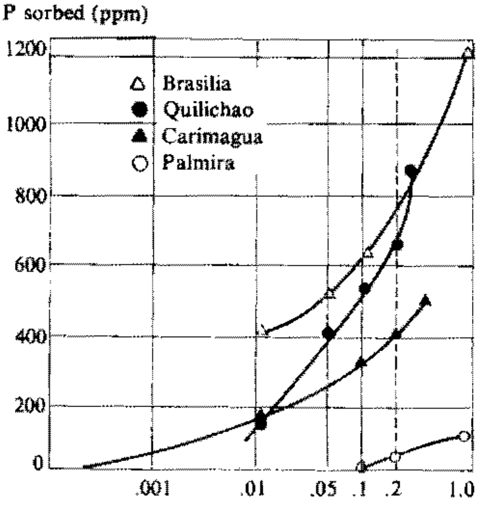


Figure 26. **Phosphorus fixation isotherms of research sites at Brasilia, CIAT-Quilichao, Carimagua and CIAT-Palmira.**

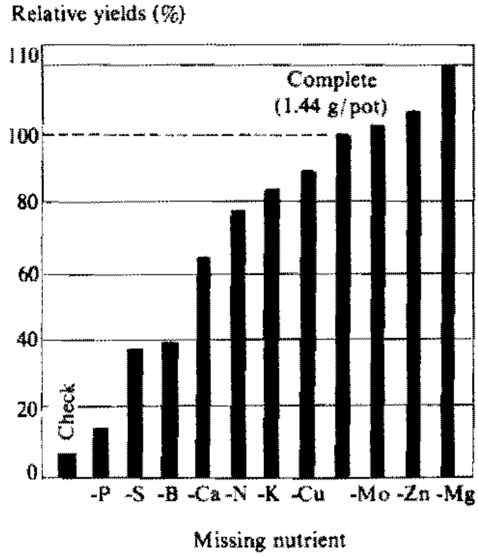


Figure 27. **Response of *Centrosema plumieri* to missing nutrient elements in the Quilichao Ultisol. (Dry matter production, at first cutting, mean of four replications.)**

Detailed mineralogical analyses conducted at North Carolina State University (USA) show that kaolinite and halloysite are the dominant layer silicate minerals. The well-drained soils average 15 percent free Fe_2O_3 and 11 percent free Al_2O_3 contents, which account for their high phosphorus fixation capacity.

FERTILITY LIMITATIONS AT CIAT-QUILICHAO

A series of greenhouse experiments were conducted with the topsoil samples of the Quilichao Ultisol described in Table 26 in order to describe its fertility status. A missing element trial showed this soil to be extremely deficient in phosphorus, sulfur and boron and, to a lesser extent, calcium (Fig. 27). The extremely low yield of the check plot created the suspicion of aluminum and manganese toxicity.

The magnitude of phosphorus response was then tested with *Panicum maximum* and a *Centrosema* hybrid (CIAT 1733). Both species responded sharply to

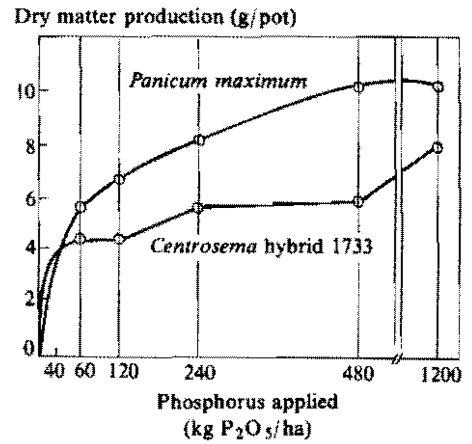


Figure 28. Phosphorus response by a grass and a legume species in the Quilichao Ultisol. (Sum of two cuts and mean of four replications.)

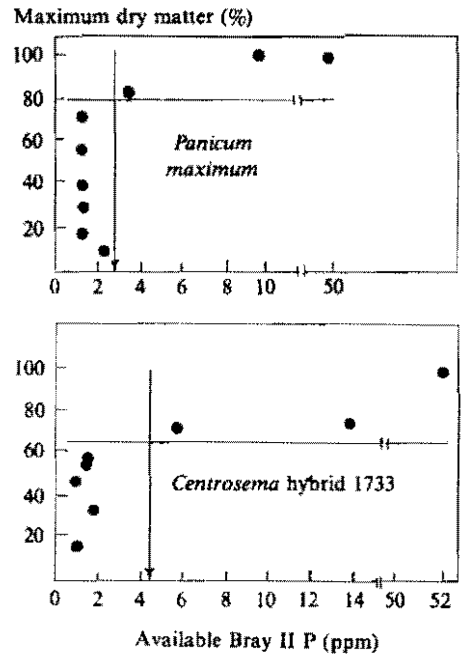


Figure 29. Estimation of the critical phosphorus levels in the Quilichao Ultisol in the greenhouse. (Sum of two cuts and mean of four replications.)

superphosphate applications but the amounts required to approach maximum yields were higher in the grass than in the legume. The response curves show the first inflection point at 40 kg P_2O_5/ha for *Centrosema* and 60 kg P_2O_5/ha for *P. maximum*, but each species yielded only 56 percent of its maximum at those levels (Fig. 28). The subsequent gradual increase may be related to the ameliorating properties of superphosphate although soil chemical analysis did not show marked differences.

An estimation of critical soil test phosphorus levels in the unlimed Ultisol is shown in Figure 29. In both cases, the Bray II critical level is about 3 ppm phosphorus. In order to obtain about 80 percent of the maximum yield, these two figures suggest a broadcast rate of about 240 kg P_2O_5/ha for either species.

The relationship between pH,percentage aluminum saturation and exchangeable manganese as a fuction of liming are shown in Figure 30. The buffering capacity of this soil is extremely high, probably because of its high organic matter content. In order to raise the soil pH to 5.5 approximately 16 tons/ha of $CaCO_3$ are needed. The contrasting lime response of three forage legumes is shown in Figure 31. *Stylosanthes guianensis* 136 yielded best without lime applications, confirming its tolerance to the relatively high aluminum saturation and exchangeable manganese levels. The decrease at high lime rates is due to a calcium:magnesium inbalance. The *Centrosema* hybrid (CIAT 1733) showed a marked response to the 1 t/ha lime rate and decreased afterwards. The reasons for this response are unknown. *Centrosema plumieri*, a species adapted to high pH soils, required 8 t/ha of lime to approach maximum yields. This figure underscores the importance of selecting for aluminum tolerance as part of CIAT's low input strategy.

In summary, the Quilichao Ultisol is extremely deficient in phosphorus, sulfur and boron, moderately deficient in calcium, potassium and nitrogen and aluminum toxic for certain species.

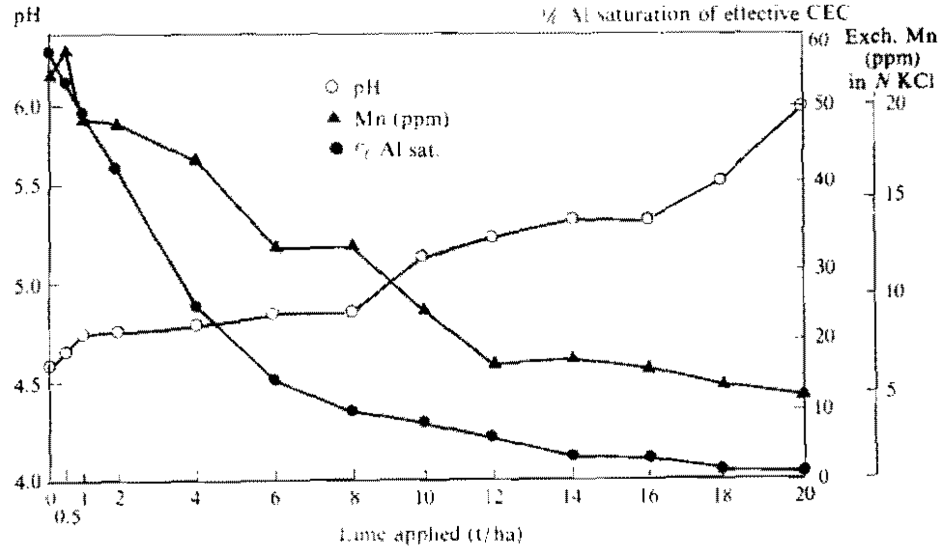


Figure 30. **Soil pH, exchangeable manganese and percentage aluminum saturation of effective CEC as affected by increasing lime rate of application on an Ultisol from CIAT-Quilichao. (Incubation time 60 days.)**

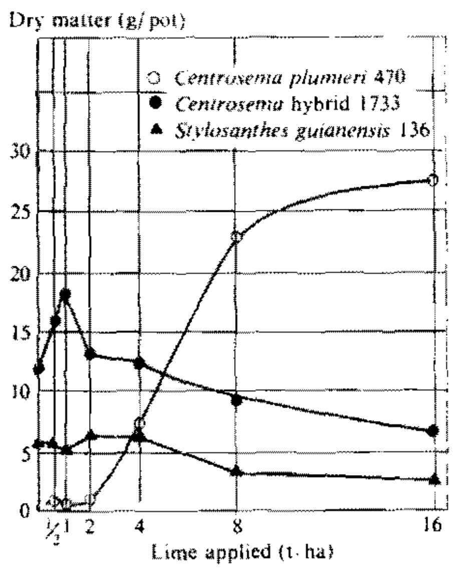


Figure 31. **Lime response of three forage legumes in the Quilichao Ultisol under greenhouse conditions.**

ROCK PHOSPHATE EVALUATION

Direct application of rock phosphate to acid soils offers a promising low-cost alternative for supplying this element in Oxisols and Ultisols that are both extremely deficient in phosphorus and fix large quantities of phosphorus fertilizers. Since late 1975 CIAT has been evaluating the various rock phosphate deposits found in Latin America. In July 1977 a special project on phosphorus was established, with International Development Research Centre (IDRC) financial support as a collaborative project between the International Fertilizer Development Center (IFDC) and CIAT. IFDC has stationed two of its senior scientists at CIAT to conduct this work. The project is an integral part of the Beef Program although work with other crops is also done, and is described elsewhere in this annual report.

Initial greenhouse experiment. Figure 32 shows the results of initial evaluation in the greenhouse with *Panicum maximum* growing on an unlimed Oxisol from Carimagua. High reactivity rocks from Sechura (Peru) and North Carolina (USA) were superior to triple superphosphate applications and similar to basic slag. The two Colombian rock phosphates, Huila and Pesca, considered of medium and low reactivity, respectively, were less efficient than superphosphate. Figure 32 also

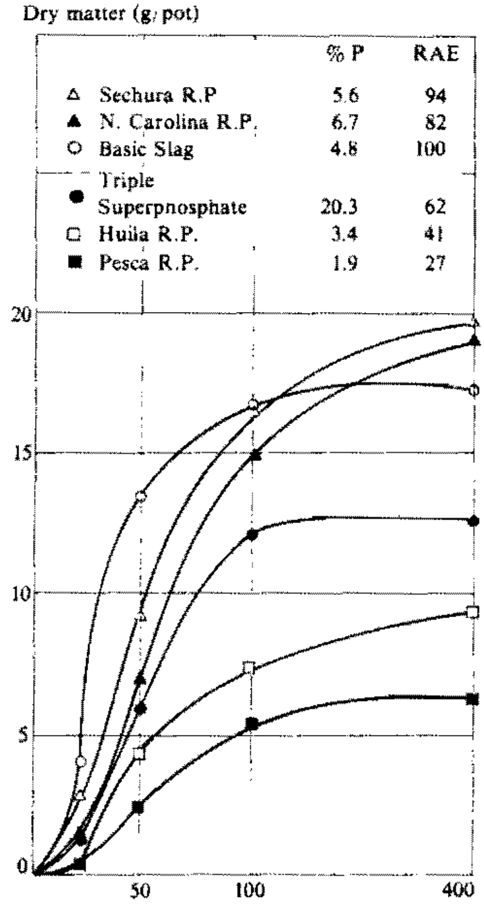


Figure 32. **Effect of sources of pnosphorus on *Panicum maximum* dry matter production (sum of three cuts) grown in the Carimagua Oxisol without liming in the greenhouse. (% P = citrate-soluble P of entire material; RAE = relative agronomic effectiveness.)**

illustrates tne Relative Agronomic Effectiveness (RAE) of each rock relative to basic slag. The poor response to superphosphate is probably related to inhibited growth by the low calcium and high aluminum saturation level of the soil. The Sechura and North Carolina rocks and basic slag ameliorated the soil because of their calcium release properties.

The relative availability of phosphorus from phosphate rock sources has been shown to be well-related to the citrate-soluble phosphorus content of the material. The correlation between citrate-soluble phosphorus in the phosphate rock and yield or phosphorus uptake was highly significant and improved as the rate of application increased. The citrate-soluble P_2O_5 of the phosphate rock was better correlated with yields when expressed as "percent of the rock" rather than "percent of total P_2O_5 in the rock" (Fig. 33).

Differences in reactivity of phosphate rocks were also reflected in the soil test parameters. The citrate-soluble P_2O_5 content of the pnospnate rocks was well-correlated with Bray I extraction. Higher crop response was observed with the phosphate rocks than with triple superphospnate at a given level of Bray I extractable pnosphorus (Fig. 34). This suggests that *P. maximum* was responding to the calcium supplied by the phosphate rock in addition to the phosphorus. Citrate-soluble phosphorus in the rock was significantly correlated with the concentration of water-soluble phospnorus in the soil at the 200 and 400 ppm pnosphorus rates. At the 50 and 100 ppm phosphorus rates, however, there was not a significant correlation.

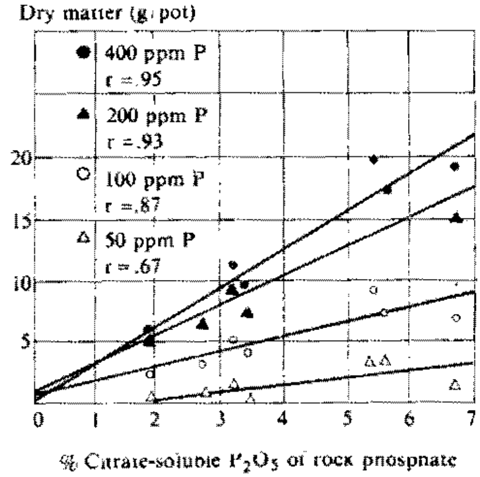


Figure 33. **Relationship between yield of three cuttings of *Panicum maximum* ana citrate soluble phosphorus in rock pnospnate (Sig. 0.01 level).**

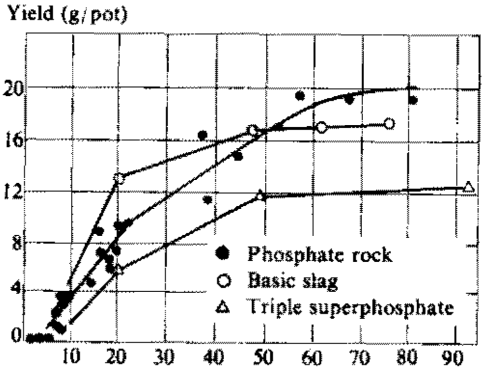


Figure 34. **Relationship between yield of three cuttings of *Panicum maximum* and Bray P-1 extractable phosphorus measured 90 days after application to a Carimagua Oxisol in the greenhouse.**

Phosphorus uptake by *P. maximum* was linearly correlated with water soluble phosphorus (r = 0.918**). Dry matter yield was related to water soluble phosphorus by one curvilinear relationship for the phosphate rocks and basic slag, and another curvilinear relationship for triple superphosphate (Fig. 35).

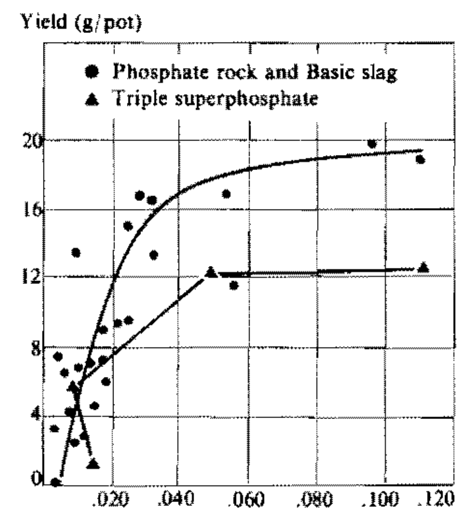


Figure 35. **Relationship between yield of three cuttings of *Panicum maximum* and water soluble phosphorus in a Carimagua Oxisol, in the greenhouse.**

Field Experiment. A long-term field experiment with *Brachiaria decumbens* was established in May 1976 at Carimagua to compare effects of six rock phosphates with triple superphosphate. Application rates range from 0 to 400 kg P_2O_5/ha, all broadcast and incorporated into the topsoil. The first four cuts of this experiment were harvested at 3, 6, 13, and 16 months after phosphorus applications. The lag between the second and third harvest includes the dry season.

The absolute and relative yield responses are shown in Figures 36 and 37, respectively. Triple superhosphate was only superior to rock phosphates during the first cut; afterwards all rock phosphate sources increased their effectiveness with time, approaching or surpassing the yields from superphosphate during the third and fourth cuts. The overall results during the first 16 months show that the high reactivity rocks Gafsa and Sechura were 105 and 99 percent as effective as superphosphate; the medium reactivity Huila rock was 91 percent as effective, and the low reactivity rocks, Tennessee and Pesca, were 87 and 88 percent as effective as triple superphosphate.

Figure 37 shows excellent performance of low and medium reactivity rocks not previously reported elsewhere. Normally, phosphorus from these rocks is very unavailable during the first year. By keeping the pH low (4.6 to 4.8), the soils became, in effect, an efficient superphosphate factory. By using a species tolerant to the high levels of aluminum saturation encountered (72 to 85 percent), the low pH did not affect growth. Total dry matter produced was 13.1 t/ha in 16 months, without irrigation and a basal fertilization of only 50 kg N, 100 kg K_2O and 20 kg S/ha. This indicates a very exciting potential for the medium and low reactivity rocks, so common in Latin America, as an important component of the Program's low input strategy.

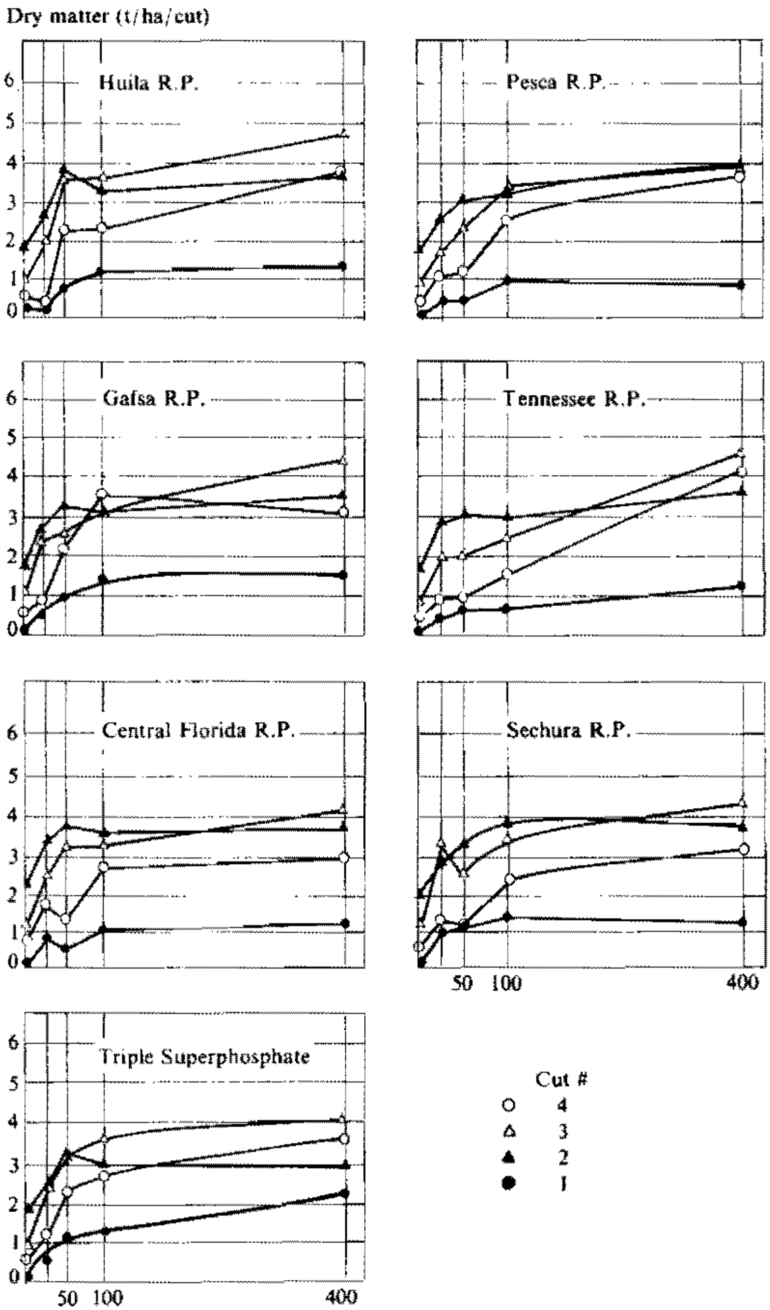


Figure 36. **Dry matter yield of four cuttings of *Brachiaria decumbens* as affected by rate and source of phosphorus in a Carimagua Oxisol.**

An evaluation of the residual effect must continue for several years, in order to fully appraise the value of such applications. An extra set of treatments of annual

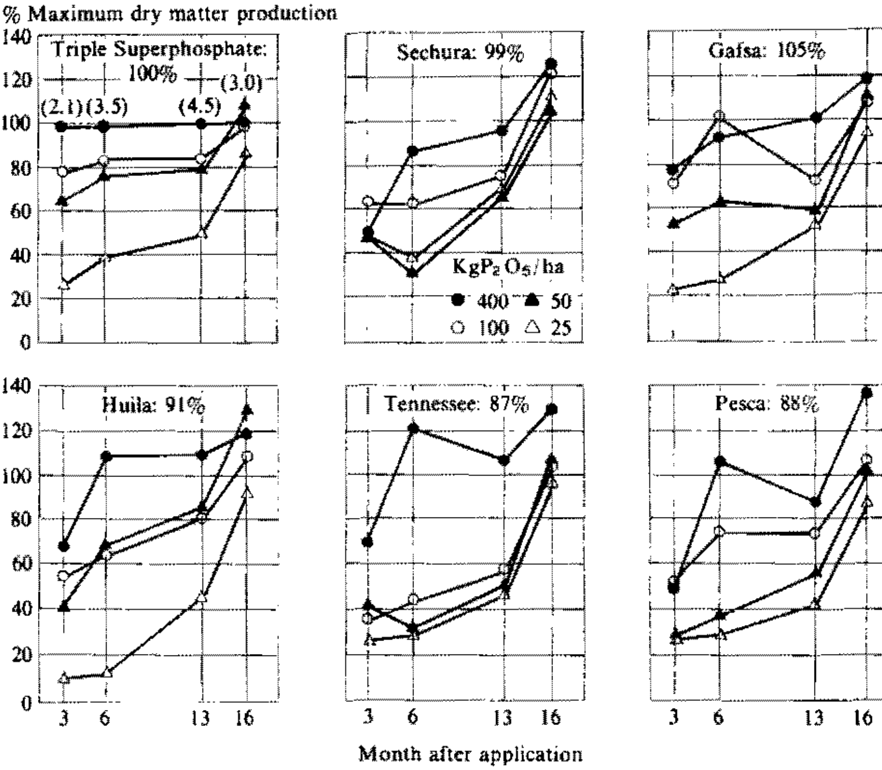


Figure 37. **Initital and residual effects of five phosphate rocks relative to superphosphate applications on** ***Brachiaria decumbens*** **yields in an Oxisol from Carimagua. (Percent figures indicate Relative Agronomic Effectiveness; maximum yields for each cut shown in parenthesis as t D.M./ha.)**

applications of triple superphosphate is being included for comparison.

Figure 38 shows that the application of the different phosphate rocks and soluble phosphorus fertilizers modified some chemical properties of the soil measured 12 months after application. This modification is more pronounced when phosphorus is applied at 400 kg P_2O_5/ha. Available phosphorus, measured as Bray I, increased substantially in the soil after application of triple superphosphate and high to medium reactivity rocks like Gafsa, Sechura and Central Florida. Changes in pH were not significant, but increases in exchangeable calcium were remarkable in the high reactivity rocks. Applications of 400 kg P_2O_5/ha of Huila tripled the exchangeable calcium in the soil, while the same amount of Sechura rock doubled it. These changes produced a decrease in aluminum saturation from 85 to 72 and 78 percent, respectively.

The greenhouse and field results show that direct applications of low (Pesca), medium (Huila) and high (Sechura) reactivity Latin America rocks to aluminum-tolerant grasses such as *Brachiaria* and *P. maximum* are superior to triple superphosphate in Oxisols of the Llanos of Colombia. A rate of 100 kg P_2O_5/ha appears optimum. Considering the low relative cost of a kilogram of P_2O_5 as rock phosphate compared with superphosphate, rock phosphates can significantly lower pasture establishment costs in the impact area.

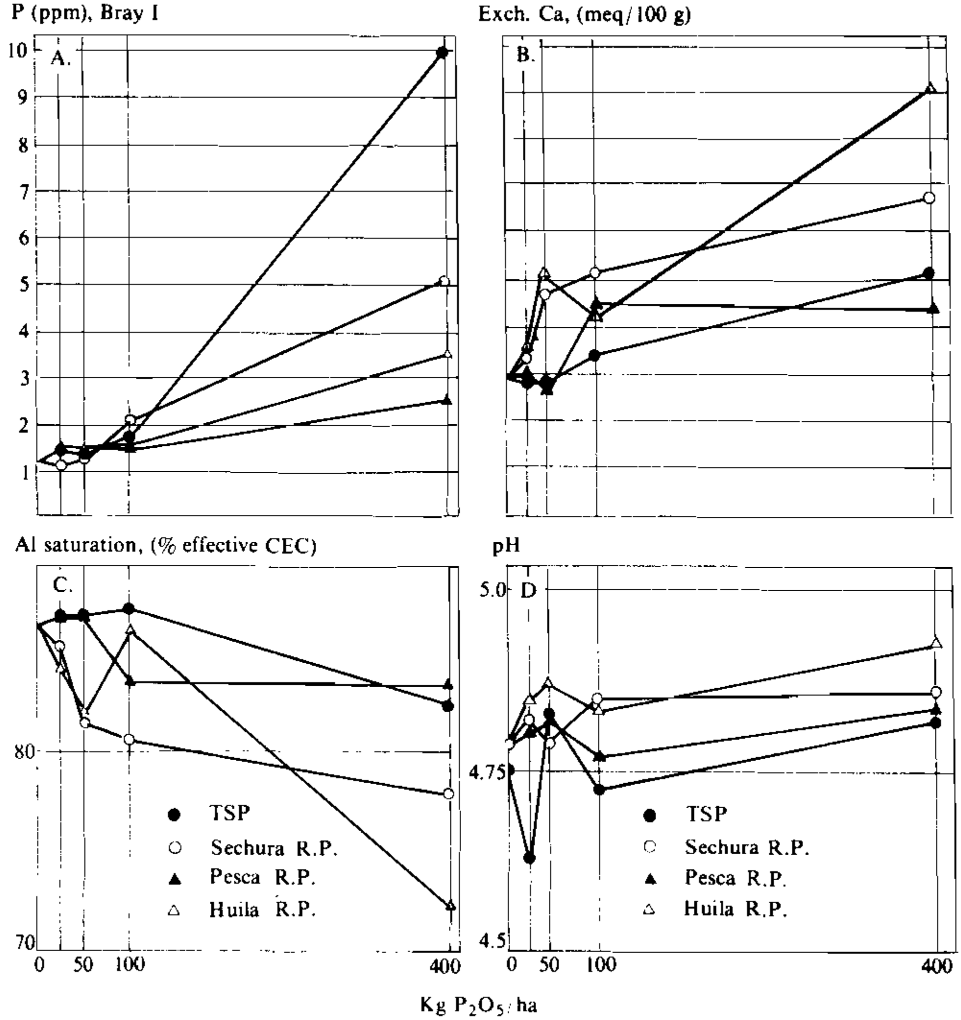


Figure 38. **Chemical properties of a Carimagua Oxisol supporting *Brachiaria decumbens* as affected by rate and source of phosphorus, measured 12 months after application.**

THERMOPHOSPHATE EVALUATION

Fused magnesium phosphate (FMP) is a phosphorus source produced by fusing rock phosphate with magnesium and silicate, usually supplied in the form of serpentine or a related material. The product is a glass whose chemical characteristics are very similar to basic slag. The latter has been shown to be more effective than triple superphosphate in Colombian Oxisols, but unfortunately, the supply is very limited.

This experiment was designed to compare the FMP produced in Japan with two other thermophosphates produced with native Colombian phosphate rocks and with other phosphorus sources in use. Materials were evaluated in the greenhouse with *Stylosanthes guianensis* (CIAT 136) on Carimagua Oxisol. Treatments with magnesium (as MgO) and silicate (as calcium silicate slag from TVA) equivalent to the amounts contained in FMP were included to separate the possible contributing factors, Lime was also included to separate the effect of the liming capacity of the calcium silicate from the possible beneficial effects of silicate anion.

Dry matter yields of the average of two cuttings are in Figure 39. In general, *S. guianensis* responded up to the highest rate of phosphorus applied. Only when the phosphorus source was TSP was the increase in yield between the two highest rates not significant. On the other hand, when TSP was mixed with MgO and calcium silicate or lime the response was almost linear.

When FMP was added to the soil yields were comparable to those produced by fertilization with basic slag supplemented with MgO and much higher than those of the TSP treatments.

Yields were not very different due to the use of coarse or fine FMP, but coarse Rhenania phosphate presented the lowest yields in this experiment. The Huila (Huila phosphate rock fused with serpentine) and Pesca thermophosphates (Pesca phosphate fused with dolomite) give better yields than TSP and coarse Rhenania phosphate, but were very similar to those produced using Huila phosphate rock mixed with MgO and calcium silicate. The results in Figure 39 also show that both magnesium and silicon are probably limiting the phosphorus response of *S. guianensis* in this soil.

Soil analyses did not show important variations in the chemical properties of the soil, except for available phosphorus measured as Bray I-P. There was little or no influence in the exchangeable magnesium of the soil. On the other hand, the thermophosphates and the Huila phosphate rock with MgO and calcium silicate increased appreciably the percentage of phosphorus and magnesium in the tissue of *Stylosanthes*. The use of TSP or Rhenania phosphate decreased the magnesium content of the tissue. Calcium content was also increased by the application of these thermophosphates to the soil.

SILICATES AND MAGNESIUM APPLICATIONS

In order to study the effect of silicates and MgO on the response of *S. guianensis* (CIAT 136) to phosphorus, a greenhouse experiment was established using an Oxisol from Carimagua. Triple superphosphate and Huila phosphate rock were the phosphorus sources. Magnesium oxide and calcium silicate were mixed and applied with the phosphorus sources at three different rates but always keeping the same ratio MgO: SiO_2 of 0.75:1.00.

Dry matter yields of the first cut are shown in Figure 40. When no phosphorus was added to the soil, stylo responded slightly to the first increment of MgO and SiO_2 but no response was detected afterwards. With added phosphorus, the response to MgO and calcium silicate was appreciable for the lowest level of these two compounds when TSP or Huila phosphate rock were used. Magnesium oxide and calcium silicate produced strong yield responses at high rates of TSP. Stylo yields are not markedly influenced by applications of MgO and calcium silicates when high levels of phosphorus are applied as Huila phosphate rock. It is possible that high rates of phosphate rock are adding enough calcium, magnesium and silicate to the soil to supply the plant requirements.

MIXING PHOSPHATE ROCKS WITH TRIPLE SUPERPHOSPHATE

One possibility for improving phosphorus availability in phosphate rocks is by mixing them with acid-forming substances like sulfur or triple superphosphate. Two greenhouse experiments were conducted using mixtures at different ratios of Huila phosphate rock and labeled triple superphosphate in a

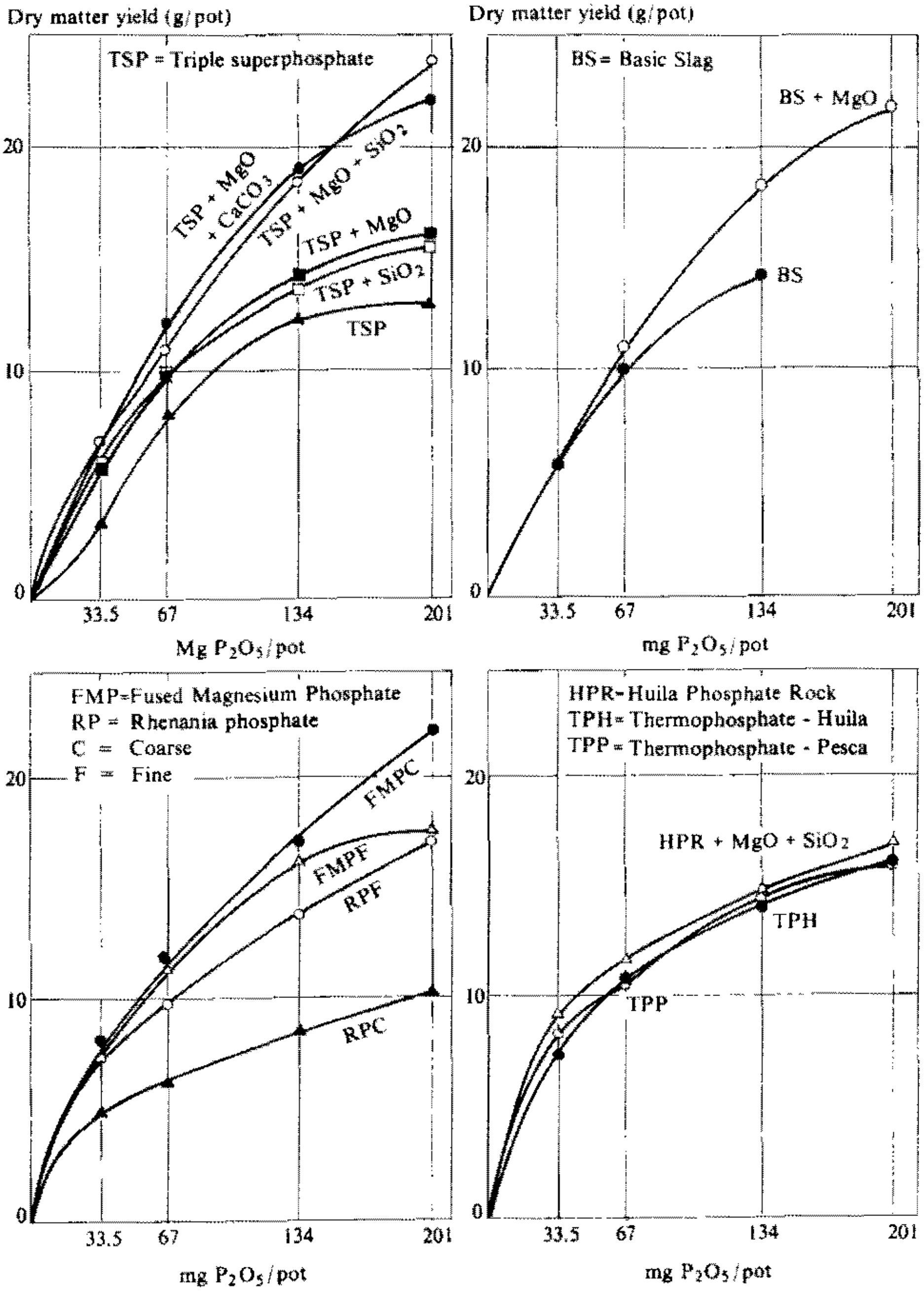


Figure 39. **Dry matter yield of two cuttings of *Stylosanthes guianensis* 136 as affected by rate of phosphorus with MgO, $CaCO_3$ and SiO_2 and by different thermophosphate, on a Carimagua soil in the greenhouse.**

Carimagua Oxisol and Quilichao Ultisol. *Desmodium distortum* (CIAT 335) and *P. maximum* were used as indicator plants, respectively. Figure 41 shows that yields

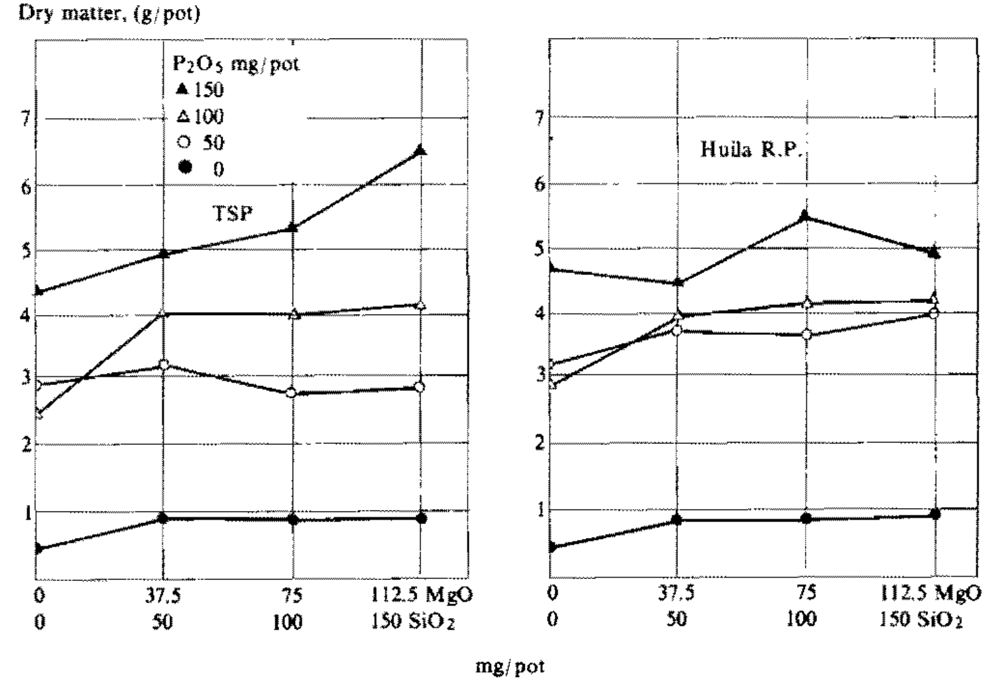


Figure 40. **Dry matter yield of one cut of *Stylosanthes guyanensis* 136 as affected by rates of MgO and SiO_2 and by rate and source of phosphorus on a Carimagua soil in the greenhouse.**

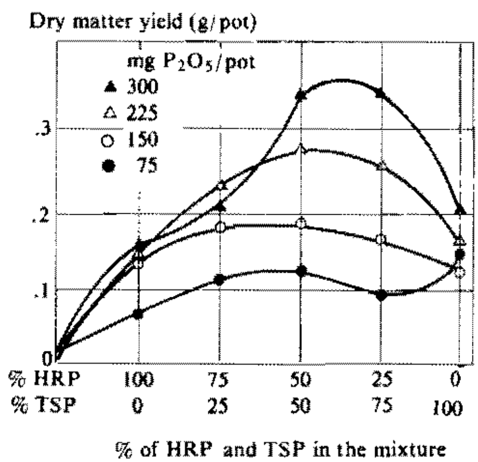


Figure 41. **Dry matter yield of *Desmodium distortum* CIAT 335 as affected by rate of P and mixtures of Huila rock phosphate (HRP) and triple superphosphate (TSP) on a Carimagua soil in the greenhouse.**

increased with the addition of triple superphosphate to the rock.

In the Ultisol from CIAT-Quilichao *P. maximum* responded almost linearly to phosphorus fertilization and there was no appreciable difference in yield by the use of 100 percent Huila phosphate rock or triple superphosphate and the mixture of the two products (Fig. 42). Only at high rates of phosphorus did the grass respond markedly to the increase in soluble phosphorus in the fertilizer. It seems that *P. maximum* can use phosphorus from insoluble forms. The mixtures of soluble and insoluble phosphorus sources, therefore, are of limited value in such circumstances.

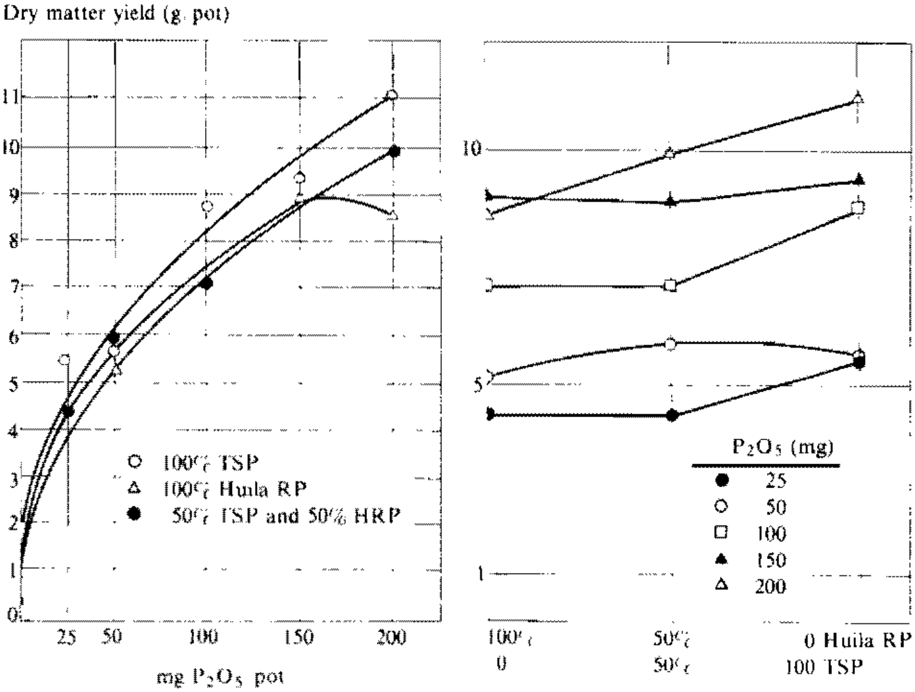


Figure 42. Dry matter yield of *Panicum maximum* as affected by rate and mixture of phosphorus sources on an Ultisol from CIAT-Quilichao. (Sum of averages of two cuttings.)

Plant Nutrition

The nutritional requirements of many grass and legume species of interest to the Beef Program are not well understood. During 1977 studies conducted by agronomists and soil scientists provided new information on: (1) tolerance to soil acidity (aluminum toxicity) and response to liming, and (2) tolerance to low available phosphorus. A Plant Nutrition section will be established with the arrival of a full time senior scientist in 1978.

ALUMINUM TOLERANCE

Fourteen grass and 24 legume species have been planted on existing lime blocks at Carimagua to study their tolerance to aluminum. Lime levels are 0, 0.5, 2 and 6 t/ha of calcium carbonate equivalent as described in previous annual reports, which provided topsoil aluminum saturation values of approximately 90, 85, 50, and 10 percent respectively. Dry matter yields were recorded in a series of harvests and the average yields for all cuts to date as affected by lime levels are shown for 11 grasses in Figure 43. Excellent aluminum tolerance was observed for a number of the most important grass species including *Brachiaria decumbens*, *Andropogon gayanus*, *Panicum maximum*, and other species of *Brachiaria*, all of which approached maximum yields at the 0 or 0.5 t/ha lime levels. In the case of *A. gayanus*, *B. humidicola* and *B. radicans*, maximum yields were attained without lime applications. In contrast, *Hyparrhenia rufa*, a very common grass throughout the

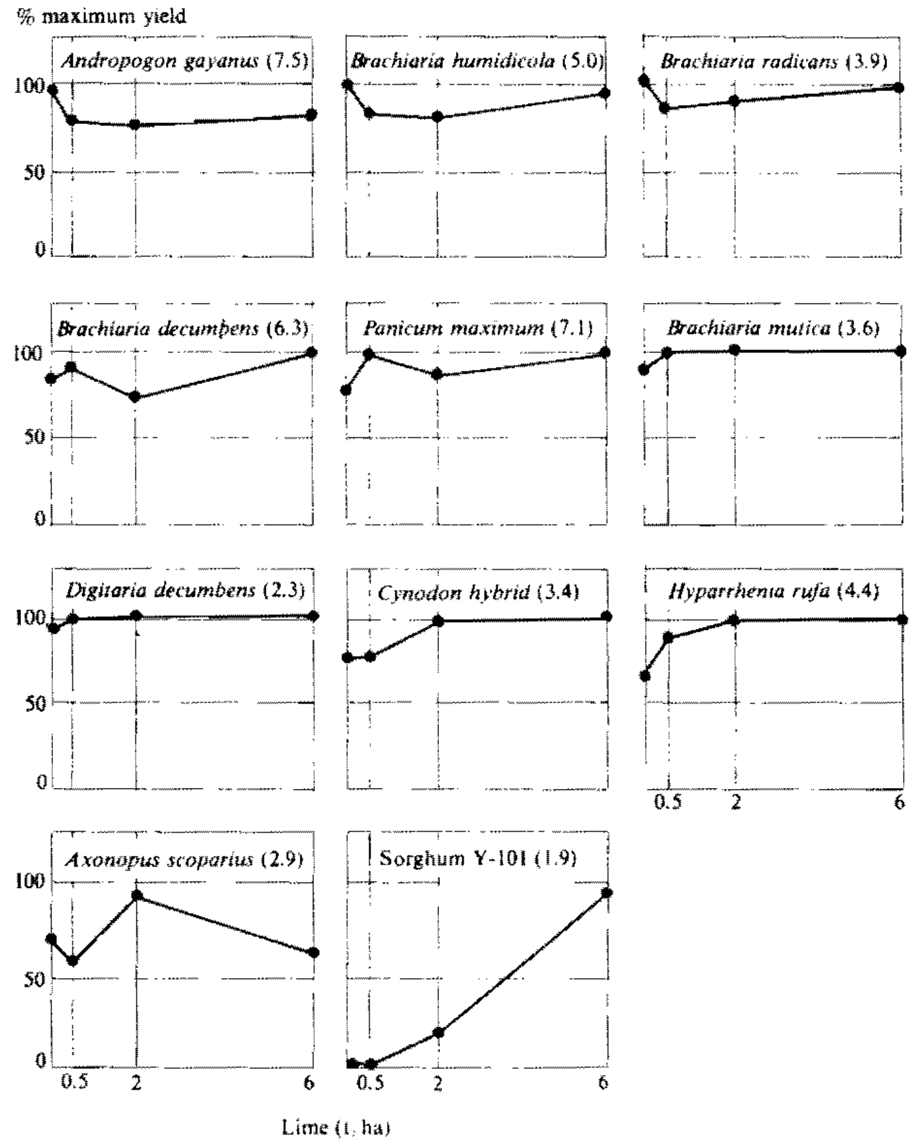


Figure 43. Differential response of 11 grass spzcies to liming in an Oxisol from Carimagua. (Maximum yields in t/ha/cutting of dry matter are in parentheses and are averages of four and five cuttings in one season.)

tropics, responded strongly to the relatively high level of 2 t/ha. This observation confirms greenhouse experiments conducted in 1976 in which six tropical grasses were grown in solution cultures ranging in aluminum concentration from 0 to 4 ppm. The effect of aluminum on four species can be seen in Figure 44. *Cenchrus ciliaris* was the most severely affected of all the grasses, followed by *H. rufa*. *P. maximumum* reponded positively to the first increment of aluminum and was adversely affected only at the highest level of aluminum. *B. decumbens* was unaffected over the range of concentrations studied. *H. rufa* is clearly much more susceptible to aluminum

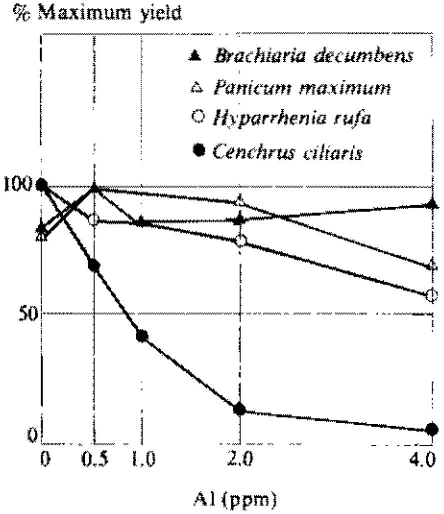


Figure 44. The effect of aluminum concentration on dry matter yields of four tropical grasses grown in solution culture.

toxicity than *B. decumbens* in both greenhouse and field trials. Yields of *P. maximum* were reduced at the zero-lime level (highest aluminum level) in the field as they were in solution culture.

Digitaria decumbens appears to be tolerant to aluminum, although the absolute yield levels were rather low. A *Cynodon* hybrid (African Star Grass) and Imperial grass *(Axonopus scoparius)* responded strongly to lime. The grain sorghum hybrid Taylor Evans Y-101 was included because of reported aluminum tolerance in the Cerrado of Brazil. The strong response observed indicates that it is more susceptible to aluminum toxicity than any of the forage grass species used.

Dry matter yields of eight legumes are shown in Table 27. These data are from the first harvest only. Magnesium was subsequently added to the zero lime treatment which had not previously received that nutrient. All other lime treatments had received magnesium to maintain a constant calcium: magnesium ratio of 10:1 in lime added. Some of the responses to 0.5 t/ha lime may well be to magnesium, especially in the case of *Desmodium ovalifolium* and *Pueraria phaseoloides* and possibly in the case of *Centrosema pubescens* and the hybrid *Centrosema sp.* 1733. *Stylosanthes capitata* and *Zornia sp.* 728 are notable for their vigor and lack of response to lime, whereas *C. plumierii* is obviously the most sensitive species to soil acidity in this group of legumes.

TOLERANCE TO LOW AVAILABLE PHOSPHORUS

Twenty *Stylosanthes* species and ecotypes were screened for their phosphorus requirements in a pot trial with the Carimagua Oxisol using the following levels of applied phosphorus: 0, 5, 10, 20, 30, 60, 120 and 240 kg P/ha. The critical level of phosphorus according to the Bray II soil test was chosen as an

Table 27. Effect of lime on dry matter yields (kg/ha) of tropical legumes, first cutting, 1977.

Species	Lime (t/ha)			
	0	0.5	2	6
Centrosema plumieri 470	0	0	582	1698
Centrosema sp. 1787	445	912	2014	2769
Centrosema sp. 1733	356	1330	1568	1317
Centrosema pubescens	680	1729	1996	2035
Desmodium ovalifolium	1118	2302	2018	2480
Pueraria phaseoloides	1286	1688	1422	1434
Zornia sp. 728	3000	3108	2686	2628
Stylosanthes capitata 1019	2365	2361	3011	2458

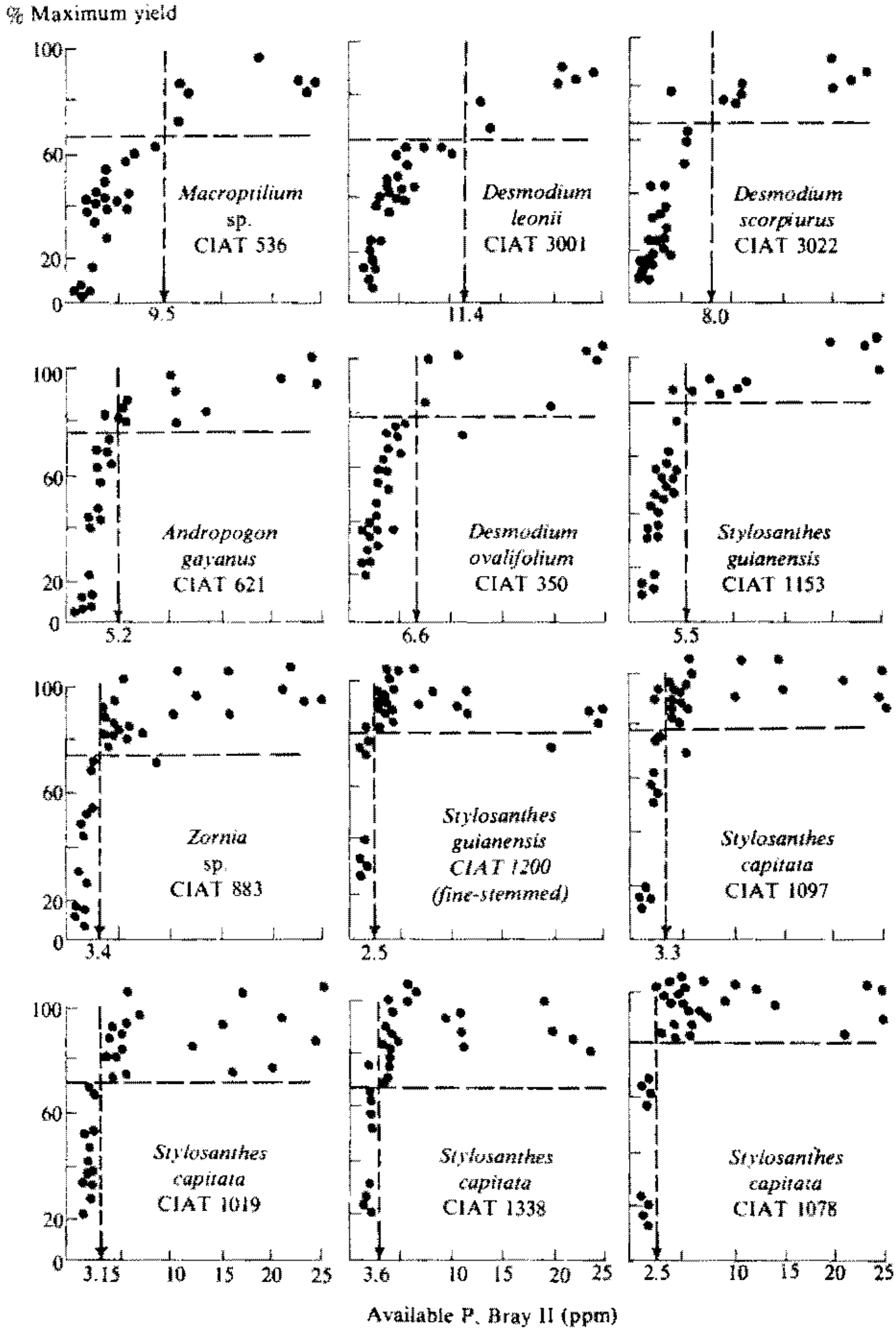


Figure 45. **External phosphorus requirements of 12 CIAT forage accessions on Carimagua Oxisol.**

indication of the external phosphorus requirement of the species. Attempts to estimate the internal phosphorus requirements were not successful, because of the small changes in percentage phosphorus in plant tissue at the crucial

Table 28. Relationship between phosphorus applied in the field and in the greenhouse to phosphorus content (% P in dry matter) of plants of *Andropogon gayanus*

	Rate applied (kg P_2O_5/ha)								
Test	0	10	20	40	60	80	120	160	240
Greenhouse	0.10	0.09	0.10	-	0.10	-	0.12	-	0.15
Field	0.09	0.08	0.09	0.09	-	0.12	-	0.16	-

low phosphorus rates. This is shown in Table 28.

The external phosphorus requirements are given in Figure 45 using the Cate-Nelson method to determine the critical soil test level. Large differences among forage species and ecotypes can be observed from this figure. The two lower rows include accessions with critical levels of 4 ppm or less available phosphorus. There are four accessions of *S. capitata*, a fine-stemmed *S. guianensis* and one *Zornia*. These accessions utilized limited amounts of phosphorus more efficiently than others. They are among the most promising entries for Carimagua conditions, except for *S. guianensis* 1200 which does not produce seed.

Three other accessions have a critical level between 5 and 6 ppm phosphorus, thus showing considerable adaptation to phosphorus stress. Two of them: *A. gayanus* and *D. ovalifolium*, are in the most promising list for Carimagua conditions.

Finally, three species have critical levels higher than 8 ppm: *Macroptilium* 536, *D. leonii* 3001 and *D. scorpiurus* 3022. They are not well-adapted to Carimagua conditions. The generally accepted critical level of Bray II phosphorus for crops in Colombia is on the order of 15 ppm. All forage species tested have lower phosphorus requirements than most arable crops, confirming the comparative advantage of tropical pastures adapted to low input management in Oxisol savannas.

Pasture Establishment and Maintenance

Two new Pasture Development units were established this year at Carimagua and Brasilia with the overall objective of developing systems for pasture establishment and maintenance at different levels of investment in tropical savannas. The different systems are illustrated in Figure 46. Studies will include: (1) low cost methods of establishing improved pastures on native savanna; (2) establishment of grass-legume mixtures after plowing native savanna; (3) using crops as precursors to pasture establishment at a somewhat higher level of investment; and, (4) establishment of intensively managed grass, legume or mixed pastures for small irrigated areas or pockets of fertile soils to provide cut forage for strategic supplementation. The maintenance requirements of all these systems will also be studied, The main variables involve land preparation, planting methods and fertilization rates for establishment and maintenance under different grazing intensity. Work reported this year concentrates on a new low-cost pasture establishment system, and fertilization requirements of the principal grasses both at Carimagua.

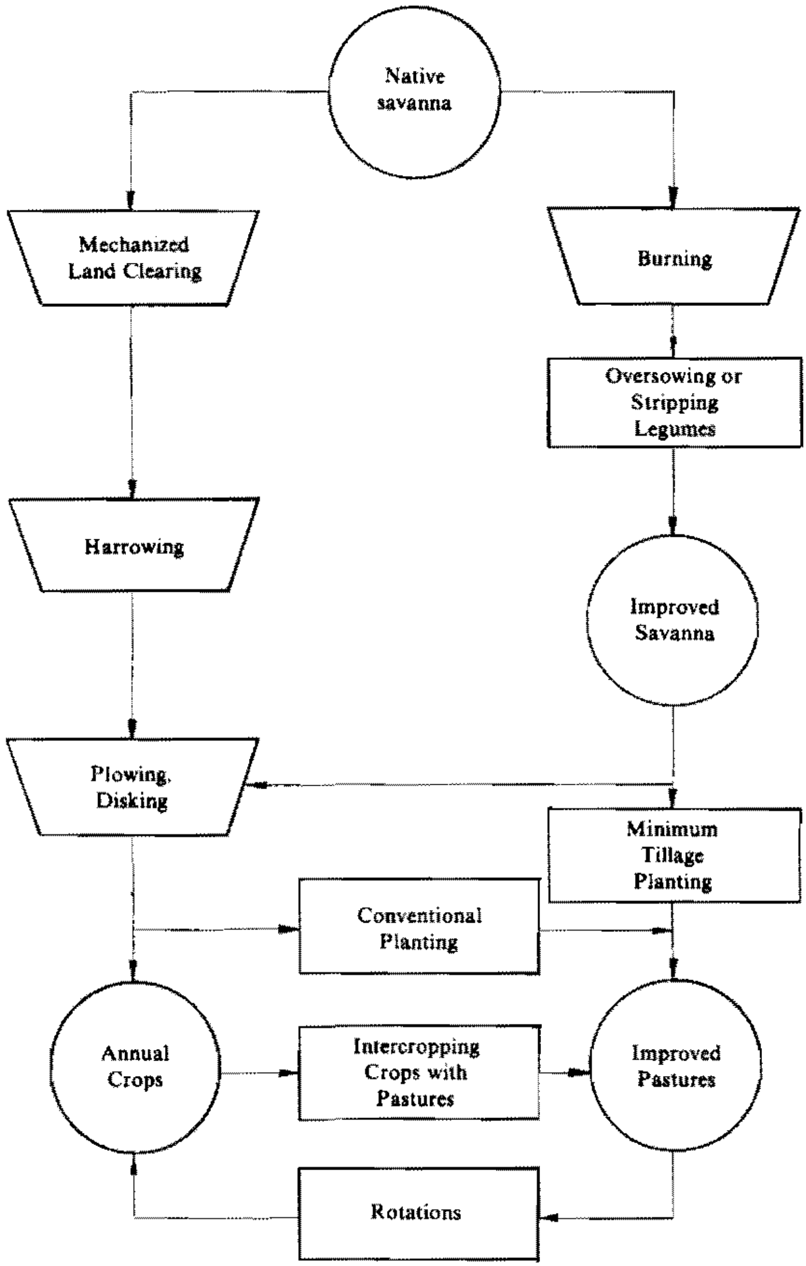


Figure 46. Outline of pasture establishment and maintenance systems for Oxisol-Ultisol savannas.

LOW DENSITY ESTABLISHMENT SYSTEM AT CARIMAGUA

Resources such as capital, labor and fertilizer are almost always limiting in savanna areas. In the particular case of improved pastures, seed or vegetative planting material is rarely available in sufficient quantity and is often very expensive in the early stages of livestock development programs. An experiment was initiated in 1977 to study the feasibility of low density plantings of ten species expected to self-seed or spread via stolons and provide an acceptable stand in one year or less, taking advantage of the lack of weed competition for several months after land preparation and before fertilizer application in Oxisols of the Colombian Llanos.

A three-hectare field was prepared with an offset disc to control native vegetation. Fertilizer was initially applied only in the planting hill in a manner to affect approximately 0.1 m^2. With a population of 1000 plants/ha, the initial rate of phosphorus application ranged from 0.5 to 9 kg P_2O_5/ha. Within the 0.1 m^2 treated area, phosphorus application rates ranged from 50 to 900 kg P_2O_5/ha. Potassium applications ranged from 0 to 1.5 g K_2O/hill, equivalent to 0 to 1.5 kg K_2O/ha initial application and from 0 to 150 kg K_2O/ha for the area treated.

The second stage of fertilizer application in the area between hills will be completed after initial stolon development (or seed production from non-stoloniferous species) to avoid weed competition until stands are assured. *Brachiaria decumbens*, *B. humidicola*, *B. radicans* and a *Cynodon* hybrid were expected to spread primarily via stolons although *B. decumbens* is already setting seed. *Andropogon gayanus*, *Panicum maximum*, *Zornia* sp., *Pueraria phaseoloides*, *Desmodium ovalifolium* and *Stylosanthes capitata* depend primarily on seed production for self-propagation, but some also spread by trailing stems. Five different fertilizer treatments will be applied in the area between hills in order to cover the range of probable response of the 10 species which vary in fertilizer requirements. All are assumed to be reasonably well-adapted to the acid soil environment.

Figure 47 includes results for four stoloniferous grasses showing the response to phosphorus and potassium in terms of percentage maximum length of the four longest stolons per plant and number of solons per plant longer than one meter, and in the case of *B. radicans*, stolons longer than two meters. Stolon length was only slightly affected by phosphorus, primarily in the range of 0.5-1.0 g/hill for *B. decumbens*, *B. humidicola* and *B. radicans*. The *Cynodon* hybrid responded up to 3 g/hill. However, the effect of phosphorus on number of stolons longer

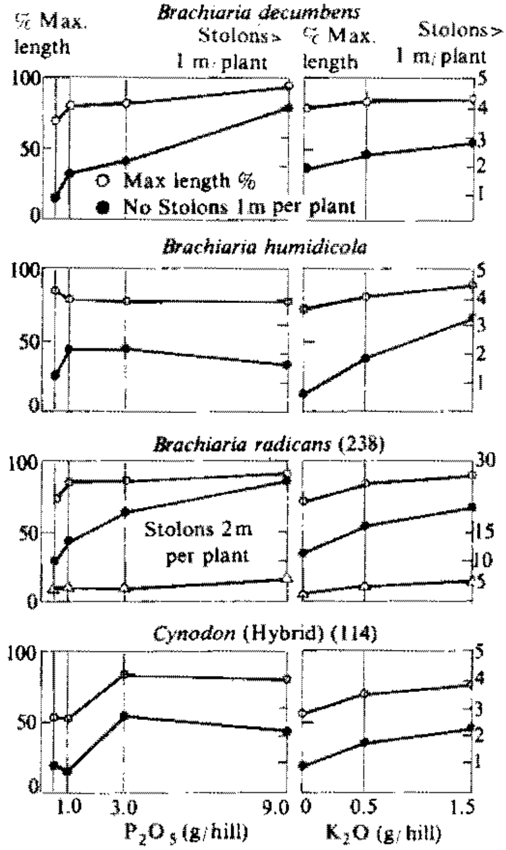


Figure 47. Effects of phosphorus and potassium on stolon number and percentage maximum length of the four longest stolons for four grasses, 12 weeks after planting vegetative material in hills 3.16 meters center to center (1000 hills/ha) on an Oxisol in Carimagua. The average length (cm) of the four longest stolons per hill in the best treatment is shown in parenthesis.

than one meter was very striking for both *B. decumbens* and *B. radicans* over the entire range of phosphorus application (0.5 - 9 g/hill). Response to potassium was especially marked in terms of number of stolons longer than one or two meters.

In less than three months, *B. radicans* has covered almost the entire area between hills, spaced at 3.16 meters, center to center. *B. humidicola* is also providing rapid cover but was slower in establishing and initiating vigorous stolon growth. *B. decumbens* has developed rapidly but initial development is largely vertical before appreciable stolon development occurs. Leaf cutter ants caused damage during the establishment phase, especially on *D. ovalifolium*.

This system may result in important advantages in pasture establishment in savanna areas characterized by infertile, acid soils where labor, capital, seeding material and fertilizer are scarce and where the farmer is willing to trade time for initial capital investment.

FERTILITY REQUIREMENTS FOR CONVENTIONAL ESTABLISHMENT AT CARIMAGUA

The major limiting fertility factors for pasture establishment and maintenance in the Oxisols of Carimagua appear to be nitrogen, phosphorus, potassium, magnesium and sulfur. Response profiles of four grasses to phosphorus, potassium, magnesium and sulfur are shown in Figure 48. All four species responded strongly to applied phosphorus; *P. maximum* and *H. rufa* were the most responsive and *A. gayanus* the least responsive. *H. rufa* was by far the most responsive to potassium. In the absence of applied potassium, the population of *H. rufa* deteriorated very rapidly; yields of treatments without potassium averaged over all levels of phosphorus were only 15 percent of maximum. Nitrogen has become a severely limiting factor during 1977 and uniform applications are now being made to all treatments. Sulfur and magnesium have also become limiting for some species; uniform applications of both nutrients were made to all treatments except controls.

Four legumes were seeded in 1976 but establishment was unsuccessful and the experiment was reseeded in June, 1977 with *P. phaseoloides* (kudzu), *D. ovalifolium*, *Zornia* sp. (CIAT 728) and *Centrosema pubescens*. Early stands were excellent for all four species but *C. pubescens* later failed. Only one harvest was made in 1977, the results of which are shown in Figure 49.

Zornia sp. is the least demanding of the three species that survived. *D. ovalifolium* is intermediate in response to phosphorus and potassium. *P. phaseoloides* development was limited so severely by magnesium deficiency that data on the response to phosphorus and potassium are not included. *D. ovalifolium* is also extremely responsive to magnesium as shown in Table 29. *Zornia* was least affected by addition of magnesium; *D. ovalifolium* yields doubled and *P. phaseoloides* yields tripled after adding magnesium. Uniform applications of magnesium and sulfur have now been made to all plots except controls.

STRIP PLANTING OF LEGUME-GRASS MIXTURES

Pueraria phaseoloides (tropical kudzu) is being grazed in association with *B. decumbens*, *M. minutiflora* and *H. rufa* in a trial established in 1976. The legume was seeded in 2.5-meter strips alternated with 2.5-meter strips of the associated grass. The trial includes three rest periods of 28, 42 and 56 days and three maintenance fertilizer rates and is managed with mob grazing. The strip system and grazing management has resulted in good legume-grass balance between kudzu and *B. decumbens* and legume dominance over both *H. rufa* and *M. minutiflora* during the

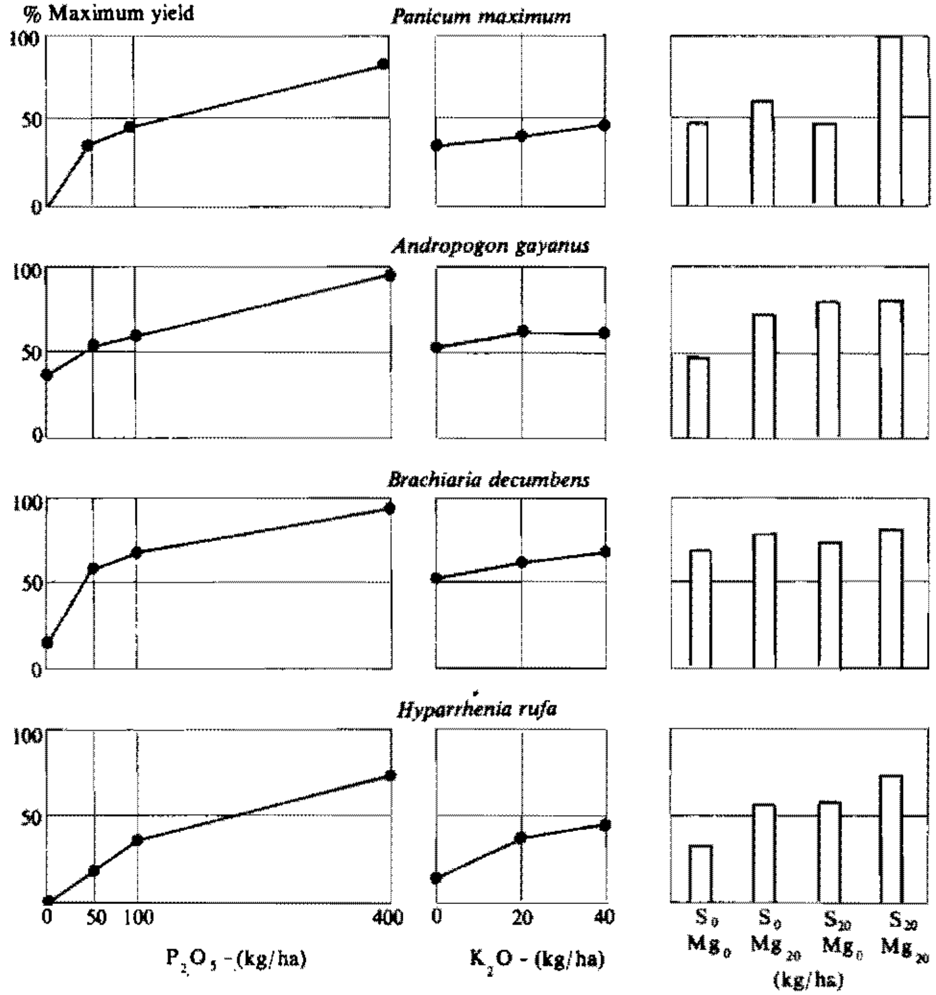


Figure 48. Response of four grasses to phosphorus, potassium, magnesium and sulfur in an Oxisol at Carimagua. Dry matter yields are averages of three and four harvests during the first year after establishment.

first season of grazing. *B. decumbens* is producing three or more times the volume of forage produced by the other two grasses and is invading the companion legume strips while the kudzu is also invading the *B. decumbens* strips. It appears that the two species may remain compatible for a reasonable period of time using this planting system.

PASTURE MAINTENANCE FERTILIZATION REQUIREMENTS

Small enclosures within grazing paddocks have been used for the past year to study the response of previously grazed grass pastures to phosphorus, potassium, magnesium and sulfur. Nitrogen was applied in 1977 on a split-plot basis. Yield responses have been erratic, with no consistent response to the fertility variables.

During the 1976-77 dry season, stands of *H. rufa* in three grazing paddocks were almost entirely lost but variability within the plot area was too great to permit positive identification of causal factors. In

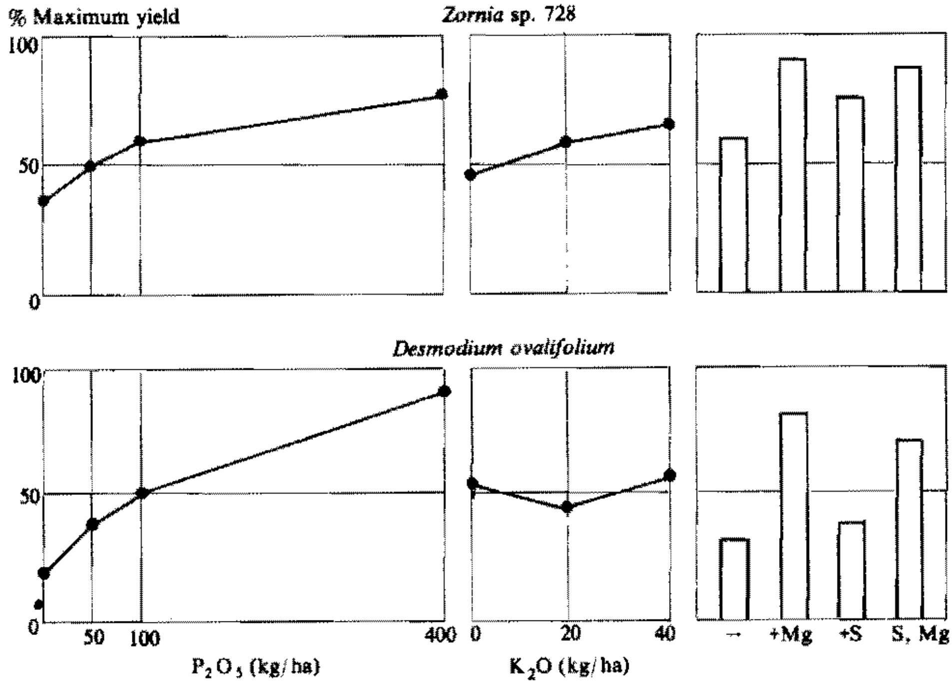


Figure 49. The effect of phosphorus, potassium, magnesium and sulfur on dry matter yield (kg/ha) of two tropical legumes; first cutting, 1977. Rates of magnesium and sulfur were 20 kg/ha.

other trials reported in the Plant Nutrition section, *H. rufa* was shown to be extremely susceptible to both phosphorus and potassium deficiency and only moderately tolerant to acid soil conditions. These stresses, exaggerated by drought, were probably the principal causes of failure.

Work is continuing with stubble mulch sweeps as a low cost alternative for control of the native savanna and seed bed preparation with minimum erosion hazard. Satisfactory control of vegetation requires several days mithout rain after cultivation, thus limiting the use of sweeps to very early in or late in the rainy season (December-November or March-April).

Table 29. The effect of magnesium on dry matter yields (kg/ha) of three forage species, at first harvest, 1977.

Species	(kg Mg/ha) 0	20
Zornia sp. 728	2436	3151
Desmodium ovalifolium	675	1552
Pueraria phaseoloides	229	739

ANNUAL CROPS AS PRECURSORS OF PASTURES

In many savanna regions crops such as upland rice, corn, and peanuts are sown following land clearing, and after their harvest the land is planted to pastures. Two field trials were established at Quilichao and Carimagua to study the possible use of several crops as pasture precursors, in which forage legumes and grasses are interplanted at different stages of crop growth and at different fertility levels. The results will be available in the next Annual Report.

Pasture Utilization

Activities of the Pasture Utilization Section of the Beef Program were discontinued at CIAT-Palmira. Towards the end of 1977 a series of experiments were established in the newly acquired substation of CIAT-Quilichao. The acquisition of this substation provides the opportunity to study the grazing management of grass-legume mixtures—particularly of new CIAT germplasm—as they relate to managing potentially useful mixtures for Ultisol areas of low climatic stress.

At Carimagua, two grazing experiments were terminated in December 1977, at the end of the rainy season. One experiment was designed to measure the beef production potential of the tropical savanna under two systems of management of fire. This trial started in 1971 and after six years had given valuable information. The second experiment terminated, studied, in its first part, the effect of phosphorus and potassium fertilization at the time of establishment on the beef production of *Melinis minutiflora* and, in its second phase, measured the effect of three grazing managements. The first part started in 1971 and the second, in 1973.

CIAT-QUILICHAO

Two types of research activities are being conducted at this station. The first will measure the nutritive value of new, promising accessions of legumes and grasses, particularly those about which little information is available. Nutritive value measurements include *in vivo* digestibility and intake studies with the plant material offered unchopped and fresh to crated wethers. In instances when nitrogen utilization appears of interest, nitrogen balance is measured.

The other projects involve the study of the grazing management of CIAT selections which are in advanced stages of selection (Category 4). Each is studied in mixtures with several grasses and subjected to various levels of fertilizer application, varying rest periods between grazing and at least two grazing pressures.

Two such projects were established in 1977, one with the *Centrosema* hybrid (CIAT 1733) and the other with *S. guianensis* (CIAT 136). Grazing will begin approximately in February 1978.

CARIMAGUA

The grazing year between November 1976 and November 1977 was a hard one in Carimagua. The dry season, which normally ends in late March or early April, extended until May. In most instances this meant that rainy season stocking rates could not be adjusted until May and, in a few instances, until June 1977. Also, weight losses were unusually high in all of the pasture treatments involved. This was the first year in which weight losses of any magnitude were registered in *B. decumbens* pastures.

Table 30. Body weight changes (kg/animal) of steers grazing an Oxisol savanna in Carimagua (November 1976 - November 1977).

Stocking rate (steers/ha)	Burning the total area: Dry season	Burning the total area: Rainy season	Burning the total area: Year	Sequential burning: Dry season	Sequential burning: Rainy season	Sequential burning: Year
0.20	-7	83	75	-20	110	90
0.35	-43	98	55	-44	104	60
0.50	-50	72	22	-52	78	26

Table 30 presents the weight changes of steers on the native savanna. Losses were registered in all treatments and amounted to as much as 50 kilograms per animal in the higher stocking rates. Weight gains in the following rainy season were high, compensating strongly for the poor performance of the dry season. Gains registered in this period ranged from 365 g/day/animal in the highest stocking rate to as high as 558 g in the lowest stocking rates. On a yearly basis, gains were similar to preceding years, averaging 16 kg/ha/yr. This underscores the low beef production levels of native savanna per unit area.

Also because of the severity of the dry season, supplementation with urea + molasses (80 g/animal/day + 400 g/animal/day) to animals grazing *M. minutiflora* had a greater effect this year than previously. It was calculated that 0.28 kilogram of urea and 1.40 kilograms of molasses were required to produce one kilogram of additional weight gain in the pastures grazed at 0.44 animals/ha while 0.71 kilogram of urea and 3.50 kilograms molasses were required in pastures stocked at 0.44 animals during the dry season and at 0.88 animals in the rainy season. The difference is only due to the lower rate of gain during the rainy season between the two groups, as can be seen in Figure 50. At the prevailing prices of the area, the supplement costs equal 46 and 116 percent of the cost of one kilogram of liveweight at the lower and higher stocking rates, respectively.

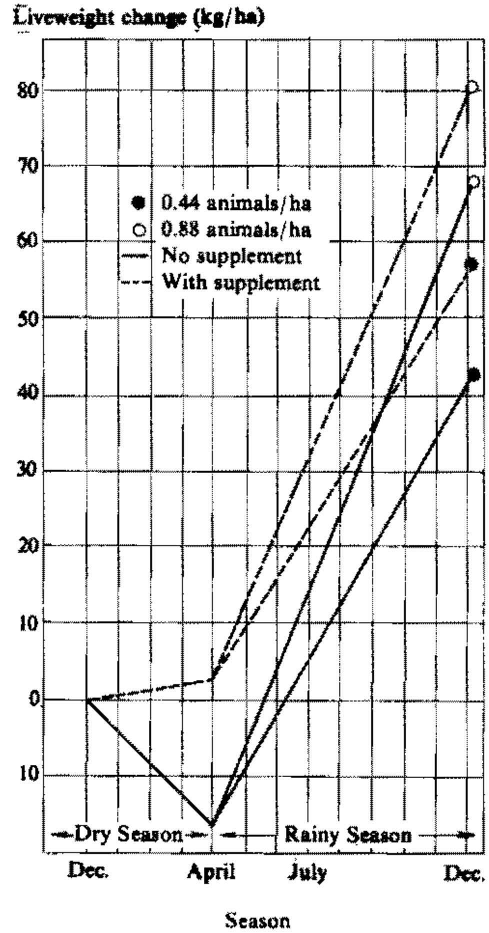


Figure 50. Four-year average per hectare weight change of steers grazing *Melinis minutiflora* in Carimagua. (Supplemented animals received 80 g/day of urea + 400 g/day of cane molasses during the dry period.)

Supplementation of animals grazing the native savanna, with urea + cassava meal, was studied again during the 1977 dry season. One comparison included a 3 x 3 incomplete factorial of 0-40-80 grams of urea and 0-200-400 grams of cassava meal/animal/day, fed mixed with a salt + dicalcium phosphate mineral mixture. Table 31 presents the average weight changes. There was a response during the dry period to urea + cassava meal, but no effect to urea alone. Actually, after a few weeks of supplementation it was realized that the steers did not totally consume their diet of urea + cassava meal without the addition of a small quantity of molasses; 50 grams of cassava were replaced by 50 grams of molasses, by weight, starting in February 1977. Consumption of urea when not fed with cassava meal was not 40 grams as designed, but averaged 23 g/animal/day. Consumption of urea in the 40-gram urea + cassava treatments averaged 36 g/animal/day and 52 grams in the 80

Table 31. **Weight changes (kg/animal) of steers grazing an Oxisol savanna in Carimagua with various levels of urea + cassava meal supplementation.**

Level of cassava meal (g/animal/day)	Level of urea (g/animal day)								
	0			40			80		
	Dry season	Rainy season	Year	Dry season	Rainy season	Year	Dry season	Rainy season	Year
0	-7	65	58	-6	55	49		-	
200	1	48	49	10	54	64	13	37	50
400		-		20	34	54	14	44	58

grams urea + cassava groups. These averages include the period prior to and during the time when molasses was added.

Because of the very strong compensatory gain during the rainy season, there were no differences in the yearly weight gain. The large compensation can be observed in Figure 51. The slope of the line indicates the proportion by which the weight gain of the rainy season is influenced by the weight change of the dry season. Figure 52 presents a similar relationship for the burning management trial. In both cases compensatory gain was 74-78 percent.

The second comparison of this trial was a 2 x 3 factorial in which the interaction of mineral supplementation at different times of the year and nitrogen supplementation during the dry season was studied. Minerals offered were salt + dicalcium phosphate (50% + 50%) *ad libitum* and

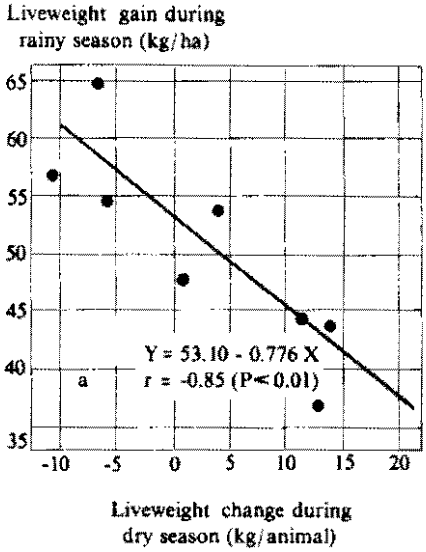


Figure 51. **Relationship between weight change during the dry period and gain during the rainy period in supplemented steers grazing the Carimagua savanna. Point a, not included in the regression, corresponds to a group of totally unsupplemented animals.**

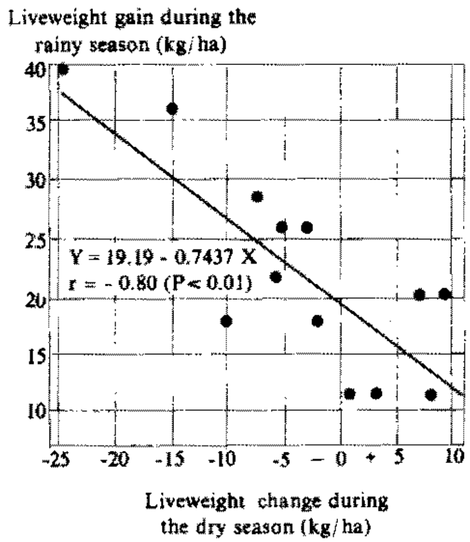


Figure 52. **Relationship between body weight change during the dry period and gain during the rainy period in a burning management trial in the tropical savanna of Carimagua. Individual values represent average of one stocking rate group in one year and cover a period of four years.**

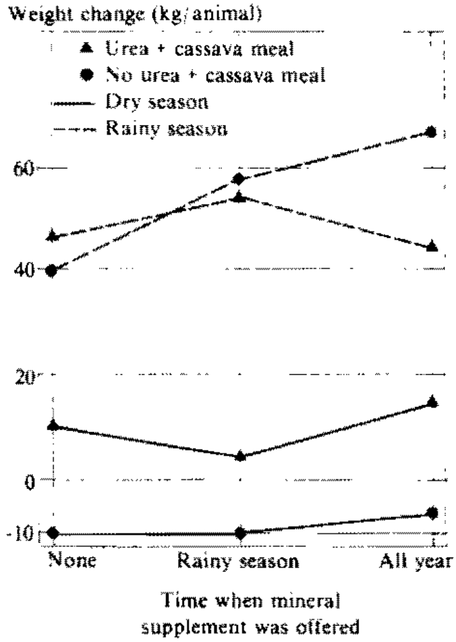


Figure 53. **Relationship between mineral supplementation and urea + cassava meal supplementation during the dry period, to steers grazing the tropical savanna at Carimagua.**

the nitrogen supplement was 80 grams of urea + 400 grams of cassava meal/animal/-day. Also in this trial, 50 grams of cassava were replaced by 50 grams of molasses. Consumption of urea averaged 69 g/animal/day in those treatments receiving the nitrogen supplement. Figure 53. represents the weight changes during both seasons. The results suggest a response to nitrogen supplementation during the dry period, independent of the supplementation of minerals and a linear response to mineral supplementation during the rainy season. This part of the trial will be repeated in 1977-78 with twice the animals to help understand the large between-animal variation found.

The results of the third year of grazing of *B. decumbens* at fixed stocking rates during the year are presented in Table 32. Weight losses for the dry season were large and increased with increasing stocking rates. Annual production was, however, very similar to the previous year. Average annual per hectare production over all stocking rates was 110 kilograms in 1975-76 and 105 kilograms in 1976-77.

A second experiment with *B. decumbens* explores the possibility of increasing per hectare production using high stocking rates during the rainy season and a low stocking rate during the dry season. Table 33 presents the results of the second year of grazing of this pasture. At the higher stocking rates, rainy season weight gains decreased markedly, but per hectare gains reached as much as 200 kilograms per year.

A third pasture of *B. decumbens* was incorporated this year to explore the effect of varying the stocking rate during the dry season and maintaining a medium stocking during the rainy season. Table 34 indicates gains of around 200 kg/ha/year. The paddocks appear to be depleting, par-

Table 32. Liveweight changes of steers on *Brachiaria decumbens* pastures in Carimagua in the third year of grazing.

Stocking rate **(steers/ha/year)**	Liveweight changes					
	kg/animal			kg/ha		
	Dry season	Rainy season	Year	Dry season	Rainy season	Year
0.9	- 6	124	118	- 5	111	106
1.3	-21	118	97	-27	153	126
1.7	-19	105	86	-32	179	147

Table 33. **Liveweight changes of steers on *Brachiaria decumbens* pastures in Carimagua in the second year of grazing with low stocking in the dry season and variable stocking in the rainy season.**

Stocking rate (steers/ha)		Liveweight change				
		kg/animal		kg/ha		
Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Year
0.7	1.63	-11	81	- 8	132	124
0.7	2.34	-16	77	-12	180	168
0.7	3.06	16	63	12	193	205

ticularly at the higher stocking rate and their future is uncertain.

Three small areas of these pastures were fenced and nitrogen fertilization experiments were initiated in July 1977. The response to nitrogen, in the three pastures of different ages, was very evident, suggesting that this may be one of the limiting factors involved. The quantification of this observation must wait until the 1978 Annual Report.

Twenty-five hectares of land were planted, by cuttings, with *A. gayanus,* to measure the beef production potential of this species in the tropical savanna. Grazing will start during the rainy season of 1978.

Table 34. **Liveweight changes of steers on *Brachiaria decumbens* pastures in Carimagua in the first year of grazing with a variable stocking in the dry season and medium stocking in the rainy season.**

Stocking rate (steers/ha)		Liveweight change				
		kg/animal		kg/ha		
Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Year
0.72	2.18	3	87	2	190	188
1.03	2.08	9	114	9	236	227
1.36	2.04	-8	112	-11	227	216

Animal Management

The objective of the Animal Management section is to develop economically-sound production systems in the impact area, through herd management research emphasizing the utilization of natural and improved pastures. Main activities during the year were: (1) analysis of the results of the Carimagua Herd Systems experiment, which terminated in May 1977; (2) description and evaluation of the prevailing beef production systems of the impact area in order to obtain a range of their technology and productivity, with emphasis on herd productivity and particularly, reproductive performance; (3) research on the effect of single herd management components and their interaction with improved pasture availability; and, (4) management of the Program's test herd to provide animals for research and training functions.

HERD SYSTEMS

The extensive cow-calf operation is the predominant beef production system in the Llanos of Colombia. Under these environmental conditions, herd productivity generally is low. In 1972, ICA and CIAT started a cooperative research project at Carimagua, to study the effects of several management techniques on reproductive and growth performance of breeding herds on a life-cycle basis. The experiment included the following variables: mineral supplementation, utilization of savanna and molasses grass *(Melinis minutiflora)* pastures, urea and molasses supplementation, and early weaning.

Data on animal performance were recorded over four reproductive years and the experiment was concluded in May 1977. Size and structure of the data set are summarized in Table 35. The Harvey method was applied in analyzing main effects. Therefore, not the given absolute values, but the **differences** between values are relevant, in quantifying treatment effects. The following parameters are used in reporting this experiment:

μ = overall mean values

$\bar{c}$ = least squares corrected means

n = number of observations

Mineral Supplementation

The effect of mineral supplementation can be analyzed by comparing Herds 2 to 5, all on native savanna. The treatment included *ad libitum* supplementation of salt (Herds 2 and 3), and a mixture of minerals (Herds 4 and 5), with 47 percent salt, 47 percent dicalcium phosphate and 6 percent of a minor elements premixture. The minerals mixture contained 7- 7.5 percent phosphorus.

Overall average intake was: salt 33.5 g/A.U./day (12.2 kg/A.U./year) and of minerals 59.5 g/A.U./day (21.7 kg/A.U./year). Therefore, 4.0-4.5 grams of phosphorus were consumed, or approximately 50 percent of the daily requirements. There was no seasonal effect on mineral consumption.

The minerals intake of animals grazing molasses grass *(M. minutiflora)* year-round (Herds 8 and 9) was 70 percent higher (71.2 grams) than that of animals grazing native savanna. This may indicate that periodic burning of the savanna could contribute to satisfying mineral requirements, through the mineral content of the ash.

Mineral supplementation resulted in higher body weights of dams at different reproductive stages, as shown in Table 36. Minerals are particularly effective on lactating cows, thus favoring reconception. This becomes evident when fertility parameters are analyzed (Table 37). Conception rates were increased through mineral supplementation and a sharp decrease in abortions was observed. As a result, a 29 percent increase in calving rate was obtained when breeding stock was supplemented with minerals when grazing on native savanna

Mineral supplementation also reduced pre-weaning mortality of calves. While mortality in Herds 2 and 3 was 19.2 percent, in Herds 4 and 5 it was 10.5 percent. Likewise, mineral supplementation positively affected calf growth, as shown in Table 38. All differences in body weight were significant, and, of all the systematic effects, mineral supplementation was the most important source of variance, across all ages. According to the results in Table 38, mineral supplementation has maximum effect on calf weight at 6 and 9 months. This may indicate higher

Table 35. **Structure of data in analysis of Carimagua Herd Systems Project.**

	Treatments				Performance (4-year total)				
Herd	Pasture	Minerals	Urea/Molasses dry season	Cows[1] n	Cows[2] n	Parturitions n	Early weaning n	Abortions n	Mortality pre-weaning n
1	native	salt	no	36	26	46	-	32	13
2	native	salt	yes	35	33	68	16	13	17
3	native	salt	no	36	30	65	14	12	13
4	native	minerals	yes	35	32	88	18	1	11
5	native	minerals	no	34	33	93	17	1	8
6	mol.+nat.	minerals	no	36	35	95	17	4	8
7	mol.+nat.	minerals	yes	35	35	94	17	0	8
8	molasses	minerals	no	36	29	86	17	1	8
9	molasses	minerals	yes	37	32	90	15	4	11
Total				320	285	725	131	68	97

Initial herd at end of experiment
At end of experiment.

Table 36. **Effect of mineral supplementation on body weight (kg) of dams,[1] grazing on savanna.**

Reproductive Status	μ		Salt only		With minerals	
	n	$\bar{c}$	n	$\bar{c}$	n	$\bar{c}$
At mating	131	304	67	292	64	316
Prior to calving	308	352	130	335	178	369
After calving	307	307	131	285	176	327
At weaning	194	289	72	272	122	305

[1] Nearest body weight to indicated status.

milk production of dams and/or a higher roughage intake of calves older than 3 months.

In summary, it can be concluded that supplementation of breeding herds with minerals substantially increased overall productivity through:

(1) a 29 percent increase in calving rate, mainly due to a reduction in abortions;

(2) a 26 percent increase in weaning weight of calves, and 17 percent increase at 18 months of age; and

(3) a 45 percent reduction in pre-weaning calf mortality.

The results suggest that in the Llanos of Colombia, mineral deficiency and particularly phosphorus, may be considered the primary limiting factor for cattle reproduction and growth. This conclusion agrees with Faber's study of the heifers' performance at Carimagua (see publications list).

Early Weaning

In 1973-74, five cows from Herds 2 to 9 were selected for early weaning at 86 days. All other cows had their calves weaned normally at nine months. During the first 30 days after early weaning, the calves received 750 g/day of concentrate and cut Imperial grass *(Axonopus scoparius).* Afterwards, calves grazed on planted pastures *(Hyparrhenia rufa, M. minutiflora* and *Stylosanthes guianensis,* when available) and were supplemented with 500 g/day of concentrate. At six months the calves were placed on savanna, without concentrate supplementation.

As reported for previous years, the 1976-77 early weaned cows had higher calving rates compared to the others (Table 39), indicating that under the conditions of this experiment, early weaning can increase calving rate by 18-21 percent.

Analyzing the calving interval, only the cows which calved in the first year were

Table 37. **Effect of mineral supplementation on fertility rates of dams, grazing on savanna.**

Reproductive parameters	μ		Salt only		With minerals	
	n	$\bar{c}$	n	$\bar{c}$	n	$\bar{c}$
Conceptions[1]	140	73.2	71	69.5	69	76.8
Abortions[1]	140	4.9	71	9.3	69	0.4
Calving	140	67.9	71	59.4	69	76.4

[1] Assumed, through palpation.

Table 38. Effect of mineral supplementation on calf growth (body weights, kg) on savanna (Herds 2-5).

Age of calves (months)	μ		Salt only		With minerals		Relative to Salt=100
	n	$\bar{c}$	n	$\bar{c}$	n	$\bar{c}$	
3	228	72.2	87	66.5	141	77.9	117
6	213	104.0	80	92.4	133	115.7	125
9	191	131.8	72	116.7	119	146.9	126
12	169	134.3	59	122.1	110	146.5	120
15	156	138.3	61	125.7	95	151.0	120
18	138	162.1	51	149.6	87	174.6	117

considered. Results (Table 40) indicated that regardless of other treatments, early-weaned cows had a calving interval of 15 months, while normally weaned cows varied between 18 and 20 months. With this technique, a cow would produce one more calf during her lifetime.

However, in these tropical savanna regions, early weaning seriously affects calf growth, as shown in Figure 54. Between 6 and 9 months, early weaned calves showed a severe growth check, which was still not compensated by 18 months. This applied especially to cows born during the late rainy season (September to December) and weaned during the dry season (January to April). This is illustrated in Figure 55, which shows least square constant estimates of the interaction season x type of weaning for calf weight at 9 and 18 months.

Early weaning of calves has serious limitations in the Colombian Llanos, with regard to animal management and, especially, calf feeding. Due to low soil fertility and rainfall distribution, there is presently no technology available to produce on-farm at low input levels: (1) the components for an adequate concentrate; (2) year-round high yielding cut forage species; and (3) pasture species with adequate feed value. This emphasizes the need to develop a forage base for the region which would assure satisfactory calf growth after weaning.

Pasture Treatments

The type of pastures used in Herd Systems generally had little effect on animal performance. Pastures were: savanna throughout the year; molasses grass

Table 39. Effect of age at weaning on percentage calving rate.

Weaning treatment	1976-77 Herds 2-5[1] $\bar{c}$	1976-77 Herds 4-9[2] $\bar{c}$	Average 1975-77 Herds 2-5[1] $\bar{c}$	Average 1975-77 Herds 4-9[2] $\bar{c}$
Early (86 days)	80.0	66.7	76.7	78.9
Normal (270 days)	62.7	59.8	63.1	66.6

[1] Herds on savanna with mineral treatments.
[2] Herds with pasture treatments, all with minerals.

Table 40. **Effect of early weaning on calving interval (days).**

Weaning treatment	Herds 2-5[1]		Herds 4-9[2]	
	n	$\bar{c}$	n	$\bar{c}$
Normal (270 days)	39	595a[3]	103	541a
Early (86 days)	19	450b	30	450b
μ	58	523	133	496

1 Herds with mineral treatment

2 Herds all supplemented with minerals

3 Values in columns with different letters are significantly different (P< .05).

throughout the year; and molasses grass during the rainy season and savanna during dry season.

Cows grazing native savanna were heavier after parturition and at weaning than those grazing molasses grass. Cows on molasses grass plus savanna had intermediate body weights. Consequently, cows grazing savanna were slightly more fertile than cows on molasses grass.

Pasture treatments had no effect on calf growth performance. Nevertheless, due to the different stocking rates, 3.3 times more

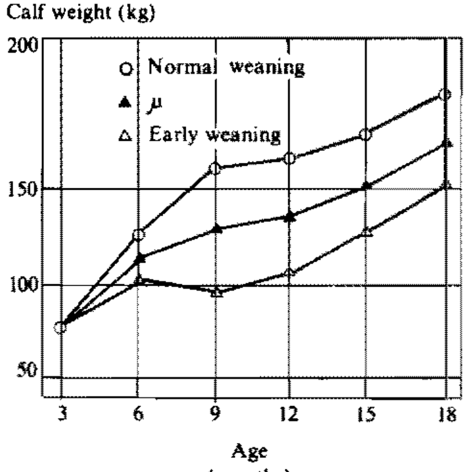


Figure 54. **Effect of weaning age on calf growth in Herds 4-9 (corrected LSQ means).**

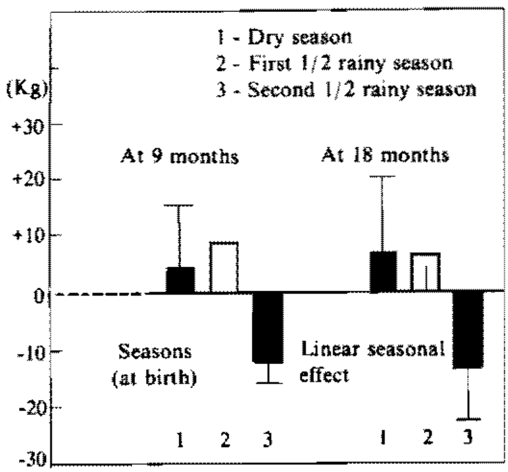


Figure 55. **Season-weaning age interaction effects on weight of early weaned calves (86 days old).**

calves (kilogram basis) have been weaned per hectare of molasses grass, and 2.5 times more on molasses plus savanna, than on savanna all year-round (Table 41).

Urea and Molasses Supplementation

Cows from Herds 2, 4, 7 and 9 were supplemented daily, during the dry season, with a mixture of 500 grams molasses, 80 grams urea and 4 grams sulfur per animal. The supplementation period averaged 90 days. No effect of supplementation on reproductive parameters was detected. Supplemented cows were slightly heavier than non-supplemented ones on the average. Although calves from supplemented cows were eight kilograms heavier at 6 months and seven kilograms heavier at 9 months of age, this difference did not persist after weaning.

It is not clear if the quantity of supplementation was sufficient, particularly for an adequate period of time, to compensate the effect of the dry season. On the other hand, even if substantial animal response could be obtained, the economy of urea-molasses supplementation is

Table 41. **Calf production in relation to pasture treatments and stocking rate.**

Pasture treatments	Weaned calves n	Weaning weight (kg) c̄	Stocking rate ha/A.U.[1]	Calf production (kg/ha/year)	Relative production
Savanna	162	130	3.5	16.0	100
Molasses grass	157	126	1.7	52.6	329
Molasses + savanna[2]	173	132	2.3	39.7	248

1 Weighed means
2 Molasses nine months, savanna three months.

questionable, since the ingredients of the mixture must be imported to the region at a high transport cost.

Seasonal Effects

To identify techniques to increase productivity within an ecosystem, it is necessary to have quantitative information on the influence of natural environment on animal performance. The most important environmental factor is the seasonality of feed availability, determined in the tropics mainly by rainfall regime.

The seasonal effects on relative calving distribution are illustrated in Figure 56. Independent of the treatments, the most common season for conception is between April and July, i.e., at the beginning of the rainy season, since 46 percent of all cows calve between January and April.

An analogous seasonal effect on calf

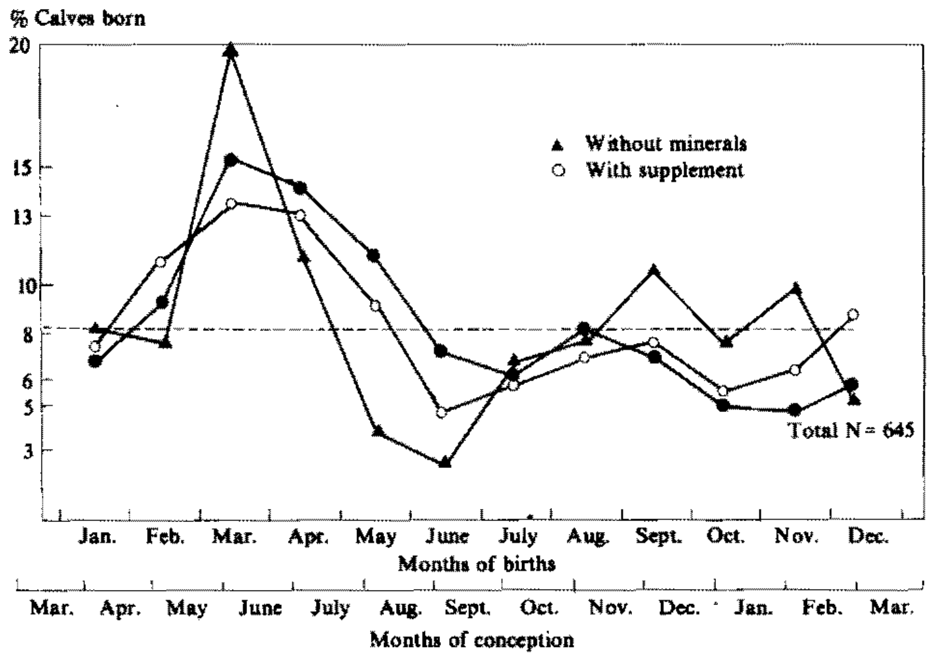


Figure 56. **Seasonal effects on relative calving distribution**

Table 42. **Influence of season at birth on calf weight (kg) (Herds 4-9).**

	Season born					
	Dry		First half rainy		Second half rainy	
Age of calves	January n	April c̄	May n	August c̄	September n	December c̄
3 months	213	79a[1]	143	79ab	91	75b
9 months	188	145a	129	129b	66	114c
18 months	142	195a	89	179b	57	152c

[1] Values followed by different letters are significantly different ($P < .05$).

growth can be observed. The results are summarized in Table 42.

Although calves born during the dry season showed the strongest growth depression after weaning, which coincides with the end of the rainy season, at 18 months they weighed 43 kilograms more than calves born during the second half of the rainy season. A similar seasonal effect on body weight of dams was found.

Considering the significant influence of season on animal performance, the importance of adapting the critical periods of the production cycle (conception, calving, lactation) to the most favorable season of the year becomes evident.

Calf Mortality

High calf mortality is one of the reasons for low extraction rates of herds in the region. The overall mean for all treatments of calf mortality before weaning was 13.4 percent. The analysis of relative distribution of mortality according to age showed that 9 percent of all calves born died within the first 30 days (Table 43). Mortality between 9 and 18 months of age was 2.5 percent.

Through improved management and closer supervision of calves in special paddocks calf mortality rate could be considerably reduced, especially during the first stage of life.

EVALUATION OF BEEF PRODUCTION SYSTEMS IN SAVANNA REGIONS OF LATIN AMERICA

This project is a cooperative effort of the Animal Management and Economics sections, in collaboration with the Institute of Animal Production, the Technical University of Berlin. The main objective of the study is the identification of management technology which assures an economic increase in reproductive efficiency, under actual beef production conditions. At the same time, the feasibility of transferring modern technology is also being studied.

The management aspects of the project are: (a) a situational analysis of reproductive performance of breeding herds in relation to different technology levels

Table 43. **Relative distribution of calf mortality until weaning.**

Life Period	% of dead calves
Perinatal	35
Between 2 and 30 days	37
Between 31 and 270 days	28

existing on commercial beef cattle ranches; (b) quantification of the effects of management techniques, combined into systems, which increase herd productivity; and, (c) specification of demand for new technology and possibilities of adoption.

This study constitutes a part of the Impact Area Survey. Data will be collected on selected farms at different locations, in the following countries: (1) Colombia: Eastern Plains; (2) Brazil: Cerrado; (3) Venezuela: Orinoco Plains; and (4) Peru: Jungle Region.

Outside of Colombia, the project will be in collaboration with national research institutions. In Brazil and Venezuela, activities will begin in December 1977 or early 1978, as soon as the German collaborators are integrated into the team.

In Colombia, the project started in August 1977. Twenty farms, characterized in Table 44 were selected and in October 1977, the CIAT team began collecting data. Locations of the farms are shown in Figure 57.

The following characteristics are evaluated for each farm.

(1) Farm characteristics: location, area, soil properties, physical inputs, production system.

Table 44. **Characterization of selected farms in Colombian Llanos portion of beef cattle technology project.**

Farm No.	Intensity level[1]	Type of operation[2]	Total (ha)	Area: Planted pastures (ha)	Animals: Cows	Animals: Total
1	III	Cr-L	900	150	200	500
2	III	Cr-L	2000	140	150	400
3	IV	L	800	400	-	400
4	II	Cr-L	3200	-	250	750
5	IV	Cr-L	1200	10	66	230
6	IV	Cr-L-C	3500	250	400	900
7	IV	Cr-L-C	5200	900	180	1000
8	IV	Cr-L	600	60	60	120
9	I	Cr-L	1100	-	50	96
10	IV	L-C	2800	1500	-	500
11	IV	Cr-L-C	5000	30	450	1100
12	III	Cr-L-C	3000	120	210	600
13	I	Cr-L	1500	-	150	300
14	I	Cr-L	3000	30	200	500
15	III	Cr-L	4300	-	500	1000
16	I	Cr-L	4000	-	200	400
17	II	Cr-L	6000	130	200	400
18	III	Cr-L-C	5000	80	200	600
19	I	Cr-L	4500	-	150	400
20	III	Cr-L	2500	250	200	500

1 Intensity levels: I — Savanna pasture only, few minerals, without weaning, without herd subdivision, II — Savanna pasture only, minerals, with weaning, with herd subdivision; III — Improved pastures, few minerals, without weaning, without herd subdivision, IV — Improved pastures, minerals, with weaning, with herd subdivision.

2 Operation: CR = Cow-Calf; C = Fattening; L = Raising.

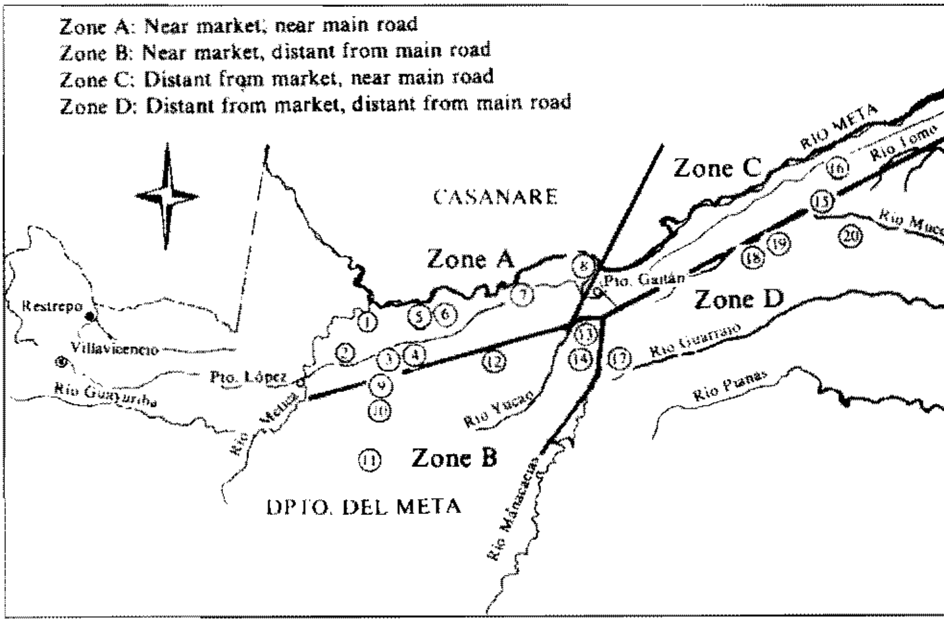


Figure 57. **Location of the 20 farms selected for characterizing beef production systems in the Colombian Llanos.**

(2) Feed resources: savanna, planted pastures, other feed resources.

(3) Utilization of feed resources: stocking rates, pasture management.

(4) Animal production: reproductive performance, mortality, type of animal product, animal output.

(5) Production techniques: with regard to feeding, herd management, animal health.

BREEDING HERDS MANAGEMENT SYSTEMS

In August 1977, an experiment on managing breeding herds was initiated at Carimagua. After a preliminary period, the experimental phase will start in May 1978. The data collection period will include three reproductive cycles.

The main objective is to study reproductive performance of breeding herds related to: (1) strategic use of planted pastures (5 percent of total available area), for the critical periods of the year (dry season) or critical growth stages (parturition, lactation, reconception and weaning); (2) adaptation of the critical periods (of higher demand) to periods of better forage availability, by restricted mating seasons; and (3) duration of lactation.

To study these components of herd management systems, six herds were established with the treatments described in Table 45.

For Herds 2,4 and 6, 120 hectares of *B. decumbens* and 30 hectares of *S. guianensis* were planted. The mating periods have been established according to the findings from the Herd System experiment, in relation to seasonal effects on animal performance. All herds will be supplemented *ad libitum* with minerals, and undergo preventive health measures.

Table 45. **Treatments in breeding herds management system experiment, Carimagua.**

		Treatments between herds[1]			
			Mating period		
Herds	No. of cows	Pastures	Type	Months	Duration (days)
1	50	Savanna	Continuous	Jan-Dec.	365
2	50	Savanna+*Brachiaria*+Legumes			
3	50	Savanna	1 Period	June-Sept.	120
4	50	Savanna+*Brachiaria*+Legumes			
5	50	Savanna	2 Periods	May-July	150
6	50	Savanna+*Brachiaria*+Legumes		Dec.-Jan.	

1 Also, within herds, 50 percent of calves weaned at 6 months, 50 percent weaned at 9 months.

TEST HERD

At Carimagua Pasture Utilization, Animal Management and Animal Health sections are carrying out or have planned large experiments with cattle. In practice, it is difficult to purchase sufficient numbers of cattle having uniform ages, weights and health status and with good background information on pre-experimental treatments. At Carimagua, with its 22,000 hectares of savanna, it is feasible to produce the stock required for experiments.

After new working agreements were developed this year, the land, part of the infrastructure and cattle stock became available to set up a cattle pool with the following objectives:

(1) To provide adequate animals for experimental purposes.

(2) To collect detailed information on herd performance under reasonable, commercial-like management.

(3) To verify management techniques which have been experimentally tested or observed to work in the environment, under practical conditions and with large herds.

On a total area of about 4,600 hectares, there are 16 fenced savanna fields, from 150-750 hectares in size, and four paddocks, totaling 100 hectares of *B. decumbens*. Overall carrying capacity of savanna pasture is estimated to be 6-7 ha/A.U. Further area for expansion is available.

Cattle stock in the Test Herd as of 30 September 1977 was as listed below:

Breeding cows	195
Unweaned calves (0-9 months)	89
Replacement heifers for mating	149
Heifers (9 months - 3 years)[1]	306
Steers (9 months - 3 years)[1]	265
Bulls	35
Total	1039

1 Includes animals that were later culled.

By late 1978 it is hoped to have 300 breeding cows, to produce 160-180 steers and heifers per year.

Table 46. **Breeding stock in the Carimagua Test Herd.**

Category	No.	Lactating cows	Pregnant cows	Abortions
Cows	197	108	69	14
Mated heifers[1]	51	9	40	-

[1] These heifers have been made available for an experiment

Two small herds—of 20 Zebu and 65 San Martinero cows, with their respective calves and bulls — are managed within the cattle pool, to maintain a pure breeding stock of these two breeds.

Comparing the available fenced land and the existing stock, it is evident that grazing areas are partially overstocked, the main reason for low animal performance in the past.

Table 47. **Animals culled from Carimagua Test Herd.**

Category	No.	Reason
Cows	34	No calf over 2 years
Heifers	17	Genital infantilism
Heifers	4	Underdeveloped
Steers	187	Unsuitable for experiments
Cows	28	Unsuitable, crosses with European breeds
Bulls	24	Age, fertility
Bulls	14	San Martinero breed
Total	308	

The first activity (June 1977) was to initiate selection or screening, based on existing records and individual checks, with the results shown in Table 46. Approximate calving rate for 1977 will be 63 percent, compared to 36.4 percent in 1975 and 42 percent in 1976.

Based on this thorough check of all animal categories, the animals were culled in June, and in November, all herds were checked again for records information and further culling. (Table 47). It was decided to replace all San Martinero bulls by Zebu, bulls to obtain a more uniform calf crop. Twelve young Zebu bulls were purchased.

Numbers of cattle furnished for experiments are listed below.

Category	No.	Section
Mated heifers	51	Herd Management
Steers	77	Pasture Utilization
Steers	15	Legume Agronomy
Heifers for mating	149	Animal Health
Total	292	

Animal Health

Activities in animal health are centered on problem analysis and problem solving investigations. The section is responsible for establishing and maintaining preventive medicine schemes in animals under experimentation and herds that provide experimental cattle. Monitoring of health in both groups of cattle is a complementary activity.

Investigations continue in areas associated and complementary to the main thrust of the program, the increase in feed supply. Four main areas have been identified. (1) Diseases associated with or augmented by nutritional deficits (leptospirosis and others). (2) Diseases expected to increase as animal density increases because of improved feed supply. They include gastro-intestinal parasitism, infectious bovine viral rhinotracheitis and viral respiratory infections. (3) Epidemiological surveillance of cattle at the Carimagua station, preventive medicine and control. (4) A disease inventory of the impact area as part of the overall survey. (5) Disease-nutrition interaction studies through blood parameter analysis in the Herd Systems trial.

LEPTOSPIROSIS

Infectivity under High Nutritional Stress

Observations continued on natural infection occurring in a herd of 100 breeding cows and seven bulls grazing in 400 hectares of native savanna and receiving salt and bonemeal supplementation. The farm is located 65 kilometers from Puerto Lopez in the Meta region.

The basic objective of this study is to obtain a thorough understanding of the pathogenesis, epidemiology, diagnosis and effect on productivity of *Leptospira hardjo* while at the same time, studying a control procedure.

The herd is examined every 10 weeks. Blood samples are examined for clinicopathological measurements and serum examined for leptospiral antibodies, which are used to monitor evolution of infection. Urine samples are obtained from animals with increasing antibody titers and cultured for isolation of Leptospiras to identify shedders and chronic infections.

Animals in the herd have been assigned to three groups. One group of 35 cows received two doses of Streptomycin by intramuscular injection 16 weeks apart at the end of the rainy season October-December 1976. The second group of 35 cows received one dose of Streptomycin (intramuscularly) at the end of the dry season (April 1977). A third group of 30 cows remains untreated as the control. The three groups graze the same pasture.

Infection has appeared to diminish overall in the herd as a consequence of the treatment (Fig. 58).

It could be argued that infection in the herd is slowly decreasing by itself. However, some decrease in the number of infected animals in the untreated group could be expected since all cows are in the same pasture, and a decrease in shedders in one group reduces the chances of reinfection in other groups. Also, infected titers are kept apparently by constant reinfection.

Animals with high serum titers —1:400 or more— have also decreased as a whole in the herd (Fig. 58), as have average titers, which decreased from 447 to 300. At this rate it would seem possible to eliminate the infection from the herd by further treatments.

Some cows with active infection seem to have abortion problems; however, of 35 abortions occurring from July 1976 through September 1977, 14 were in cows with no detectable infection (Table 48).

Twenty-five abortions occurred in late pregnancy, a characteristic of Leptospira infection. Some of these fetal deaths reported as abortions might actually have been perinatal mortality (calves dying in the first 24 hours of life) which is sometimes undetected in the field. This is especially interesting in view of the findings from experimental reproduction of the disease reported below. Abortion data should be carefully interpreted since most cows have not had a chance to have at least two pregnancies. The Leptospira strain isolated from this herd, and reported last year, was confirmed at the Pan-American

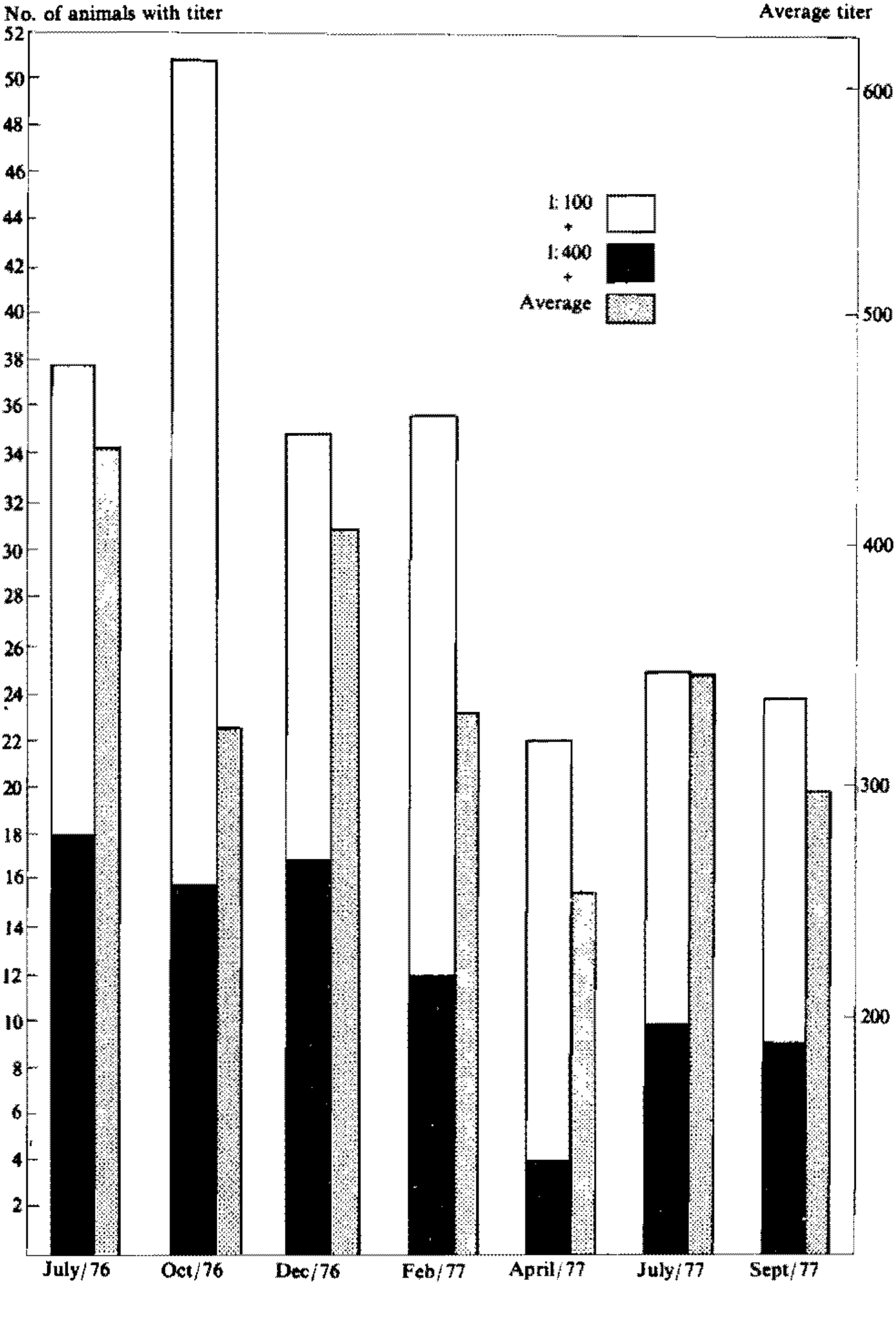


Figure 58. Cows from the Colombian Llanos trial herd with antibody titers over 1:100 and 1:400 compared with average titers at ten-week intervals.

Table 48. **Abortions in Colombian Llanos trial herd, comparing Leptospira infection in the cow and stage of pregnancy, July 1976 thru September 1977.**[1]

	Pregnancy		
Detectable infection	Late	Early	Totals
With antibodies	16	5	21
Without antibodies	9	5	14
Totals	25	10	35

[1] All abortions detected by palpation.

Zoonosis Center, Buenos Aires, to be *L. hardjo*. This strain is being used to experimentally reproduce the disease. Urine cultures from infected animals have produced three more isolations tentatively identified as *L. hardjo*.

Culturing could be a very useful tool for diagnosing the disease and detecting shedders. However, chronically infected animals with high titers did not give rise to cultures. All three isolations came from cows with low serum antibody levels.

Infectivity in Well-nourished Cows under Artificial Inoculation

The *L. hardjo* isolated from naturally occurring infections was inoculated into 10 pregnant cows to study its capacity to produce infection and alterations in well-fed animals. Cows are receiving sugar cane, cottonseed meal and minerals. Six cows have ended their pregnancies. Cow No. 4 gave birth, almost at full term, to a very weak calf that died after 36 hours, with damages in the liver and kidneys. This cow had a retained placenta and developed a severe metritis. She was treated locally to control secondary infections but died 30 days after parturition with evidence of Leptospira infection in the kidneys and secondary bacterial infections in other organs. Three cows gave birth to weak

Table 49. **Alterations observed in pregnant cows inoculated with *Leptospira hardjo* and neonatal changes, at 110 days after challenge.**

Cow No.	Age pregnancy at inoculation (months)	Average cow antibodies[1]	Retained placenta and Metritis	Calf condition	Calf antibodies
1	5.0	80	+	O.K.	
2	6.5	110	—	O.K.	
3	7.0	235	—	Weak	1600
4[2]	6.5	35	+	Weak-died	No serum available
5	5.0	185	—	Weak	400
6	5.0	105	+	Weak	400
7	4.0	145	(Still pregnant)		
8	4.0	255	(Still pregnant)		
9	3.5	605	(Still pregnant)		
10	3.5	255	(Still pregnant)		
11	Non-inoculated	Control	—	Normal	
12	Non-inoculated	Control	—	Normal	

[1] 110 days after inoculation.
[2] Cow died 120 days after inoculation and 30 days after parturition.

calves that were infected, as evidenced by high serum antibody levels (Table 49). Calves were sacrificed 24 hours after birth.

All cows developed antibody levels immediately after challenge; antibodies peaked at 14 days (Fig. 59). Infection levels decreased and reached their lowest level after 75 days, after which a second rise occurred, reaching a smaller peak at 102 days. Apparently, after the initial infection recedes, re-infection occurs in some animals that are exposed to shedders, since cows are all in the same pasture. Animals that remain infected tend to increase their antibody levels even further and could remain chronically affected.

There are obvious differences in individual animals (Fig. 60). Cow No. 4 developed a low level of infection, and antibody defenses did not last over 52 days. This might be one of the reasons this animal died later from a complicated infection in which the primary cause was leptospirosis. It might also explain the *in utero* infection of the calf and its death some hours after birth. Cow No. 5 developed high antibody levels from 14 to 32 days after challenge and dropped to low levels up to 109 days. The calf from this cow developed a reasonably high infection level corresponding to the dam's level. Cow No. 3 had a very clear re-infection after initial infection and decreased antibody levels from 39 to 75 days. This high infection seems to be reflected in her calf's reaction, which has been the greatest in the group.

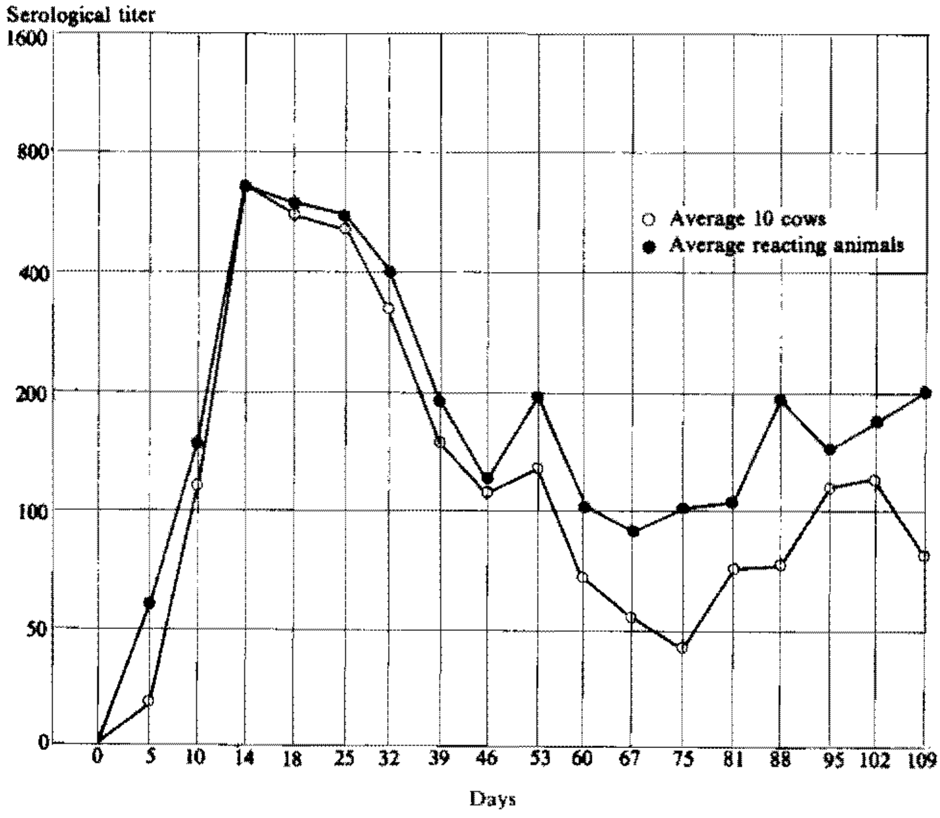


Figure 59. **Infection measured by antibody response in ten pregnant cows inoculated with** *Leptospira hardjo*.

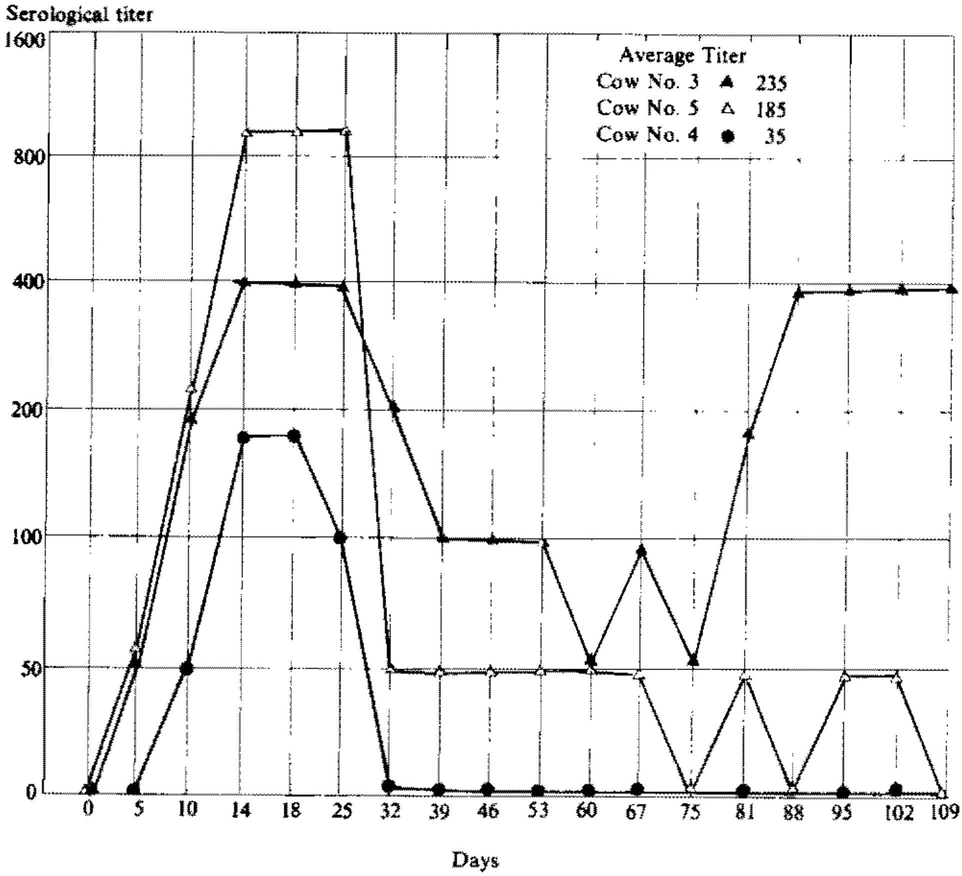


Figure 60. **Infection detected by antibody response in three pregnant cows inoculated with** *Leptospira hardjo.*

Isolation of Leptospira from urine samples has closely followed the antibody levels in the blood serum. Leptospira were isolated from most cows up to 75 days post-inoculation and are beginning to appear in animals that are getting re-infected. Shedding of Leptospiras in the urine began five days after inoculation. It has been possible to detect shedders by direct examination of the urine under dark ground illumination. When bacteria are observed with this procedure, it has also been possible to isolate them in artificial media and, very frequently, by hamster inoculation. Even though the trial is continuing (four more cows have to calve), it appears that the *L. hardjo* isolated from field cases in the Llanos of Colombia has considerable ability as a pathogen. The kidney and the liver lesions with generalized icterus seen in a calf, have not been described in the literature for this Leptospira. There is some tendency to produce weakened calves that might not survive under field conditions. This could explain some calf losses in cows at full term that are reported in the field as abortions, since very few cows are seen during parturition. Some abortions apparently related to Leptospira infections have not been explained by the artificial infection and some unknown triggering mechanism may exist.

From the natural and artificial infection results it can be hypothesized that cows in late gestation (over 6 months) will lose their calves to perinatal death, if exposed to *L. hardjo* infection and not having antibodies. It is not known if treatment or vaccination could prevent this. Also the influence of nutritional deficiencies on the development of the infections is still unclear. On the other hand, with natural infections, cows with chronic infection and elevated antibody levels tend to lose condition.

Response to Vaccination In Heifers before First Pregnancy

Strategic use of a vaccine might give sufficient protection to a heifer in overcoming a Leptospiral infection. A commercial vaccine (not available locally) containing *L. hardjo, L. pomona* and *L. gryppotyphosa* was obtained. One-hundred and fifty heifers to be kept for breeding in the herds of the experimental cattle pool were vaccinated with this product. Fifty of these heifers are kept in a separate group and closely observed for development of protective serum antibody levels. Vaccine will be applied every six months and blood serum samples collected at 30 days, and every two months thereafter. Antibody development is compared against a similar group of non-vaccinated heifers. Both groups are exposed to low-level field challenge.

EPIDEMIOLOGICAL STATUS OF THE CARIMAGUA HERD

Epidemiological surveillance of cattle in Carimagua is done by a pathologist, who will be joined by an ICA senior parasitologist and a research assistant at the end of the year. The most common clinical conditions encountered have been: bone fractures, retained placenta, polyarthritis, metritis and wasting disease. Ectoparasites (ticks and *Dermatobia hominis)* and internal parasites are commonly in an equilibrium state with the host and become problems if not strategically treated. A search is underway for an inventory of diseases in the area of influence of this experimental station.

Polyarthritis is a bacterial infection of various joints. Bacteria probably enter the system through a non-treated navel infection. The condition is gaining importance in Carimagua due to the extensive areas where calving takes place. Because many calves are not seen in the first 48 hours, infection can easily occur. A limited trial will be set up to prepare an immunizing product that, given to the cow, would help the calf withstand infection.

Routine vaccination schemes for brucellosis, aftosa, black-leg and hemorrhagic septicemia are being used and adapted to management conditions.

Internal nematodes interfere with normal growth and performance of beef cattle. Parasite control, however, should be used strategically to insure economic use of resources. Seasonal changes in parasite content of calves in the Carimagua area will be determined with a *bio-climatogram* where the level of parasitism is compared against climatological data such as temperature, rainfall, and potential evapotranspiration. For the analysis, fifty calves born during the rainy season were selected and 50 more will be selected from animals born during the dry period. A comparison will be established between level of parasitism and nutritional status measured by weight and some blood parameters.

IMPACT AREA SURVEY

A disease inventory of the Beef Program's impact area is being constructed. The basis for analysis of the information will be gathered by the impact area survey project of the Program.

Local teams of scientists will collect

information and, when possible, samples for laboratory analysis. Professionals from national institions are also being contacted to obtain descriptions as complete as possible. While initial information is not necessarily quantitative, it is hoped to obtain rather precise information for calf mortality causes, reproductive diseases and internal parasitism.

Work began in Brazil through EMBRAPA and in collaboration with their staff at the Cerrado, Center, Brasilia and the Centro Nacional de Pesquisa de Gado de Corte in Mato Grosso. Data collection also started in Paraguay with the collaboration of the Diagnostic Center of the Ministry of Agriculture. Blood serum samples for examination of reproductive problems from the three places will be analyzed in CIAT laboratories. Other examinations will be performed locally.

DISEASE-NUTRITION INTERACTIONS

In large parts of the tropics the main animal health problems are associated with killing diseases such as the tsetse-transmitted trypanosomiasis, rinderpest, theileriasis and contagious bovine pleuropneumonia. In Latin American countries, however, synergism between malnutrition and disease probably is the main factor influencing livestock productivity.

Epidemiologic studies, clinical investigations and laboratory experiments have clearly shown that malnutrition and infectious diseases are mutually aggravating and together, they can produce more serious consequences for the animal than would be expected from the sum of independent effects. In veterinary medicine, the close association of nutrition and husbandry to production disease is marked in tropical countries where grazing and crops are dependent upon a seasonal rainfall.

A one-year experiment was conducted on the nine herds of Zebu breeding cows of the Carimagua Herd Systems trial. The objective was to evaluate the usefulness of blood parameters in identifying abnormal situations arising in beef animals subjected to severe climatic stress, different management practices and production inputs.

Most blood parameters studied indicated the effect of season, mineral supplementation, urea-molasses-sulfur supplementation, type of weaning, reproductive condition and pasture type.

Blood parameters influenced by season in herds receiving salt and/or mineral supplementation (Group I) were packed cell volume (PCV), serum glucose, urea, inorganic phosphate, calcium, magnesium, sodium, potassium, total protein, globulin, hemoglobin, weight and weight gain ($P<0.01$); albumin was the least variable parameter ($P<0.05$) Most variable, as influenced by mineral supplementation, were serum urea, inorganic phosphate, total protein and weight ($P<0.01$); serum magnesium and globulin were the least variable ($P<0.05$). For urea-molasses-sulfur supplementation, the most variable parameters were PCV, serum urea, calcium, sodium, inorganic phosphate, hemoglobin and weight ($P<0.01$); albumin was the least variable ($P<0.05$). For weaning type, serum albumin and weight gain were most variable ($P<0.01$); globulin was the least variable ($P<0.05$). For reproductive condition, most variable were PCV, serum inorganic phosphate, albumin, hemoglobin, weight and weight gain ($P<0.01$); glucose was the least variable ($P<0.05$) (Table 50).

Blood parameters influenced by season in Group II (Herds 4, 5, 6, 7, 8, 9) are shown in Table 51. They were: PCV, serum glucose, urea, inorganic phosphate, calcium, magnesium, sodium, potassium, total protein, albumin, globulin, hemoglobin, weight and weight gain ($P<0.01$). Most variable, as influenced by pasture treatments were serum glucose, urea, inorganic phosphate, calcium,

Table 50. **Effect of seasonal periods, pasture type, urea-molasses-sulphur supplementation weaning type and reproductive conditions on blood parameters, weight and weight gains of beef cattle in Group II (herds 4, 5, 6, 7, 8, 9), June 1976 to May 1977.**

					Blood Parameters													
Treatment	Herd	Year	Season	No. of cows	PCV[1] (%)	Glucose (mg/100 ml)	Urea (mg/100 ml)	P (mg/100 ml)	Ca (mg/100 ml)	Mg (mg/100 ml)	Na (meq/100)	K (meq/100)	Total Protein (g/100/ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Hemoglobin (g/100 ml)	Weight (kg)	Weight gains (kg)
Control	1	1976	1	52	40.29	72.96	29.35	3.09	10.70	2.37	138.60	5.68	8.22	2.56	5.66	14.38	317.87	-0.75
	1	1976	2	50	41.54	65.60	21.17	6.64	10.68	2.98	178.28	7.18	7.84	2.49	5.34	13.94	319.02	3.58
	1	1977	3	49	39.08	82.30	29.16	5.85	9.12	2.70	144.23	4.16	7.84	2.58	5.29	13.14	282.76	-28.96
	1	1977	4	24	41.77	77.60	36.56	5.07	13.11	2.69	151.11	3.85	8.15	2.61	5.50	13.72	306.79	43.08
Season																		
Early rainy season	4,5,6,7,8,9	1976	1	385	37.84	67.18	23.74	5.16	10.17	2.17	145.26	5.79	7.84	2.57	5.26	13.90	328.54	31.58
Late rainy season	4,5,6,7,8,9	1976	2	390	41.45	79.12	17.27	6.36	9.71	2.32	146.39	5.68	7.85	2.46	5.40	13.93	340.06	7.11
Dry season	4,5,6,7,8,9	1977	3	385	39.35	74.77	23.18	6.19	8.97	2.32	144.04	4.52	7.33	2.51	4.82	13.29	309.29	-25.45
Early rainy season	4,5,6,7,8,9	1977	4	196	39.53	83.49	28.47	5.15	10.31	2.24	132.02	3.71	7.95	2.64	5.31	13.26	327.03	33.86
Pasture[2]																		
Native grass	4,5	1976-77	1-4	450	39.66	74.84	26.67	5.39	10.11	2.57	148.11	5.09	7.97	2.63	5.34	13.69	339.98	3.53
Native grass + molasses grass	6,7	1976-77	1-4	481	40.11	79.27	21.33	5.57	9.36	2.16	136.36	5.19	7.68	2.54	5.15	13.77	332.34	2.73
Molasses grass	8,9	1976-77	1-4	419	38.79	70.55	18.97	6.38	9.61	2.06	144.01	5.01	7.47	2.41	5.05	13.46	304.24	2.32
Supplement (Dry season)[3]																		
None	5,6,8	1976-77	1-4	664	39.32	73.66	21.88	5.85	9.64	2.28	140.58	5.13	7.69	2.52	5.17	13.60	318.96	1.20
Urea + molasses	4,7,9	1976-77	1-4	686	39.78	76.47	22.85	5.75	9.73	2.26	146.05	5.07	7.74	2.54	5.19	13.69	333.14	4.48
Weaning																		
Normal	4,5,6,7,8,9	1976-77	1-4	1141	39.39	75.44	22.67	5.78	9.70	2.27	143.41	5.12	7.70	2.54	5.16	13.59	321.50	3.25
Early	4,5,6,7,8,9	1976-77	1-4	209	40.44	73.19	29.78	5.92	9.62	2.24	143.15	5.00	7.80	2.49	5.32	13.96	351.65	0.78
Reproductive state control herd																		
Lactating - pregnant	1	1976-77	1-4															
Dry pregnant	1	1976-77	1-4	76	41.98	73.31	26.88	5.57	10.75	2.76	150.61	5.29	8.06	2.61	5.43	14.37	324.76	5.39
Lactating - open	1	1976-77	1-4	36	36.89	72.10	29.44	4.40	10.45	2.61	154.50	5.29	7.60	2.38	5.28	12.72	277.11	-11.78
Dry - open	1	1976-77	1-4	63	40.58	75.39	28.39	5.07	10.46	2.63	155.91	5.67	8.14	2.59	5.55	13.78	302.22	-3.67
Reproductive state experimental herd																		
Lactating - pregnant	4,5,6,7,8,9	1976-77	1-4	65	38.45	76.52	23.74	5.33	10.06	2.37	143.70	5.22	7.91	2.63	5.27	13.36	316.71	6.69
Dry - pregnant	4,5,6,7,8,9	1976-77	1-4	590	41.50	73.49	21.54	6.10	9.71	2.33	143.00	5.04	7.81	2.59	5.23	14.23	352.44	18.00
Lactating - open	4,5,6,7,8,9	1976-77	1-4	549	37.60	76.04	23.76	5.42	9.60	2.22	142.49	5.08	7.60	2.45	5.14	13.01	301.72	-16.47
Dry - open	4,5,6,7,8,9	1976-77	1-4	146	39.52	77.33	19.97	6.24	9.71	2.16	147.98	5.35	7.66	2.34	5.32	13.82	316.14	12.72

[1] Packed cell volume or hematocrit.
[2] L.S.D. between mean values at .01 and .05 levels.
[3] From January to April, 1977.

Table 51. **Effect of seasonal periods, mineral supplement, urea-molasses-sulfur supplementation, weaning type and reproductive conditions on blood parameters, weight and weight gains of beef cattle in Group I (herds 2, 3, 4, 5). June 1976 to May 1977.**

Treatment	Herd	Year	Season	No. of cows	Blood Parameters: PCV[1] (%)	Glucose (mg/100 ml)	Urea (mg/100 ml)	P (mg/100 ml)	Ca (mg/100 ml)	Mg (mg/100 ml)	Na (meq/liter)	K (meq/liter)	Total Protein (g/100 ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Hemoglobin (g/100 ml)	Weight (kg)	Weight gains (kg)
Control	1	1976	1	52	40.29	71.96	29.35	3 09	10.70	2.37	138.60	5.68	8.22	2.56	5.66	14.38	317.87	-0.75
	1	1976	2	50	41.54	65.60	21.17	6.64	10.68	2.98	178.28	7.18	7.84	2.49	5.34	13.94	319 02	3.58
	1	1977	3	49	39.08	82.30	29.16	5.85	9.12	2.70	144.23	4.16	7 84	2.58	5.29	13.14	282.76	28 96
	1	1977	4	24	41.17	77.60	36.56	5.07	13.11	2.69	151 11	3 85	8 15	2 61	5.50	13.72	306.79	43 08
Season																		
Early rainy season	2,3,4,5	1976	1	254	37 63	77.70	28.88	3.78	10.33	2.24	144.36	5.92	7.90	2.63	5.27	14.42	326.67	7 08
Late rainy season	2,3,4,5	1976	2	253	41.76	76.03	29.04	5.90	9.58	2.58	153.67	5 81	8.21	2.57	5.63	13.99	343.57	13 33
Dry season	2,3,4,5	1977	3	247	39.89	71.22	26.66	5.51	9.37	2.67	147.28	4 36	7 41	2.62	4.78	.3.44	313.77	-25.90
Early rainy season	2,3,4,5	1977	4	123	40 39	84.23	36.08	4.32	11.85	2.57	153 28	3 67	8 05	2.68	5.38	13.55	328.73	29.07
Minerals																		
Salt	2,3	1976-77	1-4	427	40.05	77.86	32.09	4.50	10.00	2.43	150.23	5 17	7 77	2.61	5 16	14.12	315 78	1 78
Salt + minerals	4,5	1976-77	1-4	450	39 66	74.84	26.67	5.39	10.11	2.57	148.11	5 09	7 97	2.63	5.34	13.69	339.98	3.53
Supplement (Dry season)[2]																		
None	3,5	1976-77	1-4	432	39 28	75.85	27.64	5.22	9.92	2.50	146.11	5 18	7.87	2.61	5 25	13.68	320.04	1 36
Urea + molasses	2,4	1976-77	1-4	445	40.40	76.75	30.93	4.70	10.19	2.51	152.08	5.08	7.87	2.62	5.25	14.11	336 13	3 96
Weaning																		
Normal	2,3,4,5	1976-77	1-4	739	39.60	76.79	29.76	4.96	10.07	2.50	149.07	5 14	7.86	2.63	5.22	13 84	327.16	2.82
Early	2,3,4,5	1976-77	1-4	138	41.17	73.74	26.87	4.97	9.99	2.52	149.48	5.06	7.95	2.56	5.39	14.21	333 80	1 91
Reproductive stage control herd																		
Lactacting - pregnant	1	1976-77	1-4															
Dry-pregnant	1	1976-77	1-4	76	41.98	73 31	26.88	5 57	10.75	2.76	150.61	5.29	8.06	2.61	5.43	14 37	324 76	5 39
Lactating - open	1	1976-77	1-4	36	36 89	72.10	29 44	4.40	10.45	2.61	154.50	5 29	7 60	2.38	5.28	12.72	277 11	-11 78
Dry - open	1	1976-77	1-4	63	40 58	75.39	28.39	5.07	10.46	2.63	155.91	5 67	8 14	2.59	5.55	13.78	302 22	-3 67
Reproductive state experimental herd																		
Lactating - pregnant	2,3,4,5	1976-77	1-4	36	37 75	77 02	31 68	4.54	10 54	2.61	147.18	5 08	8.08	2.75	5.35	13.11	317 78	9.44
Dry - pregnant	2,3,4,5	1976-77	1-4	415	41.74	74.00	27.94	5.40	10.05	2.51	149.07	5 14	7.96	2.66	5 29	14.50	349 85	14 29
Lactating - open	2,3,4,5	1976-77	1-4	305	37 15	75.99	30.85	4.45	10 04	2.54	149.83	5.14	7.80	2.56	5.24	12 96	304.08	-15 52
Dry - open	2,3,4,5	1976-77	1-4	121	40.81	84.82	29.41	4.84	9.97	2.36	148.20	5 09	7.70	2.60	5 10	14 46	317 87	6 69

[1] Packed cell volume or hematocrit

[2] From January to April, 1977

magnesium, sodium, total protein, albumin, globulin and weight ($P<0.01$); potassium was the least variable ($P<0.05$). For urea-molasses-sulfur supplementation, most variable were serum sodium and weight ($P<0.01$); glucose and albumin were the least variable ($P<0.05$). For weaning type, most variable were serum albumin, globulin, weight and weight gain ($P<0.01$); total protein was the least variable ($P<0.05$). For reproductive condition, most variable were PCV, serum inorganic phosphate, potassium, total protein, albumin, hemoglobin, weight and weight gain ($P<0.01$); glucose and sodium were the least variable ($P<0.05$).

The largest correlation coefficients in decreasing order of all possible pairs of blood and production parameters (Table 52), were found between total protein and globulin (0.91), PCV and hemoglobin (0.80), weight and hemoglobin (0.44), potassium and sodium (0.44), weight and PCV (0.41), magnesium and calcium (0.38), PCV and total protein (0.33), weight gain and weight (0.32), total protein and albumin (0.31), PCV and globulin (0.30), weight and total protein (0.28), hemoglobin and total protein (0.28).

Three of 12 blood parameters studied namely, serum total protein, PCV and hemoglobin, were influenced by weight. Concentrations of all three increased with weight ($P<0.01$) (Fig. 61).

Seasonal variations of blood parameters and weight in relation to reproductive condition (Herds 1 to 9), showed that the highest serum mean value concentrations for inorganic phosphate, total protein, PCV, hemoglobin and weight across seasons 1 to 4 corresponded to the dry-pregnant condition (Figs. 62, 63, 64). The condition lactating-pregnant had the highest serum mean value concentrations for albumin, urea, calcium and magnesium. The condition dry-open had the highest mean value concentrations for globulin, sodium, potassium and glucose.

The lowest serum mean value concentrations for total protein, PCV, hemoglobin, albumin, sodium, calcium, magnesium and weight corresponded to the lactating-open condition. The lowest serum mean value concentrations for glucose, potassium and urea, corresponded to the dry-pregnant condition. The condition lactating-pregnant had the lowest mean value concentrations for inorganic phosphate and globulin.

Seasonal variations of blood parameters and weight in relation to type of weaning (Herds 1 to 9) showed that the highest serum mean value concentrations for PCV, total protein, globulin, hemoglobin and weight corresponded to early weaning cows during the late rainy season of 1976 (Table 53). The highest mean values for serum urea, calcium and albumin corresponded to normal weaning cows during the early rainy season of 1977. The highest mean values for serum sodium and potassium corresponded to normal weaning cows during the late rainy season of 1976. The highest mean values for serum magnesium corresponded to normal weaning cows during the dry season of 1977. The highest mean values for serum inorganic phosphate and glucose corresponded to early weaning cows during the dry and early rainy seasons of 1977, respectively.

The lowest serum mean values for calcium, total protein, globulin, hemoglobin and weight corresponded to normal weaning cows during the dry season of 1977. The lowest mean values for serum inorganic phosphate and PCV corresponded to normal weaning cows during the early rainy season of 1976. The lowest mean values for serum glucose and magnesium, urea and albumin, sodium and potassium corresponded to early rainy season and late rainy season of 1976 and early rainy season of 1977, respectively.

Herd 1 (negative control) was not included in the general statistical analyses. However, the highest mean values for PCV

Table 52. Pearson correlation coefficient for all possible pairs of blood and production parameters.[1]

	Glucose	Urea	Albumin	Globulin	Total protein	Hemoglobin	PCV	P	Ca	Mg	Na	K	Weight	Weight gain
Glucose	1.00													
Urea	0.00	1.00												
Albumin	0.02	0.19	1.00											
Globulin	0.05	-0.03	-0.07	1.00										
Total protein	0.06	0.04	0.31	0.91	1.00									
Hemoglobin	0.02	-0.06	0.19	0.22	0.28	1.00								
PCV	0.09	-0.19	0.12	0.30	0.33	0.80	1.00							
P	-0.04	-0.23	-0.08	-0.08	-0.10	-0.07	0.05	1.00						
Ca	0.05	0.07	0.11	0.17	0.20	0.14	0.12	-0.14	1.00					
Mg	-0.05	0.08	-0.16	0.04	0.10	0.02	0.14	0.05	0.38	1.00				
Na	-0.02	0.12	0.02	-0.01	0.00	-0.03	-0.05	0.07	0.12	0.15	1.00			
K	-0.17	-0.05	-0.03	0.09	0.07	0.15	-0.02	-0.01	0.00	-0.05	0.44	1.00		
Weight	-0.13	-0.03	0.21	0.22	0.28	0.44	0.41	0.02	0.06	0.10	0.01	0.13	1.00	
Weight gain	0.03	0.14	0.24	0.08	0.17	0.16	0.06	0.00	0.18	-0.04	0.02	0.12	0.32	1.00

[1] Correlations > 0.26 have been found significant ($P \leq 0.01$) due to the high variability observed in experimental parameter values

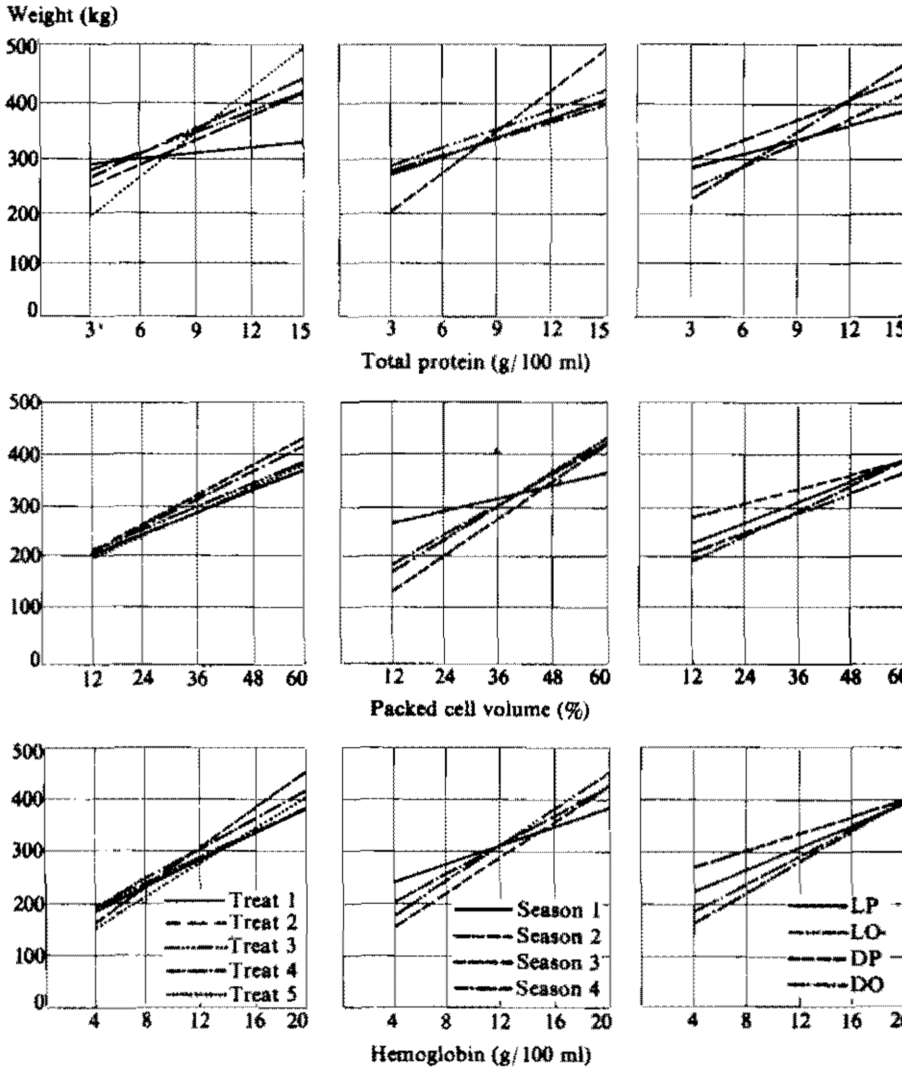


Figure 61. **Concentrations of total protein, packed cell volume (PCV), and hemoglobin, adjusted to treatment groups, seasonal periods and reproductive conditions, for 282 beef cows (Herds 1 to 9), plotted against their weights.**

serum inorganic phosphate, magnesium, sodium, potassium and weight corresponded to the late rainy season of 1976. The highest mean values for serum urea, calcium, albumin and weight gain corresponded to the early rainy season of 1977. Highest mean values for total protein, globulin and hemoglobin corresponded to the early rainy season of 1976. Serum glucose highest mean values corresponded to the dry season of 1977.

Lowest mean values for PCV, serum calcium, globulin, hemoglobin, weight and weight gain corresponded to the dry season of 1977. Lowest mean values for glucose, urea, total protein and albumin corresponded to the late rainy season of 1976.

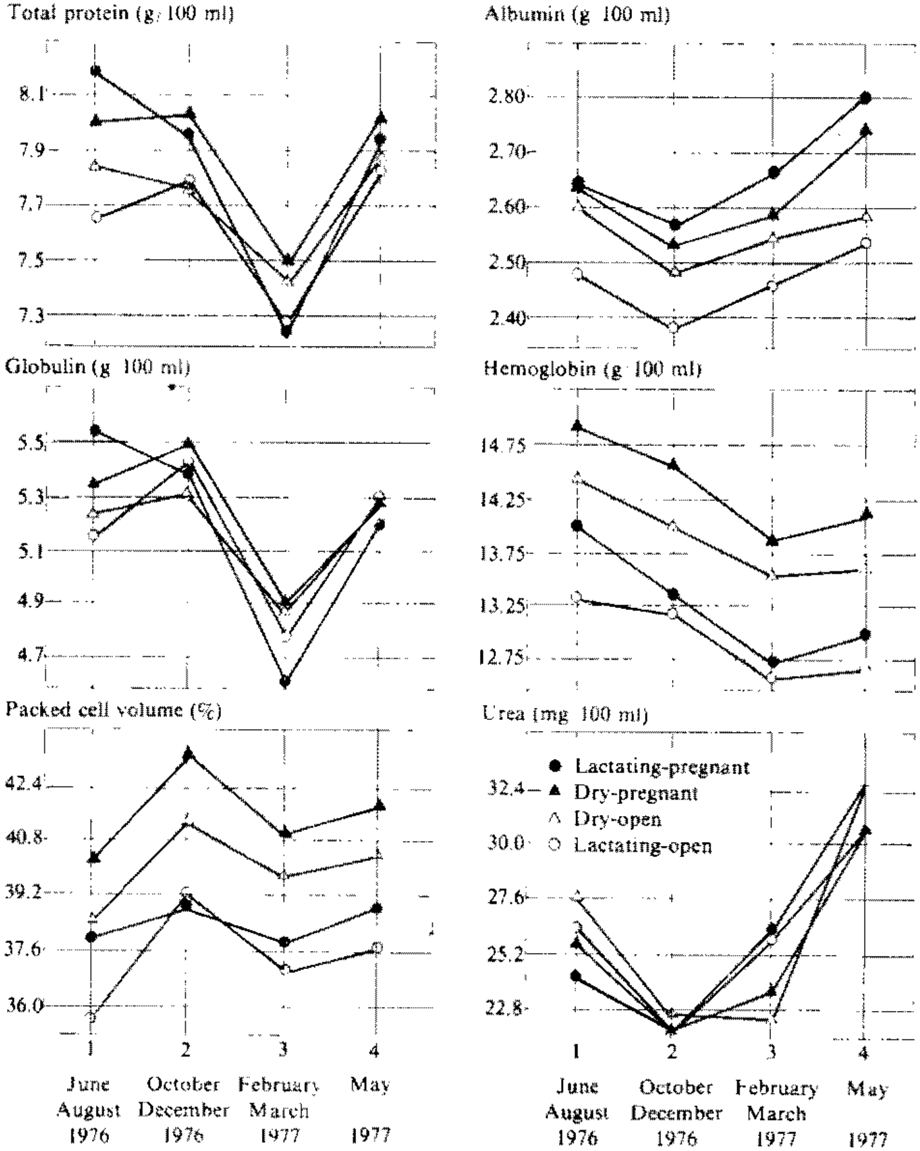


Figure 62. **Seasonal variations of serum total protein, albumin, globulin, hemoglobin, packed cell volume (PCV) and urea for 282 beef cows in relation to reproductive condition (Herds 1 to 9).**

Lowest inorganic phosphate serum mean values, magnesium and sodium, corresponded to the early rainy season of 1976. Serum potassium had its lowest value in the early rainy season of 1976.

The condition lactating-pregnant did not occur across the experiment. Highest mean values for PCV, inorganic phosphate, calcium, magnesium, albumin, hemoglobin, weight and weight gain corresponded to the dry-pregnant condition. Highest serum mean values for glucose, sodium, potassium, total protein

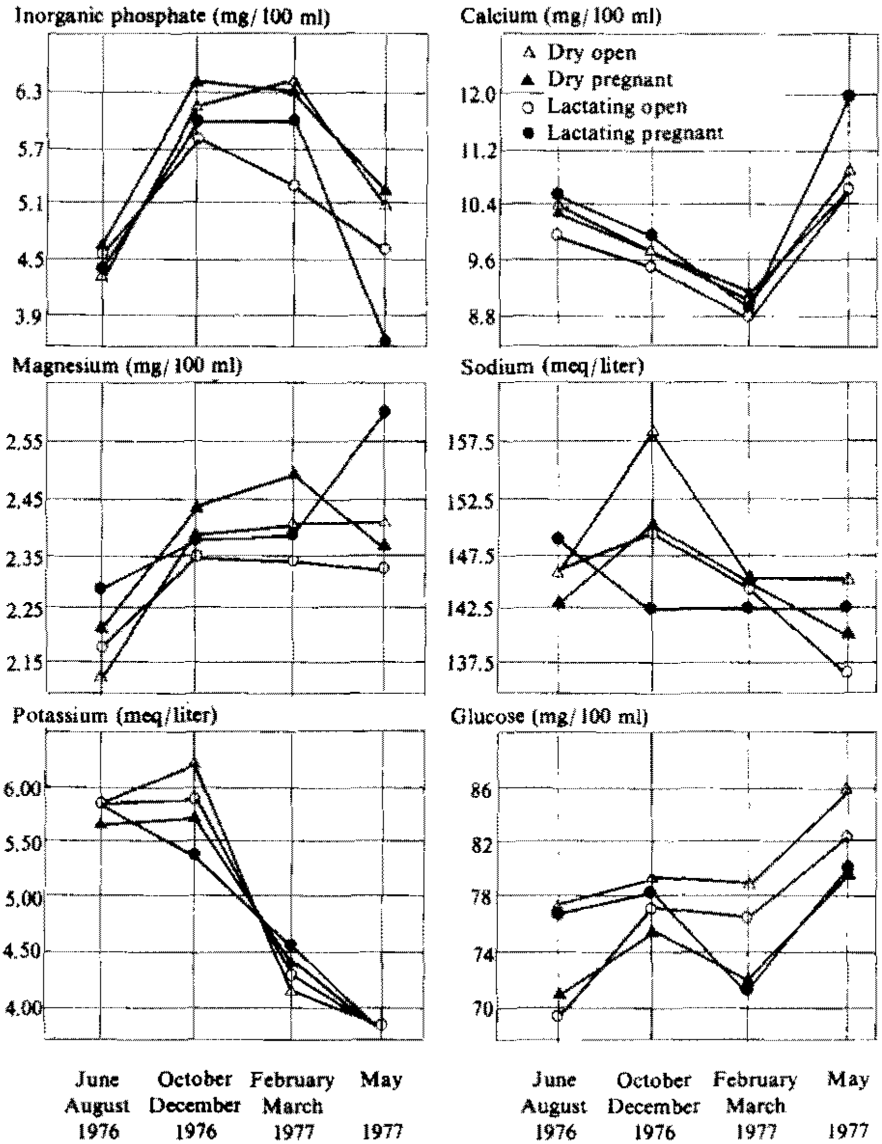


Figure 63. Seasonal variations of serum inorganic phosphate calcium, magnesium, sodium, potassium and glucose for 282 beef cows in relation to reproductive condition (Herds 1 to 9).

and globulin corresponded to the condition dry-open. Highest mean values for serum urea corresponded to lactating-open.

Lowest mean values for PCV, glucose, inorganic phosphate, calcium, magnesium, potassium, total protein, albumin, globulin, hemoglobin, weight and weight gain corresponded to the lactating-open condition. Lowest mean values for urea and sodium corresponded to the condition dry-pregnant.

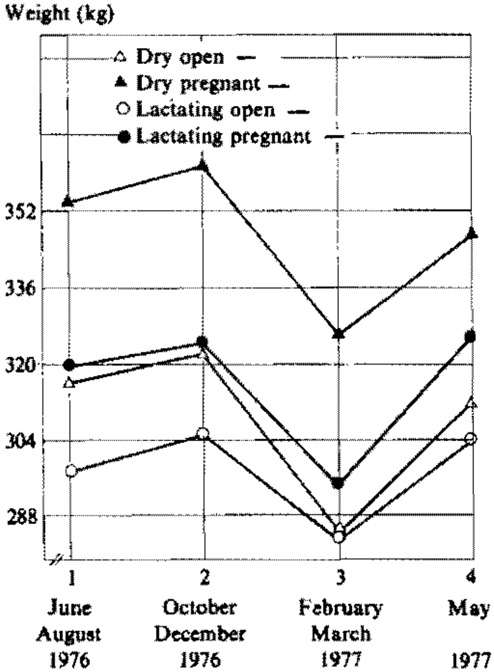


Figure 64. Seasonal variations of weight of 282 beef cows in relation to reproductive condition (Herds 1 to 9).

The soil chemical data (Table 54) showed a low pH indicating the acid nature of the soil, with a medium organic matter content. Exchangeable minerals (calcium, magnesium, potassium and sodium) were low, as well as the available phosphorus content. The aluminum saturation percentage was high, and is a common feature of Llanos soils in general.

The pasture chemical data (Table 55) showed that the phosphorus and calcium content of molasses grass was higher than that of native grass across seasons. The magnesium content was similar in both types of pastures. The nitrogen content of native grass was lowest in the late rainy season of 1976 and early dry season of 1977. The same seasons showed the highest nitrogen values for molasses grass.

Native grass had highest nitrogen values in the late dry and early rainy seasonal periods of 1977; these also showed the lowest values of the same element for molasses grass.

The interpretation of these preliminary results should be done cautiously, since many more estimates are needed. However, it has been established that blood parameters of Zebu breeding cows grazing in acid soils were influenced in decreasing order of importance by season, pasture type, reproductive condition, mineral supplementation, urea-molasses-Sulfur supplementation and weaning type. Clear seasonal patterns were evident for all twelve blood parameters studied, including the production parameters weight and weight gain. Highest mean values corresponded to wet seasons, and lowest to the dry season.

The direct relation of pasture phosphorus to phosphorus content of blood was evident. Animals on molasses grass had the highest blood concentrations, followed by those grazing native + molasses grass and native grass alone. This may partly explain the greater number of bone fractures that occurred in animals grazing native grass alone (Herds 1 to 4) from 1974 to 1977. It also suggests the advantange of establishing an improved grass efficient in phosphorus absorption in acid soils.

Low phosphorus content in these tropical soils and native grasses also leads to "pica" or depraved appetite, which predisposes animals to botulism, a toxic condition that undoubtedly killed several animals this year near the Carimagua Station.

Burning of native grass augmented the phosphorus content, as was observed by Lebdosoekojo in 1976. However, chemical analyses showed that molasses grass always had higher phosphorus content across seasons.

Other important parameters like serum

Table 53. **Seasonal variations of blood parameters and weight in relation to type of weaning (herds 1 to 9). June 1976 to May 1977.**

Type of weaning	Season	Year	No. of cows	Blood Parameters: PCV[1]	Glucose (mg/100 ml)	Urea (mg/100 ml)	P (mg/100 ml)	Ca (mg/100 ml)	Mg (mg/100 ml)	Na (meq/liter)	K (meq/liter)	Total protein (g/100 ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Hemoglobin (g/100 ml)	Weight (kg)
Normal	Early rainy season	1976	592	38.10	71.87	26.69	4.48	10.29	2.19	144.70	5.86	7.85	2.59	5.26	14.20	322.17
Normal	Late rainy season	1976	593	41.40	77.29	21.73	6.19	9.75	2.41	151.34	5.91	7.88	2.49	5.39	13.91	333.80
Normal	Dry season	1977	583	39.15	75.26	24.69	5.95	9.05	2.43	144.63	4.39	7.38	2.55	4.83	13.21	300.97
Normal	Early rainy season	1977	287	39.67	81.63	31.17	4.83	10.80	2.37	139.14	3.79	7.92	2.65	5.27	13.31	320.62
Early	Early rainy season	1976	99	38.49	70.40	23.25	4.59	10.21	2.14	142.63	5.61	7.89	2.52	5.37	14.23	341.89
Early	Late rainy season	1976	100	42.68	77.03	20.62	6.12	9.47	2.32	150.34	5.79	8.13	2.46	5.69	14.32	352.20
Early	Dry season	1977	98	41.20	71.08	22.09	6.28	9.15	2.42	145.98	4.32	7.39	2.48	4.91	13.95	325.60
Early	Early rainy season	1977	50	40.33	84.69	30.19	4.95	10.25	2.28	138.69	3.69	8.01	2.60	5.41	13.51	334.83

Table 54. **Mean chemical data for soils of pastures for experimental Herds 1-9, June 1976 to May 1977.**

					Exchangeable							Available			
Herd	Type of pasture	pH	Organic matter (%)	P Bray II (ppm)	Al (meq/ 100 g)	Ca (meq/ 100 g)	Mg (meq/ 100 g)	K (meq 100 g)	Na (meq/ 100 g)	CEC (meq/ 100 g)	% Al sat.	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)
1	Native	4.9	3.6	1.7	2.3	0.10	0.07	0.06	0.09	9.1	88	0.58	1.9	0.75	34
2	Native	4.8	4.2	2.7	2.3	0.09	0.07	0.06	0.06	9.1	89	0.69	1.8	0.38	45
3	Native	4.6	4.4	1.8	2.8	0.14	0.10	0.07	0.06	9.4	88	0.61	5.4	0.55	59
4	Native	4.7	4.1	0.9	3.2	0.18	0.12	0.09	0.06	11.0	88	0.67	6.8	0.56	45
5	Native	4.8	4.2	1.9	2.7	0.10	0.08	0.07	0.06	9.2	90	0.63	3.7	0.46	45
6	Native	4.7	4.1	1.5	3.2	0.17	0.09	0.09	0.06	11.2	89	0.54	4.6	0.54	42
7	Native	4.8	3.8	0.9	3.1	0.16	0.12	0.10	0.07	10.7	87	0.53	4.1	0.55	44
6	Molasses	4.7	4.2	1.8	3.1	0.44	0.17	0.14	0.07	11.8	79	0.61	5.7	0.62	37
7	Molasses	4.9	3.1	1.3	2.2	0.28	0.10	0.08	0.05	7.8	81	0.55	4.2	0.50	49
8	Molasses	4.8	3.8	2.0	2.9	0.51	0.16	0.11	0.05	11.0	78	0.68	7.0	0.64	65
9	Molasses	4.9	3.4	1.4	2.4	0.36	0.13	0.11	0.04	8.8	79	0.54	4.5	0.54	61

Table 55. **Seasonal variations of nitrogen, phosphorus, calcium and magnesium in native and molasses grasses.**[1]

Pasture	Sampling period	Year	Month	No. of observ.	N (%)	P (%)	Ca (%)	Mg (%)
Native savanna	Late rainy season	1976	December	5	0.53	0.04	0.14	0.12
	Early dry season	1977	February	7	0.40	0.02	0.12	0.10
	Late dry season	1977	March	7	0.60	0.04	0.10	0.09
	Early rainy season	1977	May	7	0.82	0.06	0.13	0.10
Molasses grass	Late rainy season	1976	December	4	0.58	0.08	0.15	0.12
	Early dry season	1977	February	4	0.50	0.05	0.13	0.10
	Late dry season	1977	March	2	0.48	0.05	0.14	0.09
	Early rainy season	1977	May	4	0.74	0.07	0.16	0.10

1 Values for all nutrients expressed on a dry matter basis

calcium, magnesium, sodium, urea, total protein, albumin, globulin, hemoglobin, PCV and weight were consistently higher in animals grazing native grass during the dry season, than in those grazing native + molasses and molasses grass alone during the dry season. This possibly reflects improved management practices upon animals and native savannas in this critical season, as well as the low drought resistance of molasses grass.

The condition known as "secadera" occurred more often in cows of the lactating-open condition, grazing molasses grass in the dry season (CIAT Annual Report, 1976). Animals in this condition had consistently lower mean value concentrations of total protein, albumin, globulin, PCV, hemoglobin, urea, glucose, magnesium, potassium and weight than animals in the same reproductive condition grazing other pastures. These findings support the hypothesis that the stress of lactation without adequate nutrition plays the most important role in the ocurrence of this syndrome, together with secondary infectious and parasitic diseases.

The condition Hydrallantois ("vaca inflada") was only seen in Herds 1 to 3 grazing native grass without mineral supplementation. Serum inorganic phosphate and potassium mean value concentrations for the nine cases observed were low. Other blood parameters studied were within normal limits.

Table 56. **Values of blood parameters, weight and weight gains of 282 Zebu breeding cows sampled every two months on seven occasions. June 1976 to May 1977.**

	Mean	Range
PCV (%)	39.0	23.0 - 55.0
Glucose (mg/100 ml)	102.0	13.9 - 190.0
Urea (mg/100 ml)	32.2	0.2 - 64.2
Inorganic phosphate (mg/100 ml)	9.6	0.9 - 18.3
Ca (mg/100 ml)	10.5	3.8 - 17.2
Mg (mg/100 ml)	2.9	1.1 - 4.7
Na (meq/liter)	141.4	50.1 - 232.6
K (meq/liter)	8.8	2.1 - 15.4
Total protein (g/100 ml)	7.3	4.0 - 10.5
Albumin (g/100 ml)	2.6	1.5 - 3.7
Globulin (g/100 ml)	4.7	1.4 - 7.9
Hemoglobin (g/100 ml)	14.0	8.4 - 19.5
Weight (kg)	361.0	180.0 - 542.0
Weight gain (kg)	- 13.5	-141.0 - 114.0

Mean values of blood parameters, weight and weight gains for 282 Zebu breeding cows in the Llanos were established (Table 55). Although the Herd Systems Experiment was location specific, these parameters could serve as a base for future work to be undertaken.

Economics

The Economics section is responsible for both micro-economic analyses of the experimental results and macro analyses of the beef industry in tropical America. Results presented this year concentrate on: (1) simulation of alternative beef production systems in the Colombian Llanos, and, (2) the economics of foot and mouth disease control.

ALTERNATIVE BEEF PRODUCTION SYSTEMS IN THE LLANOS

Cow-Calf Operations

Using preliminary results obtained in the Herd Systems experiment, farm level adoption of alternative cow- calf production systems was evaluated through simulation using the computerized, activity-budgeting model (HATSIM*) developed at CIAT. The experimental treatments considered as alternative systems were:

Systems 1 and 2: Traditional systems with all animals grazing native savanna and *ad libitum* salt supplementation with an average intake of 12 kg/year/A.U. of salt (as in Herds 2 and 3 of the experiment described in Table 35).

Systems 3 and 4: Same as above but *ad libitum* supplementation with a full mineral mixture with an average intake of 16 kg/year/A.U. (as in Herds 4 and 5).

Systems 5 and 6: Same as above but weaning all calves at 86 days of age. During one month, early weaned calves are fed 0.75 kg/day of a caloric-proteic supplement (20% protein) and *ad libitum* fresh chopped *Axonopus scoparius* (Imperial grass). During another two months they are fed 0.5 kg/day of the same supplement, grazing in rotation *Paspalum plicatulum* (pasto negro) and a mixture of *Melinis minutiflora* (molasses grass) and *Hyparrhenia rufa*. After six months of age, calves graze native savanna and receive only mineral supplementation. Given the location and conditions of the pastures used in the early weaning treatments of the experiment, and in order to extrapolate treatment results to farm level, it was assumed that such pastures need to be irrigated during the dry season. Hence, the cost of small-scale irrigation equipment and associated operating and labor costs are charged to this treatment.

Systems 7 and 8: Cows, bulls and unweaned calves grazing *M. minutiflora* during the rainy season and native savanna during the dry season; all animals are supplemented *ad libitum* with a mineral mixture with average intake of 22 kg/year/A.U. (as in Herds 6 and 7).

Systems 9 and 10: Same as above but weaning at 86 days, with the same early weaning treatment as Systems 5 and 6.

System 11: Same as System 7, but grazing *Brachiaria decumbens* during the rainy season with a stocking rate of 1.7 A.U./ha., and savanna during the dry season. Reproductive as well as productive performance is assumed to be the same as in System 7.

Odd-numbered systems represent experimental results (four-year averages) directly extrapolated to farm level, with the exception of Systems 1 and 11. In System 1, calf-mortality was assumed to be 15 percent rather than the experimental result of 26 percent, since this value appears to overestimate actual farm losses. In fact, even a 15 percent calf mortality implies a decreasing herd over time. In even-numbered systems, calving rates and calf mortality are hypothetical values considered valid for the farm level, based on survey experience in the Colombian Llanos and preliminary estimates of the experimental variance obtained for the corresponding treatment in the Herd Systems experiment.

The main biological parameters used to simulate herd development in each system are shown in Table 57. Based on these parameters, the same initial herd was developed over a 25-year period and the net income flow was used to calculate the internal rate of return of each system using the discounted-cash-flow method. All prices corresponded to average farm prices of 1976, which were assumed constant over time and expressed in real terms. Since prices of inputs as well as output (cattle) vary according to distance to market, the economic evaluation was carried out for two areas: (A) from Puerto Lopez to Puerto Gaitan, and (B) from Puerto Gaitan to Carimagua. Prices of both inputs and cattle were corrected for transportation costs.

Table 57. **Parameters used in herd development of alternative production systems.**[1]

	Treatments			Parameters					
					Mortality rate (%)		Heifer mating rate (%)[3]		
System	Pasture	Minerals	Weaning	Calving rate (%)	Calves[2]	Adults	1-2 years	2-3 years	3-4 years
1	native	salt	normal	46	15	5	0	60	100
2	native	salt	normal	50	8	5	0	60	100
3	native	full mixture	normal	65	12	5	0	90	100
4	native	full mixture	normal	61	8	5	0	90	100
5	native	full mixture	early	87	13	4	0	80	100
6	native	full mixture	early	77	8	4	0	80	100
7	molasses+native	full mixture	normal	64	10	5	10	90	100
8	molasses+native	full mixture	normal	60	7	5	10	90	100
9	molasses+native	full mixture	early	85	8	4	0	90	100
10	molasses+native	full mixture	early	77	7	4	0	90	100
11	*Brachiaria decumbens* + native	full mixture	normal	64	10	5	10	90	100

[1] Other parameters such as: proportion of bulls to cows (1:20), culling rates of cows (15%) and bulls (20%) and proportion of males: females at birth (50:50) are assumed equal for all systems.
[2] Up to one year of age.
[3] Weight ≥ 270 kgs.

Table 58 summarizes the performance of all systems for commercial ranches of 2500-3000 hectares. Results are described below, using the return on capital as a criterior.

Minerals. Systems 3 and 4, grazing native savanna with mineral supplementation, are the most profitable of the alternatives considered. They are followed by Systems 5 and 6 (which include early weaning), and by System 2 (native system supplementing only with salt). One of the reasons why *ad libitum* mineral supplementation is not a widespread practice in the Colombian Llanos may be the reduced net income occurring during the first few years after implementation until the additional calf crop obtained is sold.

Early weaning. This practice is not profitable at present cost and under current management (Systems 3 and 4 versus 5 and 6). It becomes an economic alternative, compared to normal weaning, only in intensive pasture systems for breeding cows (Systems 7 and 8 versus 9 and 10), by increasing breeding performance, and thus reducing pasture invest-

Table 58. Simulation performance of alternative production systems in the Colombian Llanos.

	Area of improved pasture (ha)		Breeding herd size (cows)		Initial investment[1] ($ US'000)		Annual net income[1] ($ US'000)		Rate of return (%)	
System	initial	total	initial	final	pasture	total[2]	year 4	year 13	region A	region B
1	-	-	190	127	-	90	6.4	5.2	5.5	3.6
2	-	-	190	182	-	90	7.5	7.3	8.1	6.3
3	-	-	190	230	-	91	6.3	10.7	10.0	9.0
4	-	-	190	230	-	91	5.9	10.2	9.8	8.9
5	12	12	190	190	4	97	5.0	10.8	9.1	7.5
6	12	12	190	190	4	97	5.6	7.6	8.4	7.4
7	450	650	190	325	56 (81)[3]	147 (172)[3]	6.7	9.6	5.0	3.7
8	450	650	190	325	56 (81)	147 (172)	6.7	9.0	4.6	3.3
9	450	516	190	250	61 (67)	154 (160)	4.2	18.2	6.3	4.8
10	450	516	190	250	61 (67)	154 (160)	4.7	16.0	5.2	4.6
11	100	190	190	325	13 (24)	103 (114)	6.7	9.6	8.5	n.a

1 Values corresponding to region A.
2 Includes value of cattle and improvements, excludes value of land.
3 Figures in parenthesis are investment values including the total area of improved pastures.

ment per unit of output (sales of steers). In addition to management problems, early weaning implies a substantial reduction in net income during the first few years after implementation.

The relatively poor performance of early weaned calves, (especially those weaned during the dry season), the high cost of caloric-proteic supplement and labor, and the establishment and maintenance costs of improved pasture contribute to this result, overshadowing the economic benefits from a larger calf * crop. Nevertheless, if seasonal mating can improve calf performance and, at the same time, reduce calf feeding costs by reducing the need to maintain good quality pasture during the dry season, it might become an economic alternative for the Colombian Llanos, particularly in the case of widespread adoption of improved pastures for breeding herds.

Pastures. Systems based on grazing molasses grass during the wet season (7 and 8) were found to be only half as profitable as systems based on native savanna (3 and 4), both using mineral supplementation. Total investment nearly doubled in the former systems because of the low stocking rate of this pasture (0.5 A.U./ha). With a higher stocking rate (1.7 A.U./ha) as in System 11 (a simulated case with *B. decumbens*, assuming the same reproductive and productive performance as for molasses grass), the return on capital increases markedly.

Pasture persistence and establishment failures. Table 59 illustrates the effect of pasture duration on the returns to capital. In systems using a limited area of improved pasture for early weaning (such as System 5), low persistence has a negligible effect. However, when the area planted is sizeable, returns on capital are quite sensitive to pasture duration (Systems 7 and 9).

Table 60 shows the result of a sensitivity analysis on pasture persistence and establishment losses. Two cases are considered: System 7 and 7', the latter assuming a 50 percent reduction in establishment costs of this particular pasture (molasses grass). It may be observed that reducing establishment costs without affecting carrying capacity not only increases returns to investment but also implies that these returns are less sensitive to establishment failures and to persistence risk. This is one of the reasons why a minimum input philosophy, and practices such as minimum tillage represent promising alternatives when the improved pasture is grazed by the entire breeding herd. They may not be as relevant when dealing with small areas for strategic use only.

Table 59. **Percentage rates of return of Systems 5, 7 and 9; sensitivity analysis with respect to pasture persistence.**

	Pasture persistence (years)			
System	24	12	9	6
5	9.1	9.0	8.9	8.8
7	5.0	2.8	1.3	
9	6.3	4.2	2.7	0.9

Negative value.

Financing. In Colombia, as in some other countries of Latin America, the nominal interest rate on loans is smaller than the inflation rate. This implies financing under subsidized conditions. Table 61 is included to illustrate the effect of this type of incentive on the return to the cattleman's own capital. The following are assumed: an annual expected inflation rate of 30 percent and an 18 percent nominal interest rate and four years of grace on a 12-year loan. These conditions are found in the Colombian Llanos, although they may not prevail over the long-run. As the proportion of initial investment financed under these conditions increases, so does the profitability of all systems. But, even

Table 60. **Percentage rates of return of System 7: sensitivity analysis with respect to pasture persistence and establishment failure.**

Pasture establishment failures[1] (% of area)	Pasture persistence (years)					
	24		12		9	
	7[2]	7'[2]	7	7'	7	7'
0	5.0	7.1	2.8	5.9	1.3	5.0
20	4.4	6.7	2.4	5.5	0.9	4.6
40	4.0	6.3	2.0	5.2	0.6	4.3
60	3.5	6.0	1.7	4.9	0.3	4.0
80	3.2	5.7	1.3	4.6	0.0	3.8

1 First year failures in pasture establishment.
2 7: Actual cost; 7': Assuming 50 percent reduction in establishment costs.

under 60 percent financing, System 7 (including molasses grass) is not as profitable as Systems 2 and 3 (native pasture plus salt and minerals, respectively) with zero financing. However, such is not the case with System 11 based on *B. decumbens*. Beyond 30-40 percent financing under such subsidized conditions, it becomes more profitable than Systems 2 and 3. This may explain why many producers in the Llanos are adopting this particular grass species.

Land values. When analyzing the profitability of alternative production systems which are relatively equal in intensity of land use, the value of land is not included in the amount of initial investment. The relevant question is: Which of the production systems is more profitable, given that the producer has already invested in land?

However, when comparing the returns on capital of a given technology in two

Table 61. **Percentage rates of return on producer's own capital from alternative systems receiving credit under subsidized conditions.[1]**

System	Percent financing of initial investment				
	0	20	40	60	80
2	8.1	(n.a.)	(n.a.)	(n.a.)	(n.a.)
3	10.0	10.8	(12.8)	(15.1	(18.8)
7	5.0	5.6	6.3	7.2	(8.8)
7'[2]	7.1	7.9	8.9	10.2	(12.0)
11	8.5	9.6	11.0	13.1	(16.8)

1 Figures in parenthesis are improbable cases included only for illustration.
2 7': Assuming 50 percent reduction in establishment costs.

ecologically homogeneous regions facing different input-output prices (because of distance to markets) the value of land has to be incorporated in the analysis to explain profitability differences between the regions. If the same technology is adopted in both areas, land prices are expected to compensate for the difference in profitability due to different input-output prices. The regions further from the market, and hence with the least favorable prices, will have a lower return on capital when the value of land is not included in the amount of initial investment. This explains the difference in returns between Region A and Region B, as shown in Table 58. Comparing normal weaning systems (3 and 7) against early weaning systems (5 and 9) it may be observed that the regional differences in return are larger in the case of systems incorporating early weaning. This indicates the obvious—technology using more inputs has a lower probability of adoption in regions further away from the market than in regions closer to the market. In order to obtain widespread adoption, not only it is preferable that the given technology minimize input use in terms of value, but also in terms of volume.

Table 62 illustrates the effect of a land-saving technology on the total return to producer's own capital (including land value). It was assumed that the real price of land increased at an annual rate of 2 percent. The area below the line represents situations in which System 11 (*B. decumbens* plus minerals) is preferable to System 3 (native pasture plus minerals) using total returns on capital as the criterion. This partly explains why land saving technology (pastures with high carrying capacity), even under similar ecological conditions, are adopted first in areas closer to the market which have higher land values.

Fattening Systems

Based on four years experimental results reported in the Pasture Utilization section, a 1000-hectare fattening farm in Region A of the Colombian Llanos was simulated. As in the previous cases, the economic analysis was carried out over a 25-year period. Prices of 1976 were used and were assumed constant over time and expressed in real terms. The net income flow was used to calculate the internal rate of return using the discounted-cash-flow method.

Three fattening systems were evaluated: (A) grazing molasses grass during 270 days with a stocking rate of 0.44 A.U./ha; (B) same as above but with a stocking rate of 0.88 A.U./ha; and, (C) grazing *B.*

Table 62. **Percentage rates of return[1] of System 11: sensitivity analysis with respect to land values and percent financing of initial investment[2] under subsidy conditions.**

Land value:		Percent financing of initial investment				
Col.$/ha	US$/ha	0	20	40	60	80
0	0	8.5	9.6	11.0	13.1	16.8
500	14	6.5	7.0	7.0	8.5	9.5
1000	28	5.4	5.8	6.2	6.7	7.2
1500	42	4.8	5.1	5.3	5.7	6.0
2000	56	4.3	4.6	4.8	5.0	5.2

1 Rates of return on producer's own capital and on total investment including value of land

2 Financing of initial investment excluding land.

Table 63. **Rates of return from finishing cattle on improved pastures.**

System	Pasture	Stocking rate (A.U./ha)	Production per-head (kg/270 days)	Production per-ha (kg/270 days)	Rate of return (%)
A	*M. minutiflora*	0.44	114	50	7.2
B	*M. minutiflora*	0.88	76	67	4.8
C	*B. decumbens*	1.30	103	134	12.1
D	*B. decumbens*	1.70	80	136	8.0

decumbens during a similar period, fertilized with 200 kilograms of basic slag every two years, at a stocking rate of 1.3 A.U./ha. Results for the three systems are reported in Table 63. Using return on capital (excluding value of land) as the criterion, although System B yields more output per hectare, it is less profitable than System A which has a lower stocking rate. Only in areas with high land values would System B become more profitable than A.

System C is significantly more profitable than the other two systems. This result tends to support the ones obtained in the simulation of System II with the breeding herd grazing *Brachiaria*.

Table 64 is included to illustrate the type of economic results that could be expected from different pastures needing different levels of inputs with different frequencies.

Each value in the table represents a different pasture needing application of a given amount of fertilizer (worth the amount indicated in the respective column), with a given frequency (as indicated in the row), in order to yield the same output per hectare with the same stocking rate as in System C (Table 63). In the Carimagua region and at 1976 prices, the amounts indicated in Table 64 would buy the volumes of nitrogen P_2O_5 indicated below:

Kgs of	in form of:	US$28	US$42	US$59
N	urea	50	75	100
P_2O_5	basic slag	67	101	135
P_2O_5	TSP	39	58	78

Other things being equal, pastures needing frequent fertilization (even low levels) are markedly less profitable than those needing only low establishment rates. Pastures needing the same fertilization with higher frequency are also substantially less profitable. In order to compensate for such differences in returns, animal response to fertilization of the pasture needs to be rather high. Thus, it seems logical that, in the case of the Carimagua region, pastures needing frequent fertilization could become economic alternatives perhaps only in cases of strategic grazing by those animals with high response capacity.

Alternatively, for systems grazing the bulk of the herd on improved pasture

Table 64. **Percentage rates of return on investment[1] of simulated fattening systems having identical carrying capacity and animal performance, applying inputs at different frequencies.**

Input application every:	Value of inputs (US$/ha) 0	28	42	56
year	12.1	4.6	1.0	[2]
2 years	12.1	8.5	6.7	5.0
3 years	12.1	10.2	8.7	7.6
4 years	12.1	10.4	9.7	8.9

[1] Excluding land value

[2] Negative return.

(fattening farms or grazing the entire breeding herd), the above results clearly indicate the appropriateness of selecting species and varieties based on minimum input and maximum carrying capacity criteria, reinforcing the need for seeking legume-based pastures.

ECONOMICS OF FOOT-AND-MOUTH DISEASE

During 1977, the foot-and-mouth disease (FMD) control study in endemic areas was completed with the sensitivity analysis of vaccination and the study of the eradication strategy.

Sensitivity analyses on both the private and social optimum vaccination strategies were done with respect to the main parameters in the model: results are shown in Table 65. The first 12 cases correspond to changes in one variable at a time. It may be observed that the private optimum level fluctuates between 60 and 80 percent of vaccination coverage, and the social optimum varies between 70 and 90 percent. The gap between private and social optimum is present in all cases, and increases with a lower vaccine effectiveness as shown in Table 65.

In Case 13, 20 percent lower attack rates and outbreak probabilities together with a lower vaccine effectiveness were considered. Results indicate that even in the case of a possible overestimation of these parameters, the private and social op-

Table 65. **Summary of results from sensitivity analysis of vaccination strategies for foot-and-mouth disease in an endemic area.**

Case No.	Variables changed	Change assumed	Optimum strategy: Private	Optimum strategy: Social
1	Outbreak probabilities	20% lower	60	80
2	Same as 1	20% higher	80	90
3	Mortality rates	20% higher	70	90
4	Same as 3	20% lower	70	90
5	Attack rates	20% lower	60	80
6	Same as 5	20% higher	80	90
7	Vaccine effectiveness	From 85% down to 60%	60	90
8	Weight losses from FMD	20% higher	70	90
9	Same as 8	20% lower	70	80
10	Milk loss from FMD	20% higher	70	90
11	Same as 10	20% lower	70	90
12	Vaccination costs	100% higher	60	70
13	Combination of runs No. 1, 5, 7		60	70
14	Same as 13 plus vacination costs	20% higher	50	80
15	Same as 13 plus vaccination costs	50% higher	0	70

timum levels of vaccination would be only 10 percent lower, indicating stability of results. On the other hand, if, in addition, vaccination costs were underestimated, the private optimum solution changes drastically (Cases 14 and 15).

The eradication strategy was defined as a sequence of massive vaccinations for a period of four years, followed by two years of vaccination combined with slaughter. Also, to ensure the continued disease-free status of the region, a permanent epidemiological surveillance was considered as an essential component of this strategy.

The rationale for this sequence is that after four years of vaccination, the full effect of this activity would be realized; after that, all animals becoming sick plus those in contact with them are slaughtered, while preventive vaccination continues. It is expected that after two years of slaughtering sick animals, outbreaks will terminate as will the vaccination and slaughter activities. However, efficient epidemiological vigilance continues indefinitely so that further widespread episodes of the disease are avoided.

The benefits from eradication are twofold: (1) the economic losses from the disease are eliminated; and, (2) additional foreign-exchange earnings are gained due to the price differential favoring exporting areas (countries) "without FMD", if access is gained to markets in disease-free countries. A 30-percent increase in beef export prices was estimated for Colombia, based on the long-run FOB price paid by the United States to Costa Rica, which exports a similar quality of beef. This second benefit is another type of externality, that can only be captured by a farm (or exporter) if all farms carry out the eradication strategy simultaneously. Therefore, two different cases were considered: one with and the other without access to the market in FMD-free countries. Alternative vaccination coverages of 60, 70, 80 and 90 percent were considered as part of an eradication program. As shown in Table 66 the optimum vaccination level for an eradication program is 90 percent.

Net benefits from shifting to eradication were compared with those resulting from continuing to vaccinate at 90 percent coverage indefinitely (which was reported in the 1976 Annual Report to constitute the social optimum vaccination strategy). Inspection of Table 67 indicates that, if the area is accorded a disease-free status by importing nations, FMD eradication is preferable. When there is no guarantee of access to the disease-free market once the slaughter cycle has terminated and eradication achieved, at the current opportunity cost of capital of 10 percent, the social optimum control strategy is still 90 percent vaccination coverage in the region. This result would hold even more for higher opportunity costs of capital. In this latter case, only in a situation with capital abundance and opportunity costs of less than 5 percent, would eradication be the optimum strategy.

A collaborative project with ICA was carried out during 1977, to obtain direct

Table 66. **Social net present benefits from shifting to eradication versus continuing with vaccination, in relation to level of initial vaccination[1] (in millions of Col.$, 1975 prices).**

	Level of vaccination (% coverage)			
Strategy	60	70	80	90
Continuous vaccination	2,545	3,063	3,124	3,126
Eradication[2]	-11,425	582	3,857	6,368

[1] Net benefits are discounted up to year 5, when the alternative of shifting to eradication arises, with a 10 percent discount rate.

[2] This is Case A, of "access to the market "without FMD". Values indicate net present value of benefits from year 5 onwards, if the first phase consists of the vaccination coverage shown above in corresponding column.

Table 67. **Net present value of the social benefits expected from shifting to eradication versus continuing with vaccination[1] (in millions of Col.$, 1975 prices).**

	Social discount rate (%)		
Control strategy	**5**	**10**	**15**
Vaccination (90% coverage)	6,252	3,126	2,084
Eradication			
Case A[2]	16,206	6,368	3,289
Case B[3]	6,316	2,241	966

1 Net benefits are discounted up to year 5, when the alternative of shifting to eradicatin or continuing with vaccination arises.

2 This case assumes access to the FMD-free market. Results are based on conservative estimates, assuming a price-elasticity of supply equal to zero.

3 This case assumes no access to the FMD-free market.

field information from the Urabá region (North Coast of Colombia), in order to validate the simulation results described above. This collaborative project was partially financed by the Ford Foundation. A survey was done on all cattle farms experiencing FMD outbreaks during one year. The group consisted of 49 cattle farms, equivalent to 1.24 percent of all farms in the area, at a time when an average vaccination coverage of 90 percent was achieved in the region. Data were obtained for epidemiological parameters, physical losses and vaccination costs. Information from the survey plus that collected from the ICA-USDA program in charge of the campaign against FMD in the area, provided the following results.

(1) The annual outbreak probability at 90 percent vaccination coverage was considerably lower than expected. However, data obtained correspond only to reported outbreaks. It is suspected that at high vaccination levels, many outbreaks are so mild as to go undetected. This information was used to recalculate disease incidence for all levels of vaccination coverage.

(2) Attack rates observed were higher than those expected at high levels of vaccination, but this may be explained by the fact that 90 percent coverage had only been in effect in the area for one year. Thus, the corresponding parameters in the semi-Markov model were not altered in the new calculations.

(3) Weight losses of only 15 kg/animal for steers older than 2 years of age were reported by the farmers, as compared with average losses of 35 kg/animal observed in areas with low levels of vaccination. Therefore, new estimates have been obtained with physical losses expressed as a continuous decreasing function of regional vaccination coverage.

(4) Finally, although the private costs of vaccination per head were very similar to previous estimates, the public cost in the area turned out to be considerably higher. During the one year, the average annual public cost per head vaccinated was Col.$40.50, which gave a total unit cost per head of Col.$60, at 1976 prices.

Table 68 presents the costs and benefits from all vaccination intensities estimated for the Urabá region. In spite of the higher vaccination costs, and lower outbreak probabilities, the optimum vaccination coverage from the social standpoint is 80 percent, versus 90 percent projected previously. This is within the range of results predicted with the sensitivity analysis described above.

A comparison between the on-going vaccination strategy in Urabá and alternative control programs, including eradication, is being completed and will appear in a separate report.

The study on the economics of animal health, through the case of FMD in Northern Colombia, ended during the year. The methodology developed at CIAT was transferred to ICA, the national institution in charge of disease control.

Table 68. **Social annual costs and benefits from foot-and-mouth disease vaccination in the region of Urabá,[1] Colombia, (in millions of Col.$, 1976 prices)**

Regional vaccination coverage (%)	Economic losses	Gross benefits	Vaccination costs[2]	Net benefits
0	44.2	0	0	0
10	36.8	7.5	1.8	5.7
20	30.4	13.9	3.6	10.3
30	25.5	18.7	5.3	13.4
40	19.9	24.3	7.1	17.2
50	13.7	30.5	8.9	21.6
60	7.3	36.9	10.6	26.2
70	3.9	40.3	12.4	27.9
80	1.6	42.6	14.2	28.4
90	0.7	43.5	16.0	27.5
100	0.6	43.6	17.7	25.9

1 Estimates based on a stabilized regional herd of 295.8 thousand head.

2 Annual unit cost of Col.$60 per head vaccinated.

Training and Regional Trials

In mid-1977 a senior scientist arrived to coordinate the Program's transfer of technology activities which include training, regional trials and seminars. Establishment of this section implemented the policy of integrating the development and the transfer of technology within the Beef Program. As with other new sections, a considerable part of available time was spent in developing a strategy.

STRATEGY

The objectives of the section are: (1) To develop and strengthen a network of scientists working on research and production of forages to validate, adopt, and transfer new technology developed by the Beef Program and other institutions to the impact area. (2) To establish cooperative links with national institutions for all the activities of the Program, especially on regional trials. In this fashion the principal functions of training and regional trials form a continuum. Training activities will be followed up by regional trials in cooperation with the CIAT staff to assure continuity and guarantee the feed-back of information to the research program. Figure 65 illustrates the strategy

TRAINING

In 1977, 31 postgraduate interns received individual training in pastures and forages, animal management and animal health. Trainees were selected from national institutions in Latin America for advanced training to better prepare them for research responsibilities in their countries.

Six visiting research associates are conducting dissertation research projects in the various disciplines of the Beef Program, in collaboration with the univer-

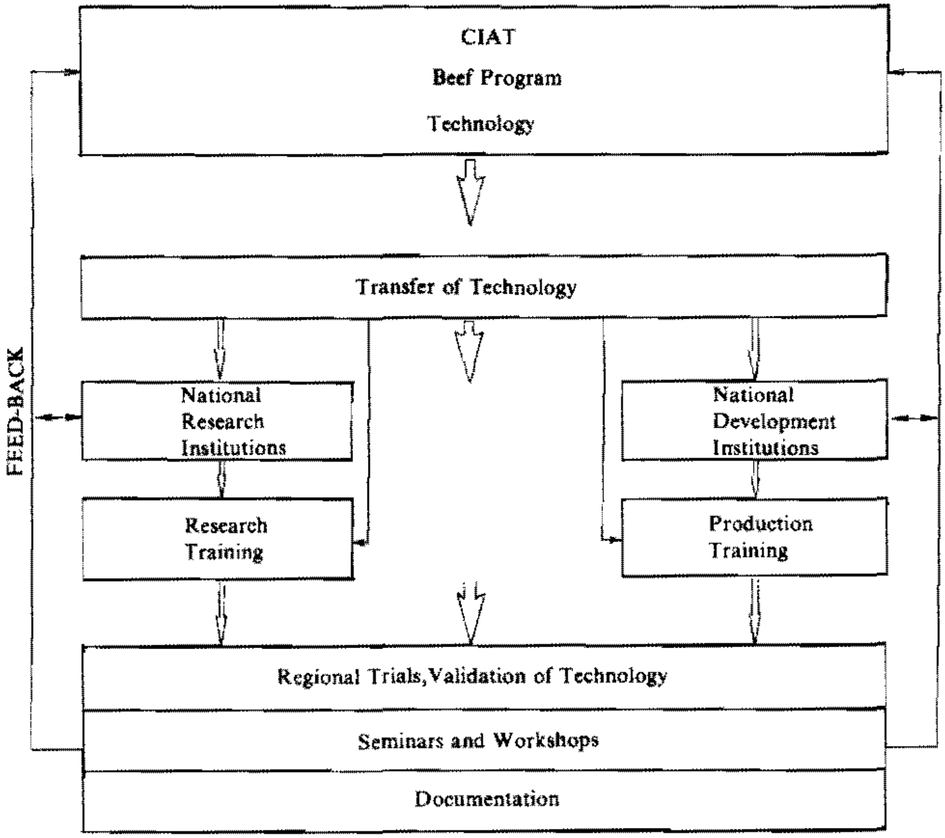


Figure 65. **Integration of research, transfer of technology and training in the Beef Production Program.**

sities where they have completed their academic requirements.

The Fifth Livestock Production Specialist Training Program began January 1977 for a group of 18 participants, 13 from Guatemala, 2 from Bolivia and 1 each from Colombia, Honduras and Panama. The trainees spent three months at CIAT (theory phase) after which 16 went to Guatemala for a ranch phase of an additional seven months under the supervision of two training assistants from CIAT. The Programa de Desarrollo Ganadero (PRODEGA) supported the training program in Guatemala.

The main emphasis in the ranch phase was on establishing and managing improved pastures, since the most critical problems associated with the development of the local cattle industry were related to lack of adequate nutrition during the dry seáson because of lack of forage, lack of persistence of improved pastures under grazing, and weed competition during establishment. Alternatives considered were the establishment of grass species that could compete fairly well with weeds, improved grazing management, weed control, and the use of sugar cane and green-chopped grasses for fodder supplementation during the dry season.

REGIONAL TRIALS

Eight priority countries —Brazil, Colombia, Venezuela, Perú, Panamá, Bolivia, Nicaragua and Ecuador— were identified within the impact area of the Program, with the possibilities of including Honduras, Paraguay, Trinidad, the Guyanas and other sections of the Caribbean region. Selection was based on the relative extent of their territory covered with acid infertile soils (Oxisols and Ultisols) and the relative importance of the beef cattle industry in relation to national agricultural development projects.

The first eight countries were visited during the year with four objectives. (1) To become acquainted with forage production conditions in relation to the development of the cattle industry. (2) To establish contacts for future collaboration with national institutions working on research and development of the beef cattle industry, especially for regional trials to evaluate the adaptation and productivity of forage germplasm developed by the Program. (3) To evaluate the training needs of national institutions and possibilities of participating in training at CIAT.

The first regional trials in cooperation with national institutions have been designed to evaluate the adaptation and productivity of promising germplasm.

Table 69. **Southern hemisphere sites selected for CIAT Beef Program regional trials of forages.**

Country	Institution	Sites
Brazil	1 Centro de Pesquisa Agropecuária dos Cerrados (CPAC)	Brasilia, D.F.
	2 EMGOPA	Goiania, Go.
	3 Centro Nacional de Pesquisa de Gado de Corte (CNPGC)	Campo Grande, M.T.
	4 Centro de Pesquisa Agropecuária do Trópico Umido (CPATU)	Belem, Pa.
	5 CPATU-UEPAE	Manaus, Am.
Perú	6 Centro Regional de Investigación III Ministerio de Alimentación/Proyecto Cooperholta	Tarapoto
	7 Universidad Estatal Carolina del Norte/Ministerio de Alimentación	Yurimaguas
Bolivia	8 Centro de Investigaciones de Agricultura Tropical/Misión Británica	San Ignacio
Ecuador	9 Instituto Nacional de Investigaciones Agropecuarias (INIAP)	Santo Domingo
	10 Instituto Nacional de Investigaciones Agropecuarias (INIAP)	Coca

Table 69 lists sites where these trials will begin during the present southern hemisphere rainy season.

Plans are being developed to include sites in other countries of the impact area beginning with the next northern hemisphere rainy season, in May 1978.

CONFERENCES

A Workshop on "Collection, Preservation and Evaluation of Tropical Legume Germplasm Resources" was organized in collaboration with the University of Florida (USA) and sponsored by the United States Agency for International Development, (USAID), be held at CIAT in April 1978. The objectives are: (1) To develop procedures for collecting, preserving and evaluating tropical legumes which may have agriculture potential. (2) To prepare a manual which would provide guidelines for a coordinated system of collection, classification, preservation, distribution, and evaluation of legume germplasm.

A Seminar on "Forage Production and Utilization on Acid Infertile Soils of the Tropics" was also organized by CIAT to follow the workshop above. Seminar objectives are: (1) To review the state of knowledge on production, management and utilization of forages under acid infertile soil conditions (Oxisols and Ultisols) in the Latin American tropics and related areas of the world. (2) To discuss the possibilities of exchanging information and technology between CIAT and national institutions and to establish the mechanisms to transfer this technology to beef cattle producers.

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Bean program

1977/CIAT

Bean Program

With the arrival of the second breeder for the Bean Program, the importance of varietal development activities by the team greatly increased. Large numbers of new crosses were inititated and the first CIAT hybrids entered the international yield testing program this year. At this level, they will compete with germplasm accessions and entries from various national programs.

The results of the first International Bean Yield and Adaptation Nursery (IBYAN) showed a 35 percent yield difference between the five best entries furnished by CIAT and the five best local materials, in favor of the former group.

The yield differences observed in the first IBYAN were equal in the tropical as well as in the temperate zones. These nurseries showed that wide adaptation to environments exists within *Phaseolus vulgaris*. This testing regime greatly increased the intensity of the Program's Latin American network. The 1977 IBYAN was composed of two different sets, according to seed coat color preference — that is, a black-seeded nursery and a non-black nursery, each containing 25 entries.

In physiological experiments, it appeared that large vegetative structures leads to increased yields if lodging resistance can be found. Lodging resistance is also thought of as an important mechanism for disease avoidance.

Also in 1977, the second pathologist arrived and greater attention was given to moving segregating populations through a set of pest resistance nurseries as well as screening them for wide adaptation. The close collaboration with national program virologists in El Salvador, Guatemala, the Dominican Republic and Brazil identified sources of germplasm resistance to bean golden mosaic virus. The first multiple-country testing of hybrids between golden mosaic-tolerant parents resulting from respective breeding programs showed transgressive segregation and gave promise of future reduction of this increasingly important virus disease in Central America and Brazil.

Sources resistant to bacterial blight in tests in the United States were rated susceptible in tests at CIAT due to lack of adaptation. Adapted, moderately tolerant germplasm was located.

Vegetable oils, at a dosage of only 5 millimeters per kilogram of bean seed, appeared to effectively control insect pests of stored beans. This method is safe, cheap and easily adapted to household use.

Training again formed an important part of the Bean Program activities. The second intensive course for bean research scientists was held; 30 Latin American professionals participated. The program was also active in training individuals at the postgraduate intern levels and several MS and PhD thesis research requirements were fulfilled with projects done in the Program. A total of 71 professionals were trained in 1977.

Breeding

Major nurseries were planted at CIAT during the 1977 rainy seasons and a seed increase *Empoasca* resistance nursery was planted in the intervening dry season. Nurseries were planted in collaboration with other program disciplines and the Instituto Colombiano Agropecuario (ICA) in four locations outside CIAT.

Selected families were evaluated in replicated yield trials and multilocation observation nurseries were planted to select progenies for international testing in 1978. With the addition of a second breeder to the program in mid-1977, increased emphasis was given to breeding for improved plant architecture, yield, and adaptation. Also, with improvements in screenhouse facilities the program reached a capacity of 1500 crosses/year.

MAINSTREAM BREEDING

Parental Selection and Hybridization

Parents which consistently gave a high frequency of good offspring, most of which were validated by Agronomy in yield tests, were emphasized in planning crosses. Priority was given to identifying better non-black parents for hybridization (Table 1). With mechanized field operations the chances were increased of getting a larger volume of hybrid progenies and a greater number of segregating plants per population and to obtain non-black segregants with multiple resistance factors. A large number of parents and progenies have been discarded (especially those susceptible to Problem X) based on more complete information provided by program disciplines to the information system (SIFRI).

Progeny Management—Early Generation Screening

The breeding program has modified the previous system of progeny management (CIAT Annual Report, 1976) such that program disciplines contribute to genetic improvement through the screening of selected bush bean progenies (Fig. 1).

Table 1. Frequencies of crosses within and among black and non-black parents[1] for the periods 1974-1976 and 1976-1977.

	Blacks	Black x Color	Colors
1974-Nov. 1976	1111 (36%)	1712 (56%)	259 (8%)
Nov. 1976-Nov. 1977	152 (22%)	216 (31%)	336 (48%)

[1] Does not include 402 intermatings of progenies.

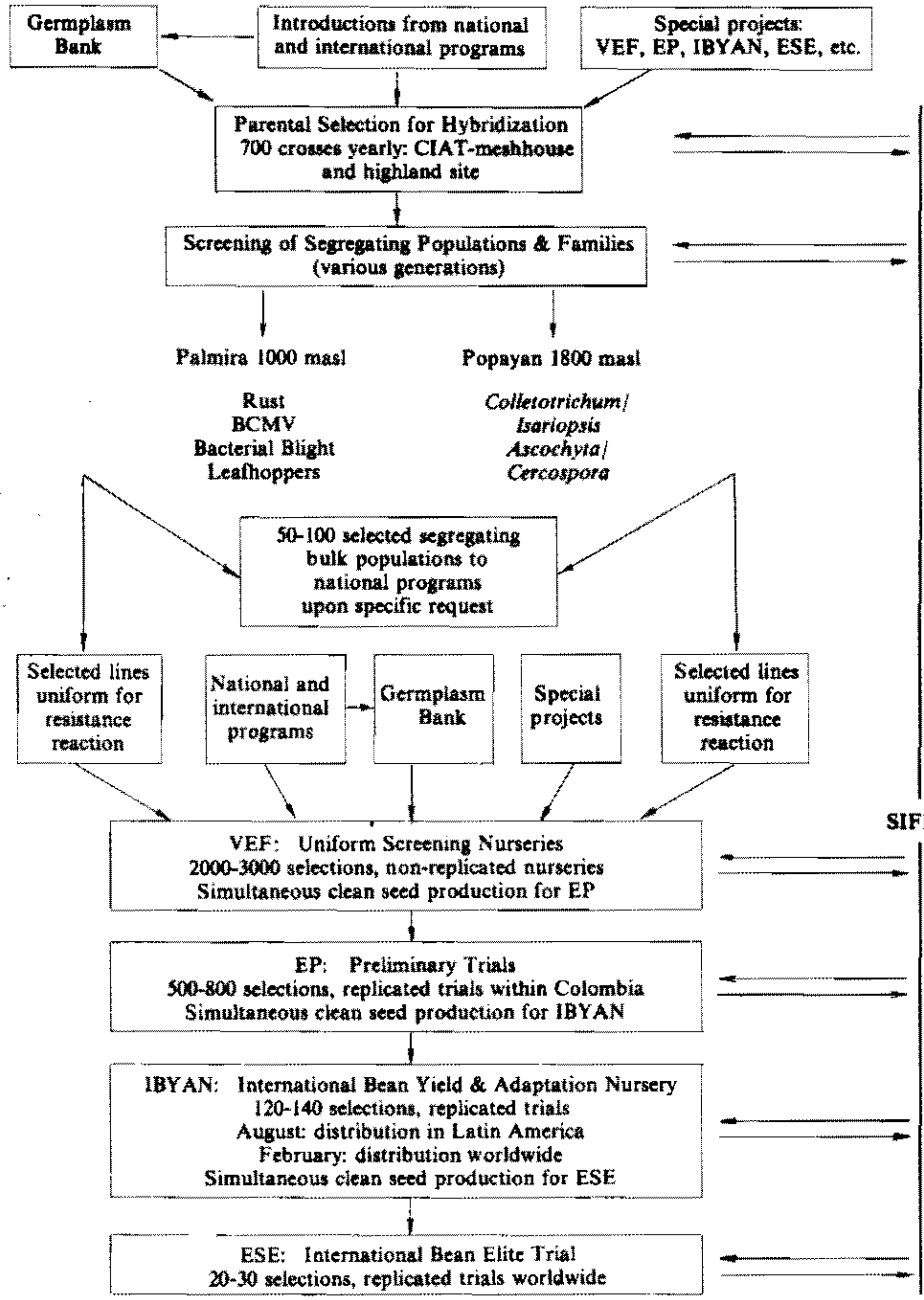


Figure 1. **Program for simultaneous and sequential development and evaluation of bean germplasm.**

Large plantings were inoculated with bean common mosaic virus (BCMV) rust and infested with *Empoasca* (see Fig. 3, Pathology). Also, angular leaf spot and bacterial blight tolerance were recently elevated to a high priority. Selections for multiple disease and insect resistance were made in a range of agronomic types and seed color combinations. Homogeneity is being sought for field tolerance to rust and anthracnose, rather than homozygosity for specific gene resistance. Progeny evaluations for anthracnose, angular leaf spot, and root rot resistance also began in the latter part of 1977.

A relatively remote combination of parents produced red-seeded progenies with reasonably erect, indeterminate growth habit combining resistance to BCMV and rust, which demonstrated the value of massive crossing. A number of populations and selections from crosses of promising bush type parents x climbing donors were given to the climbing bean section for evaluation.

Progeny Testing (Colombia)

Relatively homogeneous families selected at CIAT or Popayán from mainstream, disease-insect resistance and architectural-yield breeding, and from the national programs enter preliminary testing. This includes replicated yield trials by Agronomy, multilocation observation nurseries in contrasting environments; and screening by the program disciplines for all principal disease, insect and edaphic factors (Fig. 1). Summarized data from SIFRI is used to select entries that progress to international progeny testing, and to plan future crosses.

Yield trials of selections from earlier crosses in the program were conducted in each rainy season during 1977 but results were unreliable due to persistence over several semesters of the disturbance, Problem X.

International Progeny Testing

During 1977, breeding distributed to national programs a total of 646 F_2 and F_3 populations, and 526 early and advanced generation selections for evaluation. All selections and seed from F_2/F_3 populations originating from the breeding program are accompanied by information from the SIFRI regarding parents and their key characteristics.

SPECIAL BREEDING PROJECTS

Bacterial Blight Tolerance

Segregating populations and selected families were evaluated for bacterial blight tolerance to select parents for the first cycle of intermating. In greenhouse studies, narrow-sense heritability estimates of 0.68 and 0.27 were obtained from leaf clipping inoculation of progenies from crosses of P566 x P698, and P712 x P684, respectively. This suggested that selection for existing levels of tolerance in tropically-adapted progeny of tolerant x susceptible crosses will be easier than selection to increase existing tolerance levels.

Bean Golden Mosaic Virus Tolerance

Black-seeded progenies from crosses of parents identified by the 1976 IBGMV nursery performed very well in Central America. As a result, crosses were made among the best non-black entries in the 1977 IBGMV nursery and a recurrent selection and intermating effort was initiated with the collaboration of scientists in Guatemala, El Salvador, the Dominican Republic, and Brazil.

Bean Architecture, Yield and Adaptation Breeding (BAYAB)

CIAT bean breeding initially concentrated on the improvement of bean yield through breeding for resistance to the principal bean diseases and insects in Latin America. Selection for morpho-agronomic characters in the segregating populations was also practiced to maintain or improve current levels of yield potential.

With the arrival of a second breeder, improved bean plant architecture and lodging resistance, maximization of adaptation to climatic and edaphic factors and upgrading of yielding ability were further emphasized. In the F_2 (or equivalent) populations, emphasis was placed on selection for architectural characters. Grain yield and adaptation selection criteria will be imposed on the F_3 and F_4 generations. Presently, parents from germplasm collections, introductions, breeding nurseries, etc. are being sought.

The importance of other characteristics are also being determined. Root phyllotaxy of 36 selected parents of growth habits I, II, and III was studied to understand the variation of important characteristics within and between growth habits and to determine if any root characters are associated with resistance to lodging, drought, early vigor, and stability.

Ten seeds from each of 36 lines with three different growth habits were grown in seed germinators for seven days. Differences within and between growth habits were found only for total number of first order lateral roots and length of the primary root (Table 2). The value of these characters is being assessed.

Fourteen lines were selected for more extensive evaluation in sand culture. The factors considered were: number of first order laterals; length of the primary root; weight of roots and shoots; and shoot/root ratio. Five plants of each genotype were harvested at 10 and 24 days after planting. The greatest differences were in the number of first order laterals and total root and shoot weights of growth habit I lines as compared to those of growth habit II and III. The latter two showed similar patterns of growth.

BREEDING STUDIES

Earliness

A special project was conducted in which a series of crosses were made to generate early maturing material and to obtain heritability/inheritance estimates for earliness in three tropically-adapted F_4 populations. Eighteen superior, black-seeded F_4 lines were selected combining earliness with good yielding ability. Days to flowering and days to physiological maturity were both found to be highly heritable (Table 3). Crosses from 2 of the 3 donors demonstrated a single dominant gene for earliness, with no maternal effects

Table 2. Mean values for five root characteristics of seven day-old seedlings of bush bean lines grown in a seed germinator.

Growth Habit	No. of Entries Tested	Days to Radicle Emergence	Days to Appearance of First Order Laterals	No. of Positions of First Order Laterals	No. of First Order Laterals	Length of Primary Root (cm)
I	21	2	3	4	11.1	160.3
II	12	2	3	4	9.2	150.1
III	3	2	3	4	9.4	181.5
Mean		2	3	4	9.9	164.0

Table 3. **Inheritance and heritability of earliness in three tropically-adapted source populations[1].**

Cross	Pedigree	Days to		Hb[2]		Hn[3]	Fit to 3:1	Maternal
		Flower	Maturity	Flower	Maturity	Flow	Ratio[4]	Effects
18, 19	P569 x P721	30	60	.80	.87	.77	No	Yes
16, 17	P739 x P721	32	70	.73	.70	.72	Yes	No
20, 21	P780 x P721	30	55	.72	.80	.60	Yes	No

[1] Values represent means of reciprocal crosses.
[2] Broad-sense heritability, based on variances.
[3] Narrow-sense heritability, based on parent-offspring regressions.
[4] One major gene, earliness dominant to lateness.

(Fig. 2) while earliness in the third parent was controlled by two or more genes, with evidence of partial dominance for earliness and maternal effects. Data suggest that modifier genes were present in some crosses. The coefficient of genetic variation was high in all crosses, and days to first flower and days to physiological maturity were always highly correlated. Thus, selection for earliness could be practiced from the F_2 generation using a combined pedigree-bulk method. Transgressive segregation was observed for days to physiological maturity.

Evaluation of the Honeycomb Design

An experiment was designed to test the feasibility of using the screening honeycomb design in early generation yield testing. Forty-seven pure lines of beans were compared in two sets of four randomized complete blocks and in screening honeycomb designs with 1.15 and 0.70 meters between plant spacing. All varieties occurred randomly once within each of eight replications.

Results (Table 4) showed that there was

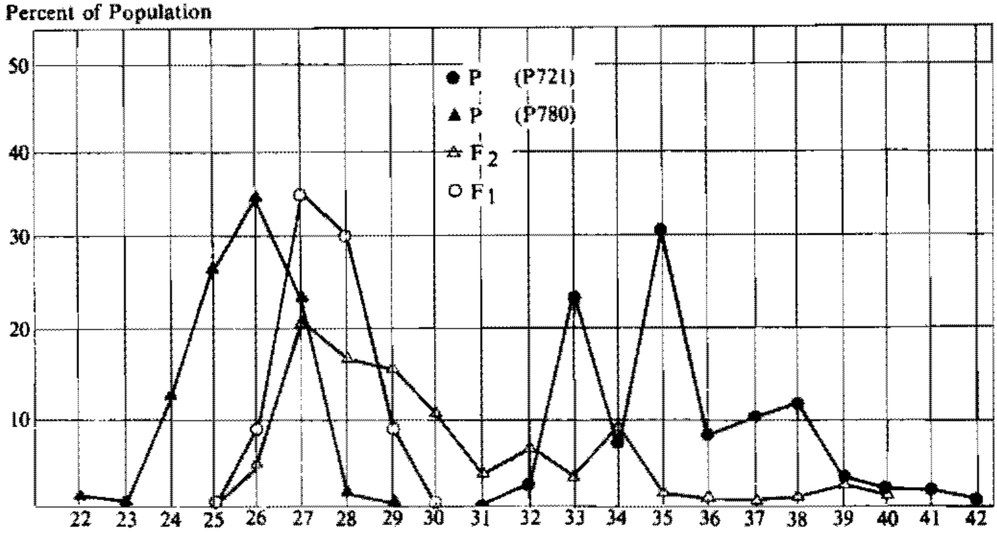


Figure 2. **Frequency distribution (percent) for parents, and F_1 and F_2 progenies from the cross P721 x P780.**

Table 4. Correlations between mean yields of 47 varieties (as a group and separated by growth habit) from randomized complete blocks and mean yields, modified and unmodified, from 8 replications of a simulated screening honeycomb design with 1.15 m. and 0.70 m. between plant spacing.

	Spacing	Unmodified Mean Yields from Honeycomb[1]	Mean Yields Corrected (Triangle)	Mean Yields Corrected[2] (Hexagon)
Yield[2] of 47 Varieties in RCB's	1.15	0.36*	0.36*	0.40*
	0.70	0.48**	0.43*	0.47**
Yield[2] of 23 Determinate Varieties in RCB's	1.15	0.48*	0.53*	0.51*
	0.70	0.49*	0.37	0.53**
Yield[2] of 24 Indeterminate Varieties in RCB's	1.15	0.29	0.24	0.36
	0.70	0.52**	0.49**	0.47*

1 Yields of individual spaced plants in the honeycomb modified either as a percent of the surrounding triangle of controls (see Fig. 1) or as a percent of the surrounding equidistant hexagon of 5 random varieties and 1 control.

2*, ** Significant at the 0.05 and 0.01 level, respectively.

no advantage in employing the honeycomb design (in which mean yield was expressed as a percent of the surrounding hexagon or control triangle) over the randomized complete block design.

Competitive Ability *vs.* Yield

Studies of competition were initiated to optimize the effectiveness of CIAT bean breeding methodologies. If the best yielders in pure stands were also the best yielders in mixtures, bulk breeding for yield could be used. If not, another method using spaced plants would have to be used.

Six determinate and six indeterminate varieties were evaluated for their competitive ability in separate tests. Between plant spacing was 6.7 cm and between row spacing was 0.6 m in a split plot design with all possible *ij* $(i \neq j)$ combinations as main plots, and two pure stands and three proportions of *i* and *j* as subplots. Table 5 shows mean values for yields in pure stands and in mixtures over two replications and three proportions.

Correlations between the yield of a variety in pure stands and its average yield over mixtures were 0.94** for the indeterminate and 0.83* for the determinate varieties, if the yield of the pure stand (the mixture of a variety with itself) were not included among the values used to calculate the means over mixtures. The yield rank order for mixtures and pure lines was identical for the indeterminate varieties (if P46 which was heavily infected with BCMV, were not considered). Although rank order was not the same for mixtures and pure stands among the determinate varieties, the top three and the lower three varieties were the same.

Table 5. **Matrices of yields in mixtures for the 6 determinate and the 6 indeterminate varieties, based on means over 2 replications and 3 (1:3, 1:1, and 3:1) proportions for the mixture plots and means over 10 individual plots for the pure lines[1].**

Determinate varieties

	Associates						
	P89	P560	P623	P635	P637	P788	Variety Mean
P89	562.1	265.7	461.8	546.2	342.8	632.7	468.5
P560	482.1[2]	623.4	515.5	862.0	625.3	955.7	677.3
P623	255.1	110.4	205.9	297.4	107.8	232.6	201.5
P635	730.7	501.7	542.0	628.0	421.2	577.0	566.8
P637	958.4	650.9	721.1	731.5	649.6	1000.7	785.4
P788	567.0	268.3	480.4	475.8	360.2	588.5	456.7
Mean of Associates	592.6	403.4	487.8	590.1	417.8	664.6	

Indeterminate Varieties

	Associates						
	P246	P498	P524	P566	P643	P698	Variety Mean
P246	201.6	225.8	149.9	160.6	194.9	147.0	180.0
P498	198.4	442.2	279.8	382.3	243.3	515.8	343.6
P524	599.3	683.0	613.1	597.0	619.3	1099.2	701.8
P566	780.9	722.2	619.5	665.5	681.0	1018.5*	747.9
P643	493.4	476.3	508.5	545.9	470.0	885.6	563.3
P698	175.6	138.5	58.4	76.2	128.1	306.2	147.2
Mean of Associates	408.2	448.0	371.5	404.6	389.4	662.1	

1 All values adjusted to a grams/80 plant basis; means for pure lines based on 800 plants, means for mixtures based on 720 plants.

2 This value (482.1) is the average yield of P560 when grown in mixtures with P89.

Correlations between yields in mixtures and the average yields of associates grown with each competitor were -0.675 (n.s.) for the indeterminate varieties and -0.420 (n.s.) for the determinate varieties. However, when P246 was removed from the analysis of the indeterminates, as well as the aberrant variety (which produced normal growth but almost no seed due to Problem X) analysis of the determinate varieties, correlations between yields in mixtures and yields of associates became -0.884* and -0.973** for the indeterminate and determinate types, respectively.

This experiment strongly suggests that the best yielding bush beans in pure stands are the best competitors in mixed stands at high densities. These results suggest that bulk breeding may prove to be the most effective methodology for yield improvement. Results are being retested in segregating hybrid populations from crosses between parents with contrasting plant architectures.

Pathology

VIRAL DISEASES

Bean Common Mosaic Virus (BCMV)

Strain Evaluation. Several isolates of BCMV, obtained from infected seeds of several varieties in the CIAT germplasm bank originating in Latin American countries and the United States, were increased in the susceptible variety, Bountiful. Fifteen to 21 days after inoculation, the virus from Bountiful was inoculated onto a set of differential varieties developed by Drijfhout in Holland and Silbernagel in the United States.

The most common strain found was BCMV-1 (NL-1, Westlandia or type strain) (60%) followed by: BCMV-3 (NL-6, Florida, Western, Idaho, B, or Colana); BCMV-4 (NL-8); BCMV-2 (NL-7); and BCMV-5 (NL-2, New York 15 or Imuna). Strains BCMV-6 and 7 were not registered.

Epiphytotic of BCMV. An epiphytotic of black-root (systemic necrosis) occurred in June, July, and August at CIAT during which abnormal drought conditions raised temperatures above the average 24°C. This coincided with a high population of aphids, the natural vectors of BCMV During this epiphytotic, many segregating materials showed a hypersensitive reaction to BCMV as evidenced by vascular necrosis of the roots, stems, leaves, and pods, which produced rapid death of the plant, thus demonstrating the presence of the dominant *I* gene.

To determine which BCMV strains were present, field and greenhouse tests were done with infected sap from plants containing the dominant *I* gene and showing systemic necrosis. The virus was mechanically inoculated on the following varieties: (1) P458, P459, P566, P675, and P714 with the dominant *I* gene for tolerance; (2) Great Northern 123 with the recessive *i* gene; and, (3) the susceptible varieties P634, P645, and Stringless Green Refugee.

Table 6 shows the results of isolation of the virus from field-infected plants with systemic necrosis. Table 7 shows the results of inoculation with sap from BCMV systemically infected plants (Table 6) which had been previously infected with sap from field-infected plants. A comparison of Table 6 and 7 shows that while the susceptible varieties presented mosaic symptoms, Great Northern 123 with the recessive *i* gene was immune to the virus strain. On the other hand, varieties with the temperature sensitive, dominant *I* gene showed leaf vein necrosis and many plants died from systemic necrosis. The low number of plants with localized or systemic symptoms (Table 6) was due to the low concentration of the virus in the inoculum source plants with systemic necrosis. It was concluded that systemic necrosis was caused by BCMV, probably by strain BCMV-1, NL-1 or type strain.

Purification and Stability of the Virus. To obtain maximum infectivity of the BCMV strain for later use in field infections and to produce an antiserum with a higher titer specific to the virus, stability experiments were done in the greenhouse with different buffers, at different molarities and pH's, and combined with reducers, oxidizers, and chelating agents. Infectivity was 95-100 percent when sap was extracted with water from mechanically infected plants. When buffers were used, molarities superior to 0.5 reduced infectivity 25 percent. The virus was more stable with a sodium citrate buffer, 0.05M, pH 7.5.

Methods of Mechanical Inoculation. Various mechanical inoculation systems were tested. Mechanical inoculation was tried with a pestle, index finger and thumb,

Table 6. **Reaction of susceptible and tolerant varieties after inoculation with sap from field-infected plants with black-root in the greenhouse at 28-30°C.**

Variety	Type of Resistance	No. of Plants Inoculated	No. of Plants with Vein Necrosis	No. of Dead Plants	No. of Plants with Typical BCMV Symptoms
P458 (Tui)	*II*	145	24[1]	28	0
P459 (Jamapa)	*II*	155	35	39	0
P566 (Porrillo Sintético)	*II*	30	0	1	0
P675 (ICA-Pijao)	*II*	149	30	25	0
P714	*ii*	43	19	11	0
Great Northern 123	*II*	44	0	0	0
Stringless Green Refugee	Susceptible	60	0	0	14
P634 (Duva)	Susceptible	43	0	0	14
P645 (Nima)	Susceptible	28	0	0	3

[1] Web-type necrosis of the veins on the inoculated leaves.

sponge, hand brush, or an airbrush at 40 kg/cm² of pressure. While all were equally effective, the index finger and thumb were more practical for mass screening. However, the airbrush method required less inoculum, and reduced the possibility of contamination by other mechanically transmissible viruses.

Selection for Resistance. Some 789 naturally inoculated, promising materials were evaluated of which 234 were resistant and 555 susceptible.

In Popayán (1800 msl), BCMV-1, was mechanically inoculated on 724 promising materials; 296 were resistant and 428 susceptible. While it was thought that symptoms would develop better with the lower temperature, and contamination by the bean rugose mosaic virus (BRMV) would be avoided, appearance of symp-

Table 7. **Reaction of susceptible and tolerant varieties inoculated with sap from BCMV systemically infected plants (Table 6) originally inoculated with virus from field-infected plants.**

Variety	Type of Resistance	No. of Plants Inoculated	No. of Plants with Vein Necrosis	No. of Dead Plants	No. of plants with Typical BCMV Symptoms
P458 (ICA-Tui)	*II*	20	20[1]	5	0
P459 (Jamapa)	*II*	21	21	17	0
P566 (Porrillo Sintético	*II*	21	21	4	0
Great Northern 123	*ii*	30	0	0	0
P634 (Duva)	Susceptible	13	0	0	12
P645 (Nima)	Susceptible	15	0	0	15
Stringless Green Refugee	Susceptible	24	0	0	24

[1] Web-type necrosis of veins on the inoculated leaves.

toms was delayed, and they were not as clear as those in CIAT.

Bean Golden Mosaic Virus (BGMV)

Presence of BGMV in America and Africa. The presence of BGMV was confirmed in Brazil, Cuba, Dominican Republic, Mexico, Venezuela and Nigeria. While different concentration levels were registered in the different isolates, the presence of different strains of the virus was not suggested. However, further analyses will be made.

Characterization of the Virus. To improve efficiency and reliability of screening progenies for BGMV tolerance under controlled conditions, a special project was initiated on characterization of BGMV, its concentration in the plant and stability in plant tissues.

It was found that viral infectivity was preserved up to 30 days in dissected leaves or sap when stored at 4°C. However, when leaves or sap were frozen, infectivity was lost at five days.

When samples were taken at 10, 15, 20, 25, 30, and 40 days after inoculation, maximum concentration and infectivity of the virus were obtained 20 days after inoculation in both susceptible and tolerant varieties. However, the concentration was much greater in the susceptible plants, and in the leaves above the third trifoliate if the primary leaves were inoculated. The first two trifoliates showed only slight disease symptoms indicating a correlation between concentration of the virus and symptom severity. Analytical density-gradient centrifugation also demonstrated that tolerant varieties which did not show as severe symptoms as susceptible ones had a lower concentration of the virus. The tolerance rating in descending order for the accessions tested were as follows: P709, P458, P704, P675, P635, and P714.

Selection for Resistance. Some 1150 germplasm accessions were preliminarily evaluated in El Salvador and Guatemala. Some red, cream, brown, and white accessions were identified as tolerant to the virus and include: G651, G716, G729, G738, G765, G843, G1069, G1080, and G1157. The black bean varieties (G951, G1018, and G1257) showed the highest tolerances so far. In Brazil, local materials, Rio Tibagi and Gioianio Precoce and a mutant, TMD-1, showed low tolerance levels.

Selection for Resistance in Different Species of *P. vulgaris*. Under greenhouse conditions, 141 CIAT accessions were mechanically inoculated and evaluated. Seven species of *Phaseolus*, 6 of *Vigna*, *Macroptilium lathyroides*, *Glycine max*, *Lens culinaris*, and *Cajanus cajan* were tested. All accessions of *P. lunatus*, *P. coccineus*, *M. lathyroides*, and *V. sesquipedalis* tested were susceptible. Resistant materials of *P. acutifolius:* PI 310,800; PI 313,205; PI 319,443; and PI 307,805 will be included in a program of interspecific crosses (see Breeding). No accession of *P. vulgaris* was resistant to BGMV; only tolerance was found.

International Bean Golden Mosaic Virus Nursery (BGMN). The 190 entries in the 1977 BGMN were sent to 3 locations in Brazil, 2 in Mexico, and 1 each in the Dominican Republic, El Salvador, Guatemala, and Nigeria. Accessions previously classified as tolerant in Central America (Puebla 441, Guatemala 388, P488, P545, P704, and P709) were also tolerant in Brazil and Africa. Tolerance was defined by symptom intensity compared with susceptible and tolerant local controls.

Chrysomelid Transmitted Bean Viruses

Chrysomelid beetles are the most important vectors of bean viral diseases whose characteristic symptoms are mosaics associated with malformations and leaf rugoses or yellow or green mottles. They are often confused with symptoms of the bean common mosaic virus (BCMV). The extent of their presence in Latin America and the Caribbean is unknown. However, bean rugose mosaic virus (BRMV) cultures from Costa Rica, Colombia, Guatemala, and El Salvador were analyzed in pathogenicity trials and with specific antisera and the existence of strains of the virus was determined, confirming results by Gamez in Costa Rica.

Bean Southern Mosaic Virus (BSMV). The symptoms of systemic infection of the bean southern mosaic virus (BSMV) on some varieties under certain environmental conditions are similar to those induced by the bean rugose mosaic virus (BRMV) or the bean common mosaic virus (BCMV), depending upon the virus strain and the bean variety. Frequently, it does not show any symptoms on beans. Since BSMV is seed transmitted, it interferes with screening for other bean viruses. Serology was done on the cotyledon, testa, embryo and whole seed and a 25 percent seed transmission rate was obtained (Table 8).

Bean Yellow Stipple Virus (BYSV). This virus was isolated from beans in Turipaná, Colombia and its symptoms were similar to those caused by BGMV but not as intense. The virus was easily isolated and purified from beans and also from cowpea *(V. anguiculata)* and *M. lathyroides* which appear to be its natural hosts and principal inoculum sources. While the symptoms are easily identifiable, no resistant bean varieties have been found. However, BYSV does not appear to cause major yield reduction in *P. vulgaris*.

Seed Pathology

Clean Seed Production. During 1977, production of pathogen-free seed continued on 351 accessions in the screenhouse and 400 accessions of promising materials multiplied in the field.

Serology of Seed-Borne Viruses. Depending on the variety and environmental conditions, there are several viral diseases which do not express disease symptoms — remaining latent in their hosts. One of these is the bean southern mosaic virus (BSMV). This is a limiting factor in a seed cleaning or seed certification program. However, by soaking bean seed overnight, the presence of the bean southern mosaic virus (BSMV) could be determined by immunodiffusion serology. Bacterial seed pathogens could also be detected.

Table 8. **Seed transmission of the bean southern mosaic (BSMV) shown by agar gel serology.**

	Seed				Plants	
Varieties	Whole	Cotyledon	Testa	Embryo	No.	%
Bountiful (CIAT)	+	+	—	—		
Bountiful (Burpee's)	—	—	+	—	1300	25
P714 (Topcrop, CIAT)	—	+	—	—		
P714 (Topcrop, Burpee's)	+	+	+	—	100	0
Improved Tendergreen (Burpee's)	—	+	—	—		
Stringless Green Pod (Burpee's)	—	—	—	—		
P704 (Porrillo 1)	+	+	—	—	1000	0
P634 (ICA-Duva)	—	—	—	—		

FUNGAL DISEASES

Bean Rust

Over the past two years, no cultivar or line was immune or resistant to *Uromyces phaseoli* at every International Bean Rust Nursery (IBRN) location. However, some entries were resistant or tolerant at many locations and were incorporated into the 1977 IBRN along with recent CIAT accessions (Table 9). The highest proportion of susceptible IBRN entries occurred at locations in the Dominican Republic, Costa Rica, Mexico and CIAT. These sites should be useful to screen hybrid materials for resistance to diverse populations of rust races.

At CIAT, field nurseries were planted to simultaneously screen hybrid progeny for resistance to the bean common mosaic virus (BCMV) and rust. Progeny were hand-inoculated with BCMV as seedlings (CIAT Annual Report, 1976) and then rust epidemics were generated on the BCMV resistant plants before flowering and pod-setting. Two-three weeks before planting of nursery entries, a mixture of 10-15 rust spreading cultivars which were susceptible, intermediate and resistant to rust were planted four rows wide and parallel to every 20 rows of nursery entries (Figure 3). Three to four weeks after germination, spreader plants were inoculated (Figure 4) with a composite of rust races collected during previous epidemics (Figure 5). The mixture of varieties maximized survival of all pathogenic variability inherent within the local bean rust population.

Germplasm and progeny were evaluated according to the following scale: resistant = no infection or a few minute pustules; intermediate = few to many small pustules, usually present only on the lower leaf surface, or pustules with limited necrotic development; or susceptible = few to many large pustules on the lower and/or upper leaf surfaces.

A total of 1643 germplasm accessions were evaluated for rust reactions in the field: 89 were resistant; 69 were tolerant

Table 9. **Reactions of the most widely resistant entries to bean rust (*Uromyces phaseoli*) in the 1975 and 1976 International Bean Rust Nursery (IBRN). Data on number of locations where the entries received disease ratings[1].**

Promising Lines	Identification	Number of Locations									
		1975					1976				
		I	R	INT	S	ND	I	R	INT	S	ND
P793	Compuesto Chimaltenango 3	4	3	2	1	5	5	9	2	1	0
P709	Turrialba 1	4	3	2	3	3	3	7	6	1	0
P675	ICA-Pijao	3	1	4	3	4	3	6	7	1	0
P699	Mexico 309	6	5	1	0	3	6	3	3	2	0
	Mexico 235	2	1	2	0	10	6	4	4	2	1
P509	San Pedro Pinula 72	4	3	3	2	3	4	6	5	2	0
P693	Ecuador 299	5	7	1	0	2	3	6	6	2	0
P685	Cornell 49-242	3	5	4	1	2	2	4	9	2	0
P239	P.I. 226-895	4	6	2	0	3	1	5	7	2	2

1 I = immune; R = resistant; INT = intermediate; S = susceptible; ND = no data.

Figure 3. Bean Common Mosaic Virus- Rust Nursery design with 4 rows of rust spreader cultivars planted parallel to every 20 rows of nursery entries.

and 1194 were susceptible. The remaining 291 accessions were variable in their reaction and provided additional sources of resistance/tolerance.

Anthracnose

Greenhouse techniques were developed

Figure 4. Inoculation of bean rust spreader rows 4 weeks after plant emergence.

Figure 5. Rust inoculum (mixture of races) stored with calcium chloride. Inoculum (2-3 ml) mixed with 20 drops Tween 20 in 4 liters distilled water and sprayed onto plants.

this year to screen for resistance to races of anthracnose prevalent in Colombia. A spore suspension, primarily of beta and gamma races at 1.2 x 10^6/ml (Fig. 6), was sprayed on leaves and injected into stems of seedlings which were incubated in a moisture chamber at 19-24°C and 90-100 percent RH. Materials were evaluated as: resistant = no infection on leaves or stems; intermediate = small, limited lesions on leaves with little development on stems; or susceptible = large lesions on leaves and stems, often causing plant death. Approximately, 100 promising lines resistant to anthracnose races in field nurseries in Popayán were also tested at other Colombian locations to identify candidates for an International Bean Anthracnose Nursery.

Root Rots

This year, experiments were initiated to develop field techniques for screening for resistance/tolerance to various root rot pathogens, principally to *Fusarium solani* f. sp. *phaseoli* and also to *Rhizoctonia solani, Sclerotium rolfsii* and *Pythium* sp. Individual pathogen nurseries were developed by inoculating seed and furrows with a mixture of isolates grown on sterilized media such as rice hulls. Optimum inoculum concentration, plant density and reliable rating scales for evaluation of segregating progeny are still being determined. However, preliminary data indicate that various accessions exhibit resistant/tolerant reactions to many or all pathogens tested (Table 10).

Some 240 accessions were also planted for field evaluation at Popayán under natural infestation with *Fusarium* and *Rhizoctonia:* 32 percent were resistant/tolerant but 10 percent of these entries contained a mixture of susceptible plants. Promising selections will be

Figure 6. Hypodermic inoculation of bean seedling with a distilled water suspension (1.2 x 10^6 spores/ml) of bean anthracnose isolates.

Table 10. Evaluation of root rot reactions[1] on promising germplasm selections at CIAT in 1977.

Promising Line	*Fusarium*	*Rhizoctonia*	*Sclerotium*	*Pythium*
P009	INT	INT-R	S	INT
P168	S	INT	INT	INT
P432	S	R	R	R
P458	R	S	R	R
P461	INT-R	S	R	INT
P566	R	R[2]	R	R
P622	R	S	INT	R
P646	INT-R	INT	S	R
P718	R	S	R	R
P746	R	R	R	R
P775	INT-R	INT-R	R	INT

[1] INT = intermediate; R = resistant; S = susceptible.
[2] P566 has been moderately susceptible in other tests at CIAT.

retested in artificially inoculated field nurseries at CIAT to determine their range of reactions to root rot pathogens.

Angular Leaf Spot

Greenhouse techniques to screen germplasm for resistance/tolerance to angular leaf spot were developed. Seedling leaves were spray-inoculated in the greenhouse with a spore suspension at 2 x 10^4/ml and incubated in a moisture chamber (90-100% RH) for 24-48 hours at 19-24°C. Symptoms appeared 12-14 days after inoculation. Field inoculations (2 x 10^4 spores/ml) were done at Popayán and an evaluation scale is being developed.

Web Blight

This year, techniques were worked out to screen germplasm for resistance/tolerance to web blight in the greenhouse at temperatures above 28°C with 95 percent RH. The fungus was grown on potato dextrose agar (PDA) and after four days, transferred to potato yeast dextrose agar (PYDA). After five more days, the fungus was then mixed in sterile soil to produce abundant quantities of basidiospores. Eight to fifteen days after germination, plants were spray-inoculated, incubated and evaluated five days later according to the following scale: 1 = no symptoms; 2 = little growth, chlorosis around the inoculation point; 3 = vein necrosis, with 33 percent leaf chlorosis; 4 = vein necrosis, 50 percent leaf chlorosis; and 5 = complete leaf necrosis. P17, P358, P488 and P566 were highly tolerant to web blight.

BACTERIAL DISEASES

Common Bacterial Blight

Greenhouse experiments were done to determine if pathogenic variation of common bacterial blight at CIAT were due to distinct races or variations in isolate virulence. The primary leaves of six cultivars with different degrees of tolerance or susceptibility were clip-inoculated at 5 x 10^7/ml with isolates from Latin America and the United States. Virulence between isolates and tolerance of the cultivars

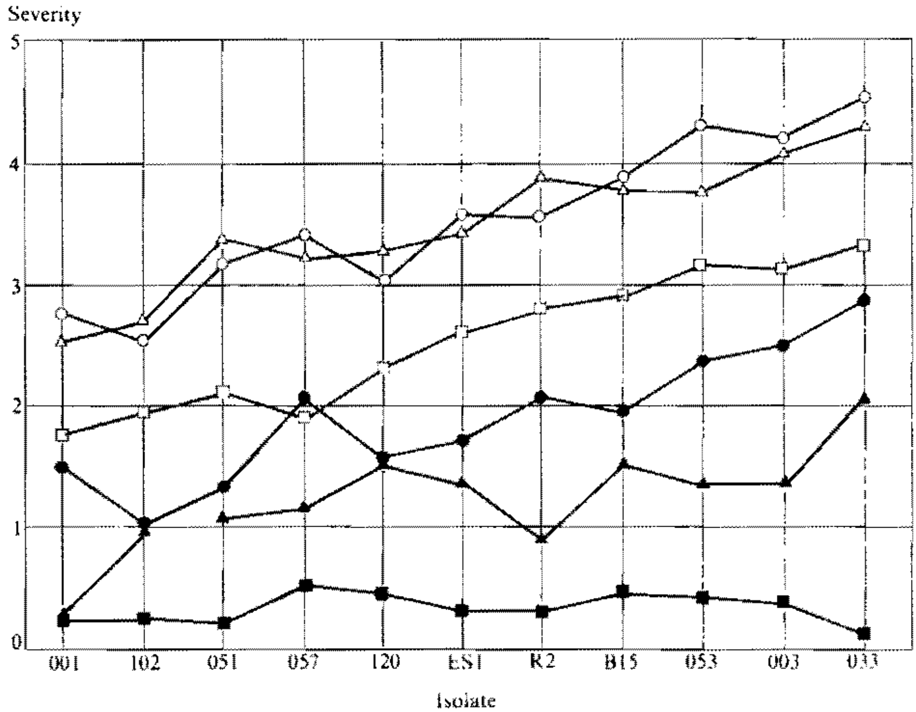


Figure 7. **Interaction between common bacterial blight isolates with different levels of virulence and bean cultivars with different levels of tolerance.**

varied, but there was no interaction at the P = 0.05 level between isolates and cultivars to imply the presence of races (Figure 7). These isolates and others from different locations in the Americas were then inoculated onto a susceptible cultivar, ICA-Pijao, to recover and estimate frequency of highly virulent isolates in natural populations (Table 11). Isolates from nearly every location were as virulent as

Table 11. **Frequency of virulent common blight isolates collected from different locations in Latin and North America, and clip-inoculated onto primary leaves of susceptible ICA-Pijao.**

Isolate Origin	Number of Isolates Tested	Number of Isolates as Virulent as XP 123	Range in Virulence[1]
Colombia, Cauca Valley	13	1	1.4- 9
Colombia, Restrepo	9	6	7.4-10.9
Colombia, other	5	0	5.0- 7.5
Puerto Rico	12	5	1.8-13.3
Mexico	8	3	4.6- 9.6
El Salvador	7	2	6.7- 8.9
Brazil	10	6	7.1-10.2
U.S.A., Michigan	2	0	5.7- 7.6

[1] Data normalized to isolate XP 123 with a virulence rating of 10 (LSD. .05 = 1.5).

XP 123 from Colombia. Therefore, the bacterial blight screening will use the most highly virulent isolate in local populations of the pathogen to evaluate germplasm for resistance/tolerance.

Several varieties tolerant to common bacterial blight *(Xanthomonas phaseoli* and *X. phaseoli* var. *fuscans)* in temperate zones are susceptible under tropical conditions at CIAT. This makes parental selection and progeny screening more difficult. Therefore, studies were initiated in 1977 to investigate the influence of plant adaptation and environmental factors upon disease reaction, and to develop reliable greenhouse and field techniques to evaluate common blight tolerance at CIAT.

Five cultivars were selected which were susceptible, tolerant, and varied for photoperiod sensitivity (Table 12). The poorly adapted cultivars, P684 and P698, were treated with supplemental lighting to simulate temperate zone lighting and to extend time to flowering. Beginning at 20 days after germination, plants were inoculated at weekly intervals by water-soaking with bacterial cells of a highly virulent Colombian isolate, CIAT XP 123 (5×10^7/ml). At 22 and 33 days after initial inoculation, the light treatment significantly delayed flowering and leaf senescence, increased foliage development and produced a tolerant response in the non-adapted P698. These differences were also confirmed with yield data, thus demonstrating the effect of poor plant adaptation on common bacterial blight tolerance. The CIAT breeding section will select parents with bacterial blight tolerance and/or incorporate tolerance from poorly adapted parents within an agronomic background well-adapted to tropical conditions.

DISEASE OBSERVATION TRIALS

In collaboration with the Instituto Colombiano Agropecuario (ICA), CIAT bean breeding and pathology planted nurseries in several areas of Colombia to simultaneously evaluate germplasm for plant adaptation and disease resistance. Several promising accessions possessed multiple disease resistance or tolerance to various plant pathogens such as rust, anthracnose, web blight, powdery mildew, gray spot, *Ascochyta* blight and common bacterial blight (Table 13).

Table 12. **Effect of different environments on common blight (*Xanthomonas phaseoli*) reactions.**[1]

		Common Blight Reaction		
		Temperate	Tropical	
Promising Lines	Adaptation at CIAT	Normal Photoperiod	Normal Photoperiod	Extended Photoperiod[2]
P684	Poor	S	S	S
P698	Poor	T	S	T
P498	Good	S	S	S
P566	Good	S	S	S
P597	Good	T	T	T

1 S = susceptible; T = tolerant

2 18 hour day; supplementation with incandescent lights in field.

Table 13. **Promising lines with multiple disease resistance or tolerance to fungal and bacterial pathogens in various field nurseries in Colombia.**

Promising Lines	Disease Reaction[1]					
	Rust	Anthracnose	Web Blight	Powdery Mildew	Gray Spot	Common Blight
P167	INT	R	S	S	INT-R	S
P168	INT	R	S	S	INT-R	T
P179	R	R	T	N	N	T
P189	R	R	S	S	INT-R	S
P203	INT	R	S	S	S	T
P204	R	INT	S	S	INT-R	T
P256	INT	INT	S	INT-R	S	S
P334	INT	R	T	S	INT-R	S
P349	INT	S	S	INT-R	S	S
P507	INT	R	T	S	T	T
P631	R	R	S	S	INT-R	S
P670	R	R	T	S	S	S
P782	INT	R	T	S	INT-R	T

[1] R= resistant; T= tolerant; INT= intermediate, S =susceptible, INT-R= resistant during natural epidemics, require controlled tests to confirm resistance. N= P Line not observed for reaction to specific pathogen

Entomology

Moderate to low levels of resistance to *Empoasca*, mostly based on tolerance, were identified in the germplasm bank and recurrent selection initiated to increase resistance levels. Cultural control of leafhoppers also appears promising. The biology of the Chrysomelid species, *Diabrotica balteata*, was studied in the laboratory and damage of the different life stages to beans at different levels of maturity. Treatment of stored beans with vegetable oils was found to be a cheap and effective method of protection against *Zabrotes subfasciatus*.

LEAFHOPPERS

Screening for Resistance

Additional sources of resistance to the leafhopper, *Empoasca kraemeri*, were found in new germplasm accessions. The International Bean Rust Nursery (IBRN) contains several entries — e.g. G05942 and Turrialba 1 — with promising resistance to *Empoasca*.

To test the feasibility of screening segregating populations for resistance based on individual plant damage scores, 38 promising lines having known and varying resistance levels identified in previous replicated trials were used to simulate resistant x susceptible crosses of an F_2 population. Individual damage scores taken twice weekly, and yield per plant in one replicate were correlated with the other seven replicates. Rank correlation coefficients between individual and replicated scores were highly significant (Table 14), indicating that selection of

Table 14. **Correlation coefficients of individual plant damage scores in 1 replicate with the 7 remaining replicates for simulated F_2 of 38 P lines scored twice weekly for leafhopper damage (damage scale 0-5).**

Evaluation Method	No. Observations	Spearman's Rank Correlation Coefficient
Visual damage score	13	0.592
Visual damage score	7	0.574
Visual damage score	5	0.549
Visual damage score	3	0.533
Visual damage score	1	0.441
Visual damage score with more weight given to later observations		0.653
Seed yield		0.585
Combined visual dam. score and yield		0.639

single plants in the F_2 generation may be an acceptable screening method.

Scoring leafhopper damage once a week was as accurate as scoring damage twice a week while yield data supplement damage scores. Yield regression between unprotected and protected plants was significant. Average yield/plant decreased from 10.42-2.63 g, respectively, but individual lines deviated significantly indicating variety x treatment interactions, i.e. genetic differences in resistance.

A 15 x 15 diallel cross was made and F_2 plants and their F_3 progeny families were evaluated in the same manner as the simulated F_2 population (calculated for 50% of the 925 F_2 selections). Heritability estimates (regression of F_3 family mean on F_2 plant value) of six crosses with black and non-black parents were low (Table 15). This may have been due to limited genetic variability and relatively large non-additive, genetic variation. Few F_3 families from superior F_2 plants demonstrated a uniformly high tolerance level to *Empoasca;* most showed wide segregation.

Capture of leafhopper nymphs on hooked epidermal hairs is an important resistance mechanism against *Empoasca fabae*. Therefore, the effectiveness of pubescence as a resistance mechanism against *E. kraemeri* was studied. Maximum capture rate of 24 percent was observed only once on Redcloud and the best average rate of nymphal capture was 5 percent on Calima, followed by 4.7 percent on Redcloud. While hairless, black-seeded varieties already have superior *E. kraemeri* resistance, nymphal capture ranged from 0.8-1.4 percent indicating that incor-

Table 15. **Correlations between individual F_2 plant damage scores of 50 plants per cross and their F_3 family damage score in 6 selected crosses using resistant and susceptible parents.**

Cross	Spearman's Rank Correlation Coefficient	Narrow Sense Heritability	% Significance Level of Herit. Estim.
P512 x P478	0.127	0.28	5
P682 x P692	0.155	0.14	31
P720 x P681	0.221	0.40	0.4
P560 x P458	0.257	0.18	20
P420 x P692	0.274	0.21	14
P682 x P681	0.422	0.22	13

porating pubescence into black-seeded varieties may further increase resistance.

Economic Damage

Studies were conducted to determine the economic threshold of leafhopper populations on Diacol-Calima, a standard susceptible control. Table 16 shows nymphal populations permitted per leaf before initiating chemical control, bean yields, production costs and sale value. As nymphal populations per leaf were reduced to nearly zero, production costs were estimated to increase exponentially with the number of chemical applications. A linear relationship between production (total returns) and nymphs per leaf was assumed and an asymptotic relationship between the number of nymphs and production costs.

The highest profit was made at 0.81 nymphs per leaf. Therefore, the economic threshold population of leafhoppers was defined as the level which allows maximum profit and not as the level at which cost of control equals expected value of yield loss (Fig. 8).

Two experiments were done to determine at which growth stage the bean plant is most susceptible to leafhopper damage. The growing season of susceptible Diacol-Calima was divided into 18 day periods and during each of these four periods plants were protected with monocrotophos or left unprotected in the control (Table 17).

In both trials, yields were highest when beans were protected during flowering and podset at 26 to 44 days but in the first experiment in which leafhopper attack came later than in the second experiment, the period from 44-62 days was most critical. The presence of leafhoppers on the plants from 8-27 days or from 62 days on did not influence yields.

These results have important implications. First, early chemical control, i.e. carbofuran as a soil treatment, is less effective and protection by mulching does not have maximum influence as the plants are already large when the most susceptible growth stage begins. By that time, plants have mostly covered the mulch.

Table 16. **Yield value of harvest and cost of production (average of four replicates) with various leafhopper nymphal populations on Diacol-Calima when sprayed with monocrotophos at 0.25 liter a.i./ha/application.**

No. of Nymphs/Leaf					
Planned	Observed to initiate Spraying	No. of Sprays	Yield (kg/ha)	Value of Product[2] (Col $)	Cost of Production (Col $)
0	0.63	5	1294a	20.704	10.572
1	1.22	4	1118b	17.888	10.257
3	3.55	2	670c	10.720	9.629
5	5.07	1	641cd	10.096	9.314
7	7.45	1	503d	8.048	9.314
Control	8.67[1]	0	38e	608	9.000

[1] Maximum population at 44 days; counts from 29-49 days after planting were mostly above 5 nymphs, leaf.
[2] 1 kg beans valued at $16.00.

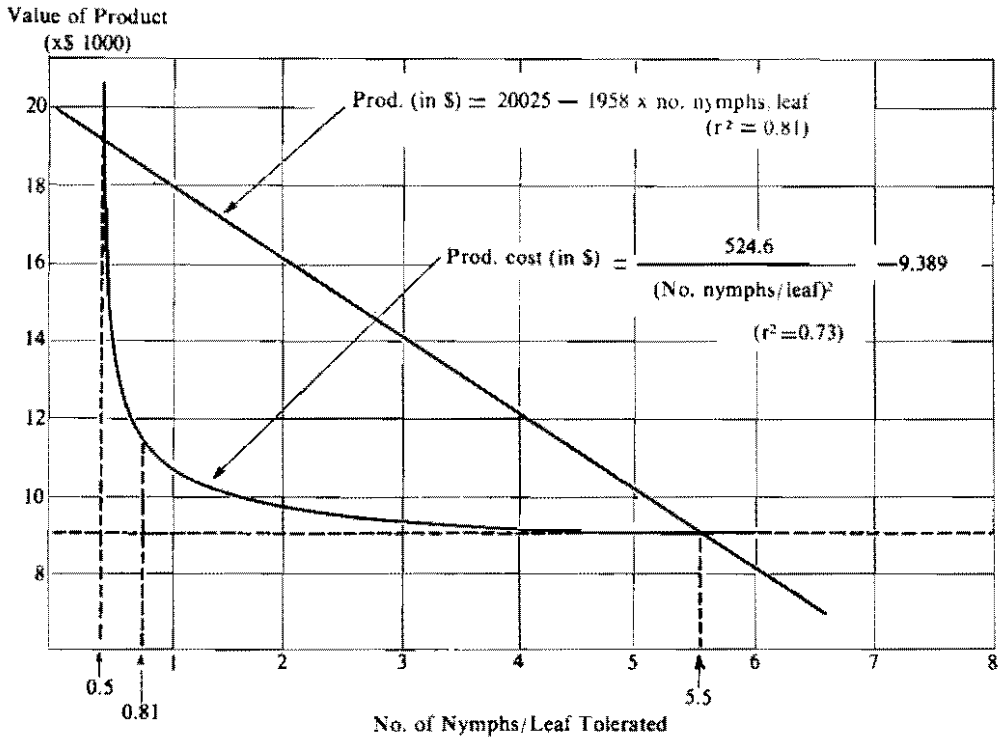


Figure 8. **Relationship between leafhopper nymphal population, value of product and production cost (in Col.$).**

Table 17. **Yield of dry beans of Diacol-Calima following insecticide treatments during different plant growth stages. (Avg. 4 replicates).**

Chemical Protection Period (in days after planting)	No. of Insecticide Applications	Dry Bean Yield (kg/ha)	
		First Experiment	Second Experiment
8-80	4	1359bc[1]	1411a
8-62	3	1385bc	1550a
8-44	2	1327bc	1241a
8-26	1	1073d	553b
Untreated	0	1002d	475b
27-80	3	1655a	1467a
45-80	2	1549ab	847b
63-80	1	1012d	583b
27-62	2	1480ab	1276a
8-27 and 62-80	2	1181cd	532b

[1] Treatments followed by the same letter were not significantly different at $P < 0.05$.

Table 18. **Yield of Diacol-Calima with different mulches providing leafhopper control (avg. 4 replicates).**

Treatment	% Light Reflection	Dry Bean Yield (kg/ha)	
		Insecticide Protected	Unprotected
Rice straw mulch	8.0	1671d	861b
Aluminum foil mulch	20.3	2312e	1296c
Black plastic mulch	5.2	1725d	395a
Control	5.4	1753d	416a

Mulching

Studies continued on the influence of straw and aluminum foil mulches on leafhopper populations and bean yield. When beans were chemically protected and mulched, yields increased 32 percent with aluminum foil mulch (Table 18), probably due to increased light intensity. (Aluminum foil reflected 20 percent of incident light compared to 5 percent reflected in non-mulched and black plastic-mulched plots.) Yields in the non-mulched plots and the black plastic-mulched plots were very low due to heavy insect pressure, but doubled by rice straw mulching. Aluminum foil mulch tripled yield as compared with the control plots. It appears that light reflection and/or color contrast are the principal factors involved in reducing leafhopper populations.

In another experiment with susceptible Diacol-Calima and P-14, a resistant variety, the nymphal populations in straw-mulched and aluminum foil-mulched plots were 30 and 17 percent of the control, respectively, during the first half of the growing season (Table 19). However, later populations were higher on mulched plots

Table 19. **Plant dry weight, dry bean yield and average nymphal populations per leaf on the leafhopper susceptible variety, Diacol-Calima, and P-14, a resistant variety, following different insect control treatments.**

Treatment	Dry Weight at Flowering (g/plant)	
	Diacol-Calima	P-14
Control	4.26	11.07
Insecticide-treated	6.78	15.25
Straw mulch	7.65	15.97
Aluminum foil mulch	9.95	15.50

	Nymphs/Leaf			
	Up to 41 days	After 41 days	Up to 41 days	After 41 days
Control	3.39	2.85	2.20	5.41
Insecticidal treated	0.06	0.01	0.11	0.01
Straw mulch	1.01	3.64	0.75	4.87
Aluminum mulch	0.59	2.46	0.59	4.76

due to increased plant vigor and reduced leafhopper damage during earlier stages. However, plant dry weights at flowering for the mulched plots were equal to or higher than plant weights in non-mulched; insecticide protected ones. Yields were generally very low, due to unusually hot weather during the flowering period, but dry bean yields of the resistant variety on non-protected plots were nine times those of the susceptible variety, confirming the value of plant resistance to the leafhopper.

Table 20. ***D. balteata* larval survival on bean and maize roots.**

Days after Hatching and Infestation	Food Medium		
	Maize Roots	Bean Roots	Bean Root Nodules
0	200	200	200
3	189	87	0
6	178	14	-
9	170	1	-
12	162	0	-
Adults obtained	95	0	0

CHRYSOMELIDS

While *Neobrotica variabilis* is most commonly found in flowering beans at CIAT, the Chrysomelid, *Diabrotica balteata,* the banded cucumber beetle, is generally more common in the fields and its biology was studied in the laboratory. Eggs of *D. balteata* hatched in seven days in the laboratory and the three larval stages required 12 to 14 days. Pupation also took 12 to 14 days. Although bean root damage from Chrysomelid larvae is common in the field, larvae could not be reared on bean roots or nodules in the laboratory. However, rearing was successful on maize roots. When larvae were fed maize roots for three days, then placed on beans, survival greatly increased (Table 20). Older larvae were often found dead on the hooked trichomes of the hypocotyles.

The effect of larval feeding on seedling development was also tested. When young larvae attack beans prior to plant emergence, feeding on primary leaves and cotyledons, primary leaves emerge with perforations, resembling symptoms of adult feeding. When seeds were infested with older larvae, one day after planting, severe damage to cotyledons and stems occurred, often impeding plant emergence or reducing plant growth. First instar larvae were most damaging to seeds when infested one day after planting. However, second and third instar larvae caused more damage, especially when seeds were infested at planting (Table 21).

Table 21. **Leaf area of Diacol-Calima beans measured 10 days after planting as percentage of leaf area of control plants, after infestation with *Diabrotica balteata* larva on three dates after planting.**[1]

No. of Larvae/Plant	Larval Stage	Leaf Area Infested as % of Control on days after Planting		
		0	1	4
5	1st instar	93.3	89.3	96.8
	2nd instar	22.3	37.3	76.0
	3rd instar	0	10.8	2.0
10	1st instar	95.3	53.4	84.2
	2nd instar	12.1	9.1	31.7
	3rd instar	0	0.5	0.8

[1] Plants grown in the greenhouse (18°-35°C avg. 23.3°C; RH 65-100%, avg. 98.5%). Average of 20 replicates for 1st instar and 10 replicates for 2nd and 3rd instars.

Table 22. **Relationship between infestation level, bean leaf area and yield (avg. 3 replicates Diacol-Calima).**

Feeding Period (days after planting)	Estimated Infestation Level (adults/plant)	Remaining Leaf Area as % of Control	Yield as % of Control
8 -15	0.9	82.9	96.1
	1.4	67.0	79.8
	3.0	52.5	72.4
15-22	1.2	83.7	113.8
	1.4	71.2	111.4
	3.7	58.3	70.1
22-29	1.1	89.0	89.8
	1.0	77.4	75.7
	3.7	53.1	48.8

The effect of adult feeding on bean yield was also studied. Preliminary results showed that up to 22 days after planting, 19 percent defoliation or up to 1.4 adults per plant can be tolerated without significant yield loss (Table 22). From 22 to 29 days after planting, one adult per plant significantly reduced yields.

BROAD MITES

In the CIAT Annual Report 1975, the Tarsonemid mite, *Polyphagotarsonemus latus*, was reported to cause up to 56 percent yield losses. Fifteen pesticides were tested for *P. latus* control, in which beans were sprayed with dimethoate to protect them from leafhopper attack and which enhances *P. latus* attack according to the literature and previous observations at CIAT. Results of the best eight compounds are shown in Table 23. Bean yield was highest following endosulfan treatment but kelthane and hostathion were also effective. Tetradifon was highly effective

Table 23. **Damage grade, mite population and dry bean yield following treatment by different insecticides (avg. 3 replicates, ICA-Pijao).**

Product	Dosis (a.i./ha)	Avg. Dam. Grade (0-3) of *P. latus* 7 Days after 1st Applic.	No. of *P. latus* 5 Days after 1st Applic.	No. of *T. desertorum* 10 Days after 2nd Applic.	Yield (kg/ha)
endosulfan	1.23 liter	0.1g	95e	178bc	2015a
dicofol	0.84 liter	0.8efg	124de	30c	1783ab
triazophos	0.40 liter	0.5fg	115de	127c	1765ab
omethoate	0.50 liter	1.5cde	35b	119bc	1711b
carbaryl	1.60 kg	1.0ef	223bcde	894a	1664b
Amitraz	0.06 liter	1.5cde	104e	42c	1648b
monocrotophos	0.28 liter	1.8cd	264bc	286bc	1578b
carbofuran	0.12 kg	2.1bc	318bc	617a	1540b
Control	—	3.0a	349b	237bc	1155c

Table 24. **Effect of different vegetable oils tumbler-applied on Bruchid biology on beans (avg. 5 replications, 100 g each, infested with 7 pairs of adults).**

Oil	ml oil/ kg seed	% Adult Mortality after Application at Days 2	7	No. Eggs/ Replic.	No. Emerged Progeny Adults/ Replic.
Soybean	1	15	52.9	107.8	6.4
	5	100	100	0	0
	10	100	100	0	0
Mixed	1	9	84.3	121.6	13.0
	5	100	100	0	0
	10	100	100	0	0
Maize	1	22.5	88.6	89.0	13.2
	5	100	100	0	0
	10	100	100	0	0
Control		0	1.4	318.8	208.0

against *Tetranychus* sp. mites but not against *P. latus*. By contrast, carbaryl was effective against *P. latus* but caused a *Tetranychus* outbreak. Elosal may be more effective by increasing the dosage.

STORED GRAIN INSECTS

About 2000 germplasm bank accessions were tested for resistance to the Bruchid, *Zabrotes subfasciatus*. In the three trials, there were variations in resistance for each entry but selections P364 and P507 maintained a low resistance level. This resistance was expressed in reduced oviposition and emergence, or prolonged development period for *Zabrotes*.

Vegetable oils were tested for control of Bruchids infestations in stored beans. Three cooking oils were tumbler-applied to the beans which were then infested with *Z. subfasciatus* (Table 24). At 5 ml/kg, 100 percent adult mortality was observed.

Table 25. **Seed germination and water absorption following treatment with maize oil and storage for 1 or 180 days (avg. 5 and 3 replicates, of 50 seeds and 100 g, respectively).**

ml oil/ kg beans	Percent Germination of Seed Stored after Oil Treatment for: 1 day	180 days	Percent Weight Increase by Soaking for 24 Hrs. after Oil Treatment and Storage for: 1 day	180 days
1	88.7	85.9	107.8a	103.8b
5	87.1	82.4	102.2b	102.2b
10	88.7	77.6	100.3b	103.5b
Control	90.0	79.6	107.7a	107.7a
Sign. level	n.s.	n.s.		

Additionally, when beans heavily infested with larvae were treated with 5 ml of cottonseed oil/kg of beans, adult emergence was also significantly reduced, indicating that the oils also affected Bruchids after their penetration in the seed. Tumbler applications were more effective than manual applications; only 1 to 2 ml of oil tumbler-applied gave complete control while up to 5 ml were required when applied manually. Oil applications did not affect seed germination or water absorption (Table 25).

Physiology

Physiological studies continued on yield limiting factors and adaptation components of *Phaseolus vulgaris* germplasm at CIAT and Dagua (altitude 830 msl) and at Popayán (altitude 1,900 msl) during 1976-1977.

GROWTH AND YIELD OF PORRILLO SINTETICO

In 1975 Porrillo Sintético was selected as a representative variety to study yield limiting factors under tropical conditions. Results are now available for 12 growth analysis experiments conducted at CIAT from 1974-1977 under irrigated and protected conditions. Yield and other parameters studied are presented in Table 26. Results for experiment 7616 are included where Porrillo Sintético was grown at four distances from a line of incandescent lights with a 16 hr 30 min daylength, causing progressive lengthening of the growth cycle due to the photoperiod sensitivity of the variety. The highest yield (4.1 t/ha) in the series was recorded for the plots adjacent to the light source (CIAT Annual Report, 1976).

Yield variability for the 12 cycles was associated with factors summarized in Table 27. Lodging, bacterial blight (chemical control was not effective) and soil factors such as high sodium saturation in one field were probably most important although the relative importance of these factors cannot be accurately indicated yet. The sum of the severity scores for the six factors in Table 27 was highly correlated with yield ($r = -0.94$). Mean radiation and temperature data recorded during the experiments (Table 28) show extremely low climatic variability.

Yield variation for one variety at one location over a number of seasons provides a useful means of evaluating the importance of various physiological parameters in yield determination. The highly significant correlation of pods/m^2, total dry matter at maturity and maximum node number, shown at the bottom of Table 26 supports the preliminary conclusions (CIAT Annual Report, 1976) that crops with larger vegetative structure have higher yields. Increased dry matter production (correlation with yield $r = 0.96$) and a relatively constant harvest index ($r = -0.28$) were associated with this yield trend. Increasing node structure increased leaf area index resulting in higher levels of photosynthate supply at least up to ceiling leaf area which was from 4.1 to 4.2 m^2/m^2 in this variety under non-lodged conditions. Further increases in leaf area in the upper nodes after flowering were balanced by leaf area loss due to senescence at the lower nodes.

Leaf area duration (LAD), the integrated leaf area available over a particular period of the growth cycle, is a measure of the total availability of green leaf area with time. Figure 9 shows the linear relationship of maximum node number to LAD for the whole growth period (emergence to physiological maturity) for the 12 cycles.

Table 26. **Yield and yield components for Porrillo Sintético in growth analysis experiments at CIAT from 1975-76.**

Experiment	Yield[1] in g/m^2 at 14% Moisture	Days to Flowering[2]	Days to Maturity[2]	Yield[3]/Day in g/m^2/day	Pods[4]/m $1/m^2$	Beans/Pod 1/pod	Bean Size in mg/bean	Total[4] Dry Matter in g/m^2	Harvest[5] Index in %	Maximum Node No. $1/m^2$
7616	412 (37)[6]	51	95	4.12	314	5.71	197	698	52	1010
7630	355 (25)	33	69	4.79	276	5.49	200	503	61	732
7616	347 (39)	43	84	3.99	255	5.79	201	562	53	806
7707	312 (28)	33	75	3.90	256	5.72	182	475	56	572
7616	298 (37)	36	71	3.92	215	5.69	208	474	54	560
7609	295 (26)	32	72	3.83	220	5.65	204	410	62	545
7616	277 (39)	36	69	3.74	202	5.59	210	409	58	549
7541	277 (4)	34	72	3.59	208	5.93	191	384	62	576
7612	265 (20)	33	76	3.27	204	5.97	186	381	59	607
7629	232 (26)	34	81	2.69	180	5.29	214	349	57	492
7503	227 (20)	32	74	2.87	210	4.87	191	343	57	598
7622	219 (30)	33	67	3.04	192	5.52	176	337	56	612
Mean	293	36	75	3.64	227	5.60	197	444	57	638
Stand. Dev.	(57)	(5.6)	(7.6)	(0.59)	(39.3)	(0.30)	(12)	(106)	(3.3)	(145)
r (*vs.* yield)		0.74	0.85	0.85	0.94	0.41	0.17	0.96	-0.28	0.81

1 Yield measured on 7 to 10 m^2 harvested area per replication, 4 replications per trial.
2 Days from emergence.
3 Yield/day from planting to physiological maturity.
4 Data corrected by ratio of yield of main plot: yield in $1m^2$ component subsample.
5 Ratio yield: total dry matter at harvest (minus leaves and petioles at maturity).
6 Standard deviation.

Table 27. **Severity scores[1] for possible limiting factors in each of the growth analysis experiments with Porrillo Sintético at CIAT from 1975-77.**

Experiment	Lodging	Bacterial Blight[2]	*Heliothis* sp.	Mites[3]	Soil Salinity[4]	Poor Drainage	Total Score
7630	1	1	1	1	1	1	6
7707	1	1	1	1	1	1	6
7609	1	1	1	1	2	1	7
7541	2	3	1	1	1	1	9
7616	2	1	3	1	1	1	9
7612	3	1	1	3	1	1	10
7629	4	1	1	1	1	3	11
7503	5	2	3	1	1	1	13
7622	4	1	1	1	4	1	12

1 Severity score: 1= factor not present; 5=factor at high level of severity; estimates based on global experience in physiology experiments at CIAT.
2 Bacterial blight control was ineffective with available chemicals.
3 Mite resistance to various materials was encountered.
4 Maximum salinity: 2-3% Na saturation in exchange complex.

Table 28. **Data for mean solar radiation and mean temperature for growth analysis experiments[1] (for period from emergence to physiological maturity) with Porrillo Sintético at CIAT from 1975-77.**

Experiment	Radiation in cal/cm²/day	Temperature in °C
7616 (a)	497	23.1
7630	496	23.3
7616 (b)	506	24.1
7707	472	23.4
7616 (c)	504	24.3
7609	496	23.3
7616 (d)	503	24.3
7541	426	22.0
7612	460	23.2
7629	483	23.1
7503	444	22.9
7622	473	23.0
Mean	480	23.4

1 Data Source: ICA Meterological Station, Palmira.

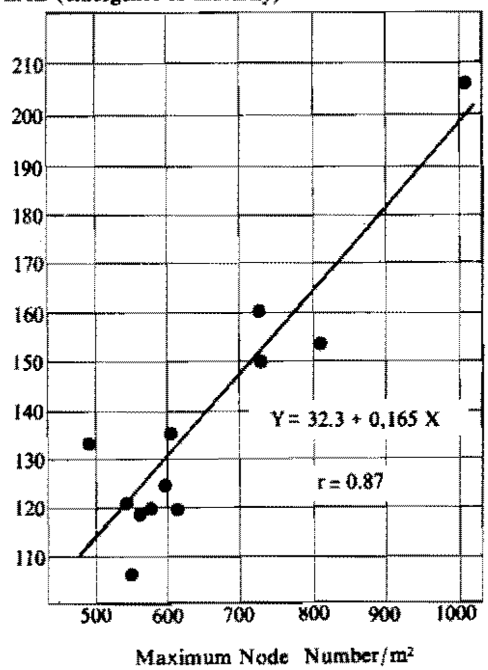


Figure 9. **Regression of LAD (leaf area m² days/m² land area) from emergence to physiological maturity on maximum vegetative node number measured after flowering for Porrillo Sintético in 12 growth analysis experiments at CIAT from 1976-77.**

Crops with a larger total node structure maintained leaf area at a higher level throughout the growth cycle. Increased LAD is in turn correlated with final yield (Figure 10). However, the relationship was somewhat influenced by lodging. Three of the crops in the bottom left of Figure 10 were heavily lodged (experiments 7629, 7503, and 7622) which resulted in an apparent decrease in the efficiency of the leaf area available. This suggests that an increase in leaf area duration without a concurrent improvement in lodging resistance will not produce higher yield levels due to the inefficient use of solar radiation by lodged canopies.

The influence of lodging on canopy height for two typical experiments is shown in Figure 11. Experiment 7622 lodged immediately prior to flowering during a heavy storm while 7609 suffered a gradual decrease in canopy height as the crop approached maturity. The most common type of lodging does not involve stem bending *per se* but rather root lodging which causes the whole plant to fall over.

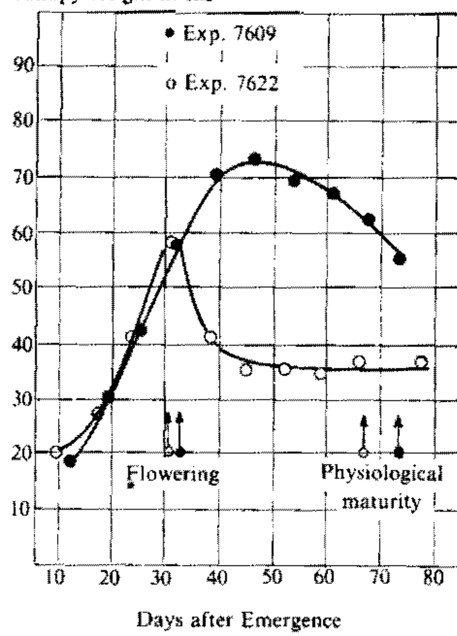


Figure 11. **Effect of lodging on canopy height in two growth analysis experiments with Porrillo Sintético.**

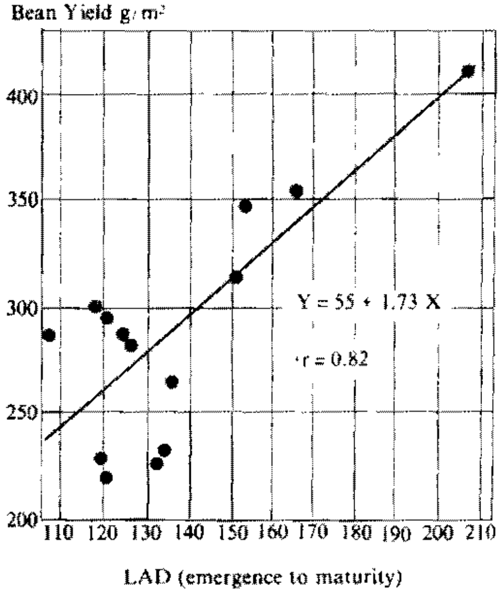


Figure 10. **Regression of grain yield (14% moisture basis) on LAD (leaf area m² days/m² land area) from emergence to physiological maturity for 12 growth analysis experiments for Porrillo Sintético at CIAT from 1975-77.**

The regression of yield on LAD for various periods of growth are shown below:

Yield (Y) *vs.* LAD (emergence to maturity): $Y = 55 + 1.73X, r = 0.82$
Yield (Y) *vs.* LAD (emergence to flowering): $Y = 155 + 3.49X, r = 0.80$
Yield (Y) *vs.* LAD (flowering to maturity): $Y = 45 + 2.94X, r = 0.78$

From these data, it is obvious that a general increase in leaf area at all growth stages may be necessary rather than particular emphasis on the post flowering period. It is also obvious from the overall data that a high LAD before flowering normally means a high LAD after flowering. This also implies that an increase in

LAD and presumably photosynthate supply, leads to increased sink size and also to increased post-flowering source to fill the available sink.

The relationship of crop growth rate (CGR, g/m²/day) of Porrillo Sintético for the above-ground portion of the crop to leaf area index (LAI) is an important consideration with respect to the above conclusions. Crop growth rate was calculated from the weekly total dry matter samplings up to 56 days from emergence (heavy leaf loss after 56 days prevents an assessment of CGR for the whole crop during the maturation phase). The data (Figure 12) show a curvilinear relationship to mean LAI with a mean maximum growth rate of ~ 12 g/m²/day at LAI between 3.0 and 4.0. Up to a mean weekly LAI of ~ 4.0 m²/m² there is no real suggestion of an optimum type response in these data. Variability of CGR within a particular LAI range was probably associated with lodging, solar radiation received, and other factors. Research is continuing on the factors associated with this variability. Any improvement in maximum LAI above average levels may

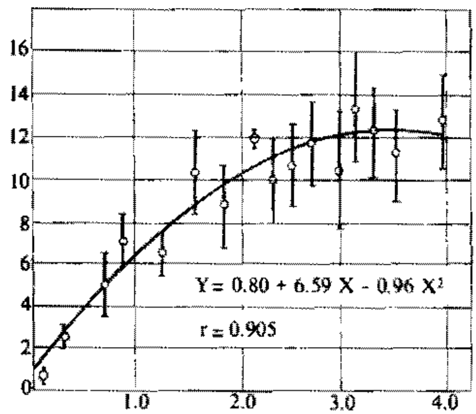


Figure 12. Relationship of CGR (g/m²/day) to mean LAI. Mean of weekly samplings in 12 growth analysis experiments with Porrillo Sintético at CIAT, from 1975-77.

not be associated with increases in CGR at higher LAI values. However, if lodging resistance can be improved, increased maximum leaf area should result in the maintenance of a higher LAD.

High yields in experiments 7616, 7630 and 7707 were associated with either (a) an increased length of the growth cycle by manipulating the flowering date using photoperiod response (for 7616), or (b) were within the normal growth cycle for this variety (for 7630 and 7707). In the latter case, both crops had little lodging and disease, insect and soil problems were minimal (Table 27).

GROWTH AND YIELD IN RELATION TO GROWTH HABIT

A summary of growth analysis data for five varieties, representative of the four growth habits defined at CIAT is presented in Table 29. Mean yield range in the data is typical for the varieties at CIAT under monoculture conditions. Mean data for Porrillo Sintético from Table 26 is included for comparison (treatments in experiment 7616 which were influenced by artificially increased daylength have been excluded).

While less data is available for these growth habits the conclusions which can be drawn are similar to those for Porrillo Sintético. Increased node structure and leaf area are strongly related to yield. The comparative earliness of the determinate varieties (P635 and P788) apparently limits the maximum leaf area and thus the LAD. Mean yield per day is slightly lower than in Porrillo Sintético.

Leaf area efficiency (bean yield/LAD) for the four nonclimbing varieties is very similar ranging from 1.95 to 2.12 g/m² days/m². This strongly suggests that the differences in canopy type in these lines does not greatly influence the yield capacity of the photosynthetic system. However, leaf area efficiency for the

Table 29. **Mean yield and other parameters measured for five cultivars from four types in growth analysis experiments at CIAT, 1975-77.**

Parameters	P635 I	P788 I	P566 II	P498 III	P589 IV	r[1]
	Cultivar and Growth Habit					
Mean yield (14% moisture), g/m^2	230	242	273	322	365	
Number of experiments	3	2	9	3	3	
Pod number/m^2	142	246	216	265	294	-
Bean per pod	2.55	3.20	5.56	4.36	5.69	-
Bean size, mg/bean	544	272	195	240	185	-
Maximum node number/m^2	363	413	587	923	864	0.94
Maximum leaf area index	3.03	3.43	3.57	4.14	5.99	0.94
LAD[2] (E-F)[3]	23	18	36	41	81	0.93
LAD (F-M)	95	96	94	123	180	0.91
LAD (E-M)	118	114	130	164	261	0.93
Days to flowering (E-F)	25	25	33	33	41	0.95
Days to maturity (E-M)	64	67	73	81	89	0.99
Yield/day (planting to maturity)	3.31	3.36	3.51	3.73	3.88	0.83
Yield/LAD (E-M)[4]	1.95	2.12	2.10	1.96	1.40	-

1 Correlation with yield (r)
2 LAD m^2 days m^2
3 E = emergence, F = flowering, M = physiological maturity.
4 Leaf area efficiency, g/m^2 days/m^2 land area.

climbing variety used here was much lower even when supported on a trellis, possibly due to excessive leaf area development (maximum LAI 5.99) which caused self shading of the lower leaves. This conclusion is supported by yield profiles by node reported for P589 in the CIAT Annual Report, 1976.

Crop growth rate data for the limited number of cycles with P589 suggests a lower rate of growth at higher LAI values than was the case with P566. Further data will be needed to reach firm conclusions.

CROP MANIPULATION

Carbon Dioxide Fertilization

In the first experiment carbon dioxide supplementation (1200 ppm) was applied to Porrillo Sintético growing in 1 m^2 open-topped, ventilated chambers over two growth periods: (a) Period 1(-5 to +15 days from flowering); and (b) Period 2(-5 to +35 days from flowering). The objective was to evaluate the relative importance of increased photosynthate supply during the period after first flowering when final pod number is being determined (Period 1) compared to the whole of the flowering, pod set and bean filling period up to physiological maturity (Period 2). A 40 percent yield increase was obtained in Period 1, compared to 43 percent in Period 2 (Table 30). The benefits of increased photosynthate supply appear to be of primary importance during the immediate post-flowering period due mainly to increased pod set and mature beans/pod. An additional 20 days of CO_2 supplementation in Period 2 produced only a 3 percent yield increase over Period 1.

Table 30. **Effect of carbon dioxide fertilization[1] applied over two periods on yield and other parameters of Porrillo Sintético at CIAT.**

Period[2]	Treatment	Yield in g/m² (14% moisture)	No. Pods/m²	No. Beans/Pod	Mean Bean Wt. mg/bean	Node No. Maturity 1/m²	Total Dry Weight	Harvest Index
-5 to +15	CO_2	340 (140)	264	5.63	195	545	494	(59.1)
	Control	243 (100)	221	5.11	185	507	367	(56.9)
-5 to +35	CO_2	446 (143)	328	5.44	215	542	660	(58.3)
	Control	311 (100)	244	5.16	213	535	466	(57.4)
L.S.D. 0.05		33	25	0.32	11	53	54	(2.1)
C.V.%		9.0	8.9	4.4	3.9	7.8	8.0	(3.7)

[1] Applied to 1m² ventilated open-topped chambers in the field at 1200 ppm CO_2 (approx. 900 ppm above ambient CO_2 levels); control chambers ventilated at ambient CO_2 level.

[2] Days from flowering.

Increased photosynthate supply did not significantly alter final node number suggesting that overall canopy structure was not altered. The increased dry matter production was divided between vegetative and reproductive parts with a slight increase in harvest index in the CO_2 treatment in both periods.

The results strongly suggest that photosynthate supply in the immediate post-flowering period controls pod set and yield in this variety. An improvement in photosynthate supply should be possible by either increasing leaf area and leaf area duration or by increasing the photosynthetic efficiency of the available leaf area. Both will be aided if stem erectness and lodging resistance can also be improved.

Carbon Dioxide/Major Element Fertilization

A second experiment was conducted to test the hypothesis that foliar application of major nutrients (N, P, K and S) to the canopy could increase yield although the crop had been fertilized with all the critical elements at sowing. Research in soybeans in the United States had suggested this possibility. The possibility of an interaction between increased photosynthate supply and increased nutrient supply was also evaluated. The results of a 2x2 factorial experiment with the appropriate treatment combinations are presented in Table 31. The overall yield increase due to CO_2 fertilization from -5 to +35 days from flowering was only 21 percent (Treatment 1) compared to 43 percent in the first experiment. The crop was well grown and lodging was not a problem: leaf area of adjacent control crops approached 4.0m²/m². Probably, the control canopy was more efficient in this experiment suggesting that photosynthate supply was not as limiting. The effects of NPKS fertilization were entirely additive with no suggestion of a positive interaction. A 6 percent increase in yield was recorded for NPKS application with or without CO_2 fertilization. In this experiment, the yield increase due to CO_2 supplementation was related almost entirely to an increase in pod set which emphasizes the importance of photosynthate supply during this phase.

Foliar Fertilization at Different Growth Stages

An experiment was also conducted to

Table 31. **Effect of carbon dioxide fertilization (-5 to +35 days from flowering) and foliar application of NPKS on yield and parameters of Porrillo Sintético at CIAT.**

Treatment[1]	Yield g/m²	Pods/ m²	Beans/ Pod	Bean Weight in mg/bean	Node Number 1/m²	Total Dry Matter g/m²	Harvest Index %
CO_2	471(121)	328	5.64	219	605	706	57.4
NPKS	412(106)	286	5.73	216	501	608	58.3
CO_2 + NPKS	493(126)	330	5.83	220	505	716	59.2
Control	390(100)	273	5.59	219	504	574	58.4
Field plot	353(90)	248	5.78	212	527	510	59.5
L.S.D. 0.05	45	36	0.52	13	62	63	3.8
CV. %	6.6	6.5	4.8	3.1	6.2	5.4	3.4

[1] Treatments 1-4 in 1m² chambers; CO_2 treatments 1200 ppm CO_2; NPKS equivalent to 80:12 23:5 kg/ha in 5 foliar applications; field plot and control yield without chambers.

evaluate the effects of NPKS application at different growth stages and with increasing applications up to a maximum of 80: 12:23:5 kg/ha of NPKS, respectively. Yield data is presented in Table 32. Most treatments produced a slight but non-significant increase (mean 5.2 percent) in yield which supports the results of the

Table 32. **Yield and yield components of Porrillo Sintético for 10 foliar spray application treatments[1] of NPKS applied at 5 different growth stages at CIAT.**

Total Nutrient Application NPKS kg/ha	Stages[2] of growth	Yield (14%) g/m	No. Pods 1/m²	No. Beans/ pod	Bean Wt. in mg/bean	N % Beans
Control	-	312 (100)	239	5.71	228	4.21
80:12.0:33.0:5.0	1,2,3,4,5	323 (104)	252	5.51	232	4.02
16: 2.5: 6.6:1.0	1	339 (109)	253	5.70	235	4.10
16: 2.5: 6.6:1.0	2	313 (100)	231	5.72	236	4.14
16: 2.5: 6.6:1.0	3	333 (107)	257	5.59	239	4.08
16: 2.5: 6.6:1.0	4	332 (106)	249	5.33	234	4.10
16: 2.5: 6.6:1.0	5	320 (103)	244	5.26	237	4.22
32: 5.0:13.2:2.0	1,2	328 (105)	255	5.49	233	4.11
48: 7.5:19.8:3.0	1,2,3	339 (109)	280	5.13	223	4.18
64:10.0:26.4:4.0	1,2,3,4	324 (104)	250	5.39	237	4.18
L.S.D. 0.05		39	36	0.59	16	0.20
C.V. %		8.2	9.5	7.5	4.8	3.3

Applied as urea, potassium sulphate and potassium polyphosphate neutralized with phosphoric acid and applied in aqueous solution at the rate of 16:2.5:6:1 kg/ha of NPKS per growth stage.
Growth stages: 1= -7 days from flowering; 2= day of flowering; 3= +7 days; 4= +14 days; 5= +21 days.

previous experiment. While further research may be necessary, it appears that when a bean crop is well provided with soil-applied nutrients at planting there does not appear to be any real response to the use of foliar-applied soluble nutrients during the growth cycle. On the other hand, where definite soil deficiencies exist, foliar applications could be of value when applied at critical growth stages.

ADAPTATION COMPONENTS

Research continues on physiological components of adaptation considered important in determining the range of adaptation of germplasm. Screening methods are being developed to select suitable parents with desirable characteristics. The components under evaluation include: photoperiod sensitivity, excess soil water tolerance, water stress resistance, temperature (altitude) adaptation, planting density response and growth habit stability. The latter is under study at Cornell University in a collaborative research project; work in this area at CIAT will begin in 1978.

Screening for Photoperiod Response

Photoperiod screening of all promising lines has been completed by studying the phenology of the material under the lights (18 hr/day) compared to that of controls grown at the normal day length (12hr 20 min). The field light system for screening was altered prior to the last two screenings to accommodate more materials. The new system utilizes an overhead light bank (83 x 300 w incandescent bulbs mounted 2.5 m over an area 25 m x 25 m). The system accommodates 500 different materials grown in staked hill plots (1 m x 50 cm) in two replications per treatment.

A comparison of the earlier linear light system with the new overhead method for 10 test varieties is presented in Table 33. The close agreement between methods suggested that the results for all four screenings could be combined. A summary of the combined data for 808 materials, mostly P lines, is presented in Table 34. Forty-one percent of the lines tested were photoperiod insensitive (< 4 days flowering delay in 18 hr days). The data also

Table 33. **Comparison of two systems to screen for photoperiod response at CIAT: comparison of data for number of days of flowering delay in 18 and 12hr 20 min photoperiods for 10 control varieties.**

Promising Line Tested/ Experiment	Days of Flowering Delay			
	Linear Light Source		Overhead Light Source	
	Experiment 7501A	Experiment 7501B	Experiment 7617	Photoperiod[1] Classification
P005	17	10	15.5	3N
P006	0	1	1.5	1N
P008	15	15	15	3N
P012	-1	2	0.5	1N
P302	1	-2	0	1N
P306	23	21	23.5	4N
P459	7	3	0.5	1N
P566	14	10	13.5	3N
P514	29	18	16.5	3N
P540	16	16	17	3N

[1] 1N =<4 days delay; 2N=4-10 days delay; 3N= 10-20 days delay; 4N=20-30 days delay; 5N = 30 days delay. N = absence of abnormal flower abscission in long days.

Table 34. **Summary of combined data for photoperiod response screenings by growth habit of germplasm selections at CIAT, from 1975-77.**

Growth Habit	Classification of Photoperiod Response					Total
	1	2	3	4	5	
	<4[1]	4-10	11-20	21-30	> 30	
I	97	22	59	30	18	226
	(43)[2]	(10)	(26)	(13)	(8)	(100)
II	163	40	67	17	7	294
	(55)	(14)	(23)	(6)	(2)	(100)
III	61	26	41	38	40	206
	(30)	(13)	(20)	(18)	(19)	(100)
IV	15	7	18	10	32	82
	(18)	(9)	(22)	(12)	(39)	(100)
Total	336	95	185	95	97	808
	(41)	(12)	(23)	(12)	(12)	(100)

1 Days of flowering delay at 18hr days as compared to natural daylength of 12hr 20 min
2 Data in table gives number and percent of genotypes within growth habits

confirmed the tendency reported earlier for a lower proportion of insensitive materials in growth habits III and IV. In particular, the very high proportion (39 percent) of extreme sensitivity (>30 days delay) in the Type IV material is an interesting feature of these data. Evaluation of possible reasons for this tendency is somewhat hampered since the exact origin of the original germplasm material is often unknown.

The importance of photoperiod insensitivity in beans with respect to wide adaptation has not yet been fully evaluated, but when complete results of the first IBYAN have been analyzed a clearer picture should emerge. One of the objectives of Ideotype B breeding (CIAT Annual Report 1976) at CIAT is to increase the preflowering period. While the search for lateness to flower in photoperiod insensitive and acceptable agronomic types in the germplasm bank has not proved very fruitful to date, lateness for higher latitudes (i.e. >15ºN or S) could be improved by using parents with intermediate levels of sensitivity. Provided the relevant cropping system allows production during long days (i.e.>12 hours), an increase in the preflowering period should result, relative to photoperiod insensitive material.

Screening for Tolerance to Excess Soil Water

Bean production in some parts of the world is limited by heavy rainfall leading to water logging in poorly drained soils. Two experiments evaluated a possible screening method for tolerance to excess soil water under CIAT conditions. A suitable site was leveled and banks constructed so that water could be maintained in furrows at a height of 5 to 8 cm below the crest of two row beds (1 m center to center). Water was maintained at this height from 12 days after emergence until physiological maturity. In the first experiment 25 P lines were

Table 35. **Yield[1] data for first experimental screening at CIAT for excess soil water tolerance for selected varieties.**

P Line	Name	Growth Habit	Yield g/m Control	Yield g/m Excess Water	% Yield Reduction
P566	Porrillo Sintético	II (B)[2]	240	207	14
P757	Porrillo 1.	II (B)	228	175	23
P675	ICA-Pijao	II (B)	260	190	27
P458	ICA Tui	II (B)	243	175	28
P511	S-182N	II (B)	241	141	41
P302	PI 309 804	II (B)	248	135	46
P643	Nep 2	II (W)	219	117	47
P788	PI 284 703	I (Y)	216	115	47
P737	Jamapa (VEN)	II (B)	268	142	47
P459	Jamapa (CRI)	II (B)	271	141	48
P692	Diacol Calima	I (R)	242	112	54
P637	Línea 17	I (R)	252	109	57
P512	S-166 AN	III (B)	297	118	60
L.S.D. (Var x Treat.) 0.05			49.9		
C.V. %			16.2%		

1 Mean of three replications per treatment

2 Seed color: B= black; W=white; Y=yellow; R=red.

evaluated and 100 lines in the second. The results suggest that large genetic differences exist for resistance to excess water in the material evaluated. Table 35 shows that the 'Porrillo' types (P566, P757, P675) showed excellent tolerance while the 'Jamapa' type material (P302, P737, P459) had a relatively uniform yield reduction of 46 to 48 percent. The largest yield reduction in the first experiment (60%) was for the black-seeded P512. While black Type II varieties showed the highest tolerance level, it is clear that the response is not related to seed color *per se*. A summary of the screening results for the second experiment is presented in Table 36.

Table 36. **Results[1] of the second excess water tolerance screening experiment at CIAT: data for the number of varieties within three tolerance classifications by growth habit.**

Growth Habit	Percent Yield Reduction[2] Low <40%	Moderate 40-68%	High > 68%	Total
I	6	14	1	21
	(29)	(67)	(4)	(100)
II	4	26	5	35
	(11)	(74)	(14)	(100)
III	2	19	6	27
	(7)	(71)	(22)	(100)
Total	12	59	12	83[1]
	(14.0)	(71.1)	(14.4)	(100)

1 100 varieties screened, 17 excluded due to the virus symptoms.

2 Percent yield reduction: Yield Control-Yield Treatment/Yield Control (in percent); mean percent yield reduction 54 ± 14.

Screening for Water Stress Resistance

In previous stress screenings, many materials were poorly adapted to Peruvian coastal plain conditions at La Molina. An experiment was conducted at CIAT to evaluate a possible screening method using infrared thermometry. A hand-held thermometer, sensitive to ± 0.2°C, with a target zone of 20 to 30 cm diameter was used to evaluate the canopy temperature differential (ΔT) between irrigated plots and those experiencing water stress during a drying cycle following irrigation. Stomatal closure during the onset of stress normally results in higher canopy temperatures up to a limit determined by the reradiation characteristics of the leaves. Varieties experiencing progressively higher Δ T values during a drying cycle suffer higher levels of tissue water stress. Measurements were initiated at approximately maximum leaf area index (7 days after previous irrigation) at 1100-1230 daily in 44 varieties (growth habits I,II and III). Results are available for five days of measurements before the first rains of the wet season in September 1977 forced early termination of the study. Data in Figure 13 show Δ T values for two extreme genotypes P692 and P729. Measurements for P692 indicated that it suffered greater stress which was also verified by visual observation. P729, which was previously identified in Peru (CIAT Annual Report, 1975) as having possible stress resistance, had a stressed canopy temperature slightly below the control plot. Table 37 summarizes the Δ T readings over five days according to growth habit. There is a definite tendency for higher "stress" in Type I materials compared to the indeterminate types which was also verified in field observations.

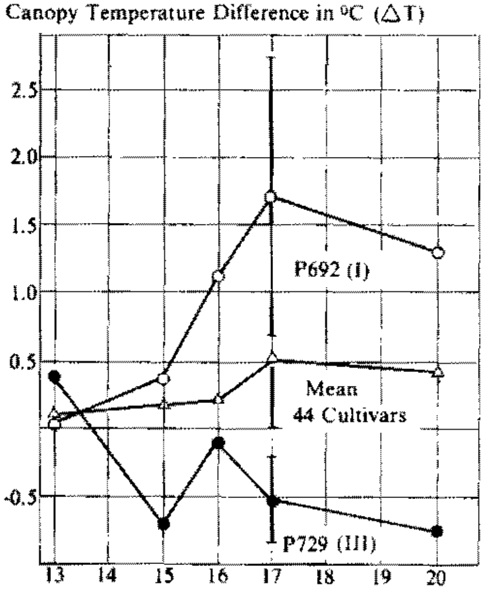


Figure 13. Canopy temperature differences (days) for 5 days during a drying cycle for 2 varieties showing contrasting responses and the mean of 44 cultivars.

Table 37. Summary of canopy temperature screenings of 44 materials according to the numbers of materials in each growth habit within differential canopy temperature ranges.

Growth Habit	Differential Canopy Temperature °C <0.20	0.20-0.40	>0.40	Total
I	3	4	7	14
II	8	4	3	15
III	6	5	4	15

The results are promising for quickly and quantitatively evaluating water stress resistance on large numbers of materials without relying on the subjective method of visual scoring or other more time-consuming methods. Dry season research at CIAT is planned to correlate the results of the method with yield reductions in stress treatments. The method could provide a useful tool for screening of advanced material.

Screening for Temperature Adaptation

In uniform yield trials by the agronomy group at various altitudes in Colombia and Ecuador certain germplasm selections showed good adaptation over a range of altitudes, from 14-1,900 msl. On the other hand, other materials showed poor adaptation at lower altitudes. Forty contrasting genotypes (10 from each growth habit) were selected for physiological evaluation at four altitude/temperature regimes. Soil fertilization and liming were applied to reduce the influence of adverse soil conditions. Disease control was also effected to avoid interactions with respect to differential disease resistance in the material.

Experimental data are available for the first three locations. Of the 40 varieties, data for 8 were not included due to severe virus symptoms at CIAT. In addition, the trial at Popayán suffered water stress at various growth stages due to lack of irrigation facilities and overall yields were low.

The data in Table 38 gives yield of cultivars in Types I and IV where the largest cultivar x temperature interactions were measured. In Type I, P637 showed above average yields at each location while Diacol Andino proved poorly adapted at lower altitudes but very well adapted at the highest altitude, almost equalling yield of P637 at 1900 msl. This same pattern was repeated for P589 in the Type IV group which showed excellent adaptation at all altitudes, while P590 (Cargamanto) produced virtually no yield at the lower altitude locations. Although P590 plants were vegetatively vigorous, they produced only isolated pods with very few seeds. The cultivars P759 (I) and P260 (IV) showed some tendency to decrease relative yields with increasing altitude but this could be related to the dry conditions at Popayán in the latter part of 1976 rather than to temperature conditions *per se*. The experiments are being repeated this year and the physiological factors associated with these interactions are being evaluated.

The data in this and other trials including the 1976 IBYAN show that *Phaseolus* germplasm has quite a wide

Table 38. **Yield of selected varieties from temperature adaptation experiments at three altitudes in Colombia: CIAT; Las Guacas, Cauca; Dagua, Valle.**

Location	Dagua	CIAT	Las Guacas
Altitude, m	825	1001	1850
Temperature mean °C	25.1	23.9	19.1
Temperature max. °C	29.7	28.7	24.7
Temperature min. °C	20.6	19.2	13.5
Identification	Bean Yield in g/m² (14% moisture)		
Growth Habit I			
P637	198(120)[1]	314 (113)	169 (115)
Diacol Andino	36 (22)	200 (72)	166 (113)
P759	206 (124)	316 (114)	115 (78)
Mean of G.H. I (n = 8)	165 (100)	278 (100)	147 (100)
Growth Habit IV			
P589	402 (142)	382 (130)	197 (113)
P590	7 (2)	20 (7)	150 (86)
P260	323 (114)	298 (102)	161 (92)
Mean of G.H. IV (n=8)	282 (100)	293 (100)	175 (100)

1 Percent of the mean yield within each growth habit.

adaptation with respect to temperature conditions within a range 18-26ºC mean growing season temperature.

Screening for Response to Planting Density

Results reported in 1976 showed a variety x density interaction in bush beans. Recommendations for ideotype development at CIAT include Ideotype C with expected adaptation to low density production conditions typical of most small farms in Latin America. One-hundred promising materials were screened at two densities (8 plants/m^2 and 30 plants/m^2) in early 1977 to evaluate parents for this ideotype. Results suggest that there are differences in density response characteristics. The field variability encountered was very high and the experiment is being repeated. Results of density trials at CIAT were heavily influenced by lodging and to some extent, by "Problem X" which appears to be density dependent for its expression. Symptom severity is highly variety-dependent.

Microbiology

This year, varietal differences in nitrogen fixation and cultural factors affecting active nitrogen fixation were emphasized. Computer programs for data storage relating to the *Rhizobium* collection were also developed (see also Microbiology section, Beef Program and Biometrics Unit reports).

VARIETAL DIFFERENCES IN NITROGEN FIXATION

During 1977, more than 700 P lines were evaluated for symbiotic nitrogen fixation with CIAT 1057 at Popayán. Although cultivars were generally poorly adapted to the lower temperatures, determinate, early flowering cultivars such as P635 consistently fixed less nitrogen than indeterminate cultivars in Types III and IV. While this experiment is still being analyzed, these varietal differences were confirmed in other studies undertaken this year.

In Popayán, Type I and II cultivars were evaluated for nitrogen fixation potential in relation to Types III and IV. Eleven cultivars of *P. vulgaris* analyzed included: Type I — P243, P403, P536, P635, P637, and P692; and Type II — P561, Seafarer and Nep 2. P498 (Type III) and P590 (Type IV) were the controls. As in previous studies P590 proved stronger in N_2 fixation than the other cultivars (Fig. 14) with a peak N_2 fixation of 37.7 *u*moles C_2H_4 produced/plant/hour, six weeks after planting. When corrected for diurnal variation in N_2 fixation and using the hypothetical 3: 1 ratio for C_2H_2:N_2 conversion, this cultivar fixed the equivalent of 73.7 kg/ha of nitrogen/cycle (Table 39). This was considerably higher than had been obtained with this cultivar in previous studies. P498, a bush cultivar, also achieved a relatively high fixation rate

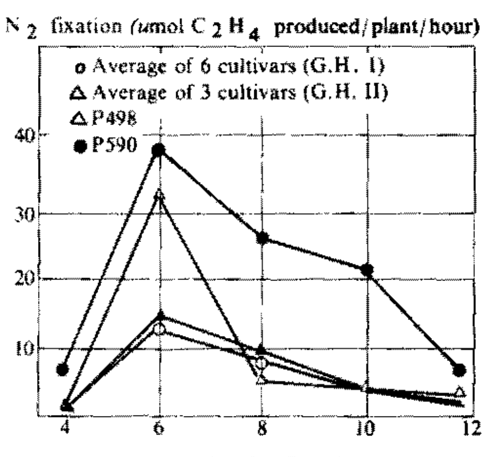


Figure 14. Varietal differences in nitrogen fixation in relation to growth habit.

Table 39. **Parameters of nitrogen fixation in 11 cultivars of *Phaseolus vulgaris*, 6 weeks after planting.**

Identification	Nodule Dry Weight mg/plant	SNA[1]	Acetylene Reduction[2]	Theoretical N_2 Fixation/ha	Growth Habit	Days to Flowering	Days to Maturity	Yield kg/ha
P243	24	371	8.9	12.2	I	45	110	2,200
P635	32	349	11.2	13.5	I	44	104	2,200
P692	35	318	12.8	27.6	I	47	104	1,900
P637	41	383	15.8	25.1	I	47	114	2,300
P402	59	339	20.1	25.1	I	47	110	2,300
P536	34	294	10.0	18.2	I	41	114	2,800
P561	34	257	8.8	19.8	II	43	110	3,000
Seafarer	33	539	17.6	21.2	II	45	120	1,900
NEP-2	29	447	12.9	26.0	II	53	116	2,600
P498	75	431	32.2	34.5	III	50	104	3,600
P590	106	355	37.7	73.7	IV	66	130	3,800

1 μmol C_2H_4 produced/g nodule dry weight/hour

2 μmol C_2H_4 produced/plant/hour

but no other Type I or II cultivar approached this level. It is often inferred that cultivars active in nitrogen fixation will be poor yielders. Here, P498 had both higher yield and more active nitrogen fixation than other bush cultivars.

In this experiment, the soluble carbohydrate content of nodules and concentration of soluble carbohydrates were greater in P590 than in P498 (Fig. 15). Further studies with these two cultivars are underway.

DENSITY EFFECTS ON NITROGEN FIXATION

The effect of planting density on nitrogen fixation in P498, P590 and P635 was studied using the Bleasdale parallel row design. Between and within row spacings were varied on a 1.1/1.0 ratio and plant densities increased from 5.5 to 120 plants/m².

At 39 days after planting, the effect of population density on nitrogen fixation varied according to cultivar. On a per plant basis, N_2 fixation of P590 peaked at 8.5 plants/m² and rapidly declined at higher densities (Fig. 16). P498 reached a maximum at 18.5 plants/m and slowly declined

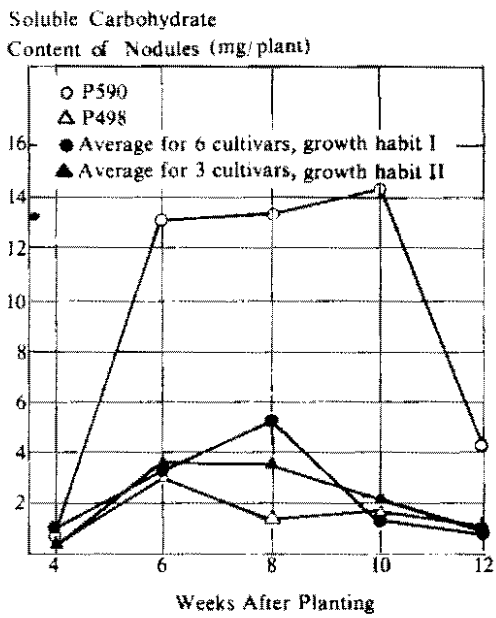


Figure 15. **Differences in the soluble carbohydrate content of nodules in 11 cultivars of *Phaseolus vulgaris*, in relation to growth habit.**

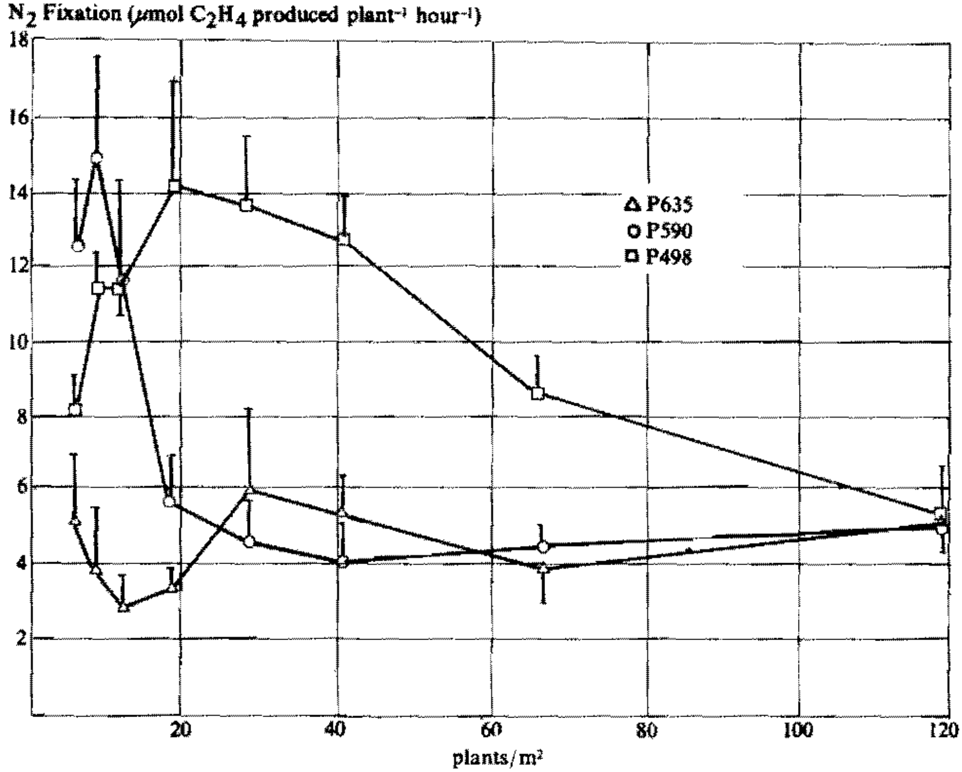


Figure 16. **Influence of planting density on nitrogen fixation in 3 cultivars of *Phaseolus vulgaris*, 39 days after planting.**

at higher densities. However, N_2 fixation per unit land area showed that all three varieties had maximum fixation at the highest density (Fig. 17a). The relative insensitivity of nitrogen fixation in P498 to plant density parallels yield-density responses in this cultivar (CIAT Annual Report, 1976).

Although some variation in specific nodule activity (SNA) was detected (Fig. 17b), much of the difference in fixation was attributable to change in nodule fresh weight/plant (Fig. 18). Increasing density also changed the pattern of nodulation in all three cultivars. At the higher plant densities, nodules contained both an increasing proportion of the total plant carbohydrate (Fig. 19) and somewhat elevated concentrations of soluble carbohydrate (Fig. 20).

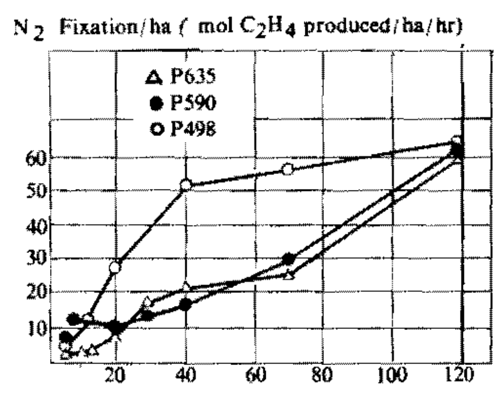


Figure 17a. **Effect of planting density on nitrogen fixation in 3 cultivars of *Phaseolus vulgaris*.**

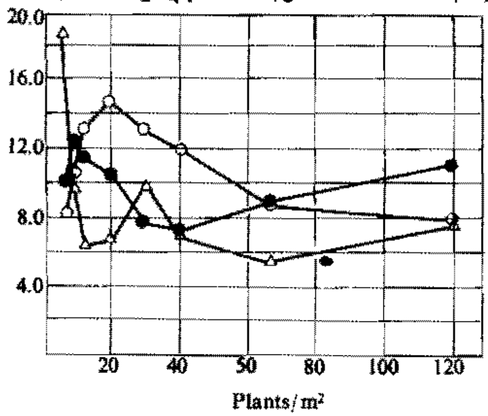


Figure 17b. Effect of planting density on specific nodule activity in 3 cultivars of *Phaseolus vulgaris.*

EFFECTS OF BEAN/MAIZE ASSOCIATION ON BEAN NITROGEN FIXATION

The influence of a bean/maize association on bean nitrogen fixation was evaluated using bean cultivars P590 and P526 and two maize populations — one a vigorous type used on small farms and the other similar to improved maize types.

Bean plant and pod weight/plant for P590 in monoculture, or associated with the two maize populations is shown in Figure 21. When P590 was grown with Amarillo Tropical, plant growth and pod development was not significantly different from that obtained in monoculture, even at 92 days after planting. However, plant and pod development was reduced when P590 was associated with the more vigorous landrace maize. Plant development for the bean cultivar P526 was inhibited by association with the landrace maize (Fig. 22) as early as 50 days after planting. Although monoculture maize plots were not planted for com-

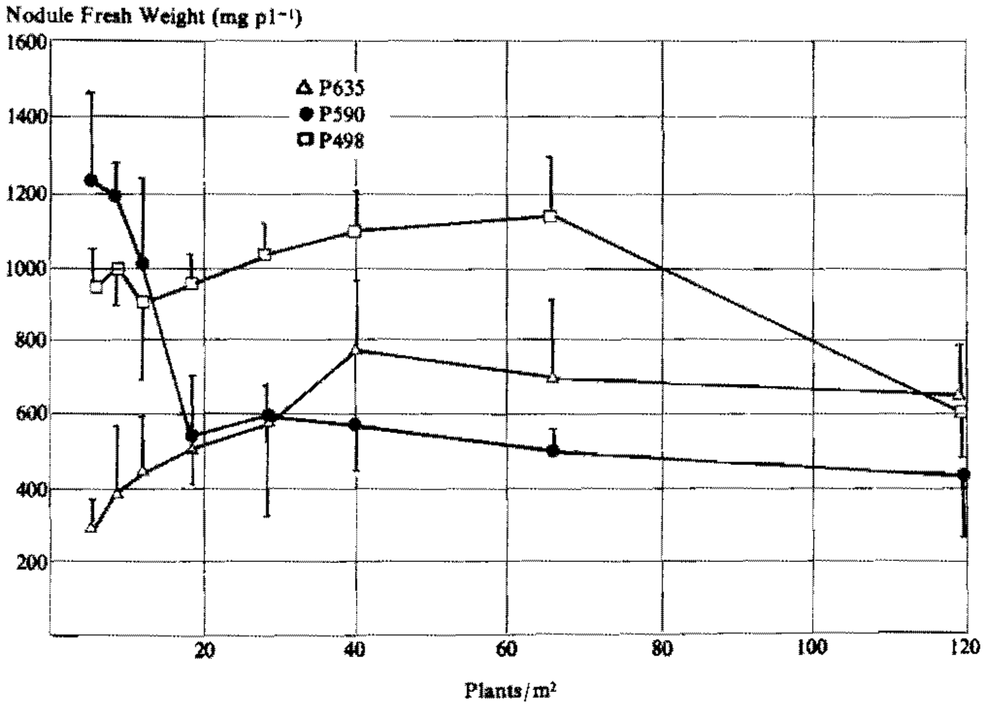


Figure 18. Influence of planting density on nodule fresh weight in 3 cultivars of *Phaseolus vulgaris* 39 days after planting.

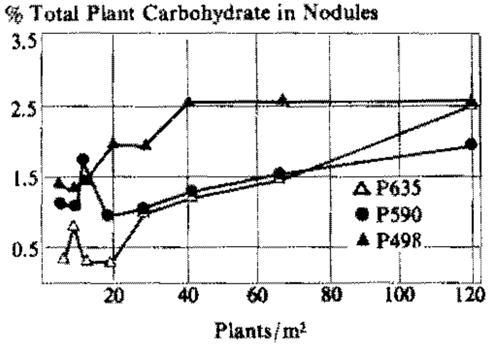


Figure 19. Influence of planting density on the percentage of total plant carbohydrate recovered in nodules of 3 cultivars of *Phaseolus vulgaris*.

parison, both maize populations tested developed less vigorously in association with the more aggressive P590 than with P526.

Figure 23 shows seasonal profiles of N_2 fixation for P590 and P526, grown in monoculture or associated with maize. With P590, fixation reached a maximum of 20.6 μmoles/plant/hour, 68 days after planting and declined rapidly thereafter. No difference was detected between fixation levels and duration in monoculture or associated with maize. In the symbiotically weaker P526, maximum fixation in monoculture occurred 50 days after planting. Fixation was reduced slightly by association with either maize. By the 68 day harvest, fixation in all P526 treatments had declined, and no further differences were apparent. It appears therefore that while competition for light and/or nutrients limits plant development in maize/climbing bean associations, this

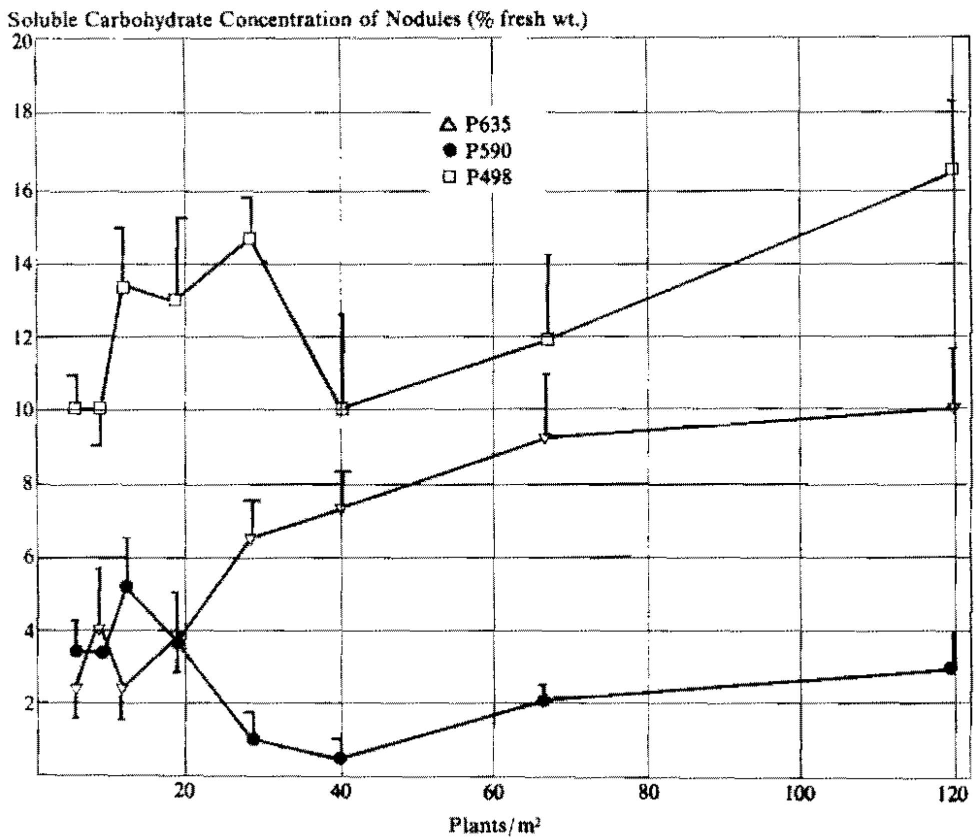


Figure 20. Effect of planting density on the ethanol soluble carbohydrate content of nodules in 3 cultivars of *Phaseolus vulgaris*.

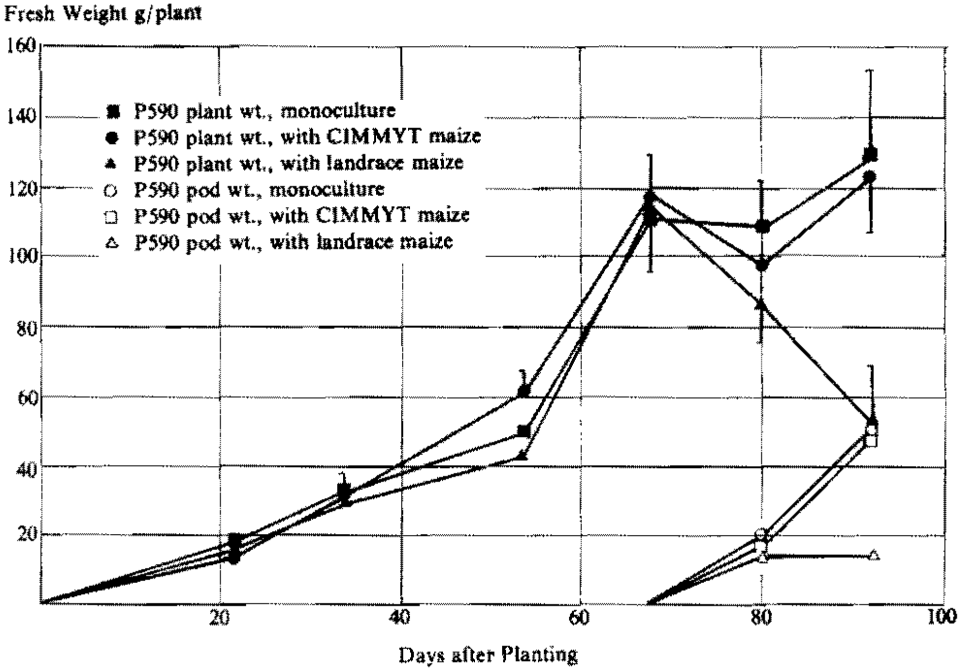


Figure 21. **Bean plant weight and pod weight for the cultivar P590 grown in monoculture or associated with a landrace or CIMMYT maize.**

growth limitation does not normally occur during the period of active nitrogen fixation. Studies are in progress to evaluate fixation in maize/bush bean associations.

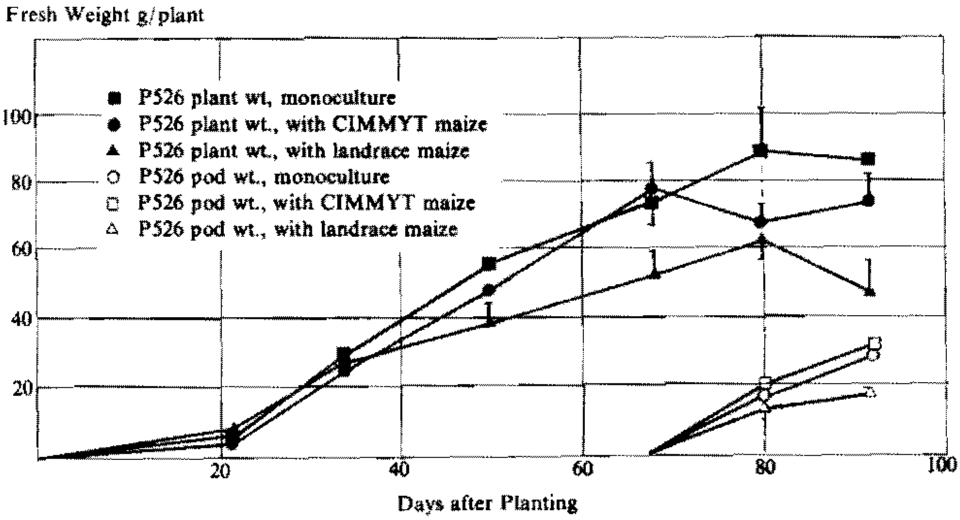


Figure 22. **Bean plant weight and pod weight/plant for the cultivar P526 grown in monoculture or associated with a landrace or CIMMYT maize.**

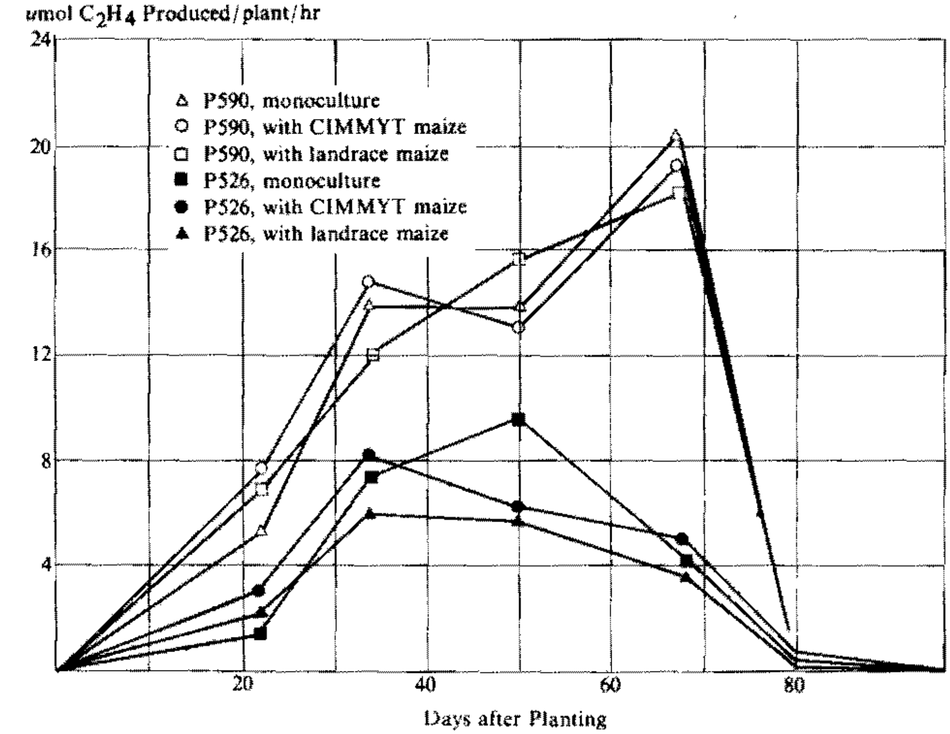


Figure 23. Seasonal profiles in N_2 fixation for P590 and P526 grown alone or associated with a landrace or CIMMYT maize.

PHOSPHORUS FERTILIZATION AND NITROGEN FIXATION

The CIAT Annual Report for 1976 showed tested black beans slightly more tolerant to low soil phosphorus than colored cultivars. This year, cultivar-phosphorus interactions and their influence on nitrogen fixation were studied. A continuous phosphorus gradient was established in which fertilization with triple superphosphate varied from 0-750 kg/ha in increments of 50 kg/ha. Thirty cultivars of *P. vulgaris* were sown along the P gradient and evaluated at flowering and maturity for plant development, phosphorus uptake and nitrogen fixation.

As shown in Figure 24, nodule fresh weight at flowering in each type increased with increasing levels of phosphorus. Type III and IV cultivars consistently produced more nodule tissue/plant.

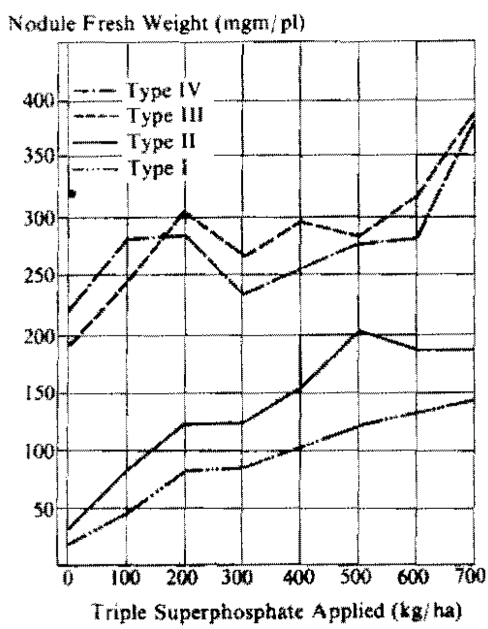


Figure 24. Response in nodule fresh weight development to P fertilization as influenced by growth habit. (Data taken at flowering.)

Nodule fresh weight increased from 28 to 257 mgm/plant and percent of nodule phosphorus from 0.20 to 0.27 percent with increasing phosphorus but root fresh weight increased from 941 to only 2211 mgm/plant and from 0.14 to 0.16 percent P content. Thus increasing P levels increased the percent of P in the nodules and leaves more than in the roots (Fig. 25 a, b).

N_2 fixation at flowering was also markedly influenced by phosphorus supply, though not all cultivars reacted equally. Figures 26 and 27 show nodule fresh weight and fixation increases in four cultivars of *P. vulgaris* relative to the mean for all 30 cultivars. These differences were not due to the production of more nodule tissue per mgm of P in the nodules; to differences in specific nodule activity; nor to the plants' ability to provide a greater percentage of the available phosphorus to

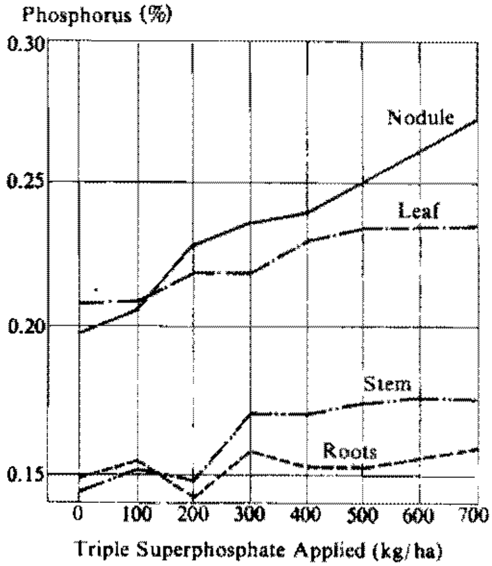


Figure 25b. **Increase in % phosphorus in plant parts as a consequence of increasing P fertilization. (Average of 30 cultivars.)**

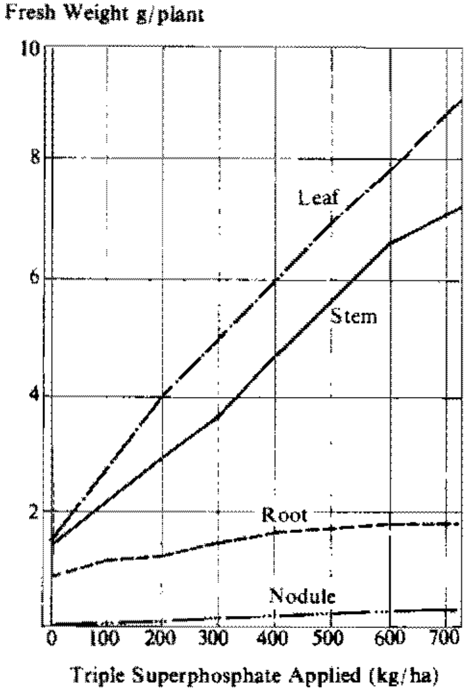


Figure 25a. **Fresh weight increases in individual plant parts as a consequence of increasing P fertilization. (Average of 30 cultivars).**

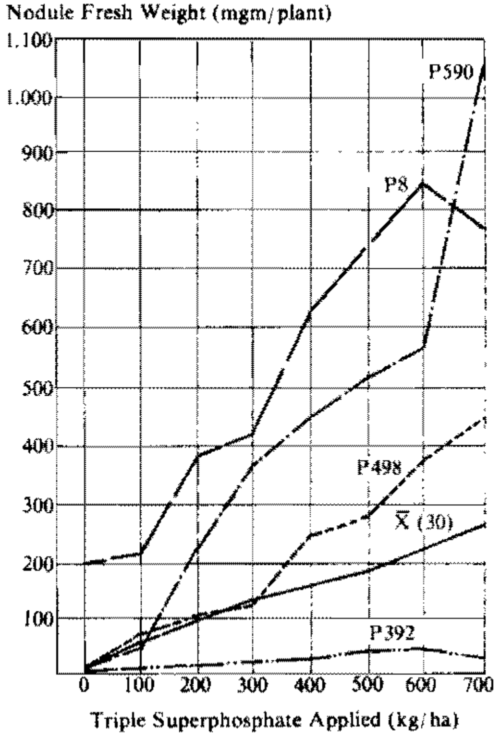


Figure 26. **Nodule fresh weight increases in cultivars of *Phaseolus vulgaris* as influenced by increasing P fertilization. (Data taken at flowering.)**

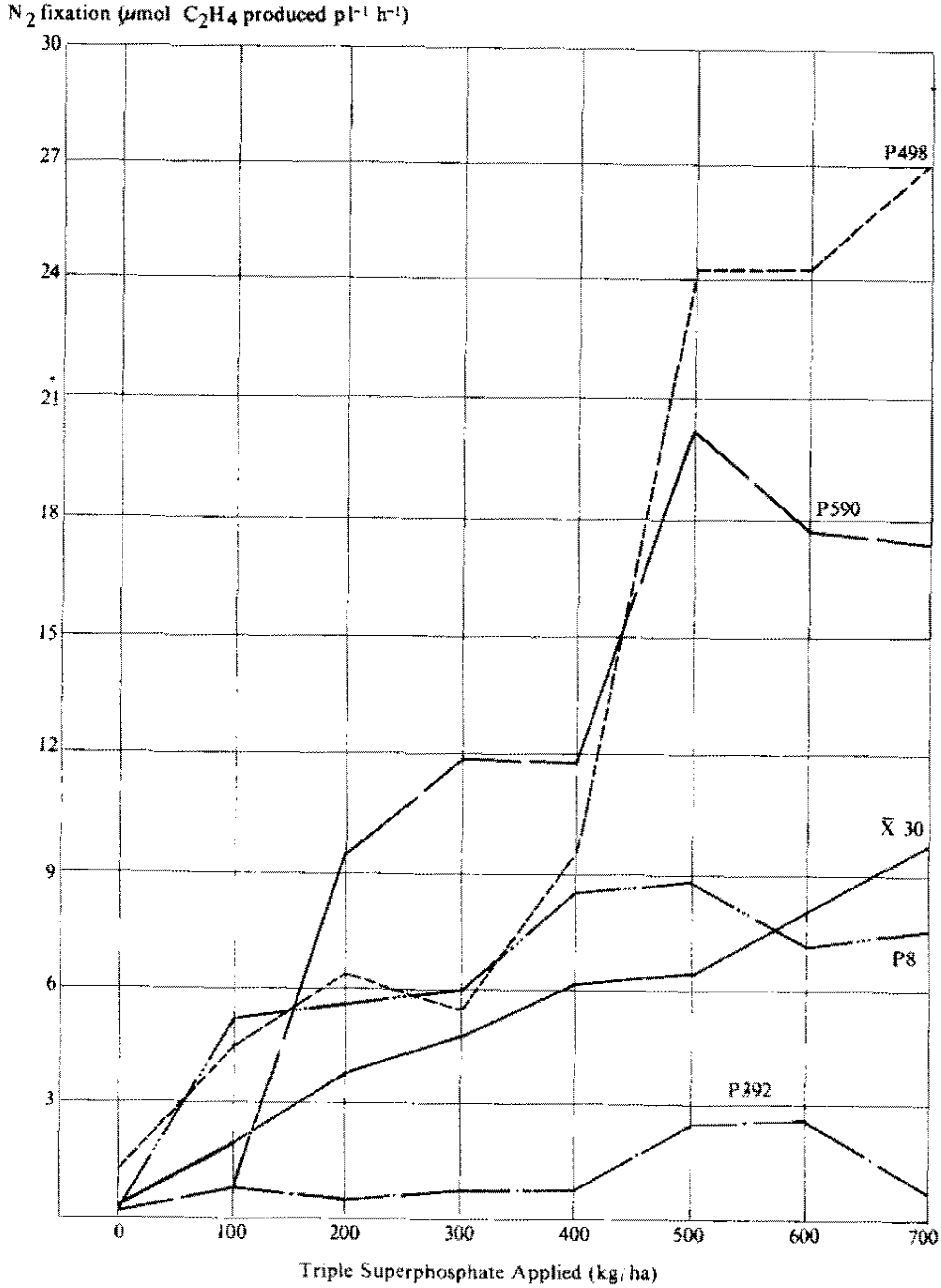


Figure 27. **N fixation in selected cultivars of *Phaseolus vulgaris* as influenced by increasing P fertilization. (Data taken at flowering.)**

the nodules. Although P8 and P498 grew proportionately better at low phosphorus than most cultivars, P590 was below average. Further studies are being done.

Soils and Plant Nutrition

Research continued on major and minor element nutrition of beans; germplasm accessions were screened for tolerance to low soil phosphorus; plant phosphorus requirements were estimated; methods of application and sources of phosphorus were tested. Nitrogen fertilization and the management of alkaline soils were also studied.

SCREENING FOR TOLERANCE TO LOW SOIL PHOSPHORUS

Germplasm selections continued to be screened for tolerance to low phosphorus levels in Popayán. Since previous work indicated that the zero P level was too severe a stress to screen varieties for P tolerance, germplasm was screened at 50 and 300 kg P_2O_5/ha, band-applied as triple superphosphate (TSP) under the seed. Some 432 varieties were planted in single rows with two replicates in each of two plantings. The same P levels were reapplied for the second planting.

Since the direct yield ratio at low/high P levels tended to select varieties with low yields at the high P level due to poor adaptation, a tolerance index was calculated by multiplying yield ratio with the relative yield at the low P-level.

In the first screening, average yields were 85 and 189 g/m² at the 50 and 300 kg P_2O_5/ha, respectively, giving an average tolerance index of 15. Germination was poor due to severe drought after seeding, and plants suffered from water stress throughout the growth cycle. However, 11 varieties yielded over 200 g/m² at the low P level and 4 varieties yielded over 350 g/m² at the high P level.

Table 40 shows the yields of the 10 most P-tolerant varieties and their tolerance

Table 40. **Yield and tolerance index of the 10 most P-tolerant varieties selected in two field screenings in Popayán.**

	1976B Yield in g/m² kg P_2O_5/ha				1977A Yield in g/m² kg P_2O_5/ha		
Variety	50	300	Tolerance Index[1]	Variety	50	300	Tolerance Index[1]
P178	259	249	104	P744	256	173	130
P401	219	201	92	P438	229	183	99
P743	193	163	88	P678	201	145	96
P194	255	302	83	G-04231	236	230	83
P289	235	296	72	P649	291	351	83
P10	188	201	68	P439	231	229	80
P211	196	231	64	P778	199	187	73
P169	122	094	61	P763	214	220	71
P589	186	222	60	P779	161	130	68
P699	206	281	58	P259	204	221	65

1 tolerance index $= \frac{(\text{Yield low P})^2}{\text{Yield high P}} \times \frac{\text{Yield low P}}{\text{Highest yield low P} \times 100} \times 100\%$

index. P178 gave the highest yield at low P and had the highest tolerance index. This was followed by P401 and P743. Thus, it can be seen that several varieties may yield as well or better at a low P level than at a high rate of application.

For the second set of varieties tested, yields were 121 and 181 g/m^2 at the 50 and 300 kg P_2O_5/ha levels, respectively, giving an average tolerance index of 28 percent (Table 40). Due to better climatic conditions and residual effect of P applied in the first screening, yields of the second set were considerably higher. There were 29 varieties yielding over 350 g/m^2 at the high P level. The highest yielding varieties were: P507, P167, P495, P639, and P468.

EXTERNAL P REQUIREMENT OF BEANS

Conventional soil analysis provides a relative measure of phosphorus availability, but does not indicate the P fertilization level required to obtain certain yield levels since this depends on the crop's P requirement, i.e. the P concentration in soil solution to obtain nearly maximum yield, as well as the P fixing capacity of the soil. The latter can be determined by snaking soil for six days with 0.01 M $CaCl_2$ of various P concentrations and analyzing the supernatant solution for P. From this the P-sorption isotherm can be calculated, indicating the amount of P to be applied to a certain soil to obtain a specific P concentration in soil solution.

To determine the P requirement of beans, the variety ICA-Huasano was planted in Popayán in plots to which TSP was applied and incorporated at eight levels ranging from 0 to 2060 kg P_2O_5/ha corresponding to a soil solution concentration range of 0.01 to 0.112 ppm P. The plots were limed at 2 t/ha and received 100 kg N, 5 kg Mg, and 1 kg B/ha, and two bean crops were planted. The second crop measured the residual effect of applied P.

Figure 28 shows the response to applied P for both plantings. While plants suffered from severe drought during the first planting, yields increased from 500 kg/ha without P to 3.7 t/ha at 2060 kg P_2O_5/ha. Although no additional P was applied in the second planting more favorable climatic conditions produced higher yields with a maximum of 3.7 t/ha with the initial application of 870 kg P_2O_5/ha.

Figure 29 shows the relative yield of the two bean plantings in relation to the P concentration in soil solution. The external P requirement of the crop was defined as the P concentration at which 95 percent of maximum yield was obtained. Thus, the requirement for beans was calculated as 0.08 ppm for the first and 0.054 ppm for the second planting, which is comparable to the 0.06 ppm determined for corn in Hawaii. Although both crops have similar P requirements for maximum yield, bean yields (especially during the drought-affected first seeding) were much more affected by a lack of P than corn. This indicated the high susceptibility of beans to P deficiency.

A critial P content in the leaves of 0.38 percent was determined, which agrees with

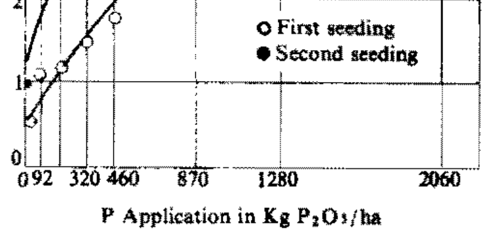


Figure 28. The initial (first seeding) and residual effect (second seeding) of various levels of applied P on bean yields in Popayán.

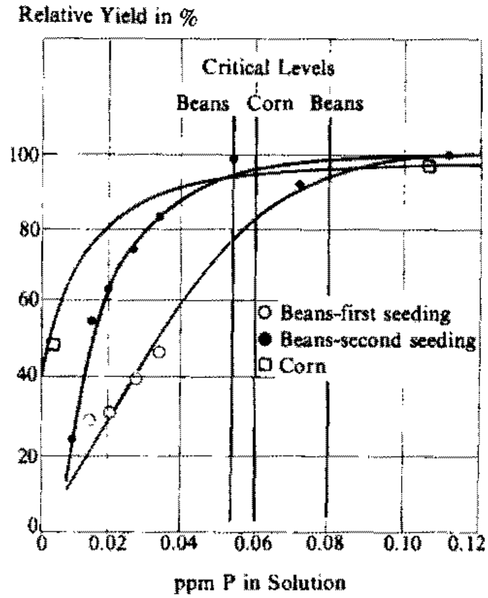


Figure 29. The relative yield of corn and two seedings of beans as affected by the P concentration in solution as determined from sorption isotherms. Corn data are from two volcanic ash soils in Hawaii.

the 0.34 - 0.40 percent reported in 1976. Similarly, the critical level of Bray II extractable soil P was found to be 14 ppm.

Soil analysis after each harvest showed that high P application increased soil pH from 4.7 to 4.9 and from 4.5 to 4.8 in the first and second planting, respectively. However, in these two consecutive bean plantings, pH declined 0.4 units and Al increased 0.4 me Al/100 gm. This decrease in pH may be counteracted by application of about 400 kg/ha of lime at each planting. High P applications (especially of basic slag or rock phosphates) are also effective.

APPLICATION METHOD

In soils with high P fixation, the application method is as important as the level of application — the optimum method often varying with the P source. The P concentration in soil solution depends on the rate of P release of the source and the rate of P fixation by the soil: slow release sources require good soil-fertilizer contact to dissolve and should be broadcast and incorporated, but banding is recommended for water soluble P sources to reduce fixation. The optimum application method for each source may be something between broadcast and banding, depending on the release and fixation rates.

To determine the optimum application method, three P fertilizers — TSP, basic slag, and Huila rock phosphate — were applied in small triangles as shown below Figure 30; the triangle base simulated broadcast application; the tip, band application; and the intermediate section, strip application. Fertilizers were applied at the rate of 75, 150, and 300 kg P_2O_5/ha.

Figure 30 shows the response to the different application methods for the three levels and sources. Yields were significantly better when TSP was band-applied than when broadcast or strip-applied, especially at the higher rates. Seventy-five kg P_2O_5/ha band-applied was as effective as 300 kg/ha broadcast. Thus, minimum soil-fertilizer contact increased efficiency by reducing fixation of this highly soluble source. Application method did not affect efficiency of basic slag, but that of rock phosphate was slightly higher when incorporated. Basic slag gave slightly higher yields than TSP while both were significantly better than the rock phosphate.

The second trial was reseeded in the same rows as the first without disturbing or reapplying the P treatments. Figure 31 shows the average response for the initial and residual effect. In the second seeding, application method had no effect on the efficiency of any of the P sources. Thus, banding TSP was beneficial for the first planting, but was not subsequently effective for maintaining a high P concentration. In the residual plots, yields were almost twice those of the first planting,

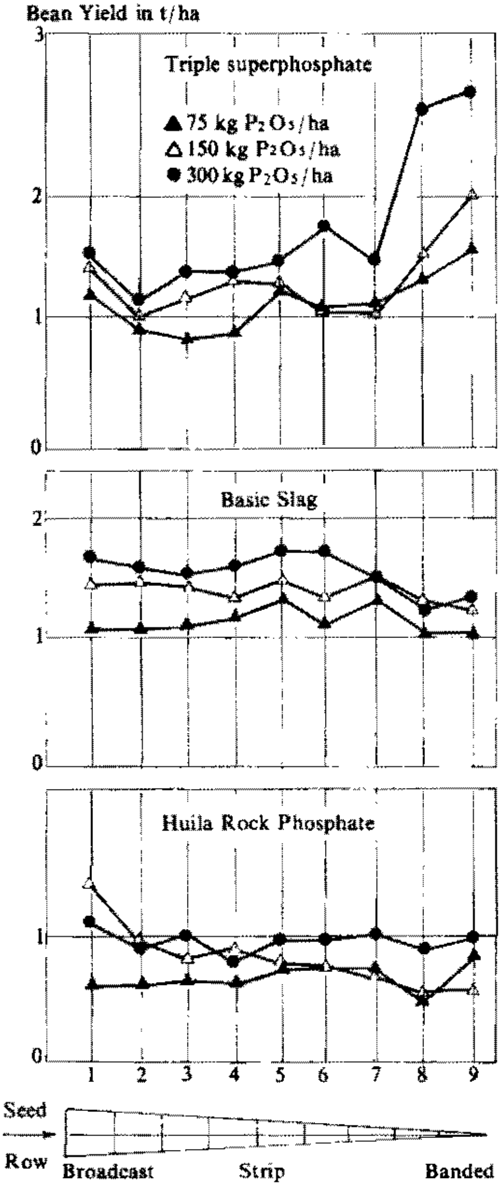


Figure 30. The effect of fertilizer distribution, applied at three levels and sources of phosphorus, on bean yield in Popayán.

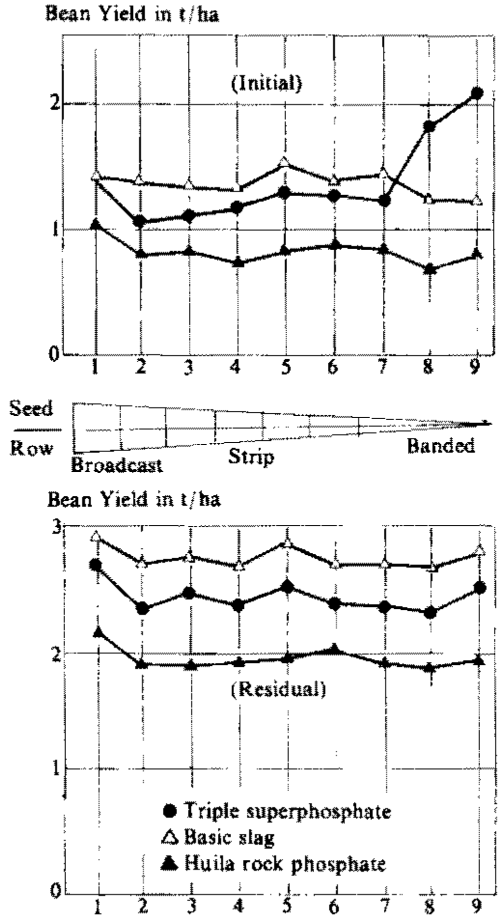


Figure 31. Bean yield (average of three P-levels) showing initial and residual effects of the distribution of fertilizers applied as three sources of phosphorus.

indicating the importance of the residual effect of these P fertilizers and improved moisture supply. Basic slag was significantly superior to TSP which in turn was superior to the rock phosphate. However, the residual effect of 300 kg P_2O_5/ha applied as rock phosphate still produced 2.4 t/ha of beans. Plots without P in an adjacent trial produced only 930 kg/ha.

PHOSPHORUS SOURCES AND LEVELS

The 1976 Annual Report reported the response of beans to various application levels and sources of rock phosphate. This year, the same trial was repeated in two consecutive plantings to measure the residual effect of the P sources. Of two

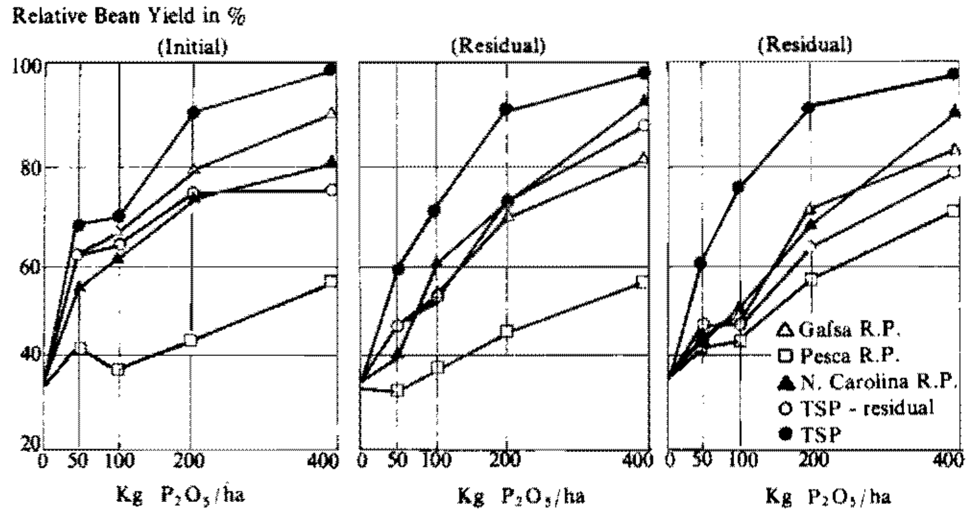


Figure 32. Relative yields of beans in three plantings after applications of various levels and sources of phosphorus, Popayán.

original TSP treatments, one was used as an optimum control in which the same amount of P was reapplied at every planting and the other measured residual effect.

Figure 32 shows the relative yields of various sources during the three seedings. In the first seeding last year responses varied significantly according to the citrate-solubility of the source. In subsequent plantings, less soluble sources such as Pesca and Tennessee became relatively more effective, while the very soluble sources such as TSP and Gafsa rock became relatively less effective. Thus, the large initial differences in effectiveness between sources tended to disappear with time. For all sources, beans responded positively to applications of 400 kg P_2O_5/ha, without reaching a yield plateau. For the residual effect plots, the response was nearly linear up to that level. Therefore, relatively cheap rock phosphates may effectively replace the more expensive TSP in acid, high P fixing soils.

A critical P content of 0.33 percent was obtained by relating bean yields to P contents of upper leaves at flower initiation. Similarly, the relation of yield and Bray I extractable soil P indicated a critical level of 9 ppm P, Bray I, in both the second and third plantings. The critical level defined by the Cate-Nelson method is 4.5 ppm P, Bray I (Fig. 33). The Bray II

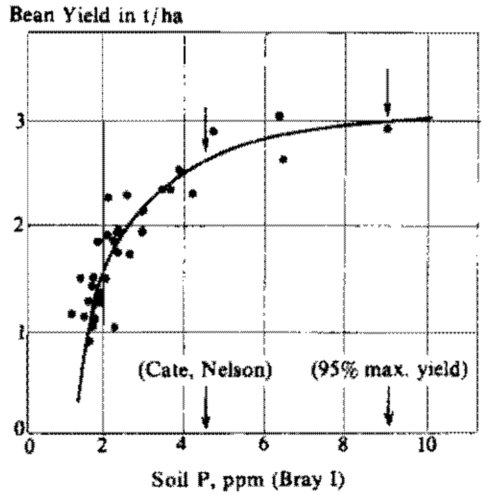


Figure 33. The relation between bean yield and soil phosphorus as determined at Popayán by Bray I. Arrows indicate critical levels according to the Cate, Nelson and the 95 percent maximum yield methods.

extractant cannot be used for rock phosphate treated soil as the acid dissolves more P than is available to the plant.

METHOD AND LEVELS OF NITROGEN APPLICATION

Nitrogen experiments in Ecuador (Annual Report, 1975) showed a positive response of beans up to 200 and 400 kg N/ha and broadcast application was superior to banding. However, in three consecutive plantings in Popayán no significant N response was obtained except for a slight negative response at the highest N level.

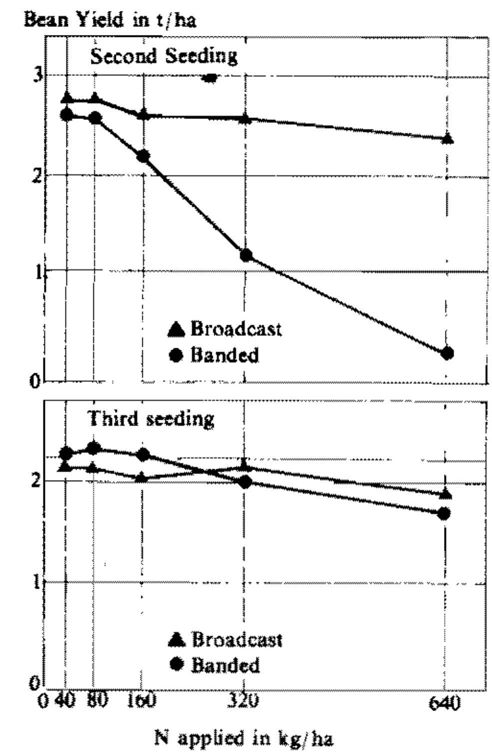


Figure 34. The response of beans to various levels of N applied as urea either broadcast or in bands. The indicated N levels were reapplied before the second seeding, and measured as residual effect in the third seeding.

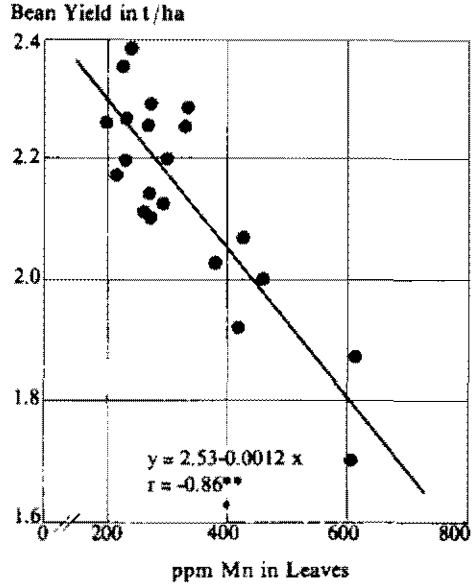


Figure 35. Relation between bean yield and Mn content of upper leaves at flower initiation.

After the first planting, N was reapplied to 1/2 of each plot to measure the recent as well as the residual effect of N. Germination was poor at band-applied N levels of 160, 320, and 640 kg/ha due to fertilizer burn caused by dry weather. This produced a marked negative response to high levels of banded N, while broadcast application only slightly affected yield (Figure 34).

When the residual effect was measured in the third seeding, germination was normal but yields were depressed by high levels of banded N, from 2.26 to 1.71 t/ha at levels of 160 and 640 kg N/ha, respectively. This was apparently due to N-induced Mn toxicity at high levels of banded urea. Reapplied banded N decreased the soil pH from 4.8 to 4.1,consequently increasing exchangeable Al and available Mn. Figure 35 shows that bean yields in the third seeding decreased linearly from 2.4 to 1.7 t/ha as the Mn content in bean leaves increased from 200 to 600 ppm. Although toxicity symptoms were only observed at more than 400 ppm Mn, yields were affected when the Mn was above 200 ppm in the leaves.

MINOR ELEMENT FERTILIZATION

Beans grown on alkaline soils at CIAT may suffer from boron and other minor element deficiencies. Foliar sprays of Zn, Fe, Mn, and B were applied singly or in combination as 1 percent $ZnSO_4$, 2 percent Fe-sequestrene-330, 2 percent $MnSO_4$ and 1 percent Solubor, respectively. The varieties ICA Guali and Porrillo Sintético were sprayed at the second trifoliate leaf stage and one week before flowering. Control plots also included soil applied Zn, Fe and Mn (10 kg/ha each) dissolved in water and band-applied below the seed.

Plants without foliar- or soil-applied Zn were stunted, showing severe interveinal yellowing of upper leaves, which later spread throughout the whole plant. Porrillo Sintético recuperated markedly after flowering but ICA Guali remained stunted with many necrotic lower leaves. In Porrillo Sintético, foliar-applied Mn prolonged indeterminate growth without flowering and pod-set. Foliar analysis indicated that plants in all treatments were B-deficient except for those with soil-applied B. Foliar-applied Mn and Zn induced a more severe B deficiency than other treatments.

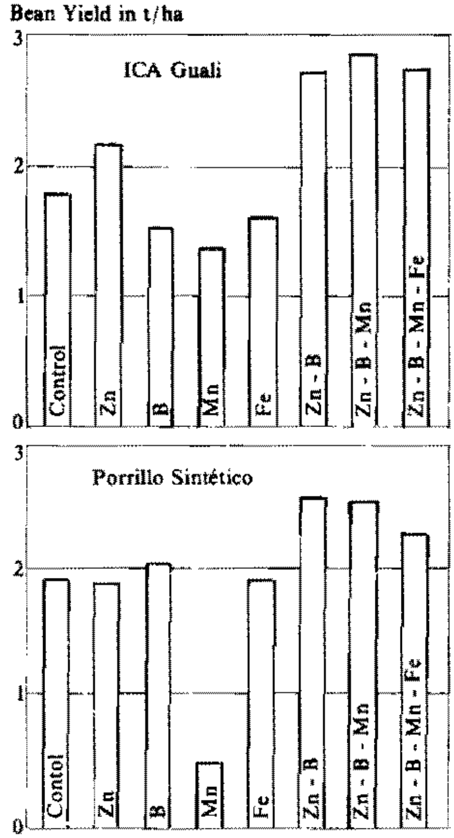


Figure 36. The response of 2 bean varieties to foliar application of minor elements in CIAT.

Figure 36 shows the yield response of selected treatments. ICA Guali responded mainly to Zn alone or combined with B. Porrillo Sintético responded to B alone or combined with Zn. There was a marked negative response to foliar-applied Mn, especially in Porrillo Sintético. Thus, the indiscriminate application of various minor elements to soils deficient in only one or two elements, may actually induce more severe deficiencies.

As observed previously (CIAT, Annual Report 1975); black-seeded varieties like Porrillo Sintético are more susceptible to B deficiency than the red-seeded ICA Guali, while ICA Guali is more susceptible to Zn deficiency. The critical level of Zn deficiency in both varieties was found to be 17 ppm Zn in upper leaves at flower initiation. Soil application of B and Zn was slightly more effective than foliar application, but both methods can be used if the deficiency is not severe enough to limit initial growth.

MANAGEMENT OF ALKALINE SOILS

At CIAT, bean yields may be affected by a combination of high pH, high Na saturation, salinity, poor drainage and deficiency of one or more minor elements. To test the susceptibility of beans to alkaline conditions, six varieties were grown in plots, used previously for cassava, which had been treated with

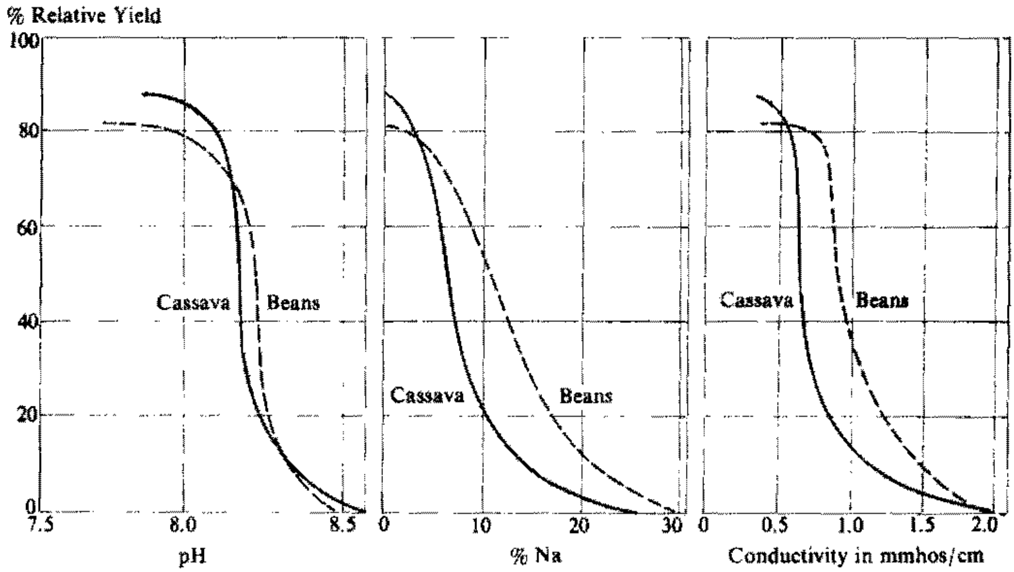


Figure 37. The relative yield of beans and cassava as affected by soil pH, percent sodium saturation and conductivity of saturation extract.

gypsum, elemental sulphur, sulphuric acid, rice straw, Zn, Fe, and Cu.

Yields of P498 (Puebla 152) were extremely low because of B deficiency. Average yields of the remaining five varieties responded to application of 1 and 2 t/ha of S, 5 t/ha of gypsum and to 10 kg zn/ha. Figure 37 shows the relation between the relative yield of P788 and pH, percentage Na saturation, and electrical conductivity compared with M Col 22, the most tolerant of the three cassava varieties previously studied in the plot. There was little difference in response among three bean varieties. Bean yields decreased drastically as pH increased above 8.2, when Na saturation increased above 5 to 10 percent and the conductivity increased above 0.75 to 1.0 mmhos/cm. Beans were considerably more tolerant than M Col 22 but bean yields were drastically reduced at levels far below the 15 percent Na saturation and 2 mmhos/cm conductivity that define "sodic" and "saline" soils, respectively.

Agronomy

Agronomic research in monoculture and in associated maize/bean systems continued at CIAT and Popayán. Monoculture bush bean research concentrated on: (1) preliminary yield evaluation of germplasm selections and advanced breeding lines; (2) uniform yield trials in Colombia; and (3) the International Bean Yield and Adaptation Nursery (IBYAN). Further agronomic studies continued on maize/bean associations and preliminary yield evaluations of climbing bean (Type IV) germplasm selections.

BEAN MONOCULTURE TESTING

Preliminary Yield Trials

Two preliminary yield trials at CIAT evaluated 117 non-black, bush bean (Type

I, II, III) selections (Table 41). Yield levels for Type I varieties such as P776 and P788 were outstanding. (P788 has the characteristics of Swedish Brown which has been widely utilized as a parent in the United States.)

Another preliminary yield trial at CIAT also evaluated 25 advanced breeding lines according to color (Table 42). Among the non-black materials, five white and brown lines showed excellent yield compared to the highest yielding variety in the control group (P302). In almost all cases the pedigrees included the high-yielding black Type II selection, P459 (Jamapa). However, in the black-seeded group yield levels were similar to the best of the controls suggesting that there were higher yield gains in brown and white-seeded material than in black-seeded lines.

Table 41. **Yield of the best entries in two Preliminary Yield Trials[1] at CIAT.**

Identification	Name	Growth Habit	Seed Color	Yield kg/ha
Preliminary Trial No. 1				
P776	Tortolas	III	Beige	3213
P788	PI 284-703	I	Yellow	3168
P153	PI 179-715	I	Brown (m)[2]	3155
P138	PI 176-694	I	White	2980
Controls				
P692	Diacol Calima	I	Red (m)	2731
P458	ICA Tui	II	Black	2388
P675	ICA Pijao	II	Black	2372
Mean of 81 materials				2376
L.S.D. .05				494
C.V. %				13
Preliminary Trial No. 2				
P684	PI 207-262	III	Beige	2925
P766	Aurora	II	White	2774
P622	PI 211-412	III	Beige	2720
Controls				
P675	ICA-Pijao	II	Black	3052
P756		II	White	2875
P692	Diacol Calima	I	Red (m)	2345
Mean of 36 materials				2112
L.S.D. 0.05				440
C.V. %				13

1 Trial 1: 81 lines in a 9x9 lattice, 3 reps. Trial 2: 36 var., in a 6x6 lattice, 3 reps.
2 m = mottled

Table 42. **Yield of the most promising advanced breeding materials in the Preliminary Yield Trials[1] at CIAT.**

Identification	Generation	Pedigree	Growth Habit	Seed Color	Yield Kg/ha
Non-Black Materials					
FF 12-13-1	F5	P459 x P567	II	White	3114
FF 11-6-1	F5	P459 x P008	III	Brown (d)[3]	2897
FF 16-3	F5	P459 x P004	II	Brown (d)	2845
FF 16-26-3	F5	P459 x P004	III	Brown	2822
FF 17-4-4	F5	P566 x P004	III	Beige	2739
Controls[2]					
P302	PI 309 804		II	Black	2764
P459	Jamapa		II	Black	2739
P675	ICA Pijao		II	Black	2679
Mean of 11 controls					2513
Mean of 36 entries					2465
L.S.D.					440
C.V. %					11.2
Black Materials					
FF 6-9-1	F5	P566 x P459	II	Black	2954
FF 49-1-1	F4	(P459 x P008) (P008 x P568)	III	Black	2827
FF 4-13	F5	P459 x P568	II	Black	2812
FF 2-6-3	F4	P459 x P006	II	Black	2806
FF 24-9-1	F4	(P459 x P488) (P459 x P568)	II	Black	2793
Controls[2]					
P675	ICA Pijao		II	Black	2958
P758	Puebla 152		III	Brown	2637
P498	Puebla 152		III	Black	2630
Mean of 11 controls					2410
Mean of 36 entries					2540
L.S.D. 0.05					457
C.V. %					11.2

[1] 36 Varieties in a 6 x 6 lattice with 3 reps., including 11 control varieties for each trial.
[2] Yield of three highest yielding controls in each trial.
[3] d = dark brown.

Uniform Yield Trials

Results are available for uniform yield trials planted in the second semester of 1976 at CIAT and Popayán with black and non-black varieties. Generally, the more recent selections were not superior to the best control varieties (Table 43). Results are also available for uniform yield trials at CIAT with black and non-black lines in which both germplasm selections and advanced breeding lines were compared with control varieties (Table 44). Two black, advanced breeding lines (also included in Table 42) were superior to the best controls. Within the non-black group some of the germplasm selections also showed high yield levels. Uniform yield

Table 43. **Yield of the most promising black and non-black materials in the Uniform Yield Trials at CIAT and Popayán.**

	CIAT			Popayan	
Identification	Seed Color	Yield Kg/ha	Identi-fication	Seed Color	Yield Kg/ha
Non-Black Materials[1]					
G4826	Cream (m)[2]	2700	G01224	Brown	1980
P788	Yellow	2478	P017	Brown	1874
G1212	Red	2469	G00805	Red	1565
G6391	Cream (m)	2388			
Controls					
P692	Red (m)	2726	P524	Cream	2477
P756	White	2645	P459	Black	2422
P392	White	2418	P756	White	2064
Mean of 16 materials		2378			1544
L.S.D. 0.05		279			675
C.V. %		8.5			25.7
Black Materials[3]					
P014	Black	2451	P009	Black	2937
P422	Black	2269	P226	Black	2801
P199	Black	2247	P437	Black	2763
Controls					
P459	Black	2238	P675	Black	2830
P675	Black	2229	P459	Black	2600
P566	Black	2013	P566	Black	1639
Mean of 25 materials		1988			2271
L.S.D. 0.05		350			674
C.V. %		12.7			18.6

1 16 varieties, 4x4 lattice, 3 reps.

2 m = mottled

3 25 varieties, 5x5 lattice, 3 reps.

Table 44. **Yield of the most promising entries in two Uniform Yield Trials[1] at CIAT.**

Identification	Pedigree	Growth Habit	Yield Kg/ha	Identi-fication	Growth Habit	Yield Kg/ha	Seed Color
	Black-seeded material				**Non-black-seeded material**		
FF 2-6-3	P459 x P006	II	2617	P141	I	2831	Red (m)[2]
P455		II	2531	P138	I	2732	White
FF 6-9-1	P566 x P459	II	2458	P708	I	2536	Beige
P533		II	2404	P060	I	2467	Brown (m)
P280		II	2403	FF 17-4-4[3]	II	2163	Beige
			Controls				
P675		II	2162	P756	II	2446	White
P459		II	1950	P675	II	2153	Black
P498		II	1924	P692	I	1929	Red (m)
Mean of 36 entries			2096			2039	
L.S.D. 0.05			381			448	
C.V. %			11.3			13.7	
Efficiency of lattice design			12%			106%	

1 36 lines in each trial, 6x6 lattice, 3 replications.

2 m= mottled with secondary color

3 Pedigree: P566 x P004

trials at other locations will evaluate yield stability of this material across environments and promising lines entered into the IBYAN program for 1978.

International Bean Yield and Adaptation Nursery (IBYAN)

Results for the 1976 IBYAN are available for 41 locations which range in latitude from 1°S to 55°N. Twenty varieties including a range of seed colors were selected for all locations.

Mean yield of the five best IBYAN entries (in both tropical and temperate zones) for the first 41 sites (Table 45) was 35 percent higher than the mean of the five local entries. This suggests that germplasm material selected under tropical conditions has a wide adaptation range. The four highest yielding materials across locations were the black-seeded Type II varieties: P302 (PI309-804); P459 (Jamapa); P560 (51051, I-1138); and P675 (ICA-Pijao). Some of which were also outstanding in previous CIAT yield trials at altitudes up to 2000 msl in Colombia and Ecuador and in earlier research by the Programa Cooperativo Centroamericano de Mejoramiento de Cultivos Alimenticios (PCCMCA) in Central America.

Mean yield for both IBYAN and local

Table 45. **Mean yield of 20 common and 5 local entries in the 1976 IBYAN at 31 tropical and 10 temprerate locations.**

Group	Zone	Yield in kg/ha		
		Group Mean	Mean of 5[1]	Mean of Highest yielder[2]
IBYAN entries	Tropical	1392	1758(135)	1959(118)
	Temperate	2078	2601(135)	2768(116)
IBYAN entries	Tropical	—	1303	1660(100)
	Temperate	—	1925	2391(100)

[1] Mean of five highest yielders at each location among IBYAN entries and mean of five local entries at each location.
[2] Mean of highest yielding variety at each location within each zone.

entries in the temperate zone was higher than that of the tropics where disease development was severe in some locations. The factors associated with yield variation between locations will be evaluated when the full data set is available.

Data in Table 46 shows the frequency of

Table 46. **Frequency of moderate (1500-1999 kg/ha) to excellent yields (≥ 3000 kg/ha) achieved by the lines tested in the first International Bean Yield and Adaptation Nursery (IBYAN).**

Lines	Seed Color	Growth Habit	Frequency of Yields				
			≥3000	2500-3000	2000-2499	1500-1999	Total
P566	Black	II	1	1	7	19	28
P512	"	II	-	4	6	15	25
P302	"	II	3	2	9	10	24
P459	"	II	1	4	8	11	24
P458	"	II	1	4	8	11	24
P675	"	II	-	4	11	8	23
P560	"	II	3	2	9	8	22
P402	Brown	I	1	3	5	13	22
P524	Cream	II		2	8	9	21
P498	Black	III	1	5	8	7	21
P539	"	II	1	5	8	6	20
P757	"	II	-	6	5	9	20
P643	White	II	-	3	7	10	20
P755	Red	I	-	4	3	13	20
P756	White	II	1	2	6	10	19
P758	Brown	III	1	3	7	7	18
P637	Red	I	1	2	5	8	16
P692	"	I	1	2	2	10	15
P759	"	I	-	2	4	9	15
P392	White	I	-	2	5	7	14

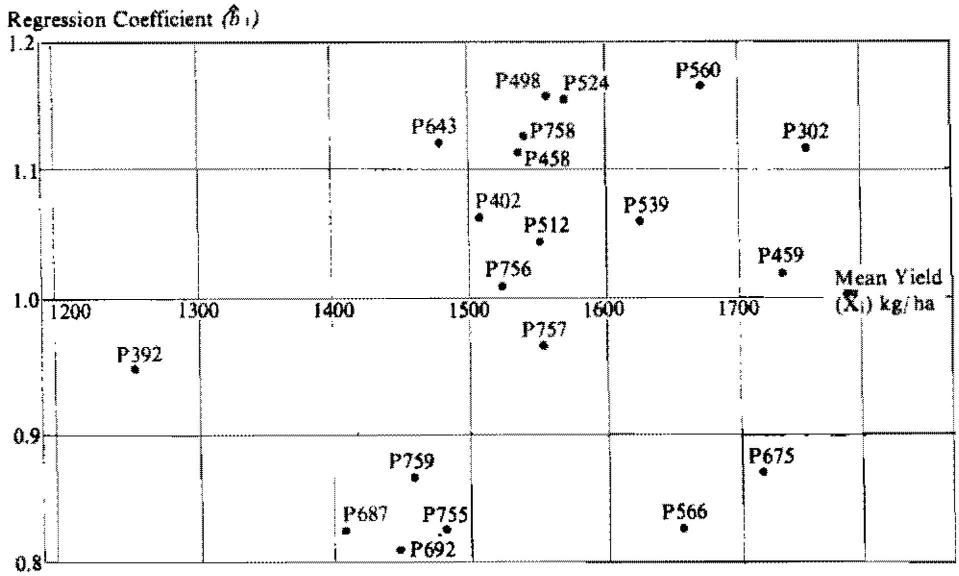


Figure 38. Plot of regression coefficient ($\hat{b}_i$) vs mean yield across locations for 20 common IBYAN entries (3 highest yielding entries/location) in 39 sites in temperate zones.

yield over 1500 and more than 3000 kg/ha at 41 locations. The wide adaptation of the black-seeded, Type II entries is notable. The poorer performance of lines such as P755 (Pompadour 2); P637 (Linea 17); P692 (Diacol Calima); P759 (Redcloud) and P392 (Sanilac) appears to be associated with the determinate Type I and possibly the comparative earliness of these lines.

A regression analysis of mean cultivar yield/location on site mean yield (including zero yields where these occurred) for the first 39 locations (Fig. 38), shows that five black Type II varieties (P302, P459, P675, P560, and P566) had the highest average yield (1.6 t/ha) but with wide variation in $\hat{b}$ values. P566 was better adapted to the lower yielding sites ($\hat{b}$ = 1.13). The lowest yielding group (≤ 1.4 t/ha) of four non-black Type I varieties (P392, P637, P692, P755) all had $\hat{b}$ values less than 1.0, indicating low mean performance across environments. A central group of 11 Type I, II, and III materials with mean yields of 1.4-1.6 t/ha showed wide variation in $\hat{b}$ values.

Figure 1 also shows materials clearly grouped according to subtype: the "Jamapa" group (P459, P302) are in a similar area of the graph, as well as the "Porrillo" group (P566, P757) and the Puebla 152 group (P498, P758).

Table 47 compares the yields of the variety means by type in 10 temperate and 31 tropical locations. Northern hemisphere breeders concentrate on Type I material for dry bean production but Type II material outperformed Type I at temperate locations. In addition, black-seeded selec-

Table 47. **Average yield in kg/ha of the 20 1976 IBYAN varieties grouped according to growth habit which were tested in 41 sites.**

Zone	No. of Experiments	Growth Habit I	II	III
Tropical	31	1701	1871	1492
Temperate	10	2428	2673	2276
Difference		-727	-802	-784

Table 48. **Average yield (kg/ha) of the 20 1976 IBYAN varieties grouped according to grain color, tested in 41 sites.**

Zone	No. of Experiments	Grain Color			
		Black	Red	White	Brown
Tropical	31	1877	1584	1411	1609
Temperate	10	2619	2137	2352	2500
Difference		-742	-553	-941	-891

tions were the highest yielding at temperate locations (Table 48). The tables also show the superior performance of Type II materials for 31 locations in the tropics. For tropical locations, black-seeded varieties were generally superior to non-black materials.

The 1977 IBYAN was divided into black-seeded and non-black-seeded sets of 20 varieties since the collaborators expressed seed color preferences. At all locations the best five local materials selected by the collaborators were included in a 5 x 5 lattice with three or four replications. Some 34 countries collaborated and 108 sets have been forwarded.

BEAN/MAIZE ASSOCIATION TESTING

Density Response in Climbing Beans

Two trials at CIAT evaluated optimum plant density for P589 in monoculture and in association with four population densities of maize over a range of conditions. Figure 39 shows that the optimum bean plant population was uniform at 120,000 plants/ha. However, as bean density increased maize yields decreased.

It was determined that economic optimum density is obtained when the value of the marginal increase in yield equals the price of the seed for planting an increased density and a seed/bean price ratio of 2:1 was assumed.

From eight trials with P259, the average optimum density for monoculture was

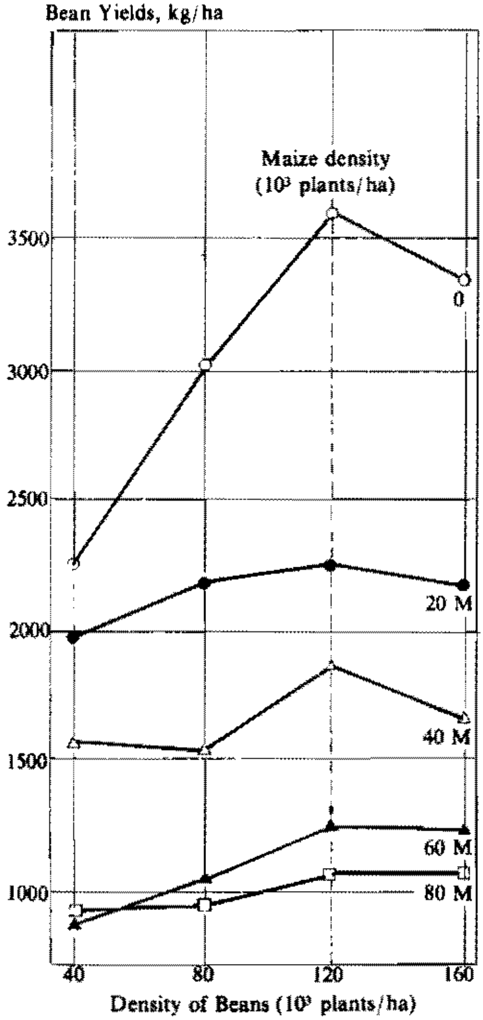


Figure 39. **Yield of climbing bean, P589, as affected by maize (H-210) and bean density.**

100,000 plants/ha but there was a wide range of optimum densities for this cultivar depending on environmental conditions. Low densities for climbing beans in monoculture were recommended since they can branch when light is not a limiting factor. There is no evidence that the farmer will achieve much yield response over 100,000 plants/ha of beans regardless of environmental conditions.

Competition between Beans and Maize

It was found that for all four *Phaseolus* bean types the bean yield was sharply reduced by simultaneous planting compared with planting 10 days before maize (Figure 40). However, the effect of planting Types I and II bush beans 10 days after maize was not significant whereas the yields of Types III and IV (semi-climbing and climbing, respectively) were severely reduced. Apparently, climbing types could not cope with strong maize competition from ICA H-207. Figure 41 shows the

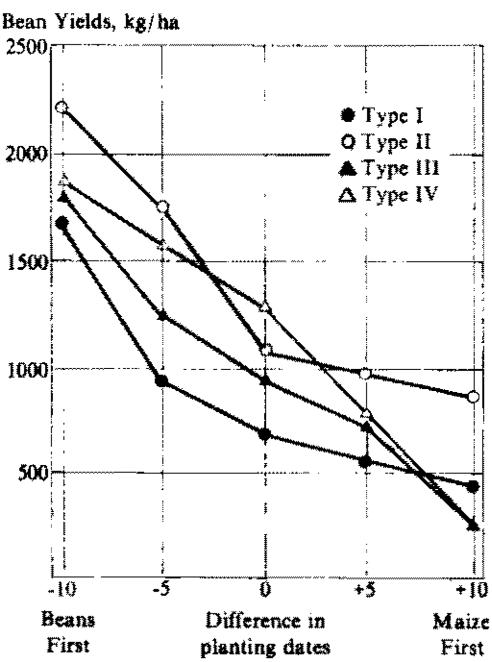


Figure 40. Effects of relative planting dates of bean/maize association on bean yields.

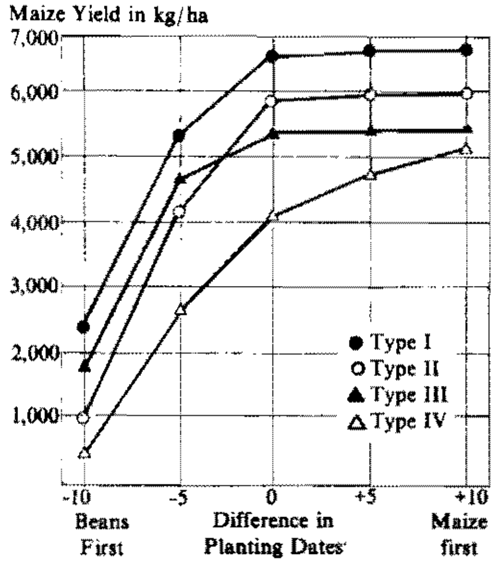


Figure 41. Effects of relative planting dates on yields of maize (H-207) with 4 types of beans.

maize yields with four types of beans demonstrating that the climbing beans reduce maize yields more than the other types, especially when the two crops are planted simultaneously. At CIAT, simultaneous planting produced optimum yield of both crops in association but preliminary observations at Popayán indicate that this is temperature dependent and relative to the early crop vigor of the two species.

The relative competitive ability of 20 different maize genotypes in association with beans was also investigated. Figure 42 compares the yield of the 10 best yielding maize varieties both in monoculture and associated with Type II and IV beans. Maize yields were more severely reduced by Type IV than by the Type II. However, there was also evidence for differences in competitive ability among the maize genotypes. There was less reduction in the yield of tall maize genotypes, especially those with a tendency to lodge. Root lodging of the maize was sharply reduced in association with beans. In many trials with tall maize genotypes this factor has

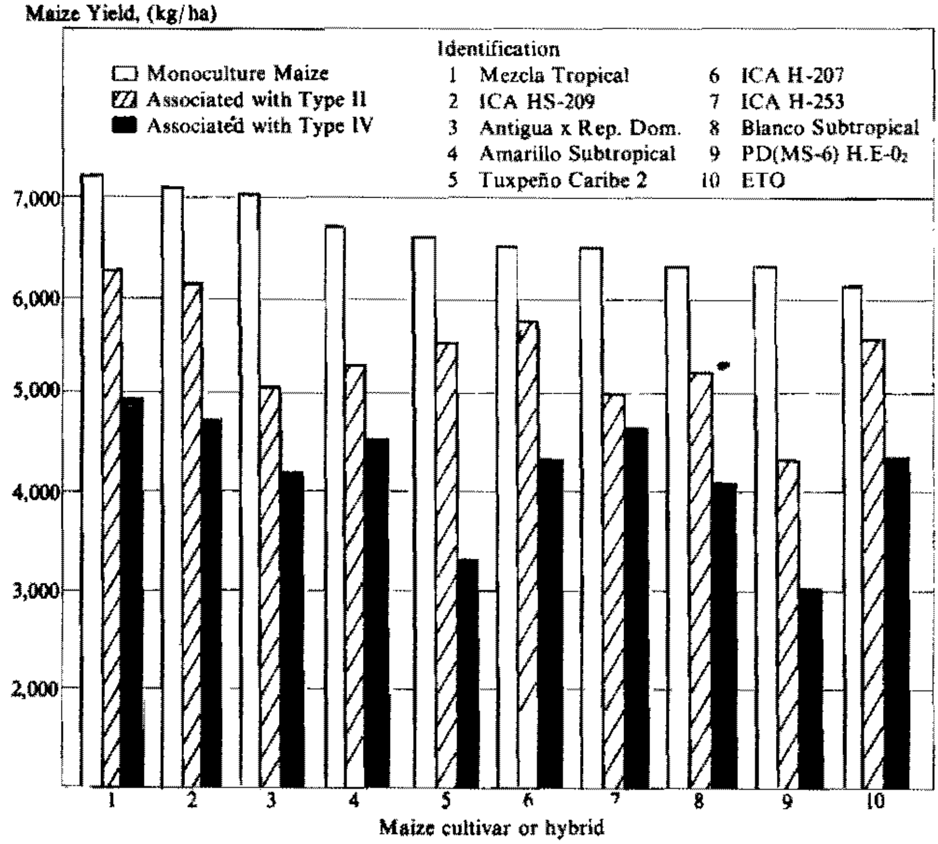


Figure 42. **Yield comparison of 10 maize varieties in monoculture and associated with two bean cultivars of contrasting growth habit.**

resulted in insignificant yield differences between associated and monocrop maize yields.

The yield of Type II beans was dependent on the yields of the maize genotypes (r = -0.89***) whereas there was no relationship with the yield of climbing beans. Low yielding maize genotypes gave insufficient support to the climbing beans to allow a high yield, whereas high yielding maizes were more competitive.

Genotype x System Interactions

Since varieties which perform well in monoculture may not be the best for associated cropping, 20 bush bean varieties were tested in monoculture and in association with maize during three consecutive seasons. Results for one season are shown in Figure 43. Average monocrop yields were reduced 58 percent in association with maize. Significant varietal differences were observed in each system and between the two systems. In the three seasons, the correlations between yields in the two systems were: 0.51, 0.88 (both in 18 d.f.) and 0.91 (7 d.f.), while rank correlation coefficients were 0.54, 0.58, and 0.93. Yield reduction and varietal ranking both were influenced by seasons.

Climbing beans were also tested for three seasons in monoculture and in association with maize and the results of

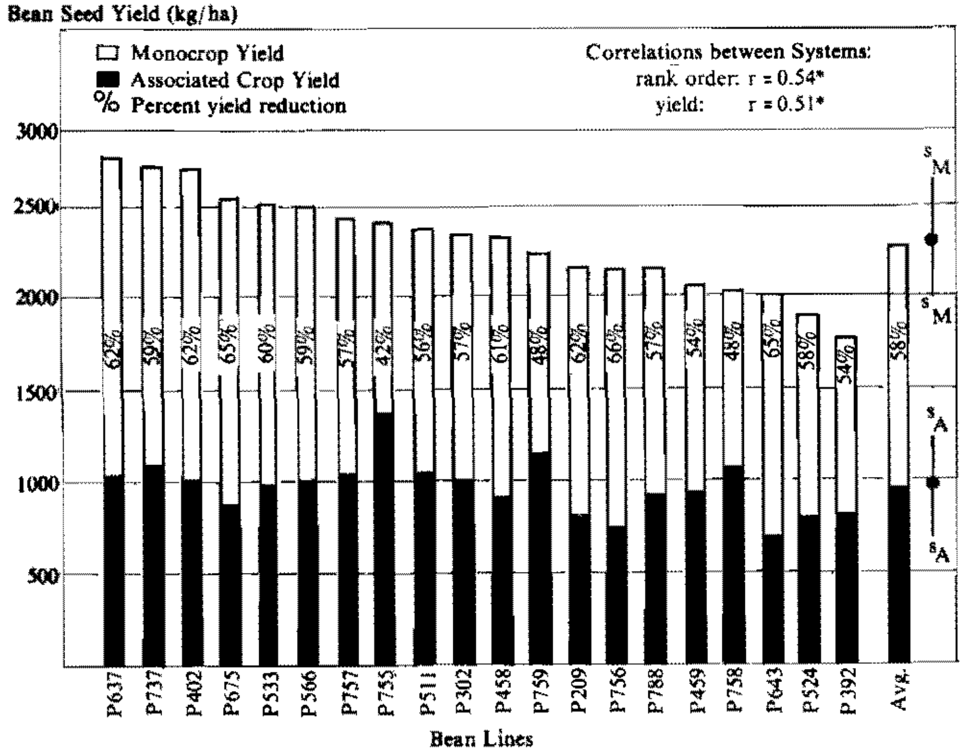


Figure 43. **Bush bean yields obtained from two cropping systems (Trial 7625).**

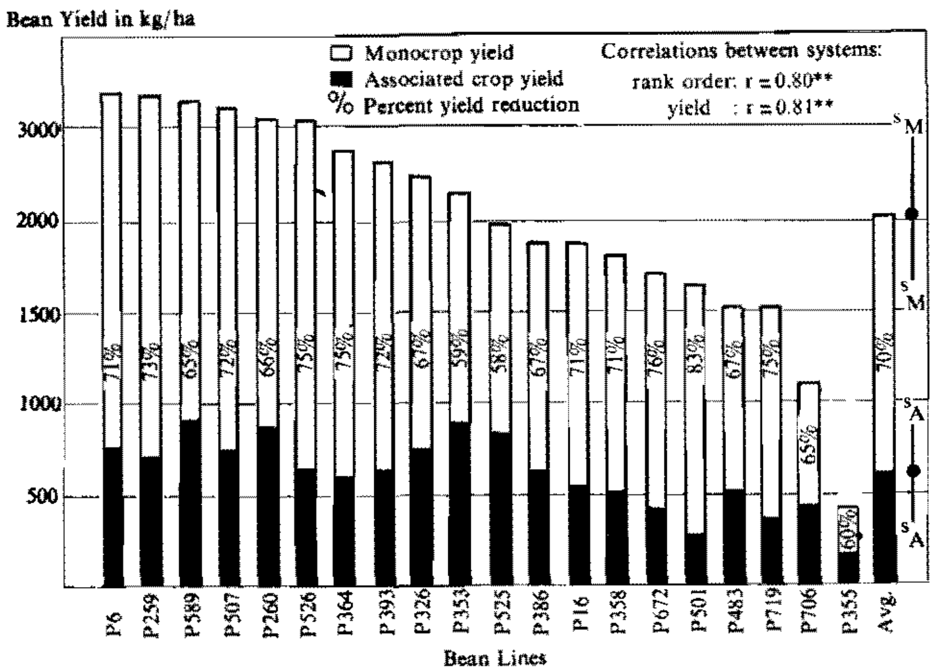


Figure 44. Climbing bean yields obtained from two cropping systems (Trial 7605).

one of these trials is shown in Figure 44. Correlations between yields for the two systems were: 0.41, 0.81 (both with 18 d.f.) and 0.90 (7 d.f.) and rank correlations were 0.09, 0.80, and 0.88 for the three seasons, respectively. Yields and varietal ranking also varied among seasons. In each trial, there were significant varietal differences among yields and percentages of yield reduction.

The disadvantages of using an associated cropping system to test breeding materials include poor separation of variety yields, limited seed production in each cycle and complexity of the system for observing individual lines. The improved separation of yields in monoculture, shown in Table 49, was due to greater absolute differences between the means combined with a reduced coefficient of variation for error in monoculture.

Table 49. Climbing bean results from Trial 7624[1].

	Bean Seed Yield in kg/ha		% Yield	Yield Rank No.	
Variety	Mono	Assoc.	Assoc./Mono	Mono	Assoc.
P501	2782d-g	971ab	35	13	15
P364	3453a	1245a	36	1	1
P6	3030a-e	1075ab	35	8	11
P449	3225a-c	951ab	29	4	16
P589	2950c-f	1242a	42	11	2
P483	2771d-g	1048ab	38	14	12
P393	3113a-d	934b	30	6	17
P706	3355a-c	1084ab	32	3	9
P353	2969b-f	1183ab	40	10	3
P260	2745d-g	1089ab	40	15	8
P259	3400a-c	1010ab	30	2	14
P326	3041a-e	1142ab	38	7	5
P504	3187a-d	926b	29	5	19
P355	2947c-f	1079ab	37	12	10
P16	2975b-f	1091ab	37	9	7
P719	2149i	472c	22	20	20
P507	2443g-i	932b	38	18	18
P525	2557f-i	1098ab	43	17	6
P672	2607e-h	1045ab	40	16	13
P526	2239hi	1143ab	51	19	4
Mean	2897	1038	36	-	-
C.V. (%)	9.8	19.0	-	-	-

1 Data in each column followed by same letter do not differ significantly (5%); absence of letters in a column indicate no significant differences among treatments.

Climbing Bean Variety Trials

Some 300 Type IV varieties selected for yield potential and grain color were sown with maize ICA H-207 in preliminary yield trials at CIAT. They were also planted at Popayán using old maize stems for support. In Table 50, the mean yields of the best 20 varieties at CIAT are compared with the best of eight standard control varieties representing the best varieties currently identified. A number of new (colored-seeded) materials including black showed good yield potential.

The yields of the best 20 varieties in Popayán are presented in Table 51. All but one of the varieties originated from Mexico. P364 was the highest-yielding control variety at both Popayán and at CIAT, but none of the 20 high-yielding varieties at either site yielded well in both locations. Six of the varieties were significantly higher yielding ($P < 1\%$) than

Table 50. Yields of the best 20 varieties of climbing beans associated with maize (H-207) at CIAT.

Identification	CIAT No.	Origin	Color	Yield Kg/ha
PI 201-348	G844	Mexico	Cream	1967
PI 311-861	G2227	Guatemala	Yellow	1907
Boyacá 21	G4590	Colombia	Cream	1790
P 114	G417	Turkey	White	1740
PI 310-767	G2026	Guatemala	Black	1737
Antioquia 130	G4567	Colombia	Cream	1720
Chiapas 163	G14762	Mexico	Cream	1718
PI 224-738	G983	Mexico	Brown	1696
PI 200-978	G1253	Guatemala	Brown	1692
Chiapas 163 (N)	G4762	Mexico	Black	1674
PI 310-680	G1962	Guatemala	Black	1639
PI 311-191	G2161	Guatemala	Black	1639
PI 282-024	G1079	Chile	Brown	1634
PI 310-767	G2026	Guatemala	Brown	1585
PI 204-721	G891	Turkey	White	1579
PI 209-801	G1365	Kenya	Coffee	1575
PI 311-904	G2258	Mexico	Purple	1571
Boyacá 21	G4590	Colombia	Black	1569
PI 310-783	G2033	Guatemala	Black	1569
PI 189-012	G731	Guatemala	Brown	1565
Best Control P364				1416
Mean of controls (n=8)				1099
Overall mean				1319
L.S.D. at .01 level = 392				

Table 51. **Yields of the best 20 varieties of climbing beans at Popayán.**

Identification	CIAT No.	Origin	Color	Yield Kg/ha
[illegible]	G3352	Mexico	Yellow	4502
P468	G3469	Mexico	Brown	4443
Guanajuato 22	G3445	Mexico	Yellow	4353
Black bean	G3208	Guatemala	Black	4348
Guanajuato 116-A	G3451	Mexico	Purple	4338
PI 313-724	G2597	Mexico	Yellow	4305
Puebla 422	G3391	Mexico	Yellow	4121
PI 313 730	G2602	Mexico	Grey (m)[1]	4076
PI 203 930	G875	Mexico	Yellow	4025
PI 313 758	G2620	Mexico	Yellow	4024
PI 313-730	G2602	Mexico	Grey	3998
PI 311-908	G2262	Mexico	Cream	3994
PI 319 631	G2829	Mexico	Brown	3963
PI 311-917	G2270	Mexico	Cream	3947
PI 201-317	G838	Mexico	Cream	3944
PI 313-776	G2634	Mexico	Brown	3919
PI 309-797	G1814	Mexico	Yellow	3891
Guanajuato 22(R)	G3445	Mexico	Red	3876
PI 313-514	G2497	Mexico	Black	3849
PI 313-755	G2618	Mexico	Brown	3833
Best control P364			White	3487
Mean of controls (n = 8)				2277
Overall mean				2505
L.S.D. at .01 level				778

[1] m = mottled

the best control variety, and the yields in Popayán were remarkably high considering the relatively simple and inexpensive support system used.

Economics

The principal economic research objective is to estimate the profitability of new technology and to identify the constraints to its introduction in Colombia and other countries. Results of experiments in Honduras and Restrepo, Colombia are included in this section. A secondary objective is to collaborate with other program scientists in the economic evaluation of their data. The economic aspects of some of the work with Agronomy are presented.

ON-FARM TECHNOLOGY TESTING

Honduras

For over a year CIAT has been collaborating with a Honduran program, Programa de Maíz y Frijol (PROMYF) to increase the income of small and medium farmers through productivity increases in beans and corn. New bean varieties, fertilizers, insecticides and herbicides were tested on farmers' fields in seven locations during the "Postrera", the second Honduran planting season, which is characterized by more irregular and reduced rainfall than the first season. Most of the beans are produced during the Postrera following the corn of the first season. In most years water stress can be expected,hence varieties must be developed for these conditions.

Varietal Testing. In six of seven yield trials different CIAT selections (black-seeded varieties) gave significantly higher yields than the local reds. However, there is a local market price discount for black varieties due to consumer preferences for reds, and export markets for blacks have been unstable. When profitability of the red and black-seeded varieties was compared rather than yields, the red varieties gave significantly higher returns in four of seven trials. These results emphasize the importance of considering consumer preferences as well as yields. Farmer profits and the feasibility of a new technology fitting into a production system are the appropriate measures of the success of a new technology while comparative yields are often poor indicators.

Fertilizers. Using incremental budgeting, almost all fertilizer treatments in all regions resulted in an income loss as compared with zero fertilizer. Although an earlier planting date might have reduced the losses, these results indicate that fertilizer is a risky input under irregular rainfall conditions and without control of other yield-reducing factors. Risk as well as the expected return for all possible agroclimatic conditions must be considered when evaluating introduction of new technology.

Insecticides. *Empoasca kraemeri* and *Apion* are considered to be two of the principal constraints to increased bean yields in Central America. However, in these trials low incidence or poor application made "preventive" insecticide treatments consistently unprofitable at all locations. The cost of insecticide could be reduced by initiating control when populations reach economically damaging levels. The effectiveness of field identification of pests before "curative" insecticide spraying is being tested.

Herbicides. It was found that herbicides have several types of effects — on yields, on labor costs of weed control, and on the area cultivated when seasonal labor availability for weeding is a critical constraint. When the first two effects were evaluated, one traditional herbicide consistently lost money and reduced yields in fifty percent of the trials. Another herbicide, methobromuron, was profitable in six of the seven sites even when zero opportunity cost for family labor was assumed. During this season the use of the appropriate herbicide had an effect on yield, perhaps resulting from the increased water availability to the beans.

Simple economic analysis indicated the importance of seed color in evaluating varieties and the riskiness of high inputs for the Postrera season given the high probability of water stress. The development of an improved early red variety to fit better into the Postrera season is believed to be the most important component of a new technology package for the PROMYF program.

Restrepo, Colombia

Agronomic experiments to identify an improved technology for small farmers

Table 52. **Input use and returns data per hectare for best farmer practices, and new bean technologies in Restrepo.**

		New Bean Technology			
		On-farm Trials		Synthetic Data	
		Improved Practices and			
	Best Farmer Practices in Bean Production	Calima (Bush)- No Herbicide	New variety (Climbing)- No herbicide	Calima with Herbicide	New Climbing variety with Herbicide
Yields (kg/ha)	957[3]	1256	1419	1256	1419
Price of beans (pesos/kg)[1]	21.5	21.5	17.6	21.5	17.6
Variety	Several varieties including Calima	Calima	(P103, S220, P364)	Calima	(P103, S220, P364)
Labor requirements (man-day per ha)	97.3	122.5	132.5	111.5	121.5
Density (plants/ha)	110,000[4]	250,000	120,000	250,000	120,000
Fertilization	1.8 tons chicken manure	——50 kg P_2O_5/ha plus one ton of chicken manure——			
Pest control	None	—— 4 sprayings of fungicide-insecticide——			
Weed control	—— Manual labor (14 man-days)——			——Herbicide-cost of $819/ha plus 3 man-days for application.	
Gross income	20,575	27,004	24,974	27,004	24,974
Cost of purchased inputs	-5,752	-6,920	-3,930	-7,739	-4,749
Labor cost[2]	-6,587	-8,609	-9,312	-7,836	-8,539
Net Income	8,238	11,475	11,732	11,429	11,686

[1] The Calima price was the average price received in the region for this variety. The new variety prices were for red beans except for P364, a white bean, and were discounted. However, this is a very conservative adjustment because among the red beans Calima has a substantial discount compared to Cargamanto, Radical or other large-seeded varieties.

[2] Family labor was priced at the going wage rate. In the programming family labor was treated in the standard method as a fixed cost.

[3] The average yields were based upon a survey of 22 farms.

[4] This was the average density for single cropping in the region. When beans were intercropped with coffee, the density was 40,000 plants/ha.

were conducted the past two years in this region (see Hudgins). Experiments with improved climbing selections and Calima continued with a minimum input package since the costs of inputs in previous trials were still considered too high for the small farmer. Profitability estimates were made for two new bean technologies in on-farm trials. The technologies included improved climbing selections, phosphorus, increased organic fertilizer, and insect and disease control (Table 52). Results showed that new technology for climbing beans reduced the cost of purchased inputs. The higher population density of Calima and associated inputs increased the costs of the new bush bean technology. Nevertheless, new bean technologies increased farmer income by approximately 40 percent.

Labor availability *vs.* Herbicides. The principal constraint on new technology adoption in a coffee zone such as Restrepo may be seasonal labor availability. Labor requirements increased 26 to 36 percent with the new technologies. Synthetic data were derived for two labor saving technologies with herbicides[1] (Table 52). Herbicides slightly reduced net income as the cost was greater than that of the released labor; however, they would still be utilized if seasonal labor availability were a pressing constraint.

To evaluate the feasibility of introducing these four new bean technologies into the Restrepo farming system, profit-maximizing plans for farms of different sizes were computer programmed, considering available land, labor, capital, and alternative activities in the region. Results indicate that if the yields of Table 1 can be obtained on farmers' fields, then the new bean technology package will be profitable over a wide range of farm sizes (Table 53). Profit maximization estimates were made on the effects of the new technology on farm level profits and labor use for a typical Restrepo farm (7.8 ha) before and after the new technology introduction (Table 54). Results show that the new technology increases farm income, farm employment and bean area. Farm level profits should be further increased with improved red climbing and bush type germplasm incorporating resistance to some diseases for which spraying is now necessary.

Storage in Restrepo. Previous field research in Huila and Nariño indicated that small farmers sold 94 percent of their beans soon after the harvest. Therefore, beans had little effect on farm family nutrition and farmers suffered from the post-harvest price collapse. An analysis of bean samples from 18 Restrepo farms showed that all had serious problems with storage insects, principally *Zabrotes subfasciatus*. Eight farmers sold their beans rather than keep them for home consumption; none stored beans for more than two or three months; and four treated the beans with aldrin or dried them in the sun.

The risk of storage and the necessity for immediate post-harvest sale at lower prices may be important factors in the lack of farmer interest in increasing bean productivity. CIAT Bean Entomology has found that vegetable oils effectively control *Z. subfasciatus* in stored beans (see Entomology) and is presently testing this practice in farm level trials.

ECONOMICS OF THE BEAN/MAIZE ASSOCIATION

Economic analysis of twenty agronomic trials at CIAT provided information on yields over seasons for monoculture climbing beans, monoculture maize, and bean/maize associations (simultaneous planting). Sensitivity of net income to change in production costs, yields of each crop, and relative prices of beans and maize were evaluated for a series of conditions relevant to Latin America. While there is a range in bean/maize price ratios in Latin America — 2:1 in Mexico and up to 7:1 last year in Brazil — the ratio in Colombia is relatively stable at 3.5 to 4:1. (See Francis and Sanders).

[1] The farm level testing in Restrepo did not include herbicides. It was assumed that herbicides would have no effect on yields. Costs and labor requirement of the technologies with herbicides were obtained from Colombian market data and other studies, respectively.

Table 53 Profit maximizing farm plans for three different farm sizes in the coffee zone of Restrepo, Colombia.

Activity	Unit	Farm Size		
		2.5 Ha	7.8 Ha	22.7 Ha
		Activity Level		
Gross Margin[1]	Colombian Pesos	102,042	276,410	667,875
Old coffee area[2]	Ha	1.5	1.5	1.5
New coffee area	Ha	.5	2.3	9.3
Cassava	Ha	-	0.2	4.1
Bean Technology IV (1st. semester)	Ha	.5	3.9	7.8
Labor selling : Jan.-Mar.	Man-days	1	-	-
Labor selling : Apr.-June	Man-days	23	-	-
Labor hiring : Jan.-Mar.	Man-days	-	280	956
Labor hiring : Apr.-June	Man-days	-	123	456
Family labor : Jan.-Mar.	Man-days	84	84	84
Family labor : Apr.-June	Man-days	84	84	84
Bean Technology II (2nd. semester)	Ha	.5	3.9	-
Bean Technology IV (2nd. semester)	Ha	-	-	1.8
Labor selling : July-Sept.	Man-days	18	-	-
Labor selling : Oct.-Dec.	Man-days	11	-	-
Labor hiring : July-Sept.	Man-days	-	192	399
Labor hiring : Oct.-Dec.	Man-days	-	191	449
Family labor : Jul.-Sept.	Man-days	100	100	100
Family labor : Oct.-Dec.	Man-days	100	100	100

[1] This is a programming concept equal to gross returns minus variable costs. When fixed costs are amortized between years and deducted, net profit is obtained.

[2] The old coffee plantation was considered to be fixed on all farms due to the high investment cost of replacing it.

Table 54. **Profit maximizing farm plans for the typical Restrepo farm (7.8 Ha) before and after the introduction of new technology in bean production.**

Activity	Unit	New Bean Technology	
		Before	After
		Activity Level	
Gross Margin[1]	Colombian Pesos	225,190	276,410
Old coffee area	Ha	1.5	1.5
New coffee area	Ha	2.3	2.3
Cassava	Ha	1.1	0.2
Best Farmer Bean Technology (1st. semester)	Ha	2.8	-
New Bean Technology IV (1st. semester)	Ha		3.9
Labor hiring : Jan.-Mar.	Man-days	168	280
Labor hiring : Apr.-June	Man-days	148	123
Family labor : Jan.-Mar.	Man-days	84	84
Family labor : Apr.-June	Man-days	84	84

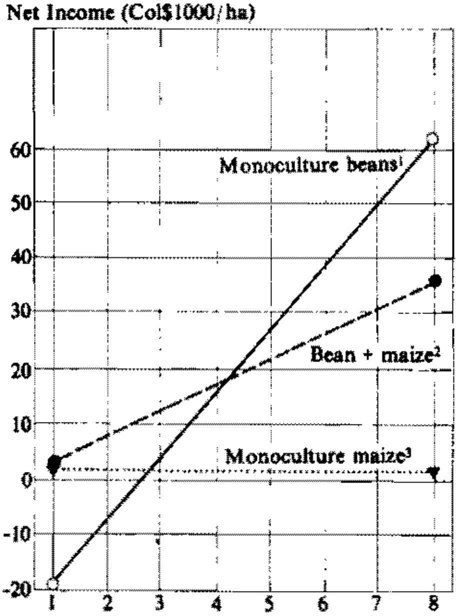
[1] See footnote 1 of Table 53.

Table 54. (continued)

Activity	Unit	New Bean Technology Before	After
		Activity Level	
Gross Margin[1]	Colombian Pesos	225,190	276,410
Best Farmer Bean Technology II (2nd. semester)	Ha	3.0	
New Bean Technology II (2nd. semester)	Ha	-	3.9
Labor hiring : July-Sept.	Man-days	124	192
Labor hiring : Oct.-Dec.	Man-days	184	191
Family labor : July-Sept.	Man-days	100	100
Family labor : Oct.-Dec.	Man-days	100	100

[1] See footnote 1 of Table 53.

Figure 45 shows that monoculture maize is the least profitable of the three alternatives. Monoculture climbing beans are more profitable above a 4:1 price ratio, and the bean/maize association more profitable below this ratio. The equal profitability of the two bean systems at the 4:1 ratio prevailing in Colombia is consistent with farm data collected in Huila where both systems gave almost identical returns, and the choice of the system appeared to be a function of farm size and labor availability.



[1] Monoculture bean yields 3000 kg/ha with production costs of Col$31,000/ha.

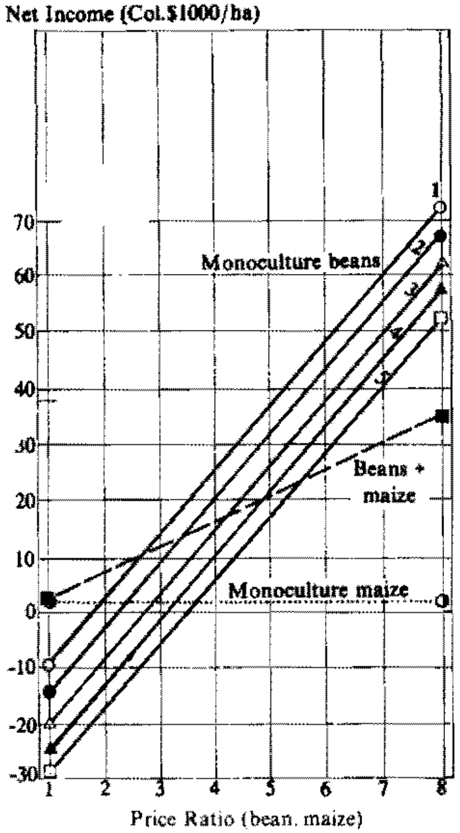
[2] Bean yields of 1200 kg/ha and maize yields of 5000 kg/ha with production costs of Col$22,000/ha.

[3] Monoculture maize yields of 5000 kg/ha with costs of Col$18,000/ha.

Figure 45. Net income from 3 cropping systems at several bean/maize price ratios.

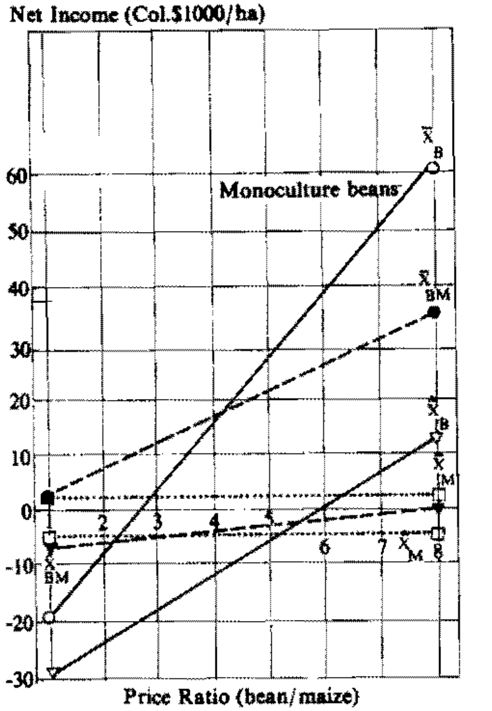
The advantage of monoculture climbing beans depends critically upon the labor and support costs. In a small farm system with surplus family labor and local materials available on the farm for artificial support, monoculture beans could be profitable at substantially lower price ratios, between 2 and 3:1 (Figure 46).

This analysis has only considered expected income. However, small farmers are also concerned with income variation (risk). Using the "guaranteed income" concept, risk is calculated as the minimum income produced by each activity with a given level of probability. Guaranteed income can be calculated as $\widehat{X} = \overline{X} - t_g s$, where $\widehat{X}$ is the minimum income goal, $\overline{X}$ is mean income, t_g is the "t" level at "g" probability and "s" is the standard deviation. This minimum income assures the farmer that in almost all cases his maximum loss or minimum gain under most agroclimatic conditions will be above the given $\widehat{X}$. In Figure 47, it is clear that beans



[1] Stakes = 0, labor = 0, total Col$21,000
[2] Stakes = Col.$5000, labor = 0, total 26,000
[3] Stakes = Col.$5000, labor = Col.$5000, total 31,000
[4] Trellis = Col.$15000, labor = 0, total 36,000
[5] Trellis = Col.$15000, labor = Col.$5000, total 41,000

Figure 46. Net income from three cropping systems at several bean/maize price ratios, with variable monoculture bean costs.



[1] Lower line ($\hat{X}_i$) for each system represents level above which income will occur with 90% probability ($\hat{X} = \bar{X} - t_1$ s where $t_{.10} = 1.6448$)

Figure 47. Guaranteed net income from three cropping systems at several bean/maize price ratios.[1]

alone are riskier than the bean/corn association until the price ratio is over 5.5:1 (90% probability). Small farmers who avoid high risks may prefer associated cropping even when the monoculture beans are more profitable. Most farmers, who have the necessary labor to use these associated cropping systems, must be concerned with the risks of crop loss. Therefore, they may be expected to choose associated cropping to reduce production costs and to achieve greater income stability.

Appendices

Appendix A. List of Promising Lines of *Phaseolus* referred to in the 1977 Bean Program Annual Report.

Program Promising No.	CIAT Accession No.	Identification or Registration	Source
P004	G0 2115	PI 310-878	USA
P005	1741	PI 307-824	USA
P006	2005	PI 310-739	USA
P008	2056	PI 310-814	USA
P009	2959	Pecho Amarillo	GUA
P011	3729	Argentina 2	VEZ
P012	5474	BRZ 1289 (69-6584-3)	BRZ
P014	2146	PI 310-909	USA
P016	3873	Trujillo 4	VEZ
P017	3719	Mexico 12-1	VEZ
P060	0143	PI 164-746 (SEM)	USA
P089	0302	PI 169-844	USA
P114	0417	PI 173-022	USA
P138	0556	PI 176-694 (Oturak)	USA
P141	0569	PI 176-713	USA
P153	0645	PI 179-715 (Rong)	USA
P155	0651	PI 180-729	USA
P167	0685	PI 182-007	USA
P168	0686	PI 182-011	USA
P169	0687	PI 182-026 (Windsor long pod)	USA
P174	0716	PI 186-492	USA
P178	0728	PI 186-505	USA
P179	0684	PI 181-996	USA
P182	0756	PI 193-569	USA
P189	0780	PI 194-578	USA
P194	0797	PI 195-391	USA
P199	1220	PI 196-927 (F. Criollo)	USA
P203	0818	PI 197-970 (Bayo Berendo)	USA
P204	0819	PI 197-971 (Berendo)	USA
P209	1259	PI 201-333	USA
P211	1264	PI 201-489	USA

Program Promising No.	CIAT accession No.	Identification or registration	Source
P226	1308	PI 207-198 (C.C.G.B-44)	USA
P239	1423	PI 226-895	USA
P243	1434	PI 226-938 (wachs hundert fur eine)	USA
P246	1050	PI 269-634	USA
P256	1524	PI 282-052	USA
P259	1093	PI 282-063	USA
P260	1098	PI 282-074 (Ocanero)	USA
P280	1682	PI 306-159	USA
P289	1694	PI 307-752 (S-137-N)	USA
P302	1820	PI 309-804	USA
P306	1833	PI 309-853	USA
P318	1962	PI 310-680	USA
P326	2006	PI 310-740	USA
P332	2026	PI 310-767	USA
P334	2034	PI 310-784	USA
P349	2281	PI 311-930	USA
P353	2327	PI 311-992	USA
P355	2337	PI 312-004	USA
P358	2382	PI 312-064	USA
P364	2540	PI 313-653	USA
P365	2549	PI 313-662	USA
P386	3269	Aguascalientes 70	MEX
P392	4498	Sanilac	USA
P393	3736	Alabama 1(I-1012)	VEZ
P401	3065	Blanco (GUA-0137)	GUA
P402	3807	Brasil 2 (Bico de Ouro)	VEZ
P420	3607	C.C.G.B.-44 (I-462)	VEZ
P422	3724	Compuesto negro (I-996)	VEZ
P432	3153	F. de parra (GUA-0350)	GUA
P437	3128	F. negro (GUA-0321)	GUA
P438	3131	F. negro (GUA-0325)	GUA
P439	3205	F. negro (GUA-0426)	GUA
P449	3451	Guanajuato 116A	MEX
P455	2960	Hailillo (GUA-0016)	GUA
P458	14454	ICA Tui	CLB
P459	3645	Jamapa (I-810)	VEZ
P461	3974	Jin 10B (C-90)	CRI
P468	3469	Michoacan 70	MEX
P478	4177	12-B-P-3 (N-159)	CRI
P483	3565	Oaxaca 39	MEX
P488	4142	Porrillo 70 (N-579)	CRI
P495	3352	Puebla 151B	MEX
P498	3353	Puebla 152	MEX

Program Promising No.	CIAT accession No.	Identification or Registration	Source
P500	3360	Puebla 173	MEX
P501	3363	Puebla 199	MEX
P504	3374	Puebla 304	MEX
P507	5693	California small white 643	USA
P509	4487	San pedro pinula 72	GUA
P511	3627	S-182-N (I-714)	VEZ
P512	4122	S-166-A-N (N-555)	CRI
P524	4421	S-630-B (C-63)	CRI
P525	3871	Trujillo 2	VEZ
P526	3872	Trujillo 3	VEZ
P533	3526	Veracruz 56	MEZ
P536	3531	Veracruz 157	MEZ
P539	3776	Venezuela 2 (I-1062)	VEZ
P540	3784	Venezuela 29 (I-1071)	VEZ
P545	3786	Venezuela 36 (I-1073	VEZ
P560	3834	51051 (I-1138)	VEZ
P561	4152	50609 (N-283)	CRI
P566	4495	Porrillo Sintético	HON
P567	5478	Tara	PRI
P568	5479	PR-70-15R87 (PR-5)	PRI
P569	5481	Cacahuate 72	MEX
P588	4455	ICA huasaño	CLB
P589	2525	PI 313-624	USA
P590	5702	Cargamanto	CLB
P597	1222	PI 196-932	USA
P622	5697	2114-12	USA
P623	4458	27R	CRI
P631	5696	Cornell 046-C	USA
P634	5683	ICA dura	CLB
P635	4452	ICA guali	CLB
P637	4523	Línea 17	CLB
P639	3467	Michoacan 31	MEX
P643	4459	NEP - 2	CRI
P645	3597	Diacol nima (I-204)	VEZ
P646	0881	PI 203-958 (N-203)	USA
P649	4312	Puebla 439	MEX
P670	3059	Mateado sesentano	GUA
P672	4164	G1-1-5-1 (N-315)	CRI
P675	4525	Línea 32 (ICA pijao)	CLB
P678	3058	De vara (GUA-0129)	GUA
P681	5054	H1 Mulatinho (BRZ-343)	BRZ
P682	5208	BRZ - 1087 (I-162)	BRZ
P684	1320	PI 207-262 (tlalnepantla 64)	USA

Program Promising No.	CIAT accession No.	Identification or registration	Source
P685	5694	Cornell 49-242	USA
P691	4489	Cuilapa 72	GUA
P692	4494	Diacol calima	CLB
P693	5653	Ecuador 299	ELS
P696	4791	Honduras 46	NIC
P698	5476	Jules	USA
P699	5652	Mexico 309	ELS
P704	4795	Porrillo 1	ELS
P706	5701	Rojo 70	ELS
P708	4473	Titan	CHL
P709	4485	Turrialba 1	GUA
P712	4792	51052	NIC
P714	4505	Top crop	USA
P718	4789	Cubagua	VEZ
P719	5710	G.N.UI.31	USA
P720	0832	PI 200-974	USA
P721	1401	PI 224-743	USA
P729	1951	PI 310-668	USA
P737	4456	Jamapa	CRI
P739	4509	Masterpiece	UTK
P743	4829	Paraná (lote 3)	BRZ
P746	4830	Rio tibagi (lote 10)	BRZ
P755	4460	Pompadour 2	CRI
P756	4445	Ex-rico 23	CLB
P757	4461	Porrillo 1	CRI
P758	4446	Ex-puebla 152 (Brown seeded)	MEX
P759	0076	Red kloud	USA
P763	3329	Puebla 38-1	MEX
P766	5719	Aurora	USA
P775	4197	Black turtle soup B.	CRI
P776	4472	Tortolas	CHL
P778	4637	Cundinamarca 115C (arbolito)	CLB
P779	4638	Cundinamarca 116 (arbolito)	CLB
P780	2997	Rabia el gato	GUA
P782	6380	Kaboon	NET
P788	1540	PI 284-703	USA
P793	5712	Comp. chimaltenango 3	GUA

Appendix B. List of CIAT accessions (not classified as Promising Lines) of *Phaseolus* referred to in the 1977 Bean Program Annual Report.

CIAT accession No.	Identification or registration	Source
GO0729	PI 186-506	USA
0731	PI 189-012 Tsib. Tsinap'ul	USA
0738	PI 189-406 Piligue	USA
0805	PI 197-034	USA
0838	PI 201-317	USA
0843	PI 201-345	USA
0844	PI 201-348	USA
0875	PI 203-930	USA
0891	PI 204-721	USA
0951	PI 209-479	USA
0983	PI 224-738	USA
1018	PI 244-715	USA
1069	PI 281-979	USA
1079	PI 282-024	USA
1080	PI 282-025	USA
1157	PI 299-388 *Phaseolus lunatus*	USA
1212	PI 196-299	USA
1224	PI 196-936	USA
1253	PI 200-978	USA
1257	PI 201-300	USA
1365	PI 209-801 Kapumbu	USA
1814	PI 209-797 F. azufrado amarillo	USA
2033	PI 310-783	USA
2161	PI 311-191	USA
2227	PI 311-861	USA
2258	PI 311-904	USA
2262	PI 311-908	USA
2270	PI 311-917	USA
2497	PI 313-514 Negro	USA
2597	PI 313-724	USA
GO2602*	PI 313-730	USA
2618	PI 313-755	USA
2620	PI 313-758	USA
2634	PI 313-776	USA
2829	PI 319-631 Fríjol apetito	USA
3208	Fríjol Negro (GUA-431)	Guatemala
3391	Puebla 422	Mexico
3407	Puebla 441	Mexico
3445*	Guanajuato 22	Mexico

CIAT accession No.	Identification or registration	Source
4016	Stringless Green refugee (P-120)	Costa Rica
4231	Mexico 21N (N-22)	Costa Rica
4503	Widusa	Francia
4567	Antioquia 130	Colombia
4590*	Boyaca 21 Sangileno	Colombia
4762*	Chiapas 163	Mexico
4826	Pintado	Brazil
5487	Great Northern U.I. 123 (V-1217)	United Kingdom
5714	Seafarer	USA
5732	Mexico 235	Salvador
5772	Diacol Andino	Colombia
5942	PR-70-15R-55 (PR3)	Puerto Rico
6014	Guatemala 388 (HON-0491)	Honduras
6374	Bountiful	USA
6391	Linea 20667	Colombia
6719	Jubila	Holanda
6732	Stringless Green Pod	USA
6734	Improved Tender Green 40031	USA
7121	Goiano Precoce (HON-2633)	Honduras
	TMD-1	Brasil*
	Zamorano	Honduras*

Appendix C. **Description of growth habits of *Phaseolus vulgaris* L. used by the CIAT Bean Program.**

Following are the definitions of the growth habits for *Phaseolus vulgaris* L., as used by the CIAT Bean Program.

TYPE I: Determinate growth habit; reproductive terminals on main stem; with no further node production on the main stem after flowering commences.

TYPE II: Indeterminate growth habit; vegetative terminals on main stem with node production on the main stem after flowering commences; erect branches borne on the lower nodes of the main stem; erect plant with relatively compact canopy; guide development variable depending on environmental conditions and genotype.

TYPE III: Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of prostrate branches borne on the lower nodes; prostrate plant with spreading habit; guide development extremely variable with some tendency to climb in some materials under certain conditions but generally showing only weak climbing ability.

TYPE IV: Indeterminate growth habit; vegetative terminals on the main stem; heavy node production on the main stem after flowering commences; branches not well developed compared to main stem development; types which show moderate to strong climbing tendencies on supports.

Notes: The most important distinguishing features of the four growth habits are as follows: terminal raceme on main stem for Type I; indeterminate with erect branches for Type II; indeterminate with prostrate habit and branches for Type III; and indeterminate with well developed climbing ability in Type IV. Intermediate types occur between Types II and III and between III and IV. Growth habit is not a stable characteristic of many genotypes since drastic changes in growth habit occur from one location to another. Relative guide development is not a good indication of growth habit due to extreme instability in this character.

Appendix D. **Description of bean ideotypes according to their characteristics under development in the CIAT Bean Program.**

Following are summaries of the main characteristics of four ideotypes which have been defined as goals for selection in the breeding program at CIAT.

IDEOTYPE A: Indeterminate growth habit (Type II) with a short growing season (less than 70 days to physiological maturity); erect plant type with erect branches; limited node production on the main stem after flowering; pods borne as high as possible to avoid pod contact with the soil; lodging resistant. Defined for cropping systems (monoculture, association or relay) which require bush beans of early maturity and where plant densities can be maintained at approximately 250 x 10^3 plants/ha.

IDEOTYPE B: Indeterminate growth habit (Type II) with a long growing season of more than 90 days to physiological maturity with a long preflowering period of more than 50 days; erect main stem with few branches borne erectly; moderate node production on the main stem after flowering but with limited guide development; highly lodging resistant; pods borne out of contact with the soil.

Defined for monoculture cropping systems requiring a late high yielding variety which can be mechanically cultivated or associated and relay systems where plant densities can be maintained at approximatelly 250 x 10^3/ha.

IDEOTYPE C: Indeterminate growth habit (Type III) with a range of maturity types; prostrate plant type with well developed branches which show ability to compensate for low plant densities and irregular distribution; long flowering period (compared to ideotypes A and B) but with relatively even pod maturity; some ability to climb weakly could be an advantage.

Defined for cropping systems requiring bush beans with stable yields under suboptimal growing conditions; monoculture associated or relay systems where plant densities are usually below 200 x 10^3/ha and where the level of agronomic inputs in restricted.

IDEOTYPE D: Indeterminate growth habit (Type IV) with a range of maturity types; climbing beans with vigorous climbing ability on associated or relay crops or in monoculture on artificial support; limited branch development and with stable growth habit.

Defined for cropping systems requiring climbing ability to exploit the yield advantage of climbers and where a relatively high level of manual labor input is possible; cropping systems with maize in direct association or in relay or in systems where artificial support systems are possible under monoculture conditions.

NOTE: A determinate (Type I) ideotype is not included in these recommendations. However for areas where extreme earliness in required the only alternative may lie in the use of determinate materials. Type I materials have shown poor adaptation and strong instability of yield in many CIAT experiments and the 1976 IBYAN.

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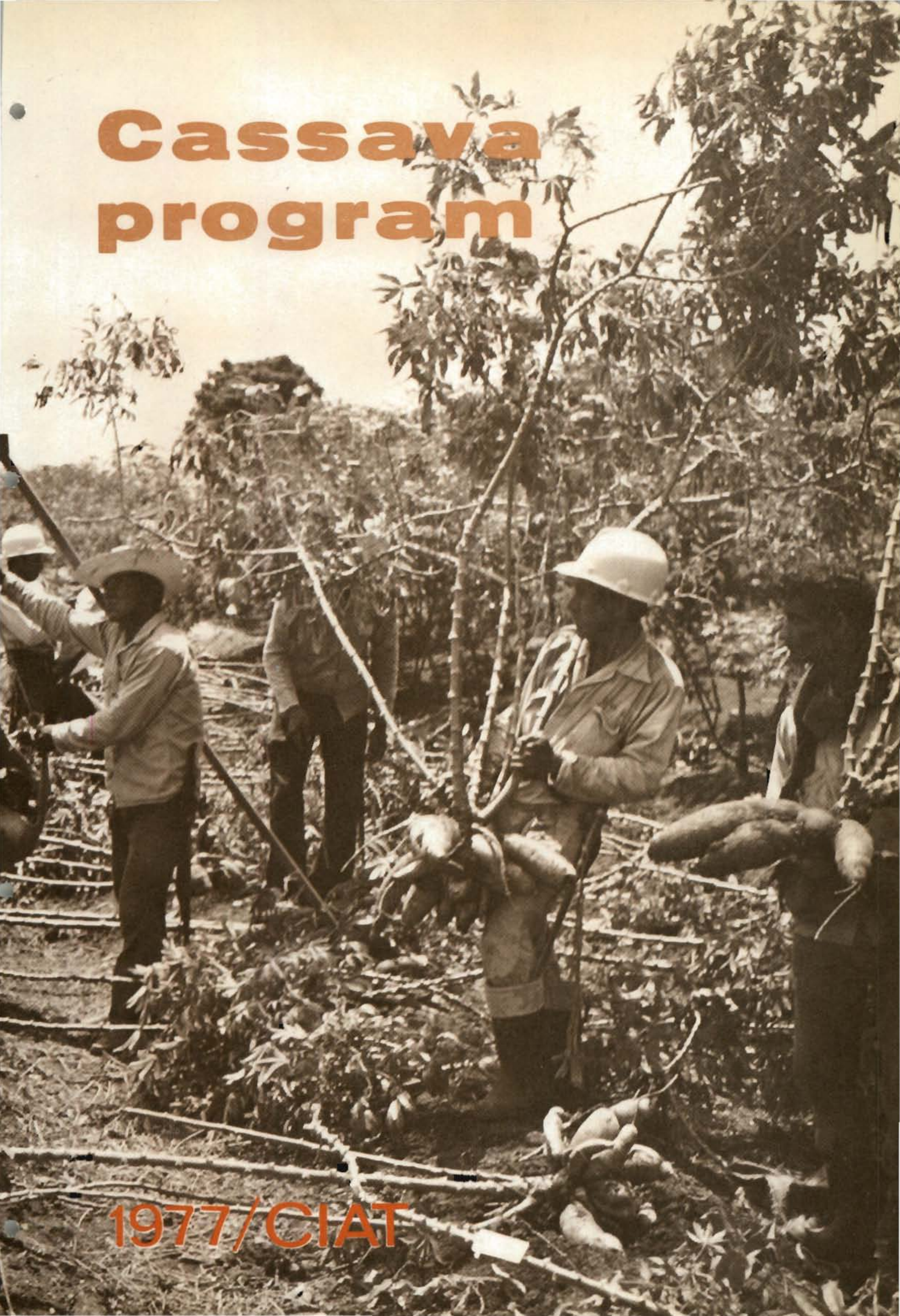
Hudgins, R.E. 1977. Adapting agronomic technology for small farm bean production in highland Colombia. Unpublished PhD. Thesis. University of Florida, Gainesville, Fla.

Cassava program



1977/CIAT

Cassava Program

During 1977 the Cassava Program continued its efforts to reach its objectives of: (1) producing a low-input technology for increased cassava production in areas where it is presently grown; (2) developing technology for cassava production of the infertile acid soil areas of the tropics; and (3) diffusing these technologies to national and local agencies and assisting them where possible.

A multidisciplinary team works as a group to resolve problems associated with meeting these objectives. Of primary importance in the program strategy is to have a plant that is *per se* efficient in converting solar energy to carbohydrates. The characters of a plant to achieve this were described last year on the basis of a computer model. Experiments this year have confirmed the importance of long leaf life and late branching. Furthermore, efforts to seek variability in photosynthetic rate, which may ultimately be used to increase yield potential, showed that variation in this character is considerable.

Different genotypes were grown at three sites with average temperatures of 20°, 24° and 28°C. The same plant type yielded best in all sites, however, for the coolest site, which is at the lower limit of cassava's range of adaption, a different, more vigorous genotype was required.

Cassava is frequently found on the acid infertile soils and tremendous potential exists for increased production in these zones. Cassava will give good yields at low levels of lime (0.5 t/ha), however, new trials this year have shown that there is scope for selecting lines that do exceptionally well at this level or with even lower lime levels. Similarily lines were identified with good potential yields at very low levels of applied phosphorous.

Although the technology being developed aims to use the lowest possible fertilizer levels, fertilizers yield a high rate of return on investment. The use of rock phosphates show particular promise as a source of cheap fertilizer. With moderate fertilizer levels yields of 25-28 t/ha can be obtained on acid infertile soils.

A major problem in these low-fertility areas and the regions where cassava is already widely grown is the control of diseases and pests. Poor germination is often due to a number of organisms that attack the planting piece, especially if it is not planted immediately after cutting. A simple fungicidal and insecticidal dip that costs only 3US$ per hectare was found extremely effective in eliminating this problem.

The emphasis of disease and pest control is, however, not chemical. The extremely devastating disease cassava bacterial blight can be controlled by planting resistant varieties. Many of the new hybrids from the program have been tested for resistance and have shown acceptable levels even when infected with the most virulent strains.

The superelongation disease, first reported in 1974, was identified in several countries of Latin America where it causes severe losses. Although it can be disseminated by infected planting material, the fungicidal dip described above eliminates the diseases thus preventing early infection. Unfortunately, different races of the causal organism, *Sphaceloma manihoticola* exist. A small number of cultivars showed high tolerance to all known races.

One of the most widespread problems in cassava in the Cercospora diseases. These often cause yield losses of 20 to 30 percent but resistant lines were found which were not affected.

During the dry season severe attacks of thrips and mites occur and cause yield losses of up to 50 percent. The cassava germplasm at CIAT was screened for resistance to thrips and more than half the material showed high levels of tolerance. In the case of mites, high levels of resistance have not been encountered, nevertheless, massive screening showed that a number of varieties are tolerant to both *Mononychellus* and *Tetranychus* mites.

No varietal resistance to the hornworm has been found, however, biological control can be based on maintaining *Polistes* populations in the field, with strategic release of *Trichogramma* and applications of the bacterial disease *Bacillus thuringiensis*. These techniques are being tested on a commercial scale; early results suggest that the system is effective.

The cassava fruitfly *Anastrepha* spp. bores in the stem and allows the entry of *Erwinia caratovora* var. *caratovora*, which causes rotting of the interior stem parts. Stakes taken from damaged plantations and used for planting material give poor stands and reduced yields. Merely by proper selection of planting material, yields can be increased by up to 20 percent.

Although the desirable characters of an efficient plant type, lines tolerant to the acid infertile soils and resistant to major diseases and pests exist, they have yet to be combined in a single line. The breeding section tests more than 20,000 hybrids, from controlled crosses, each year in order to obtain new varieties with most of the desirable characters. New hybrids have good yield potential, 60 t/ha under the fertile CIAT conditions, 40 t/ha in Caribia with less fertile soils and a very pronounced dry season and 30 t/ha in the acid infertile soils of the Llanos Orientales. Disease and pest problems are still serious but progress was made this year to combine resistance with high yield potential.

Promising selections from the germplasm bank and the new hybrids are multiplied with the rapid propagation technique. This system was further refined and simplified and is now used routinely. The promising material after multiplication, promising materials are planted in regional trials throughout Colombia. No fertilizer or post-emergence applications of insecticides or fungicides were used except for an intermediate application of fertilizer in the trials on the acid infertile soils. Carefully selected plant material is treated with fungicides and insecticides and planted, good weed control is practices but otherwise, no special care is given to the trials.

The year 1977 provided the third year of results from these trials. In the first two years when only preliminary selections were used, the advantage of selected lines over the best local lines was quite small. However, with the final selections from the germplasm a tremendous advantage was evident from combining good cultuval practices and selected material.

Previously, all work at CIAT has been on cassava as a monoculture crop. Much of the world's cassava is grown as a mixed culture. Cassava was grown in association with beans to test the potential of cassava grain legume association. Very high Land Equivalent Ratios were obtained — greater than 1.7 when cassava and beans were planted at the same time, and at their normal plant population. Yields of both crops were high at 34 t/ha and 2.9 t/ha of fresh cassava and dry beans, respectively.

A major problem faced by all cassava producers is the difficulty involved in handling the crop due to its extreme perishability after harvest. The perishability is due to physiological deterioration which often occurs within 48 hours of harvest and microbial deterioration which occurs five to ten days after harvest. It was found that the physiological deterioration can be prevented by either pruning the tops three weeks before harvest or by putting roots in to polyethylene lines papar bags directly after harvest. Microbial deterioration was prevented by treating the roots with a broad spectrum fungicide.

The international cooperation activities markedly increased in the Cassava Program in January 1977 with the assignment of two staff possitions — one based at CIAT to coordinate Latin American activities and the other, posted at SEARCA, the Philippines, to coordinate outreach activities in Asia.

Physiology

Temperature Effects on Cassava Growth

Preliminary results reported last year (CIAT Annual Report, 1976) suggested that different genotypes of cassava are required below about 24°C. These results have now been confirmed. The variety Popayan was the highest yielding at 20°C (Table 1) and by 16 months had produced 39.7 t/ha. On the other hand, at 24° and 28°C Popayan was the lowest yielding variety tested. M Col 22 was the lowest yielding line at 20°C at all harvests but showed good yield potential at 24° and 28°C.

Temperature adaptation of a variety appears to be directly related to its vigor. Popayan is very vigorous while M Col 22

Table 1. **Fresh and dry root yield of four contrasting cassava genotypes at different times after planting at altitudes with three different mean temperatures.**

	Avg. mean temperature								
	20°C Harvest date (months)			24°C Harvest date (months)			28°C Harvest date (months)		
	8	12	16	8	12	16	8	12	16
Fresh yield[1] (t/ha)									
M Col 22	2.7	9.3	13.3	22.1	22.7	48.3	23.9	39.4	53.1[2]
M Mex 59	9.2	22.8	32.8	25.3	38.8	57.0	21.3	30.4	60.3
M Col 113	14.2	24.2	28.6	16.4	26.1	51.3	20.2	23.9	55.0
Popayan	10.7	28.9	39.7	6.3	15.7	13.3	4.6	9.4	13.2
Dry yield[1] (t/ha)									
M Col 22	0.9	3.3	5.6	8.4	11.5	18.0	8.8	14.2	18.4
M Mex 59	3.0	8.2	12.9	8.2	14.2	18.1	7.5	10.1	19.7
M Col 113	4.5	8.4	15.6	5.4	10.0	19.1	6.2	7.5	17.0
Popayan	3.1	10.7	16.2	1.9	5.1	2.6	1.1	2.2	3.0

1 For fresh and dry root yields temperature x variety interaction was significant at P = 0.01

2 This yield was reduced due to robbery in the experiment plot.

has very low vigor. In general, vigor at 20°C was lower than at 24° and 28°C, as measured by leaf area index (LAI) (Fig. 1), and root bulking is maximized only over a small range of LAI (Fig. 2). The vigorous variety, Popayan, reaches its optimum LAI at a lower temperature than M Col 113 and M Mex 59 that in turn reach optimum LAI at lower temperatures than M Col 22. It follows that more vigorous varieties must be selected for maximum yields at lower temperatures and less vigorous varieties for higher temperatures.

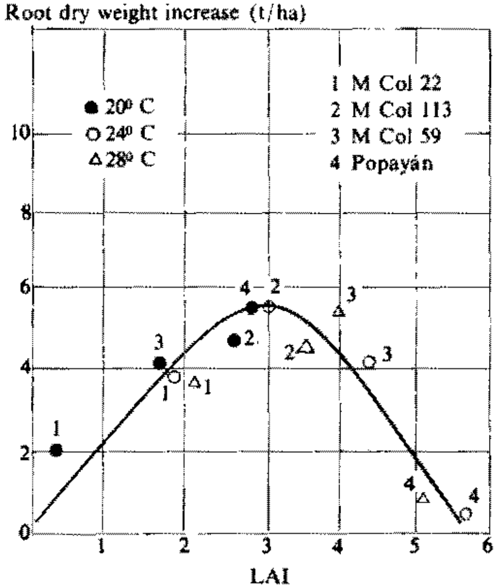


Figure 2. Root dry weight increase as related to mean Leaf Area Index (LAI) of four cassava varieties at 8-16 months after planting in locations having three mean temperatures.

Leaf Life

Simulation results suggest that increased leaf life should be a useful character for improving yield. The simulation model used assumed that older leaves were photosynthetically efficient. The older leaves are always lower in the canopy and receive less light than the upper ones. Photosynthetic rate of leaves of different ages was measured at 1500 $\mu Em^{-2} sec^{-1}$ and 500 $\mu Em^{-2} sec^{-1}$ (about three-quarters and one-quarter full sunlight, respectively). At 500 $\mu Em^{-2} sec^{-1}$, the photosynthetic rate of leaves up to 56 days after emergence was very little less than that of younger leaves (Fig. 3) suggesting that even these older leaves can contribute actively to total plant photosynthesis.

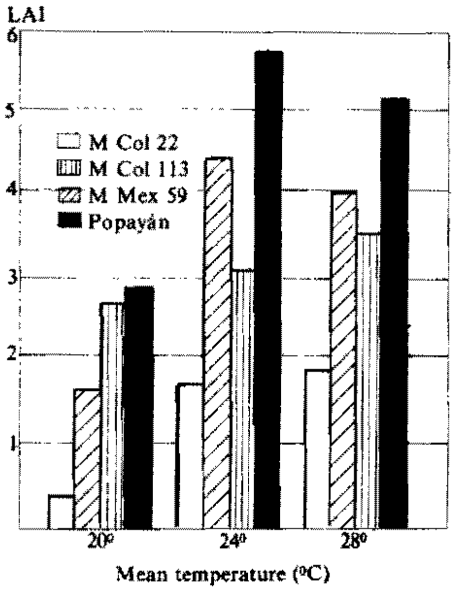


Figure 1. Mean Leaf Area Indices (LAI) from 8-16 months after planting for four cassava varieties grown in locations having three mean temperatures.

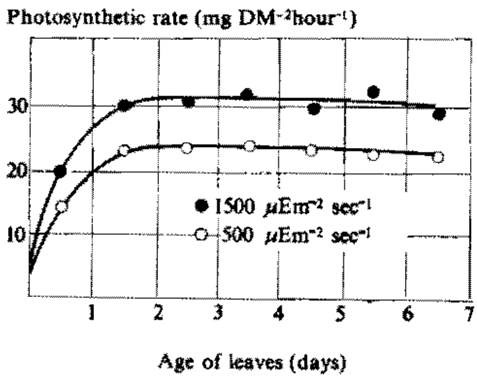


Figure 3. Effect of leaf age on photosynthesis of leaves of cassava variety M Col 72.

Rather than depend entirely on simulation data to assess the effects of leaf life on yield, M Col 72 with a leaf life of 120 days or more was planted at 20,000 plants/ha and leaf life artificially reduced to 49 or 84 days or left at its natural level. The natural leaf life was no greater than the 84-day treatment for leaves tagged up to two months after planting and therefore yields were similar for the 84-day treatment and control at the six month harvest but the plots with the 49-day leaf life had markedly reduced yields. By nine months after planting, leaf life of the controls was considerably greater than either treatment and yield was also greater when leaf life was longer (Fig. 4).

To obtain varieties with a long leaf life, a suitable screening technique was needed. Leaf life was measured on more than 200 new hybrid lines by tagging newly formed leaves at two, three and four months after planting. Only a small variation was found between varieties when leaves were tagged at two months after planting. However, when leaves were tagged at either three or four months large differences were found, ranging from 60 to 150 days. The high correlation between the two observations suggested that screening for different leaf lives can be done by tagging leaves at three to four months. In another trial where leaf life was measured, little difference was found in leaf lives of early-formed leaves but later-formed leaves showed large differences depending on the variety (Fig. 5). This confirmed that leaves formed in the first two months after planting are not suitable for screening for varietal differences in leaf life.

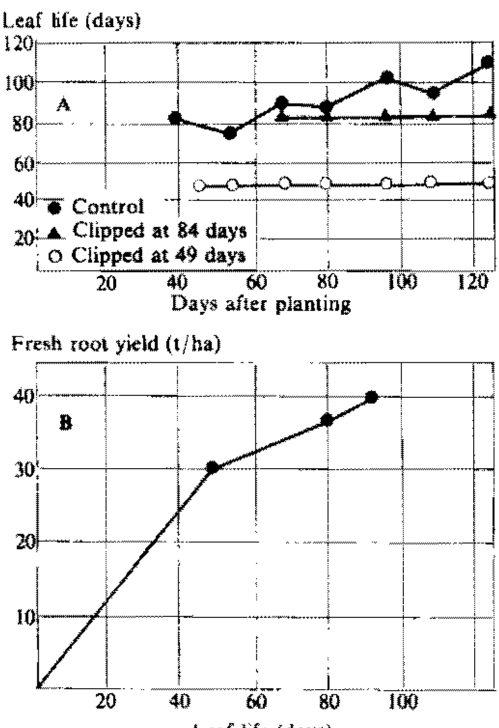


Figure 4. Leaf life of cassava variety M Col 72 with two clipping treatments (A), and effect of leaf life on fresh root yields nine months after planting (B).

Leaf Size

Leaf size in most varieties increases with increase in canopy height and then declines (Fig. 6). However, the leaf size of M Col 72, a non-branching variety, shows a much smaller decline than other varieties which have varying degrees of branching. When branching was restricted in M Col 113, a branching variety, the decline in leaf size did not occur, at least up to seven months after planting when the experiment terminated, while in natural branching plots leaf size at seven months was less than half that at four months (Fig. 7). This suggests that maximum leaf size is not affected by branching habit but that leaf size decline after four months is greater when branching occurs.

Last year (CIAT Annual Report, 1976) a computer simulation model was used to predict yields of cassava lines with different branching habits on the assumption that leaf size declines with time in all types. This would indicate that predicted yields of single stem types would be slightly lower than can be expected when leaf size decline does not occur.

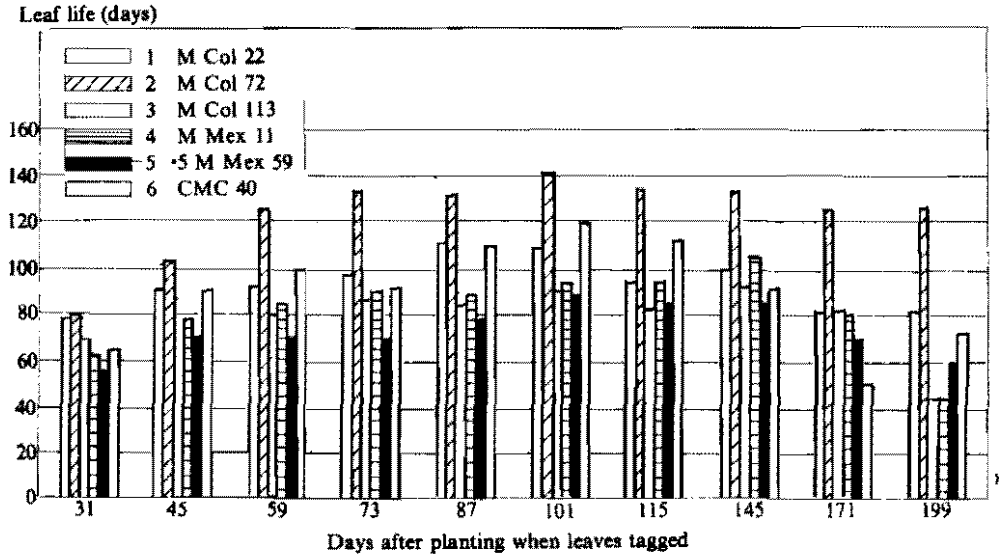


Figure 5. **Leaf life of six cassava varieties at different times after planting.**

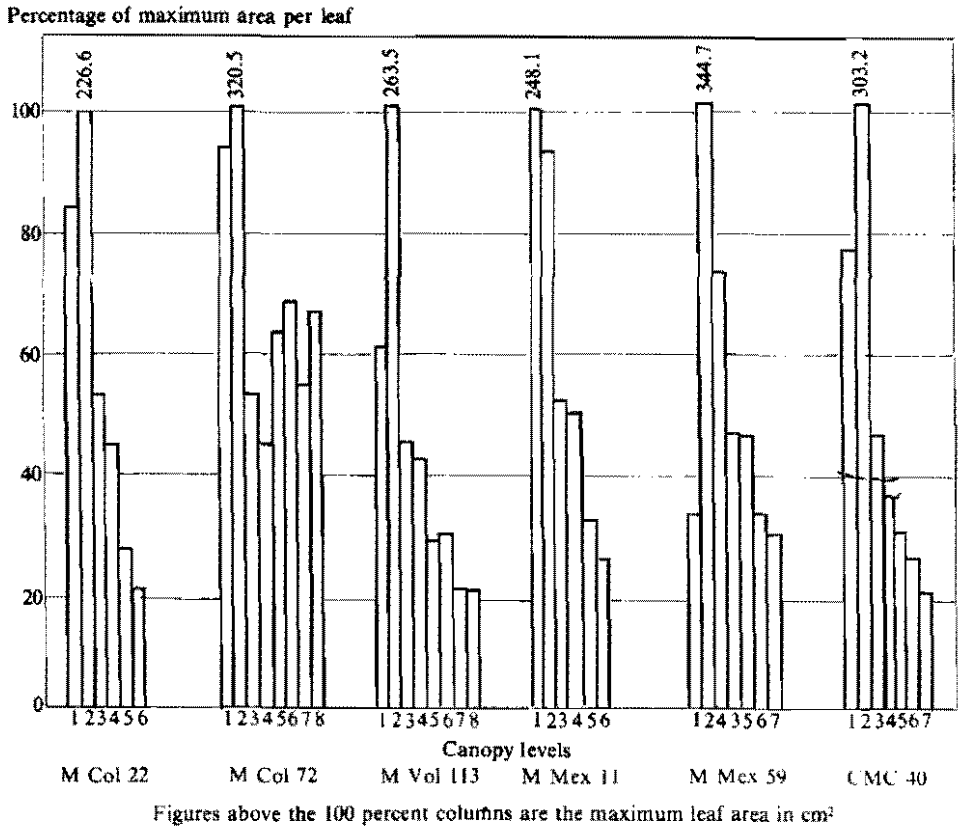


Figure 6. **Leaf size as affected by canopy-level of six cassava varieties.**

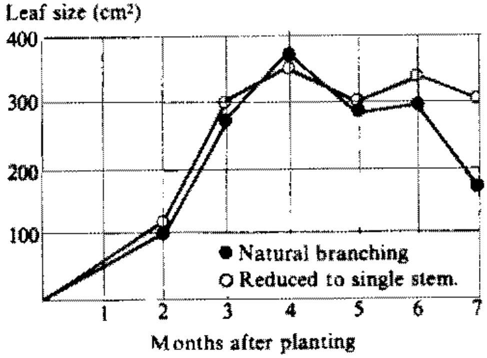


Figure 7. **Interactions of branching pattern and leaf size of cassava variety M Col 113.**

Root Sink Capacity

In previous reports, experiments to reduce root numbers by clipping suggested that the remaining roots have the capacity to accept more carbohydrate than is available (CIAT Annual Report, 1976). However, when root number was decreased there was always a slight decrease in total root yield, suggesting a sink limitation on root expansion.

During the early growth phase of cassava top growth is very vigorous and roots do not normally swell rapidly. It is not certain whether the roots do not expand due to inability to accept carbohydrates or to lack of available carbohydrate. Similarly, vigorous top growth at this period may be due to lack of alternative sinks (i.e. roots).

When top growth was reduced by apex removal total crop growth rate (as a function of LAI) was not affected (Fig. 8), demonstrating that top sink did not limit total photosynthesis and crop growth rate. Additionally, while LAI (and hence crop growth rate) was reduced, root growth rate was increased (Table 2). The roots clearly can accept more carbohydrate than is normally available in the early growth phase. These results also indicate that top growth has preference over root growth and that roots accept carbohydrate in excess of the needs of the tops.

The data demonstrate that top growth is a strong attractant of carbohydrates and in previous reports (CIAT Annual Report, 1976) it was suggested that in certain cases limitation of top growth could be used to increase yield. In fact, yield was increased 25 percent by restricting top growth. The vigorous variety M Col 113 was planted and different branching patterns were produced by clipping (Table 3). The most effective treatment increased yield 70 percent showing that the branching habit is extremely important for yield. There was also a close relationship between the actual yield obtained in the field and simulated yields (Fig. 9) suggesting that the simulation model described last year (CIAT Annual Report, 1976) can be used to predict high-yielding types.

Photosynthetic Rate

The simulation model was used to predict the effects of increased crop growth rate on yield. The model suggested that very small increases in crop growth rate should lead to large increases in yield (e.g. a

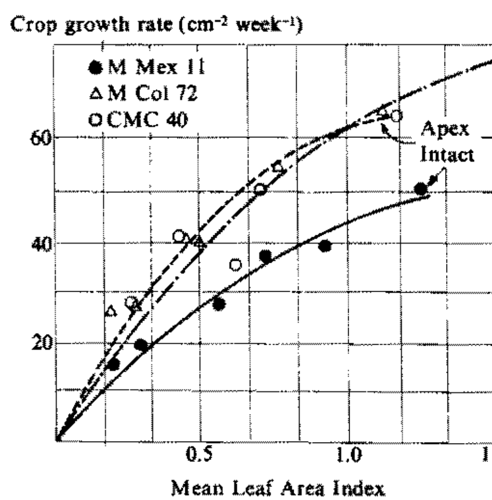


Figure 8. **Crop growth rate as a function of Leaf Area Index of three cassava varieties.**

Table 2. **Effects of apex clipping on crop growth rate and root growth rate of three varieties of cassava.**

	Crop growth rate (gm^{-2} wk^{-1})	Root growth rate (gm^{-2} wk^{-1})	$\frac{\text{Root growth}}{\text{crop growth}}$ x 100 (%)
M Col 72			
Control	67	18	28
Apex-clipped	54	23	42
CMC 40			
Control	77	18	23
Apex-clipped	64	21	33
M Mex 11			
Control	49	7	13
Apex-clipped	38	10	25
Mean			
Control	64	14	22
Apex-clipped	52	18	34

10 percent increase in crop growth rate at all LAI's should result in a yield increase of slightly more than 20 percent). Several varieties were screened for photosynthetic rate of individual leaves and large, consistent differences were found between varieties (Table 4). (It remains to be seen whether these differences can be related to differences in crop growth rate in the field.) Large differences in crop growth rate between three varieties were encountered and these differences maintained over a range of LAI's (Fig. 8). The cause of these differences has not been determined but the data suggest that yield may be increased via increased crop growth rate.

Harvest Index

In the CIAT Annual Report, 1974, it was suggested that the harvest index is a useful selection tool for cassava breeders. It has also been frequently noted that harvest indices in cassava are very high which is

Table 3. **Fresh and dry root yields of cassava variety M Col 113 with different branch controls.**

Branch time (weeks after planting)	No. of branches at each branch point	Dry root yield (t/ha)	Fresh root yield (t/ha)
12, 19, 27, 40	3 - 4	5.5	**17.6 (100)**[1]
14, 20, 28, 38	3	7.3	22.3 (127)
13, 20, 24, 33	2	10.3	29.6 (168)
No branching	1	8.4	26.9 (153)
26	3 - 4	8.5	25.4 (144)
27, 33	3 - 4	9.8	30.0 (170)
26, 32, 39	3 - 4	9.3	27.6 (157)

[1] Figures in parentheses are percentages of control.

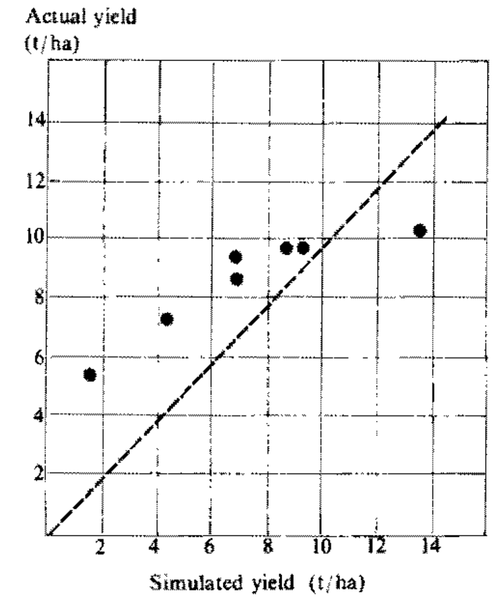


Figure 9. **Relation between actual yield and simulated yield of cassava variety M Col 113 with branch control (yield in terms of root dry matter).**

one of the reasons for its high yield potential.

The measured harvest index of cassava does not usually include fallen leaves. Nevertheless, when fallen leaves are included, real, high harvest indices of over 50 percent are still obtained. The relationship between real and measured harvest indices is consistent and therefore, measured harvest index is still a valid selection index although it has a systematic bias (Fig. 10).

INTERCROPPING

Relative Planting Dates

As cassava is slow to establish and form a canopy, it may be possible to intercrop cassava with a short-season crop such as beans. It was thought that one of the most important factors in determining the success of intercropping would be the

Table 4. **Photosynthetic rate of individual cassava leaves of 15 varieties at 100 uE $m^{-2}sec^{-1}$ of light intensity. (Mean of nine replicates).**

	DM Rate (mg dm^{-2} hr^{-1})	Standard Deviation	Percentage of maximum
M Col 72	33.2	2.6	100
M Col 22	32.1[1]	3.3	96
M Col 1292	31.5	2.9	95
"	31.5	2.8	95
CMC 40	31.0	3.3	93
M Col 113	30.9	2.7	93
M Col 946	30.9	2.5	93
M Mex 17	30.8	3.2	92
M Col 12	30.7	3.1	92
"	29.4	3.7	88
M Col 667	30.5[1]	2.6	92
CMC 84	29.7	2.1	89
M Col 638	29.8	3.9	89
M Mex 11	28.5	2.5	86
M Col 119	28.4	2.3	85
"	26.8	2.3	80
Popayan	27.1	2.1	81
"	26.7	3.2	80
M Mex 59	26.8	2.4	80

[1] Only six replicates compared to nine in the experiment.

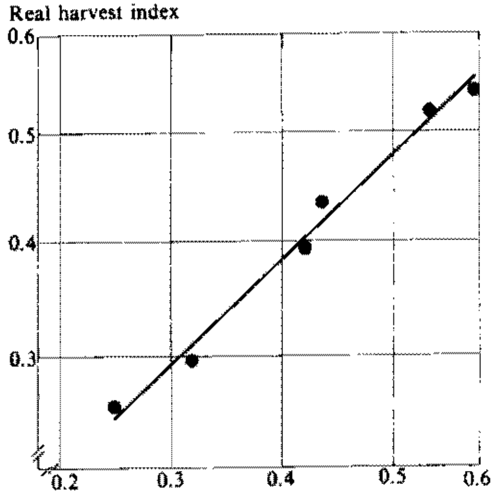


Figure 10. **Relation between measured and real harvest index of cassava.**

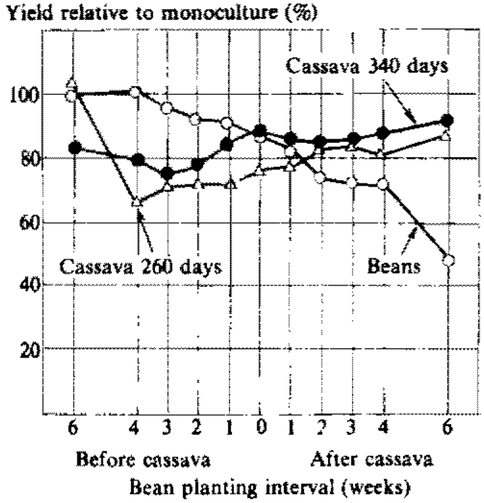


Figure 11. **Root dry matter yield of cassava at 340 and 260 days and yield of beans at maturity when beans were planted with different planting dates.**

relative planting dates of the two crops so that neither suffers from excessive competition.

When cassava and *Phaseolus* beans were intercropped at CIAT, cassava root yield was little affected by the planting date of the beans (Fig. 11) compared with monoculture cassava harvested at 340 days. When intercropped cassava was harvested earlier at 260 days, the effects were more pronounced with cassava yields being markedly reduced when the beans were planted four weeks before the cassava.

Bean yields were not reduced by intercropping with cassava when the beans were planted from four to six weeks before the cassava. However, bean yields showed a marked decline when beans were planted from three weeks before to six weeks after the cassava (Fig. 11).

When beans were planted six weeks before the cassava, total land use time for the two crops was 382 days. However, when they were planted at the same time or later, total land use time was 340 days when the cassava was harvested 340 days after planting. The Land Equivalent Ratio (LER) of the various planting dates was calculated as the ratio of the land area needed in intercropping/monoculture for both crops. (The land equivalent ratio was corrected so that all comparisons were made on equivalent total land use time.) The most efficient biological land use measured by the LER was 1.7 when crops were planted at the same time, or beans one week earlier (Fig. 12). This very high LER suggests that there is great potential for intercropping with cassava. Yields indicated that one hectare of land can

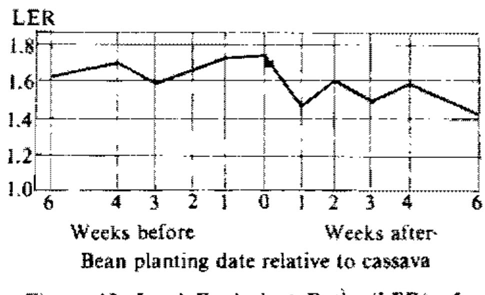


Figure 12. **Land Equivalent Ratio (LER) of a cassava/bean association at different relative planting dates (cassava M Mex 11).**

optimally produce 34 t/ha of fresh cassava and 2.9 t/ha of beans in less than one year.

Intercropping did not affect root dry matter percentage but the starch content on a dry matter basis was markedly reduced when beans were planted before cassava.

Plant Populations

When two different crops are planted together they compete for light, nutrients and water. As the density of each crop increases, competition increases. As the cassava density is increased in monoculture root yield either reaches a plateau or a marked optimum, depending upon the variety. As bean populations increase yields also increase and then reach a plateau. However, optimum plant populations for yield in intercropping may be different from those in monoculture.

Two varieties of cassava, M Mex 11, a non-leafy, late-branching type, and M Col 113, early-branching, leafy type, were planted at different population densities with P302, a bush bean with few branches, and Puebla, a prostrate, heavy-branching bean type. There was no obvious interaction of increasing densities of bean populations x cassava populations on yield of beans or cassava.

Since cassava was planted two weeks before the beans, yields of intercropped beans were low due to the bean planting date. Yield of Puebla in monoculture tended to increase slightly as density increased but no effect was observed in intercropping. However, the yield of the intercropped bush bean P302 increased with population density (Fig. 13). Bean yield was more severely reduced over all population densities when intercropped

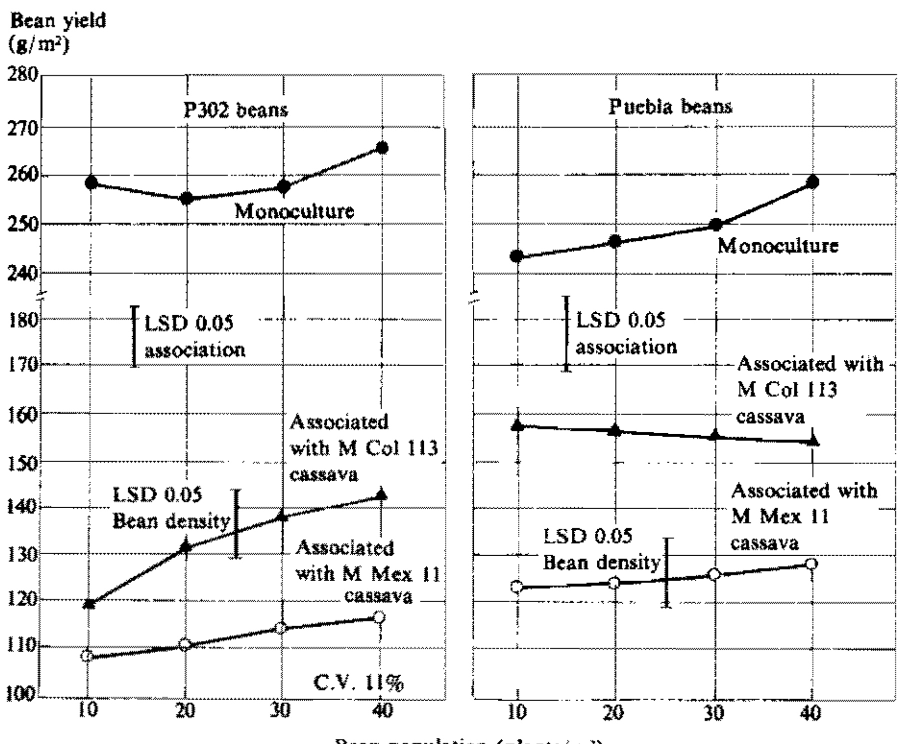


Figure 13. **Dry bean yield of two varieties as affected by plant density of beans alone and in association with two cassava varieties.**

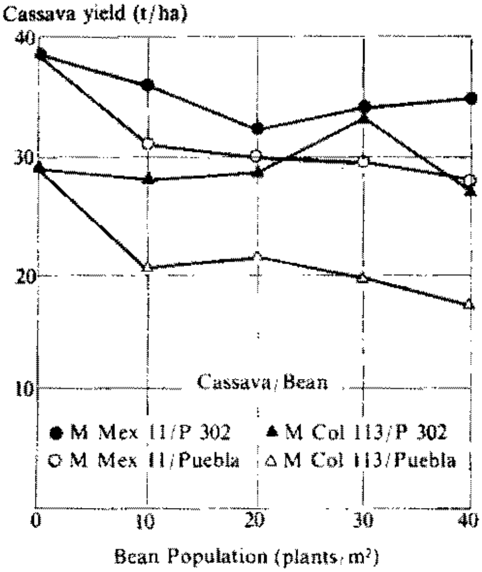


Figure 14. Cassava yields as affected by intercropping with two bean varieties at varying densities.

with M Mex 11 than with M Col 113. (M Mex 11 has more early vigor than M Col 113 and emerged above the bean canopy two weeks earlier.) However, bean density above 10 plants/m² did not affect cassava yields (Fig. 14).

When cassava density was increased bean yield was markedly reduced (Fig. 15). However, yield of M Mex 11 increased with plant population in both monoculture and intercropping. Yield of M Col 113 in monoculture reached a maximum at about 5000 plants/ha and then declined. When M Col 113 was planted at more than 6900 plants/ha and intercropped with P302, the cassava yield was superior to the monoculture level at any density. This suggests that intercropping beans with cassava in certain cases may increase the yield of M Col 113 above the monoculture level although yield never reached that of

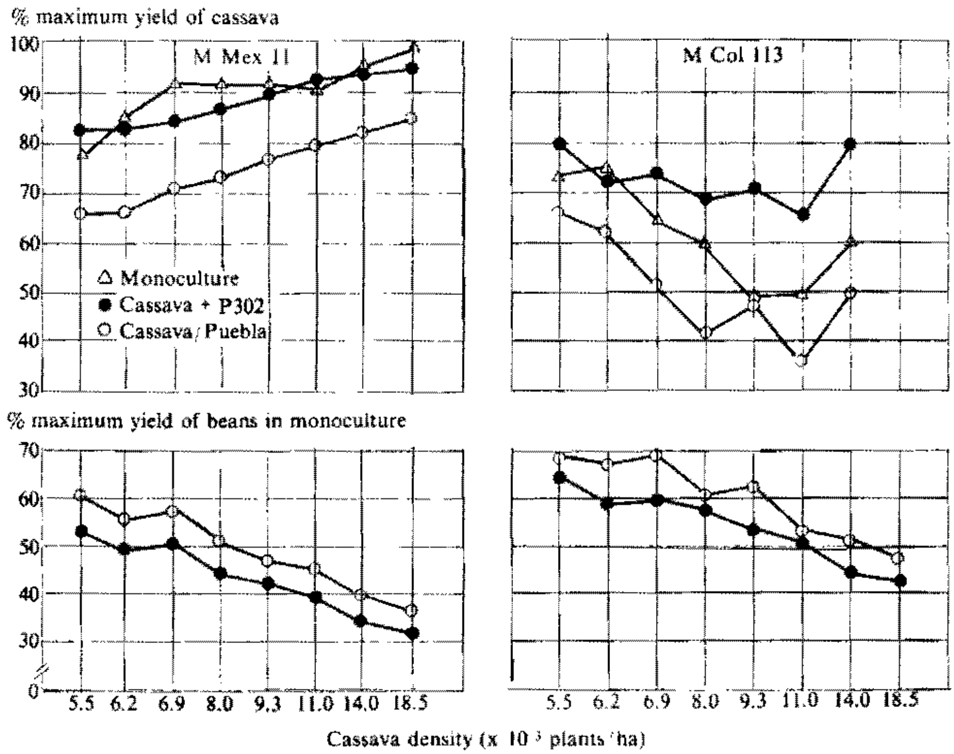


Figure 15. Cassava yields and bean yields as percentage of maximum yield as affected by cassava plant densities in association with beans and in monoculture.

M Mex 11 in monoculture. While the yield increase of M Col 113 may appear anomalous, early competition may have lowered early growth vigor reducing the later LAI to near optimum; consequently, yield improved in a process similar to that which occurs when apices are removed.

These data suggest that it may be difficult to breed for high yield in intercropping systems without depressing the yield of the associated crop. Nevertheless, when the best monoculture yields of 39.4 t/ha by M Mex 11 and 2.6 t/ha by Puebla were used as a reference, LER's of greater than 1 were consistently obtained in this trial (Fig. 16). As cassava density increased when M Col 113 was planted with Puebla, Land Equivalent Ratios declined but remained fairly constant in other combinations. Yields in this experiment were lower than those of the planting date trial; this may have been due to Problem X in the beans. The highest yields of cassava (M Mex 11) were obtained at the highest plant population (18,500 plants/ha) whereas the highest LER's were obtained at much lower plant populations of cassava. This suggests that optimum cassava populations may be different for intercropping cassava and beans, however, bean populations commonly employed can be used.

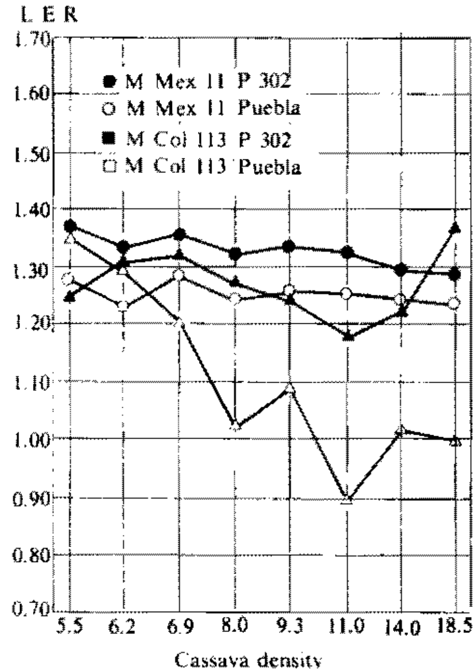


Figure 16. **Land Equivalent Ratio (LER) of different cassava/bean associations compared to best monoculture yield of cassava and beans.**

Pathology

Special emphasis was placed on research to determine losses due to *Cercospora* leaf diseases and the use of cassava bacterial blight (CBB) infected planting material. The efficacy of greenhouse and field screening evaluations for resistance to CBB were also determined and studies were done on the variability of the causal agents of CBB and superelongation.

Varieties, from the CIAT germplasm bank, and promising hybrids were evaluated for resistance to CBB, superelongation, *Cercospora* leaf diseases and Phoma leaf spot. Preliminary etiological studies were also undertaken on an unreported bacterial species that induced stem galls on several cassava clones. The effect of protectant fungicides on storage and germination of cuttings was also determined under field conditions to evaluate losses caused by the lack of sanitary precautions for planting material.

BACTERIAL DISEASES

Cassava Bacterial Blight (CBB)

Studies on pathogenic variability of the causal agent continued this year with 29 cassava varieties with different degrees of resistance and using two strains representative of each of the virulence groups 1, 2, 3, and 4 reported last year (CIAT Annual

Report, 1976). Ten 45-day-old plants/variety/strain were clip-inoculated. Results confirmed differences in virulence among the strains of this pathogen, but the strains did not interact differently with the cassava genotypes tested. Consequently, the existence of distinct races of the CBB pathogen has not been determined; the most virulent strains must be used for screening purposes.

Field *vs.* greenhouse screening methods. The efficacy of greenhouse screening for resistance to CBB (CIAT Annual Reports, 1975 and 1976) was determined by comparison with field evaluations in areas with high rainfall (2200 mm/year) for prolonged periods (nine months). Some 109 varieties were evaluated in the greenhouse and in Carimagua, using a highly virulent Carimagua strain. Twelve plants/variety were planted in Carimagua, at the beginning of the rainy season and six months after planting, naturally infected plants were evaluated.

Results showed a statistically significant correlation between greenhouse and field evaluations for identification of resistant varieties (Fig. 17). Even though some varieties showed moderate resistance in the greenhouse evaluation and susceptibility in the field, it was concluded that the greenhouse technique is useful as a rapid method of screening for CBB resistance, but later testing for resistance under field conditions is required.

When the same varieties were evaluated in the Cauca Valley (400 mm of rainfall scattered over six months), the most susceptible varieties in both the greenhouse and the Carimagua trials were only moderately infected eight months after planting. Therefore, it appears that field evaluation for CBB resistance requires: (1) initial inoculations; (2) several months of host exposure to the pathogen during rainy periods; (3) heavy rainfall (minimum of 120 mm/month) for at least four months; and, (4) evaluation at the end of rainy periods to avoid confusion with symptoms induced by other factors (insects, drought, etc.) and plant recovery due to the effect of dry periods on disease development.

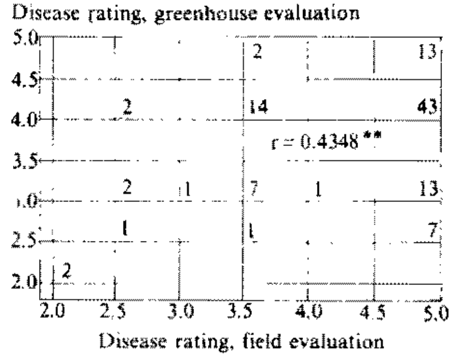


Figure 17. **Relationship between greenhouse and field evaluations (at Carimagua) for resistance to cassava bacterial blight (CBB) of 109 cassava varieties. (Resistant = 2.0; Susceptible = 5.0).**

(Figures within the matrix are the number of varieties for each pair of ratings.)

Field losses due to cutting infection. Disease losses caused by CBB in plantations infected at monthly intervals were determined last year (CIAT Annual Report, 1976) under Cauca Valley conditions, using the moderately resistant variety Llanera and the susceptible M Col 113 and M Mex 23. This year, three replicated plots of these varieties (36 plants/plot) were planted with cuttings taken from 10-month-old plants that had been infected at monthly intervals. No artificial inoculation was done and the rainfall was scattered, totaling only 688 millimeters.

When yields of plants from cuttings infected at nine months were compared with yields of controls (Fig. 18), yield reductions were 27, 29 and 31 percent, respectively, for Llanera, M Col 113 and M Mex 23. Cuttings taken from plants infected at two months yielded 38, 34, and 46 percent less than the disease-free controls. This suggests that CBB can seriously reduce yield when planting material is taken from infected plantations

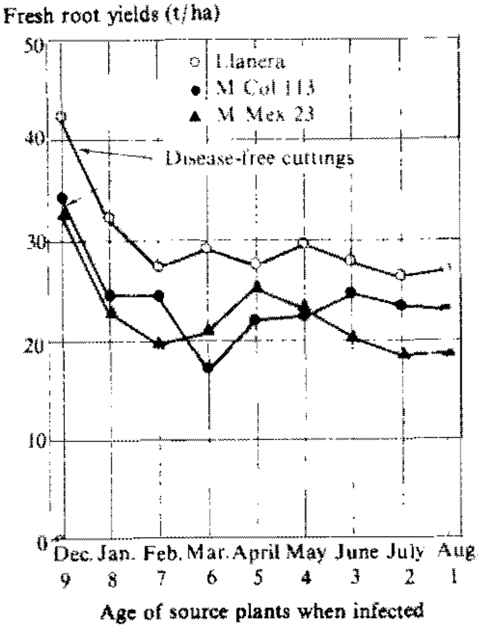


Figure 18. Yield losses of cassava when cuttings were taken from plants infected with cassava bacterial blight (CBB) at monthly intervals.

of susceptible or even moderately resistant varieties.

As rainfall was low and scattered during the experiment, yield losses can be principally attributed to the effect of primary CBB infections, reflected in reduced establishment and death of young plants during the first two months. In areas with periods of higher rainfall, disease losses could be considerably higher due to secondary infections.

Evaluation for resistance. To identify new sources of resistance to CBB 328 varieties were evaluated under greenhouse conditions; two were resistant, 90 tolerant, and 236 susceptible. Another 585 varieties were evaluated under field conditions at Carimagua; 5 were resistant, 31 moderately resistant and 549 susceptible. Additionally, 668 high-yielding hybrids developed by the Varietal Improvement section were evaluated under greenhouse conditions (Table 5).

Bacterial Stem Gall

A previously unreported bacterial disease of cassava has been found affecting three-year-old cassava plants. Infected plants are stunted and have large galls on the nodes of the most lignified part of the stem (Fig. 19). The galls are characterized by the presence of several germinal buds.

Isolation of the pathogen was made by grinding surface-sterilized tissues taken from galls, suspending them in sterile distilled water and streaking on Schroth's and Clark's media in petri dishes. Well-developed, white, mucoid bacterial colonies developed after two days incubation at 28°C. Pathogenic tests by direct stem inoculation with a needle prick were done on one-month-old plants of different varieties. Thirty days after inoculation symptoms appeared as normal tissue proliferation around the inoculation site; fifteen days later, galls were clearly formed; two months afterward, plants were weak and stunted; and three months after the inoculation over 90 percent of the plants showed dieback. However, the new shoots which developed below the galls were apparently healthy.

Galls were induced by this bacterial species on 30-day-old tomato plants by direct stem inoculation during a 20-day period. Also, galls were produced on young freshly sliced carrots on the secondary phloem two weeks after inoculation with cotton saturated witha heavy suspension of bacterial isolates.

Pathogenicity results and preliminary physiological and biochemical tests suggest that this pathogen belongs to the genus *Agrobacterium.*

Diseased cuttings produced 13 percent diseased plants in sterile soil under greenhouse conditions, but when apparently healthy cuttings were taken from diseased plants, no diseased plants were produced. Apparently, this bacterial

Table 5. **Greenhouse evaluation of resistance to cassava bacterial blight (CBB) of F_1 crosses from cultivars with different degrees of resistance.**

Cross combination	Reaction of parents	Reaction of hybrids[1] (%) R	MR	S	No. of hybrids
M Col 22 x M Mex 59	S x S	7.4	42.6	50.0	68
M Col 22 x M Ven 318	S x S	-	81.2	18.2	11
M Col 22 x M Ven 307	S x ?	-	70.0	30.0	10
M Col 22 x M Col 647	S x R	26.8	42.1	31.6	19
M Col 113 x M Col 22	S x S	-	43.8	56.2	16
M Col 113 x M Mex 55	S x S	-	66.7	33.3	18
M Col 113 x Llanera	S x MR	-	8.3	91.7	12
M Col 113 x M Col 638	S x R	18.5	22.2	59.2	27
M Col 113 x M Col 647	S x R	7.1	42.9	50.0	16
M Col 755 x M Ven 143	S x S	-	27.8	72.2	18
M Col 755 x M Col 655A	S x S	13.2	5.3	81.6	38
M Col 755 x M Col 690	S x S	20.0	30.0	50.0	10
M Col 755 x M Col 1684	S x MR	9.5	19.0	71.5	21
M Col 755 x M Col 647	S x R	6.9	41.4	51.7	29
Llanera x M Col 690	MR x S	-	12.5	87.5	16
Llanera x M Col 1684	MR x MR	6.7	6.7	86.6	15
Llanera x M Col 647	MR x R	7.8	23.5	68.6	51
M Col 647 x M Ven 143	R x S	10.0	30.0	60.0	10
M Col 882 x 7 varieties	S x [2]	17.6	26.5	55.9	34

[1] R = resistant; MR = moderately resistant; S = susceptible

[2] Susceptible: 5, Moderately resistant: 1, Resistant: 1.

pathogen can be disseminated by planting infected cuttings, but healthy planting material can be obtained from diseased plantations if stem pieces are carefully selected and sterilized knives are used.

FUNGAL DISEASES

Superelongation Disease

Pathogenic variability. Studies continued on the variability of *Sphaceloma manihoticola*, the causal agent of superelongation disease (CIAT Annual Report, 1976). Fourteen varieties, selected for their reaction to this pathogen in field and greenhouse inoculations, were artificially inoculated with 1.5 x 10^6 spores/ml with seven strains, from different geographical areas, under controlled environmental conditions.

Groups of strains of *S. manihoticola* interacted differently with cassava genotypes (Table 6). Of the cassava varieties, four differential groups were identified that showed resistance to three physiological races among the seven

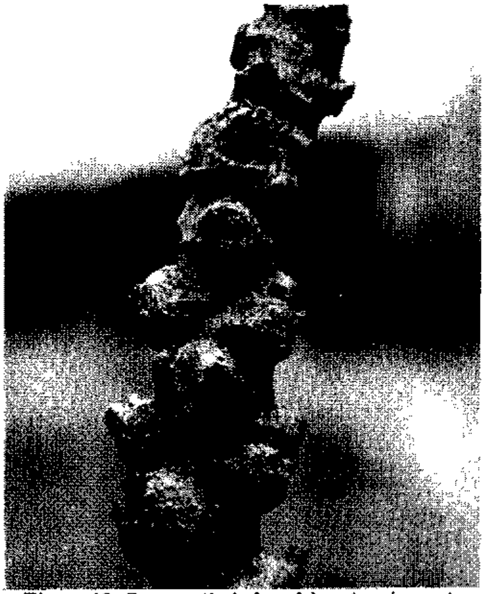


Figure 19. Stem galls induced by *Agrobacterium* sp. on a 2.5-year-old cassava plant growing in the field. Galls are on the stem portion nearest the ground.

strains of *S. manihoticola* tested. These physiological races have the following pathogenic characteristcs: Race 1 produces a susceptible reaction on differential groups of varieties I and II and a resistant or tolerant reaction on differentials III and IV; Race 2 produces a susceptible reaction on differentials I and III and a resistant or tolerant reaction on differentials II and IV; Race 3 produces only a susceptible reaction on differential group I.

The existence of physiological races of *S. manihoticola* was confirmed during field evaluations. Some 297 cassava varieties were planted at Quilichao and Carimagua, where Races 1 and 3, respectively, were detected. Some of the resistant varieties at Quilichao were susceptible at Carimagua and vice versa (Table 7). Consequently, disease reaction was interacting differently with genotypes at both locations. Seven of these varieties showed field resistance at both Quilichao and Carimagua. Further-

Table 6. **Reactions of 14 cassava varieties to seven strains of *Sphaceloma manihoticola* from different geographical areas.**

Differential group	Variety	Strain group, number[1] and varietal reaction[2]						
		Group 1			Group 2		Group 3	
		1	2	3	4	5	6	7
I	M Col 126	S	S	S	S	S	S	S
	M Col 115	S	S	S	S	S	S	S
	M Col 113	S	S	S	S	S	S	S
	M Col 61	S	S	S	S	S	S	S
	M Col 22	S	S	S	S	S	S	S
	M Col 23	S	S	S	S	S	S	S
	M Col 19	S	S	S	S	S	S	S
	M Col 133	S	S	S	S	S	S	S
II	M Col 39	S	S	S	R	T	R	T
	M Col 907	S	S	S	R	R	T	R
III	M Col 148	T	R	R	S	S	T	R
	M Col 645	R	T	T	S	S	R	T
IV	M Col 33	R	R	T	R	R	I	R
	M Col 96	R	R	T	R	R	T	R

[1] Area of strain collection. 1 = Jamundi (Col.), 2 = Pance (Col.), 3 = Santander (Col.), 4 = Quilcace (Col.), 5 = CIAT (Col.), 6 = Costa Rica; 7 = Carimagua (Col.)

[2] Disease rating: R = resistant (immune reaction), T = tolerant (leaf and petiole cankers), S = susceptible (elongation, leaf, petiole and stem cankers).

Table 7. **Reactions of 297 cassava varieties to *Sphaceloma manihoticola* in the field at Carimagua and Quilichao.**

Location	Reaction	
	Susceptible	Resistant, Moderately Resistant
Carimagua	284	13
Quilichao	270	27
Quilichao/Carimagua	290[1]	7[2]

[1] Varieties susceptible in either one or both sites.
[2] Varieties resistant at both sites.

more, they have shown the same disease reaction in the Quilichao area over a three-year period of continuous planting.

S. manihoticola also attacks the following perennial and annual alternate host species: *Manihot* spp., *Euphorbia pulcherrima*, *E. heterophylla*, and *Euphorbia* sp.

Pathogen survival. When samples were stored at 23°C (+ 8°C) and 70 percent relative humidity, the fungus was isolated from diseased stems, petioles and leaf tissues for up to six months. This indicates that the pathogen can survive long dry seasons.

Pathogen eradication from cuttings. As reported, the pathogen was eradicated from cuttings dip-treated for three minutes in captafol at 8000 ppm a.i. (CIAT Annual Report, 1976) which was confirmed this year. Also, copper hydroxide and captan reduced infection, but eradication was not complete (Table 8). Consequently, cuttings should be treated with captafol when material is taken from areas where superelongation is present.

Evaluation for resistance. Evaluation of selected varieties and promising, high-yielding hybrids was done at Carimagua and Quilichao. Of 1027 and 297 varieties and hybrids evaluated at Carimagua and Quilichao, respectively, 5.1 and 16.5 percent showed resistance. The varieties, M Col 19 and 258 were resistant to superelongation at both locations. Both varieties were also highly resistant to CBB in both greenhouse and field evaluations at Carimagua. M Ven 39 was resistant to superelongation and CBB in the greenhouse at CIAT and at Carimagua. It was not evaluated for resistance to superelongation at Quilichao.

Some 16.5 percent of 175 high-yielding hybrids were resistant to superelongation at Quilichao. The same material will be evaluated at Carimagua.

Phoma Leaf Spot

Of 260 varieties evaluated for Phoma leaf spot under field conditions at Popayan, only 2 percent showed any resistance to the pathogen. An evaluation of 343 hydrids from crosses between susceptible parents showed no resistance; 3.2 percent tolerance; and 96.8 percent susceptibility. This confirmed last year's results that the frequency of resistance to this disease is low (CIAT Annual Report, 1976) and that resistance can only be achieved with controlled hybridization using resistant sources.

Resistant varieties—CMC 92, Popayan, M Col 712, M Col 303 and Dovio—were

Table 8. **Control of *Sphaceloma manihoticola* on cassava cuttings by dipping for three minutes in fungicides.**

No. of Treatment[1]	No. of healthy plants	No. of diseased plants	Percentage of infection
Control	30	95	76
captafol	44	0	0
copper hydroxide	23	8	26
captan	38	4	10

[1] All solutions with chemicals contained 8000 ppm a.i.

planted continuously for the past four years in areas where this disease is endemic and epidemic (on susceptible varieties). These varieties have shown stable reactions which may indicate that resistance to this disease is stable. Similar results were obtained following artificial inoculations under controlled environmental conditions.

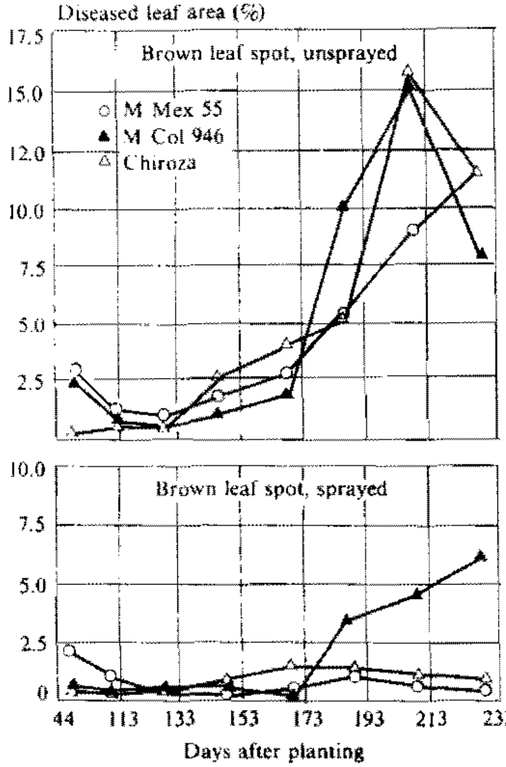


Figure 20. Percentage of diseased leaf area in cassava plots infected with brown leaf spot.

Cercospora Leaf Spots

Studies were done on the epidemiological aspects of brown leaf spot *(Cercospora henningsii)* and of leaf blight *(C. vicosae)* and the yield losses they cause. Five varieties and four hybrids were planted in a split plot design at Caicedonia (to study brown leaf spot) and Quilcacé (to study leaf blight). One-half the plots at each location were sprayed weekly with benomyl (150 ppm a.i./100 liters) for disease control. The development of each disease and its effect on leaf fall and yield losses were compared for the sprayed and unsprayed plots. Disease development was assessed at three-week intervals, based on percentage of diseased leaf area and number of lesions/leaf.

Brown leaf spot. Disease development with time is shown for three susceptible varieties in Figure 20. Results indicate that the lag in the inoculum build-up phase of this disease occurred during the first 183 days of planting, followed by an exponential phase (epidemic stage) of approximately 20-60 days which varies according to variety. The long time period required for the exponential phase indicates that it might be possible to prevent or reduce the exponential phase by programming planting with the rainy seasons. In areas with only one annual rainy season, planting at thz end of the rainy season can reduce the inoculum potential during the dry season, avoiding or reducing epidemics during the rainy season. In areas with bi-modal rainfall patterns, it might be better to plant at the beginning of the heaviest rainy period so that inoculum build-up would be reduced by the next dry period; if the second rainy period were mild the chances of an epidemic would thus be reduced.

Leaf fall was assessed as the inverse of leaf retention percentage. Differences were highly significant (P = 0.01) between sprayed and unsprayed plots. Similarly, the variety/disease interaction in percentage of defoliation was highly significant (P = 0.01) (Fig. 21).

The disease reduced fresh root yield significantly in susceptible varieties but not in resistant varieties (Table 9). Root starch content was also reduced 7.3 percent in the susceptible variety M Mex 55. These results indicate that fresh root yield and

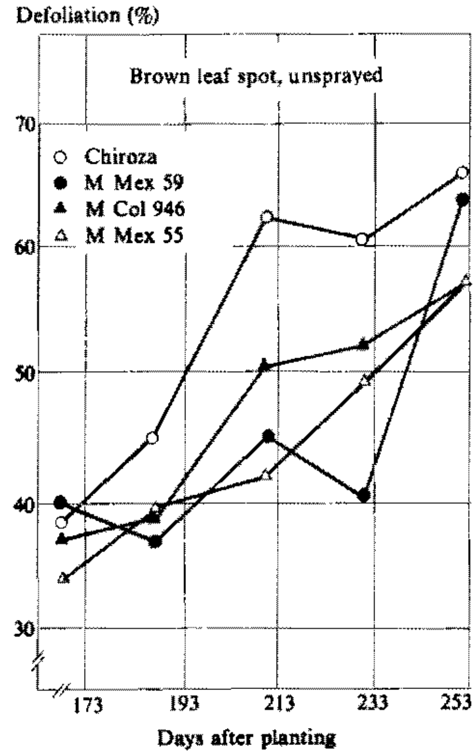


Figure 21. Relative defoliation of resistant and susceptible cassava varieties infected with brown leaf spot.

starch content are reduced on susceptible genotypes attacked by brown leaf spot.

Cercospora Leaf Blight. The development of this disease with time is shown in Figure 22. Apparently, the lag phase for this disease is shorter than that of brown leaf spot. This may indicate (as shown by yield assessments in Tables 9 and 10) that yield reductions caused by leaf blight could be higher than those for brown leaf spot; consequently, control by varietal resistance is more important for this disease. However, since the lag phase is long, programmed planting according to rainy/dry seasons should reduce epidemics.

Disease attack caused severe defoliation, as shown in Figure 23. M Col 803 showed relatively low leaf infection (Fig. 22), and hence, considerable defoliation (Fig. 23), possibly indicating this variety is highly sensitive to fungal infection (i.e. sensitivity to fungal toxin production). Similar data were obtained with other varieties. Yield was significantly reduced by the disease (Table 10) and root starch content was also reduced (Table 11).

Table 9. Fresh root yield of cassava genotypes infected with brown leaf spot (*Cercospora henningsii*).

Genotype	Reaction[1]	Yield (t/ha)			Percentage increase in yield
		Sprayed[2]	Unsprayed	Increase	
Varieties					
M Mex 55	S	27.96	23.79	4.17	14.91
M Col 946	S	29.70	26.65	3.05	10.27
Chiroza	R	29.13	29.57	-0.44	- 1.51
M Mex 59	R	32.72	32.95	0.23	- 0.70
Hybrids					
CMC-323-334	S	31.89	26.73	5.16	16.18
CMC-323-497	S	23.21	17.83	5.38	23.18
CMC-323-178	R	22.33	20.70	1.63	7.30
CMC-323-492	R	15.58	15.70	-0.12	- 0.77

1 S= susceptible; R= resistant; T = tolerant

2 Sprays were applied weekly, benomyl at 150 ppm a.i. 100 liters was the fungicide.

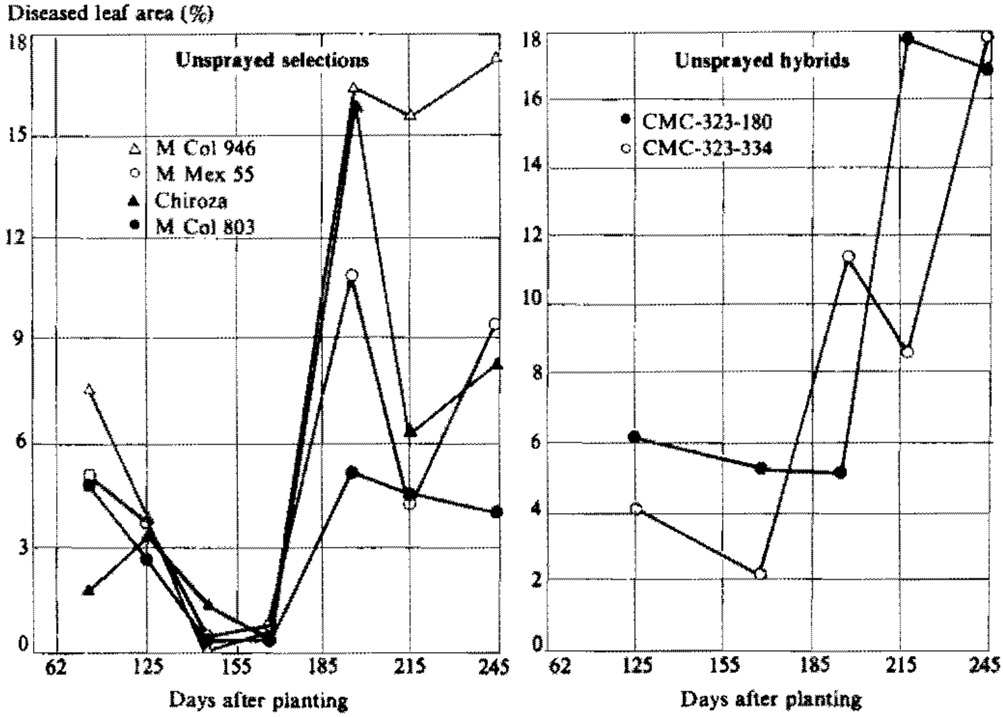


Figure 22. **Percentage of diseased leaf area in unsprayed cassava selections and hybrids infected with** *Cercospora* **leaf blight.**

Table 10. **Fresh root yield of cassava genotypes infected with leaf blight** *(Cercospora vicosae).*

Genotype	Reaction[1]	Yield (t/ha)			Percentage increase
		Sprayed[1]	Unsprayed	Increase	
Varieties					
M Mex 55	S	23.36	19.74	3.62	15.50
M Col 946	S	16.24	14.21	2.03	12.50
M Col 803	S	20.83	14.86	5.97	28.66
M Mex 59	R	24.90	24.28	0.62	2.55
Chiroza	T	15.13	14.80	0.33	2.18
Hybrids					
CMC 323-180	S	35.40	24.65	10.75	30.36
CMC-323-334	S	34.40	25.43	8.95	26.08
CMC-323-483	R	27.30	27.14	0.16	0.59
CMC-323-497	R	28.20	28.90	-0.70	-2.48

1 S = susceptible, T = tolerant, R = resistant

2 Sprays were applied weekly; benomyl at 150 ppm a.i./100 liters was the fungicide

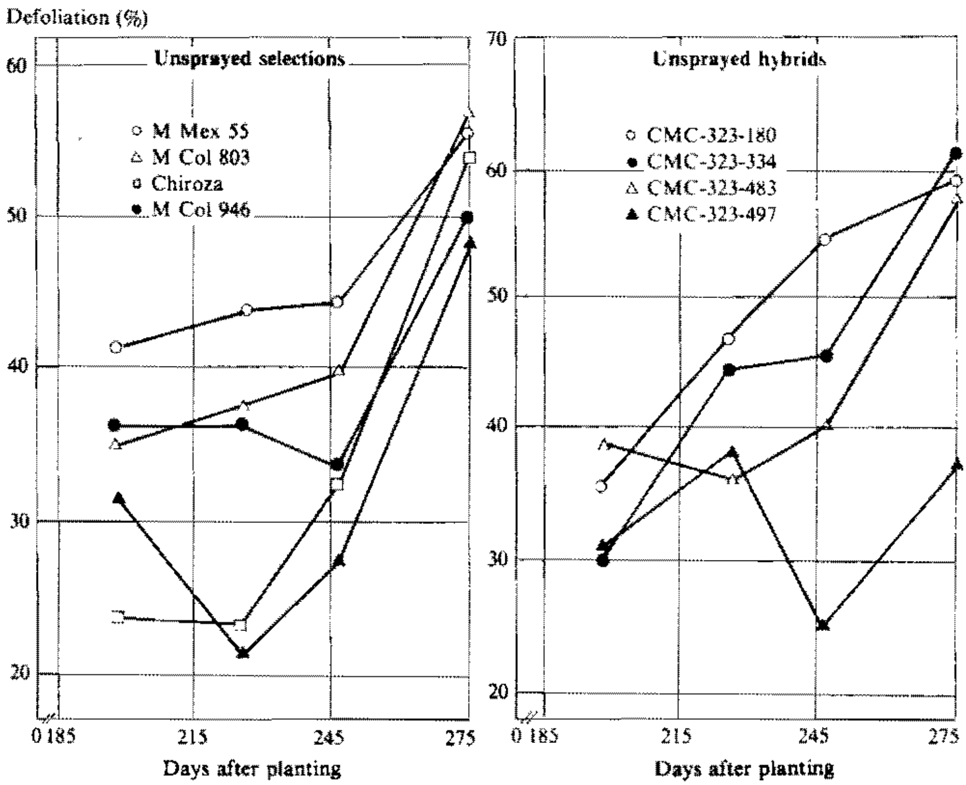


Figure 23. **Relative defoliation in resistant and susceptible cassava varieties and hybrids infected with** *Cercospora* **leaf blight.**

Relative importance of Cercospora diseases. Given the losses induced by these two *Cercospora* diseases and their occurrence in most cassava-growing areas, they are both economically important. Leaf blight may cause greater yield losses than brown leaf spot, but losses induced by both in areas where they occur simultaneaously may be higher than in areas where only one disease is present. Control methods that combine varietal resistance, with planting dates and spacing must be developed.

Table 11. **Percentage root starch content in cassava varieties infected with leaf blight** ***(Cercospora vicosae)*** **(sprayed/unsprayed plots).**

Variety	Reaction[1]	Root starch content decrease (%)
M Mex 55	S	3.6
M Col 803	S	8.2
M Mex 59	R	1.7
Chiroza	T	1.0

S = susceptible, T = tolerant, R = resistant

OTHER DISEASES OF CASSAVA

Frog Skin Disease

Investigations on transmission have shown that in addition to dissemination in cuttings (CIAT Annual Report, 1976), the disease is also transmitted by grafting (100%) and by using infested knives (about 5%). Furthermore, 90 percent of shoots taken from infected cuttings and rooted in sterile water produced diseased plants. New assessments of disease losses in the field were done in cooperation with the Secretaría de Agricultura of the Departamento of Cauca. These experiments showed that when diseased cuttings were used, complete loss of commercial root production was completely lost. But when healthy planting material of the same variety was used, yield was 22 t/ha.

Anthracnose

This year, it was found that this disease develops only in a high humidity environment. Following artificial spray inoculation, disease damage was severe (dieback on more than 50% of the plants) only on one-month-old seedlings when high humidity conditions were maintained for more than 24 hours. If the relative humidity dropped below 90 percent, plants tended to recover, producing new shoots. It appears that this disease is important only when cassava is planted during a heavy rainy period and when plants are attacked during the first two months. Nevertheless, disease damage to the stem can reduce the quality of the planting material. Germination of cuttings with heavy anthracnose damage (cankers) was reduced by about 15 percent, and about 20 percent of the germinated plants were weaker and smaller than controls.

TREATMENT AND STORAGE OF PLANTING MATERIAL

The effects of fungicidal treatment of cuttings on the variety M Mex 55 are shown in Table 12. Untreated control cuttings were attacked by insects and stem pathogens and were deliberately non-selected, to simulate what farmers normally do in the field. From the results, it is evident that unselected cuttings germinate poorly and plants have low yields. When these cuttings were treated with fungicide solutions, germination increased and plant yields were high. Results showed that captafol, which also controls superelongation in cuttings is a promising fungicide for cassava cutting treatments.

Table 12. Yield of M Mex 55, 12 months after planting unselected cuttings dip-treated for three minutes with different fungicide solutions.

Chemical	Germination (%)	Yield (kg/plant)
captafol	78[1]	4.1[1]
carbendizim + captan	75	3.5
carbendizim + captafol + PCNB	74	3.1
carbendizim	74	2.7
carbendizim + PCNB	74	2.3
carbendizim + maneb	66	2.3
maneb	62	1.9
Control	44	1.7

1 A significant difference (P = 0.01) existed between chemical treatments and the control.

To study the effect of fungicide treatments on storage of cuttings, long (70 cm) and short (20 cm) stem cuttings of M Col 946 (a good germinating variety) and M Col 803 (a poor germinating variety) were dip-treated for three minutes with BCM and captan (2000 ppm a.i. each) or chlorothalonil and maneb (4000 ppm a.i. each). Cuttings were stored in the shade in the field and weekly germination was tested by planting the cuttings at 50 plants/variety/treatment in a split plot design. Results (Figs. 24 and 25) indicated that: (1) there are varietal differences in germination over length of storage; (2) treatment of cuttings with fungicides prevents germination losses due to storage (BCM + captan appeared to be much better than other combinations); (3) germination losses are largely caused by pathogens and insects during storage (slight dehydration of cuttings does not seem to effect germination during the first month of storage); (4) short cuttings (20 cm) of a good germinating variety can be stored for a month without affecting germination if

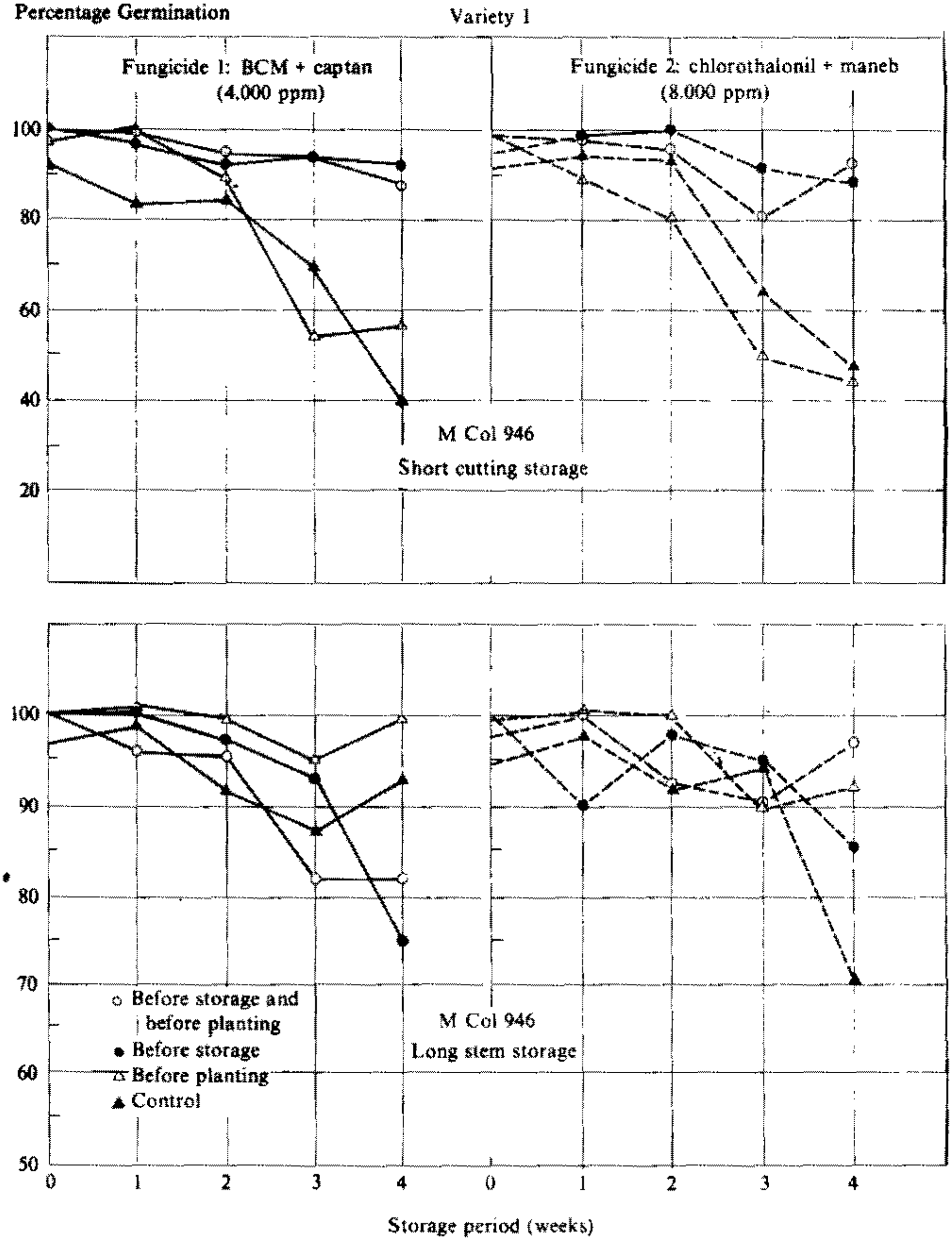


Figure 24. Effect on germination of cuttings after time of storage and treatment with two combinations of fungicides, field experiment.

they are treated with appropriate fungicide solutions: (5) for varieties with poor germinating ability, planting material should be stored in long (70 cm) stem pieces; and, (6) all planting material should be treated with appropriate fungicide solutions before storage. A second treatment before planting is recommended to

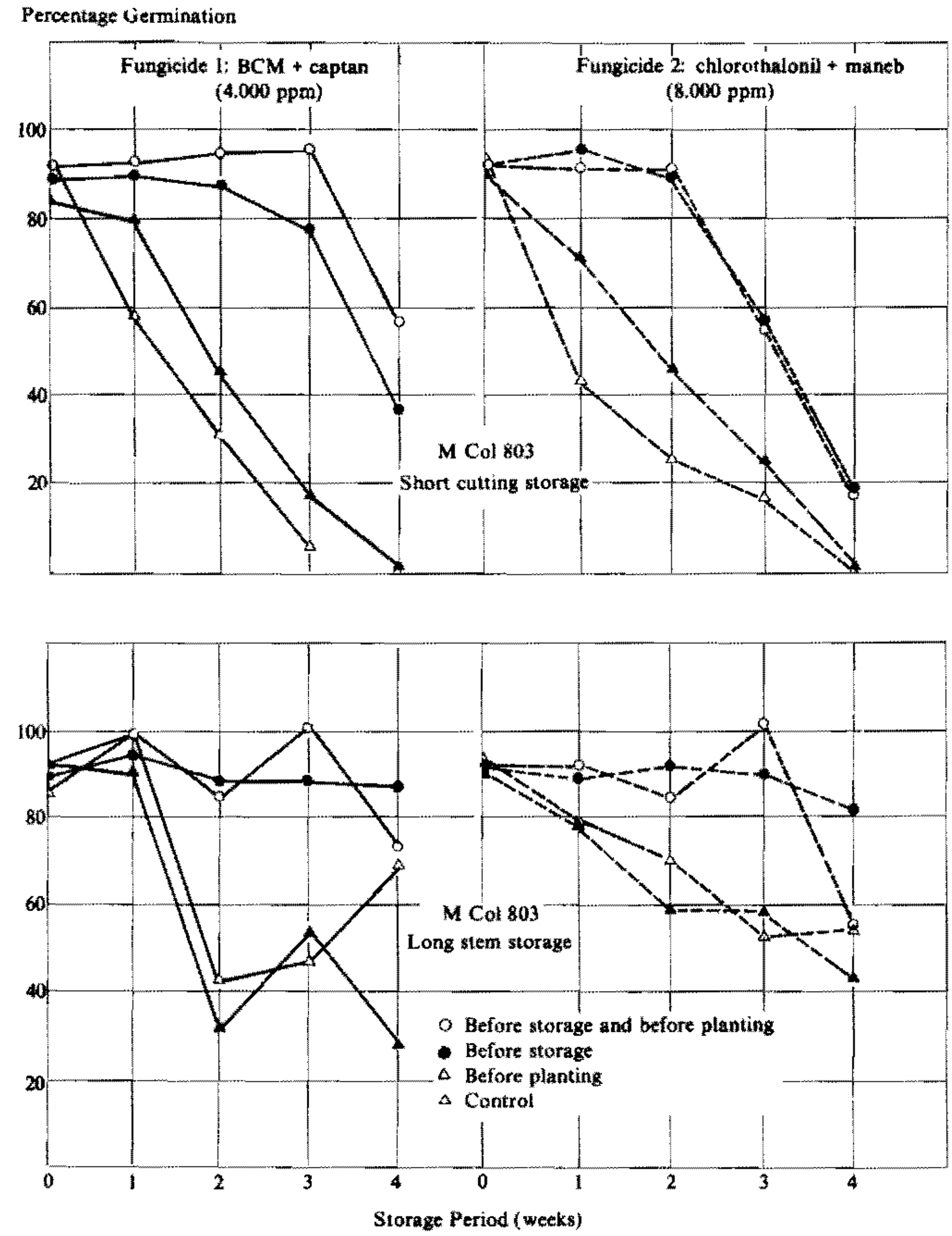


Figure 25. Effect on germination of cuttings after time of storage and treatment with two combinations of fungicides, field experiment.

protect cuttings of long stem pieces from microbial invasions through wounds made during shipping and preparation of cuttings.

Entomology

The main objective of the cassava pest management program is to suppress insect pests and maintain populations below their economic damage threshold avoiding the use of pesticides and other costly inputs when possible. Cassava entomology efforts emphasize the determination of yield losses, biology and ecology of pests, the use of insect-free planting material, and the development of control methods using host plant resistance, biological control, cultural practices and economic and discriminate use of pesticides.

CASSAVA HORNWORM

Economic Damage

The cassava hornworm *(Erinnyis ello)* has been described as a voracious feeder, defoliating extensive cassava hectarage and feeding on stem tissue and lateral buds. Yield losses have been estimated at 20-53 percent in damage simulation experiments (CIAT Annual Report, 1976). On a severely attacked commercial cassava farm where Chiroza, a vigorous, high-yielding variety was grown, four plots of 25 completely defoliated plants were maked near four plots of 25 undamaged plants. The plants were three months old when attacked and the crop was harvested at 12 months. Damaged plants had less foliage and were shorter than non-damaged plants. Average yield of undamaged plants was 4.58 kg/plant while defoliated plants yielded 3.75 kg/plant. This 18 percent yield loss equalled 6 t/ha on this farm.

Biological Control

Egg parasitism. Hornworm populations are cyclic and sharply increased oviposition during certain periods can disrupt natural predator equilibrium in many cassava plantations. However, natural egg parasitism by *Trichogramma* has been observed in many cassava fields and timing the liberation of *Trichogramma* parasites to coincide with increased oviposition could reduce subsequent hornworm populations (CIAT Annual Report, 1976).

This year two studies evaluated the effectiveness of liberating *Trichogramma* on the parasitism of hornworm eggs. During a period of high hornworm oviposition at CIAT, about 100,000 *Trichogramma* were released in a one-hectare field. A nearby field where no parasites were released was used as a control.

Natural egg parasitism before *Trichogramma* release in this experiment was 52.6 percent and 48.3 percent in the control and the treated field, respectively. Fifty plants/plot were sampled. Four days after parasite liberation percentage parasitism in the treated field increased by 24.8 percent but only 2.7 percent in the non-treated field— a difference of 22 percent increase in parasitism between the treatment and control.

In the second experiment, a field of cassava was sprayed with dichlorvos (a non-residual insecticide) to reduce natural hornworm egg parasitism. The field was then divided— the control portion having a 45 percent initial egg parasitism and the portion for *Trichogramma* release having 30.8 percent. *Trichogramma* were released at a rate of 100,000/ha and 150 plants/plot were sampled. After four days, the difference in percentage parasitism increase between the treatment and control was 23 percent (Table 13)— a rate similar to that recorded in the previous trial. One day later, parasitism of the control field increased to 74 percent and that of the release field reached 93 percent, demonstrating the effectiveness of release. These results indicate that *Trichogramma* release during periods of high hornworm

Table 13. Percentage of cassava hornworm *(Erinnyis ello)* eggs parasitized by *Trichogramma* sp. in release vs. Control fields.

	Release Field		Control		
Days after liberation	% of hornworm eggs parasitized[2]	% increase in parasitism	% of hornworm eggs parasitized	% increase in parasitism	% increase of liberated, non-liberated
1	30.8		45		
2	54.2	23.4	61	16	7.4
3	80	49.2	73.8	28.8	20.4
4	76	45.2	67	22	23.2
5	92.7	61.9	74.3	29.3	32.6

1 *Trichogramma* released 100,000/ha.

2 Sample of 150 plants/plot.

oviposition will significantly increase natural egg parasitism.

Larval parasitism. *Apanteles congregatus* and *A. americanus* are important larval parasites of the cassava hornworm in Colombia. These braconid wasps oviposit in hornworm larvae and the parasite larvae develop there. Mature larvae migrate from the host and pupate on the outer skin, forming a white cotton-like cocoon around the carcass of the hornworm larva.

Larval parasitism by *Apanteles* probably occurs during the first three hornworm instars. Observations indicate that during the later instars *Apanteles* usually emerge and pupate on the external surface of the hornworm larvae a few hours after emergence. The pupal cocoon encompassing the hornworm carcass averages 3.8 centimeters wide by 4.1 centimeters long. Each cocoon contains an average of 257 *Apanteles* pupae, about 80 percent of which emerge after 6-7 days.

Apanteles adults were liberated into hornworm-infested fields during 1977 to evaluated larval parasitism. In the first trial 11 cocoons were released in an isolated field and 408 cocoons collected after three weeks. At that time, 382 unparasitized hornworm larvae and 633 hornworm pupae were collected in the same field from which it was calculated that *Apanteles* produced about a 29 percent parasitism rate of hornworm larvae. A drawback to the use of *Apanteles* as a hornworm larval parasite is the high percentage of hyperparasitism observed. Seven different hyperparasites were collected from *Apanteles* at CIAT and a study of 112 *Apanteles* cocoons collected on three occasions showed an average of 56 percent hyperparasitism.

Bacillus Thuringiensis

Applications of *B. thuringiensis,* a commercial bacterial disease of hornworm larvae, were made when there were high populations of different larval instars. *B. thuringiensis* was effective against the first four instars (the fifth was not tested) but most effective against the first. In the treated fields four days after application first instar larval populations decreased 88 percent and second instar larvae, 46 percent. After six days third instar populations decreased 84 percent and after three days, a 70 percent decrease was observed for fourth instars. It should be noted that the untreated first instar hornworm population of the control was reduced 45 percent, probably due to natural parasitism in the field prior to the beginning of the experiment; the third instar hornworm population of the control was also reduced 53 percent due to extremely heavy rains.

HOST PLANT RESISTANCE

Mites

Screening in greenhouse and screenhouse. Screening of cassava varieties for resistance to *Mononychellus* and *Tetranychus* mites continued under controlled conditions in the screenhouse and greenhouse. Promising varieties selected during previous screenings (CIAT Annual Report, 1975, 1976) were re-evaluated in replicated trials to identify the most promising varieties, and 705 additional varieties were evaluated using the resistance scale (0-1 resistant; 2-3 intermediate resistance; 4-5 susceptible). Fifty-eight varieties were selected as promising for resistance to *M. tanajoa* and 31 as most resistant to *T. urticae*. Twenty varieties had resistance to both *M. tanajoa* and *T. urticae*, indicating a degree of cross resistance not previously suspected.

Field screening for M. tanajoa resistance. Almost 2200 cassava varieties were evaluated for *M. tanajoa* resistance during a natural outbreak at CIAT. One hundred and fifty-two varieties (6.9%) were scored resistant and 485 (38.5%) varieties showed intermediate resistance. Undoubtedly, a more severe mite attack would have resulted in fewer resistant varieties and some varieties selected as resistant may have been escapes. However, these results indicate considerable resistance to *M. tanajoa* under CIAT conditions which, because of the short dry seasons (2-3 months), do not allow large mite populations to build up.

Whiteflies

One hundred sixty-nine lines of cassava germplasm were evaluated for resistance to the whitefly *(Aleurotrachelus* sp.) When the plants were 2, 4 and 6-months-old, three separate ratings were made: one based on the level of whitefly infestation; one based on the number of whitefly pupae per leaf; and the third, on the degree of plant damage.

All 169 varieties were heavily infested by whitefly adults and pupae. However, the damage symptoms rating indicates that physical damage may be only moderate although the plant may be heavily infested. While yields of these varieties may not be directly affected by heavy whitefly infestations, these varieties may be susceptible to viruses transmitted by the whitefly.

Thrips

The CIAT cassava germplasm bank (2,247 accessions) was evaluated for resistance to the thrips, *Frankliniella williamsi*, during natural infestation in a three-month dry season. Results (Table 14) showed abundant sources of resistance to thrips in the cassava accessions. More than 58 percent were highly resistant (0-1 on a damage rating scale of 0-5) and only 20 percent were susceptible (3-5 on the damage rating scale). While more severe

Table 14. Evaluation of 2,247 varieties of cassava for resistance to the thrips *Frankliniella williamsi* with natural infestations in the yield.

Damage scale	No. of varieties	Percentage within grades
0	656	29.2
1	656	29.2
2	369	16.4
2.5	124	5.5
3	129	5.5
3.5	102	4.5
4	176	7.8
4.5	34	1.5
5	1	0.04

attacks of thrips could alter these ratings, these results indicate that resistance to thrips is the rule rather than the exception in cassava germplasm.

Scales

The adverse effect of scales on the germination of cassava cuttings during dry seasons has been previously reported (CIAT Annual Report, 1974). A study was designed to evaluate damage of the white scale *(Aonidomytilus albus)* to cassava cuttings of M Col 22 (a highly susceptible variety) treated with methamidophos and stored for one month before planting. Damage grades were also correlated to germination of the cuttings after planting in a randomized block of four plots with 25 cuttings per plot (Table 15). Germination was considerably reduced when scale-infected cuttings were stored for one month and insecticide treatment did not increase germination.

Treatment of planting material. Observations of cuttings of CMC 40 and M Col 113 (selected for tolerance and susceptibility, respectively, to scales) infested with only one or two scales around the bud showed that a severe scale attack can be produced when cuttings are planted vertically in the field under ideal environmental conditions (when the dry season begins shortly after planting). However, it was found that the insecticides—malathion, 4 percent at 1 g/liter; triazophos, 1 cc/liter; methamidophos, 1 cc/liter; and Triona + malathion, 2 cc + 1g/liter— all prevented a rapid increase of scale populations after planting. The treatments were more effective for CMC 40 than for M Col 113, indicating a varietal response to scale attack.

Table 15. **The effect of the white scale (*Aonidomytilus albus*) on the germination of cassava cuttings (var. M Col 22) treated with methamidophos and stored for one month prior to planting**

Damage rating scale[1]	% germination			
	Stored		Unstored	
	Treated	Untreated	Treated	Untreated
0	84	72	95	95
1	33	40	88	91
2	17	16	40	85
3	12	3	10	23
4	0	4	2	9

[1] Damage rating scale: 0 = no scales; 1 = few scales around buds; 2 = about 50% of buds covered with scales; 3 = scales covering buds and part of internodes; 4 = scales completely covering cuttings.

Yield losses. A field of M Col 22 was evaluated at harvest for scale damage using a damage rating scale of: 0 plants with considerable foliage and none or few scales on stems; 1 reduction in foliage and scales covering less than 50 percent of stem surface; and 2 severe defoliation, dead terminal buds and scales completely covering the stem surface. One hundred plants of each damage grade were harvested their weight recorded, and individual damage grades correlated with yield losses. Results showed a yield loss of 4 percent for those plants in damage grade 1 and a loss of 19 percent for damage grade 2; The latter damage represents a loss of 3 t/ha.

Biology of Aonidomitylus albus. The biology of the white scale, *Aonidomitylus albus* Cockerell, was studied in the laboratory (temp. 26°-28°C, RH 75-85%) on excised cassava stems (M Col 22 and M Col 113). Male scales passed through two nymphal instars averaging 10 and 6.5 days, respectively, and a prepupal and pupal stage totaling 4.5 days. Adults lived 1-3 days and the male life cycle was about 23 days. In a sample of 30 females, three nymphal instars were observed averaging 10, 5 and 9 days, respectively. The third nymphal instar is the adult stage. Eggs are oviposited under the scale and nymphs emerge during a seven-day period. Peak emergence occurred from day 3-5 and each female produced an average of 43 nymphs. Nymphs, or "crawlers" are mobile for up to three days, at which time they become stationary and feeding initiates. Males have wings and can fly while the female is wingless and stationary. Differentiation between the male and female occurs during the second instar. Copulation occurs when the female reaches the third instar.

Fruit Flies

Cassava fruit flies *(Anastrepha pickeli* and *A. manihoti)* damage planting material by tunneling in stems of growing plants and providing an entrance for the bacterial pathogen *Erwinia caratovora* var. *caratovora* which causes severe rotting of stem tissue.

The effects of fruit fly damage and subsequent attack by *E. caratovora*, on cassava (Var. Chiroza) in farmers' fields in Caicedonia, Colombia, were evaluated according to five damage grades which were correlated to yield losses (Table 16). Yield losses of the damaged cuttings ranged from 4.2 percent for grade 1 (least damage) to 33.1 percent for grade 3. Yield losses for grade 4 were less than in grade 3 for every trial. This may have been due to the possibility that while the grade 4 cuttings were more damaged, they may have come from a better part of the plant. In addition, this yield loss pattern observed on the three farms was not repeated in the trial at CIAT where a different variety, CMC 40, was used. Only three damage grades were used in the CIAT trial since damage was less severe. Results showed that cuttings with damage grade 3 yielded slightly higher than undamaged cuttings, possibly because they may have been taken from a better part of the plant as well.

Mealybugs

Outbreaks of the mealybug, *Phenacoccus gossypii*, caused severe defoliation and dessication of cassava stem tissue on the CIAT farm again this year but malathion effectively reduced populations.

The biology of the female mealybug was studied with 24 females placed on excised cassava stems (M Col 113) in the laboratory (temp. 26°-28°C, RH 75-85%). There were three nymphal instars with averages of 8.6, 5.7, and 6.3 days, respectively. Adult females survived up to 21 days. Oviposition was initiated between the fifth and seventh day and continued for

Table 16. **Effect of damage caused by the fruit fly *Anastrepha manihoti* and the bacterial pathogen *Erwinia caratovora* on germination of cassava cuttings.**

Damage scale[1]	Germination (%)	Yield (t/ha)[2] Farms 1	2	3	$\bar{X}$	% Yield reduction	Yield at CIAT (t/ha)[3]
0	90.3	38.9	41.0	41.7	40.2		23.9
1	85.7	32.9	38.1	44.5	38.5	4.2	21.9
2	83.7	26.3	39.2	38.4	34.6	13.9	22.1
3	82.7	19.9	26.5	34.2	26.9	33.1	26.2
4	74.0	29.3	31.6	37.7	32.9	18.3	

1 Damage scale: a brown discoloration in the pith area; 2= discoloration and some rotting at both ends of cuttings, 3 = severe rotting of pith; 4 = severe rotting of the tunnel and the pith area
2 Variety planted was Chiroza
3 Variety planted was CMC 40

five days. An average of 328 eggs per female were oviposited with the most eggs produced the first day and steadily decreasing thereafter. All eggs remain in an egg pouch on the posterior of the female's body until the nymphs hatch.

While nymphs in all instars are mobile they may feed in one area for several days. They prefer to feed on the undersides of leaves or on tender stems. The female is wingless, whereas males have wings and fly.

Several predators and parasites of mealybugs and scales were collected at CIAT (Table 17); not all the parasites have been completely identified.

Termites

Termites *(Coptotermes* spp.) attack cassava mainly in the tropical lowlands. They feed on propagation material, growing plants and roots. Principal damage appears to be loss of cuttings; during prolonged dry periods plant establishment can also be severely affected.

Since cassava propagation material is commonly stored for several months during dry periods before planting begins at the onset of the rainy season, a preliminary study was done to determine the effect of termites on stored planting material. One-hundred untreated cassava stems and 100 stems treated with a spray mixture of 10 percent aldrin and 10 percent parathion were stored for 80 days in the field. Insecticide applications were made every 20 days. All the untreated stems had termite damage while treated stems showed a 24 percent loss of planting material.

Two experiments were conducted to further study prevention of termite attack on stored propragation material and prevention of termite damage to cuttings after planting. In the first experiment, bundles of 15 cassava stems each were treated with an insecticide and stored in the field for 80 days. The most effective treatments (Table 18) were aldrin applied as a dust at 1 g/stem, (0% loss) Clorvel applied as a spray at 1 cc/liter of water (0% loss) and sevin in a dust application at 1 g/stem (6.6% loss) Meanwhile, 46 percent of the untreated stems were destroyed by termites.

Table 17. **Natural predators of *Aonidomytilus albus* Cockerell and *Phenacoccus gossypii* Townsend and Cockerell in cassava, at CIAT during 1977.**

Order	Family	Genus	Species	Predation
Coleoptera	Coccinellidae	*Cleotera*	*onerata*	Mealybug eggs and nymphs
		Cleotera	sp.	Mealybug eggs and nymphs
		Scymnus	spp.	Mealybug eggs and nymphs
		Coccidophilus	sp.	White scale all nymphal stage
Neuroptera	Chrysopidae	*Chrysopa*	*arioles*	Mealybug eggs and nymphs
	Hemerobiidae	*Sympherobious*	sp.	Mealybug eggs and nymphs
Dipteria	Syrphidae	*Ocyptamus*	*stenogaster* complex	Mealybug nymphs
Lepidoptera	Cosmopterigidae	*Pyroderces*	sp.	Mealybug and white scale eggs and nymphs

Table 18. **Effects of applying several pesticides on the prevention of termite damage on cassava propagating material stored 80 days in the field.**

Treatment	Application[1]	Loss (%)
Aldrin	dust	0
Clorvel	Spray	9
Sevin	dust	6.7
Chlordane	spray	8.3
Fenthion	spray	33.3
Control		46.7
Monocrotophos	spray	66.67
Aldrin (10%) + parathion (10%)	spray	73.3
Thiram	spray	86.7
Thiram	dip	86.7

Spray and dip applications applied at 1 cc/liter water and dust applications at 1 g/stem

In the second experiment cuttings were individually treated with an insecticide and planted in a randomized block with four plots of 25 cuttings/plot and evaluated 80 days after treatment. The most successful treatments were aldrin applied as a dust (3% loss) and a cutting dip with 10 percent aldrin and 10 percent parathion (6% loss). Termites destroyed 15 percent of the untreated cuttings.

INTERCROPPING POPULATIONS

A preliminary experiment was done on the protection potential of intercropping cassava/beans. The following insect populations— the hornworm *(Erinnyis ello)*, the cassava lace bug *(Vatiga manihoti)*, whiteflies *(Aleurotrachelus* sp.) and the shootfly *(Silba pendula)*—were monitored weekly for 2.5 months in monoculture cassava and intercropped cassava/beans. In addition, a comparison was made between insecticide and non-insecticide treatments in the intercropping system.

Table 19. **Insect population in cassava monoculture *vs.* intercropping (cassava/beans) with and without insecticide.**

Insect	Monoculture[1]		Intercropping[2]		% population reduction in intercropping/ monoculture without insecticide
	With insecticide[3]	Without insecticide	With insecticide[3]	Without insecticide	
Lace bug: 3 leaves/plant	4.5	5.6	2.7	3.8	32.1
Whitefly: 3 leaves/plant	7.2	6.5	3.3	4.5	30.0
Shoot fly/plot	2.1	2.0	1.5	2.2	
Hornworms/plot	0.5	0.8	0.5	0.6	30.0
Hornworm eggs/parasitized/plot	50.7	52.4	51.2	45.5	

1. Cassava variety M Mex 11.
2. Bean variety Porrillo Sintetico with M Mex 11 cassava.
3. Endosulfan

Hornworm larval populations were lower in the intercropped cassava than in monoculture cassava but lowest when insecticides were applied to cassava monoculture or intercropping (Table 19). However, egg parasitism was lowest in the intercropped, non-sprayed plants and highest in the cassava monoculture. Lacebug and whitefly populations were also lower in the intercropping system than in cassava monoculture with or without pesticide application. However, the lowest insect populations were obtained when an insecticide was applied to the intercropping system.

Varietal Improvement

This year hybridization, evaluation and selection were intensified at CIAT and in outlying trials in Colombia. Data were also obtained on the first groups of hybrids from crosses among selected parental genotypes.

Two replicated yield trials were harvested at CIAT, Caribia and Carimagua. Each plot of all trials had 30 plants per genotype and each trial had two replications. Plant spacing was 1 x 1 meter at CIAT, 1 x 1.5 meters at Caribia, and 0.8 x 1 meter at Carimagua. After 12 months the central nine plants of each plot were harvested for data, leaving two border rows.

REPLICATED YIELD TRIALS

First Season Trial at CIAT

Total rainfall for the year was 655 millimeters and the experiment was not irrigated. No fertilizers, fungicides or insecticides were applied. Two-hundred hybrids and 25 germplasm selections and control cultivars were planted in July 1976 for evaluation. Results are in Table 20.

Yields were generally low (average of all genotypes was 26.2 t/ha, fresh weight). Nevertheless, many materials yielded more than 40 t/ha and some more than 50 t/ha fresh weight — outyielding the local cultivar by nearly 100 percent. The average fresh weight yield of the top ten cultivars, 48 t/ha/year, or 16 t/ha/year dry weight with less than 700 millimeters of rainfall is acceptable.

Second Season Trial at CIAT

This trial was planted in December 1976. During the trial total rainfall was 705 millimeters and was well distributed. The experiment was not irrigated and no fertilizer, fungicides or insecticides were applied. Results are in Table 21.

Yields were generally high (average of all genotypes was 35 t/ha, fresh weight). The average root dry matter yield of the top ten genotypes was 21 t/ha/year or 57 t/ha/year fresh weight. Twenty-one hybrid selections yielded more than 50 t/ha fresh weight, outyielding the local cultivar more than 100 percent.

First Season Trial at Caribia

This trial was planted in June 1976. Total rainfall was 1100 millimeters and the dry season (with less than 50 millimeters of rain) lasted four months. The experiment was not irrigated and no fertilizer, fungicides or insecticides were applied. Eighty-one hybrids and nine germplasm selections and control cultivars were evaluated. Results are in Table 22. The average fresh weight yield of the top ten hybrid selections (39 t/ha fresh weight) was double the yield of the local cultivar.

Table 20. **Selected results of the first season replicated yield trial at CIAT (harvested 15 April 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selections				
CM 309-211	50.8	.353	17.9	.57
CM 308-197	50.3	.350	17.6	.66
CM 323-30	48.3	.344	16.6	.54
CM 317-16	48.1	.320	15.4	.49
CM 91-5	48.1	.288	13.9	.73
CM 321-170	47.8	.330	15.8	.64
CM 96-23	47.8	.280	13.4	.61
CM 309-281	46.9	.306	14.4	.68
CM 321-15	46.1	.344	15.9	.58
CM 323-69	46.1	.291	13.4	.61
CM 152-12	45.0	.327	14.7	.62
CM 181-14	44.4	.288	12.8	.75
CM 307-135	44.0	.349	15.4	.43
CM 152-30	43.9	.321	13.7	.58
CM 308-1	43.3	.376	16.3	.60
CM 309-32	43.3	.296	12.8	.69
CM 2-6	42.8	.332	14.2	.65
CM 309-11	42.2	.342	14.4	.57
CM 157-7	41.7	.296	12.3	.61
CM 307-133	41.1	.297	12.2	.52
CM 309-84	41.1	.375	15.4	.47
Germplasm selection				
M Col 1684	41.9	.321	13.4	.56
M Ven 218	41.7	.328	13.7	.62
M Mex 17	39.0	.334	13.0	.52
M Mex 59	37.6	.290	10.9	.48
M PTR 26	34.7	.305	10.6	.51
M Pan 70	33.6	.312	10.5	.54
M Col 1468	33.6	.307	10.3	.51
M Col 1292	28.6	.344	9.8	.41
M Ven 270	26.7	.348	9.3	.53
M Col 655A	26.1	.355	9.3	.38
Control cultivars				
M Col 113 (Local)	25.6	.327	9.4	.44
Llanera	24.7	.321	7.9	.50
M Col 22	19.7	.358	7.1	.51
Average of all genotypes	26.2	.324	8.5	.56

Table 21 Selected results of the second season replicated yield trial at CIAT (harvested 20 October 1977).

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 323-275	63.1	.365	23.0	.60
CM 321-188	60.6	.388	23.5	.69
CM 327-514	57.2	.346	19.8	.71
CM 326-407	56.7	.376	21.5	.67
CM 305-122	56.1	.401	22.5	.62
CM 327-135	55.3	.402	22.2	.62
CM 305-118	55.0	.372	20.5	.70
CM 344-27	54.7	.353	19.3	.65
CM 340-138	54.2	.329	17.8	.68
CM 344-17	54.2	.329	17.8	.59
CM 340-30	53.3	.328	17.5	.60
CM 323-142	52.2	.327	17.1	.55
SM1-150	51.7	.323	16.7	.65
CM 305-38	51.4	.376	19.3	.60
CM 344-71	51.4	.335	17.2	.55
CM 311-69	51.1	.364	18.6	.66
CM 314-12	50.8	.384	19.5	.57
CM 305-120	50.8	.332	16.9	.56
CM 345-68	50.6	.324	16.4	.64
CM 327-383	50.3	.346	17.4	.69
Germplasm selection				
M Pan 70	46.7	.367	17.1	.54
M PTR 26	44.4	.378	16.8	.55
M Mex 17	43.7	.367	16.0	.69
M Ven 270	42.8	.376	16.1	.51
M Ven 218	41.1	.371	15.2	.59
M Col 1468	33.3	.319	10.6	.61
M Ecu 47	32.5	.325	10.6	.54
M Col 638	30.6	.336	10.3	.47
M Col 1347	28.3	.245	6.9	.40
M Col 655A	27.2	.370	10.1	.33
M Col 1684	25.0	.307	7.7	.66
M Mex 59	22.5	.338	7.6	.32
Control				
Llanera	28.5	.323	9.2	.58
M Col 22	26.1	.370	9.6	.60
M Col 113 (Local)	22.2	.286	6.4	.30
Average of all genotypes	34.6	.350	12.1	.54

Table 22. **Selected results of the first season replicated yield trial at Caribia (harvested 29 April 1977, 11 months after planting).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 309-163	44.3	.288	12.8	.66
CM 320-2	42.0	.327	13.7	.51
CM 309-50	41.7	.328	13.7	.50
CM 309-32	38.0	.282	10.7	.63
CM 321-78	38.0	.290	11.0	.64
CM 323-75	37.8	.323	12.2	.62
CM 323-41	37.6	.324	12.2	.65
CM 322-20	36.7	.329	12.1	.56
CM 321-85	36.1	.320	11.6	.66
CM 309-128	34.8	.318	11.1	.60
CM 308-197	34.5	.332	11.4	.66
CM 309-227A	34.5	.302	10.4	.64
ICA, 72-8-07	33.7	.323	10.9	.58
ICA, 72-3-58	32.0	.290	9.3	.52
CM 308-75	31.3	.307	9.6	.48
CM 309-61	31.1	.325	10.1	.63
CM 321-58	30.9	.323	10.0	.53
CM 309-165	30.8	.330	10.2	.43
SM 92-73	29.9	.287	8.6	.47
CM 309-110	29.3	.279	8.2	.55
Germplasm selection				
M Mex 59	42.0	.327	13.8	.44
M Col 638	30.6	.321	9.8	.57
M Col 1684	25.2	.304	7.7	.61
M Col 1468 (CMC 40)	21.9	.240	5.5	.66
Control cultivars				
M Col 22	33.6	.341	11.4	.64
Llanera	20.7	.288	6.0	.47
Manteca (Local)	18.1	.279	5.0	.48
Montero (Local)	12.6	.342	4.3	.37

Second Season Trial in Caribia

This trial was planted in October 1976 and was irrigated twice during the dry season; no fertilizer, fungicides or insecticides were applied. Twenty-five hybrid selections and two control cultivars were evaluated. Results are in Table 23.

One of the hybrid selections yielded nearly 50 t/ha fresh weight, and the average yield of the top ten hybrid

Table 23. **Selected results of the second season replicated yield trial at Caribia (harvested 6 September 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 309-196	49.8	.295	14.7	.56
CM 323-403	47.6	.309	14.7	.71
CM 178-4	38.7	.308	11.9	.64
CM 309-163	37.1	.290	10.8	.58
CM 326-151	35.6	.294	10.5	.56
CM 310-140	35.2	.273	9.6	.54
CM 309-713	35.0	.291	10.2	.58
CM 314-2	34.8	.301	10.5	.60
CM 309-206	33.5	.294	9.8	.52
CM 309-146	32.5	.297	9.7	.46
CM 315-101	32.1	.299	9.6	.51
CM 309-303	31.4	.283	8.9	.58
CM 146-4	31.0	.302	9.4	.51
CM 309-239	29.8	.308	9.2	.46
CM 305-40	24.9	.307	7.6	.48
CM 305-17	24.7	.295	7.3	.62
CM 309-227	24.5	.277	6.8	.46
CM 314-20	24.5	.294	7.2	.59
CM 320-2	23.0	.309	7.1	.54
CM 309-93	22.3	.293	6.5	.42
Control cultivar				
M Col 22	35.0	.310	10.9	.66
Manteca (Local)	21.9	.313	6.9	.47
Average of all genotypes	29.8	.299	8.9	.53

selections (38 t/ha fresh weight) was nearly twice the yield of the local cultivar.

First Season Trial at Carimagua

The trial was planted in June 1976. The equivalent of 100 kg/ha of nitrogen, 200 kg/ha P_2O_5, 200 kg/ha K_2O, 500 kg/ha dolomitic limestone and 52 kg/ha of magnesium were applied. Fungicides were applied four times but failed to control superelongation. Cassava bacterial blight (CBB), the most devastating cassava disease in the area, was effectively controlled using disease-free planting material in an isolated field. Thirty-six hybrid selections and 14 germplasm selections and control cultivars were evaluated. Results are in Table 24.

Yields were generally low (average of all genotypes, 17 t/ha fresh weight) compared with those at the other two locations. However, the average of the top ten genotypes (29 t/ha fresh weight) was nearly 50 percent higher than the yield of the local cultivar and is acceptable for the poor soil conditions at Carimagua.

Table 24. **Selected results of the first season replicated yield trial in Carimagua (harvested May 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 323-52	33.0	.303	10.0	.68
SM 92-73	33.0	.321	10.6	.71
CM 308-197	30.6	.324	9.9	.74
CM 323-142	26.0	.287	7.5	.62
CM 314-2	25.7	.328	8.4	.64
CM 323-99	24.3	.321	7.8	.55
CM 305-11	24.0	.288	6.9	.68
CM 323-41	24.0	.275	6.6	.58
CM 309-2	23.3	.322	7.5	.60
CM 321-88	21.5	.328	7.1	.62
Germplasm selection				
M Col 1684	32.3	.321	10.4	.74
M Mex 16	29.9	.318	9.5	.69
M Pan 114	29.9	.317	9.5	.64
M Ven 218	27.8	.317	8.8	.62
M Mex 59	25.7	.323	8.3	.53
M Col 638	25.3	.324	8.2	.60
M Ven 77	25.0	.323	8.1	.60
M Ecu 47	18.4	.281	5.2	.54
M Col 1292	17.4	.330	5.7	.46
M Mex 52	16.3	.290	4.7	.44
Control				
Llanera (Local)	21.5	.320	6.9	.63
M Col 22	19.4	.309	6.0	.64
M Col 113	10.4	.260	2.7	.47
Average of all genotypes	19.1	.313	5.9	.56

Second Season Trial at Carimagua

This trial was planted in November 1976; 25 hybrid selections and six germplasm selections and control cultivars were evaluated. Results are in Table 25.

The experiment was heavily attacked by superelongation disease and the hornworm, accounting for the low yield (average of all genotypes was 18 t/ha fresh weight). This is supported by the fact that the genotypes which showed some resistance to superelongation disease — such as CM 323-52, SM 92-73 and CM 308-197, in the first season trial, and SM 92-73, CM 321-15 and CM 181-13, in the second trial — produced the highest yields. Even under these conditions, the top hybrid selection out-yielded the local cultivar by more than 50 percent and the average yield of the top ten genotypes (30 t/ha fresh weight) was 35 percent higher than the yield of the local cultivar.

Table 25. **Selected results of the second replicated yield trial at Carimagua (harvested 19 September 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
SM 92-73	24.7	.320	7.9	.72
CM 321-15	24.3	.318	7.8	.76
CM 181-13	23.6	.328	7.7	.68
CM 309-56	21.5	.342	7.4	.68
CM 305-1	21.5	.283	6.1	.75
CM 309-37	21.2	.323	6.8	.72
CM 309-41	20.5	.333	6.8	.71
CM 180-4	20.5	.325	6.7	.73
CM 180-2	20.1	.316	6.4	.76
CM 315-101	20.1	.303	6.1	.71
CM 309-196	19.8	.314	6.2	.68
CM 309-165	18.4	.346	6.4	.65
CM 91-3	18.1	.327	5.9	.70
CM 305-15	17.4	.340	5.9	.83
CM 323-87	17.4	.335	5.8	.83
CM 91-1	16.7	.332	5.5	.75
CM 308-26	16.3	.300	4.9	.70
CM 304-160	16.0	.341	5.5	.56
CM 309-189	16.0	.335	5.4	.65
CM 328-10	16.0	.327	5.2	7.2
Control cultivar				
M Col 1684	21.5	.301	6.5	.77
M Col 1468	18.0	2.92	5.3	.72
Llanera (Local)	16.0	.330	5.3	.54
M Mex 59	15.6	.291	4.5	.64
M Ven 218	13.2	.314	4.1	.73
Average of all genotypes	18.0	.321	5.8	.70

PROMISING LINES

It has been shown that in the absence of CBB and superelongation disease, the top ten CIAT hybrid selections yielded at least 20 t/ha dry weight on fertile soils with less than 1000 millimeters of rainfall, and without fertilizer, fungicides, insecticides or irrigation, and 10 t/ha on extremely poor soils of the tropical savanna. These hybrids out-yielded local cultivars by 50-200 percent depending upon the soil and climate. The high yields of CM 308-197 in all three locations suggest that one genotype can cover a broad range of environments with temperature means **above 24ºC (see Physiology section).**

Over the past three years, the initial harvest index average (0.42) of the original

Table 26. Rankings of several promising cassava lines for 14 important characteristics.

	Characteristics													
	Yield at CIAT	Yield at Caribia	Yield at Carimagua	Lodging resistance	Ease of harvest	Shape and color of root	Eating quality	Starch content	HCN content	Post-harvest root durability	CBB resistance	Superelongation resistance	Mite resistance	Thrips resistance
Hybrid selection														
CM 181-13	2[1]	2	4	4	2	4	4	2	2	1	3	2	1	1
CM 308-297	4	3	4	4	3	3	2	2	2	2	1	2	2	4
CM 309-41	3	2	3	3	1	2	4	3	2	1	3	1	1	3
CM 309-56	2	2	3	3	2	3	2	3	2	1	4	1	1	2
CM 309-163	3	4	2	3	3	3	2	2	2	1	1	1	1	3
CM 309-196	2	4	2	3	1	2	3	3	2	2	4	1	1	3
CM 321-15	3	2	4	4	4	3	2	2	2	2	1	1	1	1
CM 323-52	2	2	4	3	3	4	3	2	2	1	1	2	2	2
CM 323-142	4	2	3	1	1	2	2	2	2	2	1	1	1	3
SM 92-73	2	2	4	1	4	4	1	2	2	1	1	2	1	2
CM 305-38	4	[2]		2	3	2	4	3	2	1	1	1	2	4
CM 305-120	4			3	4	4	4	2	2	2	1	1	2	4
CM 305-122	4			3	3	4	4	4	2	1	2	1	2	3
CM 311-69	4			4	4	4	4	3	2	1	1	3	1	3
CM 321-188	4			3	4	4	3	4	2	1	1	1	1	3
CM 323-375	4			3	3	3	3	3	2	1	2	1	2	4
CM 326-407	4			4	2	2	3	3	2	1	1	2	1	3
CM 340-30	4			3	4	4	2	2	2	1	2	1	1	3
CM 344-27	4			3	2	2	3	3	2	1	1	3	1	3
CM 344-71	4			1	2	2	4	2	2	2	2	3	1	3
Germplasm selection														
M Col 1684	3	3	4	4	1	2	1	2	1	1	1	2	1	1
M Ven 218	4	2	3	2	1	3	4	3	2	1	1	2	1	3
M Ven 270	3	2	2	2	3	3	2	4	2	1	1	1	1	2
M Pan 70	4	2	3	2	1	3	4	3	2	1	1	2	2	3
M Mex 59	2	3	2	1	1	2	2	2	2	1	1	1	1	2
Control or local cultivar														
Llanera	2	1	2	3	1	3	3	2	2	1	2	3	1	2
M Col 22	2	3	2	4	4	3	4	4	2	1	1	2	1	3
M Col 113	2	1	1	1	1	2	2	2	2	2	1	1	2	4
M Col 638	2	1	3	2	3	2	1	2	2	1	4	3	1	3
M Col 1468	3	3	1	2	4	4	3	1	2	2	1	1	1	1

1 4 = Very good; 3 = Good; 2 = Acceptable; 1 = Poor

2 Blanks indicate selections not tested at these locations

Figure 26. An excellent selection of roots from one of the promising CIAT-developed hybrid lines.

germplasm population has been increased to 0.55 in the latest populations. Table 26 shows the 14 breeding characteristics used for comparing promising hybrid selections with the best germplasm selections. These promising lines are the result of hybridizations in late 1973 and early 1974, and increasing numbers of new hybrids have been added each year. The outstanding hybrid materials were sent to the Agronomy section for rapid multiplication and further evaluation in regional trials. However, the emphasis in varietal improvement has now shifted to incorporating disease and insect resistance into high-yielding lines.

Agronomy

In 1977, the Agronomy section completed three years of regional trials with selected varieties and work has begun with testing the first generation of CIAT-produced hybrids regionally. Also, with the addition of two new agronomists to the team, research on cultural practices received major attention. Rapid propagation and testing of new promising lines from the Varietal Improvement section were also emphasized.

REGIONAL TRIALS IN COLOMBIA

Again this year in regional trials CIAT selections out-yielded local varieties in all locations except Popayan (Table 27). Table 28 shows the ecological and edaphic conditions for testing sites within and outside of Colombia.

The highest yield thus far in the regional trials of 1977 was produced by M Pan 70

Table 27. Fresh root yield of ICA-CIAT promising cassava varieties at ten locations in Colombia.

	Locations									
	Pereira	Rionegro	Media Luna	Carimagua	Caicedonia	CIAT	Nataima	El Tambo	Popayán	Florencia
	Days to harvest									
	416	369	387	355	370	352	363	357	460	393
Varieties	Fresh root yield (t/ha)									
CMC 40 (M Col 1468)	48.8[2]	32.4[3]	16.6[3]	22.1[2]		45.6[3]	27.8[3]	21.5		20.6
M Mex 59	25.3	45.0[3]	16.6[3]	26.3[3]	52.0[3]		7.2	24.3		21.2
CMC 84 (M Col 1513)		47.9[3]	7.9	23.2[2]		43.6[3]	---	24.4[2]		12.2
MPTR 26						34.1[1]	31.9[3]	12.2		
M Mex 17						38.6[3]	28.6[3]	13.6		
M Ven 218				22.4	45.8[1]		28.7[1]	20.9		
M Pan 70				21.0	54.3	33.9[1]	32.5[1]	17.6		
M Ven 156		33.0[1]	14.2[1]	21.6	41.4	37.3[1]	18.8	20.0		
M Col 1684						30.0	36.6[3]	32.3[1]		
CMC 57 (M Col 1486)		18.3	3.3	14.6	26.9	35.8		23.7		
CMC 59 (M Col 1488)	44.3	17.1	4.9	16.4	27.9	36.4	24.5	28.5		
CMC 76 (M Col 1505)	37.0	32.4[3]				33.7[3]				21.6[1]
CMC 99 (M Col 1529)		42.9	11.1	17.0	42.3	28.1	26.0	21.6		
M Col 1686						21.6	31.2[1]	15.0		
M Col 670		31.0	4.7	18.4	35.7	34.1[1]	16.6	17.7		
M Col 561		23.8	4.1	16.3	28.8	33.6[1]	27.3	23.1		
M Ven 77		38.5	11.4	20.1	45.9		28.0			
M Col 677		39.1[2]		12.5	37.2[2]	17.5		13.4	2.7	14.0
M Col 1292		24.2[2]	3.6	14.9	47.5[1]		8.9			
M Col 655		19.4	2.9	12.6	44.7	12.4	12.1	13.6		
M Ven 168						31.2	13.7	20.2		
M Col 22			18.1[3]			24.8	26.8[3]			8.8
M Ecu 159	38.3	15.7	3.4	13.2	42.8				4.3	15.3
M Col 673		41.8							1.7	9.9
M Mex 23					37.4	22.9				
M Ven 119	26.3								1.3	10.1
M Ven 119	28.1								3.4	12.2
M Col 113	36.8					---		---		10.5
Other varieties[4]	40.6(1)			22.1(7)					12.4(3)	
	32.5(6)								9.9(4)	
	28.9(2)								17.6(2)[2]	
									2.5(5)	11.5(5)
Regional varieties[5]	45.8(8)	16.1(9)	5.7(11)	17.3(12)	41.2(8)	22.5(13)	8.0(16)	26.2(13)	14.3(14)	18.5(15)
		14.1(10)								
Average including regional varieties	36.0	29.5	8.5	18.4	40.7	30.7	23.7	20.3	7.0	14.3
Average of best promising variety	48.8	47.9	18.1	26.3	54.3	45.6	36.6	32.3	17.6	21.6

[1] and [2] Respectively, varieties approved for second and third year evaluations at the same locations.
[3] Varieties that completed three years of evaluations in the same location.
[4] Other varieties: (1) CMC 39 (M Col 1467); (2) CMC 92 (M Col 1522); (3) CMC 102 (M Col 1530); (4) CMC 52 (M Col 1481); (5) M Mex 55; (6) CMC 71 (M Col 1500); and (7) Chiroza.
[5] Regional varieties: (8) Chirosa Gallinaza; (9) Colombiana; (10) Tornana Negrita; (11) Secundina; (12) CMC 9 (Llanera or M Col 1438); (13) M Col 113 (Valluna); (14) Regional (Popayán); (15) Caqueteña (Florencia); (16) CMC 84 (M Col 1513)

Table 28. **Main edaphic and climatological characteristics of the sites used in national and international yield trials with promising cassava materials during 1976-77 cycle.**

Sites	Latitude	Longitude	Altitude (masl)	Mean temperature (°C)	Rainfall (mm/year)[2]	Soil Texture	pH	Organic Matter (%)	P Bray II (ppm)	K (meq 100 gr)
Enmore (Guyana)[1]										
Anira Peat No. 20	6°25'N	52°30'W	0	27.0	2.928	Silty clay	3.7(VA)	52.0	37.5(M)	0.17(M)
Inky Clay No. 100	6°25'N	52°30'W	0	27.0	2.928	Clay	4.2(VA)	10.0	1.2(L)	0.30(M)
Xulha (Quintana-Roo, (Mexico)	18°24'N	88°38'W	10	26.0	1.608	Clay loam	7.8(AL)	5.3(H)	5.1(L)	2.18(H)
Medialuna (Magdalena, Col.)	10°33'N	74°30'W	10	27.2	1.326	Sandy	7.0(AL)	0.6(L)	7.3(L)	0.06(L)
Pichilingue (Quevedo-Ecuador)	1°06'S	79°29'W	100	25.0	1.483	Silt loam	6.5(N)	4.9(H)	45.8(H)	1.10(H)
Carimagua (Meta, Col.)	4°40'N	71°24'W	200	26.2	1.586	Clay loam	4.9(VA)	3.6(M)	1.0(L)	0.25(M)
Nataima (Tolima, Col.)	4°10'N	74°56'W	430	27.8	1.249	Sandy	5.8(A)	1.2(M)	51.0(H)	0.35(H)
Florencia (Caquetá, Col.)	1°31'N	75°14'W	450	25.0	3.186	Silty	4.7(VA)	3.9(M)	8.0(L)	0.38(H)
Rionegro (S. del Sur, Col.)	7°15'N	73°09'W	480	26.6	1.134	Clay loam	5.0(A)	2.3(M)	10.4(L)	0.15(M)
El Tambo (Cauca, Col)	2°19'N	76°54'W	900	26.0	1.797	Clay loam	4.9(VA)	5.1(H)	1.8(L)	0.16(M)
CIAT (Valle del Cauca, Col.)	3°31'N	76°21'W	1000	23.8	684	Clay	7.4(AL)	4.1(H)	81.5(H)	0.69(H)
Caicedonia (Valle del Cauca, Col.)	4°20'N	75°50'W	1100	22.2	1.684	Silt loam	5.6(A)	2.7(M)	13.8(L)	0.18(M)
Pereira (Risaralda)[1]	4°49'N	75°41'W	1480	19.0	3.171	Silty clay	5.3(A)	7.8(H)	20.0(M)	0.18(M)
Popayan (Cauca, Col.)[1]	2°27'N	76°34'W	1760	18.0	2.035	Clay loam	5.5(A)	7.4(H)	2.0(L)	0.04(L)

[1] Pereira, Popayán and Guyana data respond to 1975-76 cycle.
[2] Corresponds to actual rainfall during growing cycle.
[3] Fertility codes: (N) Neutral; (AL) Alkaline; (A) Acid; (VA) Very acid; (L) Low; (M) Medium; (H) High.

(54 t/ha fresh weight) in Caicedonia, a major cassava-producing area of Colombia. A good local variety, Chiroza, yielded 41 t/ha in the trial there. Farmers of the region had not believed that there were better varieties than Chiroza. However, after results of the regional trial were presented this year, farmers took home planting material of the highest yielding varieties.

The lowest yield (1 t/ha) was produced by M Ven 119 at Popayan where the local variety yielded 14 t/ha. M Ven 119 suffered a serious attack of Phoma leaf spot while the local variety showed good resistance. This indicates that good selections for high altitude, cool locations are still lacking.

An examination of the performance of the three highest yielding varieties at each site over three years shows that not only was the mean yield of these varieties always superior to the best local variety, but yields were also more than three times the Colombian national average (estimated to be 8 t/ha) (Table 29). Mean yield of selected varieties in the third testing cycle was higher because better selections were included while the yield of local varieties was stable.

While the mean yield of the local varieties remained at 19.6 t/ha over the three-year period, this was more than double the national average. This indicates that with simple and inexpensive uniform technology used in these trials, Colombian cassava farmers can double their production with local varieties. However, the overall mean of the best three selections (28.8 t/ha) was 47 percent higher than the mean of the best local varieties, thus validating the CIAT selection procedures.

In 1977, the first generation of CIAT hybrids was planted in nine sites in Colombia. The varieties M Mex 59, CMC 40 (M Col 1468), CMC 84 (M Col 1513) and M Col 22 have shown high yield and stability across sites over the past three years and will serve as controls.

Cooperation also continued with the

Table 29. **Mean fresh root yield of the three best promising varieties of cassava in nine locations of Colombia, compared with the best local variety at each location during three years.**

	Fresh root yield (t/ha)							
	Crop cycle							
	1974-75		1975-76		1976-77		Mean yield/site	
Sites	Promising	Local	Promising	Local	Promising	Local	Promising	Local
Rionegro	29.7	15.7	21.9	11.7	45.2	16.1	32.2	14.5
Media Luna	26.7	17.7	17.6	4.0	17.1	5.7	20.4	9.1
Carimagua	6.2	3.8	25.6	22.9	23.9	17.3	18.5	14.6
CIAT	40.6	26.3	30.9	22.1	42.6	22.5	38.0	23.8
Caicedonia	37.3	32.3	25.0	15.8	51.2	41.2	37.8	29.7
Popayán	10.8	14.5	13.3	14.3	[1]	[1]	12.0	14.4
Pereira	19.8	16.9	44.5	45.8	[1]	[1]	32.1	31.3
El Tambo	—	—	22.4	22.3	28.4	26.2	25.4	24.2
Nataima	41.1	33.6	28.4	16.3	33.6	8.0	34.3	19.3
Mean yield/cycle	26.5	20.1	25.5	19.4	34.5	19.5	28.8	19.6

[1] Popayan and Pereira sites not yet harvested (30 October 1977).

Instituto Colombiano Agropecuario (ICA), the Federación Nacional de Cafeteros (FEDECAFE) and the various departmental Secretaries of Agriculture. This year, the ICA experimental station in Palmira sold 60,000 cuttings of promising varieties tested by ICA and CIAT to local farmers.

REGIONAL TRIALS OUTSIDE COLOMBIA

Regional trials were planted in Argentina, Costa Rica, Ecuador, Mexico and Venezuela. Similar trials were harvested in Ecuador, Guyana and Mexico; results of these trials are in Table 30.

In Ecuador, the best CIAT-selected variety, M Mex 59, out-yielded the best local variety, Yema de Huevo, by 6.7 t/ha fresh weight. Since the local variety is already the result of considerable selection by the Instituto de Investigaciones Agropecuarias (INIAP), these results indicate that CIAT-selected varieties, even before hybrids are released, can be of considerable use in that country.

CULTURAL PRACTICES

This year, research on cultural practices in cassava became a major part of the program with emphasis on: (1) identifying and resolving cassava production

Table 30. **Fresh root yield of promising cassava varieties in Guyana, Ecuador and Mexico.**

		Locations			
		Enmore, Guyana		Pichilingue, Ecuador	Kulha, Mexico
		Anira Peat 20 Inkv clay 100			
		Days to harvest			
		361	361	314	398
		Fresh root yields (t/ha)			
Varieties	Origin				
Tacana	Brazil	28.0	24.3		
Iracema	Brazil	27.6	23.3		
M Mex 23	CIAT	23.2	16.8		
Piracununga	Brazil	18.3	19.7		
CMC-40 (M Col 1468)	CIAT	17.9	18.1	24.6	7.2
M Mex-59	CIAT	17.3	16.1	28.3	13.0
Llanera CMC-9	CIAT	16.9	18.3	17.3	0.9
M Col-673	CIAT	14.2	12.3	7.3	0.9
Del País	Pto. Rico	13.0	11.5		
Badwoman	Guyana	11.6	10.0		
Twelve month	Guayana	8.6	5.5		
M Mex 55	CIAT	8.2	12.0		

Table 30. (Continued)

Varieties	Origin	Fresh root yields (t/ha)			
Four month	Guyana	6.7	5.0		
Chinese stick	Guyana	6.4	4.3		
M Col-22	CIAT	6.3	9.9	18.8	14.0
Uncle Mack	Guyana	5.3	8.0		
Brancha Butterstick	Guyana	4.6	6.4		
Bitterstick	Guyana	4.4			
R. Singh	Guyana	3.8	5.6		
L.H.Z.	Guyana	2.9	1.8		
CMC-844 (M Col 1513)	CIAT			25.6	9.3
Yema de Huevo	Ecuador			21.6	
Negrita	Ecuador			21.1	
Quintal	Ecuador			19.5	
CMC-76 (M Col 1505)	19.4	6.7			
M Ecu 159	CIAT			17.2	1.7
M Mex 52	CIAT			15.7	
M Col 113	CIAT			15.6	1.6
M Ven 156	CIAT			11.1	9.0
M Ven 119	CIAT			10.8	0.1
M Ven 218	CIAT				7.2
SMI 150	CIAT				8.6
M Col 677	CIAT				4.1
CMC-59 (M Col 1488)	CIAT				5.7
CMC-57 (M Col 1486)	CIAT				0.0

problems; (2) integrating the best cultural practices into a cassava production technology package; and, (3) developing simple, effective experimental designs to validate technology and adapt it to local conditions.

Long-term Fertility Trials

Although cassava is generally considered a soil-exhausting crop, there is little data on the effect on yield of interactions among fertilization, plant phenotypes and plant densities across a broad spectrum of soil fertilities.

Three phenotypes of cassava were each planted at populations of 5-, 10-, 15- and 20,000 plants/ha without fertilizer or with 50-100-100 kg/ha of split-applied N-P-K at CIAT (high fertility soil) Caribia (medium fertility) and Carimagua (low fertility). Preliminary, first-year results have been obtained from CIAT and Caribia.

Under CIAT conditions, fertilization did not affect root yield within varieties (Table 31) and no interaction was found for fertilization x plant density on total root yield. However, over all treatments, CMC 40 and M Col 22 produced

Table 31. **Effects of fertilization on fresh root yields of three cassava cultivars, means of four planting densities, CIAT, 1977.**

Fertilizer (kg/ha) $N-P_2O_5-K_2O$	Fresh weight yields (t/ha)		
	CMC 40	M Col 22	M Mex 52
CIAT			
None	50.5[1]	31.6[1]	19.2[1]
50-100-100	49.2[1]	33.8[1]	20.4[1]
Caribia			
None	25.9[2]	34.9[2]	18.4[2]
100-0-150 + 20 kg Zn	33.7[2]	38.3[2]	22.0[2]

1 F. test (P = 0.05) not significant within varieties.
2 LSD (5%) 7.4 within varieties.

significantly higher root yields with higher plant densities in contrast to M Mex 52 (Fig. 27). Commercial root production was only significantly affected (P = 0.05) by plant density with the cultivar CMC 40.

In Caribia, fresh root yield was significantly higher (P = 0.05) only for CMC 40 planted at 10,000 plants/ha, **although M Col 22 tended to increase its yield when planted at 15,000 plants/ha (Fig. 27). In Caribia, as in CIAT, the interaction of fertilization x planting density was not significant.**

The lack of response to first-year fertilization may be explained by the high- and medium-fertility conditions at the two locations, (pre- and post-harvest soil analyses at CIAT and Caribia (Table 32) did not show significant improvement of fertilities.) However, second cycle crops are already showing fertilizer effects on top growth of the more vigorous cultivars.

Spatial Arrangements

Good cultural practices require ridging in certain types of soils to improve surface drainage and to avoid root rotting. However, it was not known if plant spatial arrangements in ridges would affect yields. Three different phenotypes of cassava — CMC 40, M Col 22 and M Mex 52 — were planted at CIAT at 10,000 plants/ha in five different patterns (Fig. 28). Results showed that spatial arrangements did not significantly effect total and commercial root yields within varieties (Fig. 29). As expected, yields differed significantly among varieties.

Modification of Rapid Propagation

This year, it was proven that shoots for rapid propagation do not need to be placed in individual rooting flasks, as has been the custom. Forty young shoots can be rooted in a 500-cc beaker containing 200-cc of cool, previously boiled water. This new technique saves both time and effort.

Bud Quality and Planting Position

Planting position and bud quality of cassava cuttings were studied for their effects on the percentage and rate of germination, shoot production, callus formation and root initiation using the rapid propagation method.

Two hundred cuttings with two normal buds and 200 with one bruised and one normal bud were cut from mature (12-month-old) stems of CMC 40 variety (M Col 1468) and planted in a rapid propaga-

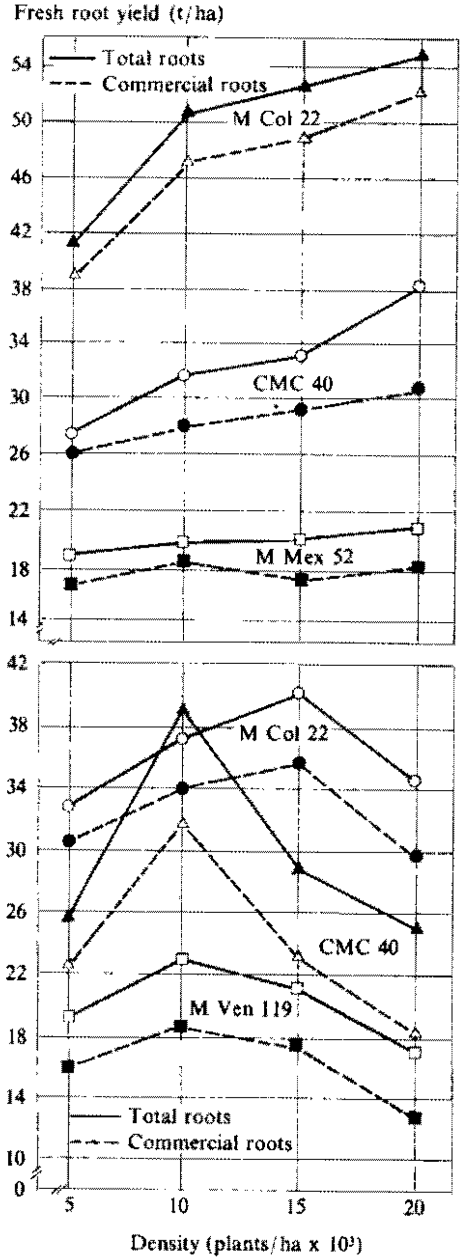


Figure 27. **Effects of plant density on root yields of cassava cultivars grown at CIAT (A) and Caribia (B), 1977.**

tion chamber in replicated blocks of 50 cuttings each. The cuttings were planted in four treatments: (1) 100 normal, two-node cuttings planted horizontally in the chamber; (2) 100 normal, two-node cuttings planted with one bud facing upward; (3) 100 two-node cuttings with one normal bud and one bruised bud, both oriented horizontally; and (4) 100 two-node cuttings with one bruised and one normal bud planted with the normal bud facing upward.

Germination of the cuttings in each treatment was recorded for 21 days after planting. The 5-centimeter shoots were excised and transferred to 500-cc beakers holding 200-cc of cool, boiled water to examine callus formation and root initiation.

Results (Table 33) showed the rate of germination increased rapidly beginning on the sixth day, reaching a maximum on day 12, after which germination continued to increase slowly until day 21. Treatment 1 had the greatest final germination.

The number of shoots produced monthly from the cuttings over a five-month period is shown in Table 34. Although differences among treatments were significant during the first three months, this was not so in the last two months. Treatment 1 produced the most shoots. However, in each treatment, the number of shoots produced was highest in the second month and then decreased slowly.

Callus formation was constant for all treatments. Eight days after shoots were placed in the flasks, calluses formed. Two days after callus formation, rooting began and at 18 days more than 95 percent of shoots in all treatments had rooted.

Interactions were evident between quality and planting position of cuttings and these factors affected germination and shoot production. The horizontal planting position favored only the normal two-bud cuttings but had no effect on the production capacity of cuttings with only one normal and one bruised bud (Table 34). A

Table 32. **Soil analyses of CIAT and Caribia plots before planting and after the first harvest of cassava.**

	Soil status		
	Organic matter (%)	P Bray II, (ppm)	K (meq, 100 g)
CIAT			
Initital status	3.8	36	0.55
After harvest, no fertilizer	4.1	46	0.49
After harvest, with fertilizer[1]	4.2	51	0.54
Caribia			
Initital status	1.9	81	0.13
After harvest, no fertilizer	2.3	93	0.12
After harvest, with fertilizer[2]	2.4	96	0.13

[1] 50-100-100 kg/ha N-P_2O_5-K_2O
[2] 100-0-150-20 kg/ha N-P_2O_5-K_2O-Zn

comparison of Tables 33 and 34 shows that as the number of germinated buds increased, shoots produced increased, indicating that shoot production was closely correlated with the number of germinated buds.

Selection of Two-node Cuttings

The same two varieties of the previous experiment were used to evaluate the effect of selecting two-node cuttings from the apical, middle or basal part of the stem on the percentage and rate of germination, shoot production, callus formation and root initiation. Six-hundred cuttings each were taken from 12-month-old plants of the two varieties and planted for rapid propagation in a completely randomized block design.

The two-node cuttings taken from the basal, middle and apical parts of stems of CMC 40 and M Col 22 constituted Treatments 1, 2, 3, 4, 5 and 6, respectively. Two to three weeks after planting, ger-

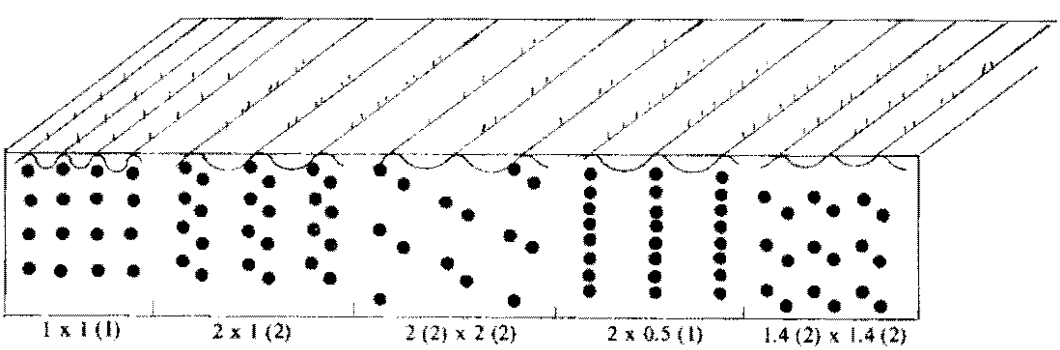


Figure 28. **Spatial arrangement of cassava planted at 10,000 plants/ha, at CIAT, 1977. First figures are distances (meters) between ridges, second figures are distances within ridges. Figures in parentheses are number of plants per site.**

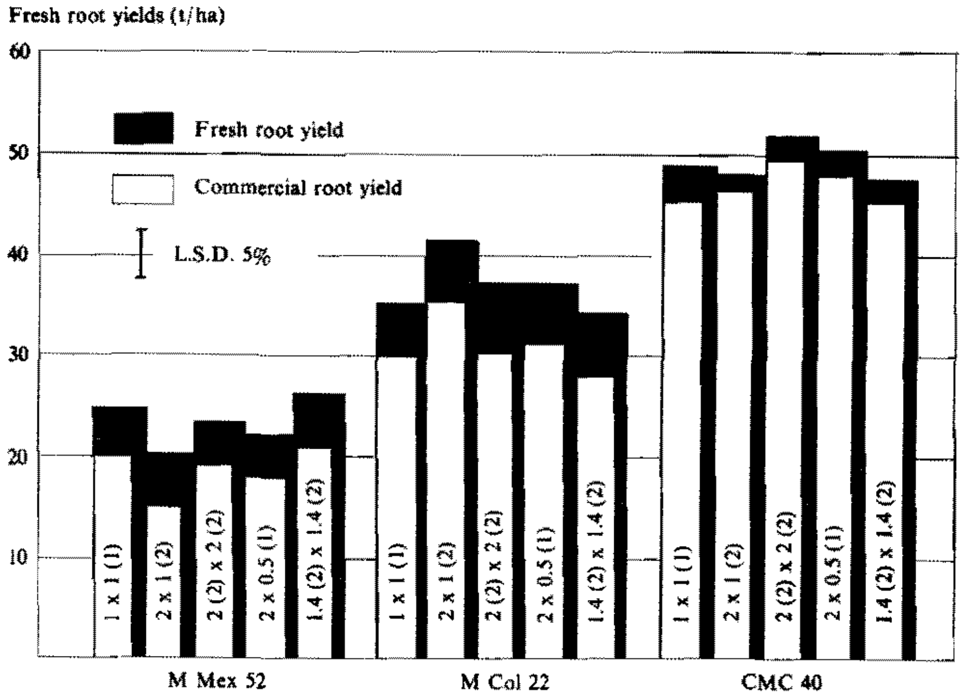


Figure 29. Effects of planting patterns on total and commercial root yields of three cassava varieties at a standard density of 10,000 plants/ha, at CIAT, 1977. First figures in columns are distances (meters) between ridges, second figures are distances within ridges. Figures in parentheses are number of plants per site.

mination of cuttings was recorded (Table 35). After shoots were excised from the cuttings, callus formation and root initiation were examined.

The shoot production capacity/node of the two-node cuttings is shown in Table 36. Cuttings taken from the middle of the stem of CMC 40 produced the highest

Table 33. **Cumulative percentage germination at times up to 21 days after planting of two-node cassava cuttings planted in two positions and with different bud qualities.**

	Days after planting					
Treatment[1]	6	9	12	15	18	21
1	9b[2]	52a	78a	80a	84a	87a
2	23a	48a	57b	60b	64b	72b
3	5b	32b	45b	47c	53c	58c
4	12b	34b	49b	54b	54bc	57c
C.V. (%)	21	3	9	6	5	4

[1] Treatments: 1 = cuttings planted horizontally in propagation chamber; 2 = cuttings planted with one bud facing upward; 3 = cuttings planted with one bruised and one normal bud, both horizontal; 4 = cuttings planted with one bruised and one normal bud, the latter facing upward.
[2] Values followed by different letters are significantly different (P = 0.05) by Duncan's multiple range test.

Table 34. **Number of shoots produced each month over five months on 100 two-node cassava cuttings planted in two positions and having different bud quality.**

Treatment[1]	Months after planting 1	2	3	4	5	Total shoots
1	111a[2]	144a	115a	100a	82a	553a
2	85b	119b	100ab	87a	84a	476b
3	66c	107b	91b	82a	60a	416c
4	79bc	110b	90b	76a	65a	421c
C.V. (%)	7	3	5	9	8	2

1 For description of treatments, see footnote 1, Table 33.
2 Values followed by different letters are significantly different (P = 0.05) by Duncan's multiple range test.

germination while cuttings from the apical section of the stem of M Col 22 produced the lowest percentages. Overall germination of cuttings from the three different stem parts of CMC 40 was above 90 percent but it was less than 80 percent for M Col 22.

In both varieties, cuttings from the middle part of the stem produced the highest germination percentage. Germination rate for all treatments increased rapidly from the sixth day, peaking at 12 days and then continuing to increase slowly. The number of shoots produced was highest during the second month and then decreased slowly over the rest of the period for all treatments (Table 37). Treatment 2 gave the highest shoot production and Treatment 6, the lowest. Treatment 1 produced the highest average of shoots/node and Treatment 6, the lowest. Eight days after planting, callus formation occurred and rooting began two days later. At 18 days, root initiation was 90 percent in all treatments. At earlier

Table 35. **Germination percentage at different times during 21 days after planting of two-node cuttings taken from different stem parts of two cassava varieties.**

Treatment[1]	Days after planting 6	9	12	15	18	21
1	16a[2]	65abc	78a	84a[1]	88a	90ab
2	14a	82a	88a	91a	94a	96a
3	18a	73ab	86a	89a	90a	91ab
4	3a	44cd	62b	67b	70b	71c
5	2a	50bcd	65b	70b	71b	77bc
6	2a	33d	57b	65b	66b	68c
C.V. (%)	69	10	5	2	3	4

1 Treatments: 1,2,3,4,5,6 are cuttings from basal, middle and apical parts of stems of CMC 40 and M Col 22, respectively.
2 Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

Table 36. **Shoot capacity production after six months per node of two-node cuttings taken from different stem parts of two cassava varieties.**

Treatment[1]	No. of buds germinated	Total shoots produced	Shoots per node
1	190ab[2]	1453a	8a
2	192a	1481a	7ab
3	132ab	1209b	6c
4	143c	1018bc	7bc
5	154bc	817cd	5d
6	137c	656d	4d
C.V. (%)	4	5	3

1 For description of treatments, see footnote 1, Table 35.
2 Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

stages, percentage of root initiation was higher in CMC 40 than in M Col 22.

Results indicate that CMC 40 is more vigorous than M Col 22 for germination and shoot production. This could be due to the larger size of the cuttings — a varietal characteristic. Therefore, it is suggested that two-node cuttings from different varieties will give different germination and shoot production percentages. When cuttings are taken from different parts of the stems of the same variety, germination percentage is fairly constant. Cuttings from the basal part of the stems produced the most shoots/node (Table 36). Perhaps these cuttings are more vigorous. Nevertheless, when planting material is scarce, basal, middle or apical cuttings can all be used effectively (however, apical cuttings must be woody).

Table 37. **Number of shoots produced monthly for six months after planting by 100 two-node cuttings from different stem parts of two cassava varieties.**

	Months after planting						
Treatment[1]	1	2	3	4	5	6	Total shoots
1	241ab[2]	429a	315a	196a	147ab	125a	1453a
2	295a	418a	293a	191a	166a	117a	1481a
3	220ab	356a	247ab	154a	129abc	101a	1209b
4	134b	225b	213ab	164a	132abc	149a	1018bc
5	148b	173b	148b	132a	110bc	105a	917cd
6	107b	116b	141b	111b	85c	95a	656d
C.V. (%)	13	9	12	15	9	16	5

1 For description of treatments, see footnote 1, Table 35.
2 Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

Soils and Plant Nutrition

Since cassava is generally tolerant of soil acidity it is frequently grown on acid and rather infertile soils. However, within the species different degrees of tolerance exist and varieties can be selected requiring minimum liming and fertilizer to produce good yields on poor soils. In 1977, a start was made to screen the germplasm collection for tolerance to soil acidity and low levels of phosphorus and potassium— the three most limiting factors on yield in the low fertility Oxisols and Ultisols of tropical Latin America and Africa. Work also continued on the nutritional requirements of the crop and the most economical application methods.

SCREENING FOR ALUMINUM TOLERANCE IN NUTRIENT SOLUTIONS

This year, a greenhouse technique was developed to screen for aluminum tolerance using cassava shoots, rooted by the rapid propagation method. Shoots were placed in nutrient solutions containing 3 and 30 ppm aluminum. In a preliminary trial, growth was better at 3 than at zero pp, aluminum, and therefore, this level was used as the optimum. Dry matter production of each variety was determined after three weeks in both solutions, and dry weight at 30 ppm over that at 3 ppm aluminum was used to indicate aluminum tolerance.

FIELD SCREENING FOR SOIL ACIDITY TOLERANCE

Fifty varieties from the germplasm bank, including some promising hybrids were planted in single rows with three replicates in Carimagua at four levels of lime: 0,0.5,2 and 6 t/ha MgO was incorporated with the lime at a calcium:magnesium equivalent ratio of 5:1. These lime applications increased the pH from 4.3 to 5.3 and decreased exchangeable aluminum from 2.0-0.3 meg/ 100 mg, essentially eliminating aluminum at the highest liming rate. Plots were fertilized as indicated in Table 38; in addition, zinc, copper, boron, molybdenum and manganese were applied

Table 38. **Fertilizer levels used in cassava experiments at Carimagua.**

Experiment	Lime	N	P_2O_5	K_2O	S	Zn
			(kg/ha)			
Lime screening 1976A	variable	100	100	200		15
Lime screening 1976B	variable	100	100	200		10
P screening 1976A	500	100	variable	200		stake streatment
P screening 1976B	1000	100	variable	200		10
K screening 1976A	500	100	150	variable	20	stake treatment
K fertilization	500	100	100	variable	20	stake treatment
Rock phosphate trial 1976B	500	100	variable	200		10
N x K interaction	500	variable	100	variable		10
Zn fertilization	6000	100	100	200		variable
Manure fertilization	500	variable	variable	variable		

to prevent lime-induced micronutrient deficiencies. Plants were harvested at 14.5 months.

Although plants were completely defoliated at eight months by a severe hornworm attack, yields were quite high. Several varieties were eliminated because of extreme superelongation disease. Without lime, plants were short (56 *vs.* 90 centimeters with 6 t lime/ha) and had yellow bottom leaves due to calcium and magnesium deficiencies.

Figure 30 shows the average response of the 42 cassava varieties compared with those of other crops screened for acid-soil tolerance in Carimagua. On the average, cassava and cowpea are much more acid soil tolerant than rice (dwarf varieties), corn, sorghum or beans. Overall cassava yields without lime were about 40 percent of those with lime. However, specific rice

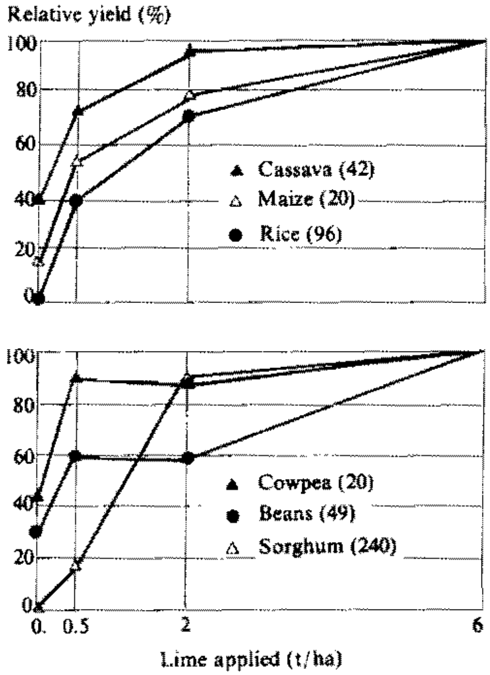


Figure 30. Relative average yield of cassava and five other crops as affected by applications of various levels of lime, at Carimagua. F;gures in parentheses are numbers of varieties tested.

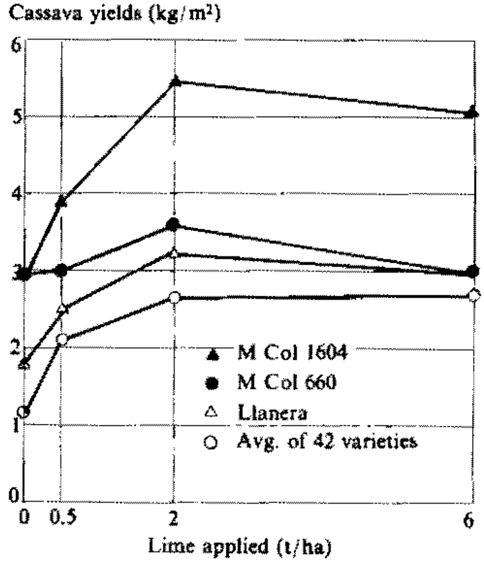


Figure 31. Single-row yields of three high-yielding cassava varieties selected from 42 varieties tested, as affected by lime applied at Carimagua.

varieties and cassava varieties may be tolerant of extremely acid soil as shown by the response of M Col 1604 in Figure 31. Without lime, this variety yielded 83 percent of maximum yield obtained with 2 t lime/ha. The control variety, Llanera, used in nearly all the fertility trials, was among the most acid soil tolerant, producing 55 percent of maximum yield without lime. Table 39 shows the yields and the tolerance index of the ten most tolerant varieties per trial, where the square of the yield at zero lime divided by that at 6 t/ha lime was used as the tolerance index.

Another group of 183 varieties were screened in early 1977 at lime levels of 0.5, 1, 2, and 6 t/ha. Although top growth was extremely vigorous, root yields were relatively low. The majority of varieties were affected to some degree by superelongation disease and a few by bacteriosis and by scales. Average yields were 13.9, 16.4, 16.0, and 17.1 t/ha for lime levels of 0.5, 1, 2, and 6 t/ha, respectively. Thus, with only 0.5 t lime/ha applied, cassava produced 81 percent of its max-

Table 39. **Root yields and tolerance to soil acidity of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)				Tolerance index
	Lime applied (t/ha)				
1976A	0	0.5	2	6	
M Col 660	29.3	39.2	54.7	50.9	16.9[1]
M Mex 59	24.0	35.9	55.8	48.2	11.9
CM 334-25	14.2	22.1	23.6	21.5	10.7
SM 1-133	18.9	26.7	31.7	33.3	10.7
Llanera	17.8	24.6	32.3	29.9	10.6
M Ven 168	19.4	37.7	55.2	42.5	8.8
M Pan 114	19.9	31.3	39.5	51.6	7.7
M Col 22	13.0	18.0	30.7	23.4	7.2
CM 308-23	19.0	37.3	38.6	50.9	7.1
M Ven 270	15.6	23.7	39.9	41.3	5.9
1976B	0.5	1	2	6	
Llanera	27.9	29.2	12.5	5.4	144.1[2]
M Col 88	26.2	20.0	7.9	9.6	71.5
M Col 1879	32.5	16.2	16.7	17.1	61.8
M Ven 33	38.3	23.2	30.4	27.9	52.6
M Col 565	26.7	33.3	14.6	15.8	45.1
M Ven 186	29.2	27.1	33.3	25.0	34.1
M Ven 183	35.8	21.2	25.8	39.2	32.7
M Col 1421	28.3	31.2	14.6	24.6	32.6
M Col 988	31.7	24.2	28.3	32.5	30.9
M Col 1468	38.3	19.6	52.9	55.0	26.7

1 Tolerance index = $\frac{(\text{Yield 0 lime})^2}{(\text{Yield 6 t lime/ha})}$

2 Tolerance index = $\frac{(\text{Yield 0.5 t lime/ha})^2}{(\text{Yield 6 t lime/ha})}$

imum yield. Table 39 shows the yield of those ten varieties with the highest tolerance index. Llanera had the highest index, although yields at 2 and 6 t lime/ha were unusually low, possibly due to induced zinc deficiency.

FIELD SCREENING FOR LOW PHOSPHORUS TOLERANCE

One hundred varieties were planted in single rows with two replicates with levels of 0 and 150 kg P_2O_5/ha, band-applied as triple superhosphate (TSP) at planting. Plots were limed and fertilized as indicated in Table 38.

At 2.5 months, plants without phosphorus were short (47 *vs.* 68 centimeters with phosphorus) and lacked vigor. Many varieties showed yellowing or purpling of lower leaves which also were flaccid. Phosphorus contents of purple and yellow leaves were 0.09 and 0.11 percent, respectively, while the same varieties with applied phosphorus had 0.21 percent in their bottom leaves.

Table 40 shows the response of the most tolerant varieties and Figure 32 (part A) shows the response of some selected varieties. On the average, the absence of phosphorus reduced yields from 1.7 to 0.5 kg m² or 29 percent of maximum in the first trial. M Col 1684 was the most phosphorus tolerant, but its yield was unusually low. Llanera had a low tolerance index of only 1.28.

In the second trial, another 160 varieties were screened for phosphorus tolerance in a different plot. Due to disease problems,

Table 40. **Root yields and tolerance to low soil phosphorus of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)		Tolerance index
	P_2O_5 applied (kg/ha)		
1976A	9	150	
M Col 1684	8.6	10.7	6.9[1]
M Col 660	13.6	30.1	5.1
M Pan 114	14.4	37.3	5.5
CM 213-9	9.2	17.2	4.9
CM 309-25	8.4	15.4	4.6
M Col 1686	9.0	19.3	4.2
M Ven 168	11.5	32.9	4.0
M Mex 59	11.3	31.8	4.0
CM 323-64	8.2	17.9	3.7
M Col 22	7.2	14.0	3.7
1976B	0	150	
M Mex 59	23.0	23.6	22.4[1]
M Pan 102	12.1	8.9	16.4
M Ven 246	12.1	10.5	13.9
M Col 1505	12.1	11.1	13.9
M Col 1524	13.4	15.0	12.0
M Ven 217	18.7	32.3	10.8
M Ven 156	14.0	19.1	10.3
M Ven 187	11.9	14.0	9.7
M Col 1513	8.2	7.2	9.3
M Mex 23	12.3	16.8	9.0

[1] Tolerance index = $\frac{(\text{Yield 0 P})^2}{\text{Yield (150 kg } P_2O_5\text{/ha)}}$

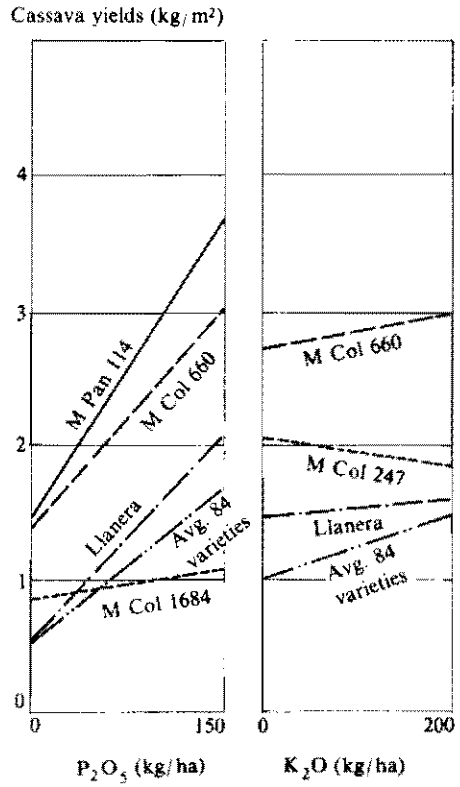


Figure 32. **Single row yields of several cassava varieties and the average yields of 85 varieties as affected by two levels of phosphorus and potassium.**

yields of the plot with 150 kg P_2O_5/ha were slightly lower, while some residual phosphorus in the soil raised the yields of the zero-phosphorus plot slightly higher than those of the first screening, resulting in a higher tolerance index as indicated in Table 40. M Mex 59 had the highest tolerance index.

Due to non-uniformaty of soil and climatic conditions, tolerance indices of varieties in different field screenings cannot be compared; screening in nutrient solution produces more uniform conditions. Moreover, differential susceptibility to diseases is seldom a complicating factor in nutrient solution screenings. Hence, in the future, nutrient solution screening will be emphasized.

FIELD SCREENING FOR LOW POTASSIUM TOLERANCE

The same 100 varieties used for the first phosphorus screening were also screened for low potassium tolerance by planting with two potassium levels— 0 and 200 kg K_2O/ha, **applied as KCl, split applied at** planting and at 60 days. The plots were limed and fertilized as indicated in Table 38.

Table 41. **Root yields and tolerance to low soil potassium of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)		Tolerance index
	K_2O applied		
1976A	0	200	
CM 308-23	19.1	13.6	26.8[1]
M Col 660	27.1	29.7	24.7
M Col 247	20.7	18.5	23.2
M Ven 83	25.2	28.1	22.6
M Mex 23	11.5	6.4	20.7
CM 320-19	13.0	10.0	16.9
M Ven 168	21.6	27.7	16.8
M Ven 1823	17.5	22.0	13.9
M Col 783	10.9	8.6	13.8
Llanera	14.6	15.6	13.7

1 Tolerance index $\frac{(\text{Yield 0 K})^2}{\text{Yield (200 kg } K_2O/\text{ha)}}$

Without **applied** potassium plant growth was only slightly reduced from 66 to 60 centimeters at 2.5 months. Potassium content of upper leaves decreased significantly from 1.70 to 0.98 percent, while contents of nitrogen, phosphorus and magnesium increased in the absence of potassium. The calcium content was not affected. Figure 32 (part B) and Table 41 give the response to potassium of the most tolerant varieties tested. On the average, lack of applied potassium reduced yields from 1.45 to 1.0 kg/m^2, that is, to 70 percent of maximum yield.

LEVEL AND TIME OF POTASSIUM APPLICATION

Under high rainfall conditions applied potassium can be lost partly through leaching. Therefore, **split applications of** potassium are generally recommended. To study this effect, the variety Llanera was planted, and levels of 0, 50, 100, 150, and **200 kg K_2O/ha were applied as KCl in a** single or split application at various times after planting. The fertilization regimes are indicated in Table 38.

Application increased potassium contents of upper leaves at three months from 1.83 to 2.21 percent while calcium and magnesium contents were low but not significantly affected by potassium application. However, at nine months, plants in high-potassium treatments showed yellowing of lower leaves with magnesium contents of only 0.06 percent compared with 0.15 percent in plots without potassium. This suggests that high potassium applications induced magnesium deficiency, but calcium status of the plant was not affected. Figure 33 shows the yield response. Though yields

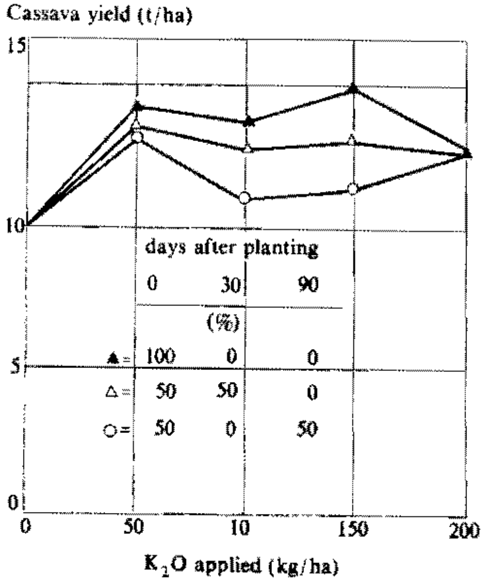


Figure 33. **Response of the cassava variety Llanera to several levels of potassium applied at various times after planting at Carimagua.**

were low, there was a significant response to potassium application, but no significant difference between levels of application; a single application at planting was superior to any split application or single application at 30 days. Thus, under the climatic and soil conditions of Carimagua a split application of potassium does not seem necessary. The application of 20 kg Mg/ha did not prevent magnesium deficiency induced by high potassium treatments.

RESIDUAL EFFECTS OF ROCK PHOSPHATES

The 1976 CIAT Annual Report showed the response of cassava to applications of various rock phosphates in Carimagua. This year, the trial was reseeded to measure the residual effect of the phosphate applications. One of the two sets of plots on which TSP had been applied was used to measure residual effect, while in the other set the same amount of TSP was reapplied as an optimum control. Nitrogen, potassium and zinc were uniformly reapplied to all plots. Plants were harvested at 11 months.

Yields of all plots were considerably lower in the second planting than in the first; the highest yield was 21.9 t/ha obtained with 400 kg P_2O_5/ha of reapplied TSP. Figure 34 shows the relative yields of both plantings. Application of basic slag produced the highest yields in the first planting, and had a better residual effect than any other source in the second planting. Of the rock phosphates, the residual effect of Gafsa rock was better than that of TSP and North Carolina rock. In the first planting, cassava only responded to 100 kg P_2O_5/ha, but in the second planting there was a significant response to 400 kg P_2O_5/ha, both for the residual and reapplied phosphates, indicating that 100 P_2O_5/ha was not sufficient for maximum yields.

POTASSIUM X NITROGEN INTERACTIONS

Results of a potassium x phosphorus systematic design trial with Llanera were reported in the 1976 CIAT Annual Report. A similar trial for potassium x nitrogen was planted in Carimagua using 14 levels of potassium combined with 14 levels of nitrogen, band-applied at seeding as K_2SO_4 and urea, respectively. Yields of Llanera varied between 17 t/ha at low nitrogen and potassium rates to 30 t/ha with the application of 130 kg N/ha and 160 K_2O/ha. No nitrogen response was observed in the absence of potassium nor a potassium response in the absence of nitrogen. Both elements were equally important in increasing yield but neither produced the large response obtained with phosphorus in the potassium x phosphorus trial.

Using values of $1, 500/t of cassava and $17,50/kg N, $18,50/kg K_2O, and $23.20/kg P_2O_5 (all in Colombian pesos), the value of the increased yield due to fertilization exceeded the cost of the fertilizers and transport.

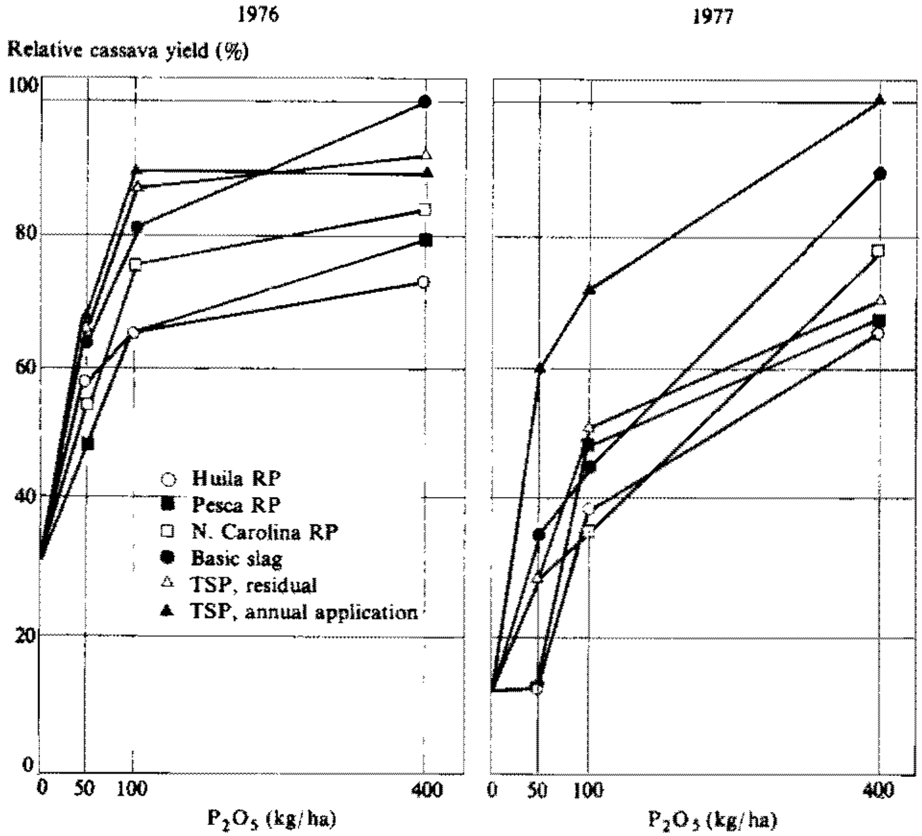


Figure 34. Initial (1976) and residual (1977) effects of various levels and sources of phosphorus on the relative yield of cassava variety Llanera in Carimagua.

Figure 35 shows the effect of nitrogen, phosphorus and potassium fertilization on the harvest index. Both nitrogen and potassium applications decreased the harvest index, indicating that the fertilizer stimulated top growth more than root growth. With phosphorus fertilization the harvest index increased up to 50 kilograms of applied P_2O_5/ha and then decreased. This initial increase in harvest index as phosphorus levels increased was also found in other phosphorus trials (CIAT Annual Report 1976) and indicates that phosphorus at low to intermediate levels is most efficient for root formation.

ZINC FERTILIZATION

Since zinc deficiency is very common in cassava on both acid and alkaline soils, a trial on sources, levels, and methods of application of zinc was conducted in Carimagua on acid soils and in CIAT on alkaline soils. Fertilization regimes at Carimagua are shown in Table 38; at CIAT, plants were only fertilized with zinc. The test varieties in Carimagua were M Mex 23 and M Mex 59, and in CIAT, Llanera. Plants were harvested at 12 months in Carimagua and at 15 months in CIAT.

Table 42 shows the responses to zinc application. Both varieties in Carimagua produced low yields due to a severe hornworm attack and infection with CBB. However, they responded significantly to soil application of 5 kg Zn/ha, but gave no

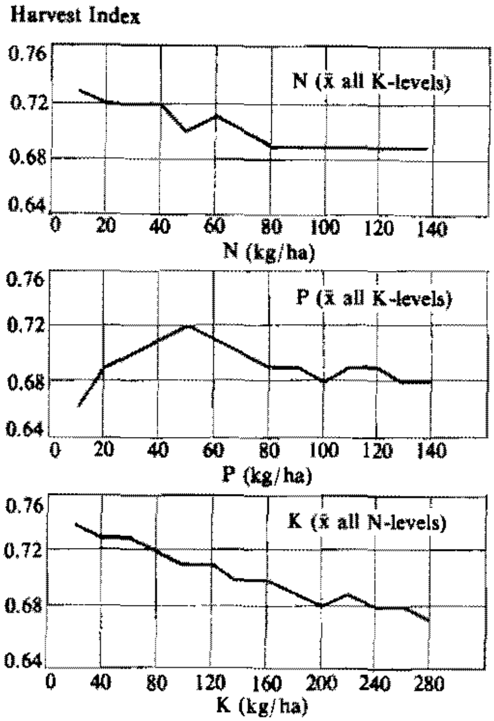


Figure 35. Effects of various levels of nitrogen, phosphorus and potassium on the harvest index of cassava variety Llanera at Carimagua.

additional response to higher levels; there was no significant difference between band-applied $ZnSO_4$ or broadcast ZnO. Foliar application or stake treatments were less effective than soil application. When yield was correlated to zinc contents of upper leaves at three months, a critical level for zinc deficiency of 37 ppm was determined for M Mex 59 and 51 ppm for M Mex 23.

In CIAT, Llanera responded very well initially to stake treatments of 2 and 4 percent $ZnSO_4$. However, most plants recuperated from zinc deficiency, while some suffered from soil salinity. Yields varied greatly because of soil variability (pH 6.7-8.0). Best yields were obtained with 15-minute stake dips in a suspension of 4 percent ZnO or a solution of 4 percent $ZnSO_4$ prior to planting. High yields were correlated with high zinc content (more than 45 ppm) of upper leaves but no critical level could be determined.

Thus in acid soils, soil application of ZnO or $ZnSO_4$ is effective, while under

Table 42. **Zinc content of upper leaves at three months and root yield as affected by various zinc treatments applied to two varieties of cassava in Carimagua and one variety in CIAT, Palmira.**

	Carimagua				CIAT	
	Yield (t/ha)		Zn in leaves (ppm)			
Treatment	M Mex 59	M Mex 23	M Mex 59	M Mex 23	Yield (t/ha) Llanera	Zn in leaves (ppm)
Control	8.3	1.7	25	21	34.7	38.2
5 kg Zn/ha, $ZnSO_4$	12.7	8.4	35	34	33.2	37.2
10 kg Zn/ha, $ZnSO_4$	13.2	7.8	41	37	31.9	40.5
20 kg Zn/ha, $ZnSO_4$	14.1	7.4	60	52	40.0	42.2
5 kg Zn/ha, ZnO	15.1	6.0	45	32	39.1	42.2
10 kg Zn/ha, ZnO	12.5	10.2	50	34	27.8	35.0
20 kg Zn/ha, ZnO	13.0	10.7	50	45	38.8	39.5
1% $ZnSO_4$, foliar	10.9	4.2	—	—	38.4	44.7
2% $ZnSO_4$, foliar	11.2	6.2	—	—	32.3	43.0
4% $ZnSO_4$, foliar	13.2	4.4	—	—	37.4	45.0
1% $ZnSO_4$, stake	6.5	3.5	34	30	35.6	32.0
2% $ZnSO_4$, stake	10.7	5.5	26	27	34.3	37.5
4% $ZnSO_4$, stake	13.8	3.3	32	25	43.4	38.0
1% ZnO, stake	9.4	4.8	30	26	29.9	31.7
2% ZnO, stake	8.6	5.5	28	26	29.8	39.2
4% ZnO, stake	11.1	5.6	26	25	52.1	32.7

alkaline conditions stake treatments are recommended since soil-applied zinc is rapidly precipitated at a high pH.

FERTILIZATION WITH COW MANURE

Areas with acid infertile soils, presently used for beef production, are also areas of potential cassava production. The use of locally available cow manure to fertilize cassava is an obvious alternative to the use of imported chemical fertilizers. The effectiveness of various levels of cow manure was tested against manure combined with phosphorus or potassium applications, and against complete chemical fertilizers (10-20-20) applied in equivalent amounts of phosphorus as in the manure. Llanera was the cassava variety used. The manure was incorporated while chemical fertilizers were band-applied alongside the stakes.

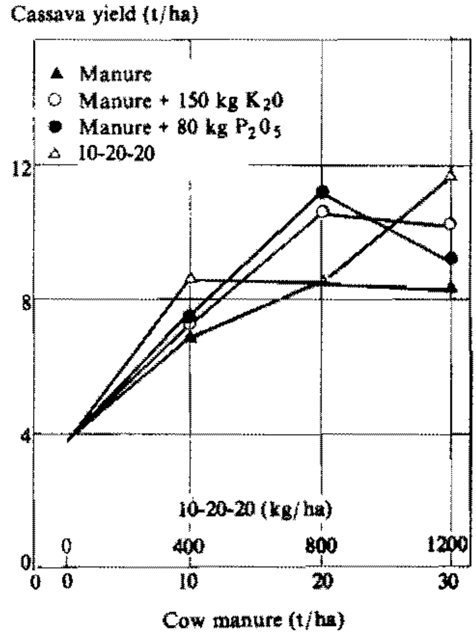


Figure 36. Response of cassava variety Llanera to various levels of cow manure, applied either alone or combined with phosphorus or potassium, compared to equivalent amounts of applied 10-20-20 chemical fertilizers.

Figure 36 shows that the application of 20 and 30 t/ha of manure doubled the yields, but that the addition of 80 kg P_2O_5/ha or 150 kg K_2O/ha significantly increased yields over those with manure alone. The application of equivalent phosphorus amounts of 10-20-20 fertilizers was generally superior to the use of manure alone, but not significantly different from the manure combined with phosphorus or potassium.

Using current prices (Colombian pesos) of $1,500/t for cassava and $8,400/t for 10-20-20 fertilizer (including transport), the use of manure on the average gave a higher net return only if the value of the manure, including cost of collection and application, were less than $200/ton. Generally, yield increases obtained by applying phosphorus or potassium to the manure did not compensate for the additional cost of these fertilizers.

Cassava Storage

Cassava roots deteriorate rapidly after harvest. Deterioration is either physiological or microbial, but the former generally occurs within 48 hours of harvesting. Physiological deterioration is characterized by a dry brown to dark necrosis, normally appearing as rings around the periphery of the cortex. This deterioration often appears on susceptible varieties within 48 hours of harvesting. Microbial deterioration commonly begins as vascular streaking, followed by soft rot, fermentation, and maceration of the root tissues. This type of deterioration, which does not occur in any special order, is normally noticeable five to eight days after harvesting (Fig. 37).

Figure 37. Two forms of deterioration of cassava roots. (Left) Physiologic: dry brown-dark necrosis in the form of rings around the periphery of the cortex. (Right) Microbial: soft rotting, with fermentation and maceration of the root tissues.

PRUNING

An experiment was done to evaluate the effect of pruning on cassava deterioration. Eight cassava varieties were selected with varying resistances to both physiological and microbial deterioration (see Cassava Storage, CIAT Annual Report, 1976). Plants of each variety were pruned to remove all green material (leaving only a 25-centimeter stem) and left in the ground for varying intervals before harvest. The results showed that the percentage of both physiological and microbial deterioration decreased with time from pruning to harvest for up to 14-21 days (Fig. 38).

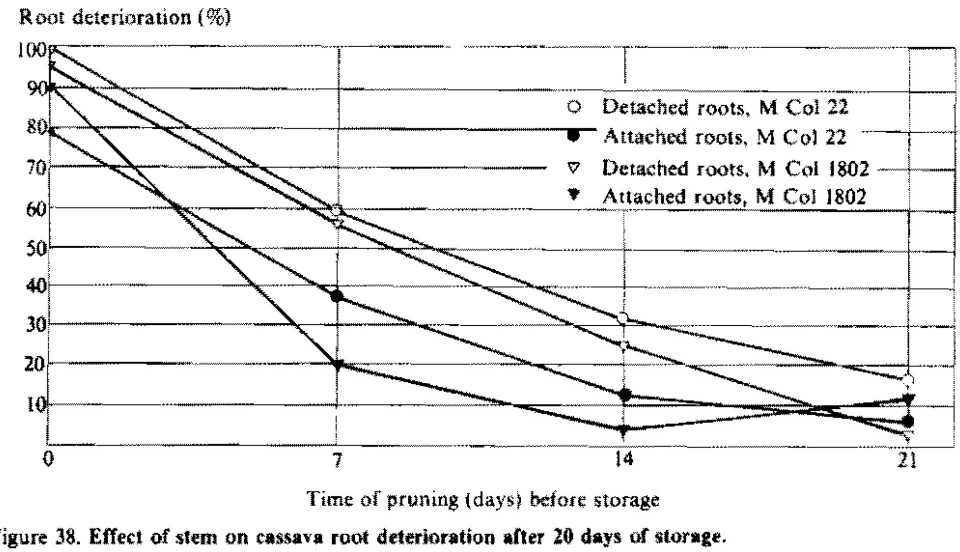


Figure 38. Effect of stem on cassava root deterioration after 20 days of storage.

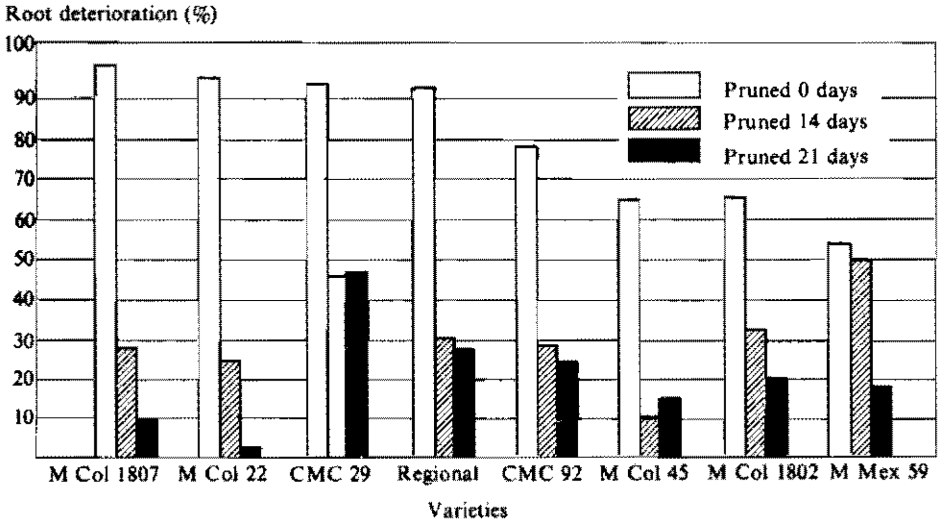


Figure 39. **Root deterioration of eight cassava varieties pruned 0, 14 and 21 days before harvesting and stored for 20 days.**

Roots left attached to the stem always deteriorated more slowly than those which had been detached. As indicated last year, susceptibility to deterioration is a varietal characteristc, for example, M Col 1807 and M Col 22 were more susceptible than M Col 1802 and M Mex 59 (Fig. 39). However, after 21 days, when these varieties were pruned, the first two varieties had deteriorated less than the latter two. Hence, varietal reaction to pruning varies and resistance without treatment is not related to resistance with treatment.

Normally, damaged roots deteriorate more rapidly than undamaged ones. However, after pruning, roots cut to

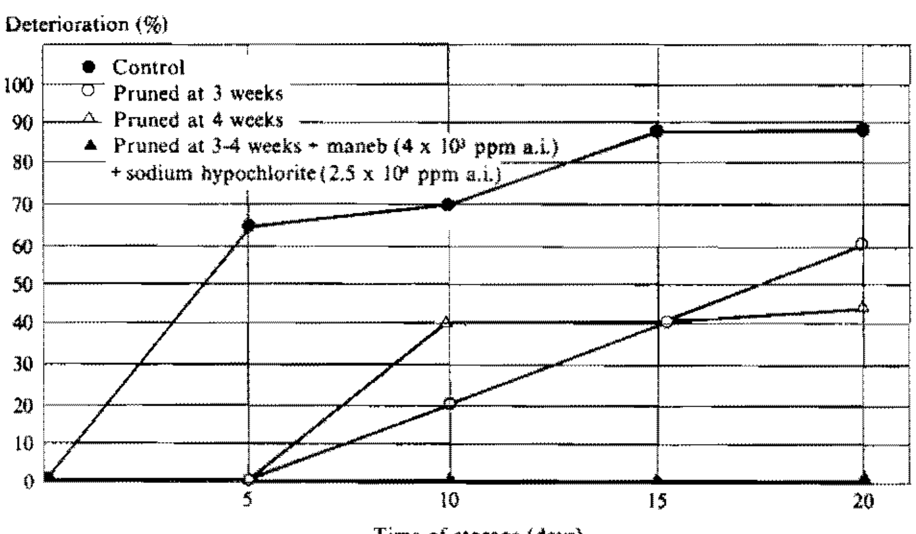


Figure 40. **Effect of plant pruning and chemical treatment on root deterioration of cassava variety M Col 113.**

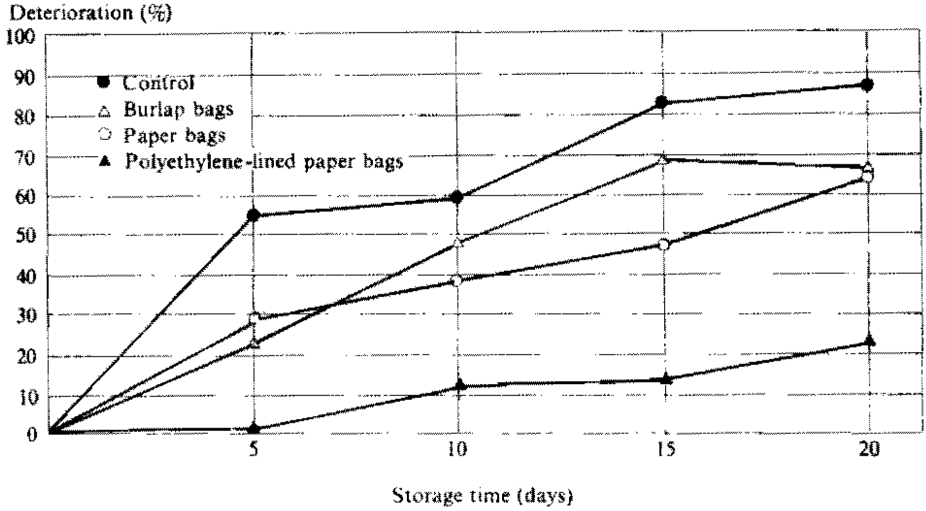


Figure 41. **Effect on deterioration of storing root of cassava variety M Col 113 in bags.**

simulate damage deteriorated at the same rate as treated, undamaged roots even when held at low humidity to prevent curing.

When roots with stems were stored after pruning, the physiological deterioration which normally occurs during the first two days was prevented. However, after ten days microbial rotting occurred but this was prevented by dipping roots in maneb and sodium hypochlorite (4×10^3 and 2.5×10^4 ppm a.i., respectively) (Fig. 40).

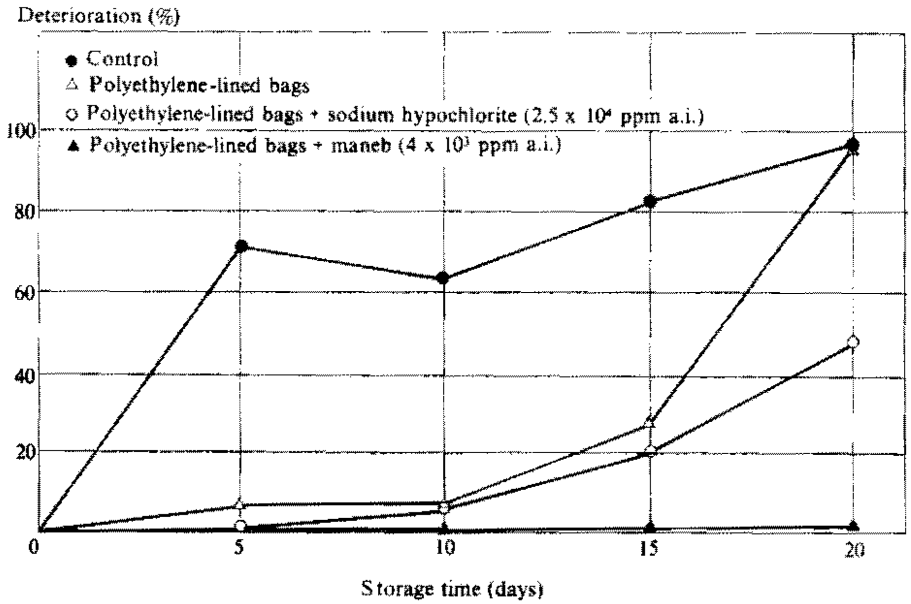


Figure 42. **Effects of polyethylene-lined paper bags and chemical treatments on deterioration of stored cassava roots.**

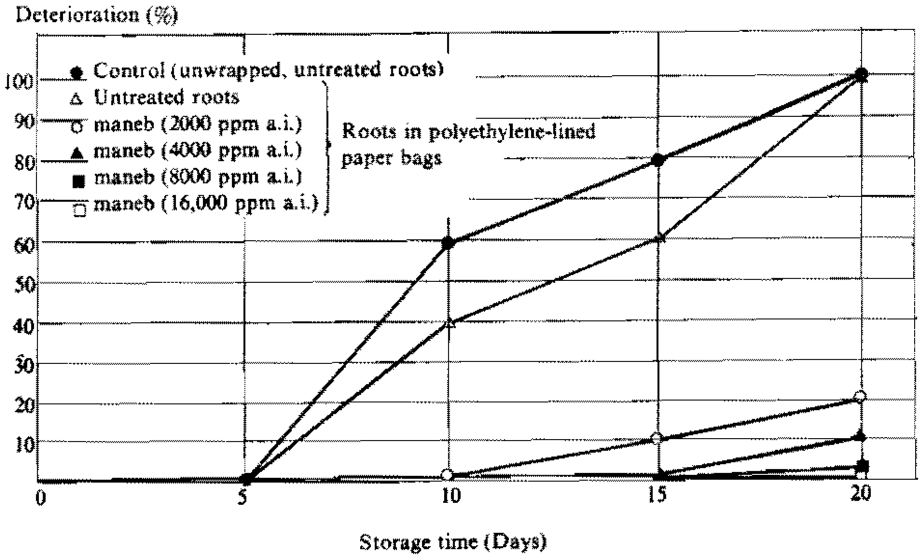


Figure 43. **Prevention of cassava root microbial deterioration with maneb treatments.**

STORAGE IN BAGS

Storage in burlap and paper bags increased the number of undeteriorated roots when compared with controls (Fig. 41), but treatments still gave a high percentage of both microbial and physiological deterioration. There was, however, a tendency for microbial deterioration to begin after about five days, similar to results for the pruning treatments. This was partially prevented by treating the roots with sodium hypochlorite (2.5 x 10^4 ppm a.i.) and completely prevented by a treatment of 4 x 10^4 ppm a.i. of maneb (Fig. 42). Further trials showed that at this concentration of maneb, some microbial rot occurred but that at concentrations of 8 x 10^4 ppm a.i., excellent control was obtained (Fig. 43).

International Cooperation

International cooperation activieties were markedly increased in the Cassava Program in January 1977 with the assignment of two staff positions— one based at CIAT, to coordinate Latin American activities and the other, posted at SEARCA, Philippines, to coordinate outreach activities in Asia. Both positions are funded by the International Development Research Centre (IDRC), of Canada.

However, outreach and international cooperation activities were initiated as early as 1972 when several Latin American countries were visited. CIAT, being an apolitical organization, can only influence what happens by demonstrating the usefulness of what it has to offer. The network of technical visits, training, and interpersonal and friendly communications, are the basis of this program. Throughout these years, these approaches have served as a means to: (a) help other countries to organize, with different degrees of success, their research on cassava; (b) to adapt, adopt and apply some of the minimal input technology developed at CIAT; (c) to field test CIAT-developed and other cultivars and hybrids; and (d) to cooperate in establishing an international network for exchange of information and germplasm, the latter through uniform regional trials using selected cassava cultivars. Two cassava scientists, upon special request, have worked with several sponsoring countries providing special assistance on specific problems.

The international cooperation philosophy is to *Inform* of what CIAT can offer, *Wait* until the national agency decides on what action it wishes to take, and then *Assist* the national agency in solving their problems. (The demand from the collaborating countries is mainly centered on germplasm exchange, technology, training, and assistance in program development).

Training plays a major role as a first step in international cooperation and it has changed from a rather opportunistic position of accepting random trainees to a very selective attitude that concentrates efforts in given countries at a given time, consequently providing training to several scientists in order to form teams for research in production in those countries.

The Cassava Program, as a result of its research and outreach activities, has decided that it is not only technology that needs to be transferred, but rather the ability to define the optimum technology that can be adapted to specific conditions by national agencies.

Experience has shown the effectiveness of the regional trials methodology as published in "The International Exchange and Testing of Cassava Germplasm", the result of a workshop in which country representatives presented their needs. Work is now concentrated on designing a series of standardized simple experiments to validate the technology generated at CIAT.

The development of international cooperation activities in Asia, being newer in its outreach than in Latin America, has as its major present responsibilities the multiplication and exchange of germplasm, including the establishment of regional trials; selection of candidates for training, and coordination of their work after training; and definition of the *status quo* of cassava production in Asia.

At this early stage, only five countries in Asia are involved in the Asian Outreach Program— India, Indonesia, Malaysia, the Philippines and Thailand. In the immediate future, other Asian countries, notably Sri Lanka, Burma and Vietnam, will be informed of the CIAT program and what it has to offer. Visits and program discussions had already been done with cassava scientists in the first five countries, and correspondence for possible cassava linkages with agricultural agencies for the other Asian countries has been initiated. In the field of manpower development for the countries, the response from developing national cassava programs to send participants to the January 1978 Intensive Cassava Course at CIAT has been encouraging. It is expected that some 25 Asians from India, Indonesia, Malaysia, the Philippines and Thailand will be selected for this course.

In the future then, the regional trials network will serve as an effective means of informing national agencies about their potential production capacity and the scope of the regional trials will be expanded so as to validate the low-cost cultural practices technology implementing the international collaboration activities in those countries wanting to commit their interest to increased cassava production. However, understanding that CIAT's clients are the national institutions and, that consequently, it does not have the responsibility nor the right to transfer technology directly to farmers, it cannot commit itself to cause any increase in yields in any region or country, unless the committment originates in the national institutions.

Achievements and projections in international cooperation activities can be summarized as follows:

Since the first visit to Brazil in 1972, and by special request of national research institutions and organizations of several countries, 124 scientists have been trained in cassava research and production at CIAT. Of these, 37 have come from Brazil, 12 from Mexico, 20 from Colombia, and 35 from other Latin American and Western countries; four have come from Malaysia, 11 from Thailand and five from Africa. Many of the professionals were trained in two intensive courses and two more intensive courses are programmed for 1978, one for participants from Asia, the other for Latin Americans. Twenty other agronomists have participated in longer training periods (3 to 12 months), and 14 have completed postgraduate research projects on cassava at CIAT.

As a result of this diversified training, some countries have taken longer steps in defining their cassava programs.

In Brazil, the National Cassava Center has been organized and CIAT, by special request of the Empresa Brasilerira do Pesquisa Agropecuaria (EMBRAPA), assisted in the planning and organization. CIAT's cassava agronomist has also spent over a month in the Brazilian Cassava Center, assisting in organizing a national network of regional trials, and in 1978, the cassava entomologist will help them in organizing the program in Brazil.

Consultations and visits to the Instituto Nacional de Investigación Agropecuaria (INIA) of Mexico, by the pathologist, agronomist and coordinator of CIAT's cassava program, resulted in the writing of a National Cassava Program for Mexico, which has been approved. A national center has been established.

Training in pathology by a Costa Rican agronomist at CIAT and visits of the CIAT cassava pathologist to that country, resulted in the eradication of bacteriosis from the experimental fields in Santa Clara and a program to eradicate cassava bacteria blight from major cassava growing areas in the country. Additional visits of the international cooperation specialist and other personal communications resulted in the establishment of an international regional trial with CIAT's best selections and later, in a formal agreement between the Ministry of Agriculture of Costa Rica and CIAT's Cassava Program, assistance in developing cassava research and production.

In the Dominican Republic, former trainees from CIAT will be assisted in organizing their cassàva program and in establishing an international regional trial.

Ecuador, through its Instituto Nacional de Investigaciones Agropecuarias (INIAP), asked for specific assistance to define the *status quo* of cassava production in that country, with special emphasis on economic aspects. CIAT assisted, with the funding of IDRC, in the design and data processing of an agro-economic survey that showed yields were only of the order of 10 t/ha. This was low compared with what should be expected. Hence, an international regional trial was established in a major cassava growing area and has shown that yields of more than 20 t/ha, are easily obtainable.

In Colombia, the Federación Nacional de Cafeteros has adopted CIAT's technology for a specific program in the Caicedonia area, and, at least for those farmers who keep production records, showed increased yields from 25 to 45 t/ha over a five-year period. This is a clear example of how a national institution has assimilated CIAT's technology and transferred it to farmers. In both the Cauca Valley and the Atlantic Coast regions, ICA is multiplying new lines selected in the ICA/CIAT regional trials for later distribution to farmers.

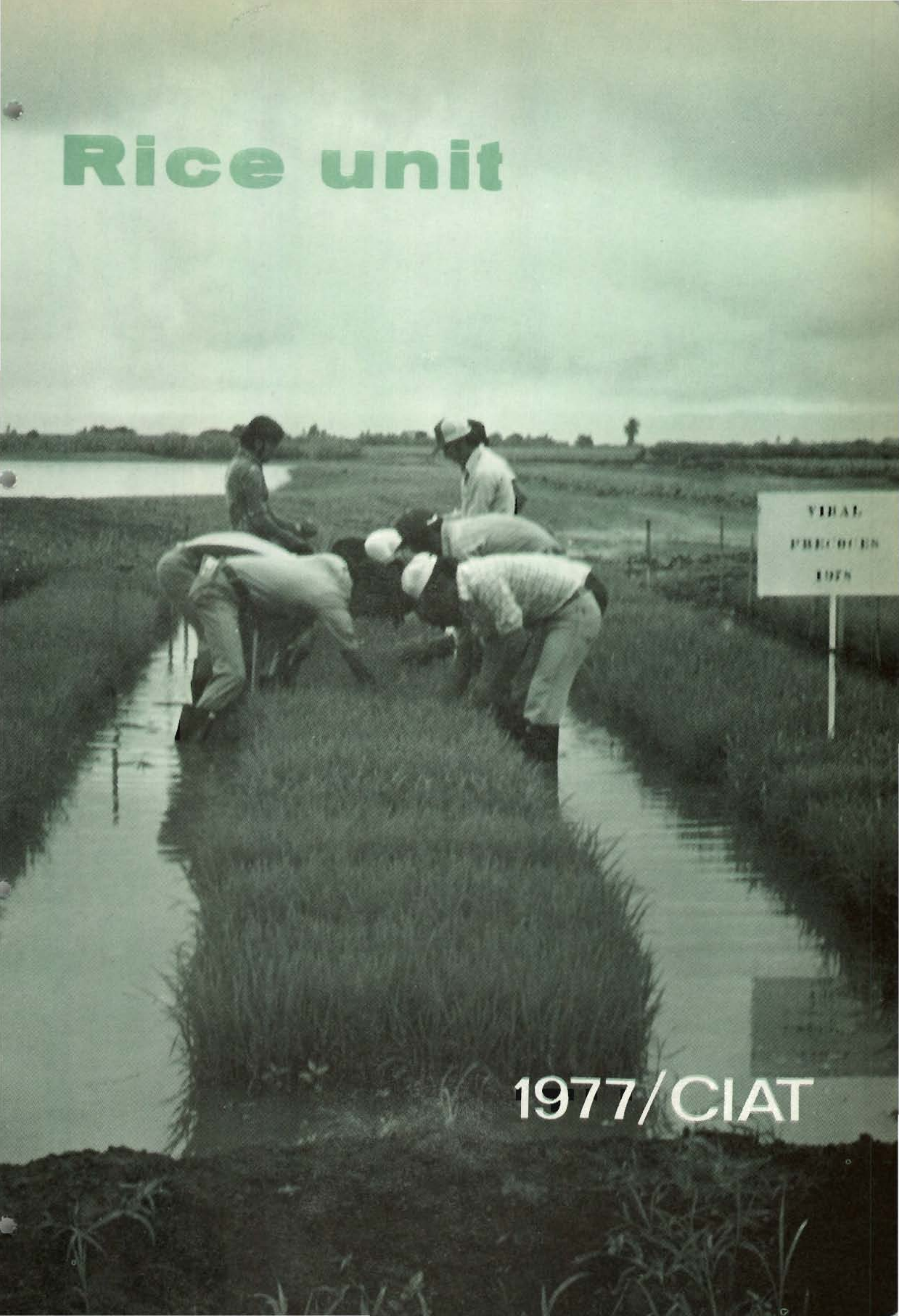
In other countries complete success has not been achieved. IDRC has provided special funds for Peru, but the objectives proposed have not yet been accomplished. Others have been informed, and have not responded yet, while others have called for assistance.

The network of regional trials has produced yield data from 48 different sites, within and outside Colombia. Of these, in 47 cases, CIAT's selected cultivars have produced highest yields indicating an adaptability to a wide range of ecological conditions. It has also proved that the local varieties can yield 50 to 100 percent more, even with minimal inputs, if CIAT's technology is adopted.

The collaborating countries in this regional trial network have been Guyana and Ecuador (two cycles), Mexico (three trials), Venezuela (two trials), and Costa Rica, Argentina, and the U.S.A. (one trial). Selected varieties, hybrids and seeds from controlled crossings have been sent to more than 30 countries, and the first results and comments are being received.

The success achieved so far has proven the validity of the technology generated, and the many problems faced indicate that research has to continue.

Rice unit



1977/CIAT

Rice Unit

Rice is basic in the nutrition of the Latin American people, particularly in the lowland tropics where per capita consumption is above 50 kilograms.

While production has been increasing in some countries, in the majority, yields and productivity are still low and insufficient to meet the demand. Insufficiency is primarily due to the lack of appropriate varieties with tolerance to adverse climatic and soil conditions and with tolerance or resistance to pests and diseases. Moreover, the lack of properly trained technicians prevents the transference of farming technology to farmers in those regions where suitable varieties are available and where conditions are favorable for increased production.

In 1977, CIAT's Rice Unit continued to develop its projects in international cooperation, varietal improvement and training, to help fulfill the primary objective of contributing to increasing national yields per surface unit in Latin America.

International Cooperation

Results were compiled this year for the First International Rice Yield Nursery for Latin America (VIRAL-76). Additionally, the following International Rice Research Institute (IRRI) nurseries received in mid-1976 were evaluated at CIAT: two yield nurseries of early- and medium-maturing varieties; two for evaluation in upland conditions; one for sheath blight; one of floating varieties; and another for soil salinity and alkalinity problems. These nurseries were planted at CIAT between July and November 1976 and the material evaluated, the seed multiplied and the most promising varieties or lines for Latin America selected. Particular emphasis was placed on plant type, grain quality, resistance to *Sogatodes* and good yield.

FIRST INTERNATIONAL RICE YIELD NURSERY FOR LATIN AMERICA (VIRAL-76)

In 1976, the First International Rice Yield Nursery for Latin America (VIRAL-76) was formed with 24 varieties from Colombia, Costa Rica, the Dominican Republic, Ecuador, Guatemala, Mexico, Peru, the Philippines, Sri-Lanka and Surinam. Twenty-eight sets were distributed to 17 countries. Yields obtained in several countries are shown in Table 1. Some varieties in this nursery outyielded the local varieties, e.g., Juma 57 and 58 from the Dominican Republic, yielded more than the Peruvian local variety, INTI. Similarly, IR2863-38-1-2 from the

Table 1. **Yield of the varieties from the International Rice Yield Nursery (VIRAL-76) in several countries in Latin America.**

Variety	Country of origin	Countries and yield (t/ha)[1]							
		Colombia	Costa Rica[2] (2)	Ecuador	Guyana	México[3] (3)		Peru	Venezuela[4] (4)
CICA 4	Colombia	3.3	4.5	6.1	2.9	6.4	1.7	8.1	5.4
CICA 6	Colombia	3.9	5.3	5.5	2.7	6.7	2.5	7.2	4.8
CICA 7	Colombia	3.1	4.5	5.6	3.0	5.1	2.6	7.5	4.3
CICA 9	Colombia	4.6	5.3	6.8	2.8	5.5	2.6	8.8	5.0
P918-25-1-4-2-3-1B	Colombia	4.9	3.5	6.2	2.8	9.7	3.3	8.1	5.8
P918-25-15-2-3-2-1B	Colombia	4.6	3.4	6.1	2.9	9.5	3.6	7.7	6.4
CR 1113	Costa Rica	4.3	4.0	5.7	3.1	6.6	2.2	8.7	6.1
Juma 57	Dom. Republic	3.8	-(5)	6.9	1.8	-	2.6	9.4	5.6
Juma 58	Dom. Republic	2.5	-	6.1	-	-	3.0	9.4	7.2
118	Ecuador	4.5	3.6	6.3	2.1	4.9	2.8	7.2	5.2
Tikal	Guatemala	4.9	4.9	3.7	2.9	4.1	2.6	8.4	5.2
N (IR1055)	Guyana	3.9	-	-	4.3	8.6	-	7.0	-
77916(GR22-10-6-10)	Guyana	3.7	-	-	4.6	6.6	-	6.2	-
Macuspana A 75	Mexico	-	2.5	3.2	2.9	4.5	2.9	5.7	3.9
Bamoa A 75	Mexico	-	4.1	5.4	3.8	7.2	2.8	8.2	5.3
Inti	Peru	3.0	3.1	5.9	3.5	7.2	2.7	8.4	6.1
IR2058-78-1-3-2-3	IRRI	3.5	-	-	-	8.4	-	-	-
IR2823-399-5-6	IRRI	4.1	-	-	-	-	-	-	-
IR2863-38-1-2	IRRI	4.3	-	-	-	10.8	-	-	-
IR1529-430-3	IRRI	4.4	-	-	-	-	-	-	-
Bg 90-2	Sri Lanka	4.4	2.6	5.1	4.6	1.0	2.0	9.0	6.0
Ciwini SML	Surinam	4.3	3.3	5.2	3.1	1.9	2.2	6.9	3.4
Camponi SML	Surinam	4.6	5.6	4.1	3.7	-	2.0	6.8	5.1
Ceysvoni SML	Surinam	4.3	3.8	4.2	3.5	-	2.3	6.3	4.2

1 Under irrigated conditions, except in Costa Rica and in two sites in Mexico.
2 Under upland conditions with good rainfall distribution.
3 Under upland conditions, average of two sites with drought problems.

IRRI and the two lines from the cooperative Instituto Colombiano Agropecuario (ICA)-CIAT project from Colombia (P918-25-1-4-2-3-1B and P918-25-15-2-3-2-1B) yielded 2 to 3 t/ha more than Bamoa A75 and 4 t/ha more than Macuspana A75 in Mexico.

NURSERIES FROM IRRI

In 1977 IRRI nurseries received in mid-1976 were evaluated at CIAT. The International Rice Yield Nursery for Latin America for Early-maturing Varieties (VIRAL-P) contained 10 varieties with good grain quality and yield potential; yields fluctuated between 6.5 and 8.6 t/ha. Under CIAT conditions (1000 meters asl and 24°C) maturity varied between 121 and 129 days. At lower altitudes, time to maturity would be reduced by 10 to 15 days (Table 2). In the nursery of medium-maturing varieties (VIRAL-T) 14 lines or varieties were included with yields that fluctuated between 6.5 and 9.9 t/ha; time to maturity was 130 to 143 days (Table 3). The nursery for deep-water varieties (VIRAL-F), initially had 50 lines of which 10 were selected by the CIAT Rice Unit for plant type, grain quality and tolerance to deep waters (80 cm) and were distributed to the countries which solicited this material. This nursery was also planted at CIAT in early 1977 to multiply seed and determine potential yields of the entries under normal irrigation conditions. Table 4 shows the principal characteristics and yields of entries in VIRAL-F. In the International Sheath Blight Tolerance Nursery (VIAVAL), some lines were discarded due to unacceptable grain type, late maturity or susceptibility to lodging. From this, a small nursery more appropriate for Latin America was distributed. However, no material was eliminated from an International Observational Nursery for Salinity (VIOSAL) since only a few lines were included for specific countries.

The upland nurseries, composed of 200 lines or varieties, were planted at CIAT under upland conditions. (A drought lasted from December 1976 through February 1977). Several lines showed drought tolerance in the vegetative and reproductive stages. However, a low tolerance to iron deficiency was found in the majority of the lines, which interfered with the reliability of yield data. Fourteen varieties tolerant to drought and iron deficiency were selected —seven with medium size grains, three with short grains, and four with long grains. With this material, the International Rice Upland Yield Nursery (VIRAL-S) was formed and distributed.

Table 5 shows the nurseries and the number of sets dispatched to Latin American countries in 1977.

SECOND CONFERENCE ON INTERNATIONAL RICE TESTING PROGRAM FOR LATIN AMERICA (IRTP)

This year, the second conference on the International Rice Testing Program for Latin America was conducted at CIAT on November 4-5. Leaders and other professionals of national rice programs attended the conference whose purpose was to strengthen international cooperation within the IRTP; correct procedural problems; define the need for more nurseries; interchange ideas on current rice problems; and develop a schedule of activities to more rapidly disseminate the IRTP results to the farmers. Table 6 shows the number of participating delegates from each country represented.

When delegates were asked if they preferred to receive the nurseries directly from IRRI or after evaluation and further selection by CIAT, all the delegates except those from Mexico and Costa Rica requested the nurseries from CIAT. Mexico requested nurseries from both IRRI and CIAT and Costa Rica requested the observation nurseries directly from IRRI, and the yield nurseries from CIAT. The

Table 2. **Principal characteristics of the germplasm in the 1977 International Yield Nursery for Early-maturing Varieties for Latin America (VIRAL-P) observed at CIAT.[1]**

		Agronomy		Diseases[2]			Insects[2]	Quality		
Identification	Country of origin	Height (cm)	Maturation (days)	Blast	Bacterial Blight	Sheath Blight	Sogatodes	Grain Length[3]	Gelatinization Temperature[4]	Yield (t/ha)
BR51-46-1-Cl IR20/IR5-114-3-1	B'desh	107	129	7	3	1	4	5	I	8.0
IET2881(RP319-34-9-1-3 T141/IR661-1-175-3	India	86	123	9	5	3	4	3	IL	8.1
IET3262(RP633-95-8-1 IR8/PJ1-43/IR22	India	91	125	8	3	2	7	3	I	8.5
IET3127(RP6-516-31-4) TKM6/IR8	India	85	122	8	5	2	7	3	L	7.2
B541B-Pn-58-5-31 Pelita I-1/IP1108-2	Indonesia	103	128	7	2	2	3	3	I	8.6
IR2070-414-3-9(IR40) IR20*2/0.nivara//CP94-13	IRRI	96	125	4	4	2	6	5	I	7.3
IR2071-625-1-252(IR36) IR1561-228//IR24*4/0.n.///CR94-13	IRRI	80	124	2	6	3	3	3	I	7.7
IR2307-84-2-1-2 CR94-13/IR1561-228	IRRI	89	127	4	4	2	3	3	L	6.5
IR1561-228-3-3(check) IR8/Tadukan//TKM6*2/TN1	IRRI	83	121	7	5	2	8	3	L	8.0
CICA 7	Colombia	99	125	3	3	2	4	3	L	8.0

1 Average of two semesters
2 International resistance scale of 1-9: 1-2.9 = resistant; 3.0-3.9 = moderately resistant; 4.0-5.9 = moderately susceptible or intermediate; 6.0-9.0 = susceptible.
3 Scale for length of grain: 3 = long grain (6.61-7.50mm); 5 = medium length grain (5.51-6.60mm)
4 Gelatinization temperature scale: I = intermediate; L = low.

Identification	Country of origin	Agronomy: Height (cm)	Agronomy: Maturation (days)	Diseases[2]: Blast	Diseases[2]: Bacterial Blight	Diseases[2]: Sheath Blight	Insects[2]: Sogatodes	Quality: Grain Length[3]	Quality: Gelatinization Temperature[4]	Yield (t/ha)
BR51-46-5 IR20/IR5-114-3-1	B'desh	122	134	8	4	3	4	5	I	7.8
BR51-74-6 IR20/IR5-114-3-1	B'desh	120	133	8	4	3	4	5	IL	6.8
BR 4 (BR51-91-6) IR20/IR5-114-31	B'desh	129	137	8	3	3	3	5	I	7.5
IET1785(RP84-39-1)	India	95	132	9	6	4	4	3	L	7.2
B541b-Kn-58-5-3 Pelita 1/1/IR532E576-4	Indon.	110	130	8	4	3	4	3	I	7.0
B542b-Pn-9-2-2 Pelita 1/1/IR532E576-4	Indon.	117	134	9	3	2	6	3	I	9.9
IR2070-423-2-5-6(IR38) IR20*2/0.n//CR94-13	IRRI	91	134	4	5	3	3	3	IL	7.3
IR2071-586-5-6-3(IR42) IR1561-228/IR24*6/0.n//CR94-13	IRRI	103	143	0	3	3	8	5	L	7.9
IR2323-399-5-6 CR94-13/IR1529-680///IR24*3/0.n//IR14-16	IRRI	103	137	2	4	4	4	3	IL	7.1
IR2863-38-1-2 IR1529-680-3/CR94-13//IR480-5-9-3	IRRI	88	136	4	4	3	3	3	L	6.5
Bg 374-1 (75-311) Bg 66-1/IR20	Sri-Lanka	103	132	8	3	2	3	3	I	8.2
Bg 375-1 (75-404)	Sri-Lanka	98	132	8	3	2	3	3	I	9.1
IR2588-19-19-1-2-2 IR1544-238/IR1529-680-3	IRRI	92	139	4	2	2	3	3	L	8.5
Taichung Sen-yu 195 Bin-tang-Chien/IR661	Taiwan	89	132	6	4	3	3	3	L	8.1
CICA 9	Colombia	110	133	4	3	3	3	3	L	8.0

[1] Average of two semesters
[2] International resistance scale of 1-9: 1-2.9 = resistant; 3.0-3.9 = moderately resistant; 4.0-5.9 = moderately susceptible or intermediate; 6.0-9.0 = susceptible
[3] Scale for length of grain: 3 = long grain (6.61-7.50mm); 5 = medium length grain (5.51-6.60mm)
[4] Gelatinization temperature scale: I = intermediate; L = low.

Table 4. **Results of promising rice lines with the characteristics of floating rice under normal irrigated conditions at CIAT.**

Identification	Country of Origin	Days to Flowering	Height (cm)	Lodging %	Yield (t/ha)
BKN 6986-147-2 IR 262/Pin Gaew 56	Thailand	168	112	10	6.7
BKN 6986-81 IR 262/Pin Gaew 56	Thailand	156	150	85	4.4
BKN 6986-20 IR 262/Pin Gaew 56	Thailand	146	111	0	6.5
BKN 6987-105-4 IR 262/Khao Nahng Nuey 11	Thailand	128	109	0	8.9
BKN 6990-63 IR 262/TPG 161	Thailand	129	172	100	5.4
C 4-63	Philippines	119	115	0	6.9
R D 1	Thailand	123	113	0	6.4
BKN 6987-118-3-P IR 262/Khao Nahng Nuey 11	Thailand	123	107	0	8.2
BKN 6981-133-2-P IR 262/Khao Nahng Nuey 11	Thailand	126	111	0	5.8
BKN 6987-233-2-P IR262/Khao Nahng Nuey 11	Thailand	125	107	0	8.7

Table 5. **Number of nurseries from the International Rice Testing Program for Latin America distributed in 1977.**

	No. of nurseries[1]						
Country	VIRAL-P	VIRAL-T	VIRAL-S	VIRAL-F	VIAVAL	VIOSAL	Total
Argentina	1	1			1		3
Bolivia	1	1	2				4
Brazil	5	5	3	1	2		16
Colombia	1	1	1				3
Costa Rica	1	1	1				3
Ecuador	2	2	1	1	1	1	8
El Salvador	1	1	1				3
Guatemala	1	1	2				4
Guyana	1	1	1	1	1	1	6
Honduras	2	2	2				6
Jamaica				1			1
Mexico	4	4	2				10
Nicaragua	2	2					4
Panama	2	2	2				6
Paraguay			1				1

continued on page -7

Table 5. (continued)

Country	VIRAL-P	VIRAL-T	VIRAL-S	VIRAL-F	VIAVAL	VIOSAL	Total
	No. of nurseries[1]						
Peru			2		2	1	5
Dom. Republic	1	1	1	1	1	1	6
Surinam	1	1			1		3
Venezuela	2	2					4
Total	28	28	22	5	9	4	96

[1] VIRAL International Rice Yield Nursery for Latin America
-P Early maturing varieties
-T Medium maturing varieties
-S Upland rice varieties
-F Floating varieties
VIAVAL International Sheath Blight Tolerance Nursery for Latin America.
VIOSAL International Rice Salinity Observational Nursery for Latin America.

Table 6. **Number of delegates who participated in the second conference on the International Rice Testing Program for Latin America for 1977**

Countries	No. of Delegates
Argentina	1
Belize	1
Bolivia	2
Brazil	3
Colombia	6
Costa Rica	2
Dom. Republic	1
Ecuador	2
El Salvador	1
Guatemala	1
Guyana	1
Honduras	2
Mexico	3
Panama	3
Paraguay	1
Surinam	2
Venezuela	2
Uruguay	1
Philippines (IRRI)	3
Total	38

delegates from Brazil and Uruguay stated that they would request directly from IRRI the following specific nurseries: for resistance to low temperatures, drought, and aluminum toxicity.

The following nurseries were of interest to the delegates of several countries: yield nurseries of early- and medium-maturing varieties for upland and irrigated conditions; observational nurseries of early- and medium-maturing varieties for upland and irrigated conditions; rice blast and sheath blight nurseries; and nurseries for salinity, low temperatures and deep water. There was also a consensus of a need for future nurseries on brown leaf spot *(Helminthosporium oryzae)* and leaf scald *(Rhynchosporium oryzae)* and soil problems such as aluminum toxicity and alkalinity. Table 7 shows the types of nurseries established for 1978 and the number of sets requested.

DISTRIBUTION OF VARIETIES AND PROMISING LINES

The CIAT Rice Unit collaborated with institutions of several countries by sending seed of varieties and promising lines. Table 8 shows the quantity of seed from varieties and promising lines dispatched in 1977.

Table 7. **International Rice Testing Program for Latin America planned for 1978.**

IRTP Nurseries	Type[1]	Argentina	Belize	Bolivia	Brazil	Colombia	Costa Rica	Cuba	Ecuador	El Salvador	Guatemala	Guyana	Honduras	Mexico	Nicaragua	Panama	Paraguay	Peru	Dom. Republic	Surinam	Uruguay	Venezuela	Total
	VIRAL-P	1	1	1	6	2	1	1	1	1	1	1	2	3	1	2	1	1	1	1	1	2	32
Yield	VIRAL-T Temparano	1			4	3	1	1	1	1	1	1	2		1	2	1	1	1			2	24
	VIRAL-S		1	2	2	2	1		1	1	1	1	2	6	1	2	1	2				2	28
Observational	VIOAL Riego	1	2		3			1				1	2		1	1		1				2	15
	VIOAL Secano		2	2	5		1				1	1	2	6		2		1				2	25
Diseases	VIPAL		2	1	6	1	2	1	1	1	1	1	2	6	1	1		1	2		1	2	33
	VIAVAL				1		2	1	1			1			1	1		1				2	11
Environmental and Soil Problems	VIOSAL				1			1	1			1		1				1	1				7
	Low Temperatures Nursery				2			1										1			1		5
	VIRAL-F				1	2	1		1			1											6
TOTAL		3	8	6	31	10	9	7	7	4	5	9	12	22	6	11	3	10	5	1	3	14	186

VIRAL-P International Rice Yield Nursery for Latin America - Early-maturing varieties.
VIRAL-T International Rice Yield Nursery for Latin America - Medium-maturing varieties.
VIRAL-S International Rice Yield Upland Nursery for Latin America
VIOAL International Rice Observational Nursery for L.A.
VIPAL International Rice Blast Nursery for Latin America
VIAVAL International Sheath Blight Tolerance Nursery for Latin America
VIOSAL International Rice Salinity Observational Nursery for Latin America
International Rice Observational Nursery for Low Temperatures in Latin America
VIRAL-F International Yield Nursery for Floating Varieties for Latin America.

Country	Varieties and lines distributed (kg)													
	CICA 4	CICA 6	CICA 7	CICA 9	IR 8	IR 22	Line 4422	Line 4420	Line 4444	Line 4462	Line 4440	Colombia[1]	ICA 10	Bluebonnet 50
Argentina	0.2	0.2	0.2	0.2										
Australia		0.1	0.1	0.1										
Germ. Fed. Rep.	1.0	1.0	1.0	1.0	1.0	1.0								
Brazil	3.0	1.0	51.0	51.0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5
Bolivia			150.0	200.0					100.0		200.0			
Belgium		1.0												
Costa Rica											50.0			
Colombia				2.0							100.0			
Ecuador											10.0			
France			0.2	0.2										
Philippines			0.4	0.4					0.4		0.4			0.4
Guyana			50.0	50.0							50.0			
Kenya			0.1	0.1							0.1			
Liberia		0.02	0.02	0.02					0.02		0.02			
Mexico			1.0	1.0							1.0			
Nicaragua											50.0			
Panama											50.0			
Peru		5.0	7.0	57.0					2.0		57.0			
Venezuela				50.0							80.0			
Uruguay				1.0										
Total	4.20	5.32	211.52	414.02	1.5	2.0	1.0	1.0	103.42	1.0	658.52	1.0	0.5	0.9

Breeding

This year ICA and CIAT continued breeding rice varieties with high yields for production stability, reduced dependency on agricultural inputs and to overcome major production constraints such as rice blast *(Pyricularia oryzae)*, hoja blanca virus, the leaf-hopper *(Sogatodes oryzicola)* and minor constraints such as sheath blight *(Corticum sasakii)* and salinity.

EARLINESS

The fermers in the important Colombian rice zones of Tolima and on the North Coast prefer rice varieties which are early-maturing (100-110 days). Four early-maturing varieties—IR36, 74-5461 (blast resistant Bg 34-8), CICA 7 and IR22—were combined in 13 different simple crosses for early maturity with blast resistance from Tetep, Colombia 1 and C46-15. The simple crosses were subsequently top crossed and intercrossed to produce eight triple and five double crosses. The F_2 population of these crosses will be evaluated for earliness at the ICA Nataima and Turipana stations, in Tolima and the North Coast rice growing zones, respectively.

DISEASE AND PEST RESISTANCE

Resistance to Rice Blast

Selection for resistance to rice blast, *P. oryzae*, is one of the basic objectives of the breeding program. The achievement of stable resistance to rice blast is being pursued through multiple resistance and multiline approaches.

Multiple Resistance. Some 36,000 F_2 progeny were selected from multiple crosses with 10 improved parent lines carrying resistance factors from Tetep, Colombia 1, Dissi Hatiff, C46-15 and Carreon. The F_3 progeny combining resistance factors from three or four sources were evaluated in single row progeny trials. Some 11,000 selections combining resistance to blast, the plant hopper *(Sogatodes)*, acceptable grain quality and good plant type were derived from the promising F_3 progenies. All 11,000 selections were planted as F_4 progenies at Villavicencio and exposed to natural neck blast infection. Of 3,400 F_4 progenies that matured during the year, 330 promising lines were selected and planted at the ICA-Palmira station in unreplicated plots for yield evaluation; 1,000 selections were advanced to F_5 progenies.

Multiline Varieties. The third and final backcross for a five component multiline with five sources of resistance (Tetep, Colombia 1, Carreon, Dissi Hatiff, and C46-15) and two recurrent parents (4414, and CICA 9) was completed and their respective B_1F_3 populations were planted.

With the third backcross, the recurrent parent phenotype was fully recaptured as evidenced by the uniformity of the lines. The B_3F_1 populations were intercrossed to combine resistance factors from three different sources (Tetep with two others) as shown in Table 9 to develop a multiple resistant multiline.

Table .9. Crossing combinations with different resistance sources for rice blast.

1.	Tetep x (Carreon x Colombia 1)
2.	Tetep x (Carreon x Dissi Hatiff)
3.	Tetep x (Carreon x C46-15)
4.	Tetep x (Colombia¹ x Dissi Hatiff)
5.	Tetep x (Colombia¹ x C-46-15)
6.	Tetep x (Dissi Hatiff x C46-15)

Table 10. **Sources of resistance to blast from geographically diverse origins.**

Recurrent Parents	Sources of Resistance	Country of Origin
4440	Tetep	Vietnam
4414	Tapoo-cho-z	China
4468	Ca 902/b/3/3	Chad
CICA 4	P.I. 184675-2	Iran
CICA 9	Colombia 1	Colombia
Linea 8	S.M.L. 56/7	Surinam
Bg 90-2	Ramind Str 3	Thailand

In addition, an expanded multiline project was initiated with seven different recurrent parents and seven different sources of resistance from geographically diverse origins (Table 10). The first backcross to each of the recurrent parents was completed this year.

Five new, widely adapted, high-yielding varieties with good combining ability and resistance to several production constraints were incorporated as parents into the breeding program. Table 11 lists the parents and their desirable characteristics. The five parents were crossed in 152 triple cross combinations to combine factors for blast resistance from two different sources.

Tolerance to Sheath Blight

Presently, only tolerance has been found to sheath blight *(C. sasakii)*. Of the three tolerant varieties selected — Bahagia, Tapoo-cho-z and K8 — Bahagia and Tapoo-cho-z have been widely used in multiple crosses as tolerant sources to sheath blight. Crosses were made between the three tolerant varieties Bahagia x Tapoo-cho-z; Bahagia x K8; and K8 x Tapoo-cho-z such that each combination would have tolerance factors from the two parents. Each single cross was top-crossed to CICA 4, CICA 7, CICA 9 and 4440. The F_2 progenies will be observed under field conditions and evaluated. CICA 4, CICA 7, CICA 9 and 4440 were also crossed and backcrossed to each of the three donors for upgrading the recurrent parents with tolerance to sheath blight. Rapid seedling screening techniques for tolerant materials have not yet been developed.

Resistance to Bacterial Leaf Blight

Eleven varieties resistant to bacterial leaf blight in Asia were inoculated using isolates of *Xanthomonas oryzae* obtained in Latin America. From varietal reactions presented in Table 12, it appears that the isolates from Latin America behave similarly to those obtained in Asia.

Table 11. **Desirable traits of five parents incorporated into the CIAT/ICA breeding program in 1977.**

		Reaction[1]				
Parent	Plant Type	Bacterial Blight	Sheath Blight	Salinity	Phosphate Deficiency	Low Temperature
Remajda	Tall	HR	S	S	S	T
Bahagia	Intermediate	T	T	S	S	S
Pelita I/1	Intermediate	MR	S	HR	T	S
Bg 66-1	Dwarf	HR	S	S	S	S
Bg 90-2	Dwarf	R	S	S	S	T

Resistance scale: HR= highly resistant; MR = moderately resistant; T = tolerant; S = susceptible.

Table 12. **Reaction of several varieties to bacterial leaf blight (*Xanthomonas oryzae*).**

Variety	Reaction[1] Colombia	Asia
Remajda	HR	HR
Pelita 1/1	R	R
Tadudakan	R	R
Bg 90-2	R	R
Bg 66-1	R	R
Bg 97-2	MR	R/MR
Bg 97-3	R	R
K 8 (mutant)	MR	MR
IR 22	R	R
IR 2035-290	MR	R/MR
IR 8	SS	SS
Bluebonnet 50	SS	SS

Resistance scale: HR = Highly resistant; R = Resistant; MR = Moderately resistant; SS = Highly susceptible.

Some 832 advanced lines selected at the ICA-Palmira station from F_2 and F_4 populations (brought from Sri-Lanka) were tested under greenhouse conditions for resistance to bacterial leaf blight. Fifty-nine percent were resistant; 20 percent tolerant; and 21 percent, susceptible.

Identification of Genes for Resistance to Plant Hopper

There is a possibility of a physiological specialization of *Sogatodes* and therefore, the identification of resistant genes should be undertaken. Ten different resistant varieties are currently being researched to identify their corresponding genes.

EVALUATION OF PROMISING MATERIALS

Advanced Lines and Segregating Populations from Sri-Lanka

A total of 934 advanced lines (in the F_5 and F_6 generations) derived from 22 different crosses brought from Sri-Lanka were evaluated and 44 were selected as promising. These were tested for yield potential in two experiments both using CICA 9 as the control. Table 13 shows the results of the best eight lines in each trial.

Bulk F_4 populations from eight multiple crosses brought from Sri-Lanka (Table 14) were evaluated. From this material, 768 individual selections were made and evaluated in progeny row trials in the F_5 generation. Of these, 90 promising lines were selected for high yield potential, acceptable grain quality, plant type and resistance to hoja blanca and bacterial leaf blight and plant hopper.

Four F_2 populations from Sri-Lanka were observed and of this material 166 F_3 selections were evaluated in progeny row trials. Some 30 promising lines were obtained.

Evaluation of Introductions

Some 461 advanced lines from IRRI and Indonesia were evaluated and three lines were found to have a resistance factor for rice blast derived from the wild rice, *Oryza nivara*. These lines will be used as parents in the breeding program.

Purification and Multiplication of Line 4440

Line 4440 originated from a cross between CICA 4 and F_1 (IR665-23-3-1 x Tetep) and was selected as a pure line, with the geneology P918-25-1-4-2-3-1B. Along with CICA 7 and CICA 9, it was included in the 1976 regional trials, and the First International Yield Nursery for Latin America.

Segregation for grain type, plant height and maturity was observed in a seed multiplication lot with 4440 at CIAT. From this lot, 1600 plants were selected for purification, which were evaluated for

Table 13. **Performance of the 16 advanced lines from 22 crosses brought from Sri-Lanka.**

Lines	Crosses	Yield (t/ha)	% of Control
Trial 1			
1170	Bg 90-2 x [IR 1541 x ob678]	8.5	125
1156	Bg 90-2 x [IR 1541 x ob673]	7.8	115
1279	Bg 90-2 x [IR 1541 x ob 678]	7.7	113
1313	Pelita I 1 x [IR 1702 x IR 1529]	7.6	111
1394	Pelita I 1 x [IR 1702 x IR 1529]	7.5	110
1188	Bg 90-2 x [IR 1541 x ob678]	7.5	110
1348	Pelita I 1 x [IR 1702 x IR 1529]	7.4	109
1332	Pelita I 1 x [IR 1702 x IR 1529]	7.3	106
Trial 2			
Bg 90-2	IR 262 x Remajda	9.3	129
1724	Pelita I 1 x [ob678 x T.K.M-6]	9.3	128
1884	IR 22 x Bg 90-2	8.5	117
1843	[IR8 x T.K.M-6] x [IR665 x Bg90-2]	7.8	108
1883	IR 22 x Bg 90-2	7.7	107
1893	IR 22 x Bg 90-2	7.7	107
1895	Bg 66-1 x IR 20	7.7	107
1854	[IR8 x T.K.M-6] x [Bg66-1 x IR22]	7.7	107

grain quality and maturity. Ten improved plants were selected to continue evaluation and seed multiplication in individually seeded 200 m² plots with three replications, transplanting one seedling/site at a distance of 50 x 50 centimeters. Tables 15 and 16 present the principal agronomic characteristics and grain quality of these 10 selections. From these observations, it was decided to continue multiplication of basic seed from selections 1 and 10, transplanted in 4.5 hectares. In early 1978, one of these will be named as a variety in Colombia by the ICA Rice Program. Additionally, one kilogram of seed/selection was delivered to the heads of national rice programs who attended the second conference of the Internation Rice Testing Program for Latin America.

Table 14. **Eight multiple crosses brought from Sri-Lanka.**

IR 2042-101	x	[IR 262 x Pelita 1 1]
IR 2035-290	x	[Bg 90-2 x Pelita 1 1]
IR 2035-290	x	[IR 262 x Pelita 1 1]
IR 2035-290	x	[IR 1529 x Pelita 1 1]
Pelita 1/1	x	[IR 26 x ob678]
73-797	x	[Bkn 6809 x IR 1529]
73-669	x	[Bkn 6809 x IR 1529]
IR 262	x	[Bkn 6809 x IR 1529]

Table 15. **Principal agronomic characteristics of 10 selections from Line 4440 at CIAT.**[1]

Selection	Days to Flowering	Days to Maturity	Height (cm)	Reaction[2] Sogatodes	Reaction[2] Blast	Yield (t/ha)
1	106	143	96	2	1	7.8
2	106	144	96	2	1	7.4
3	111	146	99	3	1	7.7
4	112	147	96	2	1	7.4
5	114	148	99	3	1	7.8
6	107	145	98	3	1	7.6
7	106	143	96	2	1	7.1
8	108	145	98	2	1	7.9
9	110	142	97	2	1	7.1
10	109	146	98	2	1	7.6

1 Average of three replications.
2 According to the international resistance scale of 1-9: 1-2.9 = resistant; 2.9-3.9 = moderately resistant; 4.0-5.9 = moderately susceptible or intermediate; 6.0-9.0 = susceptible.

MECHANICAL DAMAGE IN RICE PADDIES

A duck, *Porphyla martinica,* has caused lodging and impeded the flowering of rice plants where these birds make their nests. In late 1976, when the rice planting area at CIAT was reduced, the population of *P. martinica* concentrated in a one hectare plot planted with 4440, where it

Table 16. **Grain quality of 10 selections of Line 4440 at CIAT.**

Selection No.	% Total Yield of White Rice[1]	% Head Rice[2]	Grain Length (mm)	White Center[3]	Gelatinization Temperature[4]
1	71.8	59.9	6.9	0.6	I,L
2	71.3	58.8	6.9	0.7	I
3	70.8	58.3	6.9	0.8	I
4	70.9	58.0	6.9	0.7	I
5	71.4	59.4	6.8	0.7	I
6	70.5	52.9	7.1	0.7	I
7	69.3	51.5	7.0	0.7	I
8	68.7	45.0	7.2	0.7	I
9	68.3	46.2	7.1	0.5	I
10	69.1	48.3	7.2	0.6	I

1 Based on 15 kg of paddy rice.
2 Whole white rice and 3/4 of whole grain.
3 Appearance of the white rice based on a scale of 0-5: 0 = absence of the white center; 5 = white center which fills the whole grain.
4 I = intermediate; L = low; the rice is dry and non-sticky after cooking.

caused severe damage from eating the 30-day-old seedlings down to the ground (Fig. 1). The damage affected 10 to 15 percent of the area. This observation confirms the fact that birds can, for lack of feedstuffs, significantly limit production. This is the first time this type of damage was noted in the rice paddies and its magnitude is of economic importance.

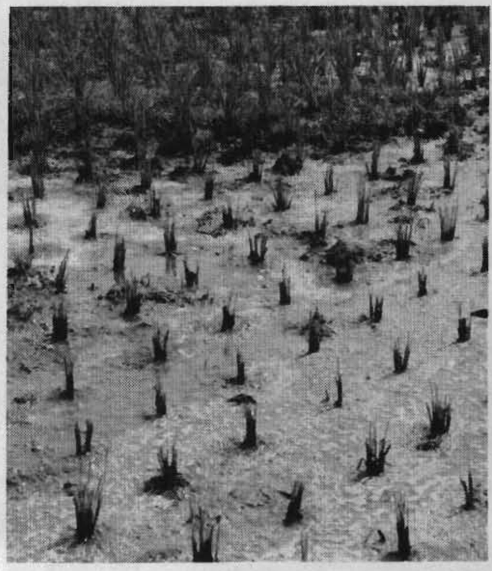


Figure 1. **Severe damage caused by** ***Porphyla martinica*** **after feeding on foliage of 30-day-old rice at CIAT.**

Training

RICE PRODUCTION COURSES

Fifteen Latin American rice professionals from Bolivia, Brazil, Ecuador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, and Panama were trained in rice production and breeding in four to six-month courses. The trainees received practical orientation in: soil preparation; planting; cultural practices; harvesting and processing; and planning and economic evaluation (Fig. 2). This was reinforced with classroom instruction and periodic conferences on economic and administrative aspects of production.

An important phase of training was the planning and execution by the trainees, of experiments to study the principal agronomic problems of the crop which are present in their own countries. The trainees planned eight experiments in which the following were evaluated: planting density and nitrogenous fertilization on direct-seeded and transplanted rice; the appearance of volunteer rice and its control; the effect of the rice leaf miner, *Hydrellia* spp. on the production of transplanted rice and on direct-seeded rice; and finally, the chemical control of weeds in direct-seeded and transplanted rice.

Experiments comparing yields of semi-commercial planting systems in one-hectare plots were also planned and conducted by the trainees. While there were no significant yield differences, the experiment is being continued with another group of trainees to evaluate production costs of these two planting systems.

Training was complemented by observation trips to rice zones in the Cauca Valley, Tolima and Huila, in Colombia, and the Guayas River Basin in Ecuador. Trainees then compared different cultural techniques in distinct ecological media and evaluated and integrated their own knowledge and experiences with other technicians.

Figure 2. As part of their field experience, trainees study the condition of transplanting beds at CIAT.

Special training was provided for professionals interested in plant breeding. Training included the basics of selection of genetic material, the establishment and evaluation of regional trials, and planning and evaluation of International Rice Yield Nurseries for Latin America (Fig. 3).

INTENSIVE COURSES

In late 1977, a short course for 20 agronomists working in technical assistance programs with ICA, Federación de Arroceros de Colombia

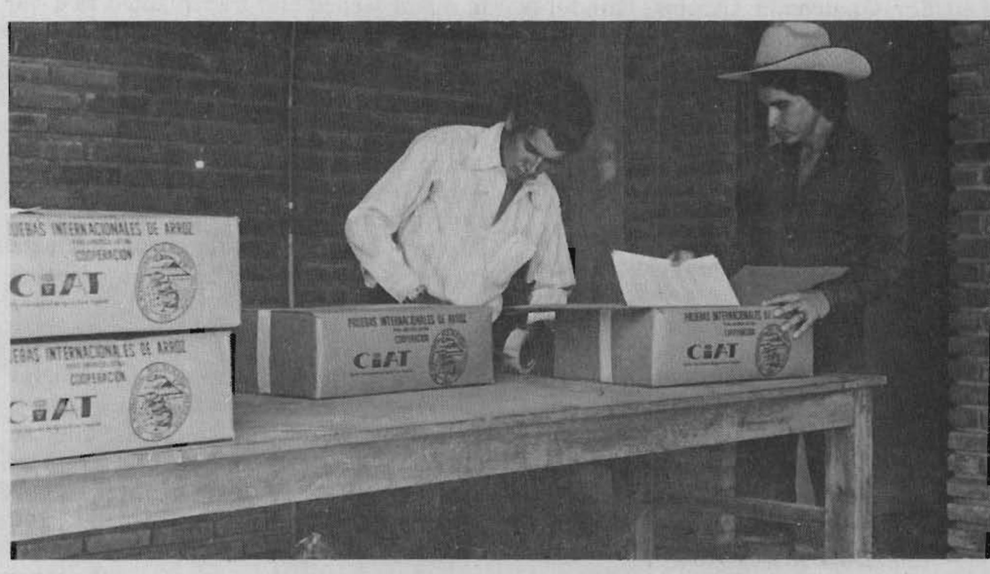


Figure 3 Ecuadorian and Mexican trainees assist in the assembly and packaging of International Rice Yield Trial Nurseries for distribution to Latin American countries.

(FEDEARROZ) and CARE provided instruction on new technology on rice production such as leveling of land underwater and transplanting.

Rice Technology Adoption

This year, a special studies project was continued on the socioeconomic effects of improved rice varieties and their associated technology on farmers in villages and farms of the North Coast of Colombia, an important rice cultivation region. The economics of upland, rainfed and irrigated rice production were analyzed to establish CIAT/IRRI research priorities for small rice producers in Latin America; and, to detail the socioeconomic adaptations of a rice farming society in transition (CIAT, Annual Report, 1976).

Two neighboring rice-growing communities were studied. In the control only traditional rice varieties and technologies were used for subsistence cultivation. Both upland and rainfed rice cultivation in the traditional community are non-irrigated. In the upland cultivation system, rice is direct-seeded in higher areas with relatively poor soil. No dikes are constructed to retain rainwater. In rainfed cultivation, rice is generally transplanted in good soils in shallow naturally flooded fields which are sometimes bounded by dikes to retain water. Most farmers in the traditional community use both rice cultivation methods, and average rice plots were 0.8 and 0.9 hectares per farmer for the two cultivation methods, respectively. Most farmers use both systems; then the average rice area per farmer is 1.26 hectares.

In the modern farming community, the majority of the farmers use the improved variety, CICA 4, on irrigated land with fertilizers, insecticides, fungicides, and chemical weed control. These inputs were supplied by credits from the Caja Agraria. (However, some farmers did not manage their credit well, became indebted, and lost their credit rating.)

Rice yields differed substantially between modern and traditional farmers (see Table 17). Modern farmers had higher net incomes due to higher yields of the improved variety, CICA 4, which also has

Table 17. **Estimated yield and breakdown of profitability of rice production in three different rice growing systems in two communities.**

	Modern	Traditional	
	Mechanized Irrigated	Manual Upland	Manual Transplanted
Yield (kg/ha)[1]	3,510	972	984
Value of production (Col.$/ha)	12,285	3,402	3,444
Total costs (Col.$/ha)	12,078	6,486	4,322
Net profit (Col$/ha)[2]	207	-3,084	-878
Net profit[3]		-1,501	315

1. Yield estimates based on questioning 100% of farmers in modern community, 25% of traditional community.

2 Family labor included as a cost.

3 Family labor not included as a cost.

Table 18. **Yield and breakdown of profit of mechanized rice production by a cooperative, per member, as compared with averages of co-villagers for 1976.**

	Cooperative	Village Average
Yield (kg/ha)	5,140	3,510
Value of yield (Col.$/ha)	18,258	12,285
Total costs (Col.$/ha)	15,819	12,078
Net profit (Col.+/ha)	2,439	207

a shorter growing period permitting two harvests per year. (One farmer produced eight tons of rice on a one hectare plot.)

It should be noted that at the time of the surveys, rice prices were low, wet season rains were late and precipitation low, adversely affecting transplants. As a result, real profits were negative for the traditional farmer and only slightly greater than zero for the modern farmers. However, farmers in a cooperative in the modern community achieve higher yields and incomes than the average (see Table 18).

Table 19 shows estimated production costs for the two communities. Of the variable costs, labor in the traditional system was very high as compared with mechanized production — 74 and 87 percent for upland and rainfed rice, respectively, as compared with 17 percent for the modern farmer. It should be noted that subsistence farmers use family labor on their farms but do not consider it a cost. However, when family labor is deducted from total production costs, only rainfed rice farmers made a profit in 1976.

Since upland farmers rent land on which other crops can be grown such as beans, maize, and cassava, the rental fees of the upland farmers are higher. At the same time, rainfed rice farmers do not compete for land with other crops and therefore have lower production costs and produce higher yields. New technology for these farmers would have a bigger pay-off.

Table 19. **Estimated costs of rice production/ha in three different rice growing systems, North Coast region, Colombia, 1976. (in Col. $).**

	Modern	Traditional	
	Mechanized, irrigated (n = 72)	Upland (n = 23)	Rainfed (n = 43)
Land rent	1,585	1,943	1,039
Land preparation	1,800	-	-
Water	526	-	-
Seed	1,242	478	255
Inputs	1,912	176	95
Input application	156	10	5
Harvesting	1,800	-	-
Technical assistance and interests	901	80	43
Transport	300	53	28
Manual labor	1,856	3,746	2,857
Total	12,078	6,486	4,322

It is evident that the modern rice-farming community is changing from a commodity-based economy into a cash based one. This has adversely affected landless, sharecropping farmers in this community for whom rice is a staple whose availability is limited in a commodity-oriented economy of scarcity. Sharecroppers, who are 50 percent of the subsistence farmers in this community generally require one-fifth of the crop to pay harvest labor, and one-third for the landowner. This indicates that subsistence farmers cannot contribute significantly to the external market or retain much of their crop for family consumption. Until recently, they supplemented rice for family consumption by working as laborers for modern rice farmers who paid them in rice shares.

When the combine harvestor was first introduced by modern families poor families in the community were allowed to recover shattered grains left by the machine, partially offsetting the reduction in rice availability. However, modern farmers now argue that 3-15 percent of the grains remain in the rice stalks and leaves cut by the machine and this rice can be consumed by the owner's family.

The reduced rice circulation in the local economy forces the subsistence farmers to buy more rice during the greater part of the year (Fig. 4). However, these cash payments buy less rice than the quantity normally paid to laborers since purchased rice passes through middlemen who raise the price.

The fact that the modern community is making an economic transition from a subsistence commodity to a cash based economy is also reflected in changing social customs. Formerly, farmers in both communities gave of rice to families and friends. Currently, 85 percent of the traditional farmers surveyed made gifts of rice, while only 65 percent of the modern farmers still continued this practice. These quantities constitute 3.4 and 0.9 percent of the farmers production, respectively. The poorest farmers, the sharecroppers, may have distributed similar quantities of rice as the modern farmers, however, they had the lowest yields and net incomes therefore distributing a higher proportion of their rice than the landowning farmers. While the quantities were small and probably more significant as tokens of social commitment than of economic importance, when these gifts were given prior to harvest, they may have been important for non-landowning farmers.

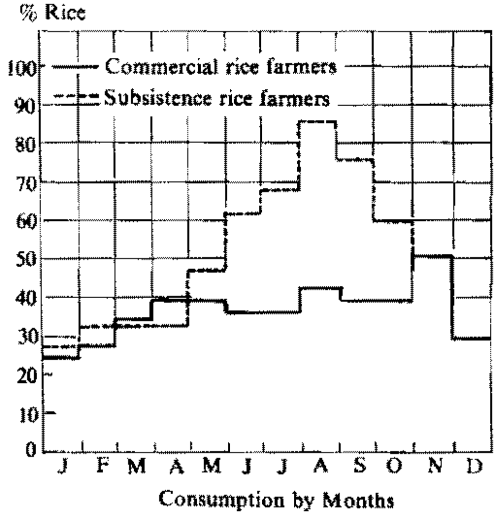


Figure 4. **Comparison of percentage of commercial farmers in the modern community and subsistence farmers in the traditional community who buy rice for family consumption during the year.**

This change to a cash-based economy is also polarizing the modern farmers from the traditional ones and the farm laborers. This is expressed in such visible items as television sets, radios, bicycles, improved housing quality and by less tangible factors as different work habits and different cosmopolitan levels.

These economic pressures are also creating a migration of less favored persons from the modern community. Preliminary analysis indicates that there are three contributing factors: (1)

mechanization of harvesting reduced the job availability for landless farmers; (2) rice distribution was reduced for landless farmers who work for wage labor on modern farms; and, (3) landowning farmers lost their credit ratings through mismanagement.

However, it appears that due to improved economic welfare, greater rice yields in the modern community is producing social changes. The average family size increased slightly as did the size of the extended household. Over the last ten years, the birth rate rose as compared with the control group, while age and sex ratios between the modern and traditional families did not differ. Desired family size of the modern farmers was also bigger. Although changes in family size were not statistically significant, these changes were directly attributed to higher yields producing higher net incomes and improved family nutrition.

Increased rice production with improved varieties and associated technologies have also produced a reversal of the economic decision-making role in the modern farmer's family. In the traditional community, the woman is the principal decision-maker as she is responsible for the family garden which is an important subsistence base. However, as the economic situation becomes more lucrative due to improved rice yields, the father who is responsible for rice cultivation assumes a more important decision-making role.

When traditional and modern farmers were asked their opinion of their future vocational expectations of their children, 30 percent of the traditional farmers wanted their children to be farmers while only 8 percent in the modern community wanted their children to continue that profession. In view of the higher profitability of farming for the modern farmers, this surprisingly low desire for their children to be farmers was interpreted as a change in perception of farming from a way of life to a means of investment. This was accompanied by the expressed desire to move to the cities. Apparently, improved yields and net profitability of improved rice cultivation is viewed as a stepping stone for social mobility.


Swine unit
1977/CIAT

Swine Unit

In 1977 the CIAT Swine Unit conducted the second Postgraduate Course in Swine Production. Sixty percent of the course was practical work assigned on swine farms in the Cauca Valley of Colombia. Twenty-five professionals from 10 Latin American countries attended the course.

The Swine Unit, through its collaborative programs with national institutions in Bolivia, Colombia, Costa Rica, Ecuador and Peru, continued to adapt swine production technology at the regional level. Nutritional studies on the use of locally available feedstuffs for swine feeding programs were also conducted as part of the cooperative projects.

Thirty-five former CIAT trainees from 12 Latin American countries participated in a workshop at CIAT to analyze the problems and future of swine production in the region, especially in those countries where the Center cooperates in projects. Workshop participants also discussed the organization of an international network for swine production.

At CIAT, experiments were done using high levels of rice polishings in diets for the gestation and lactation periods. Results showed that rice polishings are feasible as the main energy ingredient in all periods of the swine life cycle. Research on methionine supplementation in diets based on cassava meal suggested that the addition of this amino acid is not essential.

The pilot plant for producing microbial protein from cassava at CIAT continued functioning with the 200-liter fermentor. Studies indicated that the pH of the fermentation medium is an important factor for satisfactory results. The microbial biomass being produced had a fairly stable crude protein content (33-35%) in the final sun-dried product.

International Cooperation

TRAINING

Postgraduate Course in Swine Production

Twenty-five professionals from institutions which carry out swine production, training and research activities in 10 Latin American countries were selected to participate in an intensive (six weeks) course taught by specialists from state and private Colombian institutions and staff of the Swine Unit at CIAT.

Approximately 40 percent of the time was devoted to theory and the remainder to

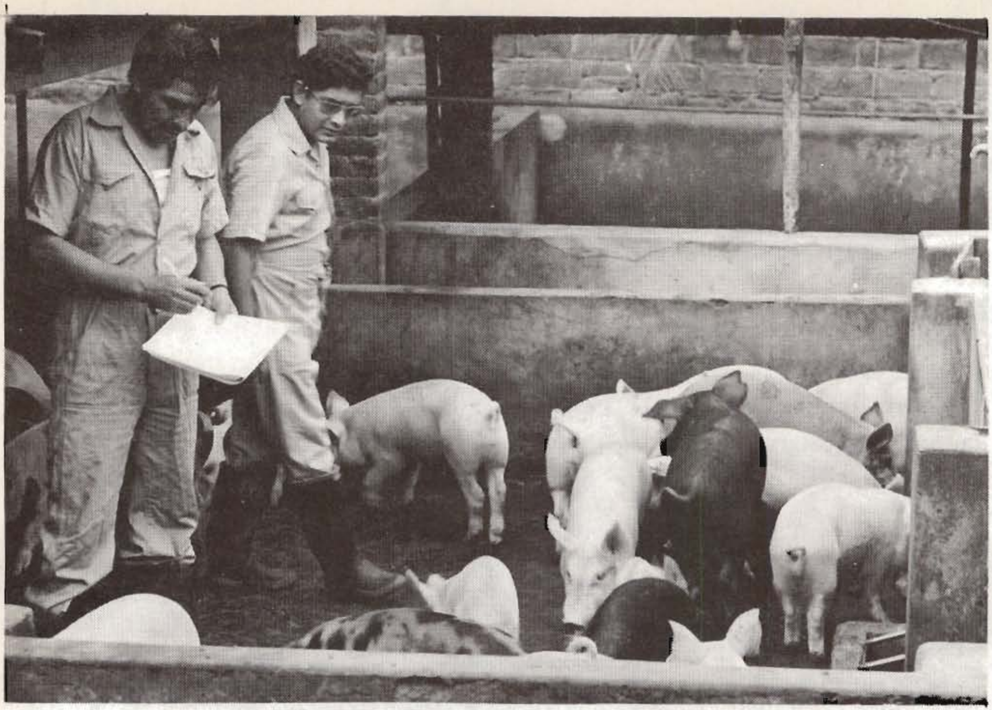


Figure 1. Trainees in the Postgraduate Course in Swine Production conducted practical activities on commercial farms in the Cauca Valley of Colombia.

practical work at the CIAT Swine Unit and at commercial farms in the Cauca Valley. The trainees worked on eight pig farms to evaluate the principal production problems and introduce some technical changes. They also visited state and private institutions involved with several aspects of swine production, such as manufacturing of composite rations or veterinary products, pig marketing and pork processing facilities. Trainees also toured a group of pig farms in part of the western region of Colombia to analyze the swine production potential of the region.

Other Training

Individualized training was also provided in the Swine Unit. Two trainees each from Bolivia and Peru who participated in the formal course received an additional month of training at CIAT in order to help plan future activities between their institutions and those formally collaborating with CIAT in these countries. One Colombian trainee spent a month at CIAT studying the genetic parameters of the Swine Unit's breeding herd, in collaboration with the CIAT Biometrics Unit. Two professionals from Thailand received special six-month training in utilizing cassava for swine feeding programs.

ASSISTANCE TO NATIONAL PROGRAMS

Bolivia

The Swine Unit of the Universidad Gabriel Rene Moreno/Heifer/CIAT Cooperative Project now has a breeding herd of 150 sows (Duroc, Hampshire and Yorkshire breeds). Selected animals of these improved breeds are being used for foundation herds of regional swine promotion programs. As part of the strategy of the cooperative project at the Swine Unit at Santa Cruz, training courses for small-scale farmers were taught using part of the educational material produced at CIAT. The physical facilities are also used for a postgraduate internship through an arrangement with the Veterinary and Animal Science Faculty of the Universidad Gabriel Rene Moreno. This internship will provide recent graduates with practical experience for their thesis projects.

CIAT's Swine Unit provided technical assistance in evaluating available local products useful as feed sources for pigs. The effect of increasing levels of a yeast *(Saccharomyces cerevisiae)* protein (levabol) locally produced from sugar cane molasses was studied as a protein source in diets for growing pigs. Chemical analyses of the final dried product showed a crude protein content of 35-45 percent. Initial results of the feeding trial (Table 1) showed that when yeast protein is used at levels of 7.5, 15 and 20 percent in maize- and sorghum-based diets, it could partially or completely replace conventional protein sources (soybean or cottonseed meal). Growth performance, expressed as weight gain and feed conversion efficiency, was similar for all three levels of yeast protein used. The preliminary results are being confirmed in further experiments during the growing-finishing periods and throughout the reproductive periods.

Table 1. Growing performance of pigs[1] receiving various levels of levabol[2] as a protein source.

Parameters	Values		
Protein sources	Diet 1	Diet 2	Diet 3
Soybean meal (%)	8	5	-
Cottonseed meal (%)	7.5	-	-
Levabol (%)	7.5	15	20
Performance factors			
Daily gain (kg)	0.77	0.80	0.79
Daily feed consumption (kg)	2.63	3.06	2.60
Consumption/gain	3.42	3.27	3.29

1 Eighteen pigs with initial weight of 28 kilograms and final weight of 64 kilograms.
2 Yeast *Saccharomyces cerevisiae*.

During 1977 the Swine Promotion Program in Chuquisaca completed construction of three swine units, each with a foundation herd of 120 Duroc and Hampshire sows and six boars. The Program has also provided credit for medium- and small-scale swine producers for maize cultivation and to buy breeding stock as part of the agreement between the Bolivian government and the Inter-American Development Bank (BID) to develop 150 swine farms in the region. CIAT provided technical assistance and training for three professionals who are to conduct the Program.

Colombia

Ten small-scale pig farmers at La Victoria (Cauca Valley) were selected for a group financing project through the Caja de Credito Agrario. Each farmer bought a group of 15 weaned pigs which was managed throughout the growing-finishing period. CIAT, collaborating with the Instituto Colombiano Agropecuario (ICA), provided the technical assistance for training the farmers, planned and evaluated their projects and conducted field days.

The growing-finishing diets utilized local feedstuffs such as sorghum, sugar cane molasses, soybean meal and cottonseed meal. Due to the easy availability and low cost of molasses in this sugar cane growing area, high levels (30% molasses diluted with water) were fed *ad libitum* separately from a controlled supply of a diet based on sorghum (75%), cottonseed meal (18%) and soybean meal (7%). Each pig consumed approximately 30 percent of its total feed intake (110 of 320 kilograms) as sugar cane molasses, producing economical daily gains above 500 grams (Table 2).

Table 2. **Average results of individual swine performances in a family swine unit.**[1]

Parameter	Values/pig
Initial weight (kg)	32.0
Final weight (kg)	90.5
No. of days	108
Feed consumption:	
Molasses (kg)	110
Concentrate (kg)[2]	211
Costs (Col. pesos)[3]	3850.00
Sales value (Col. pesos)	4500.00

[1] Each farmer received a group of 15 pigs during each cycle.
[2] Concentrate contained sorghum (75%), cottonseed meal (18%) and soybean meal (7%).
[3] Includes costs for feed, labor, electricity, water, drugs, interest and depreciation.

Costa Rica

Although construction for the Swine Unit of the Universidad de Costa Rica/CIAT project has not been finished, the University rented a swine farm to house the imported Yorkshire breeding stock and to initiate training and extension activities.

A swine development project for the banana producing area of Guapiles was initiated by an agreement of the Ministerio de Agricultura y Ganadería with the Asociación Nacional de Bananeros and the Banco Central de Costa Rica. CIAT's Swine Unit provides technical assistance to this project through the Ministry's swine specialists previously trained at CIAT.

Ecuador

Contacts were re-established between the CIAT Swine Unit and the Swine Program of the Instituto de Investigaciones Agropecuarias (INIAP) in Ecuador.

Green waste bananas were used as raw material to prepare a banana meal commercially marketed in Ecuador as a substitute for conventional energy sources in swine feeding programs. The nutritive quality of the banana meal has been evaluated through the different periods of the swine life cycle.

Experimental results suggested that up to 42 percent of banana meal can be included in the diets of growing-finishing pigs and lactating sows; for gestating sows up to 64 percent can be included. At these dietary levels, banana meal would substitute approximately 50 percent of the cereal grains in swine feeding programs.

Technical assistance has been provided by the CIAT Swine Unit to the INIAP Swine Program through regular visits and planning of future activities. Emphasis on local training and applied research has been given to encourage the development of swine production in the coastal western region of Ecuador where crops such as banana, rice and sugar cane predominate and wastes or by-products from these crops would be available for swine feed. Validation of technology on the practical level is being started at the banana producing area of the Provincia El Oro.

Peru

The Swine Unit of the Instituto Veterinario de Investigaciones Tropicales y de la Altura (IVITA) at the principal Tropical Experiment Station in Pucallpa obtained preliminary data on the technical and economical feasibility of swine production in the jungle region of Peru. Observations were made on the adaptation of an improved breed (Yorkshire) brought from the coast to the Peruvian tropics. Performance during three consecutive reproductive cycles (Table 3) indicated that under adequate nutritional and management practices satisfactory results were obtained with a Yorkshire herd of 20 sows in the tropical environment of Pucallpa. Housing facilities were constructed using local materials and pigs are managed in

Table 3. Performance of Yorkshire sows introduced in the Peruvian tropics.[1]

Parameter	Value[2]
Farrowing data	
No. of pigs/litter	11.4
Weight per pig (kg)	1.2
Weaning data (56 days)	
No. of pigs/litter	9.5
Weight per pig (kg)	16.5
Mortality during lactation (%)	17.0

1. Experiments were done at the Tropical Experiment Station of the Instituto Veterinario de Investigaciones Tropicales y de la Altura (IVITA), Pucallpa.
2. Average values for a herd of 20 sows during three lactation periods.

partial confinement. These practical conditions could be easily adapted by local farmers interested in developing swine production in this region.

Complementary nutritional studies were done on locally available feed products such as fresh cassava roots and rice polishings for growing-finishing pigs. The CIAT Swine Unit and IVITA also provided technical assistance to the integrated program of the Sociedad Agricola de Interes Social (SAIS) Tupac Amaru 1 for the development of swine production in its colonization project at Pucallpa. In addition, IVITA's Swine Program sells breeding stock to farmers interested in improving their stock and provides technical assistance in collaboration with the Ministerio de Alimentación. Currently, the IVITA-CIAT Swine Project is visiting a group of small-scale pig farmers in Masisea, on the banks of the Ucayali River, three hours by boat from Pucallpa.

Other Countries

In addition to the above collaborative projects, the CIAT Swine Unit has maintained contact with other Latin American institutions where swine production could be developed in the future. Most of the support has been through training professionals who would form core groups of swine specialists for national programs.

During 1977, the Swine Unit did a survey for the swine promotion project of the Ministerio de Agricultura y Ganadería/United States Agency for International Development (AID) Mission in Paraguay. The project is based on utilizing crops — notably cassava, maize and soybeans — produced on small farmes in swine feeding programs, which could help stabilize prices of these products at the small-farm level. Former CIAT trainees working at the Ministerio de Agricultura y Ganadería have conducted practical demonstrations for the farmers on different aspects of swine production, especially management, feeding and animal health.

WORKSHOP ON SWINE PRODUCTION IN LATIN AMERICA

Thirty-five former trainees of the CIAT Swine Unit now working with national institutions gathered at CIAT for a Workshop on Swine Production, in October. The countries represented and participants from each were: Bolivia (6); Brazil (1); Colombia (6); Costa Rica (1); Ecuador (5); Guatemala (1); Honduras (2); Mexico (3); Nicaragua (3); Panama (2); Paraguay (4); and Peru (1).

Objectives of the workshop were: (1) to review the situation of national and regional programs for development of swine production, with special emphasis on collaborative projects established by the CIAT Swine Unit; (2) to sharpen the focus on the factors limiting expansion of swine production and plan strategies for their solution; and, (3) to establish an international cooperative swine production network.

The following were identified as some of the common features of swine production in Latin America, notably in the countries where CIAT has established collaborative projects.

- Swine production is traditionally operated as a secondary livestock enterprise lacking government support, and it is not considered as part of integrated agricultural development projects.

- The extensive, small type of production using native pigs is widespread although improved breeds are being accepted rapidly.

- Swine productivity is low under most conditions and practically no extension service is available to small- and medium-scale farmers. The number of professionals and technicians trained in swine production is very limited.

- The most important constraints for swine production development are limited availability of conventional feedstuffs, deficient health programs, inadequate marketing systems, limited pork processing facilities and restricted financial support.

The conclusions and recommendations of the workshop were summarized in the following proposals.

- To undertake technical, economic and marketing feasibility studies for the integration of agricultural development and swine production as a special component. These studies should lead to establishing regional programs within a given country.

- To support swine development programs for small- and medium-scale farmers, but with an entrepreneurial focus. Associative or cooperative projects for small farmers dedicated to swine production are advisable.

- To intensify and increase extension services for transferring swine technology, notably at the small producer level. Integration of research or experimental work with extension services is required.

- To search for the means of improving the technological level of swine development and to reduce production costs, especially through the displacement of conventional feedstuffs and the maximum use of agro-industrial by-products and nonconventional feedstuffs.

- To integrate Latin American swine producing regions and to form a network to avoid duplication of efforts and to permit the more efficient transfer of technology to these areas.

Research

ENERGY FEEDSTUFFS

The feasibility of replacing cereal grains with agro-industrial by-products such as rice polishings or sugar cane molasses has been studied for diets of growing-finishing pigs (CIAT Annual Report, 1975 and 1976). However, because little information is available on the use of these by-products during the reproductive period of the swine life cycle, experiments were undertaken to study this possibility.

Rice Polishings

Partial or total substitution of cereal grains (maize and sorghum) by rice polishings was tested in diets for the gestation and lactation periods of the sow as well as for baby pig feeding. Levels of 85.3 and 60 percent of rice polishings were used for total and partial substitution, respectively; the control diet was based on common maize (78%). Experimental diets were balanced with soybean meal to provide 16 percent crude protein. The gestation and lactation diets for each experimental group were the same, varying only in quantity and form of supply during the two periods. During gestation, each sow was individually fed 2 kg/day of the diet; during lactation, diets were supplied

Table 4. **Evaluation of rice polishings in swine diets during the gestation and lactation periods.**

Parameters	Diet		
	Maize + soybean meal	Rice polishings (85%) +soybean meal	Rice polishings + maize + soybean meal
No. of sows	5	7	5
Farrowing data			
No. of pigs/litter	8.4	9.0	10.0
Weight per pig (kg)	1.11	1.26	1.24
Weaning data (56 days)			
No. of pigs/litter	7.2	7.7	9.0
Weight per pig (kg)	15.27	14.85	15.29
Litter weight (kg)	110.20	113.25	136.45

ad libitum in an automatic feeder. The diets for suckling pigs contained 18 percent protein and were supplied *ad libitum* from the tenth day after birth through weaning (56 days). Pigs in litters from sows fed diets with 85.3 or 60 percent rice polishings received the same starter diet based on 50 percent rice polishings, whereas the litters from sows on the control diet were fed a diet based on 60 percent maize. In all cases, soybean meal was used as the protein ingredient.

The results in Table 4 indicate that total or partial substitution of cereal grains by rice polishings produced similar litter performance as the control diet at farrowing and weaning. The intake of experimental diets and of the basic ingredients is presented in Table 5. Total diet consumption was similar for all experimental groups. Therefore, total substitution of

Table 5. **Consumption of diets based on rice polishings during the gestation and lactation periods of swine.**

Parameters	Diet and consumption (kg)		
	Maize + soybean meal	Rice polishings (85%) + soybean meal	Rice polishings (60%) + maize + soybean meal
Diet consumed/sow (kg)			
Gestation (115 days)[1]	230.0	230.0	230.0
Lactation (56 days)	290.3	279.6	295.4
Diet consumed/litter (kg)			
Starter diet for pigs	47.5	50.9	63.9
Total basic ingredients consumed (kg)			
Maize	434.4	7.7	128.9
Rice polishings	-	460.2	347.2
Soybean meal	102.2	61.5	79.4

Each sow received two kilograms of diet daily, and fed individually.

cereal grains by rice polishings is feasible without adversely affecting reproductive performance.

Cassava Products

Because of cassava's potential as an animal feed more detailed experimental information was obtained during 1977. Previous experimental evidence from using cassava meal or flour in feeding programs throughout the life cycle of the pig indicated that slightly inferior reproductive performance was obtained with the cassava meal-based diets as compared to the control diet (CIAT Annual Report, 1974). It was suggested that the lack of supplementary methionine could be responsible. Methionine supplemented in swine diets based on cassava has been recommended, not only to improve protein quality of the diets (particularly when plant protein sources are used), but also to provide a labile source of sulfur for detoxifying cyanide in the cassava.

The effect of DL-methionine supplementation (0.2%) to dietary combinations of cassava meal combined with various protein sources was studied in an experiment with growing pigs. Levels of 62-68 percent cassava meal were combined with either soybean meal, cottonseed meal or with a mixture of cottonseed and fish meals. Experimental diets supplied 16 and 13 percent crude protein for the growing and finishing periods, respectively. A control diet based on common maize and soybean meal and supplemented with DL-methionine (0.2%) was used.

Table 6 presents the experimental results. Body weight gains of pigs fed the cassava meal/soybean meal diets were similar to gains from the control diet; the combination of cassava meal with cottonseed meal produced the lowest body gains. Methionine supplementation did not improve the results with either soybean or cottonseed meal. The protein combination of cottonseed meal with fish meal improved the pigs' performance. The results suggest that supplementary

Table 6. Effect of supplementing methionine in swine diets based on cassava flour and combined with different protein sources and fed during growing and finishing periods (18-95 kilograms).

Diets	No. of pigs	Days on trial	Avg. daily Gain (kg)	Avg. daily Consumption (kg)	Final weight[1]	Feed/Gain
Maize + soybean meal + methionine	10	112	.70	2.17	96.1	3.10
Cassava flour +						
Soybean meal	9	112	.70	2.41	95.5	3.47
Soybean meal + methionine (0.2%)	10	112	.70	2.49	95.6	3.59
Cottonseed meal	9	133	.58	2.43	95.0	3.98
Cottonseed meal + methionine (0.2%)	9	133	.56	2.21	92.7	3.94
Cottonseed meal + fish flour	9	119	.66	2.26	95.5	3.44

1 Average initial individual weight in each group was 17.6 kilograms.

methionine is not essential in diets based on cassava meal and plant protein sources (soybean or cottonseed meal) for growing-finishing pigs. Further studies are required to determine the relationships between the quality of the supplementary protein and the addition of specific amino acids.

Experimental results (CIAT Annual Report, 1974) have indicated that feeding programs based on cassava meal produced a reproductive performance inferior to the control feeding program based on common maize. It was suggested that the lack of supplementary methionine could be at least partially responsible for these results. An experiment was undertaken to study the effect of methionine supplementation (0.3%) to cassava meal/soybean meal diets during the gestation and lactation periods. Reproductive performance did not improve by adding methionine and was similar to that of the control diet (Table 7).

Experimental evidence obtained from different periods of the life cycle of the pig suggests that methionine supplementation does not seem to be indispensable for swine feeding programs based on high levels of cassava meal. Because of the limited quantity of protein supplied by cassava, nearly all the dietary protein is supplied, and the quality of the protein determined, by the protein ingredient(s).

PRODUCTION OF MICROBIAL PROTEIN

Additional experimental information for producing microbial protein was obtained with the 200-liter fermentor installed at CIAT. Most of the studies have continued with the asporogenous mutant *Aspergillus fumigatus* I-21A. However, another mutant of the I-21 parent culture, designated ON-5, that is unable to grow at temperatures below 40°C, was isolated at the University of Guelph (Canada). The use of these mutants, along with the safety precautions normally taken, might well be considered as a sufficient safeguard during practical operation.

One problem encountered in producing microbial protein was the large quantity of soluble carbohydrates left at the end of the

Table 7 **Effect of supplementing methionine in swine diets based on cassava flour and fed during gestation and lactation periods.**

	Control	Cassava flour + soybean meal	
Parameter	Maize + Soybean meal	Without methionine	With methionine (0.3%)
Number of sows	14	10	10
Farrowing data			
No. of pigs/litter	8.5	9.1	9.4
Pig weight (kg)	1.09	1.06	1.07
Weaning data (56 days)			
No. of pigs/litter	7.1	8.2	8.0
Pig weight (kg)	16.74	16.15	16.54
Total litter weight (kg)	117.02	128.50	131.95

fermentation. This resulted in limited fungal growth and lower concentrations of protein than expected. Average data for the changes in carbohydrate concentration and product yield throughout 20-hour fermentation periods using either fresh rasped cassava roots (10 fermentations) or cassava meal (7 fermentations) as the substrates are shown in Figure 2. At the end of the fermentation period a large proportion of the original carbohydrates remained; the final concentrations of total carbohydrates were, on the average, 41.4 and 48.2 percent of the initial values for cassava mash- and cassava meal-based media, respectively. Data from laboratory scale fermentations at Guelph indicated nearly complete use of total carbohydrates by *A. fumigatus* I-21A when finely ground cassava was used. Figure 3 shows the crude protein yield for both substrates

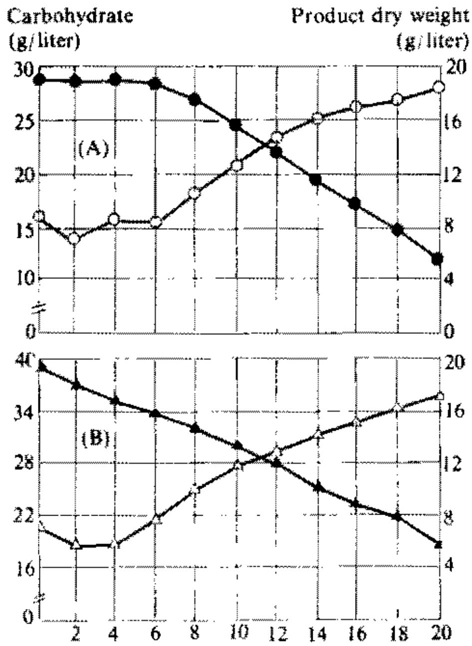


Figure 2. Changes in dry product yield (o, △) and carbohydrate concentrations (●,▲) during the fermentation of fresh cassava mash (A) and cassava meal (B) based-media by *A. fumigatus* I-21A.

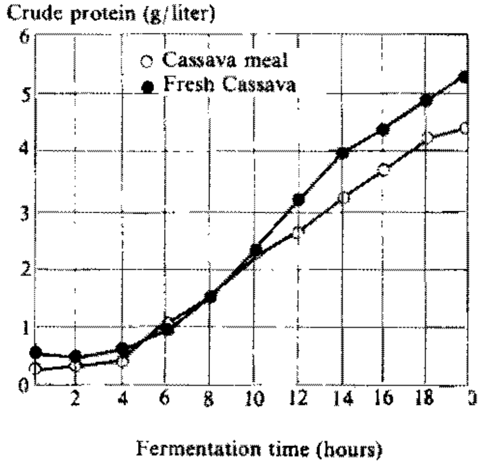


Figure 3. Changes in protein concentration during the fermentation of fresh cassava (●) and cassava meal (o) by *A. fumigatus* I-21A.

throughout the fermentation period. No major differences were observed during the first half of the fermentation period; during the second half, however, the values obtained with the cassava meal medium were lower than those observed with the fresh cassava mash. The differences found during the fermentation period are reflected in the protein content of the final biomass (Table 8). The results with the fresh cassava mash were slightly better than those previously published (CIAT Annual Report, 1976). The dry biomass yield as a percentage of the dry matter before fermentation (fermentation efficiency) was 49.7 percent in the wet mash and 44 percent in the meal treatment. The fermentation efficiency varied considerably between batches as can be seen by the magnitude of the standard deviations.

Since the protein yields reported at the pilot plant level were not as high as expected from previous experimental work at the laboratory scale, a study was done to determine the factors responsible. First, the mineral nutrients required by the fungus and added to the medium were individually varied in several fermentation

Table 8. **Fungal (*Aspergillus fumigatus* I-21A) protein production in a 200 liter fermentor using fresh roots or cassava meal as substrates (4% concentration of carbohydrates).**

Parameter	Values
Fresh Cassava Roots[1]	
Amount of cassava mash (kg)	25.51 ± 0.81
Amount of sun-dried biomass obtained (kg)	4.43 ± 0.62
Product yield (g/liter)	22.15 ± 3.08
Yield: weight of dried biomass in relation to	
Fresh cassava (%)	17.38 ± 2.42
Cassava, dry matter basis (%)	49.67 ± 6.97
Crude protein content in dried biomass (%)	29.60 ± 0.41
Cassava Meal[2]	
Amount of cassava meal (kg)	10.98 ± 0.62
Amount of sun-dried biomass obtained (kg)	4.33 ± 1.10
Product yield (g/liter)	21.65 ± 5.50
Yield: weight of dried biomass in relation to	
Amount of cassava meal (%)	39.61 ± 10.56
Cassava meal, dry matter basis (%)	44.00 ± 11.72
Crude protein content in dried biomass	26.70 ± 0.91

[1] Mean of ten fermentations ± standard deviation.

[2] Mean of seven fermentations ± standard deviation.

runs. Increased concentrations of the nitrogen source (urea) and mineral salts required did not improve yields. The mineral elements contributed by the cassava roots were determined analytically. The average cassava variety was found to supply adequate amounts of all mineral elements required except sulfur and possible zinc; the addition of zinc, however, was not found necessary.

A temperature of 45°-47°C and a pH of 3.5 are selective conditions for growth of *A. fumigatus* in the medium. Variations in these conditions were also studied throughout the fermentation period. The temperature remained constant during the process. Figure 4 shows the changes in pH when fresh cassava mash was suspended in tap water and a sulfuric acid solution was added throughout the fermentation period to maintain a pH of 3.5. This was compared with variations found when no acid solution was added to a similar medium and with those obtained for a medium using deionized water instead of tap water. With tap water the pH increased rapidly to fairly high levels, even though sulfuric acid was added every three hours. This might be due to the quality of the tap water which contains high concentrations of carbonates and bicarbonates.

The pH remained quite stable when deionized water was used and very little additional acid was required. Therefore, the quality of water used to suspend the substrate and the other ingredients may have some effect on the growth of the microorganism. The values for crude protein and true protein in the sun-dried biomass samples from I-21A and ON-5 respectively, are shown in Table 9. Proximate analyses of dry biomass samples of *A. fumigatus* I-21A and ON-5 grown in different media varied slightly in crude protein. Ether extract, crude fiber and ash contents were rather similiar for all the

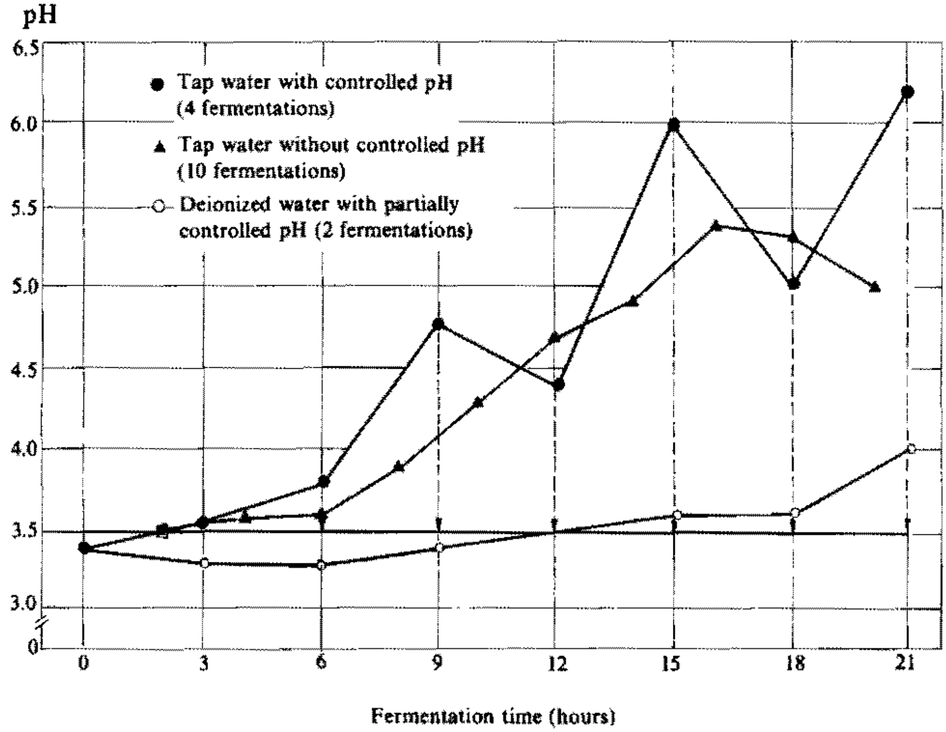


Figure 4. Change in pH during the fermentation of wole cassava media (in tap and deionized water) by *Aspergillus fumigatus* I-21A, with and without the addition of 9N sulfuric acid

Table 9. **Crude and true protein contents obtained from growth of *Aspergillus fumigatus* mutants I-21A and ON-5 on cassava-based culture media.**

Medium	No. of fermentations	Crude Protein (%)	True Protein (%)	TP/CP x 100
Mutant I-21A				
Fresh cassava, tap water				
without pH control	6	30.9	24.2	78
controlled pH	4	33.0	24.8	75
Fresh cassava, deionized water				
without pH control	3	31.1	24.8	80
Cassava meal, tap water				
without pH control	6	27.2	19.1[f]	70
Mutant ON-5				
Fresh cassava, tap water				
without pH control	3	27.6	20.7	75
Cassava meal, tap water				
without pH control	15	28.8	20.8	72

Table 10. **Comparison of the protein quality of casein, soybean meal and unsupplemented and methionine-supplemented fungal biomass grown on a cassava medium and fed to rats.[1].**

Parameter[2]	Total feed intake (g)	Total weight gain (g)	Feed/gain	Adjusted Protein Efficiency Ratio[3]
Control: casein	302.6a	78.2ab	3.9c	2.5a
Soybean meal	308.8a	68.2c	4.5c	2.2b
Biomass produced on:				
Fresh cassava				
Without methionine	195.6b	24.2d	8.5a	1.2
+ 0.3% methionine	296.0a	74.8bc	4.0c	2.5a
Cassava meal				
Without methionine	198.8b	29.7d	6.9b	1.5c
+ 0.3% methionine	323.7a	85.0a	3.8c	2.5a

1 Average results from 10 male rats per group; 28-day experimental period; avg initial wt 41.2 + 2.1 g.

2 Values followed by a common letter are not significantly different (P 0.05) according to Duncan's multiple range test.

3 Values adjusted to the standard value of 2.5 for casein.

fermentations and averaged 4.3, 19.2 and 4.4 percent, respectively.

Feeding Trials

Results of feeding trials with growing rats to ascertain the protein quality of dried fungal biomass from fermentations with either fresh roots or cassava meal substrates are shown in Table 10. The effect of methionine supplementation was studied in particular. Total weight gains over a 28-day period were very low for rats fed the unsupplemented biomass-based diets. Methionine supplementation significantly improved the quality of the fungal protein and produced weight gains similar to those obtained with casein and significantly better than those for the soybean meal-based diet (supplemented with 0.3 percent methionine). Rats fed the dry biomass-based diets, without methionine supplementation, consumed less feed than those fed methionine-supplemented diets. Rats fed the methionine-supplemented, fungal protein-based diet had protein efficiency rations (PER) similar to those of the control group receiving casein.

The results obtained from the production of this microbial protein are very encouraging and the process is on the way to being standardized with the 200-liter fermentator. A few fermentations per-fermentor. A few fermentations performed late in 1977 showed a significant improvement in the final crude protein content of the dried biomass with values ranging from 33 to 35 percent. The objective now is to begin operating the 3000-liter fermentor to produce enough material for nutritional and practical evaluations with swine.

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Associated Research Units

Genetic Resources Unit

Improved germplasm is the basic commodity of the international agricultural research centers upon which more productive farming systems will be established. The Genetic Resources Unit has the responsibility of assembling, maintaining, evaluating and distributing germplasm to support CIAT's crop development programs in *Phaseolus* beans, cassava and forage legumes and grasses. The Center's germplasm collection now has over 13,500 accessions of beans, 2400 of cassava and 3400 of forages (notably *Stylosanthes, Centrosema, Desmodium, Macroptilium* and *Andropogon).*

PHYSICAL FACILITIES

During 1977 adaptation of existing physical facilities to house the Unit was given priority and the areas mentioned below were virtually completed. The three cold storage rooms described in Table 1 are the core of the Genetic Resources Unit. Other facilities include four laboratories — for seed cleaning, for classifying and

Table 1. Storage capability of Genetic Resources Unit.

Room	Dimensions/volume	Temperature	Type of seeds	No. of bags/size	Total capacity (ton)
Short-term					
5	5.6 x 9.2 m/180m³	+ 10°C	General	64,000/200-g[1]	12.8(18)[2]
Long-term					
6A	2.0 x 5.6 m/40m³	- 15°C	Beans	16,000/200-g	3.2(4.5)
6B	2.4 x 4.0 m/33m³	0°C	Forages, Cassava (Beans)	25,000/50-g	2.5(3.5)
Total long-term	73m³			41,000	5.7(8.0)

1 Actually less since larger bags are stored during the short term.
2 Values in parentheses are capacities if 3.5-m storage racks are used instead of present 2.5-m racks.

testing seed for germination and viability, for drying and packaging seed, and, for meristem tissue culturing. Work areas are also available for field-related operations such as seed threshing, sorting and weighing. Another room is assigned to the Unit's germplasm record-keeping system. In late 1978, a computer terminal will be installed and linked to the new CIAT IBM System 34 computer to provide on-line inventory of materials, information retrieval and statistical analyses. The Unit also has office space for principal and support staff, and a small herbarium with botanical specimens of forage legumes and grasses.

SEED STORAGE

Biochemical studies this year indicated that seed dehumidification prior to long-term storage is easily and relatively quickly accomplished by drying at room temperature over silica gel. By this simple technique an initial moisture content of 23.5 percent for *Phaseolus* seed (a typical value for freshly harvested seed) was reduced to 8.0 percent in four days. Drying to that mosture content did not affect later germination. When red beans (variety Constanza) were reduced to 2.7 percent moisture after eight weeks of drying, germination was 100 percent in standard tests. However, time for complete germination was delayed, compared to that for freshly harvested seed. The ten days of germination time recommended by the International Seed Testing Association was needed to insure accurate results.

A seed packaging method for storage and distribution was developed. Dried seeds are sealed in laminated packs (of plastic/aluminum foil/paper) to provide a very durable package impervious to moisture and oxygen. The containers are easily opened to obtain samples and resealed with a simple, kitchen-type heat sealer. Packages can be sub-divided as needed; for example, 50-gram portions may be opened and used, leaving the remainder of the seed sample untouched.

Two 100-gram stocks of *Phaseolus* beans (approximately 400-1000 seeds), 50-gram, or smaller, stocks of smaller seeded forage grasses and legumes, and probably much smaller stocks of cassava seed will be maintained. Under the excellent storage conditions available in the Unit, it is expected that only about 5 percent (1000-1500 lines) of the total germplasm collection will need to be grown out in any year.

ACTIVITIES WITH PHASEOLUS GERMPLASM

In mid-1977 the Genetic Resources Unit assumed the work with the *Phaseolus* germplasm collection which was previously done in the Bean Program.

Seed Classification and Increase

During the year CIAT received 1500 new accessions of *Phaseolus* germplasm bringing the total accessions of this genus to 13,500. Major groups of accessions came from France (National Institute for Agronomic Research at Versailles), the Netherlands (Institute for Horticultural Plant Breeding at Wageningen), Peru (Agricultural Experiment Station at La Molina) and the United Kingdom (University of Cambridge). To date, 12,729 accessions have been identified and their seed increased for more complete evaluation and distribution. *Phaseolus vulgaris* accessions total 12,000; *P. lunatus*, 290; *P. coccineus*, 350; and, *P. acutifolium*, 50. In addition, 50 samples of non-cultivated *Phaseolus* species have been identified.

Evaluation of Phaseolus vulgaris

Last year CIAT's Bean Program produced a catalog describing 52 plant morphological features for 781 promising accessions of *P. vulgaris*. This year another 4000 accessions were evaluated for 32 morpho-agronomic characters, including most of the 20 descriptors recommended by the Phaseolus Germplasm Advisory Committee. In addition to those 4000 materials, another 4500 have been partially evaluated, seed of 2500 accessions were increased during the year and 1000 accessions were identified.

Distribution of Phaseolus Germplasm

The Genetic Resources Unit is a clearing house for the distribution of germplasm to national programs in Latin America and to other institutions, with the collaboration of the respective CIAT commodity programs. Since most materials requested are CIAT's own breeding stocks, germplasm requests are passed through program plant breeders.

This year, 2000 samples were distributed to national programs, especially in Brazil, El Salvador and Guatemala, and to institutions in France, New Zealand and Taiwan. In addition, the Unit provided 3500 germplasm samples, mostly *P. vulgaris*, to the Bean Program. In 1978, similar services will be provided for forage germplasm, and later, for cassava germplasm.

OTHER ACTIVITIES

During the year the Genetic Resources Unit began work on the following continuing research and development activities.

Data Management Systems

Just as important as the germplasm itself is the information which describes it. Most seed requests are based on definite seed, plant and location characters. For example, bean seed may be requested having black color, adaptation to 1200-m altitude and 1000-mm rainfall regimes, and resistance to certain diseases. The germplasm data bank descriptors can identify the desired accessions, after which staff will mail a mini-catalogue with the seed that lists all descriptors or information available for that seed.

Previously, the computer information retrieval system has been used for only a small portion of the bean germplasm holdings. In 1977, two computer files were established to expand stoarge, up-dating and retrieval of germplasm information. The first file is a seed inventory with information on seed storage dates and seed lot origin for every accession now maintained. The second file is a Crop Specific Record with information from field evaluations for 32 descriptors. Expansion and up-dating of these files will continue in cooperation with the CIAT Biometrics Unit.

Cluster Analysis for Germplasm Characterization

Preliminary investigations were begun on a cluster analysis of field data from *P. vulgaris*. Each variable was weighted as a heritability estimate. Field evaluations were done with materials of growth habits, I, II and III planted at wide and narrow spacings at CIAT-Palmira and Popayan, Principal component factoring was used to reduce the variables in the cluster analysis. Complete results are not yet analyzed. A study of the interrelationships of 25 quantitative characters from the catalog of

781 promising entries indicated that four principal components or factors accounted for 75 percent of the total variability.

Meristem Tissue Culture

As an alternative to the expensive and labor-intensive field maintenance of cassava germplasm, meristem tisssue culture offers several advantages. First, germplasm can be maintained as small plantlets in test tubes, isolated from diseases and pests. Also, virus infection in germplasm can be eliminated, and promising genetic materials can be increased rapidly. In work done in Canada by CIAT cooperators, 90 percent of the meristem tips from cassava produced complete plants and 60 percent of the mature plants were free of mosaic virus symptoms. All plants regenerated from symptom-free cassava were healthy. In 1978, emphasis will be directed to developing a procedure for distributing cassava germplasm based on: (1) meristem tissue culture; (2) testing the material for presence of virus; and, (3) shipping virus-free cultures without the usual problems of plant quarantine. While initially applied to cassava, the technique will later be adapted for vegetatively propagated forage legumes.

Chemotaxonomy Based on Tissue Isozymes

During 1978, preliminary work with cassava and beans will begin in biochemical taxonomy, also known as chemotaxonomy. This relatively new field is of particular interest to germplasm work because plant enzymes (and certain products of their activity) are direct expressions of gene action. Thus, analysis of such factors as isomeric forms of leaf enzymes gives a pattern of the genetic constitution of the seed from which a plant was grown. Several biochemical characteristics of the seed and the plant itself will be measured, to better assess genetic diversity in the germplasm, and, in particular, to identify duplicate materials.

International Cooperation

In addition to the activities mentioned, the Genetic Resources Unit is working with other international germplasm units. The International Board for Plant Genetic Resources (IBPGR) assisted in establishing the CIAT Unit and continues to serve in an advisory role. Links are being established with germplasm banks at the International Institute for Tropical Agriculture (IITA), the International Rice Research Institute (IRRI) and the International Potato Center (CIP), and with national and regional programs including the National Center for Genetic Resources (CENARGEN), in Brazil, and the Tropical Agricultural Center for Research and Training (CATIE), in Costa Rica. The integration of CIAT's Genetic Resources Unit into an international network assures availability of germplasm for crop improvement programs throughout the world.

Special Studies Unit

The primary objective of the Special Studies Unit is to evaluate food production practices that may be useful for the large number of traditional farmers in CIAT's mandated region. Practices under evaluation are of the type which do not receive attention from the commodity programs of the Center.

During the year, evaluations were made using legume cover crops in planting associations with beans, maize and cassava. Zero-tillage technology was tested in plantings of beans and maize. Finally, several groups of germplasm furnished by other international agricultural research centers were evaluated for growth response under CIAT environmental conditions.

PERENNIAL COVER CROPS

Perennial Peanut/Maize Associations

Perennial peanut *(Arachis glabrata)*/maize (variety H-207) associations established in late 1976 were harvested in January 1977. The herbicides glyphosate, dalapon and atrazine were applied at the rates shown in Table 1, and in two patterns — 50-centimeter strips and as complete coverage. Immediately following application, the maize was planted. The object was to partially erradicate or set back the *Arachis* and weeds, reducing their competition with maize. Comparative treatments included hand weeding a 50-centimeter strip of *Arachis* and the vegetation-free control.

Applications of 1.5 kg. a.i./ha of glyphosate and 2 kg. a.i./ha of atrazine to the whole plot and hand-weeding of the whole plot provided the best growth and yields of maize. All other treatments apparently allowed excessive competition from the peanuts (Table 1.). About 20 percent less lodging occurred when maize was associated with *Arachis* compared with the clean-weeded plots. Although the *Arachis*/weed-free treatment averaged 443 kg/ha more maize than associations with the peanuts, under presumably quite favorable soil fertility conditions, recycled plant nutrients from the *Arachis* averaged 21.8-3.1-14.4 kg/ha of N-P-K, respectively. It should be possible to harvest the legume foliage (and its nutrients) at least twice during the active growing period of the maize.

A similar experiment was carried out in the same plots after the previous experiment to determine the effects of fertilizers and competition by the perennial peanut on maize growth and yields. Half the treatments included a complete fertilizer (15-15-15) at 200 kg/ha at the time of maize planting and 200 kg/ha of urea side-dressed when the maize was about 60

Table 1. **Yields and lodging of maize H-207 in association with perennial peanuts (*Arachis glabrata*) and the nutrient content of *Arachis* following different herbicide treatments[1].**

Herbicide	Herbicide treatments		Nutrients in *Arachis* (kg/ha)			Maize lodging (%)	Maize yield (kg/ha)
	Kg a.i./ha	Coverage	N	P	K		
Glyphosate	1.0	50-cm strip	24.6	2.6	16.1	40	3827
"	1.0	Complete	22.5	3.4	15.5	68	4647
"	1.5	50-cm strip	23.9	3.0	16.4	48	4462
"	1.5	Complete	22.1	3.4	15.2	18	6877
Atrazine	1.5	50-cm strip	20.1	3.7	12.6	49	3715
"	1.5	Complete	21.6	3.1	18.3	65	3873
"	2.0	50-cm strip	21.0	3.4	18.9	57	3940
"	2.0	Complete	21.0	2.4	18.0	36	5600
Dalapon	8.0	50-cm strip	21.3	2.4	18.0	42	4067
"	8.0	Complete	22.2	4.4	17.0	57	3062
Hand hoeing	-	50-cm strip	19.5	3.1	19.9	46	5112
Clean weeding	-	Complete	-	-	-	68	4914
Means			21.8	3.1	17.4	49	4508

1 Maize planted 16 Sept. 1976 and harvested 24 Jan. 1977 at CIAT-Palmira.

centimeters high. Herbicides used were 2 kg a.i./ha atrazine and 1.5 kg a.i./ha glyphosate, the two treatments most effective in the first experiment. Herbicides were again applied in 50-centimeter strips and over the whole plot.

Fertilizer application produced significantly higher yields than non-fertilized treatments with or without the cover crop. It appeared that previous crops of maize may have depleted the native soil fertility since overall yields were low and a small but non-significant yield response (414 kg maize/ha) to the *Arachis* cover crop was observed in the unfertilized treatment. However, *Arachis* depressed maize yields (by 727 kg/ha) when fertilizers were applied. Lodging was erratic and quite high (mean of 62.3%) from heavy winds and rain during the trial. Analysis of recycled nutrients in the *Arachis* was very similar to results from the first trial— 21.0-2.4-17.7 kg/ha of N-P-K.

Perennial Peanut/Cassava Associations

An experiment was planted to study the competitive effect of perennial peanuts on cassava. The treatments were 1.5 kg a.i./ha of glyphosate applied in one-meter bands in the peanuts after which cassava was planted. Comparisons included hand-weeding one-meter strips or one-meter diameter circles around the cassava plants (10,000 plants/ha density) and the *Arachis*/weed-free control. Although the cassava will not be harvested until 1978, the best growth has occurred in the *Arachis*/weed-free treatment, suggesting excessive competition from the perennial peanut.

Leucaena/Bean Associations

The forage legume *Leucaena leucocephala*, a shrubby tree native to tropical America, shows considerable potential as a nutrient recycling plant when

Table 2. **Yields and lodging of maize H-207 in association with perennial peanut *(Arachis glabrata)* and the nutrient content of *Arachis* following different herbicide treatments.**

Chemical	Herbicide treatment		Fertil-ization[2]	Nutrients recycled (kg/ha)			Maize Lodging (%)	Maize yield (kg/ha)
	Kg ai/ha	Coverage		N	P	K		
Atrazine	2.0	Complete	None	22.2	2.2	16.7	52.8	2417
"	2.0	Complete	Complete	20.4	2.5	16.7	60.6	3970
Glyphosate	1.5	Complete	None	24.3	2.1	17.5	53.2	3015
"	1.5	Complete	Complete	21.3	2.6	16.7	68.8	3147
Atrazine	2.0	Strip	None	20.0	2.3	16.5	69.9	2332
"	2.0	Strip	Complete	21.0	2.4	17.8	64.7	3514
Glyphosate	1.5	Strip	None	18.6	2.4	19.8	51.5	2763
"	1.5	Strip	Complete	19.9	2.4	18.9	73.1	3361
Hand hoeing	-	Strip	None	20.6	2.6	17.0	73.7	1796
"	-	Strip	Complete	21.2	2.5	19.5	72.6	3170
Clean-weeding	-	Complete	None	-	-	-	49.5	2534
"	-	Complete	Complete	-	-	-	58.1	4159
Mean:				21.0	2.4	17.7	62.3	3015

1 Maize planted 30 April 1977 and harvested 20 Sept. 1977 at CIAT-Palmira.

2 Fertilized with 200 kg/ha of 15-15-15 at planting; and 200 kg/ha of urea when maize is 60 centimeters high.

associated with annual food crops. Experiments were done last year to test this possibility (CIAT Annual Report, 1976); these were followed by a *Leucaena*/climbing bean association trial this year. Thirteen herbicides or combinations were applied as sprays to the lower trunks of *Leucaena* in attempts to kill the stand or temporarily set it back to minimize competition to the climbing beans. Basal spray applications of the herbicides were compared with mechanical ringing at a height of 50 centimeters, which would permit *Leucaena* to regrow from below the rings. Climbing beans were planted about two weeks after treatments.

A 2,4-D ester and picloram at 4 percent were much more effective than other treatments in killing the *Leucaena*, but their residual effects were long-lasting, completely inhibiting bean germination even after repeated replantings. Applications of 2 percent 2,4,5-T effectively killed the *Leucaena* but did not inhibit bean germination. In the bark-ringing treatment, regrowth of *Leucaena* did not appear to affect the early development of beans (not yet harvested).

Following bean harvest the dead trunks of *Leucaena* could be removed for fuel or construction, allowing new growth to develop. Although the more toxic herbicides prevented bean germination in most treatments, application by brush instead of spray should reduce soil contamination. Therefore, it might be possible to utilize *Leucaena* as an *in situ* green manure plant for maize, a support for climbing beans and as a source of protein for animal feed, since the leaves contained 27.4 percent protein.

ZERO-TILLAGE CROPPING

Zero- or reduced-tillage cropping systems often reduce the energy required to prepare the land, avoid soil compaction and reduce soil moisture and erosion losses. For the small farmer, a no-till approach represents a savings in hand labor normally required at planting time, which could allow him to plant larger areas and/or do a more timely job of weeding his crops once planted. Several non-selective, non-residual herbicides are available for this purpose and two were evaluated during a three-season trial at CIAT.

Glyphosate (0.75 and 1 kg/ha) and paraquat (0.5 kg/ha) were compared with hand clearing (with a machete) to prepare the land for planting. Half of each plot received a pre-emergence herbicide treatment after planting. Five cropping systems — continuous monoculture maize, monoculture beans, rotations of maize and beans and a maize/bean association — were evaluated. Crop yields and weed control evaluations were recorded each season.

Maize

Yields in the first season (Table 3) were the same whether or not a pre-emergence herbicide was applied, but yields greatly increased the following season when herbicides were applied or hand-weeding was done. This was not the case when maize was grown with beans, indicating that the beans could effectively replace the weeds in the association. The continuous production of maize did not reduce yields nor were there beneficial yield effects from rotating beans with maize.

Beans

Yields declined when beans were grown consecutively on the same land, and including maize in the rotation actually increased bean yields in the third season (Table 4). As with maize, the use of the pre-emergence herbicide did not increase yields the first season, but it did in the following seasons. This suggests that weeds became more serious with time and that more intensive weed control measures may be required after the first season of a zero-tillage system. Moreover, there was a tendency for the predominant weed species to increase as the trial progressed (Table 5). Yields of the climbing beans grown in association with maize were generally low and there were no yield differences between those treated with a pre-emergence herbicide and the non-treated plots.

Weed control observations showed that the order of effectiveness was glyphosate (2) glyphosate (1) paraquat hand-weeding. In general, weed control was better with a pre-emergence treatment, but the differences were not as great as those normally observed when traditional tillage methods are practiced. This probably reflects the fact that no new weed seeds are being brought to the surface and that the seedbed surface is not suitable for the seeds' germination. Pre-emergence treatments were less effective when applied after removing existing vegetation with a machete than when glyphosate or paraquat was applied prior to treatment.

Purple nutsedge *(Cyperus rotundus)* infestation was not reduced by any of the treatments and increased markedly in the plots cleared with the machete. More intensive use of glyphosate (i.e. immediately after harvest or two applications prior to planting) would be required to help control this species.

GERMPLASM EVALUATION

In January 1977, ICRISAT, ICTA and the AVRDC were invited to send their most promising new germplasm of various tropical food crops to be tried under CIAT conditions. Observation and yield trials of sorghum, pearl millet, soybeans, cowpeas, mung beans, pigeon peas and some miscellaneous tropical pulses were grown (Table 6).

Cowpeas, Mung beans, Soybeans

Several promising new materials were identified among these legumes. The six best copwpea lines from IITA averaged 3 t/ha of dry seeds at CIAT. Some of these,

Table 3. **Maize yields during zero-tillage cultivation with various weed control treatments and in different sequences and associations with beans, during three successive seasons (1976-77) at CIAT-Palmira.**

	Maize yields (t/ha) in various cropping systems																			
	Maize monoculture				Bush beans/Maize/Bush beans				Bush Maize/beans/Maize				Bush Bush beans/beans/Maize				Maize with Climbing beans			
Herbicide Season:	I	II	III	Means	I	II	III	Means	I	II	III	Means	I	II	III	Means	I	II	III	Means
With pre-emergence																				
Glyphosate (0.75 kg)	3.6	3.1	4.4	3.7	-	4.3	-	-	3.0	-	4.6	3.8	-	-	5.2	-	3.9	2.0	4.6	3.5
Glyphosate (1 kg)	4.5	3.5	5.1	4.3	-	4.2	-	-	4.4	-	4.5	4.4	-	-	5.8	-	2.9	2.5	4.2	3.21
Paraquat (0.5 kg)	6.3	5.0	4.7	5.3	-	3.6	-	-	4.5	-	4.6	4.5	-	-	4.9	-	2.7	1.5	3.5	2.6
Machete	6.0	4.7	3.5	4.7	-	3.6	-	-	6.1	-	2.4	4.2	-	-	2.3	-	3.2	2.1	2.6	2.6
Means	5.1	4.1	4.4	-	-	3.9	-	-	4.5	-	4.0	-	-	-	4.5	-	3.2	2.0	3.7	3.0
Without pre-emergence																				
Glyphosate (0.75 kg)	5.3	2.8	3.8	4.0	-	2.8	-	-	5.0	-	4.7	4.8	-	-	5.3	-	2.9	2.6	4.1	3.2
Glyphosate (1 kg)	4.4	3.4	4.2	4.0	-	3.4	-	-	5.8	-	3.3	4.5	-	-	5.5	-	2.1	2.9	4.5	3.2
Paraquat (0.5 kg)	5.8	3.6	2.2	3.9	-	2.7	-	-	5.3	-	4.2	4.7	-	-	5.5	-	2.3	1.3	3.4	2.3
Machete	5.8	2.0	2.8	3.5	-	0.4	-	-	5.5	-	2.0	3.7	-	-	2.1	-	4.4	3.2	2.7	3.4
Means	5.3	2.9	3.2	-	-	2.3	-	-	5.4	-	3.5	-	-	-	4.6	-	2.9	2.5	3.7	3.0

Table 4. **Bean yields during zero-tillage cultivation with various weed control treatment and in different sequences and associations with maize, during three succesive seasons (1976-77), at CIAT Palmira.**

	Bean yields (t/ha) in various cropping systems																			
	Bush beans monoculture				Bush beans/Maize/Bush beans				Maize/Bush beans/Maize				Bush beans/Bush beans/Maize				Climbing beans with Maize			
Herbicide Season:	I	II	III	Means	I	II	III	Means	I	II	III	Means	I	II	III	Means	I	II	III	Means
With pre-emergence																				
Glyphosate (0.75 kg)	1.5	1.0	0.5	1.0	1.3	-	1.1	1.2	-	1.3	-	-	1.4	1.1	-	1.2	0.4	0.3	0.4	0.4
Glyphosate (1 kg)	1.6	1.3	0.7	1.2	1.6	-	0.6	1.1	-	1.4	-	-	1.4	1.1	-	1.2	0.7	0.2	0.6	0.5
Paraquat (0.5 kg)	1.5	1.4	0.7	1.2	1.6	-	0.9	1.2		1.4	-	-	1.5	1.1	-	1.3	0.4	0.3	0.3	0.3
Machete	1.4	1.1	0.7	1.1	1.4	-	1.1	1.2	-	1.5	-	-	1.2	1.0	-	1.1	0.4	0.4	0.3	0.4
Means	1.5	1.2	0.6	-	1.5	-	0.9	-	-	1.4	-	-	1.4	1.1	-	-	0.5	0.3	0.4	-
Without pre-emergence																				
Glyphosate (0.75 kg)	1.3	0.9	0.3	0.8	1.4	-	0.6	1.0	-	1.2	-	-	1.2	0.8	-	1.0	0.5	0.4	0.3	0.4
Glyphosate (1 kg)	1.5	1.2	0.4	1.0	1.3	-	0.2	0.7	-	1.3	-	-	1.6	0.9	-	1.2	0.9	0.3	0.5	0.6
Paraquat (0.5 kg)	1.4	0.5	0.4	0.8	1.2	-	0.5	0.8	-	1.0	-	-	1.4	0.6	-	1.0	0.6	0.2	0.4	0.4
Machete									-	0.9	-	-	1.6	0.2	-	0.9	0.4	0.2	0.3	0.3
Means	1.4	0.7	0.3	-	1.3	-	0.4	-	-	1.0	-	-	1.4	0.6	-	-	0.6	0.3	0.4	-

Table 5. **Predominant weeds in maize and beans 30 days after planting in each season at CIAT-Palmira, 1976-77.**

1st season	2nd season	3rd season
Portulaca oleracea	*Euphorbia* spp	*Euphorbia* spp.
Leptochloa filiformis	*Sida* spp.	*Digitaria sanguinalis*
Ipomoea spp.	*Leptocloa filiformis*	*Leptochloa filiformis*
	Portulaca oleracea	*Portulaca oleracea*
	Amaranthus dubius	*Ipomoea* spp.
		Cenchrus echinatus

like TVu-201-ID (VITA-1) and TVX 1193-059D combined high yield with large seed size (15.1 - 18.1 g/100 seeds); but TVX 66 -2H and TVX 1836 - 9E had better quality, cream- or light-colored seeds. Somewhat lower yields were obtained from mung beans and soybeans (both from AVRDC), and, although mung beans have been handed over to the Instituto Colombiano Agropecuario (ICA), the three best

Table 6. **Grain yields and other agronomic characteristics of some promising lines of three grain legumes and pearl millet tested at CIAT in 1977.**

Crop	Pedigree	Duration*	Seed color	100-Seed wt. (g)	Yield (t/ha)
Cowpea	TVu-354-1B	86-116	Ashy gray	10.8	3.4
	TVu-201-D	90-126	Dark red	18.1	3.0
	TVX-30-1G	88-110	Dark creamy	12.3	2.9
	TVX-66-2H	88-110	Dark creamy	11.1	2.7
	TVX-1193-059D	87-117	Bright red	15.1	3.2
	TVX-1836-9E	88-118	White	11.5	2.7
Mung bean	1380 Mg50-10A	78-99	Bright green	6.7	2.3
	2184 PHLV-18	80-99	Bright green	6.6	2.2
	1414 CES-14	78-99	Bright green	7.2	2.2
	2010 M-314	80-99	Dull green	7.0	2.3
Soybean	30096-1-9	94	Yellow	5.7	2.8
	30292-8-6	97	Yellow	5.3	2.3
	30035-2-13	94	Yellow	5.1	2.3
Pearl millet	Syn 7602	86	Ashy gray	-	1.3
	Syn 7601	88	Ashy gray	-	1.2
	ICH 13	88	Pearly gray	-	1.2
	ICH 105	83	Pearly gray	-	1.1
	Syn 7603	86	Pearly gray	-	0.9[2]

[1] Days to first and last harvest.

[2] Dwarf strain - 85 cm tall.

lines are being observed and increased at CIAT.

Sorghum and Millet

About 50 lines of sorghums and 20 millets from ICRISAT were evaluated during 1977. General growth of the millets was satisfactory but yields were somewhat disappointing under CIAT-Palmira conditions. This is at least partly attributable to bird damage in the small, isolated planting; but better conditions may occur in Colombia's North Coast region. In the case of sorghum, seeds and stands were not sufficient to obtain yield estimates. However, preliminary observations were made on general performance, disease incidence and seed qualities. Ten of the best sorghums combining good seed quality, standability and yield potential were harvested to obtain sufficient seeds for replicated yield testing in 1978.

Hemo- Ectoparasite Unit

The Hemo- and Ectoparasite Unit of CIAT is a special project in collaboration with the Institute of Tropical and Veterinary Medicine of Texas A&M University (USA). The overall objective of the unit is to assist in increasing cattle production in the American lowland tropics through the development of strategies for controlling hemoparasitic diseases.

Special attention is given to the diseases anaplasmosis (caused by *Anaplasma marginale)* and babesiosis (caused by *Babesia argentina* and *B. bigemina)* and to the tick vectors of these and other diseases. Specific activities are directed to developing (1) diagnostic methodologies; (2) efficient and economic control measures for the diseases and their vectors; and, (3) means for transferring these technologies to veterinarians through training and outreach programs.

HEMOPARASITIC DISEASES

Diagnostic Methodologies

Modification of the IFA test to detect anaplasmosis. The indirect fluorescent antibody test (IFA), developed previously by the Unit to detect *B. argentina* and *B. bigemina* (CIAT Annual Report, 1975), was adapted and tested this year for detecting *A. marginale* antibodies in the blood. Results of the comparisons between the modified IFA test and the complement fixation (CF) and card tests (CT) are in Table 1. The IFA test was significantly more sensitive (for detecting positive reactors) than either the CF or CT methods but was significantly less specific (for detecting negative reactors) than the other two tests.

A linear regression analysis performed on the average IFA and CF titers done over a 20-week period with 10 artificially infected calves inoculated with *A. marginale* showed significant regression coefficients for both tests. The regression CF titers dropped below the sensitivity threshold at 14 weeks after inoculation, while the regression line for the IFA titers was still above the sensitivity threshold 20 weeks post-inoculation, the last period tested (Fig. 1). The CT also detected antibodies until the end of the observation period.

Microtechnique for Complement Fixation Test

A technique using microquantities of serum reagents and antigens was developed and tested successfully. It provides a sensitive, reliable test while greatly reducing the amount of materials utilized, compared with the tube method.

Table 1. **Comparative sensitivities and specificities of the Indirect Fluorescent Antibody (IFA), Complement Fixation (CF) and Card Test (CT) in 130 serum samples each.**

Test reactions	Diagnosis			Percentage of	
	Positives	Negatives	Total	Sensitivity	Specificity
IFA	80	5		97[1]	90[1]
Positives	80	5	85		
Negatives	2	43	45		
Total	82	48	130		
CT				84[1]	98[1]
Positives	69	1	70		
Negatives	13	47	60		
Total	83	48	130		
CF				79[1]	100[1]
Positives	65	0	65		
Negatives	17	48	65		
Total	82	48	130		

[1] Significant difference between tests (P 0.05).

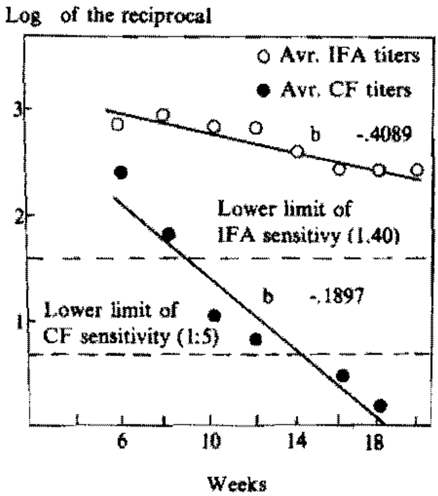

Figure 3. **Linear regression analysis of mean serum titers of Indirect Fluorescent Antibody (IFA) and Complement Fixation (CF) tests in 10 calves artificially infected with *Anaplasma marginale*.**

The total volume of reagents used per test is reduced 20-fold (from 0.5 cc to 0.025cc of each). Besides the savings in materials, the time required to process large numbers of sera is reduced by about one-third.

Serological Testing of Serum Samples

During the year more than 20,000 tests each were completed using the CF and fluorescent antibody tests. Samples were obtained from experimental work of the Unit and from other sources throughout Latin America who requested technical assistance in diagnosing hemoparasitic diseases.

EPIZOOTIOLOGY

Studies continued in order to understand more about the epidemiology of

bovine anaplasmosis and babesiosis under endemic situations such as is present in the Cauca River Valley of Colombia.

For this purpose the prevalence of anaplasmosis and babesiosis was investigated in 12 representative herds of the area. Farms selected for analysis were (a) dairy herds, (b) mixed herds (dairy and beef), and (c) beef herds.

Prevalences differed according to herd type. The prevalences by respective herd types for each of the hemoparasites investigated *(A. marginale, B. bigemina* and *B. argentina)¿* are shown in Table 2. Significant differences were found between herd types for each hemoparasite. These data indicated that within a hemoparasitic endemic area, the variations of the prevalences are more probably related to management factors than to environmental factors. The largest contributing factor to the low prevalence rates found in some of the farms was excessive tick control. Within an endemic area excessive tick control could contribute to creating an unstable epidemiological situation.

One of the 12 farms was selected to determine the incidence of anaplasmosis and babesiosis. Farm owners usually treat all animals that come down with or are suspected of having a hemoparasitic infection when they notice the first symptoms of the disease. Most of the animals recover with the exact cause of infection never known.

This study was initiated in April, 1976 on a dairy farm (Farm II), where immunization trials against anaplasmosis and babesiosis are in progress. Vacutainers with and without anticoagulants were provided with a questionnaire. The farm owner and his manager were asked to always take blood samples before treating any animals suspected to have diseases. The blood samples were kept under refrigeration until picked up. At the laboratory, PCV and thick and thin blood smears stained by Giemsa were made from the samples with anticoagulant. The sera were kept frozen at -20°C for CF and IFA analysis.

Table 2. **Prevalence of anaplasmosis and babesiosis on cattle farms in the Cauca Valley of Colombia.**

Species	Herd type	Age of animals: 6 Months (%)	6-12 Months (%)	1-2 Years (%)	2 Years (%)	Total farms (%)
A. marginale	Dairy	7.3	23.2	48.3	61.0	45.0*
	Mixed	8.9	75.8	92.1	88.4	73.0*
	Beef	45.0	79.0	100.0	96.5	88.1*
B. bigemina	Dairy	7.3	26.8	47.8	63.6	46.6
	Mixed	11.1	56.5	76.3	81.4	61.5
	Beef	70.0	89.5	96.2	88.4	87.4
B. argentina	Dairy	7.6	12.1	21.0	35.8	26.0*
	Mixed	4.4	50.0	93.4	83.7	65.4*
	Beef	25.0	63.2	46.2	44.2	44.4*

During the period from April 1976 to November 1977, 45 blood samples were obtained. Forty samples (89%) were confirmed as hemoparasitic infections with 27 cases (67%) diagnosed as anaplasmosis and 13 (33%) diagnosed as babesiosis. Of 13 clinical cases of babesiosis, 10 were diagnosed as *B. argentina* and 3 as *B. bigemina*. The incidence by management group within the herd is presented in Table 3.

SYSTEMS FOR CONTROLLING HEMOPARASITIC DISEASES

Cauca Valley Project

This immunization program against anaplasmosis and babesiosis used the minimum infective doses procedure. The work continued on eight representative commercial dairy and beef herds located in different areas of the Cauca Valley.

As of November 1977, 20 trials involving more than 400 animals had been initiated, and one-half were finished during the year. Partial results of the program are summarized in Table 4.

The incidence of natural clinical infection of anaplasmosis and babesiosis varies between farms according to the individual epidemiological situation. Farm I had the highest incidence (100%) of both diseases in control animals. Farm III had variable incidences of anaplasmosis (43 to 80%) and babesiosis (0 to 30%) in control animals, while in other farms, for example Farm IV, incidences of anaplasmosis and babesiosis in control animals were very low because most of the animals have not yet been naturally exposed to the diseases. This type of herd has an epidemiological situation known as "endemic unstable", that is, although the farm is in an area suitable for vector development (ticks) the animals do not have the chance of getting the infection due to excessive vector control.

The total incidences of anaplasmosis and babesiosis in the eight herds under study presented significant differences between vaccinated and nonvaccinated animals. Incidences of anaplasmosis and babesiosis was 2 percent in vaccinated animals and 61 and 26 percent respectively in non-vaccinated animals.

Table 3. Incidence of confirmed clinical cases of anaplasmosis and babesiosis by management groups on Farm II (April 1976-Nov. 1977).

Management group	Avg. No. of animals	Anaplasmosis No. of Cases	Anaplasmosis Incidence (%)	Babesiosis No. of Cases	Babesiosis Incidence (%)
Unweaned calves	9	3	33	0	-
Weaned calves	14	10	71	1	7.1
Open heifers	40	3	7.5	7	17.5
Pregnant heifers	40	8	20	4	10
Dry cows	32	0	-	0	-
Cows in production	92	2	2.2	1	1.1
Bulls	3	1	33	0	-
Total	230	27	11.7	13	5.7

Table 4. **Field evaluation of immunization against anaplasmosis and babesiosis using the minimum infective dose procedure.**

No. of trial	No. of vaccinated animals	No. of control animals	Incidence based on confirmed natural clinical infection: Anaplasmosis				Babesiosis			
			Vaccinated		Controls		Vaccinated		Controls	
1[1]	11	9	0/8	8%	8/8	100%	0/8	0%	8/8	100%
2[1]	12	7	0/12	8%	7/7	100	4/12	33%	7/7	100%
1	12	12	1/12	8%	9/11	82%	0/12	0%	3/6	50%
2	12	12	0/12	0%	2/7	30%	0/12	0%	/	15%
3	10	10	0/12	0%	4/9	45%	0/9	0%	0/2	0%
4	10	10	0/10	0%	2/6	33%	0/7	0%	0/1	0%
5	10	10	0/10	0%	0/3	0%	0/10	0%	0/2	0%
1[1]	7	7	1/7	14%	5/7	70%	0/7	0%	0/7	0%
2[1]	12	12	0/12	0%	5/12	42%	0/12	0%	2/12	16%
3[1]	10	10	1/10	10%	8/10	80%	0/10	0%	3/10	30%
4[1]	0	14	-	-	5/14	43%	-	-	2/14	15%
1	7	7	0/7	0%	0/1	0%	0/7	0%	3/3	100%
2	8	8	0/8	0%	0/0	0%	0/8	0%	1/2	50%
3	8	8	0/8	0%	0/0	0%	0/8	0%	0/0	0%
1[1]	11	11	0/11	0%	8/11	73%	0/11	0%	3/8	38%
2[1]	15	15	0/15	0%	3/5	60%	0/15	0%	0/12	0%
1	8	8	0/8	0%	0/1	0%	0/8	0%	0/5	0%
1[1]	12	0	0/12	0%	-	-	0/12	0%	-	-
20	203	198	4/197	2%[2]	81/133	61%	4/196	2%[2]	33/129	26%

[1] Completed trial.

[2] Significant difference (P 0.01) as compared with control group.

Summaries of results of Trials 1 and 2 from Farm I, where the immunization program was completed, are presented in Tables 5 and 6. All control animals in both groups required specific treatment against anaplasmosis and babesiosis to prevent death. Two vaccinated animals of Trial I were treated against anaplasmosis because they did not become infected from vaccination.

Results of weight gain differences between vaccinated and non-vaccinated animals in the two trials in Farm I were very significant. In trial 1 the difference between the two groups at the end of the challenge period was 28 kgs/animal. In trial 2 the difference was 32 kgs/animal. Both differences were in favor of vaccinated animals. It is very important to note that if control animals had not been

Table 5. **Response to vaccination and natural field challenge in vaccinated and control animals, Farm I, Trial 1.**

Parameters	Response to vaccination			Response to challenge		
	Vaccinated	Control	Significance	Vaccinated	Control	Significance
Duration of period (weeks)	12			18		
Number of animals	11	9	—	8	8	—
No. of animals clinically affected with babesiosis/ Total animals exposed	1/11	0/0	—	0/8	8/8	—
No. of animals clinically affected with anaplasmosis/ Total animals exposed	0/6	0/0	—	2/8	8/8	—
No. of treatments given against babesiosis/ Total animals exposed	5/11	0/0	—	0/8	8/8	—
No. of treatments given against anaplasmosis/ Total animals exposed	0/6	0/0	—	4/8	20/8	—
Average lowest PCV (%)	23	30	P 0.01	24	15	P 0.01
Average highest temperature (°C)	40.5	40.9	NS	40.2	41.2	P 0.05
Average weight at end of the period (kgs.)	195	213	NS	230	220	NS
Total weight gain (kgs)/ animal at end of the period	16.7	20	NS	35.4	7.2	P 0.05

treated, deaths due to anaplasmosis and babesiosis would probably have been very significant.

Mono- and bivalent vaccine systems against bovine babesiosis

Forty highly susceptible yearling cattle were used in this project. Three groups of 10 each were immunized against anaplasmosis and then immunized with either *B. argentina* or *B. bigemina* or both together using the minimum infective dose procedure. After immunization, the animals were subjected to field challenge with *B. microplus* ticks on a farm in the Cauca Valley. After four weeks of field exposure best protection under endemic conditions for anaplasmosis and babesiosis was obtained using the bivalent vaccine (with both *Babesis* spp.). However, some cross-protection using the monovalent vaccines was observed. Further research is planned to establish a

Table 6. **Response to vaccination and natural field challenge in vaccinated and control animals. Farm 1, Trial 2.**

Parameters	Response to vaccination			Response to challenge		
	Vaccinated	Control	Significance	Vaccinated	Control	Significance
Duration of periods (weeks)	10			12		
Number of animals	12	7	-	12	7	
No. of animals clinically affected with babesiosis/ Total animals exposed	0/12	0/0	—	3/12	7/7	
No. of animals clinically affected with anaplasmosis/ Total animals exposed	0/12	0/0	—	0/12	7/7	
No. of treatments given against babesiosis/ Total animals exposed	12/12	0/0	—	0/12	14/7	
No. of treatments given against anaplasmosis/ Total animals exposed0/12	0/12	0/0		0/12	14/7	
Average lowest PCV (%) due to *Babesia* infection	23.6	33.0	P 0.01	27.0	17.0	P 0.01
Average lowest PCV (%) due to *Anaplasma* infection	24.0	33.4	P 0.01	26.5	16.8	P 0.01
Average weight at end of the period (kgs).184	148	183	NS	222	189	P 0.05
Total weight gain (kgs)/ animal at end of the period	16.3	16.6	NS	38	6	P 0.05

practical level of cross protection using a monovalent vaccine against bovine babesiosis.

ACAROLOGY

Research continued with grasses antagnostic to ticks and with the dynamics of eliminating or maintaining field tick populations at low levels. To determine larval tick compatibility with six promising grass species, *(Cynodon dactylon, Brachiaria decumbens, Melinis minutiflora, Pennisetum clandestinum, Hyparrhenia rufa* and *Andropogon gayanus)* were established in separate plots. The grasses were then syringe-infested with 40,000 7-14 day-old *Boophilus microplus* larvae per plot. Daily measurements were taken at 0830, 1330 and 1630 of temperature, relative humidity, wind velocity and cloud cover. On days 14, 21, 29, 34, 39, 44 and 49, after infection, a flannel cloth was dragged across the plots to sample tick populations and activity.

On day 14 post-infection, *A. gayanus* and *M. minutiflora* had the lowest mean number of ticks, demonstrating high initial anti-tick properties. *M. minutiflora* also showed the highest tick deterrent properties, in which tick collection was severely reduced with no reinfestation. *B. decumbens* and *H. rufa* showed high initial infestations at day 14 but later reduction and then reinfestation with ticks over time. *A. gayanus*, however, showed low initial infestation and maintained consistently low tick populations over time.

It appears that *M. minutiflora* severely reduced tick populations so that, theoretically, cattle would not be constantly reinfected by ticks and would become extremely susceptible to tick-vectored diseases in case of accidental reinfestation. Due to the strong tick deterrent properties of this grass it would be suitable for a marginal tick zone where accidental tick infestation would be less likely to occur.

A. gayanus appears to have a low initial infestation and maintains a low tick population over time. This grass is promising for endemic tick zones where low, economically tolerable tick populations must be maintained to insure field challenge.

B. decumbens and *H. rufa* have very high initial infestations and appear to maintain unacceptably high tick populations over long periods of time Therefore, if cattle were placed on these pastures, it is possible that the tick populations would be too high. *P. clandestinum* and *C. dactylon* may have some anti-tick properties. Their initial infestation was higher than *M. minutiflora* but lower than *B. decumbens* or *H. rufa*. In addition, ticks were picked up on days 34-44 on both grasses after being absent for a number of days. This may indicate an ability to maintain a lengthy, low field tick population.

Although the build-up of the tick population would eventually require spraying or dipping of cattle it is estimated that this could be done two to four times per year compared to the 12-21 day interval now needed.

Research Support Units

Biometrics Unit

The Biometrics Unit provides assistance in the planning, design, analysis and interpretation of experiments done by the research programs and units of CIAT. During the year the Unit has played an increasing role in designing and maintaining information retrieval systems for different scientific and service units of the Center. In addition, it also participated in cooperative research projects with other programs and provided training in statistics and data processing, both through conferences and individual instruction. Training was conducted both for CIAT scientific staff and for trainees from institutions within CIAT's region of responsibility.

Cooperation with Research Programs

BEAN PROGRAM

International Bean Yield and Adaptation Nursery (IBYAN)

During 1977, 33 experiments were processed for this nursery. Because of the nursery's continuous nature, a processing and analysis methodology was developed, giving special emphasis to preliminary screening of the incoming data. In spite of the instructions for collecting information, different patterns were detected, e.g., plot areas different than planned, different unit systems, etc. After processing, each experiment had available: a general information table, a table of descriptive statistics of the most important variables, a table of averages of the five highest yielding promising cultivars provided by CIAT and the best five local varieties, and a table of rainfall data and maximum and minimum temperatures for three growth intervals: planting- flowering, flowering-harvesting and the total period of planting-harvesting.

One main problem in the comparative analysis of varieties common to the experiments of the nursery in 1976 was the difference in plant density at harvest. Although a density of 150 plants/6m^2 usable plot area was recommended, several trials were reported with actual densities very different from that one. First, it must be decided if it is necessary to correct the measured yield for density at harvest. Statisticians differ on this point. Some think that this correction must be made since certain seeds do not germinate or some plants die; this variation in the number of plants harvested contributes to the "experimental" error which affects the yield estimates of the different varieties. On the contrary, other statisticians believe no correction should be made since variations in plant densities may represent real varietal effects. This reasoning is legitimate if an increase in the precision of comparisons, was desired, but not if the purpose is to correct the observed yields so that yield comparisons be made at the planned level of plant density.

Due to this divergence of opinions, statistics are presented for both the observed yield and the corrected yield using a model of analysis of covariance, where the final degree of adjustment is determined by the level of significance of the quadratic and linear models. Another adjustment alternative — not reported in the tables, but potentially useful — was used in the first trials reported. This adjustment method is based on estimating a correction factor (F_c) as a function of the quotient K = (number of plants observed/plot) ÷ (number of plants planned/plot) which would allow to express the corrected yield as the product of the observed yield and the correction factor.

Finally, a preliminary analysis was made on the adaptability of the 20 common varieties, using the information of 23 localities with complete yield data. This analysis used the technique proposed by Eberhart and Russell.[1] The analysis and interpretation of the interaction variety x locality using pattern analysis techniques is being considered for the future.[2]

1 Eberhart, S.A. and Russell, W.A. Stability parameters for Comparing Varieties. Crop Science Vol. 4, pp 4, pp 36-r0. x966.

2 Bith, D.E., Shorter, R. Eisemann, R.L. and De Lacy, I.H. Two-way pattern analysis results for yield to evaluate cultivar adaptation and environmental differences. Department of Agriculture, University of Queensland, Brisbane, Australia, 1977.

Bean Breeding Information System (SIFFRI)

SIFFRI continued to provide support to various disciplines in the Bean Program, in two main areas: (a) information recovery, and, (b) statistical analysis of information.

In the present stage of SIFFRI's development, cooperation between the group developing the system and bean researchers has strengthened. Thus, SIFFRI has made important contributions to:

(a) planning of crosses;

(b) producing reports with information pertinent to each cross; to accompany seed sent to national bean breeding and evaluation programs;

(c) supporting the Genetic Resources Unit through the basic recording of the Bean Germplasm Bank, which reached 8261 accessions this year.

(d) producing field books for the Bean Program disciplines, and,

(e) timely and efficient processing of information requests from national bean programs in different countries.

Of the basic requirements initially proposed for SIFFRI (CIAT Annual Report, 1975 and 1976 Biometrics Sections), the majority have been met and the system is now in its optimization stage. SIFFRI is now able to:

(a) recover data on all crosses and selections from a parent;

(b) determine parents, crosses and selections corresponding to one or more selection criteria;

(c) reconstruct the pedigree of a cross or selection;

(d) provide periodic reports on missing data;

(e) perform statistical analyses of information produced by the system; and,

(f) integrate all the system's information.

With relation to (f) above and through the cooperative work of the different disciplines, the need to broaden the system's data base has become evident. SIFFRI now has information on experimental yields for 40 trials done in various localitites. Furthermore, it contains evaluations of diseases affecting the promising varieties, throughout localities and semesters.

In 1978 it is expected that information will be included on the existence and viability of seed in storage at CIAT, which will allow a stock control.

The principal support (70%) to the handling and statistical analysis of the SIFFRI information is the (Statistical Analysis System (SAS), version 76.5; the remainder is through programs developed in the Biometrics Unit.

Presently SIFFRI's data base contains the germplasm bank files, the crosses file, the promising accessions file containing all their characteristics, the file of disease reactions of the promising varieties in various localities and semesters, and other files created to meet specific needs of those using the system. The selections file will be added to the system when information on advanced selections is completed.

The handling of information on first generation crosses was completed satisfactorily with field cards identified with labels produced by the system

In the future, efforts will be directed toward further integrating the SIFFRI group with investigators of the various disciplines, to acquire a dynamic knowledge of the needs of bean researchers.

Evaluation of Hexagonal Ring Design

During 1977 an experiment was carried out with 47 pure lines of *Phaseolus vulgaris* to compare the Randomized Complete Block Design (RCBD) with the Hexagonal Ring Design (HRD)[3] at two distances between plants — 1.15 and 0.70 meters. The correlation coefficients of yields in the RCBD and the yields observed in the HRD were 0.36* (for 1.15 meters) and 0.48** (for 0.70 meter). In hopes of eliminating the effects of soil heterogeneity, the observed yields are expressed as a percentage of the surrounding plant hexagon or as a percentage of the control triangle. In the same way, it is possible to adjust the observed yields using as the covariable, the yield of the surrounding hexagon or the yield of the control triangle. Table 1 shows the yield correlation coefficients in RCBD and the yields for each one of the adjustments just mentioned.

[3] Fasoulas, A. 1973. A new approach to breeding superior yielding varieties. Thessaloniki Aristotelian Univ. Dept. Gen. Pl. Breeding. Publ. 3: 42 pp.

Table 1. **Correlation coefficients between average yields of 47 bean varieties in Randomized Complete Block Design (RCBD) and adjusted and non-adjusted yields in a Hexagon Ring Design (HRD).**

	Distance between plants	
Type of adjustment in HRD	1.15 meter	0.70 meter
None	0.36*	0.48**
Percentage of the control triangle	0.36*	0.43**
Percentage of the surrounding hexagon	0.40*	0.47**
Covariance in the control triangle	0.37**	0.48**
Covariance in the surrounding hexagon	0.37**	0.48**

* 0.01 < P ≤ p.05

** P ≤ 0.01

Correlation coefficients did not increase greatly when the varieties were grouped according to their growth habit. Furthermore, the weighted correlation coefficients between HRD replications were 0.31** (1.15 meter) and 0.46** (0.70 meter), while the average correlation coefficient between replicated pairs of the RCBD was 0.86**. Therefore, results suggest that for the yield selection of early generations of *P. vulgaris*, under our conditions, the HRD is not an efficient alternative to using a RCBD, with a similar number of plants.

However, results of a preliminary study on the increase in the precision of yield comparisons of bean and cassava varieties, adjusting the response in one plot by the response in neighboring plots[4], suggested a marked superiority of this procedure over an analysis such as would be obtained from the RCBD, but the comparisons with the lattice analysis were not conclusive[5].

Efficiency and Precision of Lattice Designs Under Different Number of Repetitions and Plot Size in Bean Yield Trials

This year a study comparing the efficiency and precision of the lattice design (5 x 5) with the RCBD was completed. Data for the study came from the results of IBYAN trials. Used as an efficiency measure was the relative efficiency concept (RE) of a design; as a precision method, the coefficient of variation (C.V.); and as a measure of sensitivity, the least significant difference (L.S.D.)which is expected to be detected at a given significance level.

Table 2 shows some of the results of this study. From data in this table it is possible to find which combinations of plot size and number of repetitions are appropriate for pre-fixed levels of C.V. and L.S.D. For the IBYAN program it was estimated that the L.S.D. is 400 kg/ha, the C.V. is 15 percent and an experimental area per trial of less than 1800m². The combinations of plot size and number of replications that satisfy these needs are shown in Table 3.

Border Effects in Bean Yield Trials

The competition effect between experimental plots known as border effect is an important factor. This effect shows up in a change in the growth and yield pattern of plants close to the perimeter of the plot compared to those located in the central part. To eliminate this effect, it is common to leave a non-experimental margin of a pre-determined magnitude.

For some time, the Biometrics Unit, in cooperation with the Bean Program, has conducted studies on border effect in yield trial plots. Results from these trials are briefly described below.

Growth Habits II and III. This trial was conducted in 1976 in CIAT. It included 25 black varieties of growth habits II and III in a balanced lattice design (5x5) with plots 12 m² in total area, and having six four-meter rows. Harvesting was by rows, leaving 0.5-meter borders at the heads to provide a cultivated area per plot of nine m². Results obtained suggested that, for bean varieties of similar growth habit, there is a highly significant effect of head borders over the yield of the experimental plot. While the average yields of plots with four and six rows without harvesting head borders were 2515.8 and 2524.1 kg/ha, respectively, yields in plots with harvested borders were 2.890.2 and 2867.3 kg/ha. However, while there was a head border effect, it was consistent throughout the 25 varieties tested.

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4 Pearce, S.C. and Moore, C.S., "Reduction of Experimental Error in Perennial Crops, Using Adjustment by Neighbouring Plots", Experimental Agriculture, Vol. 12, pp 267-272, 1976.

5 Mendoza, G. "Dos Aplicaciones Prácticas del Modelo Estadístico Lineal", CIAT, Seminarios Internos, Serie SE-03-77.

Table 2. **Values of Coefficient of Variation (C.V.) Least Significant Difference (L.S.D.), and Relative Efficiency (R.E.) for a lattice (5 x 5) design with five different replications and four plot sizes.**

No. of replications	No. of rows/plot (area/plot)		C.V. (%)	L.S.D. (kg/ha)	R.E. (%)
2	1	(1.5m²)	24.33	1004.7	122.3
	2	(3.0m²)	11.26	590.9	105.7
	4	(6.0m²)	8.10	436.2	125.9
	6	(9.0m²)	7.17	386.8	200.3
	General average		12.72	604.7	138.6
3	1	(1.5m²)	25.69	816.9	113.4
	2	(3.0m²)	11.76	476.9	106.0
	4	(6.0m²)	9.31	381.6	117.5
	6	(9.0m²)	8.07	327.4	123.4
	General average		13.71	500.7	115.5
4	1	(1.5m²)	23.70	654.5	105.0
	2	(3.0m²)	11.33	397.7	109.4
	4	(6.0 m²)	9.58	339.1	117.7
	6	(9.0 m²)	8.35	292.0	125.6
	General average		13.24	420.8	114.4
5	1	(1.5m²)	22.99	572.9	104.3
	2	(3.0m²)	10.76	341.6	110.5
	4	(6.0m²)	9.43	302.1	112.0
	6	(9.0m²)	8.59	271.4	115.1
	General average		12.94	372.0	114.4
6	1	(1.5m²)	23.29	525.1	104.5
	2	(3.0m²)	11.42	327.5	110.2
	4	(6.0m²)	9.59	276.9	115.5
	6	(9.0 m²)	8.59	245.6	119.0
	General average		13.22	343.8	112.3

On the other hand, this trial showed that there were neither lateral border effects nor interaction between the head border effects and the lateral effects.

The head border effect is explained because the plants at the heads have to compete less for light and nutrients because they are adjacent to unplanted spaces. On the other hand, the non-significance of the lateral border effect is partially explained by the relative genetic uniformity of the varieties used. This was evident in the field during the first stages of development of the experiment.

Varieties with Different Growth Habits. This trial began in September 1977. The objective is to prove the same hypothesis as for the trial mentioned above, but using varieties of different growth habits: I, II and III. The corresponding varieties used

Table 3. **Combinations of replications and plot sizes that satisfy the needs of the International Bean Yield and Adaptation Nursery (IBYAN).**

No. of replications	Useful plot area (m^2)	No. of rows	Row width (m)	Row length (m^2)	Total plot area (m^2)	Total trial area
5	2.7	2	0.9	3.0	7.6	1700
4	3.0	2	1.0	3.0	8.0	1400
3	6.0	4	2.0	3.0	12.0	1350
2	9.0	6	3.0	3.0	16.0	1100

were Calima (P692), Porrillo Sintético (P566) and Puebla 152 (P758) having red, black and seeds, respectively.

Climbing Bean (Habit IV)/Maize Association Trial. This trial was recently planted and from its results, it is hoped to derive, if necessary, adjustment procedures for data obtained in previous experiments where border effects were not considered.

Soil Heterogeneity, Plot Size and Design and Number of Optimum Replications in Bean Uniformity Trials

This study had two general objectives:

(a) To study the heterogeneity of the Q_2 experimental plot in the CIAT-Palmira experimental farm, and,

(b) To determine plot size for different numbers of treatments, replications and differences to be detected.

The trial was done on a useful area of 36 x 36 m^2 divided into 1296 plots of 1 m^2 each. The ICA-Guali (P635) bean variety was planted, because of its earliness, bush habit and high adaptation to local conditions. Yields of each unitary plot were recorded. Adjacent unit plots were grouped in 30 combinations to form the different experimental plots of the trial.

The lot did not present a definite fertility gradient, but it did show a high degree of heterogeneity: b = .768[6]. Using the methodology proposed by Hatheway,[7] Table 4 and Figure 1 were constructed. These make possible: (a) the determination of plot size for a given number of replications and a minimum difference to be detected, (b) the definition of the number of necessary replications for a given plot size and a minimum difference to be detected, and, (c) a determination of the difference between treatment averages which the design is capable of detecting if a determined plot size and certain number of replications is used.

Following Smith's[8] methodology (that the best plot size is that allowing the collection of maximum information at the minimum cost possible), the following optimum plot sizes were developed for various combinations where K_1 = percentage of the total cost of the experiment which is proportional to the number of

6 Federer, W.T. Experimental Design, Mac Millan New York, 1963.

7 Hatheway, W.H. Convenient Plot Size. Agron. XI Journal 53: 279-280, 1961.

8 Smith, H.F. An empirical law describing heterogeneity in the yields of agricultural crops. Journal of Agricultural Science. 28(1) : 1-23, 1938.

Table 4. **Plot size (m^2) calculated for the different number of treatments, replications and differences to be detected (expressed as a percentage of the mean)** $b = 0.768$, $C_1 = 21.58$, $\alpha = 5\%$, $P = 80\%$.

No. of treatments	No. of replications						
	2	3	4	5	6	7	8
	Difference to be detected (at the 5% level)						
5	834.3	309.9	186.0	100.4	99.0	78.9	65.1
10	500.2	248.3	161.3	108.2	85.3	69.8	58.7
15	441.9	233.6	144.6	108.2	85.3	69.8	58.7
20	417.0	210.3	144.6	108.2	85.3	69.8	58.7
	Difference to be detected (at the 10% level)						
5	137.2	51.0	30.6	21.4	16.2	13.0	10.7
10	82.4	40.8	26.5	17.8	14.0	11.6	9.6
15	72.7	38.4	23.8	17.8	14.0	11.5	9.6
20	68.6	34.6	23.8	17.8	14.0	11.5	9.6
	Difference to be detected (at the 15% level)						
5	47.7	17.7	10.6	7.5	5.7	4.5	3.7
10	28.7	14.2	9.2	6.2	4.9	4.0	3.4
15	25.3	13.4	8.3	6.2	4.9	4.0	3.4
20	23.9	12.0	8.3	6.2	4.9	4.0	3.4
	Difference to be detected (at the 20% level)						
5	22.6	8.4	5.0	3.5	2.7	2.1	1.8
10	13.5	6.7	4.4	2.9	2.3	1.9	1.6
15	12.0	6.3	3.9	2.9	2.3	1.9	1.6
20	11.3	5.7	3.9	2.9	2.3	1.9	1.6
	Difference to be detected (at the 25% level)						
5	12.6	4.7	2.8	2.0	1.5	1.2	1.0
10	7.6	3.8	2.4	1.6	1.3	1.0	0.9
15	6.7	3.5	2.2	1.6	1.3	1.0	0.9
20	6.3	3.2	2.2	1.6	1.3	1.0	0.9

plots per treatment, and K_2 = percentage of the total cost of the experiment which is proportional to the total area/treatment.

K_1	K_2	Optimum Size (m^2)
75	25	9.9
72	28	8.5
70	30	7.7
65	35	6.1
60	40	5.0

Finally, given the high degree of heterogeneity in this trial, plot shape contributed little in reducing the experimental error.

Other Projects

During 1977 the Biometrics Unit furnished consultation for analysis of experiments with bean maize associations done during 1976 and 1977. Furthermore, collaboration was given in planning the experiments whose final objective is determining the characteristics of a bean plant which yields well when grown in association.

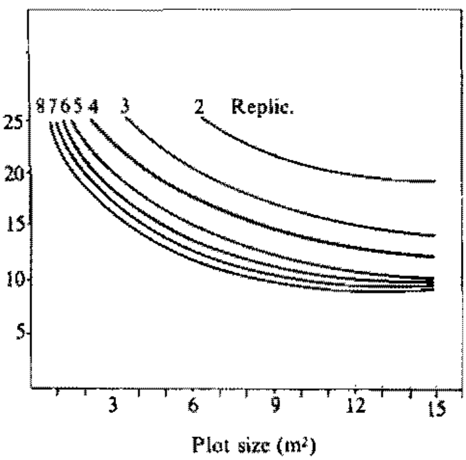

Figure 1. **Relationship between plot size, number of replications and real difference to be detected in an experiment (according to Hatheway Method).**

BEEF PROGRAM

ICA-CIAT Herd Systems Project

During 1977, the revision, processing, analysis and interpretation of data collected in this project during the last four years continued. The following studies were made this year: a complete analysis of reproductive parameters; a study of calf growth curves according to treatment, year and season, and a study of cow growth curves for the different physiological and reproductive stages according to treatment, year and season.

Metabolic Profile Tests

The Beef Program's Animal Health section completed an experiment this year to evaluate the usefulness of blood parameters in identyfying abnormal situations in animals under adverse weather conditions, different management practices and different feeding inputs. For each of the 320 cows of the Herd Systems Project data were collected every two months between June 1976 and May 1977 on 12 blood parameters, weight and weight gain. Separate analyses were made for the two groups of herds: Group I (Herds 2, 3, 4, and 5) and Group II (Herds 4, 5, 6, 7, 8, and 9) following the experimental design project. Results are discussed in the Animal Health Section, Beef Program, in this report.

Other Projects

During the year the CIAT-ICA project on foot and mouth disease control was concluded. For this project the Biometrics Unit developed a stochastic model for determining the proportion of animals in the different stages of development of the disease in the long run and a simulation model for estimating the epidemological behavior of foot and mouth disease as well as its economic impact.

Seventeen nursery and eight field experiments were consolidated and analyzed to evaluate anthracnose resistance in *Stylosanthes* cultivars. In addition, several experiments with *Stylosanthes* introductions other legume evaluations and grass-legume associations were processed.

The Unit advised the Beef Program's Economics section concerning the economic analysis of alternative beef production systems. For this two FORTRAN IV programs were written. One calculates the internal rate of return for the discounted-cash-flow method. The second determines the marginal rate of return and the marginal cost-benefit coefficient between two beef production systems using the discounted-cash-flow system.

CIAT RHIZOBIUM BANK

Due to the increasing number of Rhizobia accessions in the CIAT collection it was considered convenient to computerize the information. This systemization process has been practically concluded for forage legumes and it is expected to be broadened to cover grain legumes. With the new registration system it is possible to have available more information in a shorter time than was previously possible. Some of the activities facilitated are:

(a) the storage and updating of the information for each stock in the Rhizobium bank;

(b) production of lists with all the information to be used at CIAT; maintenance of an alphabetized catalogue of stocks for forage legumes to be distributed worldwide according to requests; and,

(d) recovery of information, both of the stocks and of their effectiveness tests, in response to CIAT's specific requirements or as required by other national and international institutions.

CASSAVA PROGRAM

Adaptability of cassava cultivars

This study was completed during 1977; it used data obtained during the first cycle of regional trials from 1975 done by agronomists of the Cassava Program. The methodology employed and results obtained are described below.

The methodology used in this study is a combination of that suggested by Plaisted and Paterson[9] and by Eberhart and Rusell[10]. An alternative for measuring the contribution of a variety to the interaction variety x locality is also presented.

Since one of the objectives of the cassava breeder is to obtain high-yielding varieties that can be recommended for a particular zone, the varieties were classified according to the two characteristics yield and adaptability. Regarding yield, the varieties were grouped by varieties which yielded below the general average, those which were within the average and varieties which yielded above the average. Regarding adaptability, a variety i is defined as adaptable according to two definitions: (a) If $b_i = 1$ and $S_i^2 = 0$ or (b) if $b_i = 1$ and $C_i = O$ where b_i = slope of the linear regression of the average yield of the variety as a function of the environmental index I = average yield of the locality — general average yield of all the localities; where S_i^2 = mean square of the error for the variety i resulting from the above mentioned regression — mean square resulting from the analysis of the overall variance, and C_i = contribution of the variety i to the interaction variety x locality = (v - 1) (estimate of the variance of the interaction variety x locality including

[9] Plaisted, R.L. and Peterson, L.C. A technique for evaluating the ability of selections to yield consistently in different locations or season. American Potato Journal, Vol. 36, pp. 381-385.

[10] Eberhart, S.A. and Russell, W.A. Stability parameters for comparing varieties. Crop Science, Vol. 6, pp 36-40, 1966.

all the varieties) - (v-2) (estimate of the variance of the interaction variety x locality excluding the variety *i*).

Table 5 shows the ecological and soil characteristics of the eight localities included in the study. Table 6 and 7 show the results for root dry matter (kg/ha/day) for each of the eight varieties being studied. According to these results and considering as a response variable the root dry matter yield, the adaptability criteria ($b = 1$, $S^2 = 0$) is satisfied by the varieties M Col 22, CMC 84, CMC 40 and CMC 9. In the same way, the criteria ($b = 1$, $C = 0$) is satisfied by the same four varieties. It should be noted that taking the root fresh weight yield (t/ha) as the response variable, the conclusions were the same except for the variety CMC 40 which is declared as adaptable only by the criteria ($b = 1$, $S^2 = 0$). In general, the results suggest that the criteria ($b = 1$, $C = 0$) is more conservative than the criteria ($b = 1$, $S^2 = 0$) in the sense that it is more difficult to be satisfied. Finally, Figure 2 is a graphic summary of the results in Table 6 and 7, combining the criteria of adaptability and yield performance.

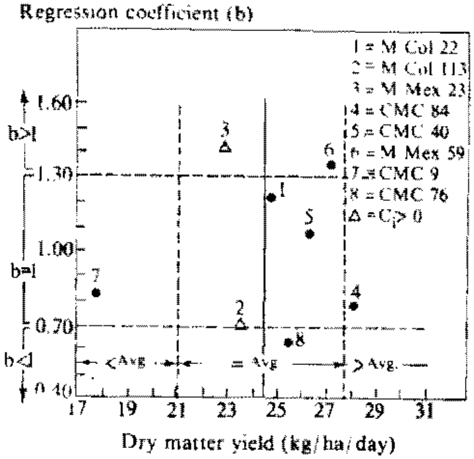

Figure 2. **Classification of eight cassava varieties according to their average yields, their regression coefficient (b_i) and their contribution to the interaction variety x environment (C_i).**

Influence of Soil and Climatic Variables on Cassava Yield

Parallel to the adaptability study, the Biometrics Unit in cooperation with the Cassava Program's agronomy group,

Table 5. **Ecological and soil characteristics of the eight sites utilized to determine the adaptability of varietal yields of cassava.**

Locality	Altitude (masl)	Annual rainfall (mm)	Temperature (°C)	Relative Humidity (%)	pH	Organic Matter (%)	P (ppm)	K (meq/100 g of soil)
1. Rionegro	480	1594	26.6	79.5	5.1	1.5	3.9	0.16
2. Nataima	430	1474	27.8	69.0	6.2	1.3	24.7	0.22
3. Zapata	1100	1219	22.7	75.2	5.2	6.8	6.0	0.14
4. Caicedonia	1100	1900	22.2	80.7	5.5	5.3	70.0	0.68
5. Media Luna	10	1486	27.2	77.6	6.3	0.7	8.2	0.06
6. El Nus	847	1875	23.7	63.6	5.0	3.8	4.3	0.11
7. CIAT	1000	1055	23.5	74.5	6.4	3.6	25.0	0.42
8. Pereira	1480	2000	19.0	80.0	5.1	8.3	8.3	0.10

Table 6 **Average and Standard Deviation of cassava root dry matter yields and position of each variety in relation to the general average values.**

	Avg. yield $\overline{X}$ (kg/ha/day)	Standard Deviation S (kg/ha/day)	Position of x in relation to the general average[1]
M Col 22	24.750	5.53	= Average
M Col 113	23.165	9.14	= Average
M Mex 23	23.015	8.00	= Average
CMC 84	28.280	6.19	> Average
CMC 40	26.327	6.84	= Average
M Mex 59	27.166	6.49	= Average
CMC 9	17.765	4.46	< Average
CMC 76	25.468	4.90	= Average

General average: $\overline{\overline{X}} = 24.492$, $S_{\overline{X}} = 3.275$

[1] These three categories were defined using a confidence interval of the form $\overline{X} \pm S_{\overline{X}}$

studied those factors which characterize the "good" and "bad" environments for this crop. In general "good" and "bad" environments for a given crop are mentioned when the crop growing in them gives high or low yields, respectively. To identify the climatic and soil variables for cassava, the step by step regression technique was used. The modality applied was that of "maximum increase in R^2". The following variables were selected for this study: temperature (TEMP) and rainfall (PREC)

[11] Barr, A.J., Goodnight, J.Hm. Sall, J.P. and Helwig: J.T. A User's Guide to SAS u6. SAS Institute, ppm 25x-25y, 1976.

Table 7. **Adaptability parameters for root dry matter yields of each of several cassava varieties.**

Variety	Regression equation $\overline{y} = f$ f (environmental index)	Significance of b_i with respect to 1[1]	$S_i 2$	C_i
M Col 22	$\hat{y} = 24.750 + 1.210x$	= 1	30.620 NS[2]	30.743 NS[2]
M Col 113	$\hat{y} = 23.165 + 0.705x$	= 1	83.588**	94.754*
M Mex 23	$\hat{y} = 23.015 + 1.430x$	> 1	63.940*	77.891*
CMC 84	$\hat{y} = 28.280 + 0.792x$	= 1	38.264 NS	40.588 NS
CMC 40	$\hat{y} = 26.327 + 1.041x$	= 1	40.732 NS	46.721 NS
M Mex 59	$\hat{y} = 27.166 + 1.347x$	> 1	42.103 NS	53.361 NS
CMC 9	$\hat{y} = 17.765 + 0.827x$	= 1	19.837 NS	25.276 NS
CMC 76	$\hat{y} = 25.468 + 0.644x$	< 1	24.028 NS	29.262 NS

[1] These three categories were defined using a confidence interval of the form $1 \pm \overline{S}_b$ where $\overline{S}_b$ is the average of the standard errors of the b_i.

[2] NS = not significant; * = significant between 1 and 5%; ** = significant < 1%

as environmental variables; organic matter (OM), phosphorus (P), potassium (K) and pH as soil variables; and root fresh weight yield (RENDF) and root dry matter yield (RENDMS).

Table 2 shows that the CIAT,Caicedonia and Nataima sites (where cassava production is high) have the highest phosphorus and potassium contents. On the other hand, the lowest values for these elements occur in sites with the lowest yield responses. These results were analytically confirmed by the following lineal models.

(1) RENDF -204.23 + 4.10pH + 7.20MO + 27.15K + 7.06 TEMP with R^2 86%. In particular, P is the variable which explains most of the changes in RENDF, being capable of explaining the 39 percent of the variation.

(2) RENDMS -134.81 + 5.96pH + 5.05MO + 33.99K + 4.08 TEMP with R^2 94%. In particular, the variable K was able to explain 69% of the variation in RENDMS.

Training and Conferences

In 1977, the Biometrics Unit participated in the following training courses: Oean Production for Latin American Researchers (March 28 to April 23) Swine Production (April 11 to May 25) and Rice Production (July 15 to August 10). Conference cycles covering the following subjects were offered in these courses: general introduction to statistics and experimental design; designs which are most used in the corresponding discipline; and illustrative examples.

With the object of stimulating personal processing of relatively simple statistical analyses, the Biometrics Unit has published the "SAS Simplified Guide" directed to CIAT's scientific personnel and trainees. This guide considers only the more common procedures and options. For more complicated situations it was recommended either to see the full manual or to ask for assistance in Biometrics.

During this year the Information System on Trainees was developed, containing relevant information of all persons who have received training at CIAT since its organization. The system is operational and allows the recovery of any information in it that satisfies some group of selection or classification criteria. A similar data file is being planned for the near future with information on the scientists who work in any disciplines of interest to CIAT.

Finally, the Biometrics Unit carried out two works which can be considered as the first steps towards systematization in the service units. The first was consulting in the design and production of labels for the physical location of the new warehouse's inventory. The second was the cooperation given to the Library in producing indexes for the collection of abstracts of documents on Cassava, Beans and the Documentation Center for Latin American Agricultural Economics.

Station Operations

CIAT's Station Operations Unit greatly expanded operations and responsibilities in 1977 after the acquisition of the new substation at Quilichao. During the second half of 1977, the Unit was able to almost completely develop the physical facilities of that site. Moreover, full support of research activities at CIAT-Palmira were continued.

CIAT-PALMIRA

Support to Research Programs

The Unit provided support to research programs through land preparation, planting, weeding, fertilizer application, pest control, harvesting and crop handling, by furnishing machinery needs and labor supply for hand operations.

Machinery was used by research programs as follows: beans (44% of total machine utilization); rice (35%); cassava (13%); forage seed production (5%); and other uses, including Special Studies Unit, Maize Unit, Swine Unit and maintenance of the station, (3%).

Support was generally spread evenly throughout the year, except for a slight decrease in June and October due to heavy rainfalls when field operations were impossible.

Construction and Maintenance

New drains and canals were constructed to extend the drainage and irrigation systems. These were also repaired when necessary to keep field operations going. A new reservoir was established and a pump installed.

Additionally, the Unit maintained a network of all-weather roads, fences, levee bridges for pedestrians and other permanent structures needed for field services on the research farm.

Crop Production

The Station Operations Unit also produced cassava, rice, beans, maize and sorghum on fields unsuitable for or not being utilized for research. These products were sold on the local market.

To help support rice improvement activities, one field was planted with the CICA 9 variety to produce certified seed for the Federación Nacional de Arroceros de Colombia. Other areas were planted with IR22 and CICA 4 varieties in compliance with a seed production agreement between CIAT and the Instituto Colombiano Agropecuario (ICA). CIAT's Rice Unit also multiplied the advanced line 4440 for possible release as a variety.

Permanent Labor Pool

The Unit provided manual labor to help in field work of CIAT's research programs. Part of this labor pool was also used by the Unit in its general field maintenance activities.

Training in Station Operations

One agronomist from El Salvador, one from Chile and three from Colombia (ICA), received training in managing experimental stations. Four of the five received five months each of training and the other professional received two months' of participatory training.

Development of New Equipment

Personnel of the Unit designed, constructed and tested an implement for harvesting cassava roots. Preliminary evaluations showed labor was reduced up to 50 percent in extracting the roots from the ground. The implement is operated from the three-point hitch of an ordinary tractor.

CIAT-QUILICHAO

In mid-1977 CIAT obtained a new research site of 184 hectares near the town of Santander de Quilichao, south of Cali and Palmira. Detailed physical and soil chemical characteristics are discussed in the report of the Beef Program in this Annual Report.

After acquisition, in May, the land was surveyed to plan the detailed development necessary for a research site. Internal roads were constructed and fences installed. One existing building was remodeled. Five water reservoirs were excavated and developed to manage and conserve runoff. Physical developments completed during the second half of the year permitted rapid establishment of several experimental plots before year's end.

Climatology

CIAT maintains research programs at sites having a variety of temperature and precipitation regimes. The sites provide the variability necessary for experimental purposes and allow the work load to be distributed throughout the year.

Mean monthly temperatures vary from over 28°C at Caribia and Turipaná to less than 19°C at Popayán (Figure 1). Sites in Colombia tend to maintain relatively stable mean temperatures throughout the year; however, mean monthly temperatures at the Centro de Pesquisa Agropecuaria do Cerrado (CPAC) near Brasilia vary considerably, reaching a high of almost 23°C in September and October and a low of approximately 19°C in June and July.

CIAT research sites also have a variety of precipitation regimes. Carimagua,

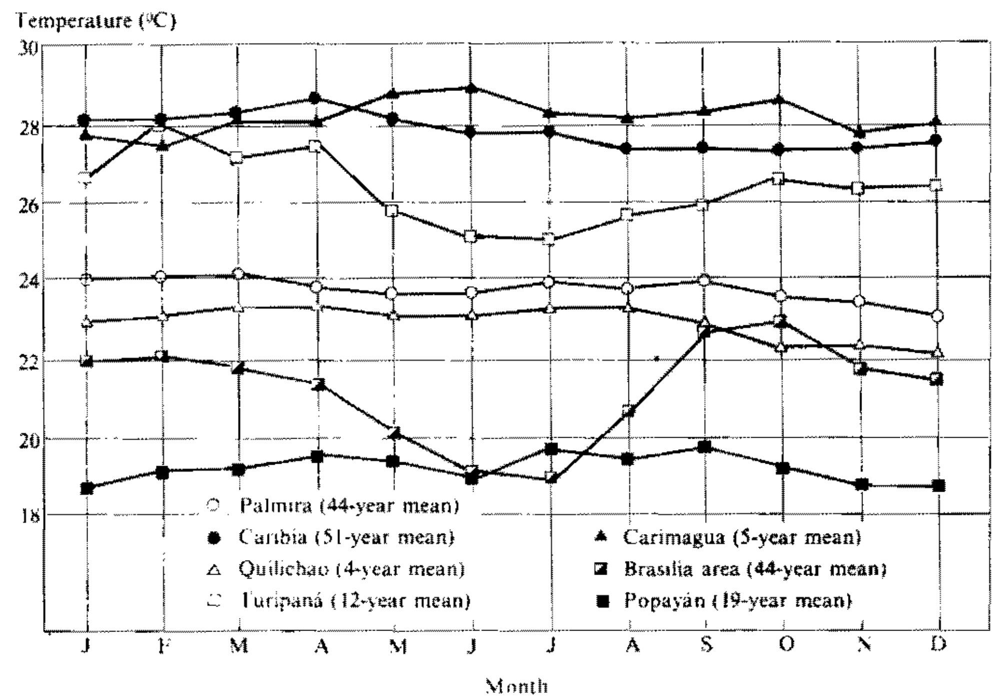

Figure 1. Long-term mean monthly temperatures at seven CIAT research stations.

Caribia and Turipaná the warmest sites, have distinct dry seasons from approximately December to March (Figure 2). Palmira has two short dry seasons, December through March and June through September (Figure 3). Quilichao and Popayán have precipitation patterns similar to that in Palmira except that mean monthly precipitation from December through March is above or only slightly below potential evaporation. In Quilichao the more favorable rainfall distribution is offset by the low water retention capacity of the soil, and frequent short-duration drought stress can be expected, especially in crops susceptible to the acid soil conditions at the site. The CPAC has the longest dry season, from April to September. As in Quilichao soil physical and chemical properties limit water availability and cause short but severe periods of drought during the wet season.

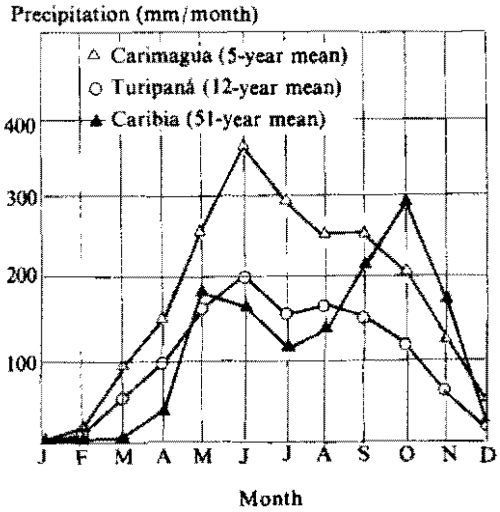

Figure 2. **Long-term mean monthly precipitation for CIAT research stations with dry seasons drom December to April.**

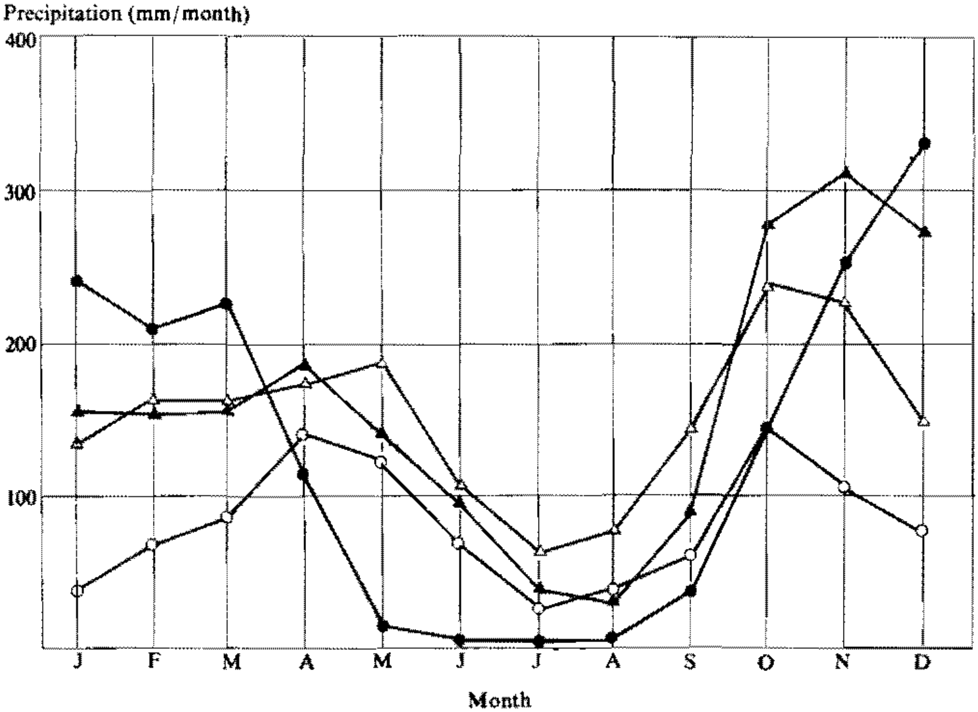

Figure 3. **Long-term mean monthly precipitation for CIAT research stations with dry seasons from June to September.**

Detailed monthly data are presented for four major research sites. Meteorological data for CIAT Palmira are from the ICA weather station approximately three kilometers east of the CIAT farm. Data for Carimagua are from the site. Data for CIAT-Quilichao are from the Corporación Autónoma Regional del Cauca (CVC) weather station at San Julián, approximately three kilometers north of the site and approximately five kilometers southwest of a Beef Program research site at El Limonar. Data for Popayán is from the research station of the Federación de Cafeteros (CENICAFE) station one kilometer from the experimental site used by CIAT.

PALMIRA

Temperatures were close to the long-term mean throughout the year (Table 1). Precipitation was considerably below normal from November 1976 through May 1977. During this period potential evaporation was above average. Except for the months of October 1976, June 1977, and October 1977, precipitation was below potential evaporation.

CARIMAGUA

Temperatures were close to long-term means. Except for the month of June precipitation was below normal. Precipitation was below potential evaporation for a period of seven consecutive months, from October 1976 through April 1977. Low rainfall in October 1977 adversely affected some late plantings.

QUILICHAO

CIAT-Quilichao has been operational since mid-1977; however, meteorological data are presented for all of 1977 since the station at San Julián is also representative of the Beef Program research site at El Limonar. Rainfall at El Limonar should be lower than at San Julián due to its greater distance from the mountains on the west.

Temperatures for the period reported were slightly below the long-term averages. Rainfall was also below average, especially for the periods January through March 1977 and May through August, 1977. This gave rainfall during 1976-77 a bimodal distribution similar to that at Palmira; normally only a single dry season occurs, in July and August.

POPAYAN

As in 1975-76 the temperature data were significantly different from long-term means. This is probably due to inadequate exposure of the station and poor calibration of the instruments. These continuing problems reflect the inadequacy of the stationfor the Bean Program's needs.

Rainfall at Popayán was below normal from November 1976 through April 1977. This is consistent with the trend observed in Quilichao, Palmira and Carimagua.

FUTURE WORK

A CIAT Meteorology Committee was established in late 1977 to improve and standardize the collection and analysis of meteorological data. The committee is obtaining the equipment for a complete weather station at CIAT-Palmira and to improve existing stations at CIAT-Quilichao and Carimagua. The Biometrics Unit is aiding in the computerization of the monthly analysis of climatic data. A computer model which simulates the soil water balance has been obtained. The model is sensitive to soil, crop, and weather parameters and will allow soil moisture stress to be routinely estimated in field experiments.

Table 1. **Monthly meteorological data for CIAT-Palmira (station at ICA-Palmira, Lat. 3°31'N; Long. 76°18'W., Altit. 1001 m)[1].**

	Temperature (°C)						Rainfall (mm/month)		Class A pan evaporation (mm/month)		Mean screen relative humidity (%)		Hours of sunshine (Campbell-Stokes) (hours/month)	
	Maximum		Minimum		Average									
Month	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77
Oct. 1976	28.8	29.3	18.0	18.1	23.3	23.2	150	230	139	151	74	75	166	170
Nov.	28.2	28.2	18.1	18.8	23.3	23.1	105	35	118	124	74	77	164	163
Dec.	29.6	28.6	18.1	18.4	23.5	23.1	79	48	131	134	73	77	185	162
Jant. 1977	30.1	30.4	18.0	18.6	23.8	24.2	71	17	142	168	70	71	199	213
Feb.	30.4	30.2	18.2	19.1	24.0	24.3	71	8	137	150	70	69	182	150
Mar.	30.3	31.4	18.4	19.9	24.1	25.0	90	78	147	188	71	69	182	176
Apr.	29.6	29.1	18.4	19.6	23.8	24.0	139	81	127	137	74	75	159	170
May	29.1	28.4	18.4	19.4	23.6	23.4	125	81	122	121	75	78	161	130
Jun.	29.3	28.7	18.1	18.5	23.5	23.0	69	132	118	120	74	78	169	165
Jul.	30.0	29.7	17.9	18.7	23.7	23.8	28	18	136	140	69	73	197	181
Aug.	30.1	30.0	17.8	18.6	23.9	23.9	37	64	145	161	67	72	185	204
Sep.	30.3	29.4	17.8	18.4	23.8	23.8	62	88	142	153	68	73	172	161
Oct.	29.2	28.1	18.0	19.4	23.3	23.3	150	161	139	140	74	74	166	160

[1] Means of temperature, precipitation, relative humidity, and hours of sunshine are averages of at least 44 years. Means of pan evaporation are averages of eight years.

Table 2. Monthly meteorological data for Carimagua (HIMART ordinary climatological station at Carimagua, Lat. 4° 2' N, Long. 71° 10'W, Altit. 200 m)[1].

Month	Temperature (°C) Maximum		Temperature (°C) Minimum		Temperature (°C) Average		Rainfall (mm/month)		Potential evaporation (mm/month)		Mean screen relative humidity (%)	
	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77
Oct. 1976	31.1	31.6	22.5	23.6	26.8	27.6	203	140	186	192	80	80
Nov.	30.6	31.0	22.2	22.4	26.4	26.7	130	72	183	189	77	75
Dec.	30.9	-	21.8	21.8	26.3	-	51	16	195	-	74	71
Jan. 1977	32.6	34.7	20.9	-	26.8	-	3	0	224	233	62	57
Feb.	32.5	31.8	22.4	22.3	27.5	27.1	18	5	214	218	59	57
Mar.	32.5	31.8	22.4	22.3	27.5	27.1	90	18	215	226	67	62
Apr.	32.1	33.8	22.8	23.2	27.4	28.5	144	83	195	213	75	74
May	30.2	30.1	22.3	22.5	26.2	26.3	272	237	164	164	84	84
Jun.	28.6	27.6	21.9	21.2	25.3	24.4	374	453	141	138	86	82
Jul.	28.6	29.0	21.5	22.0	25.1	25.5	302	210	152	158	84	81
Aug.	29.5	28.2	21.7	21.7	25.6	25.0	248	194	161	167	83	79
Sep.	30.0	29.1	21.9	21.5	25.9	25.3	259	233	165	156	82	82
Oct.	31.1	31.1	22.5	22.4	26.8	26.8	203	152	186	186	80	80

1 All means are averages of three to five years. Potential evaporation was calculated from the García-López equation. Average temperature is the mean of maximum and minimum temperature.

Table 3. Monthly meteorological data for Quilichao (CVC station at San Julián, Lat. 3°06'N, Long. 76°31'W, Altit. 990 m)[1].

Month	Temperature (°C)						Rainfall (mm/month)		Class A pan evaporation (mm/month)		Mean screen relative humidity (%)		Hours of sunshine (Campbell-Stokes) (hours/month)	
	Maximum		Minimum		Average									
	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77	Mean	1976-77
Oct. 1976	28.9	27.3	18.0	18.0	22.4	22.1	241	187	118	109	76	70	164	155
Nov.	27.5	26.6	18.1	17.5	22.4	21.5	228	209	111	111	79	76	165	177
Dec.	27.6	27.0	17.9	17.3	22.3	21.7	150	163	115	121	78	75	192	186
Jan. 1977	30.3	31.1	18.2	18.9	23.1	22.8	136	79	130	161	79	68	205	218
Feb.	30.0	30.6	18.6	18.5	23.2	22.6	166	99	126	129	78	69	165	178
Mar.	31.1	32.3	18.7	18.4	23.5	23.6	163	116	127	171	79	70	161	198
Apr.	29.6	29.6	19.3	18.6	23.4	23.2	178	182	123	135	79	75	171	163
May	29.0	29.1	18.9	18.9	23.2	22.6	189	121	112	124	80	77	155	148
Jun.	29.2	29.3	18.5	18.0	23.3	22.1	106	65	105	123	79	75	147	157
Jul.	30.4	30.2	17.5	17.8	23.4	22.6	63	92	136	143	74	70	195	182
Aug.	30.4	30.6	17.9	17.5	23.4	22.9	78	76	143	155	71	69	167	202
Sep.	30.4	30.5	17.6	17.7	23.0	23.6	147	199	138	147	73	68	159	155
Oct.	28.9	29.4	18.0	18.7	22.4	-	241	291	118	132	76	-	164	169

1 Means of precipitation are averages of 10 years. Other means are averages of five years.

Table 4. Monthly meteorological data for Popayán (CENICAFE meteorological station José María Obando, Lat. 2°27'N, Long. 76°34'W, Altit. 1850 m)[1].

	Temperature (°C)						Rainfall (mm/month)		Mean screen relative humidity (%)		Hours of sunshine (Campbell-Stokes) (hours/month)	
	Maximum		Minimum		Average							
Month	Mean	76-77	Mean	76-77	Mean	76-77	Mean	76-77	Mean	76-77	Mean	76-77
Oct. 1976	37.7	23.8	10.7	13.9	17.5	17.7	276	351	81	83	102	106
Nov.	26.4	23.8	11.1	13.6	16.9	17.8	310	137	83	83	101	141
Dec.	26.5	24.1	10.8	13.8	17.3	17.8	272	157	84	83	125	169
Jan. 1977	26.9	25.1	10.5	13.3	17.4	18.7	157	97	74	71	200	225
Feb.	27.4	24.6	11.0	13.4	17.6	17.8	154	16	80	79	127	158
Mar.	27.5	25.9	11.1	14.8	17.6	19.8	163	78	77	74	134	161
Apr.	27.6	24.3	11.4	14.2	17.5	18.5	183	139	79	89	111	125
May	27.5	23.8	11.5	14.1	17.6	18.1	142	240	82	83	96	118
Jun.	27.4	23.9	10.4	13.7	17.4	18.1	66	132	74	76	132	148
Jul.	28.8	24.9	10.6	13.8	17.6	18.6	41	21	68	71	148	161
Aug.	28.7	25.1	10.3	13.1	18.0	18.3	35	30	69	70	140	151
Sep.	29.0	25.1	10.3	13.3	18.0	18.8	93	124	72	72	142	134
Oct.	27.7	-	10.7	-	17.3	-	276	-	81	-	102	-

[1] Temperature and rainfall means are averages of 19 years; relative humidity and hours of sunshine means are averages of three years.

International Cooperation Activities

International Cooperation

International Cooperation activities at CIAT encompass all those aimed at establishing fully collaborative links with national programs of countries working with CIAT to accomplish increased outputs of rice, beans, cassava, maize, beef or swine.

Specifically, International Cooperation at CIAT operates through a series of mechanisms or strategies of technology transfer, complementing the Research objectives and strategies of the Center.

Soon after the arrival of the Associate Director General for International Cooperation (ADG/IC) (on 1 January 1977), a Strategy Paper on International Cooperation was prepared for study and definition of relevant policies for the Board of Trustees. To develop the paper, inputs were solicited from most CIAT staff, with the result that the preliminary document expressed a coherent view of the institution as to its orientation and technology transfer methodologies. The paper has served as a provisional guide for mapping and executing a series of actions in international cooperation.

INTERNATIONAL ORGANIZATION

The development of a resource base and an appropriate organization for international cooperation actions were of high priority. The following resource components were included under direct supervision and administration of the office of the ADG/IC: (1) Training and Conferences; (2) Library and Information Services; (3) cooperative relay projects, in particular, the CIMMYT/CIAT Regional Andean Maize Unit; (4) the Instituto de Ciencias y Tecnología Agrícolas (ICTA), Guatemala, Bilateral Contract Operations; and (5) outposted outreach staff members.

Moreover, appropriate steps were taken during the year to create these additional resource units in 1978: (1) a Communications Support Unit; (2) a Country Documentation Office; and, (3) a Seed Training, Outreach and Research Unit. In October 1977, the Rockefeller Foundation assigned one of its staff to CIAT where he will coordinate the development of the Seed Unit.

Effective links with outposted research staff and with commodity program outreach staff in terms of action programs and supervision were established, both at the individual level and with the respective program and unit coordinators. This organizational action permitted a functional relationship of the commodity programs, in their outreach phase, to become fully integrated with the Center's overall international cooperation activities.

COUNTRY RELATIONS

An extensive program of visits was launched to initiate or strengthen relations at the institutional level between CIAT and national programs. Most national programs in Latin America were visited at least once during the year. The ADG/IC also visited programs in India and five Southeast Asian countries, to establish working links or reinforce existing activities. These visits were directed to the levels of ministries or vice-ministries, directorates of national research systems, university rectors and managers, directors of experiment stations and commodity program leaders and research workers.

Particular efforts were made to identify research institutions and become familiar with their programs, and with promising scientists as prospective candidates for training or networking. Former CIAT trainees working in these institutions were visited whenever possible.

In Colombia, a reorientation of collaborative efforts of CIAT and the Instituto Colombiano Agropecuario (ICA), more in line with present goals, resources and capabilities of both institutions was negotiated. A new general agreement was developed that clearly aims at reinforcing links between the two groups and improves operational efficiencies by clearly defining the respective areas of action in each commodity program. In these efforts, the ADG/IC was assisted by the Center's Executive Officer.

New bilateral agreements were also signed with Panama, Costa Rica and Brazil.

At the invitation of the Cuban State Committee of International Collaboration, a CIAT delegation including the Chairman of the Board of Trustees, the Director General, the ADG/IC and several scientists visited that country. Later in the year, a Cuban delegation also visited CIAT.

During the year, several ministers of agriculture and directors of national agricultural programs from several countries in Latin America visited CIAT. Other distinguished visitors included the deans of 30 graduate colleges of agricultural universities of the region.

In addition to the visits of the ADG/IC and the visitors coming to CIAT, effective international cooperation links were continued by most of the scientific staff of the Center, in the course of their research and outreach activities in Latin America and Asia.

RELATIONS WITH INTERNATIONAL INSTITUTIONS

The ADG/IC participated in several meetings of international institutions involved with agricultural development. Visits were also made to three other international agricultural research centers, to SEARCA, in the Philippines, and the Interamerican Institute of Agricultural Sciences (IICA). An agreement was also signed with the latter organization to facilitate logistical support and other services to outposted CIAT staff members in Brazil and Costa Rica.

ADDITIONAL EXTERNAL FINANCING AND PROJECT SUPPORT

The office of the ADG/IC actively worked in securing approval of a $1.6 million special project grant to CIAT from the United Nations Development Programme (UNDP). Funds will support outreach staff in Brazil and in Central America and the Caribbean, and will expand training capabilities at CIAT.

Two agreements involving research activities were signed with the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Federal Republic of Germany, and with the State University of Glemblux, Belgium.

OUTPOSTED PERSONNEL

Including outposted outreach, outposted research and bilateral contract personnel, contractual, operational and administrative arrangements were made for establishing scientists in 13 positions, the last scientist to be on the job by February 1978. A year ago, three scientists were posted out of CIAT.

Training and Conferences

In 1977, training decentralization initiated in 1976 was largely completed. Now each commodity program plays a central role in formulating its training priorities, schedules, and activities. At the administrative level, the Training Office provides centralized coordination that assures: (1) continuity between the various training efforts at CIAT: (2) efficiency of administration of training participants; (3) adherence to Center-wide training standards by the various programs; (4) efficient sharing of training resources; and, (5) integration of relatively independent training efforts into overall CIAT training and outreach strategies.

Training

TRAINING GOALS

A positive by-product of decentralization has been a sharper focus on training goals. Now, training activities reflect the different international cooperation strategies of the Center's commodity programs. Training cannot be monolithically applied across commodities. Rather, it must be tailored to each program's state of technology development and its technology transfer objectives. Staff of the commodity programs are aware of where and how to apply their training leverage to ensure availability of a cadre of professionals in research and production at national and regional levels to validate, adapt, and disseminate research results and to feed back their results to the CIAT programs together with the concerns of producers and their representatives.

Now that training is conducted along commodity lines and is largely controlled by commodity programs, manpower assessment in countries has become more efficient; once the needs for trained personnel both in research and production in the countries of CIAT's responsibilities are analyzed from the standpoint of clear priorities in single commodities, the institutions and the individuals that need training assistance by CIAT, and the most appropriate type of training can be readily identified. By explicitly stating that the purpose of CIAT training is to strengthen counterpart institutions within countries, it has been possible to establish a functional unit of analysis to allow for meaningful needs assessment, follow-up, and valid long-term evaluation of the Center's training efforts.

PRINCIPLES OF CIAT TRAINING

Five principles of CIAT training have been adopted on a Center-wide basis.

Training on the Postgraduate Level

Since CIAT trainees will have to perform in leadership roles in technology validation, adaptation, and dissemination, training is concentrated at the postgraduate level. To qualify, a training candidate must have successfully completed at least four years of university studies. Exceptions are only made when a national institution has a demonstrated need for training assistance related to CIAT's outreach objectives but available candidates lack formal university degrees.

Critical Mass

Experience indicates that an individual trained at CIAT can have only moderate success in applying his training if colleagues and supervisors do not share his perspectives, methodological concerns and working patterns acquired at CIAT. Therefore, precedence is given to training selected individuals from priority institutions who will eventually work together in teams. Each team member possesses a specialized training background, and the team constitutes a critical mass sufficient to guarantee the application of skills acquired at CIAT.

Learning by Doing

Effective training in generating and/or using new technology not only requires a theoretical treatment of course content, but also the full participation of the trainee in actually translating this content into practice. Therefore, CIAT training policy requires that a major part of each participant's internship take place in the field, laboratory, and other work areas.

Training for Specific Skills

At CIAT training must insure that appropriate skills are acquired. Consequently, specific skills must be defined which a given training participant will need to successfully function as a link in the technology transfer chain upon returning home. Once identified, these skills become the sole criterion by which learning experiences are organized and against which the trainee's performance is evaluated.

Single Commodity Orientation

Since the trainee serves as a link for the technology transfer efforts of individual commodity programs, all training is commodity specific. Each of CIAT's programs provides commodity specific training to selected individuals in key positions in national programs so these specialists, upon returning home will be able to increase production of CIAT commodities.

TRAINING/RESEARCH RELATIONSHIP

Since CIAT's training activities are decentralized, the entire scientific staff of the Center is involved in individualized research training. Moreover, while a core of training specialists provides adequate planning, logistics, and coordination for group training, all scientists also contribute when necessary. A survey by the Office of the Associate Director General for Research at CIAT showed that senior scientists spend from 5-25 percent (average of 15 percent) of their time on training. Due to CIAT's emphasis on in-service training, teaching and research are clearly complementary activities and training efforts by the staff are seldom distinct from their research concerns.

TRAINING IN 1977

In 1977, 235 persons trained at CIAT. Of these, 195 began their training this year, while the remaining 40 began in 1976.

Table 1 shows the number of professionals who entered training in 1977 by commodity programs and training categories. Figure 1 compares the numbers

Table 1. **Professionals entering training at CIAT during 1977, by training categories and program.**

Program or Unit	Training category							
	Postdoctoral Fellows	Visiting Research Associates	Research Scholars	Research Interns	Production Interns	Course Participants	Special Trainees	Total
Beans	1	5	3	22	-	22	3	56
Cassava	1	3	2	8	-	-	2	16
Rice	-	1	-	-	11	-	5	17
Beef	1	3	2	1	18	-	7	32
Swine	-	-	-	2	-	25	1	28
Others								
Library and Information Services	-	-	-	-	-	-	4	4
Station Operations Management	-	2	-	2	-	-	1	5
Seed Production	-	-	-	-	-	34	-	34
Others	-	1	-	1	-	-	1	3
Total	3	15	7	36	29	81	24	195

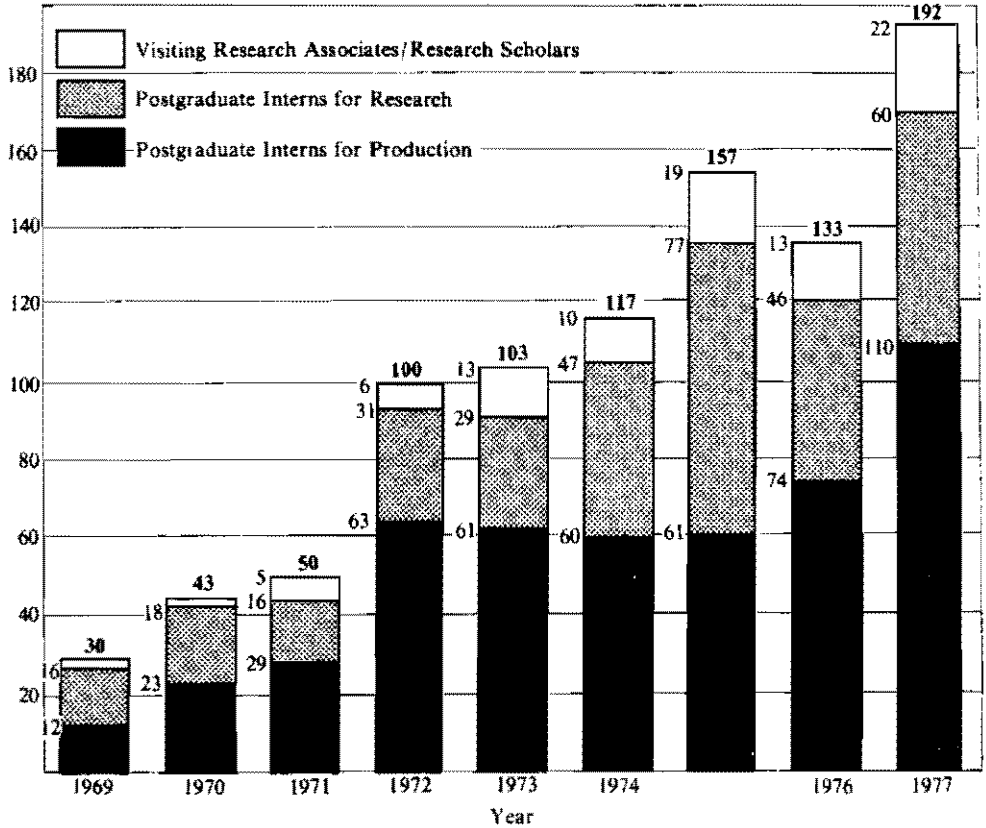

Figure 1. Number of CIAT training participants by training categories, 1969-77.

of training participants in the various categories for the years 1969-1977. Table 2 lists the professionals trained at CIAT in 1977 by programs and discipline, institution where enrolled, and funding source.

This increase in activities in 1977 illustrates both the expanded capacity of the commodity research programs to transfer new technologies, as well as the overall international scope of CIAT.

TRAINING IN RESEARCH

This training provides research-oriented individuals with skills in the investigative methodologies used at CIAT and work experiences in a specific discipline within one of CIAT's commodity research programs or support units. In 1977, there were 123 persons in research training. Participants at the postdoctoral or graduate thesis level generally spent a minimum of one year at CIAT. Research trainees coming to CIAT for postgraduate work not in a formal degree program spent from 5 to 12 months at the Center, with an average of eight months.

Postdoctoral Fellows

During 1977, eight Postdoctoral Fellows were engaged in research; five of these had joined CIAT before this year. The three new arrivals are working in the following areas: forage entomology — development of a pest management program for tropical

Table 2. Professionals trained at CIAT in 1977.

Name and Status [1]	Country	Program/Discipline	Institution where enrolled	Source of funding
Postdoctoral Fellows				
Calderón, Mario (5, P)	Colombia	Beef/entomology		CIAT
Castro, Abelardo* (1, C)	Chile	Cassava/agronomy		CIAT
Davis, Jeremy (3, P)	Unit. Kingdom	Bean/plant physiology		CIAT
Halliday, John* (6, C)	Unit. Kingdom	Bean/soils microbiology		CIAT
Lynam, John (6, P)	USA	Cassava/economics		The Rockefeller Foundation, USA
Mendoza, Gastón* (12, P)	Peru	—/biometrics		CIAT
Swindell, Richard* (12, P)	USA	Bean/breeding/agronomy		CIAT
Thung, Michael* (12, P)	Indonesia	Cassava/plant physiology		CIAT
Visiting Research Associates				
Acosta, Claudio (5, P)	Colombia	—/station operations	Instit. Col. Agropecuario (ICA)	CIAT
Beebe, Stephen (11, P)	USA	Bean/breeding	Univ. of Wisconsin, USA	National Science Foundation, USA
Bernd, Annette (9, P)	W. Germany	Rice/plant breeding	Tech. Univ. of Berlin, W. Germany	Germ. Soc. for Int. Dev. (GTZ), W. Germany
Byrne, David (7, P)	USA	Cassava/entomology	Cornell Univ., USA	Cornell Univ.
Chaves, Guillermo (5, C)	Colombia	—/station operations	Instit. Col. Agropecuario (ICA)	CIAT
Clark, Ann (7, P)	USA	Bean/physiology	Iowa State Univ., USA	Iowa State Univ.
Delgadillo, Guido (8, P)	Canada	Beef/pastures & forages	McGill Univ., Canada	CIAT
De Bouck, Daniel (6, P)	Belgium	Bean/breeding/physiology	Food & Agric. Organiz. (FAO), Rome	FAO
Diaz, Jorge Luis (2, F)	Nicaragua	Beef/pastures & forages	Paris Univ., France	CIAT
Elango, Fritz (3, P)	Cameroon	Cassava/pathology	McGill Univ., Canada	Int. Dev. Research Centre (IDRC), Canada
Evans, David* (10, C)	Unit. Kingdom	—animal health	Univ. of London, Unit. Kingdom	CIAT
Galway, Nicholas (12, P)	Unit. Kingdom	Bean/agronomy	Univ. of Cambridge, Unit. Kingdom	The Royal Soc. of London, Unit. Kingdom
Hudgens, Robert* (6, C)	USA	Bean/agronomy	Univ. of Florida, USA	CIAT
Jansen, Hendrik* (12, P)	Holland	Beef/pastures & forages	Food & Agric. Organiz. (FAO), Rome	Government of Holland
Jenrich, Herbert (8, P)	W. Germany	Beef/pastures & forages	Tech. Univ. of Berlin, W. Germany	Germ. Soc. for Tech. Coop., W. Germany
Laberry, Rafael (5, P)	Peru	Cassava/pathology	Comité Productores Arroz (FRADEPT)	CIAT
Muller, Frank* (12, P)	W. Germany	Beef/pastures & forages	Univ. of Bonn, W. Germany	Germ. Serv. for Acad. Exch., W. Germany
Plessow, Christoph (9, C)	W. Germany	—/biometrics	Tech. Univ. of Berlin, W. Germany	Germ. Found. for Int. Dev., West Germany

(Continued)

1 Trainees whose names are followed by an asterisk began training before 1977. Numbers in parentheses are the months spent at CIAT during 1977; "C" means the trainee completed his work during 1977; "P" means he is still in training.

Table 2 (continued)

Name and status [1]	Country	Program/Discipline	Institution where enrolled	Source of funding
Rubinstein, Eugenia de* *(12, C)*	Chile	Beef/economics	Univ. of Minnesota, USA	Ford Foundation, USA
Teri, James* *(11, C)*	Tanzania	Cassava/pathology	Cornell Univ., USA	Food & Agric. Organiz. (FAO), Rome
Waters, Luther *(9, C)*	USA	Bean/soils microbiology	Oregon State Univ. USA	Oregon State Univ.
Webster, David* *(8, C)*	USA	Bean/pathology	Univ. of Wisconsin, USA	CIAT
Research Scholars				
Alvarez, Germán *(4, P)*	Colombia	Bean/pathology	McGill Univ., Canada	CIAT
Argel, Pedro* *(11, C)*	Colombia	Beef/pastures & forages	Univ. of Queensland, Australia	CIAT
Calvo, Fabio* *(12, P)*	Colombia	Beef/pastures & forages	Es. Nacional Agricultura, Mexico	CIAT
Campos, José Y.* *(12, C)*	Colombia	Beef/agric. management	Instit. Tecnol. (ITESM), Mexico	Inter-Amer. Dev. Bank (IDB)
Cárdenas, Moisés* *(12, C)*	Mexico	Bean/pathology	Prog. Graduados, Univ. Nac.-ICA, Col.	Inter-Amer. Dev. Bank (IDB)
Charry, Alvaro *(3, P)*	Colombia	Beef/economics	Prog. Graduados, Univ. Nac.-ICA, Col.	CIAT
Cantillo, Stella de *(2, P)*	Colombia	Cassava/physiology	Prog. Graduados, Univ. Nac.-ICA, Col.	Univ. Nacional de Colombia
Domínguez, Carlos* *(3, C)*	Colombia	—/crop production	Univ. of Guelph, Canada	CIAT
Duran, José F. *(9, C)*	Venezuela	Bean/pathology	Univ. del Valle, Colombia	Self-supported
Galindo, José *(12, P)*	Colombia	Bean/pathology	Cornell Univ., USA	CIAT
García, Edmundo* *(12, P)*	Colombia	Rice/agronomy	Es. Luiz de Queiroz, Brazil	Inter-Amer. Dev. Bank (IDB)
García, Omar *(12, P)*	Colombia	—/hemoparasitology	Prog. Graduados, Univ. Nac.-ICA, Col.	CIAT
Gómez, William F.* *(12, P)*	Colombia	Beef/animal production	Prog. Graduados, Univ. Nac.-ICA, Col.	Inter-Amer. Dev. Bank (IDB)
Hidalgo, Rigoberto* *(8, C)*	Colombia	Bean/physiology	Cornell Univ., USA	CIAT
Leiva, Oscar *(8, C)*	Guatemala	Bean/breeding	Prog. Graduados, Univ. Nac.-ICA, Col.	The Rockefeller Foundation, USA
Mattos, Luz L.* *(4, C)*	Peru	Cassava/plant pathology	Univ. Agraria La Molina, Peru	Inter-Amer. Dev. Bank (IDB)
Moncada, Hemerson* *(12, P)*	Colombia	Beef/animal health	Univ. of Hannover, W. Germany	CIAT
Morales, Víctor* *(7, C)*	Colombia	—/soil microbiology	Univ. of Florida, USA	CIAT
Peña, Jorge *(4, P)*	Colombia	Cassava/entomology	Univ. of Florida, USA	Int. Dev. Research Centre (IDRC), Canada
Vargas, Octavio* *(6, C)*	Colombia	Bean/entomology	Cornell Univ., USA	CIAT
Postgraduate Research Interns				
Abreu, Andrés *(8, C)*	Dominican Republic	Bean/plant pathology		CIAT
Araya, Rodolfo *(6, C)*	Costa Rica	Bean/agronomy		CIAT

(Continued)

Table 2 (continued)

Name and Status[1]	Country	Program/Discipline	Source of funding
Baena, Diosdado* *(3, C)*	Colombia	Bean/biometrics	Univ. Nacional de Colombia
Bazalar, Hernando* *(1, C)*	Peru	Beef/animal health	CIAT
Bandhukul, Rangsit* *(6, C)*	Thailand	Cassava/agronomy	CIAT
Bodden, Rolando *(6, C)*	Dominican Republic	Cassava/entomology	CIAT
Castellanos, Victor Hugo* *(8, C)*	Dominican Republic	Cassava/agronomy	CIAT
Chiriboga, César *(5, P)*	Ecuador	Bean/breeding	CIAT
De Oliveira, Itamar *(3, C)*	Brazil	Bean/soils	CIAT
De Souza, Lindaurea *(3, P)*	Brazil	Bean/entomology	CIAT
Domínguez, Roberto *(5, C)*	Colombia	—/station operations	CIAT
Ekmahachai, Panya *(2, P)*	Thailand	Cassava/agronomy	Int. Dev. Research Centre (IDRC), Canada
Fiallos, Enrique *(6, C)*	Mexico	Bean/agronomy	Inter-Amer. Dev. Bank (IDB) Honduran Proj.
Flores, Jesus A. *(5, C)*	Mexico	Rice/breeding/production	CIAT
García, Rafael* *(8, C)*	Dominican Republic	Beef/animal health	CIAT
Guevara, Yolanda *(5, C)*	venezuela	Bean/plant pathology	CIAT
Kano, Yoshiaki *(1, P)*	Japan	Cassava/breeding	Japan Int. Coop. Agency (JICA)
Khelikuzaman, Hussein* *(9, C)*	Malaysia	Cassava/agronomy	Int. Dev. Research Centre (IDRC), Canada
Lezama, Francisco *(5, P)*	Honduras	Bean/entomology	CIAT
Llontop, Elva *(9, C)*	Peru	Bean/plant pathology	CIAT
López, Gustavo* *(3, C)*	Colombia	Beef/animal health	CIAT
Machado, José O. *(3, P)*	Brazil	Bean/plant pathology	CIAT
Machuca, Carlos *(6, C)*	El Salvador	—/station operations	CIAT
Michel, Manuel *(5, C)*	Dominican Republic	Bean/seed production	Agency for Int. Dev. (AID), USA
Nakavirojana, Chumpol *(2, P)*	Thailand	Cassava/soils	Int. Dev. Research Centre (IDRC), Canada
Nugroho, Johannes *(1, P)*	Indonesia	Cassava/agronomy	Int. Dev. Research Centre (IDRC), Canada
Paredes, Oscar Mario *(4, P*	Chile	Bean/breeding	CIAT
Ponce, Alfonso M. *(5, C)*	Ecuador	Bean/agronomy/breeding	CIAT
Quintero, Edgar *(4, P)*	Colombia	Bean/biometrics	CIAT
Rodas, Nery Jesús *(5, C)*	Honduras	Bean/entomology	Inter-Amer. Dev. Bank (IDB) Honduran Proj.
Rodriguez, Victor Manuel* *(3, C)*	El Salvador	Bean/plant pathology	CIAT
Romero, Alfredo *(5, C)*	Venezuela	—/communication	Fondo Nac. de Invest. Agropec. (FONIAP), Venezuela
Sañudo, Benjamin *(2, P)*	Colombia	Bean/plant pathology	CIAT

Continued)

Table 2 (continued)

Name and Status[1]	Country	Program/Discipline	Source of funding
Sanbua, Samrit *(6, C)*	Thailand	Swine/animal production	CIAT
Sanay, Nilmanee* *(5, C)*	Thailand	Cassava/plant pathology	CIAT
Suárez, Jorge A. *(6, C)*	Bolivia	Beef/pastures & forages	CIAT
Talero, Elsa Leonor *(6, C)*	Colombia	Bean/breeding	Univ. Pedagógica Nac. de Colombia
Tercero, Otho Luis *(6, C)*	Honduras	Bean/production	CIAT
Tan, Swee Lian* *(4, C)*	Malaysia	Cassava/physiology	Int. Dev. Research Centre (IDRC), Canada
Tiraporn, Charn* *(5, C)*	Thailand	Cassava/plant breeding	CIAT
Tongsri, Somsak *(2, P)*	Thailand	Cassava/plant breeding	Int. Dev. Research Centre (IDRC), Canada
Euchiewcharnkit, Kasidit *(6, P)*	Thailand	Swine/animal nutrition	CIAT
Valle, Celio E. *(5, C)* *	Honduras	Bean/agronomy	Inter-Amer. Dev. Bank (IDB) Honduran Proj.
Vila Nova Pereira, José *(3, C)*	Brazil	Bean/agronomy	CIAT
Villavicencio, Angel *(2, P)*	Ecuador	Cassava/production	CIAT
Watananonta, Watana *(2, P)*	Thailand	Cassava/physiology	Int. Dev. Research Centre (IDRC), Canada
Zimmermann, Ma. José *(3, P)*	Brazil	Bean/breeding	CIAT
Postgraduate Production Interns			
Alvarez, Juan F. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Arias, Carlos F. *(3, C)*	Bolivia	Beef production	CIAT
Barrientos, Victor L. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Bejarano, Jorge *(9, C)*	Honduras	Beef production	Ministerio de Recursos Naturales, Honduras
Castellanos, Ramón F. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Castillo, Belisario *(9, C)*	Panama	Beef production	National Bank of Panama
Dardón, Félix *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Escobar, Luis Fernando *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Flores, Victor R. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Franco, Federico E. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
González, Ramiro *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
González, Jaime *(3, C)*	Colombia	Beef production	CIAT
Larrazábal, Luis *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Pérez, Teodoro A. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Urizar, Eduardo *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala

(Continued)

Table 2 (continued)

Name and Status[1]	Country	Program/Discipline	Source of funding
Valdés, Isidro E. *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Vasquez, Juan A. *(3, C)*	Bolivia	Beef production	CIAT
Ventura, Mariano *(9, C)*	Guatemala	Beef production	Prog. de Desarrollo Ganad. (PRODEGA), Guatemala
Citalán, Wilfrido, A. *(5, C)*	Mexico	Rice production	CIAT
García, Oswaldo *(5, C)*	Guatemala	Rice production	CIAT
Herrera, Carlos *(5, C)*	Panama	Rice production	CIAT
Jarrín, Eduardo *(4, C)*	Ecuador	Rice production	CIAT
Paz, Francisco *(5, C)*	Bolivia	Rice production	CIAT
Peixoto, Afonso *(5, C)*	Brazil	Rice production	CIAT
Quiroz, Edmundo *(5, C)*	Nicaragua	Rice production	CIAT
Rea, Wilfredo *(5, C)*	Bolivia	Rice production	CIAT
Rodríguez, José *(5, C)*	Brazil	Rice production	CIAT
Rosdao, Milo A. *(5, C)*	Ecuador	Rice production	CIAT
Sánchez, Víctor M. *(5, C)*	Honduras	Rice production	CIAT
García, Olegario* *(1, C)*	Mexico	Swine production, animal health	CIAT
Venegas, Jairo* *(1, C)*	Colombia	Swine production	Germ. Found. for Int. Dev., W. Germany
Short Course Participants			
Agudelo, Gildardo *(1, C)*	Colombia	—/seed production	Fed. Nac. de Arroceros (FEDEARROZ), Colombia
Aramendis, Hernán *(1, C)*	Colombia	—/seed production	Caja Agraria, Colombia
Arango, Rodrigo *(1, C)*	Colombia	—/seed production	Compañía Proacol, Colombia
Benavides, Fernando *(1, C)*	Colombia	—/seed production	Caja Agraria, Colombia
Bortoletto, Nelson *(1, C)*	Brazil	—/seed production	CIAT
Cervantes, Oscar *(1, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Despaigne, Gabriel *(1, C)*	Panama	—/seed production	CIAT
Deza, Aulio *(1, C)*	Bolivia	—/seed production	CIAT
Díaz, Rafael *(1, C)*	Honduras	—/seed production	CIAT
Ducuara, Pedro L. *(1, C)*	Colombia	—/seed production	Compañía Agritsa de Colombia
Escudero, César *(1, C)*	Peru	—/seed production	CIAT

(Continued)

Table 2 (continued)

Name and status[1]	Country	Program/Discipline	Source of funding
Espinosa, Frank *(I, C)*	Dominican Republic	—/seed production	CIAT
Estrada, Franceny *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Fuentes, Gustavo *(I, C)*	Ecuador	—/seed production	CIAT
Gómez, Carlos *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Hurtado, Oscar *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Marroquin, Amparo de *(I, C)*	Colombia	—/seed production	Caja Agraria, Colombia
Martínez, Pablo *(I, C)*	Colombia	/seed production	Instit. Col. Agropecuario (ICA), Colombia
Mejía, Victoria E. *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Mendoza, Alejandro *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Mondragón, William *(I, C)*	Colombia	—/seed production	Fed. Nac. de Algodoneros de Colombia
Morales, Victor A. *(I, C)*	Peru	—/seed production	CIAT
Muñoz, Mario *(I, C)*	Colombia	—seed production	Instit. Col. Agropecuario (ICA), Colombia
Prendergast, Norman *(I, C)*	Jamaica	—/seed production	CIAT
Quijano, Enrique *(I, C)*	Colombia	—/seed production	Compañía Colombiana de Semillas
Recinos, José Máximo *(I, C)*	Guatemala	—/seed production	CIAT
Rojas, Hernando *(I, C)*	Colombia	—/seed production	Semillas de la Costa Norte de Colombia
Salas, Emilio *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Salinas, Jairo *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Tello, Rodrigo *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Terrassa, Christian *(I, C)*	Colombia	—/seed production	Semillas Valle de Colombia
Torres, Augusto *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Triana, Alvaro *(I, C)*	Colombia	—/seed production	Instit. Col. Agropecuario (ICA), Colombia
Vargas, Gentil *(I, C)*	Colombia	—/seed production	Fed. Nac. de Arroceros (FEDEARROZ), Colombia
Aguilar, Juan A. *(I, C)*	Honduras	Swine production	Inter-Amer. Dev. Bank (IDB)
Barreto, Juan Guillermo *(I, C)*	Colombia	Swine production	Inter-Amer. Dev. Bank (IDB)
Berrío, Luis F. *(I, C)*	Colombia	Swine production	Inter-Amer. Dev. Bank (IDB)
Castro, Galvarino *(I, C)*	Peru	Swine production	Inter-Amer. Dev. Bank (IDB)
Chavez, Roberto *(I, C)*	Bolivia	Swine production	Inter-Amer. Dev. Bank (IDB)
Colindres, Tulio *(I, C)*	Honduras	Swine production	Inter-Amer. Dev. Bank (IDB)
Cuéllar, Francisco *(I, C)*	Bolivia	Swine production	Inter-Amer. Dev. Bank (IDB)

(Continued)

Table 2 (continued)

Name and Status[1]	Country	Program/Discipline	Source of funding
Echeverry, Iván. *(I, C)*	Colombia	Swine production	Inter-Amer. Dev. Bank (IDB)
Esquivel, Iván J. *(I, C)*	Panama	Swine production	Inter-Amer. Dev. Bank (IDB)
Fernández, Amparo *(I, C)*	Colombia	Swine production	Inter-Amer. Dev. Bank (IDB)
Franco, Carlos M. *(I, C)*	Colombia	Swine production	Inter-Amer. Dev. Bank (IDB)
Gaitán, José A. *(I, C)*	Brazil	Swine production	Inter-Amer. Dev. Bank (IDB)
García, Jorge O. *(I, C)*	Colombia	Swine production	Noel-Zenú de Colombia
Grosz, María M. de *(I, C)*	Argentina	Swine production	Inter-Amer. Dev. Bank (IDB)
López, Norberto *(I, C)*	Colombia	Swine production	Int. Dev. Research Centre (IDRC), Canada
Molina, Hugo H. *(I, C)*	Ecuador	Swine production	Inter-Amer. Dev. Bank (IDB)
Moro, Jaime *(I, C)*	Peru	Swine production	Inter-Amer. Dev. Bank (IDB)
Nunes, Adolfo *(I, C)*	Brazil	Swine production	Inter-Amer. Dev. Bank (IDB)
Olivares, Mario *(I, C)*	El Salvador	Swine production	Inter-Amer. Dev. Bank (IDB)
Ramírez, José E. *(I, C)*	El Salvador	Swine production	Inter-Amer. Dev. Bank (IDB)
Ramírez, Jairo *(I, C)*	Colombia	Swine production	Int. Dev. Research Centre (IDRC), Canada
Ramírez, Rodrigo *(I, C)*	Colombia	Swine production	Int. Dev. Research Centre (IDRC), Canada
Ruiz, Eduardo *(I, C)*	Peru	Swine production	Inter-Amer. Dev. Bank (IDB)
Urrunaga, Abel A. *(I, C)*	Peru	Swine production	Inter-Amer. Dev. Bank (IDB)
Zamora, Lilieth *(I, C)*	Costa Rica	Swine production	Inter-Amer. Dev. Bank (IDB)
Alfaro, Rodrigo *(I, C)*	Costa Rica	Bean production	Inter-Amer. Dev. Bank (IDB)
Alvarado, Leopoldo *(I, C)*	Honduras	Bean production, economics	Inter-Amer. Dev. Bank (IDB), Honduran Proj.
Arrupe, Benony *(I, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Barros, Luis E. *(I, C)*	Chile	Bean production	Inter-Amer. Dev. Bank (IDB)
Bianchini, Anesio *(I, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Bonilla, Miguel A. *(I, C)*	Honduras	Bean production	Inter-Amer. Dev. Bank (IDB)
Campos, Benedicto *(I, C)*	El Salvador	Bean production	Inter-Amer. Dev. Bank (IDB)
Dos Santos, José A. *(I, C)*	Brazil	Bean production	Germ. Found. for Int. Dev., W. Germany
Estrada, Angel *(I, C)*	Mexico	Bean production	Inter-Amer. Dev. Bank (IDB)
García, Aurora S. *(I, C)*	Argentina	Bean production	Inter-Amer. Dev. Bank (IDB)
Homero, Aidar *(I, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Idrovo, Wilson *(I, C)*	Ecuador	Bean production	Inter-Amer. Dev. Bank (IDB)

(Continued)

Table 2 (Continued)

Name and Status[1]	Country	Program/Discipline	Source of funding
Irusta, Jorge *(1, C)*	Bolivia	Bean production	Inter-Amer. Dev. Bank (IDB)
López, Tiberio *(1, C)*	Colombia	Bean production	Inter-Amer. Dev. Bank (IDB)
Mansilla, Enrique *(1, C)*	Bolivia	Bean production	Inter-Amer. Dev. Bank (IDB)
Morales, Adrián *(1, C)*	Costa Rica	Bean production	Inter-Amer. Dev. Bank (IDB)
Mundstock, Egon *(1, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Nuñez, Gary *(1, C)*	Peru	Bean production	Inter-Amer. Dev. Bank (IDB)
Osoria, Luis *(1, C)*	Mexico	Bean production	Inter-Amer. Dev. Bank (IDB)
Peña, Edgar *(1, C)*	Ecuador	Bean production	Inter-Amer. Dev. Bank (IDB)
Sanches, Mauro *(1, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Tulmann, Augusto *(1, C)*	Brazil	Bean production	Inter-Amer. Dev. Bank (IDB)
Special Trainees			
Ariza, Dario F. *(1, C)*	Colombia	Beef/microbiology	CIAT
Ataide, Nilton *(2, C)*	Brazil	Beef/animal health	CIAT
Barrera, José del Carmen *(1, C)*	Colombia	Beef/microbiology	CIAT
Boonekamp, Gerardus *(7, P)*	Holland	Bean/entomology	Univ. of Wageningen, Holland
Carrico, Deon *(2, C)*	USA	Beef/pastures & forages	CIAT
Cerqueira, Jaime *(1, P)*	Brazil	Cassava/soils	CIAT
Doorman, Frans *(2, P)*	Holland	Rice/rural sociology	Univ. of Wageningen, Holland
Gooren, Gerardus* *(7, C)*	Holland	Rice/rural sociology	Univ. of Wageningen, Holland
Hirschy, Louis *(1, C)*	Bolivia	—/hemoparasitology	Swiss Technical Cooperation, Bolivia
Hoogendoorn, Cousje *(3, C)*	Holland	Cassava/breeding	Univ. of Wageningen, Holland
Hurtado, Olga *(2, C)*	Peru	—/library/documentation	CIAT
Jiménez T., Anatolio *(2, C)*	Chile	—/station operations	CIAT
Lima, Simphronio *(1, C)*	Brazil	Beef/animal health	Emp. de Asist. Téc. y Exten. Rural, Brazil
Moradel, Martha *(2, C)*	Honduras	—/library/documentation	CIAT
Múgica, José A. *(2, C)*	Dominican Republic	—/library/documentation	Agency for Int. Dev. (AID), USA
Navarro C., Guillermo *(1, C)*	Mexico	Beef/pastures & forages	CIAT
Olaya, Rafael *(3, C)*	Peru	Rice/breeding	CIAT
Orozco, Rogelio *(1, C)*	Colombia	Beef/pastures & forages	CIAT
Peña, Neptali *(3, C)*	Peru	Rice/breeding	CIAT

(Continued)

Table 2

Name and Status[1]	Country	Program/Discipline	Source of funding
Pino, Thomas *(3, C)*	USA	Bean/agronomy	Self-supported
Puerta, Oscar *(1, C)*	Colombia	Bean/plant pathology	Instit. Col. Agropecuario (ICA), Colombia
Quijano, Jorge *(1, C)*	Colombia	Swine/animal nutrition	CIAT
Rivas, Carlos *(2, C)*	Dominican Republic	–/library/documentation	CIAT
Small, Leroy *(2, C)*	Guyana	Rice/agronomy	Agency for Int. Dev. (AID), USA
Van Dorsten, Frank *(3, P)*	Holland	Rice/rural sociology	Univ. of Wageningen, Holland
Van Gent, Rudolf* *(5, C)*	Holland	Bean/entomology	Univ. of Wageningen, Holland

forages which minimizes chemical control; cassava economics — *ex-ante* analysis of impact of new cassava production technology on small farmers; and bean breeding/agronomy — breeding and screening climbing bean varieties for associated cropping with maize.

Visiting Research Associates

This training category includes PhD candidates doing all or part of their thesis research at CIAT and post-MS professionals doing research to gain experience in tropical agriculture. In 1977, eight doctoral students and seven post-MS researchers came to CIAT. In addition, seven Visiting Research Associates who began at CIAT before 1977 continued their investigations into 1977.

Research Scholars

Individuals in this category are enrolled in a master's degree program in an accredited university. After completing their academic phase, they conduct their thesis work at CIAT. This year, seven were accepted to do their master's research within the on-going research of the Center. Thirteen Research Scholars who came to CIAT prior to 1977 continued their work into 1977.

Postgraduate Interns for Research

In this category representatives from national and regional research programs receive training in advanced research techniques. Numerically, this category is the largest in research training: 36 Postgraduate Interns for Research from 24 institutions in 15 countries came to CIAT in 1977; 11 trainees entered CIAT before 1977 and completed their training this year.

TRAINING IN PRODUCTION

Production training is provided for those representatives of national and regional institutions charged with validating improved varieties and cultural practices, and with training and supervising extension workers, credit officers, and production advisors. Training in production is designed to provide or enhance skills in field experimentation and improved production technologies and methods of planning, conducting and evaluating training programs and production campaigns. CIAT's training in production has a multidisciplinary focus but it is based on single commodities. Individuals selected for training in production are classified as Postgraduate Interns for Production. Most production training is conducted through organized group courses, however, some production training is done on an individualized basis. The average production training period during the year was seven months (excluding short course participants). In 1977, there were 112 production trainees. The following production courses were offered.

Beef Production Course

The fifth Livestock Production Specialist Training course was conducted from January through October. Candidate selection was contingent upon the trainees' returning to positions where knowledge gained in the course would be utilized in training others within their own institutions. The majority of the course participants were selected from one country (in this case, Guatemala) to assure a critical mass of trained professionals to effect real change in the traditional agricultural process. Twelve Guatemalans, two Bolivians and one person each from Colombia, Honduras, and Panama participated in the course. (For further details see Training Section, Beef Program.)

Bean Production Course

CIAT's first intensive bean production course for Latin American bean researchers was held for one month in March and April. The course provided 30 persons from 12 Latin American countries with specialized information and training experiences in all disciplines related to bean production systems. Course participants represented the following disciplines: breeding (8); agronomy (7); pathology (5); soils (3); physiology (2); technology transfer (2); entomology (1); microbiology (1); and seed production (1). This diversity in backgrounds provided for interchange of ideas among the participants in the discussions of both specific problems and general investigative methodologies. (For further details see Training Section, Bean Program.)

Rice Production Course

One five-month rice production course was held in 1977. Ten professionals from Bolivia, Brazil, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, and Panama were trained in all aspects of rice production and technology validation and dissemination. (For further details see Training Section, Rice Unit.)

Swine Production Course

In the first semester of 1976, CIAT offered its first intensive swine production course. Twenty-five professionals selected from Latin American national institutions engaged in swine production training, extension, and/or investigation participated in the six-week course. Participants represented 10 countries. (For further details, see Training Section, Swine Unit.)

Seed Production Course

A four-week course in seed production was conducted at CIAT in cooperation with the Instituto Colombiano Agropecuario (ICA) and Mississippi State University, USA, with financial assistance from the United States Agency for International Development (USAID).

The course objectives were to provide skills in all aspects of seed production, processing, and commercialization, and to train participants in planning, developing, and operating seed enterprises and seed services. Specialists from CIAT, ICA, and Mississippi State conducted the course which included formal presentations, laboratory and field experiences, and visits to seed operations in the Cauca Valley of Colombia. Thirty-four professionals attended the course (10 from other Latin American and Caribbean institutions, and 24 from ICA and private seed companies in Colombia).

TRAINING IN MANAGEMENT OF EXPERIMENT STATIONS

In 1977, CIAT trained five managers of experimental stations in Chile, Colombia and El Salvador, in in-service programs lasting from two to five months. Training was supervised by CIAT's experiment station superintendent. Most of the work was in CIAT, but was supplemented by visits to substations in Carimagua and Quilichao, plus visits to other stations in Colombia and Ecuador. (For further details see Training Section, Station Operations.)

TRAINING IN DOCUMENTATION

Four Latin American information specialists from agricultural institutions in Chile, the Dominican Republic, Honduras, and Peru were trained in organizing and operating an agricultural documentation center. Specific skills taught included bibliographic searches, abstracting, and classification of documents. Documentation training was standardized to a two-month training period of formal presentations, practice sessions, and other in-service training. (For further information see Training Section, Library and Information Services.)

GEOGRAPHIC ORIGIN OF TRAINING PARTICIPANTS

One-hundred sixty-six (85 percent) of the training participants received in 1977 represented countries of the tropical Americas and the Caribbean. Ten trainees came from other developing regions of the world and the remaining 19 trainees came from developed countries.

FINANCING OF TRAINING

Of the 195 persons entering training in 1977, 72 were financed from the Center's core budget. Of the remainder, 48 trainees were financed by international funding agencies, 20 by national institutions in developed countries, 34 by governmental and credit institutions in developing countries, 10 by universities, 9 by private companies, and 2 through self-support.

WITHIN-COUNTRY TRAINING ASSISTANCE

During 1977, two projects — one in Guatemala and the other in the Dominican Republic — continued to receive CIAT training assistance.

Guatemala

Since 1975 CIAT has assisted the Guatemalan Instituto de Ciencias y Tecnologia Agricola (ICTA) in building its internal training program. Part of this assistance was to help organize and conduct a within-country crop production course for 14 professionals in 1976.

In 1977, a second crop production course was organized and held in Eastern Guatemala. With funding from the Inter-American Development Bank, CIAT stationed a training associate in Guatemala for the entire year to assist with the course in which 19 professionals participated. Nine of these persons were recent graduates in agronomy and were scheduled to begin working for ICTA after completing the training program.

The theoretical part of the course was taught in Jutiapa. For practical field experience, which represented about 80 percent of the course content, small groups were formed, assigned a vehicle, field laborers and an instructor, and sent to work in various localities. In the field they conducted validative regional trials and experiments in farmers' fields as well as disseminating technical information to local producers. These course activities followed the model developed at CIAT for within-country training. Near the end of the year an ICTA-selected evaluation group assessed the progress and accomplishments of the course; recommendations are being used to plan future training activities in ICTA.

Dominican Republic

In 1976 the Secretary of State for Agriculture, through the Under-secretary for Research, requested CIAT's assistance in organizing a series of short courses for rice production specialists. These courses constitute an integral part of the government's campaign to make the country self-sufficient in rice production.

Early in 1977 a CIAT training associate was stationed in the Dominican Republic to assist in organizing and conducting three consecutive ten-week courses. Sixty farm administrators and extension workers participated in these courses designed to provide competencies in all aspects of modern rice production, including diagnostic and problem-solving skills, plus competencies in dissemination of materials and technical information to producers. Care was taken to assure that participants would contribute to continuing the training program beyond 1977, without CIAT's direct assistance. Four more courses of this type were scheduled for 1978.

TRAINING MATERIALS

Efforts were expanded in 1977 to package a good part of CIAT-generated information on new production technologies for training purposes. Individuals charged with actually producing training materials — in the form of audio-tutorial units — completed a training phase and a considerable degree of team work was achieved among these professionals. Modifications to the facilities needed for producing and utilizing the audio-tutorial units were also completed during the year. Twenty study carrels were installed and equipped with audio and visual playback equipment.

Although full-scale production of materials did not begin until the last quarter of 1977, after final approval of the special project funding on which all production of training materials depends, during the year units were produced in cassava, beans, rice, swine, and weed control. Based upon a continuing evaluation, procedures for developing the materials were modified in an effort to make the training materials truly fit CIAT training needs. Many of the completed units were successfully used in production courses and conference events at CIAT. An appropriate infrastructure for more systematic utilization of training materials will be established in 1978.

Conferences

The CIAT Conferences Office fulfills a principal role in the Center's efforts to receive, pass on and interchange information related to its technology development and dissemination endeavors. Conference logistics support is provided on a continuing basis. Also, communication advice for planning, coordinating, and evaluating conference events is made available by staff of the Center.

The Center's conference resources are utilized for four types of events. These are briefly described below. Table 3 lists the 26 main events in categories (1), (2), and (4) which were held in 1977.

(1) CIAT-sponsored or co-sponsored scientific exchanges. These are considered crucial to the Center's achievement of its stated objectives, be they in the area of research or international cooperation, or a combination of the two. For these events, CIAT assumes responsibility for the planning, selection of candidates, conduct, evaluation, and follow-up activities.

(2) CIAT organizational events. The purpose of these meetings is to contribute to efficient and effective functioning of the Center from an organizational and administrative viewpoint. Such events include Center or program reviews and planning conferences.

(3) CIAT internal communication events. These meetings have two purposes. First, they provide an opportunity for visitors (scientists and other professionals) to formally address interested members of CIAT's community. In 1977, visitors presented 23 such meetings and seminars. Secondly, these events provide a forum for internal exchanges of technical information. To this end, an internal seminar series was reinstituted during the year. In this series CIAT scientists present 90-minute seminars with discussions, on alternate Fridays. Fifteen such presentations were given during the year.

(4) CIAT-hosted events. These events support an effort to make the Center's considerable conference resources available to outside entities whose activities relate to CIAT's objectives. For such events, the Center provides its facilities at no cost, but charges the sponsoring agency for all direct costs incurred by its conference.

Throughout the year conference facilities were utilized with great frequency by CIAT training courses and other day-to-day needs for meeting places by CIAT's programs, thus assuring a continuous high-occupancy rate of the installations.

Table 3. **Major events held in CIAT's conference facilities during 1977.**

Date	Event	No. of participants
CIAT sponsored or co-sponsored scientific exchanges		
2 - 4 May	Presentation Days	60
17 - 21 Oct.	Workshop for Swine Production Specialists	37
31 Oct. — 3 Nov.	Workshop on Development of Strategies to Improve Rice Production in Latin America	39
4 - 5 Nov.	IRRI/CIAT Meeting on Regional Rice Trials	43
7 - 12 Nov.	Workshop on Cassava Plant Protection	32
CIAT organizational events		
22-24 Feb.	Review of ICA/CIAT Cooperation	10
18 - 30 April	TAC Quinquennial Review	15
30 May — 4 June	Joint TAC/International Center Directors Annual Meeting	40
1 - 7 Dec.	CIAT Internal Program Reviews	60
12 - 13 Dec.	First Meeting of Advisory Committe, UNDP/CIAT Special Project	10
CIAT training courses		
17 Jun. — 31 March	Beef Production (CIAT Phase)	17
28 March — 22 April	Bean Production	30
11 April — 25 May	Swine Production	25
16 July — 16 Dec.	Rice Production	10
13 - 16 Sept.	Special Short Course on Continuous Rice Production for ICA Professionals	15
17 Oct. - 11 Nov.	ICA/USAID/Mississippi State Univ./CIAT Seed Production	36
CIAT hosted events, sponsored by other institutions		
27-28 Jan.	Colombian Caja Agraria: Regional Directors' Meeting	40
22 Feb.	Colombian Soc. of Soil Sciences: Management of Soils of the Cauca Valley	80
11 - 14 March	Dow Chemical Co.: Planning Research in Agrocheoicals in Latin America	25
5 - 7 May	Meeting of Directors of Latin American Agricultural Postgraduate Schools (ALEAP)	12
23 - 27 May	USAID: Workshop on Rural Development	47

(continued)

Table 3 (continued)

Date	Event	No. of participants
2 - 19 July	Latin American Confederation of Credit Cooperatives (COLAC): Seminar on Credit for Agricultural Production	25
20-22 Sept.	IDRC: Workshop to Identify Research Priorities in Bananas and Plantains	28
30 Sept.	ASOCAÑA: Evaluation of Industrial Chemicals in Sugar Production in Colombia	80
5 - 6 Oct.	Regional Committee for Agricultural Production: Evaluation	100
24 - 28 Oct.	IDRC: Communication in Rural Development	60
14 - 18 Nov.	SENA/German Technical Mission: Technical Assistance on the Andean Region	80
	Total participants	1056

CIMMYT-CIAT Regional Andean Maize Unit

The CIMMYT/CIAT Regional Andean Maize Unit is a cooperative program between the two international centers. The Unit's two senior scientists are CIMMYT staff members assigned to work out of CIAT in extending improved maize production technology to national programs in the Andean countries. The team's efforts in this region form an important part of CIAT's overall international cooperation program. About 80 percent of the team's time is devoted to various international cooperation activities with the remainder spent on breeding and evaluation work at CIAT. After the arrival of the second senior scientist at the beginning of this year, the team has been able to fully develop and carry on its planned program.

INTERNATIONAL COOPERATION ACTIVITIES

Evaluation of Materials

An important part of the Andean maize team's work is the assembly and distribution of various types of maize trials within the region. During 1977, the team assisted in placing 46 nurseries; the nurseries and the countries receiving them are shown in Table 1. These trials are being grown by the national maize programs with assistance by the local team.

Among the entries in regional variety trials are the best varieties or open pedigree hybrids from national breeding programs. These trials, which are assembled for either highland or tropical conditions, provide a convenient method to demonstrate materials that may be useful outside the area of origin. Table 2 shows how a number of varieties planted in tropical trials late in 1976 performed as well as or better than the best local check varieties.

The team also assisted in establishing 132 variety and verification trials in farmers' fields at six localities in four countries. Verification trials are designed to validate local technology packages including improved materials.

In Bolivia, 20 verification trials were planted in the Santa Cruz area in cooperation with the Centro de Investigación de Agricultura Tropical and the Instituto Boliviano de Tecnología Agropecuaria (IBTA); two variety trials were planted at Mairana, with IBTA. Colombian trials were variety evaluations at 21 sites in Antioquia, with the local Secretary of Agriculture and the Instituto Colombiano

Table 1. **Regional maize trials distributed in the Andean zone during 1977.**

Type of trial	No. of entries	Countries and No. of sets					
		Bolivia	Colombia	Ecuador	Peru	Venezuela	Total
Highland trials							
Variety Trial (ENZAS)	25	1	1	1	2	-	5
Introduction Nursery	42	1	1	3	2	-	7
Resistance to Earworm	200	1	1	1	3	-	6
Peruvian Racial Comp	26	1	1	1	-	-	3
Lowland trials							
Opaque Materials	37	2	2	2	1	-	7
Variety Trial (ENZAT)	36	2	2	2	3	2	11
Introduction Nursery	68	-	1	1	1	1	4
Early-maturing Varieties	14	-	1	1	-	1	3

Agropecuario (ICA), and another 14 variety trials in Cauca, with the Desarrollo Rural Integrado and ICA. In Ecuador, in the Imbabura area, 15 verification trials were established in cooperation with the Instituto de Investigaciones Agropecuarias. Sixty verification plantings were made at Callejón de Huaylas, in Peru, with the Programa Cooperativo de Investigación del Maíz of the Universidad Nacional Agraria "La Molina".

Figure 1. A member of the CIMMYT/CIAT maize team discusses the performance of improved materials being grown in these on-farm trials in Ecuador.

Training

The maize team helped organize or assisted with five workshops during 1977. Two tropical maize workshops were held at CIAT, in February and June, and floury maize workshops were convened in Bolivia, in April, and in Ecuador, in June. The team also participated in a floury maize workshop in Mexico during October.

Fifteen professionals from maize programs in the five Andean countries were identified to receive training at CIMMYT and five scientists from four of the countries were sent to CIMMYT to participate in maize research as visiting scientists.

Table 2. **Performance of the best maize varieties at five locations in the 1976-77 Lowland Variety Trial (ENZAT).**

Countries and best performing varieties	Locations and Yields (t/ha)					
	Peru		Ecuador		CIAT-Palmira	
	La Molina	San Ramón	Boliche	Pichilingue	I (Jan.)	II (Mar.)
Colombia						
ICA H-302	3.5 (69%)[1]	4.8 (71%)	-	-	6.7 (87%)	-
ICA V-106	-	-	3.7 (109%)	-	-	-
ICA H-154	-	-	-	5.0 (102%)	-	8.0 (72%)
Venezuela						
Comp. Semiden-71	3.2 (63%)	3.8 (56%)	-	4.6 (94%)	-	-
Comp. Int. 68-1	-	-	3.3 (97%)	-	-	-
Var. Simeto	-	-	-	-	6.9 (90%)	10.0 (90%)
Peru						
PMC-15	4.3 (84%)	-	-	-	-	-
POB-1	-	-	3.0 (88%)	5.5 (112%)	-	-
PMC-747	-	5.8 (85%)	-	-	6.5 (85%)	9.2 (83%)
Ecuador						
INIAP-515	3.7 (73%)	-	-	6.0 (122%)	-	-
Var-3 Pichil.	-	-	3.9 (115%)	-	-	-
Pichil.-504	-	6.2 (91%)	-	-	-	-
Var-13	-	-	-	-	6.9 (90%)	-
Var-2	-	-	-	-	-	8.3 (75%)
Bolivia						
Tuxp.P.B.C-2	3.9 (76%)	-	-	-	-	-
Sint. 1-Lin. (PD Ms-6)	-	6.2 (91%)	-	-	6.5 (85%)	-

[1] Values in parentheses are the yield comparison with the best local check.

ACTIVITIES AT CIAT

Variety Trials

In support of CIMMYT's international evaluation network three Experimental Variety Trials (EVT), each with 25 varieties, and four International Progeny Testing Trials (IPTT), each with 256 families, were grown during late 1976 and in 1977. Mean results in Table 3 indicate that some varieties in the EVT 14B and several families in the four IPTT's are high yielding under CIAT conditions.

The best experimental varieties from EVT's at all locations will be promoted for international testing throughout the region. Outstanding families from each IPTT will be used to form an experimental

Table 3. **Performance of maize materials in the 1976-77 Experimental Variety Trials (EVT) and International Progeny Testing Trials (IPTT), at CIAT-Palmira.**

Trial	No. of entries	Yield (kg/ha)		Days to flowering		Plant height (cm)		Lodging (%)
		Mean	Range	Mean	Range	Mean	Range	Mean
EVT 14B		5949	4871-7216	65	63-69	250	225-265	31
EVT 15		4066	2841-4953	60	57-64	238	210-220	38
EVT 16		3390	1494-4865	63	61-65	260	220-285	86
IPTT 23		4111	532-7282	63	61-68	245	208-270	47
IPTT 27		4050	1696-9491	65	61-69	261	210-298	57
IPTT 31		4815	1818-7713	69	65-72	209	143-263	19
IPTT 42		4553	1942-7673	63	60-68	249	218-280	29

variety, seed of which will be available for further testing by national programs in 1978.

Opaque-2 Materials

Breeding and selection work is being done at CIAT with two populations to develop opaque-2, hard endosperm materials. This work supports CIMMYT's strategy of creating counterpart materials with those characteristics for each of its existing populations.

In late 1976, a progeny test of the PD(Ms-6)o_2 HE population was planted for half-sib crossing. From this trial 209 families were selected for half-sib crossing again this year. Based on desirable endosperm type and protein quality, 139 families were selected. After another half-sib crossing late this year, final selections will enter regional trials in 1978.

A yield trial was planted with 29 selections made at CIAT last year from the Tuxpeño-1 populations. Twenty-four families were selected based on their endosperm type and yields, and these will be tested further. Average yield of the families was 3.5 t/ha with the best families yielding about 5 t/ha.

Brachytic-2 Materials

Progenies of full-sib and half-sib brachytic (br2) selections previously made at CIAT were planted for seed increase. Within-family sibs were made in 178 families. Progenies will be planted in yield trials at CIAT next year with the best families to be selected for regional testing. The same procedure is under way with 30 materials selected for short plant height (11 yellow grain and 19 white grain types) previously selected.

Selection for Earliness

From a trial of 600 entries originating from CIMMYT, 186 families were selected for flowering dates of 54 days or less. Sib matings were made within each family. Progenies will be in regional trials in 1978.

Fall Armyworm Resistance

Families showing resistance to the fall armyworm *(Spodoptera frugiperda)* were selected from five CIMMYT advanced populations. Selections were brought from Mexico and within-family sibs were made. Progeny will be selected under conditions of artificial infestation with promising selections to enter regional testing for eventual development of experimental varieties.

Downy Mildew Resistance

A sib increase planting was made of Suwan-1, a downy mildew resistant variety from Thailand. The variety was planted in regional trials during 1977 in Bolivia, Colombia, Ecuador and Peru. The original resistance sources (from the Philippines) were also planted in a seed increase plot at CIAT.

Venezuelan materials also resistant to downy mildew were planted this year in an observation nursery. Selected materials will enter yield trials next year.

Screening for Poor Soil Conditions

With the development of the CIAT-Quilichao substation, located on soil with low pH and high aluminum saturation, an excellent opportunity exists for screening materials for these conditions. This year, 192 maize varieties of several types and sources were planted at this site. This screening will serve as a basis for deciding which materials should be carried into a breeding scheme to develop populations tolerant to these adverse conditions.

Maize/Sugar Cane Associations

In the Cauca Valley of Colombia an experiment was developed to test the possibility of producing maize between the rows of slower growing sugar cane in the period immediately after the cane is planted or cut. A major objective was to find a system in which cane yields would not suffer, even at the expense of the maize.

Table 4. **Yields of four maize varieties grown in association with sugar cane in two planting systems and at three levels of applied nitrogen.**

Variety	Planting system	Yield (t/ha)		
		0 kg N/ha	69 kg N/ha	92 kg N/ha
ICA H-207	I	1.6	2.2	3.0
	II	1.9	2.2	2.4
ICA H-210	I	2.4	2.6	2.4
	II	2.1	2.8	2.6
ICA MB-21	I	2.3	2.6	2.5
	II	2.0	2.7	2.5
La Posta	I	2.6	3.2	2.8
	II	2.1	2.8	2.6
Mean		2.1	2.6	2.6

Trials were done in cooperation with ICA and the Ingenio Central Castilla sugar mill.

Four local maize varieties were planted in two systems — one row of maize in each alley between the cane and two rows of maize in every other alley. Urea was the only fertilizer applied, at rates of 0, 69 and 92 kg N/ha. Intended maize populations of 26,000 plants/ha for both systems were not attained because of poor germination due to dry conditions at planting.

Maize yields are shown in Table 4; sugar cane will not be harvested until mid-1978. The variety La Posta yielded significantly more than the other three maizes, and for the conditions of this experiment, it was uneconomical to apply more than 69 kg N/ha. No significant differences were found between the two planting systems.

Library and Information Services

The Library and Information Services Unit at CIAT offers a complete service of *consolidated information*, a new concept in the supply of information. There is a very close interaction between scientific research activities and information services. Teams of the different research programs are supported by an efficient and complete service; on the other hand, the Documentation Center is able to offer outstanding services because it is backed by the invaluable collaboration of specialists in the different disciplines. One of the main highlights of the Documentation Center during 1977 was the development of activities under Phase II of the special Cassava Project, funded by the International Development Research Centre (IDRC), of Canada. Under this new philosophy, documentation *per se* was better integrated with other communication activities, as can be seen from services provided during 1977.

DOCUMENTATION CENTER SERVICES

Abstract Cards

Subscribers continued to receive monthly abstract cards on articles processed in the areas covered by the Center: cassava, beans and Latin American agricultural economics. Efforts were made to recover nonconventional material from Latin America, which is often of great value to researchers.

Initial interest profiles were made for the Beef Program, as a basis for making both a five-year retroactive bibliographic search as well as to initiate a current awareness service on tropical pastures and forages in 1978. This service will operate along the same lines of the already successful experience of the Cassava Information Center.

Subscription to the large documentation services (such as DIALOG) in the developed countries opened the possibility of fast and comprehensive compilations of literature which constitute a major input for specialized abstracting services. This is possible through Telex at a moderate cost. The utilization of Telex to access large information centers on-line illustrates the advantageous use that can be made of intermediate technologies in the lesser developed countries despite the fact that in more advanced countries these technologies have been replaced by faster means such as telephone lines.

Photocopying Services

All documents covered by the Center's abstracting service are available as photocopies. The demand for photocopies generated both by the abstracting services and the Contents Pages Service is frequently met by local libraries in the countries. This is the case, for example, of the Agronomy Faculty Library at the University of Buenos Aires which has almost doubled its output of photocopies from the time CIAT's Contents Pages started to be distributed among Argentinian agricultural scientists as a service of the National Information System of Argentina.

Annual Cumulative Volumes of Abstracts

In addition to the three new cumulative volumes of abstracts produced this year (Vol. III in Cassava, Vol. II for Beans and Vol. II for Agricultural Economics), Vol. II of Abstracts on Cassava and Vol. I of Abstracts on Beans were published in Spanish.

Specialized Searches

In addition to retrospective searches in the collection, the library and documentation service prepares short, specific bibliographies on request, including as many abstracts as available. Twenty-six were produced in 1977.

Newsletter

Subscribers to the Cassava Documentation Center received the semiannual Cassava Newsletter, which gathers information about on-going cassava research, industrial applications and cultivation data. It also includes articles on who's who in the field, latest publications of interest, workshops and other general information.

Monographs and Manuals

As a vital part of *consolidated information*, the Cassava Documentation Center published a practical manual "Production of cassava planting material" in English, Spanish and Portuguese. The manual was written by four scientists from the Cassava Program, J.C. Lozano, J.C. Toro, Abelardo Castro and A.C. Bellotti.

The Center is also translating a more extensive version of the monograph "Mite and insect pests of cassava" by CIAT entomologists A.C. Bellotti and A. van Schoonhoven. Another important monograph, "The impact of high-yielding rice varieties in Latin America, with special emphasis in Colombia" by G.M. Scobie and R. Posada, former economists at CIAT, was also published.

Tables of Contents

The service of reproducing tables of contents of journals received by CIAT continued. The Selected Book Review service covering reviews published in technical journals also continued as an important current awareness tool for both scientists and librarians.

Thesauri

The two thesauri containing the specialized key words or descriptors used in the documentation center for recovering documents in the areas of cassava and beans were revised and up-dated in collaboration with an expert from IDRC, Mr. Donald Leatherdale. The Cassava Thesaurus was published for distribution to other documentation centers working in this area.

CIAT's thesauri (cassava, beans, and agricultural economics and development) were reproduced in limited numbers by the Inter-American Program for Information and Communication (PIADIC) and distributed to all Central American countries, Panama and the Dominican Republic. These countries have adopted the CIAT model of technical information management and they are setting up national information systems in the agro-industrial sector which will eventually be linked into a Central American network. In connection with this activity of PIADIC, the

Library and Information Services Unit Coordinator served as a consultant in giving two conferences in each of the abovementioned countries —one for policy-markers and other higher government officials, and another for personnel in charge of the actual operation of services—with the purpose of creating a greater awareness of such information systems.

Directory of Cassava Workers

This directory of workers and researchers in the field was updated from questionnaires sent to individuals and research institutions. The directory is distributed among cassava workers all over the world to improve communications among them.

Training

Two month in-service training courses in documentation were given to two students from the Dominican Republic and one each from Peru and Honduras. One student from the Dominican Republic was trained in administrative aspects of a library and documentation center and two other persons from the same country were given a general overview of modern library operation. Shorter informal training was given to one student each from Guatemala and Bolivia, and five from Colombia.

A special intensive course was organized for training documentalists, to be followed by practical work in their areas of interest. Beginning in 1978, this course will be offered once a year. The Unit Coordinator and the Assistant to the Coordinator did a special consultantship in the Dominican Republic, whereby a specific project and work program was adopted by that country to establish a national agricultural information system. At the same time, arrangements were made with Dominican Republic agricultural institutions for widespread use of CIAT's documentation and information services.

PUBLIC INFORMATION OFFICE

During 1977 the Public Information Office attended 3736 visitors including university students, farmers, scientists and production specialists from many parts of the world.

Emphasis has been placed on making CIAT's activities better known through the public media. Many articles and press releases appeared in newspapers, magazines and pamphlets of several Latin American countries, Canada, Europe and Southeast Asia. Several short news segments and documentaries were filmed by television networks from Canada and Colombia, the latter with emphasis on CIAT's role in national development. CIAT also provided exhibits in several national and regional agricultural fairs and related events.

INFORMATION SERVICES

Because of the ever-increasing volume of work in this section, an automatic collator, a Multilith 2850 duplicator and a photomechanical camera were acquired to facilitate the work flow, increase overall efficiency of the print shop and decrease costs.

In addition to 44 publications (including 12 Annual Report separates) in the CIAT series printed in 1977 a large volume of material (artwork, slides, study guides) was prepared for Training and Conferences, and duplicating, graphic arts, photography and editing services were provided to support CIAT's programs.

CIAT PUBLICATIONS

The following publications (grouped by series) were produced by the Library and Information Services Unit during 1977:

AE-5	Noti-CIAT
AS-5	Noti-CIAT
AE-4	Cassava Newsletter
AS-4	Yuca Boletín Informativo
AE-5	Cassava Newsletter
AS-5	Yuca Boletín Informativo
BE-8	Annual Report
BS-8	Informe Anual
BE-9	1976 Research Highlights
BS-9	1976 Progresos
CE-12	Workshop on Hemoparasites
CS-13	Memorias Seminario sobre Hectoparásitos
DS-6	La Yuca: El Desarrollo de una Red Imternacional de Investigación
ES-23	Subproductos de la caña de azúcar en la nutrición porcina
ES-24	Semilla y torta (harina) de soya en alimentación de cerdos
ES-25	Utilización de torta (harina) de algodón en alimentación de cerdos
ES-26	Sistemas de producción de cerdas lactantes y lechones
ES-28	Revestimiento de canales de riego con una mezcla de suelo-cemento
FS-13	Plegable sobre Centro de Documentación
GE-17	Production of Cassava Planting Material
GS-17	Producción de Material de Siembra de Yuca
GP-17	Producao de Material de Plantio da Mandioca
GS-18	Manejo y Control de Malezas en el Trópico
HS-28	Yuca Vol. II
HS-29	Bibliografía Frijol Vol. I
HE-31	Abstracts on Cassava Vol. III
HS-31	Yuca Vol. III
HS-33	CEDEAL Vol. II
JE-01	The impact of high-yielding rice varieties in Latin America with special emphasis in Colombia
JS-01	El impacto de las variedades de arroz con altos rendimientos en América Latina con énfasis en Colombia
IRRI-CIAT	Sistemas de Evaluación Estándar para Arroz
IRRI-CIAT	Programa de Pruebas Internacional de Arroz 1976

Note: Reports for the six commodity programs were also published separately in both languages.

ICTA-Guatemala

Since 1973 CIAT has collaborated with the Government of Guatemala in providing direct and indirect assistance to the Instituto de Ciencias y Tecnología Agrícolas (ICTA) — the national agricultural research and outreach institution of that country. From its beginning, ICTA has not only strived to generate new technologies at the national level, but also to adapt and validate technologies through on-farm testing as a part of the experimental process, insuring that farmers play an active role in validation activities.

STAFF SUPPORT

During ICTA's development, two CIAT staff members have been parts of the organizational sturcture of the institution. One scientist, serving as Associate Director, has participated in overall decision-making with special emphasis on planning, strategies and training. The second, who has served as Director of Experiment Station Operations, has supervised the development of that phase of ICTA's activities.

At the request of ICTA, this year CIAT assigned two additional scientists to work with the ICTA Bean Program — one as Plant Breeder and Coordinator of the program and the other as Plant Pathologist. In addition, other CIAT staff frequently collaborate with counterparts in ICTA as a part of their normal research and international cooperation activities.

TRAINING

An important form of collaboration with ICTA has been in the area of training. Training assistance is either provided at CIAT where selected professionals participate in scheduled courses, or as in-service training in Guatemala in structured courses in specified commodities and in the field strategies of ICTA. Twenty technicians have received training at CIAT in general agronomic production and in rice and beans production and beans production and experiment station management.

A CIAT training associate has coordinated the in-service training in Guatemala, which is directed to general agronomic production techniques. Fourteen persons received training in 1976 and a second course this year had 19 participants. The courses were designed to train agronomists at the University level for future positions with ICTA and also to train future instructors for ICTA programs. Seven instructors were trained in the two courses.

The in-service courses featured about 70 percent field work. Regular production teams were removed from the training area and the course participants assumed the responsibility for the ICTA field program. This permits traineees to spend about 50 percent of their training time contributing to institutional goals as well as participating in the learning experience.

Financial Report

Price Waterhouse & Co.

APARTADO AEREO 180 · CALI, COLOMBIA

February 16, 1978

To the Board of Trustees of

Centro Internacional de Agricultura Tropical (CIAT)

In our opinion, the accompanying balance sheet and the related statement of revenue and expenditures and unexpended funds present fairly the financial position of Centro Internacional de Agricultura Tropical (CIAT) at December 31, 1977 and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year. Our examination of these statements was 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 also encompassed the schedules of analysis of grants and related expenditures, earned income, comparison of approved budget and actual expenditures and dates of receipt of grants for the year ended December 31, 1977, which are presented as supplementary information, and, in our opinion, these schedules present fairly the information shown therein.

Price Waterhouse & Co.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
BALANCE SHEET
(Expressed in thousands of U.S. dollars)

	December 31		
ASSETS	**1977**	**1976**	**1975**
CURRENT ASSETS:			
Cash	2,481	1,481	1,152
Accounts receivable:			
Donors	288	1,616	607
Employees	91	57	66
Others	1,091	425	311
	1,470	2,098	984
Inventories	549	345	250
Prepaid expenses	10	11	5
Total current assets	4,510	3,935	2,391
FIXED ASSETS:			
Equipment	2,104	1,963	1,721
Vehicles	918	685	593
Vehicles (replacements) in transit	192	149	330
Furnishings and office equipment	1,103	938	930
Buildings	4,954	4,773	4,495
Other	69	25	46
Total fixed assets	9,340	8,533	8,115
Total assets	13,850	12,468	10,506
LIABILITIES AND FUND BALANCES			
CURRENT LIABILITIES:			
Bank overdraft		18	14
Accounts payable	1,542	807	758
Total current liabilities	1,542	825	772
GRANTS RECEIVED IN ADVANCE	228	180	250
FUND BALANCES:			
Invested in fixed assets	9,340	8,533	8,115
Unexpended funds (deficit):			
Core —			
Unrestricted		70	303
Working fund grant	700	600	600
Capital grants	1,689	1,964	185
Special projects —			
Donors	442	315	340
Other	(91)	(19)	(59)
	2,740	2,930	1,369
Total fund balances	12,080	11,463	9,484
Total liabilities and fund balances	13,850	12,468	10,506

The notes on page I-5 are an integral part of the financial statements.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
STATEMENT OF REVENUE AND EXPENDITURES AND UNEXPENDED FUNDS
(Expressed in thousands of U.S. dollars)

	Year ended December 31		
	1977	1976	1975
Revenue:			
Core:			
Operating grants —			
Unrestricted	7,847	4,500	4,180
Restricted	310	1,145	1,090
Working fund grant	100		500
Capital grants	498	1,858	257
Total Core	8,755	7,503	6,027
Special projects	785	725	593
Earned income	499	339	339
Total revenue	10,039	8,567	6,959
Expenditures:			
Core programs:			
Direct research —			
Beans	931	698	517
Beef	1,258	831	813
Cassava	743	573	413
Rice	239	206	201
Swine	144	150	211
Genetic Resources	139		
Special Studies	62		
Maize			78
Small Farm Systems			160
	3,516	2,458	2,393
Research support	1,011	602	328
Total research	4,327	3,060	2,721
International cooperation:			
Training and Conferences	798	634	527
Library and Information Services	693	515	438
Total international cooperation	1,491	1,149	965
Administration expenses	836	670	598
General operating costs	1,471	999	986
Technical Advisory Committee — Expenses of Quinquennial Review	63		
Total Core Programs	8,388	5,878	5,270
Special projects	730	710	613
Purchases of fixed assets	1,111	418	768
Total expenditures	10,229	7,006	6,651
Excess of revenue over expenditures:			
Operating grants	(70)	(233)	271
Working fund grant	100		500
Capital grants	(275)	1,779	(443)
Special projects	55	15	(20)
	(190)	1,561	308
Unexpended funds at beginning of year	2,930	1,369	1,061
Unexpended funds at end of year (see balance sheet)	2,740	2,930	1,369

The notes on page I-5 are an integral part of the financial statements.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
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	37.92	Year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	36.79	Average monthly rate of exchange applicable to sales of dollars

NOTE 3 — OPERATIONS:

The agreement with the Colombian government under which CIAT operated expired in October 1977 and is in the process of being renewed. Officials of CIAT are of the opinion that the original agreement will be extended for an as yet undefined period of time.

NOTE 4 — ACCOUNTS RECEIVABLE FROM DONORS:

Accounts receivable from donors as at December 31, 1977 comprised:	$000
Government of Belgium:	
1977 grant	149
Special project	41
	190
Government of the United Kingdom:	
Balance of 1977 grant (capital)	48
Others	50
	288

SCHEDULE 1

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
ANALYSIS OF GRANTS AND RELATED EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1977
(Expressed in thousands of U.S. dollars)

	Total funds available	Expenditures: Fixed assets	Expenditures: Total research	Expenditures: International cooperation	Expenditures: Adminis-tration	Expenditures: General operating	% of administration and general oper-ating to research and international cooperation	Transfer to unexpended balance
Unrestricted Core:								
Government of Australia	143							
Government of Belgium	149							
Canadian International Development Agency	905							
The Ford Foundation	300							
Government of the Federal Republic of Germany	606							
Inter-American Development Bank	2,167							
International Development Association	307							
Government of Japan	150							
Government of the Netherlands	200							
The Rockefeller Foundation	400							
Government of Switzerland	180							
United States Agency for International Development	2,340							
Balance from previous year	70							
Income applied in year	161							
Total unrestricted Core	8,078		4,527	1,331	805	1,415	38	
Restricted Core:								
The W.K. Kellogg Foundation	310							
Total restricted Core	310			223	31	56	39	
Working fund grants:								
International Development Association	100							
Balance from previous year	600							
Total working fund grants	700							700

Continued on page I-7

SCHEDULE 1 (cont.)

	Total funds available	Expenditures: Fixed assets	Total research	International cooperation	Adminis-tration	General operating	% of administration and general operating to research and international cooperation	Transfer to unexpended balance
Capital grants:								
Inter-American Development Bank	228							
International Development Association	68							
The Rockefeller Foundation	(5)							
Government of the United Kingdom	177							
Others	30							
Balance from previous year	1,964							
Income applied in year	338							
Total capital grants	2,800	1,111						1,689
Special projects (1):								
Government of Belgium	41		2					39
CIMMYT (Canadian International Development Agency)	80			74	4	5		3)
The Ford Foundation	76		11	10				55
Inter-American Development Bank	186		40	100	4	4		38
International Board for Plant Genetic Resources	52		52					
International Development Research Centre (Canada)	334			194	17	16		107
International Fertilizer Development Center	48		6					42
International Minerals and Chemical Cooperation	9		9					
International Rice Research Institute	8		19					11)
The Rockefeller Foundation	100			16		1		83
United Kingdom — Ministry of Overseas Development	31		5					26
United Nations Development Programme				22				22)
United States Agency for International Development	14			54	4	4		48)
Others	102		6	51				45
Total special projects	1,081		150	521	29	30	9	351
Total grants and expenditures	12,969	1,111	4,677	2,075	865	1,501	35	2,740

(1) Includes balances brought forward from previous year of US$ 296,000.

SCHEDULE 2

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1977

(Expressed in thousands of U.S. dollars)

Sources of earned income:	
Interest on deposits	301
Sale of farm produce and services	92
Use of CIAT facilities	106
	499
Applied to:	
Operations	161
Capital	338
	499

SCHEDULE 3

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1977
(Expressed in thousands of U.S. dollars)

	Core unrestricted		Core restricted		Capital	
	Approved budget*	Actual	Approved budget *	Actual	Approved budget *	Actual
Programs						
Direct research:						
Beans	995	931				
Beef	1,412	1,258				
Cassava	746	743				
Rice	316	239				
Swine	184	144				
Genetic Resources	145	139				
Special Studies	106	62				
Research support	717	1,011				
International cooperation:						
Training and Conferences	651	601	208	197		
Library and Information Services	669	667	25	26		
Administration	769	805	28	31		
General operating costs and other	1,310	1,415	49	56		
Technical Advisory Committee — Expenses of Quinquennial Review	50	63				
Total	8,070	8,078	310	310		
Capital						
Fixed assets					2,770	1,111
Total					2,770	1,111
Analysis of variances						
Budget deficit:						
Additional income		(8)				
Budget surplus:						
Transfer to unexpended balance						1,659
Total		(8)				1,659

* Revised budget approved by the Board of Trustees.

SCHEDULE 4

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
DATES OF RECEIPT OF GRANTS
FOR THE YEAR ENDED DECEMBER 31, 1977
(Expressed in thousands of U.S. dollars)

	Rec. at beg. of year	1977 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at yr. end	1978 rec. in adv.	Net 1977 grants
Unrestricted Core:																	
Government of Australia					143												143
Government of Belgium															149		149
Canadian International Development Agency									905								905
The Ford Foundation					75	25	25	25	25	25	25	25	25	25			300
Government of the Federal Republic of Germany	(34)			135		136				141		228					606
Inter-American Development Bank	(325)		325		730				718				719				2,167
International Development Association				307													307
Government of Japan									150								150
Government of the Netherlands							133	67									200
The Rockefeller Foundation			218	10	11	11	11	11	11	11	14	72	14	6			400
Government of Switzerland		180												228		(228)	180
United States Agency for International Development	(700)						700	500		500			500	840			2,340
	(1,059)	180	543	452	959	172	869	603	1,809	677	39	325	1,258	1,099	149	(228)	7,847
Restricted Core:																	
Canadian International Development Agency	(31)												31				
The W.K. Kellogg Foundation						310											310
	(31)					310							31				310
Working fund grant:																	
International Development Association				100													100
				100													100

Continued on page I-11

SCHEDULE 4 (cont.)

	Rec. at beg. of year	1977 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at. yr. end	1978 rec. in adv.	Net 1977 grants
Capital grants:																	
Government of Belgium	(135)		135														
Inter-American Development Bank	(200)		200		228												228
International Development Association				68													68
The Rockefeller Foundation	(107)		72	30													(5)
Government of the United Kindgom					86					43					48		177
Others														30			30
	(442)		407	98	314					43				30	48		498
Special projects:																	
Government of Belgium															41		41
CIMMYT (Canadian International Development Agency)									56								56
The Ford Foundation											68						68
Inter-American Development Bank								64						142			206
International Board for Plant Genetic Resources	(8)			8													
International Development Research Centre (Canada)						175	2		38								215
International Fertilizer Development Center												48					48
International Rice Research Institute															8		8
The Rockefeller Foundation	(19)		10			50	1							21			63
United States Agency for International Development	(27)			27										14			14
Others	(30)		9	1	26	3	1	3		3		4	2	2	42		66
	(84)		19	36	26	228	4	67	94	3	68	52	2	179	91		785
	(1,616)	180	969	686	1,299	710	873	670	1,903	723	107	377	1,291	1,308	288	(228)	9,540

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Printed by:	Editorial Carrera 7a. Ltda. Calle 23 No. 4-61 Bogotá, Colombia