Annual Report
1975

Centro Internacional de Agricultura Tropical, CIAT

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

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** Assignment divided between two programs
1 Until October, 1975
2 Named Leader of the program in October

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Foreword

Tropical Latin America, like other developing regions of the world, is struggling against the crushing, interrelated problems of poverty, hunger, malnutrition and inflation—problems that have been complicated by unprecedented urban expansion as a result of rapid demographic growth and migration to the cities from rural areas. Increased agricultural productivity is an essential component in the alleviation of these problems. Those who remain in the rural areas must produce more, not only to improve the standard of living of their own families but also to feed the growing percentage of people engaged in nonagricultural activities.

The combination of rapidly rising population and increased purchasing power is expected to result in an annual increase of 3 to 4 percent in demand for food during the next ten years. Unless food production rises at an equally rapid pace, growing inflationary pressures on food products can be expected. This can only create additional hardships on the lower income segments of the population who spend most of their income on food and who need to improve both the quantity and quality of their food consumption in order to overcome serious malnutrition.

Impressive progress has been made in agricultural production; however, this has been nullified by demographic growth. In Latin America, CIAT's major area of responsibility, population is currently estimated to be increasing at the rate of 2.9 percent yearly. In the world as a whole, agricultural production has advanced at a slightly more rapid pace than population during the past 20 years, but the distribution of these increases has been disastrously uneven. The tropical, developing countries who have sustained three fourths of the population increase,have achieved only one fourth of the increase in agricultural production. A look at the map will readily indicate that most of the world's hungry nations are located between latitudes 30° north and 30° south. Agricultural production in this area, in spite of warm weather permitting year-round cropping, is increasing less rapidly than population. In these parts of the world, there are technological obstacles to production, the solution of which is vital to all mankind.

Continuation of past trends is unacceptable. A great part of the increases in production in the past has been brought about by expanding the amount of land under cultivation and by using more purchased inputs. The shortage of land that can be brought into production without large investments, the rising costs of fertilizers and pesticides, the need to lower production costs in order to minimize inflationary trends, as well as the urgency of the situation, require that new technology, which will make possible dramatic increments in productivity, be developed and made available to farmers.

CIAT, as an international agricultural research and training center dedicated to the improvement of human welfare through increased food production in the tropics, can contribute to this urgent need. It must be emphasized, however, that CIAT is only one link in the chain of institutions required to accomplish this important task. The national institution is the key in the adaptation and delivery of new technology developed at the international level and in providing feedback regarding local needs and problems. CIAT is, therefore, working closely with national agencies in the development and testing of new technology and in training with the purpose of developing specific skills, as well as a sense of urgency, in the development and delivery of technology at the national level.

CIAT expects to benefit both the rural and urban poor by developing new technology that will increase food production without raising costs. It is essential that this new technology developed at CIAT increase production at lower unit costs and require a minimum use of purchased inputs. It must be economically viable, socially acceptable and biologically suitable under the conditions of low resource farmers.

Substantial progress, described in detail for each program in this report, was made toward the achievement of these goals in 1975.

Research and training highlights

In regional cassava variety trials in farmers' fields at nine ecologically different locations, ranging from 10 to 1,450 meters in altitude, and without the use of fertilizer, insecticide or fungicide, CIAT selections yielded an average of 30 tons|ha, as compared with an average yield of 18 tons|ha for the local varieties. These results indicate a great potential for improving cassava yields by varietal improvement without the need for costly purchased inputs. There are strong indications that resistance to economically important pests can be bred into future hybrids. Evaluation of a natural infestation by the **Oligonychus** spider mite in 1,884 lines in the germplasm bank indicated that 427 lines were resistant. Furthermore, evaluation of 45 lines by artificial infestation with **Mononychellus** sp. revealed several lines with good intermediate resistance.

There is also optimism that the nitrogen fixation barrier, which has so far limited this very useful process in beans, can be broken. Some variety|culture combinations have produced considerably higher levels of fixation than those previously recorded for *Phaseolus vulgaris*. Another development that points the way to future higher yielding bean hybrids is the discovery that high bean yields and high rates of nitrogen fixation are closely correlated with the length of the growing period before flowering.

In 1975 important advances were made in the building of a germplasm base for the development of legume-based pastures to increase beef productivity substantially on the vast, but infertile, allic savanna soils of the tropics. Additional collections from Brazil, Colombia, Guyana and Venezuela increased the number of total **Stylosanthes** spp. accessions to 570. Although **Stylosanthes** still appears to offer great potential, grazing trials demonstrated the serious damage that stemborers and anthracnose leaf disease can inflict. Fortunately, sources for resistance to both have been identified in the germplasm collection.

Swine feeding trials demonstrated that simple diets based on whole grain sorghum produced almost as good results as the best diets utilizing ground cereals. This should be particularly useful to small farmers who wish to feed home-grown products to swine and do not have access to grinding equipment or capital to purchase it.

CIAT's agricultural engineer recently completed and tested a prototype 24-inch diameter axial flow pump. This simple pump, driven from the power take-off of a tractor, delivers approximately 1 cubic meter per second against a head of up to 1.8 meters. Such a low-lift, high volume pump, which can be reversed to move water in either direction, appears ideal for irrigation and drainage in many of the seasonally flooded areas of South America, where even limited water control could greatly reduce crop losses and provide a tremendous potential for rice production.

Substantial progress was made in the trend towards training production and research teams for specific countries. The first experiment, combining this philosphy with the transfer of the practical training phase of the livestock production training course to the home country of the trainees, was highly successful. Eleven Paraguayans spent seven months on selected ranches learning practical skills under the supervision of CIAT and Universidad Nacional de Asunción staff.

Organizational developments

In addition to these achievements in research and training, there were a number of organizational developments designed to enhance the advancement and transfer of technology. Through workshops, procedures were outlined for the cooperative testing of new bean and cassava varieties and the establishment of the Latin American bean network, where CIAT will provide training, germplasm and consultation services under the overall guidance of a Bean Technical Advisory Committee.

A mechanism for validating technology under real farm conditions was incorporated into the individual commodity programs in 1975 through the establishment of outreach production specialist positions and the assignment of full-time economists to each of CIAT's major commodity programs.

The CIAT administration has been reorganized to replace a single Deputy Director General with two high-level positions: Associate Director General (International Cooperation) and Associate Director General (Research). The assignment of a full-time staff member at this level to international cooperation ensures an expanded effort in strengthening relations with national programs and in the transfer of technology.

International cooperation

Three Rockefeller Foundation-funded CIAT staff assigned to the Instituto de Ciencia y Tecnología Agrícolas (ICTA) in Guatemala, as well as a number of Guatemalans who completed training at CIAT, continued to contribute to the development of this innovative organization. Most of ICTA's trials of varieties and cultural practices are conducted in farmers' fields. In 1975, 229 experiments and 562 field trials were conducted with farmers in five selected regions in Guatemala. A five-year plan was drawn up for expansion of this type of work in Guatemala.

CIAT staff traveled extensively in Latin America in 1975 to establish cooperative programs and provide requested consultant services throughout the continent. Such travel involved 777 man-days of consultation in the following countries:

Argentina
Bolivia
Brazil
Chile
Costa Rica
Dominican Republic
Ecuador
El Salvador
Guatemala
Honduras
Mexico
Nicaragua
Panama
Peru
Puerto Rico
Venezuela

The Director General and the Associate Director General for International Cooperation visited most of these countries to discuss increased collaboration between CIAT and national programs.

Administrative developments

In 1975 the CIAT Board of Trustees welcomed two new members: Dr. Luis Paz Silva (Peru) and Dr. Victor Oyenuga (Nigeria). During this year the terms of office expired for Dr. Roberto Meirelles de Miranda (Brazil), Dr. Fabian Portilla (Ecuador) and Dr. Philip Sherlock (Jamaica). In addition Dr. Moisés Behar Alcahe (Guatemala) found it necessary to resign as a Board member due to his new responsibility as Chief of the Nutrition Unit at the World Health Organization in Geneva. At its annual meeting in 1975, the Board elected the following new members: Dr. Paulo de T. Alvim (Brazil), Dr. Almiro Blumenschein (Brazil), Dr. Matthew Dagg (United Kingdom, working in Nigeria) and Dr. Werner Treitz (Germany).

This year CIAT lost the services of several members of the senior staff who had contributed greatly to the establishment and execution of CIAT's programs in its formative years. These were Dr. F.C. Byrnes, who moved to New York to become Director of Research and Training in the newly formed International Agricultural Development Service; Dr. Peter Jennings, who also moved to New York to become Associate Director for Agricultural Sciences of the Rockefeller Foundation; and Dr. J.H. Maner, who moved to Salvador, Brazil, where he will head up the agricultural aspects of the Rockefeller Foundation's cooperative program with the Universidade Federal da Bahia.

CIAT welcomed the arrival of Dr. Kenneth O. Rachie, formerly Assistant Director and Leader of the Grain Legume Improvement Program of the International Institute of Tropical Agriculture in Nigeria, as its new Associate Director General for Research. Dr. Anthony Bellotti was also welcomed as a new senior staff entomologist in the Cassava Program, having been promoted from a postdoctoral position. Mr. Jesús Cuéllar was promoted to Executive Officer from his previous position as Head of Human Resources; and Mr. Alfonso Díaz, Station Superintendent, was elevated to the senior staff level.

CIAT considers that the basic food situation, particularly in Latin America where our major effort is concentrated, is urgent but not hopeless. The results now beginning to emerge from our young program are exciting, and mechanisms have been established to transfer these findings to national programs for adaptation, validation and delivery to farmers. By focusing our efforts on those areas where international centers have the greatest comparative advantage, by adhering to the principles of complementarity and cooperation with colleagues in national programs, by orienting our efforts to the important rather than the interesting, and by maintaining a multidisciplinary effort to solve important production problems, CIAT is optimistic about making significant progress. We expect that these achievements will contribute substantially to the solution of basic human problems and bring about increased welfare and human dignity to many. Our staff of outstanding scientists from 13 nations is dedicated to this task. The results on the pages that follow give us hope.

John L. Nickel
Director General

Climatological data for four CIAT research sites

CIAT scientists conduct primary research at four centers in Colombia: at CIAT's headquarters near Palmira; at the Turipaná and Carimagua research stations of the Instituto Colombiano Agropecuario (ICA); and the Popayán research station of the Secretaría de Agricultura del Cauca. In addition, testing is done at many other locations throughout Latin America. Summary data on temperature, rainfall and edaphological conditions at most of these stations are listed in the individual reports of the Beef, Bean, Cassava and Maize Programs reprinted from this comprehensive Annual Report.

In this section are data for long-term monthly temperature and rainfall averages at the four primary locations in Colombia. Data for the Turipaná station is from the station itself; data for the other locations are from adjacent (Popayán and CIAT) or nearby (Carimagua) weather measuring stations. Detailed data for other climatological factors are available for a long period at ICA's Palmira station. This data provides a comprehensive picture of conditions under which much of CIAT's primary crop screening work is conducted.

Palmira

The climate at Palmira, in the Departamento del Valle, represents a typical equatorial upland environment with a bimodal rainfall distribution (Fig. 1). The comparatively low mean annual rainfall is due to the orographic effects of both the eastern and western Cordilleras of the Andes. Negligible seasonal mean temperature variation strongly contrasts with strong seasonal variation in rainfall. The two dry seasons are normally short. July and August are the driest months with NE winds predominating.

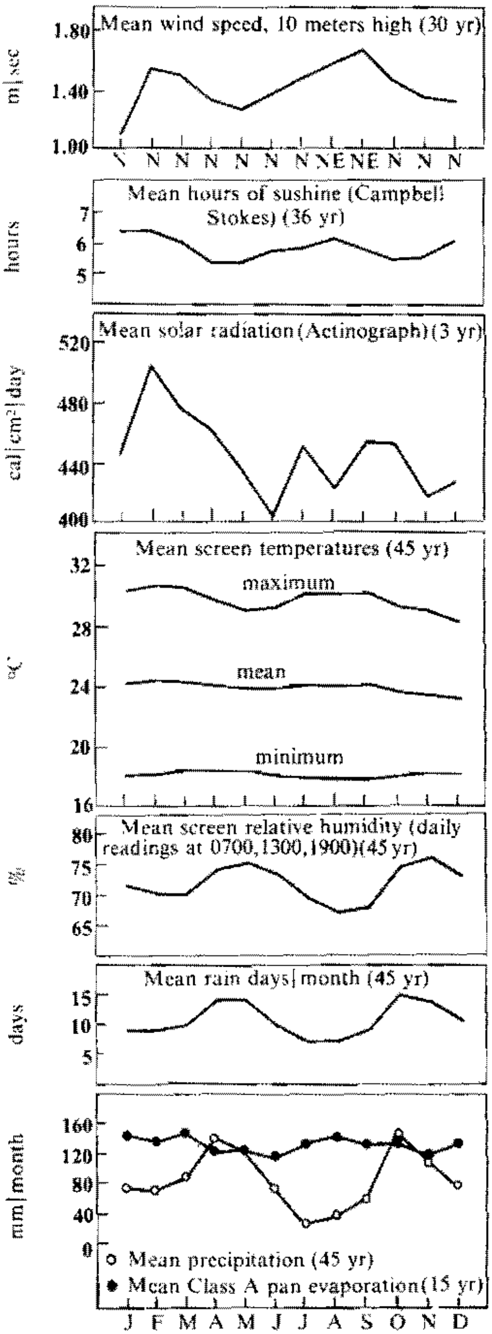

Figure 1. **Monthly means of several climatological factors for CIAT, Palmira (meteorological station at ICA research station, Palmira, Departamento del Valle: Lat. 3°31'N, Long. 76°19'W; altitude 1,001 meters).**

Popayán

The climate at the research site near Popayán, in the Departamento del Cauca, is also representative of equatorial upland climates in other areas of the world (Fig. 2). The bimodal rainfall distribution is quite similar to Palmira although rainfall, particularly in the second wet season, is much higher. The lower ambient temperatures directly reflect the higher altitude.

Turipaná

The climate at Turipaná, in the Departamento de Córdoba, is strongly representative of other lowland tropical environments with a unimodal rainfall distribution at sub-equatorial latitudes

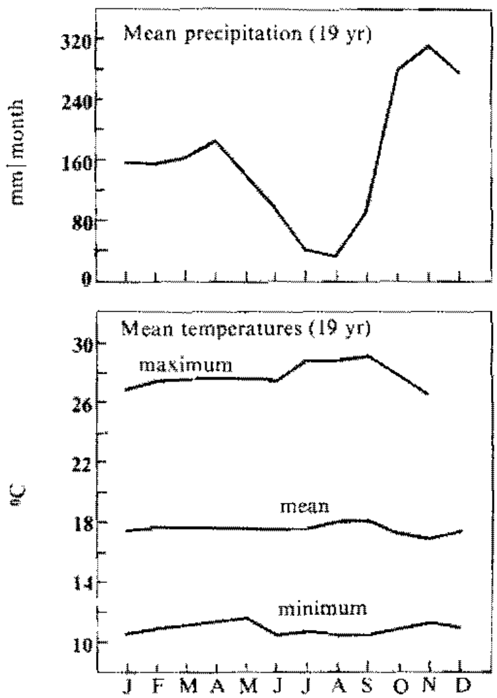

Figure 2. **Monthly mean precipitation and temperatures for Popayán research location (meteorological station at Estación José María Obando, Federación de Cafeteros, Departamento del Cauca: Lat. 2°27'N, Long. 75°35'W; altitude 1,850 meters).**

(Fig. 3). The higher mean temperature is a direct reflection of the lower altitude.

Carimagua

The tropical savanna climate at Carimagua, Departamento de Meta, is typical of inland regions in the equatorial and sub-equatorial zones with a more or less unimodal rainfall pattern, strongly contrasting wet and dry seasons, high wet season rainfall and higher temperatures during the dry season (Fig. 4).

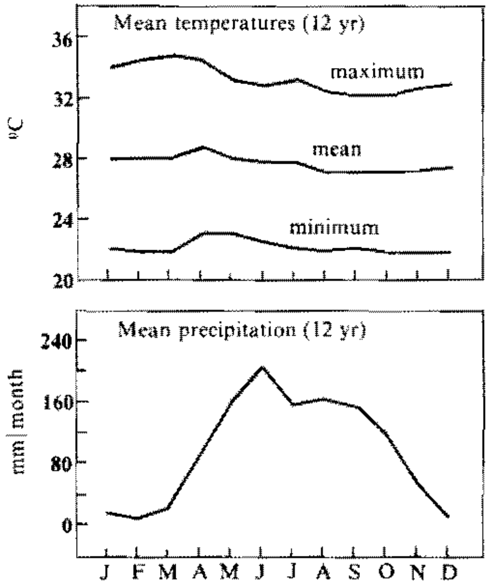

Figure 3. **Monthly mean precipitation and temperatures for Turipaná (meteorological station at ICA research station, Turipaná, Departamento de Córdoba: Lat. 8ºN, Long. 76ºW; altitude 13 meters).**

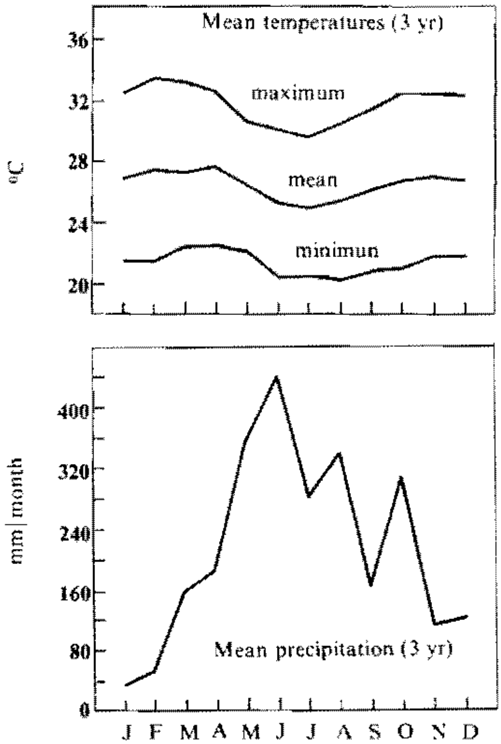

Figure 4. **Monthly mean precipitation and temperatures for Carimagua area (meteorological station at Estación Las Gaviotas, Centro de Desarrollo Integrado, Comisaría de Vichada: Lat. 4º30'N, Long. 70º40'W (approx); altitude 150 meters).**

Beef production systems

HIGHLIGHTS IN 1975

The overall objective of the CIAT Beef Cattle Production Systems Program is to develop economically viable technology to increase beef cattle production in the lowland American Tropics. Principal attention is given to the infertile allic soil savanna lands which cover an area of approximately 300 million hectares. It is estimated that one-half of the 150 million head of cattle found in the American lowland tropics are located in these allic soil areas.

Primary research emphasis is on improving the nutrition of beef cattle through the development of legume-based pasture systems. Supporting research is conducted in animal husbandry and animal health leading to integrated beef cattle production systems.

Principal field research is carried out in the Colombian Llanos. This includes work at the Carimagua station of the Instituto Colombiano Agropecuario (ICA), and also on private farms and with the Caja Agraria. Additional field research is under way in the North Coast of Colombia, with the collaboratiön of ICA, the Caja Agraria and private farmers. Supporting field and laboratory research is conducted at CIAT and other locations in the Cauca Valley.

Training for research workers includes in-service training and realization of graduate student theses. Livestock production specialists receive classroom and laboratory instruction at CIAT and field training on private farms. Technical assistance is provided to university training programs.

Major research and training highlights of the program are:

The CIAT Forage Germplasm Bank is now a working collection of international scale. The bank contains some 1,200 accessions, including 570 accessions of **Stylosanthes**, the predominant leguminous genus of economic importance in allic soil savannas.

The **Stylosanthes** screening and evaluation project seeks to identify high yielding, persistent cultivars adapted to allic soils and resistant to anthracnose (*Colletotrichum gloeosporioides* Penz) and stemborer attacks. Regional trials were initiated in Brazil to evaluate stylo germplasm. In these tests, CIAT varieties gave the highest dry matter yields and anthracnose resistance ratings.

Seed production of potentially useful accessions of **Stylosanthes, Centrosema** and **Desmodium** species has advanced in terms of seed produced and distributed and in new production areas established.

Excellent establishment of *Centrosema pubescens* and *Desmodium intortum* in Pangola pasture was obtained by seeding in strips following band application of glyphosate, to kill grass in the strips.

In native grasses, no advantage was shown for sequential burning of separate plots at eight different times throughout the year as compared to burning the entire area at the beginning of the dry season.

Cattle grazing *Brachiaria decumbens* pastures had considerably higher weight gains than cattle grazing *Hyparrhenia rufa, Melinis minutiflora,* and *Paspalum plicatulum* pasture.

Use of cassava forage as a protein supplement for low protein, elephant grass based diets improved growth rate and feed efficiency of steers.

Prevalence studies for breeding diseases, hemoparasitic diseases and ectoparasites were carried out in four tropical areas of Colombia, three of them as training exercises.

Interpretation of the results of the animal disease prevalence studies was started in terms of economic impact to the farmer. Cost|benefit studies of disease control were started with anaplasmosis and babesiosis, and model simulations were made for comparison of control strategies for foot and mouth disease.

Simulations of varying size cattle units indicate the importance of reducing total investment in the establishment of improved pastures, by limiting the amount of improved pasture to that needed for the critical phases of the livestock production cycle, and by reducing establishment costs.

Phosphorus and trace mineral supplementation of cattle grazing native grass pastures has increased calving percentage by 44 percent. Early weaning of calves at 80-90 days of age has increased calving percentage by 43 percent and reduced the rebreeding interval by 4.5 months.

Training was provided this year for 8 postgraduate interns, 13 special trainees, 7 visiting research associates conducting their doctoral research, 3 research scholars and 20 livestock production specialist trainees.

ECONOMICS

Variations in cattle production and productivity in Colombia

Investment behavior in the livestock industry in Colombia was studied in order to measure the dynamics of response to changes in beef and milk prices, credit volume, etc. as they affect slaughtering and herd size. Moreover, an explanation was sought for the annual variations in the percentage of females slaughtered, many of which were pregnant. It was necessary to reestimate herd sizes according to age and sex for certain periods of time. Although some data were available for Colombia, they seemed unreliable.

Table 1 summarizes some of the results of the series compiled by CIAT economists for the 1940-74 period. Technological parameters based upon researchers' opinions and other beef cattle studies were used in its preparation. The decreasing rate of improvement of these parameters could be partially explained because of regional cattle displacement toward areas with poorer soil. The stability of the rate of extraction (estimated at 12 percent) is indicative of the steady state of herd productivity between 1940 and 1974. As comparisons, the 1970 extraction rates in Argentina and Brazil were 25 and 15 percent, respectively.*

The second stage of this work, which is still being developed, will help in explaining the behavior of herd sizes and slaughter over a period of time.

Economics in relation to animal health

During 1975, the development of methodology for the cost-benefit analysis of various levels of foot and mouth disease control in Colombia continued.

The first stage of this investigation, done last year, consisted of estimating losses per farm due to foot and mouth disease in swine (1974 Annual Report). This research served as a basis for developing a

* For Colombia, the slaughter data did not include clandestine slaughter or illegal export activities.

Table 1. **Variations in beef cattle herd sizes, calving and mortality rates and proportion of males and females slaughtered in Colombia.**

Period	Average annual rate of: increase in herd size (%)	increase in calving rate (%)	reduction in mortality rate (%) *	**	Slaughter of females as % of males slaughtered	Extraction rate (%)
1940-49	0.6	2.2	-0.9	-2.2	65.0	12.0
1950-59	3.1	0.5	-0.2	-0.5	66.0	12.0
1960-69	2.4	0.3	-0.3	-0.3	59.0	11.8
1970-74					67.0	12.3***

* Cattle older than 1 year

** Cattle younger than 1 year

*** Figure for 1970.

microeconomic simulation model applicable to beef cattle, making it possible to study losses at the farm level. As part of the methodology, CIAT's animal health team designed an epidemiological model of foot and mouth disease occurrence for endemic regions (Fig. 1). The unit of observation is the beef cattle population of a region, distributed in nine epidemiological categories (x_i). Categories are interconnected by a series of relations that involve animal flows from one category into another (F_{ij}). Solid lines show the direction a sick animal may take in an endemic area where there are periodic outbreaks of foot and mouth disease.

This analysis was expressed as a computerized mathematical model by economists with the aid of CIAT's biometrics team. The model was developed in stochastic and dynamic terms, using Markov's theory of stochastic processes. Flows were represented by probabilities of transition (P_{ij}), which indicate for each stage of the disease the fraction of animals that are transferred from class i to j, as a proportion of the total animals that leave class i.

The model makes it possible to predict the natural course of the disease for a period of time in an endemic region or country, as well as under different methods of control. Thus one can appraise relative merits of each control method by estimating concomitant cost-benefit flows.

The economics of massive and periodic preventive vaccination is considered as a possible strategy and a set of transitional probabilities, different from those used to describe the natural evolution of the disease without this vaccination, was defined. An additional flow between susceptible and resistant animals appears for this strategy (dotted line in Figure 1). The magnitude of this flow depends upon the percentage of the population vaccinated against foot and mouth disease and the efficiency of the vaccine in relation to the degree of immunity. It is assumed that the starting point for the vaccination model is a long-run, stable endemic situation, in which there are no other interferences in the natural course of the disease. The selected unit of time was one week because it was the minimum common denominator in relation to the length of each stage of the disease. The application of Markov's processes makes it possible to simulate the proportion of animals in each epidemiological category throughout the period of time until the new long-term, stable balance is reached by means of a massive vaccination plan. The model

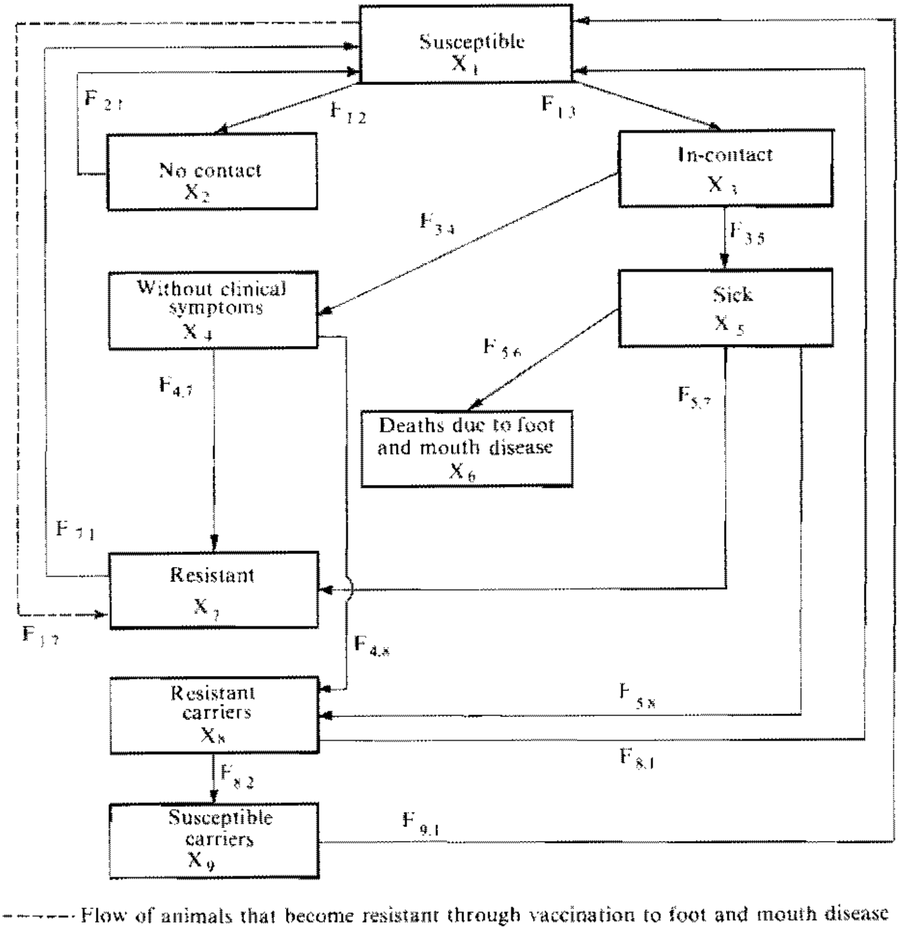

Figure 1. **Flow chart of the different epidemiological categories identified for foot and mouth disease in an endemic region.**

predicts the number of sick animals and deaths per week. The same model is applicable to alternative strategies.

Economic losses associated with each alternative will be obtained from the simulation microeconomic model. In other words, the epidemiological model will make it possible to evaluate losses at the regional (or national) level, using estimated losses per animal by means of simulation analysis at the farm level.

Tables 2-4 show some preliminary results obtained by simulating a hypothetical vaccination campaign on the Colombian North Coast, using an epidemiological model with Markov's processes. This analysis can be used to examine parameter sensitivity and confidence levels.

Economics of beef production systems

As a continuation of the project described in the 1973 and 1974 Annual Reports, some methodological elements were included during 1975 and applications of the model to a family farm prototype and to large-scale ranches operating under conditions similar to those represented by the Carimagua region were carried out.

Table 2. **Long-term estimates of the number of susceptible and diseased cattle in relation to the efficiency of foot and mouth vaccine.**

	Vaccine efficiency (%)				
	65	70	75	80	85
			(X 10,000)		
No. of susceptible animals	2,354	2,233	2,125	2,026	1,936
Annual morbidity	240	204	170	139	108

Assumptions. 90% vaccinated; 3 annual vaccination cycles; a 50% rate of attack; and an outbreak every 4 years (0.25 probability of an annual foot and mouth disease outbreak).

As regards methodology during 1975, emphasis was on risk elements such as calving rates, cattle price fluctuations and pasture establishment and longevity. The results reported below include only the probability treatment of calving as the other risk elements are still being analyzed.

Family farm prototype

The simulation of alternative production systems was conducted with data collected at the family farm unit on the Carimagua station.*

The main restriction set on the farm was a maximum herd size of 36 cows, which was estimated to generate a family income of at least US $400 annually. Table 5 summarizes some of the possible systems analyzed.

Basically, systems with or without improved legume and grass pastures were compared. For systems without improved pastures, management is being intensified by practices such as early weaning, feeding of complete minerals, technical assistance (especially in animal health), investment in stock waterers, etc.

To determine technical coefficient levels and variations within prevailing systems, a survey of the area is being done. Nevertheless, on the basis of farm visits and secondary information, it is known that the prevailing systems vary in productivity coefficients and that there are farms represented in each of the first three systems described in Table 5. Technically speaking, case 4 is also feasible on the basis

* A description of the development and facilities of the family farm unit is in the 1974 Annual Report.

Table 3. **Long-term estimates of the number of susceptible, sick and carrier animals as a percentage of a population vaccinated against foot and mouth disease.**

	Vaccinated population (%)				
	50	60	70	80	90
			(X 10,000)		
No. of susceptible animals	2,912	2,586	2,325	2,113	1,936
Annual morbidity	412	312	232	156	108
No. of carriers	191	147	111	83	58

Assumptions. 85% vaccine immunity; 3 vaccination cycles each year; a 50% rate of attack; and an outbreak every 4 years.

Table 4. **Long-term estimates of the number of susceptible and sick animals in relation to the frequency of foot and mouth disease outbreaks.**

	An outbreak every:			
	3 years	4 years	5 years	6 years
	(X 10,000)			
No. of susceptible animals	1,930	1,936	1,890	1,943
Annual morbidity	138	108	88	78
No. of carriers	71	58	39	44

Assumptions: 90% vaccinated; 85% vaccine immunity; 3 vaccination cycles each year; and a 50% rate of attack.

of previous experimental results. There are good probabilities of adopting the management improvements of case 3, which would help spread that system.

In the case of improved pastures, pasture management has been varied to change the percentage of the farm's total area with improved pastures. Cases 5 and 6 have 50 hectares of improved pastures, and cattle are vaccinated and fed 25 kilograms of complete minerals per A.U. per year. These practices result in high calving rates (70 percent) and make it possible to sell males

Table 5. **Simulation of alternative production systems for the Carimagua family farm.**[1]

System	Area: Total (ha)	Area: Improved pasture (%)	Calving rate (%)	Mortality (%)	Total initial investment[2] (1,000 US$)	Annual net income[3] (1,000 US$): year 2	Annual net income[3] (1,000 US$): year 7	Rate of return[4] (%)
Without improved pasture								
1. Breeding-Growing	500	0	40	7-5	9.7	0.55	0.84	6.2
2. Breeding-Growing	500	0	50	7-5	9.7	0.55	1.20	8.0
3. Breeding-Growing	500	0	50	5-3	9.7	0.63	1.38	10.0
4. Breeding-Growing	500	0	60	5-3	10.4	0.46	1.21	7.4
With improved pasture								
5. Breeding-Growing	250	20	70	5-3	11.9	0.63	1.92	8.7
6. Breeding-Fattening	250	20	70	5-3	11.9	0.69	1.76	9.5
7. Breeding-Growing	250	8	70	5-3	10.8	0.32	1.48	6.9
8. Breeding-Fattening	500	4	70	5-3	11.8	0.25	1.51	6.1
9. Fattening	50	100		4	11.5	2.70	2.70	24.0[5]
10. Fattening	50	100		4	13.0	2.40	2.40	18.0[6]

1 At prices for 1st quarter of 1975. Initial herd of 36 cows plus younger animals and bulls, except cases 9 and 10.
2 Includes value of cattle.
3 Excludes value of crops produced and consumed on farm.
4 On the total investment.
5 Taking into consideration pasture risk.
6 Taking into consideration pasture risk and double the cost of pasture establishment.

weighing 370 kilograms in about three and a half years. If farm activities are to include breeding, case 6 is the most profitable, with 50 instead of 20 hectares of improved pastures.

The most interesting possibility appears to be the plan of buying feeder steers for fattening (case 9). On the basis of results obtained in the first stage, the best potential is in fattening steers rather than in increasing reproduction or breeding productivity. In other words, the investment and expenses required to reach a high level of breeding productivity by establishing improved pastures appear to be unprofitable. An intermediate calving and mortality level, which gives a relatively more attractive return on income can be achieved through management alone, without improved pastures. As indicated in case 9, legume pasture is extraordinarily attractive when dedicated to fattening cattle only, provided the supply of feeder steers remains at its present level.

As regards small ranches, the feasibility of this technology should be examined remembering the following factors:

1. The initial total capital investment required to produce the predetermined minimum income is from US $10,000 to $12,000.

2. It is difficult ex ante to determine quantitatively the extent that the resultant family income is sufficient to cover not only a competitive return on capital but also to cover the alternative cost of family labor including administration.

3. The resulting internal rate of return is quite sensitive to cattle prices. In Table 5 for example, if cattle prices increase from Col $10|kg (constant) to $13|kg, in addition to a 1 percent real annual increase on the latter, the rate of return increases by 76,53, 84, 56, 63, 104 and 103 percent for cases 1, 3, 4, 5, 7, 8 and 9, respectively. In other words, price variations affect both the level and the profitability of systems.

4. In addition to the rate of return, cash flow may be used to measure the success of a system. As an illustration, this situation was presented for the second and seventh years—an initial and postdevelopment period-- but data are also available for each of the 25 years of each series.

5. The rate of return on total investment is presented rather than the rate on owned capital (or financial rate), although the latter is available. The reason for this is that although the latter is greater than the former, it is not because of technology but because of the subsidized interest rate.

6. Results are available for measuring income return and production sensitivity to variations in calving, mortality and replacement rates, pasture longevity, etc.

7. In an improved legume pasture system, a 70 percent calving rate may be lower than the real potential rates. The maximum potential level has been estimated at 75 to 80 percent.

8. Herd size in a fattening, nonbreeding system was determined on the basis that the total initial investment, including animals, was equal to the case of breeding on improved pastures. This requires a pasture that will assure a minimum gain of 500 grams per day, so that 300-kilogram animals are bought and sold within a year, weighing an average of 450 kilograms. The case analyzed was a 50-hectare farm with all improved pastures and 75 animals, with a 4 percent mortality rate.

Large-scale commercial ranches

The probable impact of alternative beef production systems on farm productivity and economics for commercial farms of approximately 5,000 hectares, located in the Llanos Orientales, was simulated in a model. Three primary systems were studied.

1. **The traditional system.** The feed supply is based only on native savanna

grass with no mineral supplementation; operations are limited to breeding and growing, selling 3- to 4-year-old steers as feeders. Heifers enter breeding herds at the age of 3, and calving rates are from 42 to 50 percent.

2. **The traditional system with complete mineral supplementation.** The feed supply in the same as the first system except for either a 14 or 27 kg|A.U.|year supplement of complete minerals. The lower mineral rate results in calving rates of 45, 57 and 50 percent, over three cycles, while the higher mineral rate increases calving rates to 45, 57 and 60 percent. Heifers enter the breeding herd at the age of 3, and steers are sold weighing 30 kilograms more than in the first system. Compared to the first, this system requires greater investments in management, feeders for the minerals and stock waterers.

3. **Improved pasture system.** In addition to the native savanna pasture, improved legume pasture is also available and animals receive the complete mineral supplement at a rate of 27 kg|A.U.|year. Calving rates increase from 50 to 70 percent. Eighty percent of the steers reach market weight at 2 to 3 years of age, the rest are sold at 3 to 4 years of age. In the steady state, 1.3 hectares of improved pasture were assigned per cow and her portion of younger animals, which for all cows is equal to 20 percent of the area.

The pasture is established at a cost of Col.$1,600|ha; there is an additional expense of Col.$25,000 for infrastructure over the estimated costs for the mineral system. These costs correspond to 1974 prices for inputs.

Each system began with either 100 or 300 cows and their younger animals; the final number of animal units was limited by the farm's stocking rate. Three beef price alternatives were examined. Each was studied with and without a loan, equal to 50 percent of the initial value of the investment at real interest rates of 0 and 5 percent, respectively, payable in 12 years, with a four-year grace period. Moreover, loans from government organizations with funds for livestock operations are analyzed.

Results of large farm analyses

The results below do not include the analysis of risk described in the introduction. All systems analyzed include breeding and growing and estimates have been developed for a 25-year period. Growing-fattening operations are included when legume pasture is available. These results are valid only at the relative prices considered. Should conditions of infrastructure improve so that relative transportation costs decrease, the traditional system tends to become less competitive.

Table 6 gives the rates of return to total investment and the rates of return to capital owned. The former is a reflection of the system's benefits; the latter reflects the cattle producer's subsidy through credit. On the basis of the interest rates considered and the proportion of credit to owned capital (maximum of 50 percent), the financial return for owned capital is considerably greater than the economic return, which could be a source of distortion in selecting technology. As observed earlier when comparing economic and financial rates, credit subsidies favor the adoption of improved systems when they oblige cattle producers to adopt a certain technology.

If the calving rate on native savanna pasture is 42 percent, rates in simulated improved systems are both economically and financially advantageous compared to traditional systems. Alternatively, if the calving rate on unimproved pasture systems is approximately 50 percent, the establishment of improved pastures does not significantly increase income returns. In terms of income returns, systems with

Table 6. **Income returns from simulated alternative systems on 5,000-ha cattle ranches in the Llanos Orientales, Colombia.**

System	Initial herd size (no. cows)	Internal rate of return: on the total investment (%)	on cattleman's own capital: real interest at 0%	on cattleman's own capital: real interest at 5%	with Fondo Ganadero
Improved pastures[1]	300	19.2	26.5	24.6	21.7
Traditional system (I-B)[2]	300	17.8	27.2	24.1	25.8
Improved pastures	100	16.4	21.0	19.2	15.0
Traditional system (I-A)[3]	300	15.0	24.0	20.3	23.4
Mineral supplement (II)[4]	300	14.7	20.7	18.2	20.4
Traditional system (I-B)	100	14.7	20.1	17.9	18.7
Mineral supplement (I)[5]	300	14.4	20.3	17.9	14.4
Mineral supplement (I)	100	13.2	16.1	14.9	14.5
Mineral supplement (II)	100	12.1	15.6	13.8	14.1
Traditional system (I-A)	100	12.0	17.7	13.7	15.4

1 Calving rate of 50, 65 and 70% (3 years)
2 Calving rate of 50%
3 Calving rate of 40%
4 Calving rate of 45, 57 and 60% (3 years) with 27 kg minerals/A.U./year
5 Calving rate of 45, 57 and 50% (3 years) with 14 kg minerals/A.U./year

mineral supplementation on unimproved pasture have no advantage over no supplementation.

In the improved system, income returns were quite sensitive to changes in input prices; therefore, the elasticity of supply for inputs (fertilizers, tractor costs, seed, etc.) will influence the rapid spread of the new technology. Within the systems studied, there are economies of scale in relation to initial herd size. These can be interpreted as each production system being more profitable when an enterprise begins near the level and composition of the corresponding steady state herd.

If the low value of the land is considered, the level of investment required for improved pastures appears to be high, compared to traditional systems. Thus, it is important to use research to reduce costs of improved pasture by varying management strategy, reducing establishment costs, using fewer inputs and adopting minimum tillage.

The alternative of fattening only was not considered in the improved system; however, on smaller farms especially, such a system is most advantageous if legume-based pastures are available, as was discussed earlier in the family farm analysis.

PASTURES AND FORAGES

Plant introduction

Systematic collection of forage legume germplasm was initiated with special funding from the International Plant Genetic Resources Board in 1975. An extensive collection of tropical forage legume genotypes was assembled from allic soil savannas of tropical South America. Regions explored include the Central Plateau and Planalto regions of Mato Grosso in Brazil, and Guyana, Colombia and Eastern Venezuela.

Most collecting was done in the allic soil savannas of tropical South America (Fig. 2). These savannas are within the 1,500- and 2,000-mm rainfall regions. Soil pH is generally less than 5 and, sometimes, as low as 3.8. The predominant exchangeable cation is Al, which often accounts for more than 60 percent of the exchangeable cations. Growth of cultivated crops is severely restricted due to toxic effects of Al.

The Brazilian Campo Cerrado is a particularly rich source of forage legume germplasm. This broad geographical region was traversed along an east-west|north-south transect from Porto Velho to Brasilia and Belem. The northeast and subcoastal central regions were explored in the S. Luis|Fortaleza|Porto Nacional triangle and in Bahia. The Gran Sabana in Venezuela and the Rupununi savannas in Guyana were the northern limits of exploration in the allic soils region.

Fifty-five legume introductions were received from Ecuador and are now being observed in the nursery. These materials were collected throughout tropical Ecuador by staff of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) and the University of Florida.

With this year's accessions, the CIAT Forage Germplasm Bank is a now a working collection of international scale. It contains some 1,200 accessions, including 570 of **Stylosanthes**, the predominant leguminous genus of economic importance in allic soil savannas. The majority of new accessions are variants and ecotypes of *S. guyanensis, S. scabra, S. viscosa, S. capitata, S. hamata, S. humilis* (Fig. 3), and species of **Centrosema, Calopogonium, Zornia, Desmodium** and **Phaseolus.**

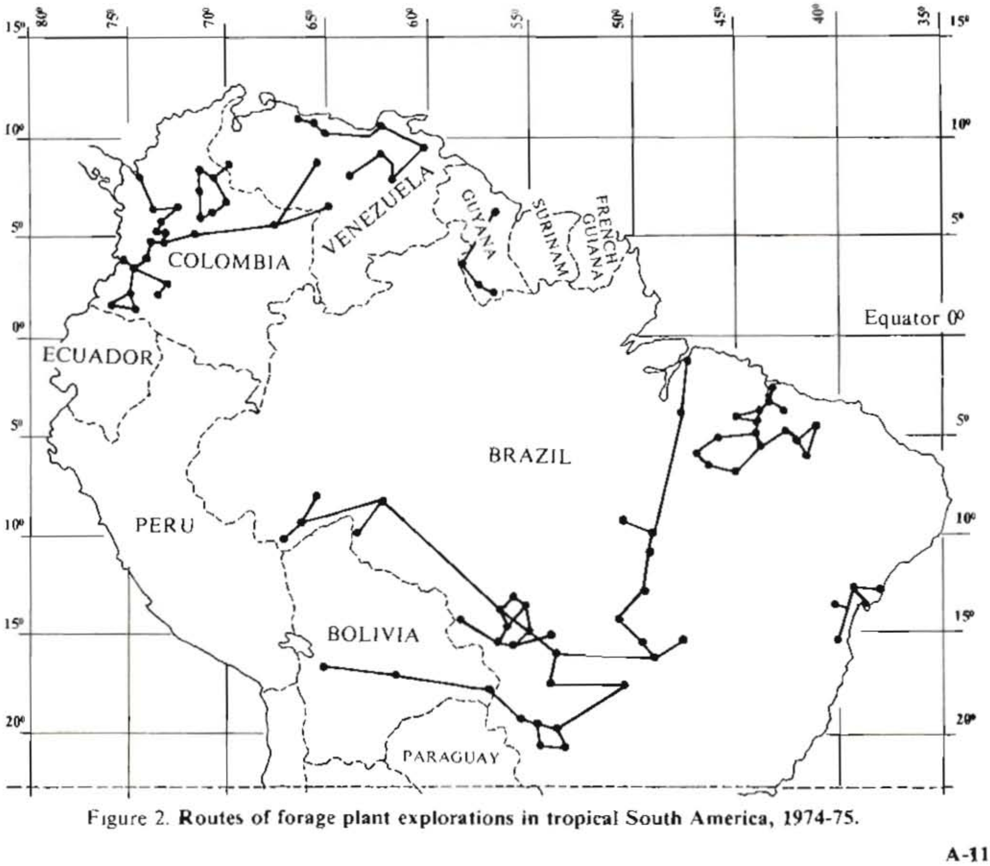

Figure 2. **Routes of forage plant explorations in tropical South America, 1974-75.**

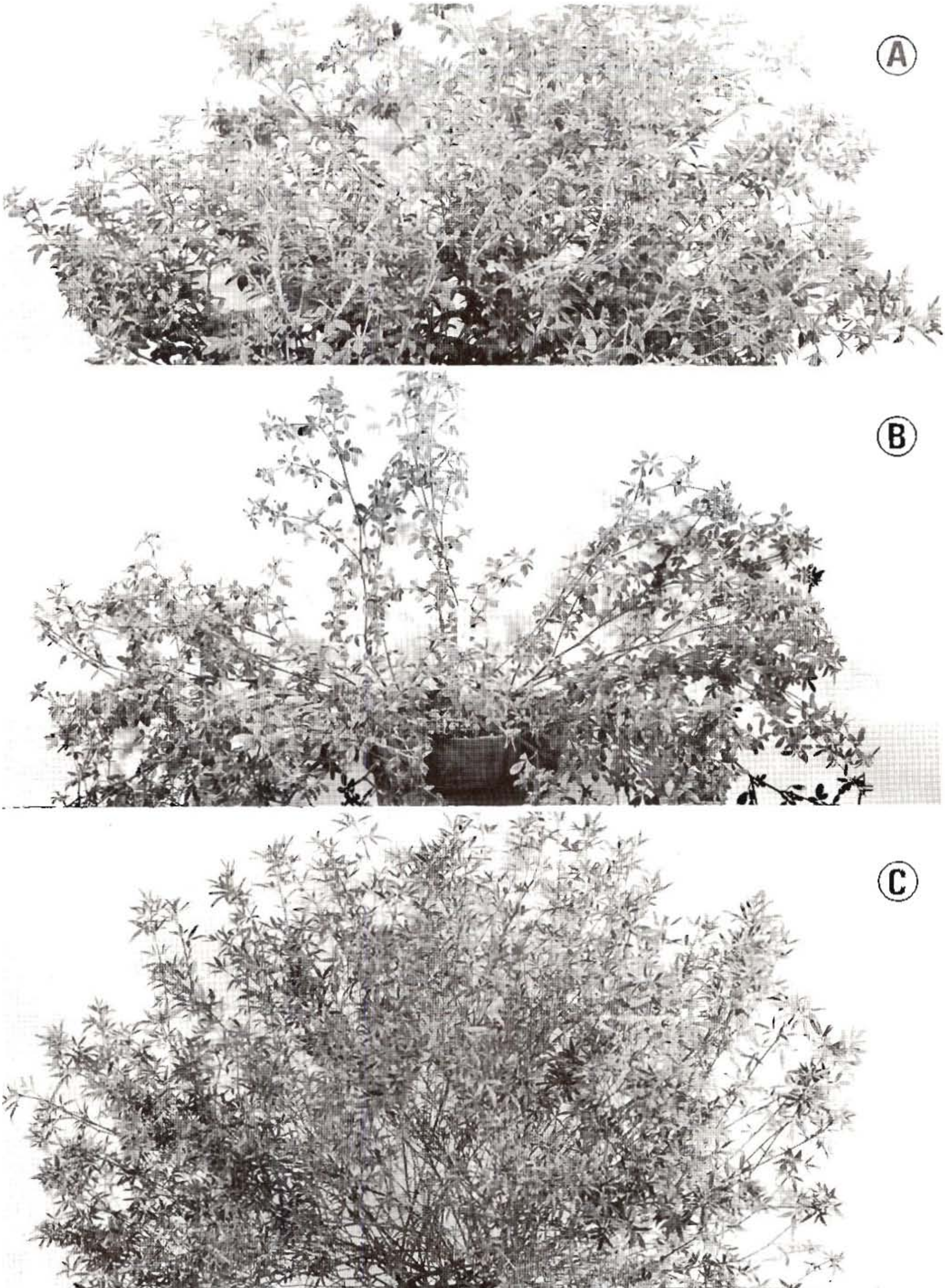

Figure 3. **Stylosanthes accessions in CIAT's forage germplasm bank are from widely differing ecological zones and possess distinctive morphological and agronomic characters. (a)** *S. scabra* **from Brazil; (b)** *S. viscosa* **from Belize; and (c)** *S. sympodialis* **from Ecuador.**

Rapid propagation of these new accessions by seed and vegetative methods, and the characterization and screening for desirable forage traits and insect and disease resistance is under way. Future plant collecting will be planned on the basis of these evaluations. Ecological regions which yielded promising material will be revisited and thoroughly searched for additional genotypes.

Propagation studies

Lacking adequate quantities of seed of new stylo accessions, a mist propagation method was developed to produce sufficient material for preliminary screening of *S. guyanensis*. The rooting medium consists of washed, fine river sand over coarse sand with perlite as a mulch. Misting is controlled by an electronic leaf.

The basal 2-2.5 cm of cuttings 20-25 cm long were dipped for five seconds into 3-indole-butyric acid (IBA) in solution at either 1,000, 5,000 or 10,000 ppm. Cuttings were then planted either 5 or 10 cm deep in the medium. Cuttings receiving the 10,000 ppm IBA treatment and planted 10 cm deep rooted significantly better than the other treatments (Table 7, Fig. 4). An average of 93 percent of cuttings receiving the optimum treatments rooted and were ready for transplanting in 16 days.

Stylosantheses evaluation

The stylo screening and evaluation project seeks to identify high-yielding persistent species and biotypes resistant to anthracnose (*Colletotrichum gloeosporioides* Penz) and stemborer attacks. Stemborer, tentatively identified as a species of the genus **Zaratha** (Lepidoptera, Blastodanidae), a previously unrecorded stylo pest, is causing serious damage in stands at Carimagua. Of 17 stylo varieties established there, only one (CIAT 191) was resistant to both anthracnose and stemborer attacks.

Twenty-nine of 105 new stylo accessions were highly resistant when inoculated with conidia in water and screened for anthracnose resistance in the planthouse. Preliminary data indicate the existence of a higher degree of resistance among varieties of *S. scabra, S. viscosa, S. hamata* and *S. capitata* than in the *S. guyanensis* group (Table 8). Resistant species and varieties are being planted at three sites — Carimagua, Palmira and Santander— to test responses to anthracnose in the field.

Regional trials to test stylo germplasm adaptation were established in Brazil at Campo Grande (Lat. 21°S) and at the Federal Experiment Station, Planaltina (Lat. 16°S). In Colombia, a new testing site

Table 7. **Effect of three concentrations of 3-indole-butyric acid (IBA) on root production by *S. guyanensis* cuttings planted at two depths.**[1]

	5-cm planting depth		10-cm planting depth	
IBA (ppm)	Mean no. roots/cutting	Mean root length (cm)	Mean no. roots/cutting	Mean root length (cm)
0	5.2	2.5	10.9	3.5
1,000	11.9	4.8	15.0	4.7
5,000	16.0	4.5	32.8	6.7
10,000	57.9**[2]	9.4*	66.8**	8.0*

1 Twenty-eight days after planting.

2 Values within columns are significantly different at the 1% (**) or 5% (*) level.

Figure 4 **Rooted stylo cuttings produced in mist propagation beds in 16 days, using 3-indole-butyric acid at 10,000 ppm concentration.**

was established near Santander (Cauca) on a red-brown, acid (pH 4.9) ultisol with a high Al content (2.4 meq| 100 g).

Of 21 varieties of *S. guyanensis* planted at Campo Grande, five late- and three early-maturing varieties had high

Table 8. **Anthracnose resistance ratings of 105 accessions of** Stylosanthes **at CIAT.**

	No. of accessions that are:			
	Highly resistant (0-0.71)*	Moderately resistant (0.71-0.88)	Susceptible (0.88-1.05)	Highly susceptible (1.05-1.17)
S. guyanensis	7	44	14	2
S hamata	4	0	0	0
S. scabra	8	4	0	0
S capitata	1	0	0	0
S. viscosa	2	0	0	0
Stylosanthes sp	7	8	1	3

* Arc sin transformed values of weighted means calculated from percentage of leaves affected and severity score of infection (0 = no infection; 1 = spots < 1 mm; 2 = 25% and 3 = 50% or more of leaf area affected

Table 9. **Regrowth yields of 14 *S. guyanensis* varieties cut ten centimeters high after 28 days.**

CIAT accession no.	Stubble leaf		Leaf:Stem ratio	Dry matter yield	
	area (cm²/plant)*	dry weight (mg/plant)*		leaves (g/plant)	leaves + stems (g/plant)
136	269.55	1,243.92	3.85	5.40	6.89
94A	241.80	1,017.42	2.48	5.36	7.63
135	215.37	934.60	2.72	5.63	7.70
69	213.88	824.42	2.90	5.09	6.97
46	211.37	1,018 17	2.14	4.91	7.43
191	208.97	1,023.35	2.80	4 86	6.84
133	199.27	1,045 90	2 68	4.79	6.74
92	199.24	1,008 26	2.57	4 53	6.33
130	189.12	901.88	2.83	5.20	7.06
50	179.72	745 32	2.96	5.29	7.16
73	176.95	880.37	2.15	4.39	6.50
126	170.12	691.56	2.63	5.40	7 47
151	163.15	771.98	3.03	5 50	7.43
77	148.76	788.72	2.19	4 64	6.96
LSD ($P < 0.05$) =	52.92	241.23	0.45	0.52	0.83

* Measured below the cutting height on day 0

Correlation coefficient for regrowth yield/stubble leaf area $r = 0.66$ ($P = 0.01$)

resistance to anthracnose. The Australian commercial cultivar Schofield, included as a check, was severely affected by the fungus. At the end-of-season harvest in May, CIAT varieties 30, 63, 135 and 136 had the highest dry matter yields and anthracnose resistance ratings.

At the Planaltina station 18 stylo varieties under observation were not affected by anthracnose whilst the Brazilian commercial variety 1022 in a nearby field was severely infected.

Growth characteristics of 14 *S. guyanensis* varieties were studied at 5 and 10 cm cutting heights. After 28 days regrowth of all varieties was significantly higher in the 10 cm cutting treatment. Varietal differences were shown in leaf area and weight remaining after cutting and these parameters were correlated with regrowth yield (Table 9, Fig. 5).

Aluminum toxicity in Stylosantheses

Aluminum toxicity in allic soils can be a major problem for nontolerant species. A preliminary experiment in the greenhouse

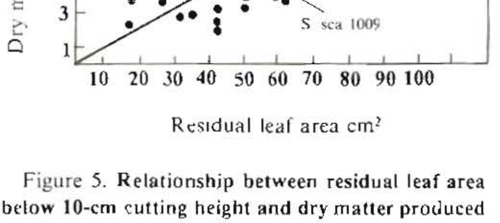

Figure 5. **Relationship between residual leaf area below 10-cm cutting height and dry matter produced by *S. guyanensis* and *S. scabra* accessions in four weeks.**

was carried out in solution culture to determine if **Stylosanthes** cultivars differ in Al tolerance. Figure 6 shows the response of one selection of *S. guyanensis* (CIAT 64A) collected from an allic soil in the Llanos Orientales, and a selection of *S. hamata* (CIAT 118) collected from a nearly neutral soil in Venezuela. The two accessions clearly differ in Al tolerance, in this case according to the acidity of the soil of origin. Screening within species will be continued to select cultivars for Al tolerance and P utilization efficiency.

The effects of Ca and P concentrations on Al toxicity were also studied. Figure 7 shows that a five-fold increase in Ca concentration greatly reduced Al toxicity symptoms in roots of *S. hamata* (CIAT 118). Small applications of lime or other Ca-bearing amendments, which are insufficient to greatly affect soil pH and Al saturation, may nevertheless have a physiological effect in reducing Al toxicity. Figure 7 also shows that an increase in P concentration stimulates root and top growth in the presence of Al but does not eliminate the darkening and deformation of the roots caused by the Al.

Corroborating the findings of the solution culture experiments, between and within species variations in response to pH and Al status in soil was observed in **Stylosanthes** accessions. At Santander a local ecotype of *S. guyanensis* (CIAT 184) and another accession from the Colombian Llanos (CIAT 64A) tolerated low pH and high Al levels, but *S. hamata* (CIAT 118) and another *S. guyanensis* (CIAT 136)

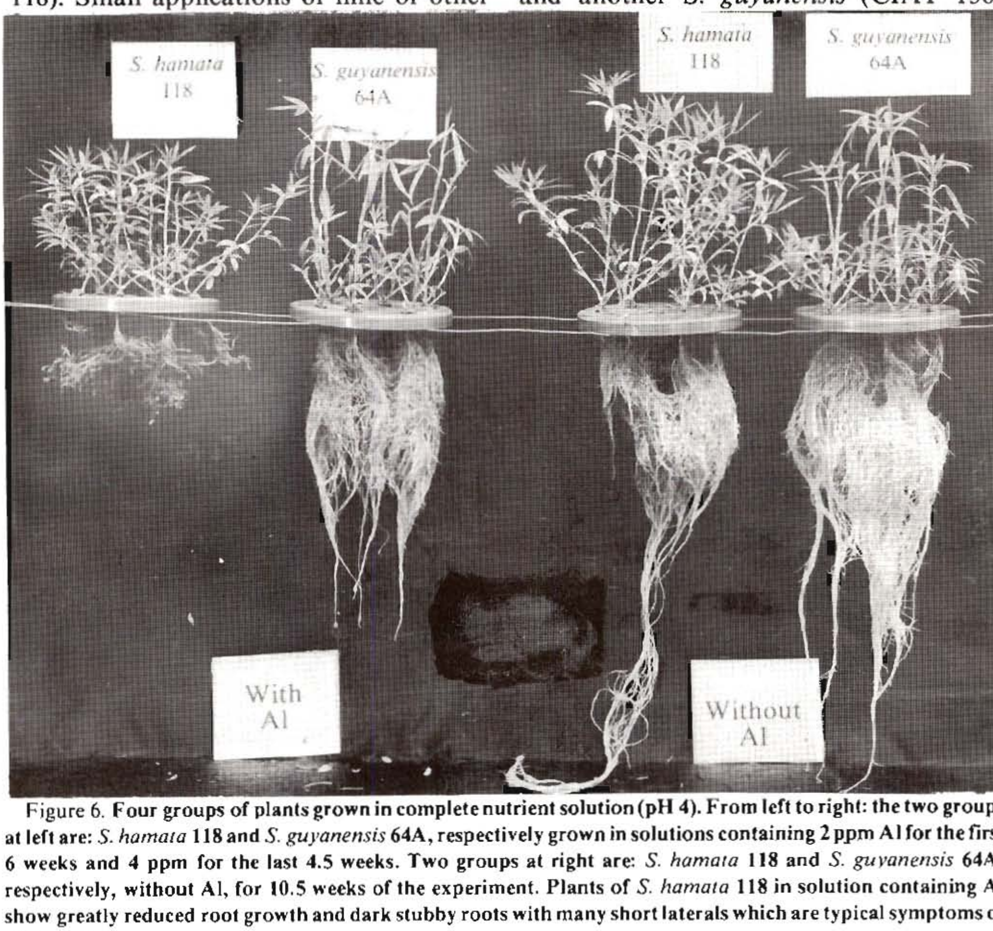

Figure 6. **Four groups of plants grown in complete nutrient solution (pH 4). From left to right: the two groups at left are: *S. hamata* 118 and *S. guyanensis* 64A, respectively grown in solutions containing 2 ppm Al for the first 6 weeks and 4 ppm for the last 4.5 weeks. Two groups at right are: *S. hamata* 118 and *S. guyanensis* 64A, respectively, without Al, for 10.5 weeks of the experiment. Plants of *S. hamata* 118 in solution containing Al show greatly reduced root growth and dark stubby roots with many short laterals which are typical symptoms of Al toxicity.**

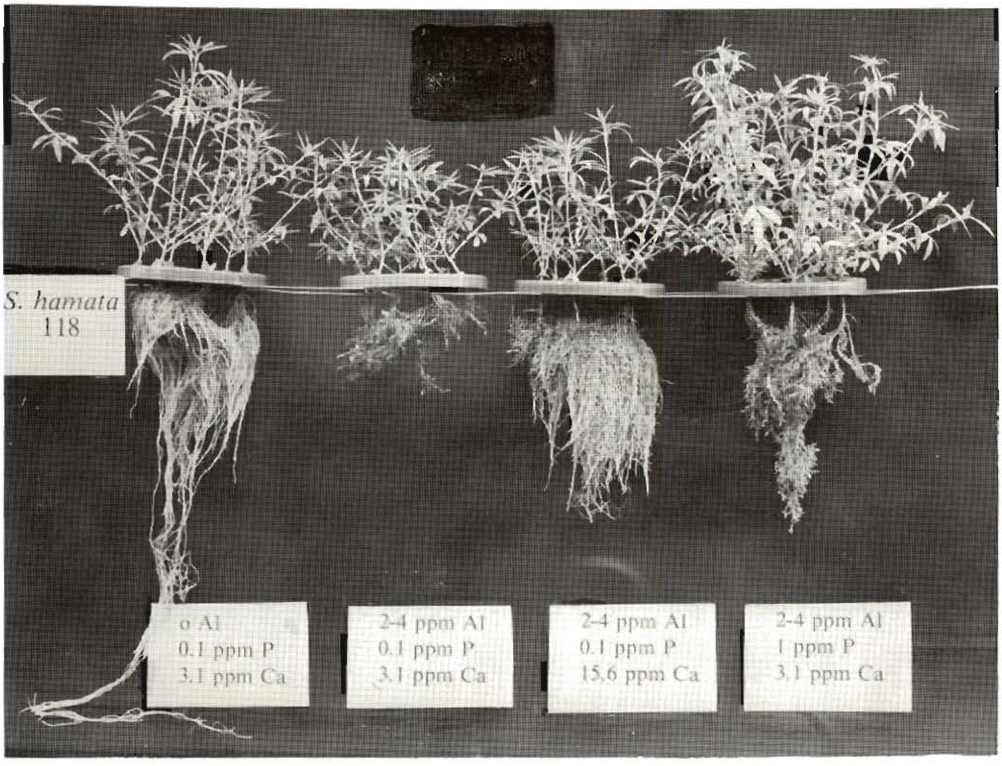

Figure 7. **Interactions of Al, P and Ca on root growth of *S. hamata* 118.**

performed poorly, exhibiting general yellowing of the plant tops.

Liming an allic soil (pH 4.4) to pH 6.1 reduced the dry weight of tops and roots of *S. capitata* and *S. guyanensis* ecotypes which originated from allic soil sites. *S. guyanensis* accession CIAT 182, from a pH 6.4 site, and **Centrosema** responded positively to lime application (4 ton| ha of $CaCO_3$) when grown in allic soil. *S. capitata* did not produce root nodules in the lime treatment, but nodulated normally at soil pH 4.4 and at an Al level of 3.0 meq| 100 g.

Forage plant improvement

Work in this area was confined to field testing and distribution of previously selected material, i.e., **Centrosema** hybrid CIAT 1733, *S. guyanensis* CIAT 136, *S. hamata* CIAT 118, **Demodium** sp. CIAT 336, *Desmodium distortum* CIAT 335, and **Macroptilium** spp. CIAT 635, 614 and 612. These legumes were also established in field trials at Santander with one of the following companion grasses: *Brachiaria decumbens, Andropogon gayanus, Urochloa mosambicensis, Hyparrhenia rufa* and *Panicum maximum*.

Collaborative forage species evaluation was initiated with Emprasa Brasileira de Pesquisa Agropecuaria (EMBRAPA), in Brazil, and arrangements were made for other trials to be conducted in the Dominican Republic and El Salvador. Seed of promising species was supplied this year to pasture researchers in 12 tropical American countries.

Seed production

The seed production unit concentrates on producing seed of potentially useful accessions to enable their extensive evaluation. In 1975, new production areas of legumes, especially **Stylosanthes** spp. and **Centrosema** spp. have been established. The unit has received harvesting and processing machinery which should greatly increase seed production capacity and efficiency.

Stylosanthes guyanensis

Two second-year stands of CIAT 18 totaling 1.2 hectares were hand-harvested at Palmira and yielded an average of 60 kg|ha of scarified pure seed. The essential ly manual system of harvesting and processing the seed required about 70 man-days|ha.

At Palmira an 0.8 hectare area of CIAT 136, with a density of 5,500 transplants|ha, yielded 160 kg|ha of scarified pure seed. Harvesting was between December and February with peak yields recorded in early January. Average plant age at maturity was eight months. Only 10 percent of the plants regenerated so the area was discontinued. Similarly populated plots of CIAT 184 and CIAT 64A yielded 48 and 11 kg|ha, respectively, in April. High soil moisture and weeds affected yields of these plots.

First-year stands of several accessions at Carimagua produced only 15 kg|ha of scarified seed. Yields were the same in both the normal January harvesting season and also in March following limited dry season irrigation.

Some 20 hectares of CIAT 136 have been established from seed at Palmira and Carimagua. These areas are almost mature and will be combine harvested early in 1976.

Weed competition is severe at Palmira. The pre-emergence herbicide DNBP has been used at planting but repeated mechanical cultivation and manual weeding are also required. A bud worm, *Stegastra bosqueella* (Chambers), (Lepidoptera, Gelechidae) is a serious pest at both Palmira and Carimagua and requires control measures. More definition is required of minor element requirements at both locations. As demonstrated at Palmira, the woody mature plant base of CIAT 136 does not recover rapidly after cutting and this will reduce the productive life of seed areas. At Carimagua stand life is also seriously reduced by a buildup of stylo anthracnose and stemborer.

Stylosanthes hamata

Fourteen accessions of *S. hamata* were established in small plots at Palmira. Average yield was 135 kg|ha of pods at first manual harvest. One hundred kilograms of pods have been produced.

Centrosema sp.

Two F_7 lines of the hybrid *C. brasilianum* x *C. virginianum* are now established at Palmira. A bamboo and wire trellis system has been constructed over this 1.5 hectare area. The first harvest is expected in February, 1976.

Desmodium spp.

A planting of **Desmodium** sp. (CIAT 336) was combined in October; the yield rate was 35 kg|ha of pure seed. An area of *D. canum* (CIAT 353) was hand-harvested twice (March and July, 1975); total yield was 40 kg|ha pure seed. A small area of *D. heterophyllum* is maintained as a source of future propagating material.

Brachiaria decumbens cv. Basilisk

Initial production areas were planted vegetatively at both Palmira (0.8 ha) and Carimagua (0.6 ha).

At Palmira, atrazine was used both as a pre-emergence and postemergence (between rows) treatment for weed control. Inter-row mechanical cultivations were also required. Three different management systems involving mechanical slashing and nitrogen application were applied to individual subdivisions. Irrigation was applied as required, trash was removed after cutting, and harvesting was by direct combining. The harvested material was shade and sun dried then processed in an air-screen cleaner and a gravity separator. Results are summarized in Table 10.

Panicum maximum cv. Makueni; Urochloa mosambicensis and Andropogon gayanus

A total of 1.5 hectares was vegetatively planted to these species at Palmira and Carimagua.

At Palmira a single management system involved mechanical slashing, trash removal, irrigation, a 50 kilogram nitrogen application per harvest cycle, and harvesting with a combine. Seeds were processed as previously described. The Makueni guinea grass has yielded a total of 17 kg|ha of gravity-cleaned seed and the *Urochloa mosambicensis* has produced a total of 70 kg|ha from three harvests between July and September, 1975.

Pasture weed control

Weed control trials in *Stylosanthes guyanensis* continued at Palmira. The best control and greatest selectivity occurred with trifluralin, 0.4 kg|ha or DNBP, 1.5 kg|ha pre-emergence, when followed four weeks later by a postemergence application of bentazon at 1.0 kg|ha. Trifluralin, dinitramine and butralin incorporated in the soil at recommended rates injured the **Stylosanthes.** Vernolate was selective and could be used when **Cyperus** spp. weeds are the predominant species.

Table 10. **Pure seed yield of *Brachiaria decumbens* under various management systems, CIAT, Palmira (1975).**

Management system		First harvest		Pure seed yield
Nitrogen (kg/ha)	No. of cuttings	Date	Age (months)	(kg/ha)
50	0	July 25	4	40
50	1	Sept. 11	6	100
100	2	Sept. 15	6	55

A similar trial in *Centrosema pubescens* at Palmira showed that pre-emergence applications of alachlor alone, 2.5 kg|ha, or in combination with linuron or fluorodifen gave excellent weed control with no crop injury. *Cucumis melo* was not controlled by alachlor alone but was controlled by the mixtures.

The weed control unit has developed a method to assist ranchers wishing to establish forage legumes in grass pastures. Glyphosate was applied in 25-cm bands spaced one meter apart at the rate of 1.0 kg|ha of the area actually treated. One week later seeds of *Centrosema pubescens* and *Desmodium intortum* were scattered in the band of dying Pangola pasture. Cattle were kept out of the area for three months and excellent legume establishment occurred.

Because most pasture weeds are seed-propagated, germination trials have been conducted over a two-year period on 12 of the most common species. Three-hundred seeds of each species were germinated every two months in Petri dishes containing a thin layer of moist sand. Figure 8 shows that most species had some dormancy and reached their peak germination four to eight months after harvest. *Steiractinia cornifolia* and *Vernonia patens* are exceptions, completely losing their viability after four months. *Paspalum fasciculatum*, *Pithecolobium lanceolatum*, *Cordia colococca* and *Cnidoscolus urens* did not germinate during the 24-month period. This indicates that they either have a very long dormancy period or they require different environmental conditions to germinate since in the field all of them are known to reproduce by seeds.

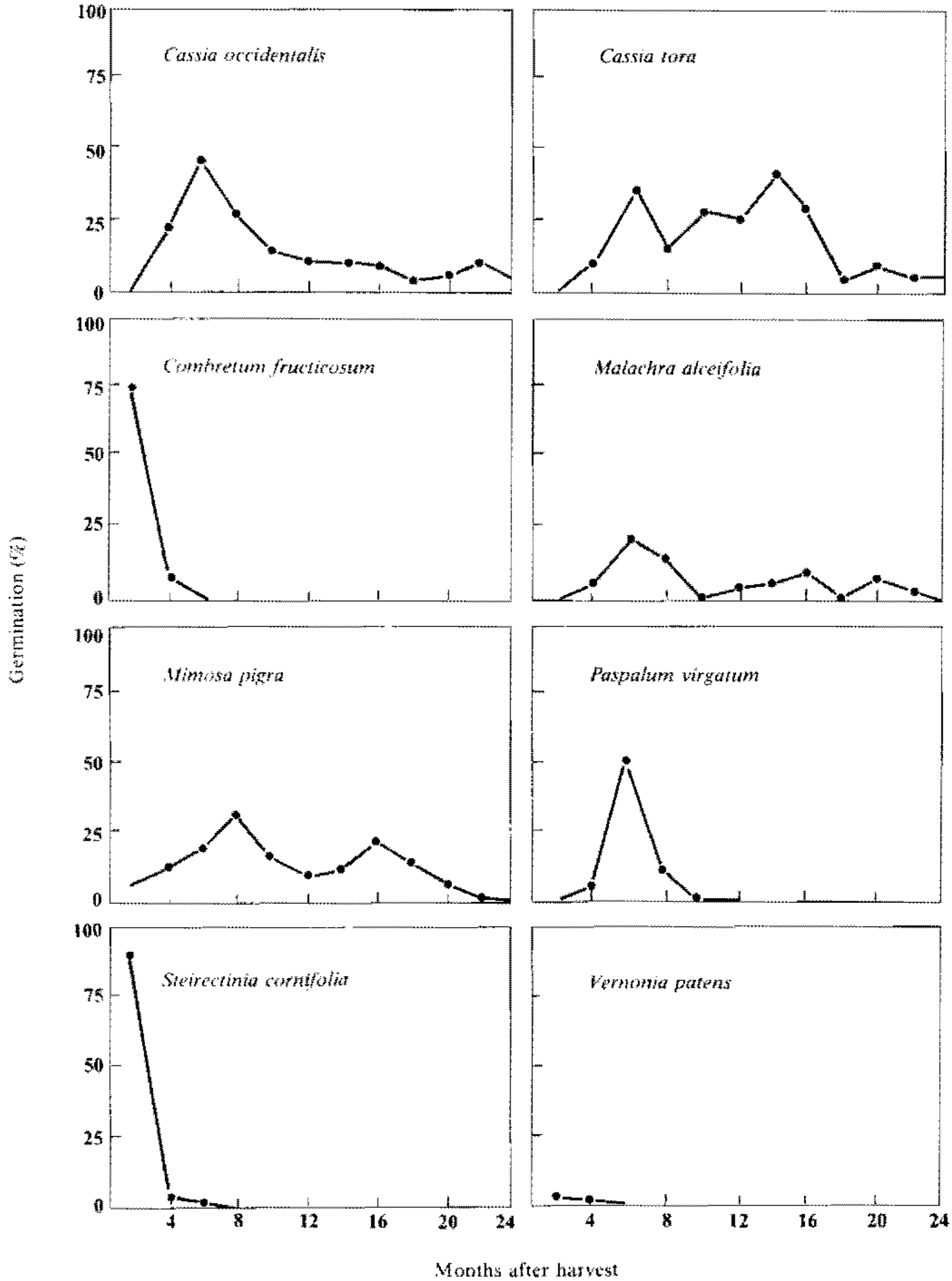

Figure 8. **Germination patterns of eight pasture weeds during 24 months after seed harvest.**

Brush control research continued in the Atlantic Coast area of Colombia. Special attention was given to species resistant to foliarly-applied herbicides. *Cordia colococca* was killed by DPX-3674 at .2 g|m² applied to the soil at the base of the plant (equivalent to 2 kg|ha on a overall treatment basis). Death was slow as the herbicide had to be leached into the root zone and then translocated throughout the plant. Nevertheless, it was the most effective treatment and by only applying the herbicide at the base of each plant, very little injury occurred to the pasture

DPX-3674, at .2 g|m², karbutilate, at .75 g|m², and tebuthiuron, at .2 g|m², all soil applied, gave good but not complete control of *Piper marginatum.* Cut-stump treatments with 2,4-D + 2,4,5-T or picloram + 2,4-D + 2,4,5-T, both in a 1 percent solution with diesel fuel, gave complete control. Another species, *Bredemeyera floribunda,* was completely killed by basal applications of diesel fuel alone or when fortified with 2,4,5-T (2%) or 2,4-D + 2,4,5-T + 2,4-DP (1%). The small brushy weed **Sida** spp. is a frequent problem. It was controlled best by combinations of 2,4-D + 2,4,5-T (2% v|v) or dicamba + 2,4-D (1% v|v). Glyphosate at 0.5 percent solution also killed **Sida** but caused excessive injury to the pasture grasses. Only in cases of severe infestations and the absence of desirable grasses could this latter compound be used.

A practical Guide for Brush Control in Pastures was prepared and is being incorporated into a general bulletin covering many aspects of pasture weed control which will summarize the results obtained during the past four years of research in this area.

Pasture and forage utilization

The Program's activities were continued at Palmira and Carimagua this year.

Palmira

The grazing trial designed to measure the effect of nitrogen fertilization on beef production on a Pangola grass (*Digitaria decumbens*) pasture was continued until October 1975 with no changes in the experimental design. Daily weight gains for steers in the experiment are presented in Table 11 and total gains from the pastures are displayed in Figure 9.

Weight gains per steer and per hectare were lower than those of the two previous years, mainly due to the lack of irrigation water for prolonged periods. Nevertheless, the responses to nitrogen applications and to increases in stocking rates were similar.

Since domestic prices for fertilizer and cattle have remained the same in Colombia, the low returns reported last year have not changed (internal rate of return adjusted to 5 percent of the capital invested because of inflation). However, this input-product price relationship does not adversely affect beef cattle producers from other tropical countries such as Venezuela and Brazil, where it would seem economically feasible to use nitrogen on pastures for intensive fattening of steers in areas near large consumer markets.

From the data obtained during three and a half years of research, it can be said that Pangola grass clearly responds to fertilization and that valid generalizations can be made. This phase of the experiment was finished in October, and the last experimental phase was begun immediately in the same area and with the same design. It will measure the net efficiency of the utilization and energy and nitrogen of the grass for beef fattening.

Desmodium distortum, an erect, annual species well-accepted by cattle, is a little-known tropical forage legume that seems to have good production potential.

Table 11. **Daily weight gains of steers grazing nitrogen-fertilized, irrigated Pangola grass.***

Nitrogen (kg/ha year)	Stocking rate (steers/ha)					
	4.17	5.00	5.83	6.67	7.50	8.33
	(g/day/animal)					
168	468	405	394			
332		303	335	395		
500			393	355	370	
672				395	327	389

* Last 294 days of the experiment

Desmodium yields were measured by making successive cuttings when the plants reached heights of 0.6, 0.9, 1.2 and 1.5 meters. Yields from successive cuttings are shown in Figure 10. Plants cut at 0.6 meter received seven cuttings, whereas those cut at 1.5 meters received only five. The gradual reduction in yields from successive cuttings, a characteristic of annual plants, can be seen; this reduction is more pronounced in older plants. Cumulative yields are presented in Table 12. Total yields increase when the plants are cut at a later stage. In practice, it seems easier to cut the plant when it reaches a height of 0.9 to 1.0 meter thus obtaining a yield of approximately ten tons of dry matter.

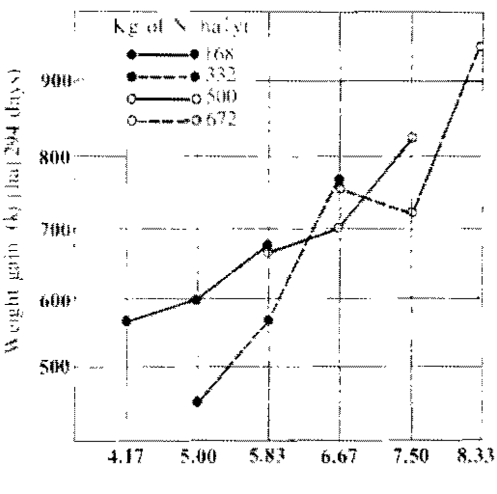

Figure 9. **Per hectare weight gains during last 294 days of grazing trial on irrigated and nitrogen-fertilized Pangola grass.**

Earlier intake studies with penned sheep (1974 Annual Report) indicated that sheep selected the different parts of the *D. distortum* plant in the following order: leaves, petioles, upper and basal parts of the stem. In terms of digestibility, this species was best among the tropical species analyzed **in vivo**, and it seemed that the digestibility of the upper parts of the stem was as good as that of the leaves. Figure 11 gives the percentages for each part of the plant. Younger cuts show a high content of leaves and young stem (internodes 1 to 11).

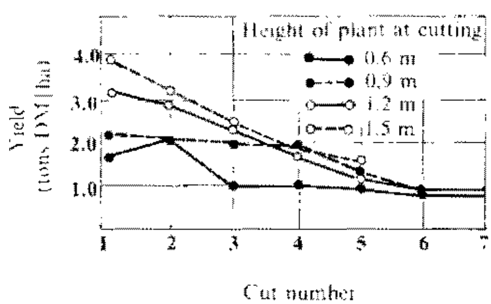

Figure 10. **Yield of *Desmodium distortum* at various cuttings.**

Table 12. Cumulative yields of *Desmodium distortum* cut at various heights.

No. of cuttings	Plant height at cutting (m)			
	0.6	0.9	1.2	1.5
	(tons of DM|ha)			
5	7.53	9.76	11.54	13.13
6	8.37	10.96	12.52	
7	9.21			

D. distortum can be recommended as a good cutting forage for supplemental feeding of cattle.

Carimagua

Grazing trials were continued with native savanna and four grasses well-adapted to the environment at Carimagua. Emphasis was placed also on the use of urea and molasses supplementation during the dry season.

Table 13 compares weight gains of steers grazing native savanna burned once (the entire pasture) at the beginning of the dry season with gains obtained after sequential burnings (using fireguards to divide the savanna into eight equal plots and burning one plot at a time during the year). During the dry season, weight losses increased as the stocking rate rose. During the rainy season, animals gained weight, compensating for dry season losses; by the end of the year, they had gained approximately 60 kilograms at the low and medium stocking rates (0.20 and 0.35 steers|ha). There was no advantage whatsoever in sequential burning during this year. Figure 12 shows changes in forage availability, which depends on the type of burning and on the subsequent pasture growth as affected by stocking rate. Initial differences lessen as the year progresses. As can be seen in Figure 13 the quantity of forage available remains at a very low level during the dry season (November to March). At all stocking rates, forage availability decreased after the first burning and then remained constant, except at the highest stocking rate when availability decreased considerably.

The evaluation of the productivity of the species *Brachiaria decumbens*, *Hyparrhenia rufa*, *Paspalum plicatulum* and the mixture *P. plicatulum* with *Indigofera hirsuta* began this year; *Melinis minutiflora* was included as a comparison. The four grasses seemed to be best adapted to the zone, although only *P. plicatulum* is native. The legume *I. hirsuta* was included because it is native to the plains of Venezuela and has many possibilities of being utilized in the zone of Barinas (Venezuela). The seed was initially obtained from Barinas and multiplied in Palmira.

Table 14 shows the weight gains obtained with the four pastures. The lots with *M. minutiflora* were not grazed during the dry season since it is known that this practice produces weight losses in cattle (Table 15). The pasture planted with a mixture of *P. plicatulum* and *I. hirsuta* was not established well enough to have animals grazing during the dry season.

The three grasses *H. rufa*, *M. minutiflora* and *P. plicatulum* gave similar results and thus offer three possibilities of low-yielding grasses adapted to allic soils. *P. plicatulum* has proven to be highly susceptible to diseases and insect pests. In addition to the stemborer and **Helminthosporium** reported the previous year, this year it was attacked by the false armyworm which ate all the foliage, making it necessary to rest the pasture for 46 days. The false armyworm also attacked *M. minutiflora* but not *H. rufa* or *B. decumbens*. *B. decumbens* yielded considerably more than the other three grasses. Weight gains on **Brachiaria** during the dry season should be interpreted cautiously, however, since during that time there was a population (estimated at less than 10 percent) of *Stylosanthes guyanensis* remaining from the combined planting

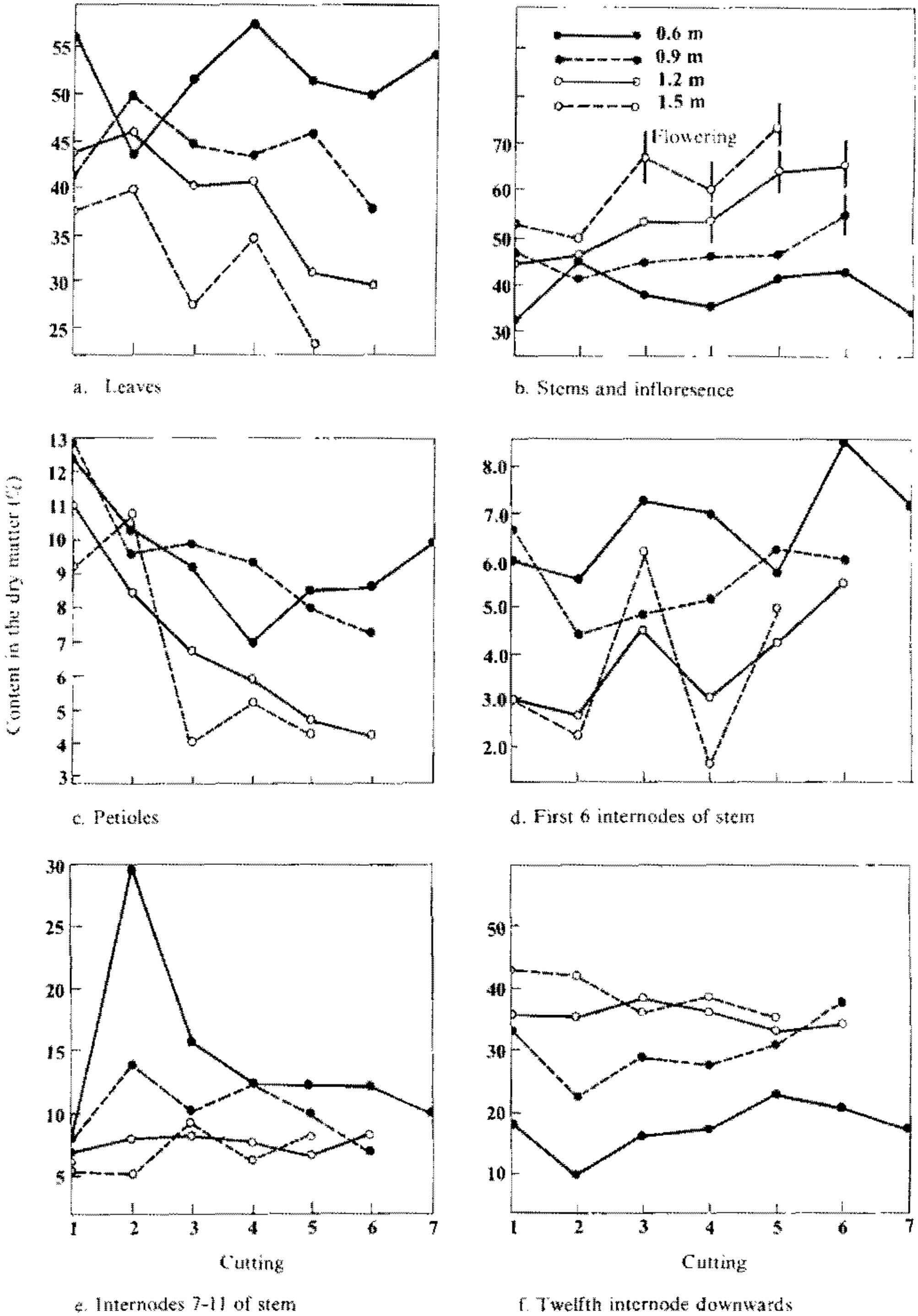

Figure 11. **Percentage yield of plant parts of *Desmodium distortum* at various cuttings.**

Table 13. **Seasonal and yearly weight changes of steers grazing tropical savanna pasture at Carimagua (Nov. 1974 - Nov. 1975).**

Pasture management	Dry season (g/day)	Dry season (kg/animal)	Rainy season (g/day)	Rainy season (kg/animal)	Year (g/day)	Year (kg/animal)
Total burning once						
0.20 steers/ha	143	16	219	55	196	71
0.35 steers/ha	-80	-9	295	74	179	65
0.50 steers/ha	-170	-19	143	36	46	17
Sequential burning						
0.20 steers/ha	-134	-15	319	80	179	65
0.35 steers/ha	-214	-24	347	87	174	63
0.50 steers/ha	-313	-35	231	58	63	23

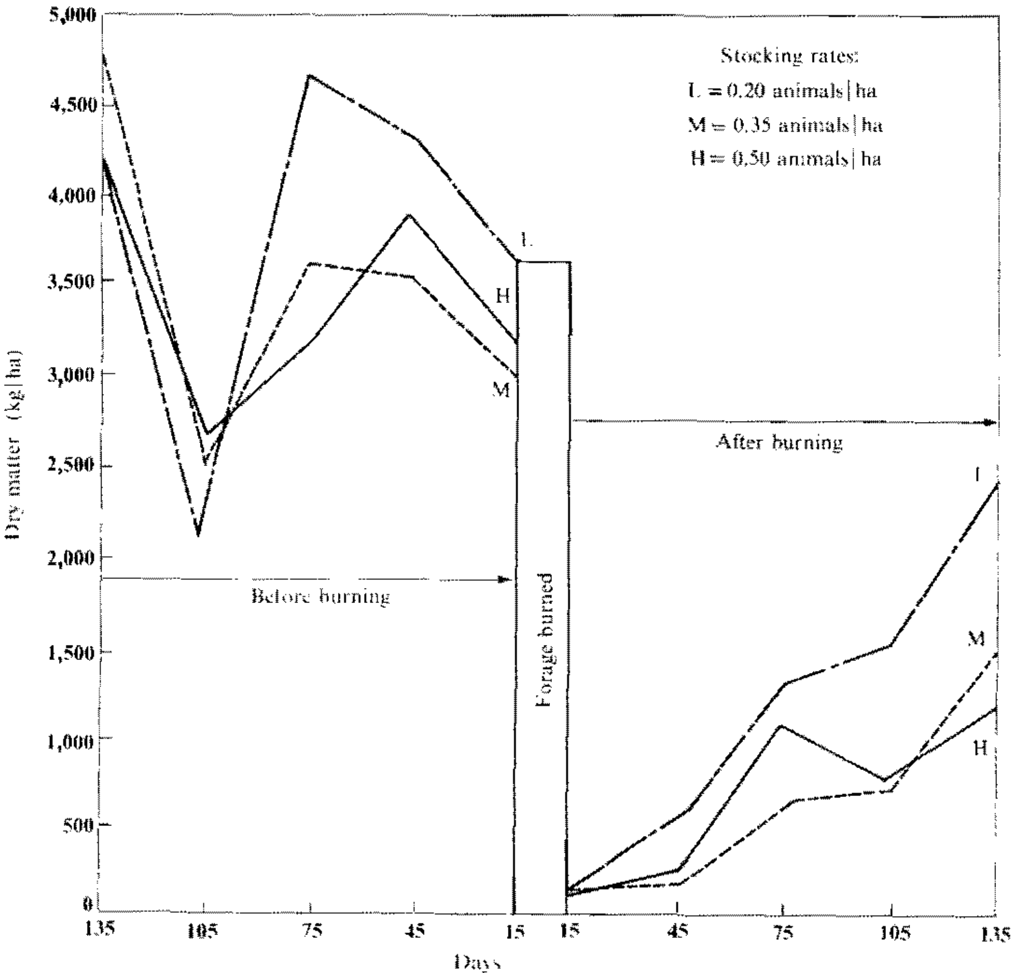

Figure 12. **Availability of forage on native savanna pasture before and after burning.**

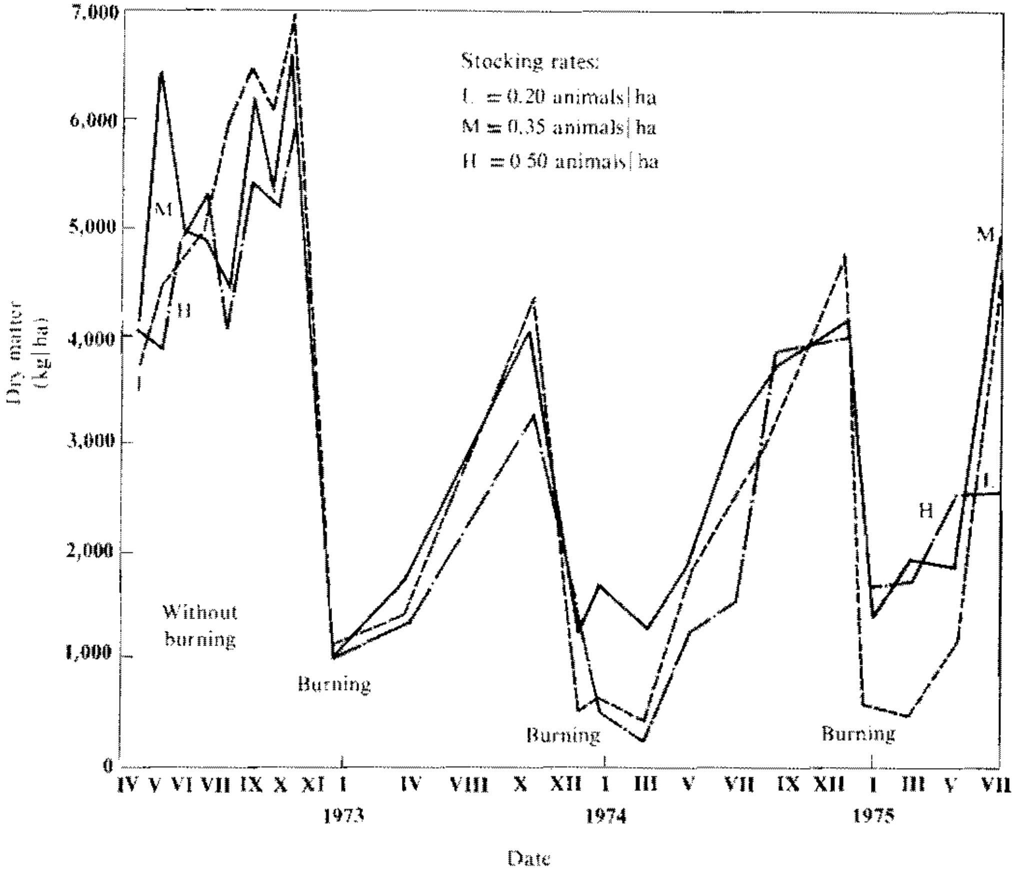

Figure 13. **Availability of forage on native savanna pasture entirely burned annually and grazed continuously at three stocking rates.**

done previously. *S. guyanensis* disappeared completely by the end of the dry season because of the stemborer and the greater vigor of the grass.

B. decumbens offers more possibilities as a producer of better quality forage than the other grasses tested. Two observations were made: The first was the death of 12 steers during the first days of grazing on *B. decumbens* during the rainy season. The symptoms of intoxication were swelling of the ears and at the base of the horns, which extended to the rest of the body. The animals died within 24 hours after the first symptoms appeared. Within the group, the younger, recently weaned animals were affected. The problem disappeared after an intensive grazing with a large number of steers. The second observation relates to the yellowing of *B. decumbens* as the rainy season progress. The symptoms are similar to a nitrogen deficiency. However, the grass showed no apparent response to urea applications. It should also be noted that the stocking rate on *B. decumbens* this year was very low during the first part of the rainy season.

Reports that animals do not consume *I. hirsuta* were received from areas of Venezuela other than the state of Barinas. Observations at Carimagua confirmed this information. Animals consumed all the grass (*P. plicatulum*) but apparently ate none of the legume.

Table 14. **Animal productivity on several forage species adopted to allic soils, Carimagua (Nov. 1974-Nov 1975).**

Forage species and stocking rate	Dry season		Rainy season	
	(g|day)	(kg|animal)	(g|day)	(kg|animal)
*Brachiaria decumbens**				
0.5 steers | ha	141	16		
0.9 steers | ha			406	102
1.3 steers | ha			473	119
1.7 steers | ha			313	79
Hyparrhenia rufa				
0.5 steers | ha	-383	-43		
0.7 steers | ha			172	43
1.0 steers | ha			148	37
1.4 steers | ha			77	19
Melinis minutiflora				
0.7 steers | ha			287	72
1.0 steers | ha			204	51
1.4 steers |			160	40
*Paspalum plicatulum***				
0.5 steers | ha	-494	-56		
0.7 steers | ha			260	66
1.0 steers | ha			133	34
1.4 steers | ha			155	39
Indigofera hirsuta + Paspalum plicatulum				
0.9 steers | ha			-164	-41
1.3 steers | ha			66	17
1.7 steers | ha			-138	-35

* Dry season gains may be positively affected by a small quantity of **Stylosanthes** remaining from an earlier planting. By the beginning of the rainy season, this **Stylosanthes** had disappeared.

** During the rainy season, animals were removed from these pastures for 46 days because of severe attack by the false armyworm that destroyed the available forage.

The grazing trial with *M. minutiflora* was repeated this year on the same pastures and with the same design. The three experimental treatments are: (a) continuous grazing the whole year with no supplementation; (b) continuous grazing the whole year but each animal receiving 80 grams of urea and 400 grams of molasses daily in the dry season; and (c) grazing the pasture during the rainy season, resting it in the dry season, and no supplements. Results are given in Table 15. It was found that weight losses of animals that were not supplemented during the dry season were less this year than for the previous year (500 versus 300 grams daily). Possibly for this reason, compensatory gains were not obtained as in the previous year.

In all treatments and on all pastures, weight gains were lower this year than in previous years, possibly due to the

Table 15. **Weight changes of steers grazing *Melinis minutiflora* under three management systems.**

	Dry season		Rainy season		Year
	(g|day)	(kg|animal)	(g|day)	(kg|animal)	(kg|animal)
Grazing all year					
0.44 steers|ha	-210	-24	437	110	86
0.88 steers|ha	-358	-40	372	93	53
Grazing all year+ urea + molasses					
0.44 steers|ha	- 10	- 1	457	115	114
0.88 steers|ha	27	3	416	104	107
Grazing only during the rainy season					
0.44 steers|ha	-	-	529	104	-
0.88 steers|ha	-	-	377	74	-
1.30 steers|ha	-	-	243	48	-

prolonged dry period lasting until May, after early rains in March.

A trial was established to determine the effect of urea and cassava meal supplementation of animals grazing native savanna during the dry season. A preliminary test was run this year including four treatments compared during the dry season: 400 g molasses + 80 g urea|animal|day; 400 g molasses|animal|day; 30 g urea|animal|day; and no supplement (control). All animals received salt and dicalcium phosphate free choice. Results are given in Figure 14. Supplementation was extended until May; nevertheless, there were weight gains after March, possibly because the two or three rains in March were sufficient to stimulate pasture growth. Weight gains from March to May were equal for all treatments, except for that of urea alone. From November to March, all animals lost weight; losses of unsupplemented animals were significantly greater than for those receiving urea and molasses. Losses of animals fed molasses and urea alone were intermediate. The effect obtained with molasses alone is interesting and seems to confirm the hypothesis that a small quantity of easily metabolizable carbohydrates facilitates the utilization of nonprotein nitrogen contained in the

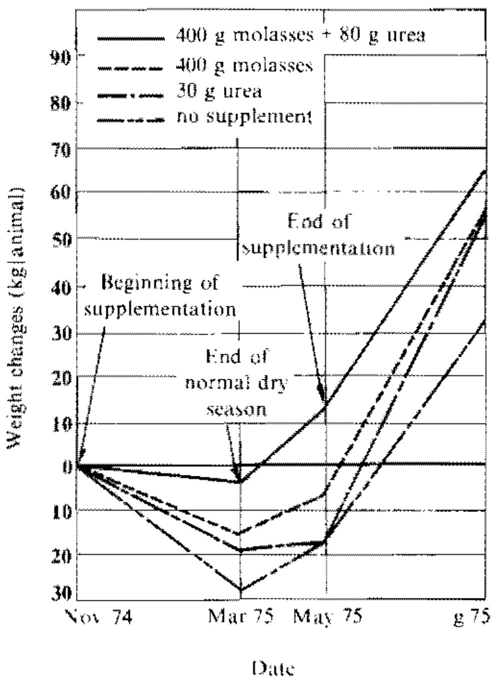

Figure 14. **Weight changes of steers supplemented and unsupplemented during the dry season on native savanna pasture.**

Table 16. **Weight gains of steers grazing native savanna at Carimagua, supplemented with soybean meal during the dry season.***

	Initial weight (kg)	Weight gain (g/day/animal)	Significance at 5%
Supplement: soybean meal			
70 g daily/animal	131	119	a
490 g every 7 days/animal	131	93	a
280 g daily/animal	131	200	b
1960 g every 7 days/animal	126	262	b

* Supplementation began in February and ended in May, 1975. The weight gain refers to this period.

animals' normal saliva. Until August, the nonsupplemented animals had managed to regain 50 percent of the weight difference registered at the end of the dry season. After March, the response of the group to urea alone is not easily explained and requires further checking.

A preliminary trial was established to study the effect of supplementing animals grazing native savanna during the dry season with soybean meal supplied daily or the weekly total in one day of the week. Results are given in Table 16.

Feeding a protein supplement daily is inconvenient in herd management. If the same results could be obtained by feeding the supplement once a week considerable labor could be saved and the problem of preferential consumption by domineering animals, could be alleviated somewhat. The advantage of the groups supplemented with the higher level of soybean meal is not surprising on pastures such as these that contain 2 to 3 percent protein in the dry season.

Forage intake and digestibility

As part of the effort to determine the nutritive value of tropical forage species, some of the more important species were fed to African male sheep. Results are summarized in Table 17.

Very important for the Program's objectives is the fact that the nutritive value of the species *Stylosanthes guyanensis* is high in both digestibility and intake even in mature plants (eight months of growth). The nutritive value of native grass is extremely low during the dry season, but it increases considerably when it is supplemented with a protein source of either urea or cottonseed meal.

These results explain the response obtained with urea and molasses supplementation of steers grazing the native savanna, as an increase in forage intake and digestibility. When molasses grass was supplemented with **Stylosanthes,** forage digestibility and intake increased; this is one more indicator of the importance of **Stylosanthes** for improving the nutrition of animals during the dry season.

ANIMAL HEALTH

The aim of the animal health team from the time of its inception has been to assist the development of economic preventive medicine programs for beef cattle in the tropical lowlands of Latin America. More specifically this can be expressed as: defining disease spectrum and prevalence; measuring the economic impact of disease; measuring the cost/benefit ratio of control; and identifying disease areas where

Table 17. **Intake and digestibility of some tropical forage species.**

	Quantity of forage offered (g DM/kg metabolic wt)	Dry matter intake (g DM/kg metabolic wt)	Dry matter digestibility (g DM/kg metabolic wt)	DM digestibility (%)
Stylosanthes guyanensis				
3 months' growth	100	63	41	65
5 months' regrowth	100	69	43	62
6 months' regrowth	100	67	43	64
8 months' regrowth	100	60	35	58
Centrosema (mature)	100	79	36	46
Eletift (early flowering)	120	57	35	61
Hemarthria				
6 months' growth	96	57	38	66
	144	62	41	67
Molasses grass (in dry season)	100	38	16	41
Native grass				
(in dry season + minerals)	89	46	15	32
(in dry season + minerals + molasses + urea)	89	61	26	39
(in dry season + minerals + cottonseed meal)	89	56	30	44

more research is required to achieve control.

The team is divided into units of microbiology, pathology, hemoparasitology, ectoparasitology and wildlife studies. Staffing has been provided by the core budget of CIAT and through two specially-funded projects, one in hemoparasitology, with Texas A&M University and the United States Agency for International Development and the other in acarology, with the United Kingdom Overseas Development Ministry (UK ODM).

Principal collaborators in Colombia have been the Caja de Crédito Agrario, Industrial y Minero (Caja Agraria) and the International Center for Medical Research (ICMR).

In the past three years the strategy has been first to work through the slaughter house, following leads back to the farms of origin of cattle. A survey was then planned in the Colombian Llanos (Departamento of Meta and Comisaría of Vichada) to determine the prevalence of diseases thought to be significant and to relate them to the management and ecology of the farms visited. As part of the input into CIAT training activities, similar work was promoted in the North Coast region (Departamentos of Córdoba and Sucre), the Cauca Valley (Departamento of Valle), and the northwest section of the Departamento of Caquetá, as well as in Paraguay. A request for survey assistance was also met from Campo Grande, Brazil. In the last year, a start was made to relate this accumulating knowledge of disease prevalence to impact at farm level and to develop the methodology for cost/benefit analysis of control strategies. Supportive research continued in order to improve the efficiency of prevalence studies, to clarify the epidemiological picture and to devise control alternatives. This report will discuss progress in all these areas.

Concurrent with this main line of development into animal disease economics, both thesis student and postgraduate intern intake sharply increased. In particular, a link was established with the training program of the Centro Panamericano de Zoonosis (CEPANZO) in Buenos Aires. Two international workshops were organized, one in hemoparasites and the other in ectoparasites, and attracted delegates from Australia, Africa, Europe and North America as well as from 11 Latin American countries. The workshops clarified the common problems of Latin American countries in the two areas, indicated the research needs, and defined a contribution which could be made by the CIAT animal health team.

Disease prevalence studies

Characterization of farms under survey

A questionnaire was devised with the help of economists in the Beef Program and completed for 37 of the farms visited in the Colombian Llanos. All farms had received loans from the Caja Agraria. Despite obvious limitations imposed by a single visit, a crude outline emerges for framing future enquiry.

The farms occupied a wide band of country stretching from the Piedmont in the West almost to the Venezuelan border in the East and bounded on the North by the Meta River. Originally, the farms were arranged into five groups, four in Meta and the other representing part of Meta as well as farms sampled in Vichada in the East. Although some management differences existed, particularly between the Piedmont and elsewhere, all 37 are considered together for the purposes of this survey.

Farms averaged 3,952 hectares (range 173-28,000) and carried an average of 594 head of cattle (range 125-1,480). The overall stocking density was one animal per 6.4 hectares. All farms except two had some area of introduced grasses. The most popular were: puntero (*Hyparrhenia rufa*), 23 farms; gordura (*Melinis minutiflora*), 23 farms, and **Brachiaria** spp. 19 farms. Thrity-one of the farms claimed to feed minerals.

Only 16 farms attempted to number their cattle and only 14 attempted to divide their herds by age or sex. The earliest age of weaning was eight months (11 farms).

The birth rate averaged 50.7 percent (range 29-75.7), calf mortality averaged 7.8 percent (range 0-60) and adult mortality averaged 2.2 percent (range 0-6). The diseases considered the most important are given in Table 18. "Secadera" emerges as the clear leader but is obscure in definition. Farmers describe the condition as being those animals which cease to thrive as if

Table 18. **The most important health problems in cattle reported on 37 ranches in the Llanos Orientales of Colombia.**

Condition	No. of ranches reporting	Percentage
Secadera (huequera)	13	35
Blackleg	7	19
Breeding diseases	7	19
Calf diarrhea	4	10
Aftosa	3	8
Colibacillosis	1	3
Dermatitis	1	3
Mastitis	1	3
	37	100

overcome by the multiple challenges of malnutrition and disease. A similar condition in the North Coast region of Colombia is called "huequera". The condition called "blackleg" also needs further identification. There may be difficulties in differentiating blackleg with hemorrhagic septicemia (bovine pasteurellosis) and common snakebite. Although ticks were not specifically mentioned as a problem, 33 of the farms regularly dipped their cattle an average of once every 29 days (range 8-180).

The most common vaccinations were (by number of farms): foot and mouth (32), blackleg (31), salmonellosis ("peste boba") (28) and brucellosis (9). The average number of vaccinations per animal per year was 4.27 (range 0-6). Disease control measures cost an average of Col. $91 annually per animal.

Improved management of existing resources combined with effective preventive medicine programs would in themselves significantly raise the level of productivity, but the lack of both social amenities and interest from absentee landlords are major restraints.

Breeding diseases

Brucellosis. The consolidated results are given in Table 19 and are similar to those published in recent years by ICA for the same areas. Since the low prevalence of brucellosis constitutes a minor reproductive hazard on the farms surveyed, no further brucellosis investigations are planned. A similar prevalence rate was found in the Mato Grosso of Brazil.

Infectious bovine rhinotracheitis/-pustular vaginitis (IBR). This viral disease causing either respiratory or genital infections is now recognized as being widespread in beef cattle in Colombia. The consolidated results are given in Table 20 and their significance is being assessed. It is not clear why the prevalence in the north of the Cauca Valley is so low.

Leptospirosis. Prevalence data for leptospirosis are displayed in Table 21 and clearly show that this group of infections is widespread in beef cattle in the tropical areas of Colombia. Table 22 shows the prevalence of those serotypes known to cause clinical disease in other parts of the world. There is evidence from Australia, New Zealand, North America and Italy of an increasing prevalence of *Leptospira hardjo* which appears to be replacing *Leptospira pomona* as the most common serotype affecting cattle. Australia reports give a 5-10 percent abortion rate and a high prevalence of mild mastitis. A similar

Table 19 **Prevalence of bovine brucellosis in areas of Colombia and Brazil, 1974-75.**

Area	Farms sampled	Sera examined*	Positive sera	Prevalence (%)
Colombia				
Llanos Orientales	48	4,844	100	2.1
Caqueta	30	487	6	1.2
North Coast	38	5,233	344	6.6
Cauca Valley	24	1,183	41	3.5
Brazil				
Mato Grosso	62	615	8	1.3

* Using plate and tube agglutination and mercaptoethanol tests

Table 20. **Prevalence of infectious bovine rhinotracheitis/pustular vaginitis (IBR) in cattle in areas of Colombia, 1974-75.**

Area	Farms sampled	Sera examined*	Positive sera	Prevalence (%)
Llanos Orientales	48	3,555	692	19.5
Caquetá	30	472	114	24.5
North Coast	30	1,640	231	14.1
Cauca Valley	25	929	7	0.75

* Using indirect hemagglutination test.

assessment of significance is being made for South American tropical situations.

Hemoparasitic diseases

Anaplasmosis. Results of field surveys for anaplasmosis are shown in Table 23. The conclusion can be reached that introducing susceptible cattle into any of the lowland tropical areas of Colombia sampled should be attempted only after immunization. However, the range of numbers of positive animals between farms in the Llanos Orientales indicated differing degrees of endemicity, that is, differing degrees of challenge. The Cauca Valley appeared to be of a lower degree of endemicity than the North Coast or the Llanos Orientales, with a complicating factor that the same farmer may keep cattle both in the endemic valley bottom and in adjacent mountain pastures where no transmission is occurring.

Babesiosis. Field survey results for the two known **Babesia** species infecting cattle are shown in Tables 24 and 25. As with anaplasmosis, the conclusion can be reached that introducing susceptible cattle into any of the lowland tropical areas of Colombia sampled should be attempted only after immunization. With babesiosis, however, prevalence differences between farms in the Llanos Orientales indicated that enough susceptible adult animals could exist in some herds to cause deaths if moved into areas of higher challenge.

Ectoparasites

Ticks. Collection and identification of ticks infesting cattle were made on 37 farms surveyed in the Llanos Orientales of Colombia. *Boophilus microplus* ticks were identified and quantitated on each farm and were almost equally distributed. *Amblyomma cajennense, Amblyomma*

Table 21. **Prevalence of bovine leptospirosis in areas of Colombia, 1974-75.***

Area	Farms sampled	Sera examined**	Positive sera	Prevalence (%)
Llanos Orientales	44	1,307	830	63.5
North Coast	8	183	163	89.1
Cauca Valley	7	131	106	80.9

* Serology carried out in collaboration with the Pan-American Zoonosis Center

** Using the microscopic slide agglutination test for 14 serotypes commonly found in cattle.

Table 22. **Prevalence of the five most common** Leptospira **serotypes detected infecting cattle in Colombia, 1974-75.***

Area	Animals sampled	Serotype (no. and % of reactors)**				
		Hardjo	Sejroe	Wolfii	Hebdomadis	Tarassovi
Llanos Orientales	1,307	575 (44.0%)	644 (49.3%)	497 (38.3%)	269 (20.6%)	289 (22.1%)
North Coast	183	114 (62.6%)	123 (67.2%)	83 (45.4%)	82 (44.8%)	78 (42.6%)
Cauca Valley	131	106 (80.9%)	113 (86.3%)	75 (57.3%)	75 (57.3%)	63 (48.1%)

* Serology performed at Pan-American Zoonosis Center

** Using the microscopic slide agglutination test.

triste and *Anocentor nitens* were detected on only three farms.

Supportive Research

Breeding diseases

Epidemiology of leptospirosis. The high prevalence of leptospirosis found in beef cattle in all tropical areas sampled required two initial investigations. Firstly, the serological results needed confirmation by the culture of organisms from infected cattle, and, secondly, to suggest control strategy, it was necessary to determine whether reservoirs of infection existed in wild animal populations.

Permission was obtained to slaughter four cows having high titers to *Leptospira hardjo* (1:800, 1:800, 1:1600, 1:1600) and attempt to culture the organisms. Although no positive cultures were obtained from the organs of any animal, histopathological examinations of all kidneys showed a chronic nephritis compatible with a leptospirosis infection.

On this same farm, three isolations of **Leptospira** have been made from **Proechymis** sp. (spiny rat) and one from *Caluromys philander* (Philander opossum), and are now being classified.

Hemoparasitic diseases

Development of diagnostic techniques. The hemoparasite workshop organized in May confirmed the need for simple farm-level tests for anaplasmosis and babesiosis. Special attention was therefore given to card agglutination tests for *Anaplasma marginale*, *Babesia argentina* and *Babesia bigemina*, and comparisons between all

Table 23. **Prevalence of bovine anaplasmosis** *(Anaplasma marginale)* **in areas of Colombia, 1974-75.**

Area	Farms sampled	Sera examined*	Positive sera	Prevalence (%)
Llanos Orientales	37	3,034	2,262	75
North Coast	4	232	211	91
Cauca Valley	10	873	538	62

* Using the complement fixation test

Table 24. **Prevalence of bovine babesiosis *(Babesia argentina)* in areas of Colombia, 1974-75.**

Area	Test*	Farms sampled	Sera examined	Positive sera	Prevalence (%)
Llanos Orientales	IFA	37	2,946	386	13
Cauca Valley	CF	6	403	247	61
	IFA	3	238	60	25

* Using the complement fixation (CF) or indirect fluorescent antibody tests (IFA)

available tests to determine sensitivity, specificity, duration of antibodies, and practicability and suitability for field and laboratory use.

The United States Department of Agriculture (USDA) provided materials for comparison testing under Colombian conditions of their card agglutination test (CT) for *Anaplasma marginale* with the standard complement fixation (CF) test used by Texas A&M staff at CIAT. A total of 342 serum samples were examined from nine susceptible cattle introduced into the North Coast region of Colombia, enabling a comparison before and during natural infection. The CT developed a positive agglutination reaction several days after the CF reaction and the positive reaction persisted. In contrast, the CF reaction fluctuated between trace (normally read as negative) and a 1:80 titer. The CT was superior in accuracy and simplicity to the CF test in the routine diagnosis of anaplasmosis, and, moreover, can be used in the field. The CF test is probably only of use in diagnosing anaplasmosis on a herd basis and in those experimental situations where it is important to recognize an initial rapid rise of complement fixation titer after natural or artificial infection.

A thesis dissertation student set up a card agglutination test (BCT) for *Babesia bigemina* and compared it with the indirect fluorescent antibody (IFA) and complement fixation (CF) tests. A *Babesia bigemina* antigen was divided into 13 fractions to compare different preservation methods. The best one—preservation in sealed glass vials at 4ºC after adding penicillin and streptomycin—gave a consistent reaction for six months. Using this antigenic fraction the BCT was carried out in the field in four regions of Colombia. Data are available for 300 plasma samples. In the samples from known endemic areas, IFA gave 91 percent positive reactions, BCT, 76 percent positive and CF, 57 percent positive. All tests read negative from areas known to be free of babesiosis. The BCT has a field application for rapid diagnosis of *B. bigemina* on a herd basis. A similar test for *B. argentina* is being developed.

Table 25. **Prevalence of bovine babesiosis *(Babesia bigemina)* in areas of Colombia, 1974-75.**

Area	Test*	Farms sampled	Sera examined	Positive sera	Prevalence (%)
Llanos Orientales	IFA	37	2,946	1,817	62
North Coast	CF	4	227	175	77
Cauca Valley	CF	7	635	420	66
	IFA	3	238	137	58

* Using the complement fixation (CF) or indirect fluorescent antibody (IFA) test

IFA and CF tests for diagnosing *B. argentina* and *B. bigemina* infections in cattle were also compared. A total of 372 serum samples were collected from nine susceptible cattle introduced onto the North Coast region of Colombia, again enabling comparisons before and after natural infection. The IFA technique detected *B. argentina* antibodies an average of 4.0 weeks earlier than the CF test and *B. bigemina* an average of 2.5 weeks earlier. Both tests could differentiate the two species but a few cross reactions occurred. IFA titers were relatively higher than those of the CF test, which occasionally gave a trace reading. Although both are laboratory tests, IFA has important advantages over CF in simplicity, economy and speed.

A postgraduate intern demonstrated a possible refinement to the CF test for *B. argentina* and *B. bigemina* by proving that complement fixation antigens were present in the plasma of acutely infected, splenectomized calves and could be used successfully in the CF test. The significance is that plasma is discarded in procedures normally used to prepare antigens from **Babesia** spp.

Development of immunizing procedures against anaplasmosis and babesiosis. A method of immunizing cattle against anaplasmosis and babesiosis is being evaluated in the Cauca Valley in collaboration with ICA. The usual method of using whole unquantitated parasitemic blood as the vaccine is too variable in result to be acceptable for use in valuable stock. Australian methods of quantitating whole parasitemic blood, and of vaccinating against *B. argentina* alone is very successful and popular there. However, Australia has no recognized anaplasmosis problem and, in Colombia, *B. argentina* and *B. bigemina* appear to be equally pathogenic in experimental situations. The method developed by the CIAT hemoparasite unit involves storing antigens for *A. marginale* and both **Babesia** spp. at low temperature and titrating the antigens in groups of cattle to calculate the minimum infective dose of each which is required to immunize animals in the field. This year adjustments were made to the low temperature storage techniques and all stabilates are now kept in liquid nitrogen. The vaccine used contains the appropriate dilution of each of the three organisms. In a laboratory trial, 14 susceptible calves were inoculated without incident and resisted challenge to homologous strains eight weeks later.

Economic analyses are being done on the same farms where the efficiency of the immunizing technique under commercial conditions is being checked. A decision to be made eventually is whether the system can be developed and expanded on a commercial scale.

Trypanosomiasis *(Trypanosoma vivax).* The existence of the African trypanosome, *Trypanosoma vivax*, in Latin America is known from a series of largely anecdotal references originating in all countries bordering the Atlantic, from Panama to Brazil. Little research has been done, probably due to the lack of adequate diagnostic methods. The method of transmission is unknown. A master's candidate from Texas A&M established the indirect fluorescent antibody test in Colombia in 1972, and proved that the infection existed in the Colombian Llanos, the North Coast and the Cauca Valley. A doctoral student is now expanding the epidemiological studies by analyzing connected outbreaks on four farms in the Cauca Valley. Economic losses included a severe drop in milk production on the one dairy farm, and emaciation of beef cattle with sporadic mortality. The symptoms are similar to African situations where cattle have been under light or occasional vector challenge. Three of the four outbreaks would not have been diagnosed without the field work of the investigator. This means trypanosomiasis may be more prevalent than recognized because of confusion with other hemoparasitic diseases.

Ectoparasitic diseases

Ticks were studied during the first full year of the special project financed by the UK ODM.

This project was established because serious production losses from tick infestations have been recorded on other continents in circumstances comparable to those in tropical Latin America. Losses are both from reduced weight gains due to the direct parasitic effect of the ticks and because they are important vectors of disease. Either cause of loss is sufficient economic reason for control.

Before a national government decideson a tick control policy the following basic information is required: (1) the tick species present and their distribution; (2) their importance in transmitting disease; (3) the life-cycles of the ticks in differing environments; and (4) whether the ticks are resistant to acaricides. The last two factors are essential in deciding the most economical control strategies. Work in the tick unit followed this total pattern of requirement.

Specialized resources were developed. A moated tick barn for disease transmission experiments and double-fenced, moated paddocks were built. Clean tick colony lines of the major bovine tick species were maintained. The *Boophilus microplus* line is now in its twelfth generation and *Anocentor nitens* in its fifth. Breeding colonies of *Didelphis marsupialis* (common opossum) and *Zygodontomys brevicauda* (cane rat) are now established as two of the laboratory hosts for rearing the different stages of tick species. The checklist of tick species and their distribution in Colombia (1974 Annual Report) was expanded. In collaboration with ICA, studies were extended from domestic and wild mammals to birds. A doctoral student reviewed the literature and prepared a manual showing the known hosts and distribution of 172 tick species in Latin America.

Research literature is unclear on the ability of *Boophilus microplus* to transmit *Anaplasma marginale* even though anaplasmosis is thought to be a major disease in the tropics and *Boophilus microplus* is common in the same localities. Transmission trials were established and the third attempt is currently under way.

A doctoral student studied several aspects of on-host ecology of selected tick species of economic importance to the cattle industry in Colombia. The work included the following segments: the establishment of a group of cattle in the field to study tick loads, distribution patterns on the animal, and seasonal incidence of *Boophilus microplus;* the field rearing of the same tick at 3,000, 2,450, 1,800 and 1,000 meters altitude for studies of oviposition success and duration, larval productivity, and longevity; collation of weather data, and the study of diurnal activity of larvae in grass to judge the ameliorating effect on litter zone microclimate of the pasture cover.

Collaboration continued with the Wellcome Laboratories, Berkhamsted, England, in acaricide resistance studies. Three further consignments of ticks were dispatched.

The ectoparasite workshop organized in August revealed the need to identify tick taxonomists in South America and to standardize taxonomic keys. A small workshop will be held in 1976 combining taxonomy with methodology in determining tick distribution.

Wild animal studies

The Annual Reports of 1973 and 1974 contained checklists of mammals together with their parasites and infections that are found at Carimagua. This work was done to determine conditions which may be pathogenic to man or his domestic animals, particularly cattle. The most important infections found were an unknown **Echinococcus** sp., *Trypanosoma cruzi* infection (Chagas' disease of man) and *Trypanosoma evansi* infection. Continuing work on these infections is reported below, but the emphasis of the wild animal studies changed. The technical staff were increasingly employed either on the farms chosen for intensive examination or on teaching assignments. One technician was loaned for a month to the ICA|USDA foot and mouth eradication project in the Chocó region of Colombia.

Echinococcus sp.: The infection was found in **Proechymis** sp. for the first time as well as in the two agouti species, *Cuniculus paca* and *Dasyprocta fuliginosa*. Attempts to establish the full life cycle for making a positive identification, continued at the ICMR. Sera from staff stationed at Carimagua were sent to CEPANZO and the results were negative. This is an area of work which has to be brought to a conclusion. If this particular species is found to be capable of infecting cattle, this represents an important potential loss of production. In Argentina, for example, infection with **Echinococcus** is a principal cause of condemnation in slaughter houses.

Trypanosoma cruzi infections: Baseline sera were collected from Carimagua staff on a voluntary basis and sent to the Instituto Nacional de Diagnóstico e Investigación de la Enfermedad de Chagas in Argentina. Five ICA employees had positive sera. They were identified, checked for heart irregularities and treated. The ICMR continues to check on the presence of infected Reduviid bugs in the vicinity of Carimagua. This is an important service to this isolated community.

Trypanosoma evansi infections: Thirteen strains from Carimagua are now stored at low temperature at Palmira. They are derived from domestic horses (2), domestic dogs (3) and capybaras (*Hydrochoerus hydrochoeris*) (8). A master's student is comparing the antigenicity of the strains from the three host sources to confirm that they are the same species of trypanosome.

Disease impact at farm level

Breeding diseases

Ten of the farms surveyed in the Colombian Llanos were chosen for closer and continuous examination. Table 26 gives the abortion rates in a single 12-month period. These are minimal figures as there may be abortions in early gestation which are unnoticed.

Farms A and B were further assessed. Farm A had a few reactors to brucellosis (6|130) that were slaughtered or transferred elsewhere. The number of IBR reactors was also negligible (4|110). However, the number of leptospirosis reactors was high (29|66). Bulls were negative for trichomoniasis and vibriosis.

Table 26. **Abortion rates in ten beef herds in the Departamento of Meta, Llanos Orientales, Colombia observed in a 12-month period.**

Farm	No. of females	No. of abortions	%
A	180	14	7.7
B	424	40	9.4
C	350	25	7.1
D	151	8	5.3
E	126	4	3.1
F	557	24	4.3
G	305	12	4.0
H	76	6	7.8
I	160	15	9.3
J	138	6	4.3
	2,467	154	6.24

Farm B similarly had minor numbers of reactors to brucellosis (2|93) and IBR (3|74) but a high number of leptospirosis reactors (69|72). Again, no trichomoniasis or vibriosis could be detected. The circumstantial evidence is that leptospirosis is the main reproductive disease problem on both farms. Observations and collation of data are continuing.

Records from the ICA|CIAT. herd systems experiment at Carimagua are now sufficiently complete to assess the calving and abortion rates in the individual herds against the elimination of brucellosis from the experiment, absence of vibriosis and trichomoniasis and observed low prevalence of IBR and leptospirosis.

Hemoparasitic diseases (anaplasmosis, babesiosis)

The prevalence data indicate that high mortality would occur if susceptible cattle were introduced into any of the areas sampled.

In studies of calf-hood infections of the four beef herds sampled in the North Coast, the 112 calves examined were first infected at a mean age of 11 weeks with both *A. marginale* and *B. bigemina*. Mean packed cell volume (PCV) values significantly decreased during a two-week period following infection but all calves recovered rapidly. The two infections did not appear to have any economic impact.

However, the situation in the Cauca Valley was different. Herds are either dairy or beef alone, or sometimes mixed operations. The housing of calves on dairy farms means that they are exposed to first infection at pasture only at about six months when innate age immunity is waning. In addition, some stock may be reared at higher altitudes where transmission is not occurring. Animals with susceptibility caused by either reason have acute and sometimes fatal infections. The direct losses described in the records of one farm studied are in Table 27. Detailed epidemiological work is being done on 12 farms to determine and collect the data for measuring economic impact.

"Secadera"

The importance of the "secadera" complex was discussed in the section on disease prevalence studies. As a result, a follow-up visit was made to one farm where production and animal health records had been maintained during 1973-75 by the resident owner who was also a veterinarian.

Twenty-seven cases of secadera had occurred in the three years, 9 in 1973, 11 in 1974 and 7 in Jan.-Oct., 1975. All cases

Table 27. **Direct economic loss on a dairy farm in the Cauca Valley, Colombia, caused by anaplasmosis and babesiosis, (Jan. 1,1970-June 30, 1975).**

	No. of animals	Total deaths	Losses from deaths (Col.$)	Costs of drugs (Col.$)	Costs for labor (Col.$)	Total loss (Col.$)	Average loss|head (Col.$)
1970	205	3	16,000	10,379	3,513	29,982	146
1971	224	5	23,250	15,398	4,801	43,449	194
1972	236	11	60,000	22,417	5,745	88,162	373
1973	218	5	27,750	22,302	7,167	57,219	262
1974	245	8	52,000	29,580	9,124	90,704	369
1975	240	3	23,500	21,441	5,431	50,372	211

occurred in cows from 3 to 11 years of age (average 5-1|2), representing in this age and sex group an annual incidence range of 4.0-6.5 percent. Twenty-three of the cases were in cows which had either recently weaned a calf or were nursing a calf when symptoms were observed. Eight animals died even though each one received a minimum of and in many cases as many as four antibiotic treatments and supportive therapy, and were given the best pasture available. Secadera has accounted for 25 percent of the total deaths in breeding cows on the farm during that period. Cows that recovered from secadera required 4-6 months to regain normal conditions, during which time they failed to rebreed.

A common opinion amongst veterinarians working in the Llanos is that nutritional stress in animals which are carriers of anaplasmosis causes a recrudescing clinical infection. The theory needs to be checked with accurate clinical and serological data.

Cost|benefit analysis of control

The work on prevalence studies and economic impact of disease progressed far enough to commence cost|benefit analysis of control.

Foot and mouth disease

CIAT economics and animal health staff are using foot and mouth disease as the main pioneering area in animal health economics. The reasons for choice have been, first, the international interest and concern; second, the availability in Colombia of outbreaks; third, the relative freedom from complicating management or concurrent disease factors; and last, the existence of large campaigns for both eradication and control so that the cost|benefit of control strategies can be compared. The successful methodology developed after outbreaks on pig farms in the Cauca Valley gives a better understanding of the requirements for work with beef cattle. An epidemiological model of the disease has been prepared to assist economists in preparing their corresponding economics model. A complementary and more detailed description is given in the Economics section of this report.

Hemoparasitic diseases (anaplasmosis, babesiosis)

Farms have been selected from the 12 under economic study in the Cauca Valley to analyze the benefits of immunizing stock against anaplasmosis and babesiosis. Equal numbers of calves under normal management and immunized calves are being compared on each farm. Calves on two farms have been immunized up to now. This study is being carried out in collaboration with ICA.

PRODUCTION SYSTEMS

Food crop production

Green manure crops for allic soils

Last year effects of liming on dry matter production and nitrogen yield (kg N|ha) of several green manure crops grown at Carimagua were reported (1974 Annual Report). Highest N yields were obtained with indigofera, followed by cowpea, velvet bean and crotalaria. After incorporating the green manures, two varieties each of corn (H-207 and Carimagua-2) and sorghum (BR-64 and E-57) were planted across the green manure treatments. They also received 50 kg|ha P_2O_5, 50 kg|ha of K_2O, and 50 kg N|ha as urea split-applied at 10 and 57 days.

Corn and sorghum are very susceptible to soil acidity and yields of both with zero and 0.5 ton of lime|ha were practically nil. The results reported are the averages of the 2 and 6 tons|ha lime treatments only. Sorghum was harvested as green forage because of bird damage to the grain. Figure 15 shows the response of the corn and sorghum varieties to incorporated green manure crops. Though yields were low, both crops responded best to incorporation of cowpea, followed by velvet bean or indigofera, and least to incorporation of crotalaria. The poor response to crotalaria could be due to its very low N-content (1.5%) compared with the other green manure crops (2.4-2.8%). Cowpea incorporation, however, consistently produced highest yields of corn and sorghum, despite its lower N yield than indigofera.

Tillage systems

With the rising cost of machinery and fuel and the availability of better herbicides, worldwide interest in systems of minimum tillage has greatly increased. Under the Llanos situation, minimum tillage for food crop production seems feasible after sufficient lime has been applied and incorporated. In 1974 a trial was established to compare effects of four tillage systems on corn yields after the initial application of 2 tons of lime|ha and the production of one uniform corn crop. Although yields were low due to Al toxicity, highest corn yields were obtained without soil tillage, placing only the corn residues from the first crop in the row as a soil mulch.

In 1975 another 2.6 tons|ha of lime was applied and uniformly incorporated, increasing the lime level to 4.6 tons|ha. The following uniform crop of upland rice (variety CICA-6) produced an excellent yield of 4.7 tons|ha. Again using four tillage systems, a crop of black beans (Porrillo Sintético) was sown. Though not yet harvested, the weight of green plants and green pods indicates best plant growth with a minimum tillage system of one disking without ridging. This system appears superior to the traditional system of plowing, discing and ridging.

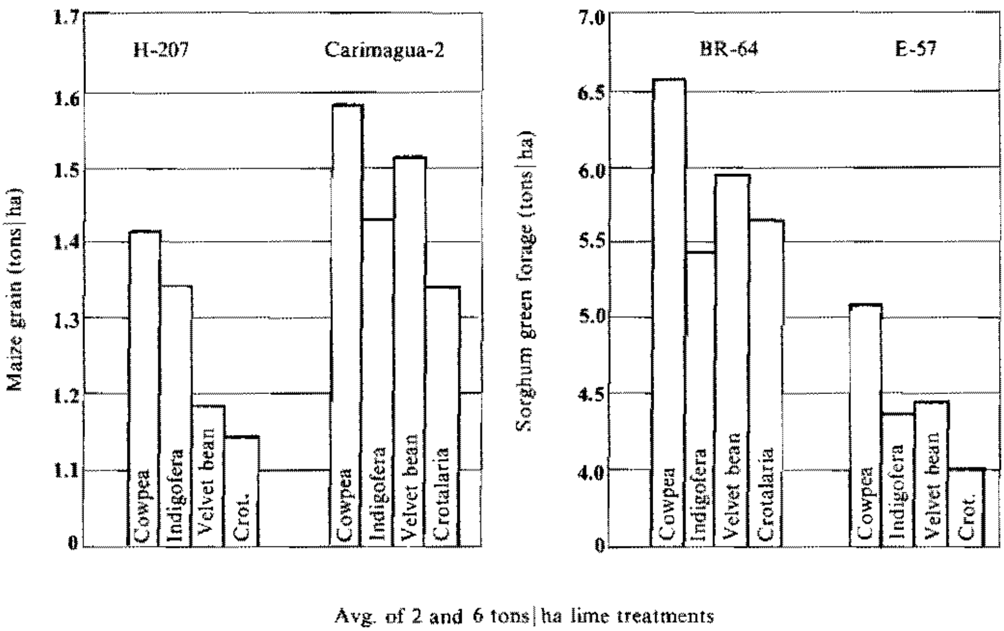

Figure 15. **Response of two maize and two sorghum varieties to the incorporation of various green manure crops before seeding at Carimagua.**

Plantain fertilization

Plantain is a staple food for people of the Llanos and is produced around the farmhouse, in old corrals, or in cleared gallery forests where it grows well and apparently without nutritional problems. However, when grown in plowed savanna, without fertilization, plants develop poorly and hardly set fruit; they seem to suffer from several nutritional problems. In order to determine the plant's main nutritional requirements on these savanna soils, an experiment was planted in 1972 with various levels of N, P, K, lime and farm manure, using a San Cristóbal experimental design. After analyzing the harvest of 1974, treatment levels were slightly adjusted. Table 28 shows the total yields for 1972 to mid-1974 and for mid-1974 to 1975, averaged for each treatment over all other treatment combinations.

In the first period, greatest response came from applications of 200 kg K_2O | ha, 100 kg P_2O_5 and 10 tons manure | ha. There was little response to liming or nitrogen. In 1975, greatest response again was obtained from the highest level of K followed by applications of P, N and farm manure. There was a large response to the recent application of 1 ton | ha of lime, compared with the residual effect of other lime treatments applied in 1972. Initially, a beneficial effect of the 1972 lime applications was also observed, but later, production dropped due to apparent disease and | or micronutrient problems.

Herd production systems

The purpose of the herd systems and related early weaning experiments is to provide information for developing life-cycle production systems that will increase productivity and profit using today's cattle, pastures, technology and management skills. In addition, this experimentation will assist integrally in identifying and characterizing technological barriers to achieving further production increases. The overriding consideration is to determine how to feed and manage the cow so she rebreeds, since most cows grazing

Table 28. **Yield response of plantain (fresh fruit) to liming and fertilization, Carimagua.**

1972 to mid-1974			mid-1974 to 1975		
Treatment (kg | ha)		Yield (tons | ha)	Treatment (kg | ha)		Yield (tons | ha)
manure	0	1.84	manure	3,000	1.28
	10,000	4.75		9,000	1.51
N	0	3.36	N	0	1.10
	100	3.23		50	1.68
P_2O_5	0	1.86	P_2O_5	30	0.81
	100	4.73		90	1.97
K_2O_5	0	0.35	K_2O_5	50	0.73
	200	6.24		150	2.05
lime	0	7.07	lime	500*	0.80
	500*	5.85		1,000**	2.09
	2,000*	8.48		2,000*	0.24
	6,000*	8.63		6,000*	1.34

* Lime applied in 1972

** Lime applied in 1975

pastures in allic soil areas don't conceive again until the nursing calf is weaned, resulting in a calf every two years.

Herd systems experiment, ICA-CIAT (Carimagua)

This experiment is designed to determine the life-cycle effects of various management practices and production inputs. Treatment variables between herds include pasture systems, mineral supplementation, and protein supplementation during the dry season. Within herd treatments include early vs normal weaning, and alternative use of Zebu and San Martinero bulls in each herd.

Pasture treatments

Pasture treatments include grazing of native pasture all year, molasses grass (*Melinis minutiflora*) in the rainy season and native grass in the dry season, and molasses grass all year. Whereas seasonal differences have been noted, year-round animal performance, as measured by growth and reproduction, have been similar on all pasture regimes where mineral supplementation has been provided. First-calf heifers which received mineral supplements weighed approximately 330 kilograms (1974 Annual Report), just before the beginning of first calving and had similar calving percentages (86 to 91%) in the first year's calf crop (Table 29). In the second calf crop for the first six months of 1975, calving percentage ranged from 54 to 83 percent, with highest percentages (65 to 83) observed with the regime of molasses grass in the rainy season and native grass in dry season (Table 30). Calving percentages for cows on either native grass or molasses grass alone were similar (55 to 61%).

In analyzing reproductive performance since the initiation of breeding between May, 1973-June, 1975, average number of calvings|cow was slightly higher for the molasses grass-native grass combination (1.62) as compared to native grass alone (1.47) and molasses grass alone (1.45). Calving interval also favored the native grass-molasses grass combination (14.9 months) as compared to native grass alone (15.4 months) and molasses grass alone (15.8 months).

These results suggest little advantage for improved molasses grass pastures.

Table 29. **Reproductive performance in the first calf crop (calves born between February and December, 1974) Herd Systems I, Carimagua.**

Treatment	Herd	No. of cows	No. of births	No. of abortions	Calving (%)	Abortions (%)	Time from beginning of breeding to conception (months)
Control	1	28	14	11	50.0	39.0	5.24
Native pasture	2	33	17	13	51.5	39.3	7.74
and salt	3	29	15	7	51.7	24.1	9.78
Nature pasture	4	31	27	2	87.1	6.5	4.27
and complete minerals	5	33	30	1	90.9	3.0	4.74
Native pasture and	6	35	30	3	85.7	8.6	4.20
molasses grass and complete minerals	7	34	31	0	91.2	0.0	5.15
Molasses grass and	8	34	31	0	91.2	0.0	4.55
complete minerals	9	32	28	3	87.5	9.4	3.85

Table 30. **Reproductive performance in the second calf crop (calves born or to be born in 1975) and total number of births and abortions to date, Herd System I, Carimagua.**

Treatment	Herd	No. of cows	No. of births, 1975	No. of abortions, 1975	1975 calving (%)	1975 abortions (%)	Time between calvings, (months)	Total births	Total abortions
Control	1	28	15	1	55.4	3.6	21.5	29	12
Native pasture	2	33	12	0	65.5	0.0	20.4	29	13
and salt	3	29	19	0	65.5	0.0	20.9	34	7
Native pasture and	4	31	19	0	61.3	0.0	15.6	46	2
complete minerals	5	33	18	0	54.5	0.0	15.2	48	1
Native pasture and	6	35	29	0	82.9	0.0	15.2	59	3
molasses grass and	7	34	22	0	64.7	0.0	14.7	53	0
complete minerals									
Molasses grass and	8	34	19	0	55.9	0.0	15.2	50	0
complete minerals	9	32	18	2	56.3	6.3	16.3	46	4

However where pasture land is limiting, production can be increased by establishing improved pastures, which will generally have a higher stocking rate than native grass pastures in the rainy season. Also, improved grass pastures will often provide a higher plane of nutrition during the rainy season, resulting in improved performance of animals in more nutrient demanding phases of the production cycle, e.g. breeding bulls, weaner calves, brood cows, fattening cattle. However, improved grass pastures may or may not have an advantage over native grasses in the dry season. Actually *Melinus minutiflora* has shown to be inferior (1974 Annual Report).

These results also indicate that the lower areas with high water tables can be used to advantage during the dry season since soil moisture is adequate to support pasture plant growth. The usual grazing procedure is to utilize the higher, well-drained savannas in the rainy season, and the lower areas in the dry season. An exception would be pastures based on tropical forage legumes, which are generally deeper rooted than grasses and can tap subsoil moisture. They will often provide good pasture during the dry season in the higher well-drained areas.

Mineral supplementation

Cows on native pasture that received mineral supplementation had significantly higher calving percentages ($P < .01$) in the first calf crop than non-supplemented cows (88 vs 52%), shorter intervals ($P < .01$) between beginning of breeding and conception of first-calf heifers (4.5 vs 8.7 months), higher number of calves|cow ($P < .001$) through mid-1975 (1.47 vs 1.02), and shorter interval ($P < .001$) between calvings (15.4 vs. 20.7 months (Tables 29, 30 and 31). Calculated abortion rates were significantly lower)($P < .001$) in mineral supplemented herds (0.5 vs .32 abortions|cow). Mineral supplementation is a readily applied production practice that will often increase productivity and profit (Fig. 16).

Protein and energy supplementation

Supplementation during the early part of the first year's breeding season (1973) with a urea-sugar supplement did not improve calving percentage, nor reduce the interval between initiation of breeding season and conception of first-calf heifers.

The foregoing treatments were discontinued, and molasses-urea-sulfur (500-80-4 g|head|day) supplementation during the dry season (December through March) was initiated in December, 1973 in one of the two herds in each pasture regime with minerals (herds 4, 7, 9) and without minerals (herd 2). Up to mid-1975 molasses-urea supplementation has had no significant effect on calving percentage or interval between calving (Table 31).

Serum phosphorus levels

Blood samples have been taken once every rainy season (April to November) and once every dry season (December to March) since heifers were first brought to Carimagua in February, 1972. Blood sera were analyzed for serum inorganic phosphorus and initially for some other minerals.

Data in Table 32 and Figure 17 are only for heifers that had not calved and did not receive a protein energy supplement just before blood sampling.

Until July 1972, all heifers were grazed together on native pasture without mineral supplementation. Serum P levels were similar for all herds during this period and were lower in the rainy season than in the dry season ($P < .01$).

After the sampling in July 1972, the heifers were divided into nine herds and

Table 31. **Calving interval, conceptions, abortions and births, May 1973 to June 1975, Herd Systems I, Carimagua.**

Treatment	No. of cows	Calving interval (months)	Total conceptions	Avg. conceptions per cow	Total abortions	Avg. abortion per cow	Total births	Avg. births per cow
Minerals								
Salt	62	20.7	83	1.34	20	.32	63	1.02
Salt + minerals	64	15.4	97	1.52	3	.05	94	1.47
Pasture								
Native grass	64	15.4	97	1.52	3	.05	94	1.47
Native grass + molasses grass	69	14.9	115	1.67	3	.04	112	1.62
Molasses grass	66	15.8	101	1.53	5	.08	96	1.45
Protein supplementation								
None	131	16.5	202	1.54	11	.08	191	1.46
Urea + molasses	130	16.8	194	1.49	20	.15	174	1.34
Weaning								
Normal	223	17.3	321	1.44	28	.13	294	1.31
Early	38	12.9	74	1.95	3	.08	71	1.87

Figure 16. Cows grazing native grass that received a complete mineral supplement had 44 percent higher calving rates than those that received only salt.

treatments began. Heifers that continued on native pasture without minerals continued to have higher serum P levels in the dry season than in the rainy season. Herds on native pasture with minerals showed much smaller differences in serum P between rainy and dry seasons, and had consistently higher serum P levels in the rainy season ($P<0.05$) than those on native pasture without minerals. In the dry season the effect of mineral supplementation was either very small or even negative (March 1973 and January 1975). Heifers on molasses grass and minerals had consistently higher serum P levels all year than heifers on native grass and minerals. This effect was accentuated in the dry season. Heifers on molasses grass had higher serum P levels in the dry season than in the rainy season. Heifers on molasses grass in the rainy season and native grass in the dry season (herds 6 and 7) confirmed these trends in that P levels during the rainy season were similar to the herds 8 and 9 on molasses grass, and P levels in the dry season similar to herds 4 and 5 on native grass.

During the beginning of the first breeding season (April-June, 1973), herds 2-9 were divided into three groups to determine the effects of supplementation with urea-sugar and cottonseed meal (1973 Annual Report). Urea-sugar supplementation significantly reduced serum P level ($P < 0.05$) (Table 33). Cottonseed meal supplementation significantly increased serum P level in cattle on native grass without minerals (herds 2, 3). Even when cottonseed meal was fed, cattle on molasses grass had higher serum P levels than those on native pasture.

Molasses-urea-sulphur supplementation during the 1973-74 dry season significantly reduced serum P levels ($P< 0.05$) of cattle grazing native pastures (Table 34). The same trend was noted in heifers that had not yet calved in January 1975 (Table 35).

In September 1974 (rainy season), cows with nursing calves had significantly lower serum P levels ($P<0.05$) than heifers which had not yet calved (Table 36). Serum P was

Table 32. **Mean serum inorganic phosphorus levels (mg P/100 ml serum) in heifers before calving.**

		Feb. 1972		July 1972			Mar. 1973			June 1973			Feb. 1974			Sept. 1974			Jan. 1975		
Herd	Trt.*	No.	Mean	Trt.*	No.	Mean	Trt.*	No.	Mean	Trt.*	No.	Mean	Trt.*	No.	Mean	Trt.*	No.	Mean	Trt.*	No.	Mean
1	A	38	5.21	A	38	3.91	A	30	6.58				A	30	5.77	A	14	4.30	A	8	6.37
2	A	38	5.49	A	37	3.84	A	31	7.29	A	6	4.62				A	22	5.51			
3	A	38	5.60	A	37	3.93	A	28	5.87	A	5	3.48	A	25	5.71	A	21	3.06	A	16	5.29
4	A	37	5.49	A	36	4.08	B	29	5.87	B	7	5.09				B	6	5.54			
5	A	38	5.30	A	31	4.01	B	25	5.34	B	7	6.22	B	28	6.14	B	9	5.12	B	7	5.20
6	A	37	5.42	A	38	3.91	B	23	5.44	C	7	6.73	B	30	5.69	C	5	5.14	B	7	5.36
7	A	38	5.28	A	35	3.99	B	36	4.86	C	7	7.02				C	9	5.53			
8	A	38	5.77	A	35	4.03	C	26	7.09	C	7	6.25	C	21	6.79	C	6	5.91	C	3	7.00
9	A	37	5.17	A	37	3.83	C	35	8.04	C	7	5.66				C	3	5.75			

* Treatment: A: native pasture + salt only; B: native pasture + mineral mix including P; C: Molasses grass + mineral mix including P

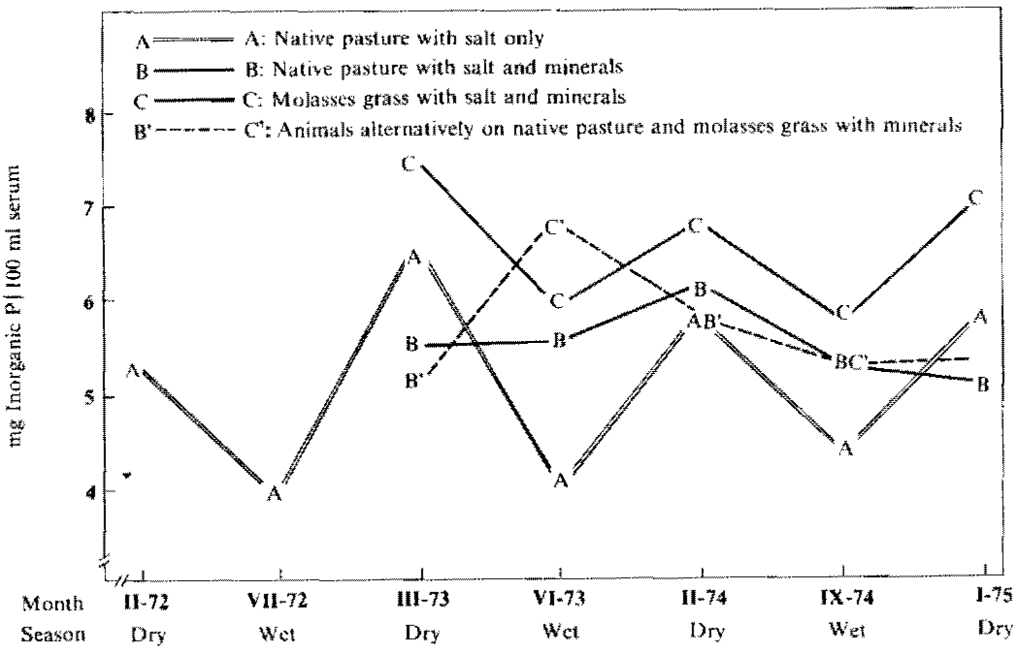

Figure 17. **Changes in serum inorganic P levels in heifers, Feb. '71-Jan. '75.**

not reduced as much in mineral supplemented herds (4-9) as in non-supplemented herds (2 and 3). At the beginning of the dry season in January 1975, lactation tended to reduce serum P levels in non-mineral supplemented herds but not in those that received a mineral supplement (Table 36).

While the above mentioned effects were marked indeed, it should be noted that after July, 1972 large differences between replicated herds also occurred.

Table 33. **Effect of urea and sugar and cottonseed meal supplements on serum P levels, June 1973.** *

Herd	Main treatment	Control No.	Control Mean	Sugar + Urea No.	Sugar + Urea Mean	Cottonseed meal No.	Cottonseed meal Mean
2	A	6	4.62	7	4.23	7	5.94
3	A	5	3.48	7	2.83	7	5.62
4	B	7	5.09	7	4.67	7	5.89
5	B	7	6.22	7	4.75	6	5.62
6	C	7	6.73	7	6.30	6	7.01
7	C	7	7.02	6	6.06	5	6.88
8	C	7	6.25	6	6.52	7	6.64
9	C	7	5.66	7	6.21	7	6.50
Mean			5.63		5.20		6.26

* Treatment: A: native pasture + salt only, B: native pasture + mineral mix including P, C: Molasses grass + mineral mix including P

Table 34. **Effect of supplementation with molasses and urea on serum P levels, February 1974.**

Herd	Main treatment	Without molasses + urea		With molasses + urea	
		No.	Mean	No.	Mean
1	A	30	5.77		
2	A			28	5.20
3	A	25	5.71		
4	B			28	5.60
5	B	28	6.14		
6	B	30	5.69		
7	B			27	5.30
8	C	21	6.79		
9	C			27	6.91

* Treatment A: native pasture + salt only, B: native pasture + mineral mix including P, C: Molasses grass + mineral mix including P

Early weaning

In each of herds 2 through 9 five cows have been selected for early weaning of all their calves in successive calf crops at 2.5 months of age. A highly significant improvement was obtained in rebreeding of heifers following the first calf crop through early weaning (1974 Annual Report). However, it is recognized that the true effect can only be measured over at least two successive calf crops, and that improvement in rebreeding would probably not be as great following later calf crops, as compared to the first. Up to mid-1975, well into the second calf crop, early weaning has had a highly significant effect ($P < .001$) in reducing the interval between calvings (12.9 vs 17.3 months), and increasing births|cow (1.87 vs 1.31), compared to normal weaning at nine months of age (Table 31, Fig. 18).

Feeding and management regimes for the early weaned calves are described in the 1974 Annual Report. Of the limited number of animals, that have reached 18 months of age, normal weaned calves weighed 50 to 60 kilograms more than early weaned calves, suggesting that basic growth was reduced in these early weaned calves.

Results of another experiment to compare effects of early weaning on rebreeding of cows from three commercial ranches and the effects of different feeding programs for the early-weaned calves are discussed in the next section.

Early weaning experiment in Llanos and CIAT

A complementary early weaning experiment with three ranchers in the Llanos was initiated to determine the effect on rebreeding, and also to compare different calf rearing techniques. A group of 100 cows were selected that had calved at the beginning of the dry season, that were open, and that had nursing calves. One-half of the calves were weaned at 90 days of age, and the other half continued nursing. All early weaned calves were taken to CIAT (Palmira) where different feeding regimes were compared (Fig. 19).

Cows whose calves were early weaned had a significantly higher pregnancy rate ($X^2 < .01$) four months after calves were weaned as compared to their herd mates who were still nursing calves (76 vs 10.9%) (Table 37). This difference, of course, will narrow with time. However, with another Llanos collaborator, a 100 percent pregnancy rate was noted in cows eight months after calves were early weaned, as compared to 50 percent in cows still nursing their calves. Removal of the nutrient drain for lactation for cows on a marginal plane of nutrition eliminates excessive weight loss, enabling the cow to rebreed sooner.

Calf rearing and feeding regimes tested in CIAT included fresh chopped *Stylosanthes guyanensis* and *Desmodium distortum* fed in corral, and *Brachiaria mutica* (Para) and *Cynodon nlemfuensis* (Star grass) as pasture, each with and without 750 g|concentrate|head|day (Table 38). Over all treatments, calves that received concentrate had significantly ($P <$ .01) higher gains (399 vs 274 g|head|day).

Figure 18. Cows whose calves were weaned at 80 days of age had 43 percent higher calving rates than those whose calves were weaned at nine months of age.

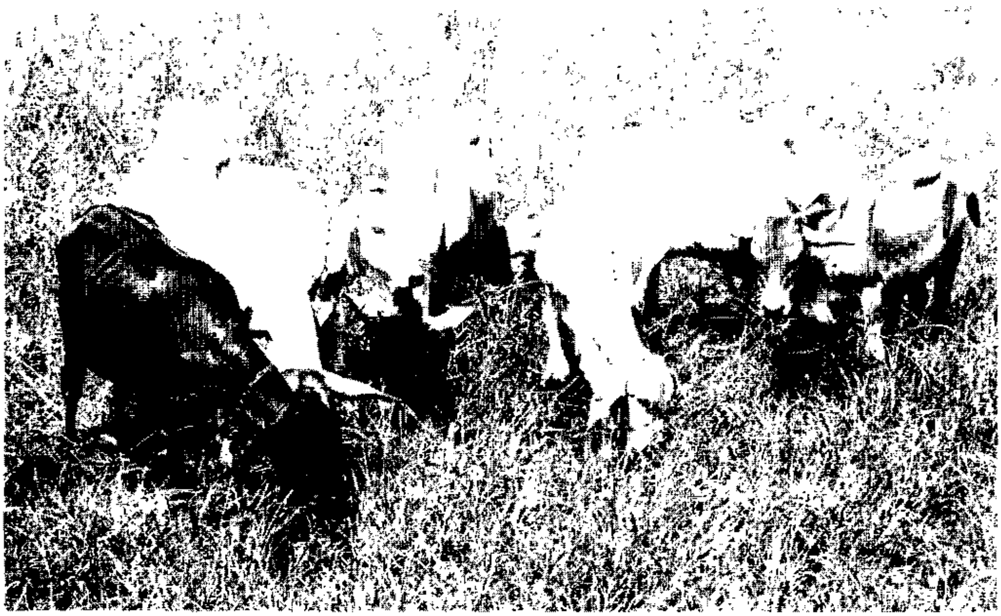

Figure 19. Weight gains of 394 g/head/day were obtained in early weaned calves maintained on *Cynodon nlemfuensis* pastures without concentrate.

Table 35. **Effect of lactation and supplementation with molasses and urea on serum P levels, January 1975.**

		Without molasses + urea						With molasses + urea					
		Heifers not calved		Cows with nursing calves		Non-lactating cows (early weaned calves)		Heifers not calved		Cows with nursing calves		Non-lactating cows (early weaned calves)	
Herd	Main treatment	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1	A	8	6.37	13	5.60								
2	A							14	4.96	9	4.64	4	4.78
3	A	16	5.29	12	4.25	3	6.38						
4	B							4	5.11	20	5.14	4	6.04
5	B	7	5.20	18	5.32	5	5.27						
6	B	7	5.36	20	5.01	5	5.45						
7	B							6	4.76	21	4.85	5	6.46
8	C	3	7.00 *	21	6.47	5	5.61						
9	C							3	5.91	18	5.65	5	6.27
Mean (unweighted)			5.84		5.33		5.68		5.18		5.07		5.89

* Treatment: A: native pasture + salt only; B: native pasture + mineral mix including P; C: Molasses grass + mineral mix including P.

Table 36. **Effect of lactation on serum-P levels of cows, September 1974.**

Herd	Main Treatment	Heifers not calved No.	Heifers not calved Mean	Cows with nursing calves No.	Cows with nursing calves Mean	Non-lactating cows (early weaned calves) No.	Non-lactating cows (early weaned calves) Mean
1	A	14	4.30	13	3.34		
2	A	22	5.51	7	3.96	5	4.60
3	A	21	3.06	9	2.02	4	2.49
4	B	6	5.54	19	5.08	5	5.52
5	B	9	5.12	20	4.38	5	5.22
6	C	5	5.14	24	4.90	5	5.12
7	C	9	5.53	19	4.78	6	5.23
8	C	6	5.91	21	5.66	6	5.40
9	C	3	5.75	19	5.32	5	5.41

* Treatment: A: native pasture + salt only; B: native pasture + mineral mix including P; C: Molasses grass + mineral mix including P.

Highest gains with forage alone were obtained with Star grass pasture (394 g|head|day) followed successively by *Desmodium distortum*, Para pasture and *Stylosanthes guyanensis* (346, 200, 157 g|head|day). These results indicate that calves weaned as early as three months of age can be successfully reared on improved grass pastures with only limited amounts of concentrates, without the need to feed fresh chopped forages in confinement feeding regimes. Pasture systems are attractive, in consideration of reduced problems with disease and parasitism, reduced labor input, and the limited amount of pasture required per calf.

Table 37. **Pregnancy rates of dams with early and normal weaned calves four months after early weaning, Caja Agraria-CIAT, Villavicencio**

Farm	Percentage pregnant: Dams with early weaned calves	Percentage pregnant: Dams with nursing calves
A	73.3	13.3
B	93.3	14.2
C	65.0	5.8
All farms	76.0	10.9

After the two-month trial, all calves were placed together in Para pasture, where they will remain until they reach 18 months of age. Ninety-two days after terminating the trial, differences between pasture treatments and concentrate feeding were much reduced (Table 38).

These data indicate that early weaning is a practice that could be applied in the short term for significantly increasing calving percentage. However, improvement in rebreeding will be economically advantageous only if cost of feeding the early weaned calf is not excessive, and if basic growth of the calf is not impaired. Investigations will continue to determine the feasibility of early weaning.

Intensive production systems

Two experiments were conducted at Palmira to evaluate performances of crossbred steers (Charolais x Zebu) fed chopped elephant grass alone or with other feeds.

In the first experiment, 16 steers were assigned randomly and fed individually according to the four treatments shown in Table 39. Due to reduced forage production later in the period, one animal was removed from each treatment group after seven months. During the 364 days of the

Table 38. **Growth performance of early weaned calves.**

Forage	Liveweight gain (g/head/day)		
	Concentrate		
	None	750 g/head/day, Period 1	Average
Pasture			
Star grass			
Period 1*	394	503	449
Period 2**	420	399	409
Para			
Period 1	200	303	252
Period 2	319	297	308
Legume			
Desmodium distortum			
Period 1	346	479	412
Period 2	370	384	377
Stylosanthes guyanensis			
Period 1	157	309	233
Period 2	337	319	328
Average, Period 1	274	399	
Average, Period 2	361	350	

* Period 1: April 17 to June 11, 1978

** Period 2: June 11 to Sept. 11, 1978

experiment, the one hectare of elephant grass produced 2,638 kilograms of liveweight gain (including the four steers during the first seven months). Table 39 shows performance for the 12 steers completing the experiment.

Steers receiving cottonseed meal and/or molasses with the elephant grass gained faster than those consuming only elephant grass. Adding molasses and cottonseed meal increased dry matter consumption, while cottonseed meal alone or combined with molasses produced more efficient gains.

In a second experiment, individually-fed steers received chopped elephant grass alone or with freshly cut cassava forage as a protein supplement in proportions shown in Table 40. Steers consuming either level of cassava forage gained significantly faster and converted feed more efficiently than steers consuming only the elephant grass. Performances of the two groups receiving cassava forage didn't differ significantly, indicating that the 25 percent level of cassava provided sufficient protein. No adverse effects were noted among steers consuming the freshly cut cassava forage.

Field application of results

Although sufficient data are not yet available to measure the individual and combined effects of the foregoing production practices, these results clearly indicate that significant increases can be achieved in animal productivity and productivity/hectare, by applying available technology. Production practices that can be applied in the short term include mineral supplementation, early weaning and pasture systems using native and/or improved grasses in

Table 39. **Performance of Charolais x Zebu steers fed chopped elephant grass alone or supplemented with cottonseed meal and/or molasses for 364 days.**

	Elephant grass alone	Elephant grass supplemented with		
		.5 kg CSM	2 kg mol.	.5 kg CSM + 2 kg mol.
Number of animals	3	3	3	3
Initial weight (kg)	250.0	257.0	248.0	265.0
Final weight (kg)	396.0	450.0	448.0	488.0
Average daily gain (g)	400.0	530.0a*	548.0a	613.00a
Feed consumption (kg/day)**	5.7	6.6	7.4b	7.4b
Protein in ration consumed(%) **	11.4	13.9	9.1	11.3
Feed efficiency**	14.3	12.5c	13.6	12.1c
Elephant grass consumption (kg/day)**	5.7	6.2	6.1	5.5

* Means followed by the same letter are not significantly different (P < .01)

** On dry matter basis

high areas during the rainy season and native pastures in low areas during the dry season. It is expected that use of legume based pastures will further increase productivity, particularly in the dry season.

Family farm unit

The family farm unit is operational under steady state conditions as described in the 1974 Annual Report. Thus far the farm operator has proven responsive to the application of improved production practices, and has demonstrated his capability to manage the unit and perform necessary farm work.

Valuable information has been obtained on the establishment and grazing of legume/grass pastures. *Stylosanthes humilis* population has markedly increased whereas *Stylosanthes guyanensis* has declined in association with *Paspalum plicatulum*. *P. plicatulum* has persisted. *Indigofera hirsuta* was readily established

Table 40. **Performance of steers fed chopped elephant grass alone or with cassava forage for eight months.**

	Elephant grass, alone	75% elephant grass +25% cassava forage	50% elephant grass + 50% cassava forage
Number of animals	3	3	3
Initial weight (kg)	265.5	276.3	270.0
Final weight (kg)	342.5	392.7	379.0
Average daily gain (g)	306.0	461.0a*	445.0a
Dry matter consumed (kg/day)	5.4	6.3	6.1
Crude protein (%)**	6.0	9.7	13.0
Feed efficiency**	17.6	13.7b	13.7b

* Means followed by the same letter are not significantly different (P < .01).

** On dry matter basis.

in combination with *P. plicatulum*. However, since cattle thus far have refused to graze the *I. hirsuta*, *Hyparrhenia rufa* was strip-seeded to reduce *I. hirsuta* population.

Calculated herd calving rate in 1975 was 50 percent, lower than expected. It is expected that calving percentage will improve somewhat when the 50 hectares of improved pasture become available on a continuing basis. There were no deaths in either calves or older animals.

Production of food crops has generally met expectations. Acceptable yields have been obtained with cowpeas and rice. Platano seedlings have made good growth. A flock of chickens to produce eggs and meat for the farm family are maintained using farm produced feedstuffs.

Model simulations of small farm units based on beef cattle enterprises are reported in the Economics section of this report.

TRAINING

Eight *postgraduate interns* received training during the year in the Beef Program. This category of training totaled 58 man-months or about seven months of training per individual. The internships deal principally with the teaching of research methodology within the disciplinary interest of the trainee. Various scientists in the animal health and forages sections supervised these trainees.

The number of *special trainees* (so classified when they stay less than three months at CIAT) increased substantially over the past year. Thirteen students (29 man-months) spent approximately two months each at CIAT. Nine of the 13 were supervised by staff in the animal health section; the others did short-term projects in the pastures and forages and weed control sections.

The number of *visiting research associates* is also increasing rapidly. Two doctoral students are now working on their dissertation projects in animal health, two in animal production, two in pastures and forages and one in agricultural economics. The major costs associated with these projects are funded by educational grants from outside CIAT. The research done by these associates contributes to the overall objective of the program as well as partially fulfilling their university requirements.

During the year, three *research scholars* received their masters degrees with either partial or total financial support from CIAT. Two degrees were awarded for projects in animal health and one in economics. Three other research scholars have begun their masters programs and will receive their degrees in 1976.

The total training time within these four categories is 366 man-months, about 30 man-years of training and two man-years of training per senior scientist in the Beef Program.

Livestock Production Specialist Training Program

The fourth Livestock Production Specialist Training Program (LPSTP) began March 1, 1975 and lasted for ten months. Based on information gained from previous LPSTP's, several changes were made to strengthen the program.

(1) Since many factors such as nutrition, management and preventive medicine are significantly different in the production of beef cattle vs. swine, it was decided to concentrate on beef cattle in the fourth course (1975) and design a separate course for swine production to be offered in 1976.

(2) In reviewing the activities of graduates from previous courses, it was found that they were doing very little to impart the knowledge gained at CIAT to colleagues withing their own institutions

—a basic objective of the LPSTP. A contributing factor to the limited success in achieving a "multiplier effect" at the national level appears to relate to the fact that only two or three participants were enrolled from each country. Thus, an insufficient number of personnel were being trained from a single country to effect any change in the traditional agricultural education process.

Therefore, in the fourth LPSTP, participants (nine Colombians and 11 Paraguayans) were selected from only two countries. Selection was contingent upon their returning to a position where the knowledge gained at CIAT would be utilized in training others within their own institutions.

(3) Realizing that recent college graduates in animal science and veterinary medicine need to be better prepared to cope with practical aspects of animal production, more university instructors (50% of the total) were selected to take the course. They will be in a position to introduce and|or improve production courses at the university level.

(4) The ranch phase of previous courses was always conducted on commercial ranches on the North Coast of Colombia, irrespective of the nationality of the participants. For ease of administration and logistic support, the location was ideal; however, it was less than ideal for non-Colombian trainees, who encountered difficulties in adapting to the local environment. The social customs, economic relationships in livestock production, trade names for local agricultural chemicals and drugs, and even the local vocabulary for agricultural terms presented problems which made the learning experience somewhat less than optimal.

To eliminate these barriers, the 1975 course was restructured so that the 11 Paraguayan trainees spent only three months at CIAT (in the theory phase, taking advantage of the facilities and learning from the scientific staff) after which they returned to Paraguay to do their ranch phase. One training assistant was placed in Paraguay to assist the local institutions in carrying out the ranch phase. The University of Asuncion's Faculty of Veterinary Medicine and the Ministry of Agriculture are supporting the training program there.

Colombian trainees are being trained in the North Coast of Colombia as before. The level of discontentment, which was a time-consuming element to be dealt with in other courses, has all but disappeared.

(5) Also, for the first time, all ranches selected for practical training have government development loans. This is viewed as a demonstration of the rancher's interest in improving his ranch and thus provides a more favorable environment for the trainee to work.

In addition to its formal training function, the LPSTP provides the opportunity for trainees (all college graduates) and CIAT staff members to study in-depth the ranchers' problems and actively participate (at the ranch level) in the search for better technology which will be accepted and will contribute to improving ranchers' situations. Following are some practical observations obtained from experience with the LPSTP.

Experiences in the North Coast of Colombia over the past four years clearly show that milk production on beef cattle ranches is an integral part of the ranch operation and accounts for a large portion of the milk produced in the region. The increasing popularity of the system would indicate that it is profitable; however, insufficient data exist to make any conclusions. Calves from non-milked cows are heavier at weaning; however, the difference at 18 months is less noticeable indicating that preweaning retardation in calf growth by partial milking of the dam may be recovered (compensatory growth) by one year postweaning.

This system requires (1) the cows to calve throughout the year, and (2) that the calf be present at each milking to stimulate milk let-down. This production system makes the adaption of conventional beef production management techniques very difficult. The establishment of a breeding season, which makes weaning, selection, herd health, record keeping and marketing less complicated, is virtually impossible. The present system (dairy|beef) approaches more closely that of a dairy operation, which requires a more intensive type of management. Thus a very elaborate management system is needed in a region where the more basic animal management and health practices are difficult to implement.

The most critical problem (in terms of available solutions) encountered by the LPSTP is that of maintaining an adequate nutritional level during the three- to five-month dry season. This problem drastically reduces annual meat and milk production in many lowland regions. The preservation of forage (hay or silage) is unattractive due to high cost and weather complications at critical harvest times. Using mature sugar cane as a dry season supplement offers promise because of its ability to produce large amounts of stored energy during the wet season and maintain its nutritive value during the dry season when it is needed. The LPSTP-cooperating ranchers who have fed sugar cane during the dry season are convinced that it has a place in their management programs.

Development of instructional materials

An important function of training in the animal sciences area is to work with the scientists in the development of instructional materials that are used in CIAT training programs and also made available to national institutions.

Prior to 1975 the majority of the training materials produced were in written form with relatively few illustrations. Color slides were used for teaching; however, copies were not available to give to the trainees because of high cost of reproduction when done on a small scale.

It was apparent that information generated at CIAT and elsewhere should be organized and put into a format most conducive to learning. By so doing, the quality of instruction would be improved and valuable time required several times each year to repeat basic principles in research and production methodology could be more effectively utilized for other topics.

This year work began on developing audio-visuals, in the form of slide|cassette programs, utilizing existing equipment and facilities. Twenty-eight programs consisting of 35-mm color slides plus a written script and|or audio cassette were begun. Thirteen of these were completed on the following topics.

(1) The care and management of baby pigs from birth to weaning.

(2) The Baerman technique for identifying **Dictyocaulus** larva.

(3) The McMaster technique for identifying gastrointestinal parasite eggs and oocist seimeria.

(4) The control of weeds in lowland tropical pastures.

(5) Identification of weeds in tropical pastures.

(6) Beef cattle management in the lowland tropics.

(7) Methods of cattle identification, castration and dehorning.

(8) Necropsy techniques in bovine.

(9) Necropsy techniques in swine.

(1) **Babesia** card agglutination test.

(11) Common diseases in swine.

(12) Preparation of antigen.

(13) Immunization practice in **Babesia.**

OUTREACH

Outreach continues to receive particular attention since the effectiveness of the Beef Program in contributing to the development of the lowland tropics will be largely determined by what is done through and with national institutions.

Follow-up continues of visits and contacts previously made in all Latin American countries to identify trainees, to provide technical counsel as possible and when solicited, and to explore possibilities for collaborative projects.

Three workshops were held. The first—on hemoparasites—brought together 85 participants from 17 countries. The second was an ectoparasite workshop on the ecology and control of external parasites of cattle of economic importance in Latin America. Participants included 75 specialists from 21 countries. The third was a workshop on the characterization of the livestock sector in selected countries, with 29 participants from the Americas.

Special project support was provided by USAID for the cooperative Texas A&M/CIAT hemoparasite project; by the United Kingdom Overseas Development Ministry for work in acarology; International Board of Plant Genetic Resources, in forages; Wageningen University, in tropical animal husbandry; International Mineral and Chemical Corporation, in soils; International Fertilizer Development Center, in soils; Ford Foundation, in livestock economics; and Inter-American Development Bank, in training.

Collaborative research and training projects were carried out in Colombia with the ICA, the Caja Agraria, and private farmers. Additionally, collaborative research and training was conducted in animal health with the International Center for Medical Research, Cali, Colombia and the Pan-American Zoonosis Center.

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Cassava production systems

HIGHLIGHTS IN 1975

The cassava program's objective is to provide the technology for obtaining high cassava yields with low input levels. It has developed simple cultural and sanitary practices to be used with improved germplasm or varieties, which are the mainstay of this technology. This new germplasm will consist of efficient plants that are naturally resistant to diseases and pests, as well as to certain soil conditions such as acidity and low fertility.

An efficient plant is one that has a correct balance between the source of production—the leaves—and the product sought—the roots. It has been found that the correct balance for an efficient plant is best achieved by varieties that maintain a leaf area index (ratio of leaf surface to ground surface area) of 3 to 3.5. Model data suggest that the best varieties are those with a long leaf life and with branches that begin to form at four to six months. In the absence of restrictions (i.e., diseases and pests) and with a nearly perfect balance, yields of about 25 tons|ha|year of dry roots should be easily obtainable under CIAT conditions.

Although CIAT had previously developed technology for producing "seed" material free of cassava bacterial blight, there were doubts as to whether farmers would always accept it; therefore, varietal resistance was investigated. A rapid inoculation procedure was developed for use in screening, whereby plants are infected by clipping leaves with infested scissors. Good resistance was found in a very limited number of cultivars; however, it was found to be transmitted to the progeny from resistant lines crossed with susceptible lines, thereby making it possible to produce high-yielding lines. Similar results were obtained with superelongation disease and Phoma leaf spot (of local importance) and with the Cercospora leaf spots (of worldwide prevalence). However, a new bacterial disease, probably spread by insects, was discovered.

Work continued on the evaluation of insect-resistant lines and on control measures. Substantial losses occurred in lines susceptible to thrips even under the conditions of high fertility and fairly uniform rainfall found at CIAT. A large part of the germplasm bank was found to be thrips resistant. Studies on spider mites, common in drier cassava-growing areas, suggest that some cassava lines may be resistant. Although the use of insecticides does not constitute a major part of our technology, low levels of insecticides placed around the seed material are effectively used to control pests nonspecific to cassava that reduce germination and seedling establishment.

The breeding program is attempting to combine the components of efficient plants and resistance with other characters such as improved postharvest shelf life and increased starch content. The disconcerting lack of correlation between single-row yield and population yield was overcome by using harvest index as a selection criterion. It was also found that there was a high correlation of yield data between seedling and stake-planted generations as early as seven months after transplanting, which is very helpful for more rapid selection. Yields of 60 tons/ha were obtained at CIAT using varieties selected by these techniques.

Data collection was completed for the agro-economic survey of cassava production in Colombia. So far, analyses have been made for disease and insect incidence, soil characteristics, yield trends and the use of improved technology in five ecological zones. Average yields were below 8 tons/ha in four of these zones and only 12 tons/ha in the best zone.

Regional trials using minimum inputs but good cultural practices (weed control, clean seed, optimal plant populations) were carried out at nine sites in Colombia. Local varieties averaged 18 tons/ha in less than a year, which is much higher than those obtained by local farmers (3 to 12 tons/ha). Using selected CIAT/ICA lines, yields were further increased to an average of 30 tons/ha. Thus large yield increases can be obtained by simple improvement in technology and dramatic increases by combining these with improved varieties. The economic survey shows that the highest yields (up to 43 tons/ha) were obtained in the Caicedonia region, where the Federación Nacional de Cafeteros cooperates with CIAT in the introduction of new technology through two extension officers trained at CIAT. In the acid soils of the Llanos, representative of vast areas of the tropics that are presently very unproductive, yields of 25 tons/ha were obtained in 9 1/2 months by using improved technology and good fertilizer practices.

These techniques are being taught to trainees; during the past year there were students from Asia, Africa and the Americas. A workshop was also held at CIAT to standardize research methods for evaluating new material; and as a result, the basis for regional testing programs in 16 countries was established.

ECONOMICS

Agro-economic analysis

The data collection and certain parts of the analysis for the agro-economic survey of cassava production in Colombia were completed during 1975. Final results are presented for disease and insect incidence, soil characteristics, yields and use of modern technology in the production process, in addition to the principal results and conclusions from a comparative economic analysis of selected cassava cropping systems.

Table 1 shows the presence of diseases on sample farms for cassava crops four to eight months of age. The presence of some diseases was greatly influenced by crop age; data for crops of other ages may be obtained directly from CIAT. While considerable differences were found among zones, brown leaf spot *(Cercospora henningsii)*, white leaf spot *(Cercospora caribaea)* and Phoma leaf spot (**Phoma** sp.) were present in many of the cassava lots in all zones. Superelongation (**Sphaceloma**) was found on a large number of farms in Zone III, while cassava bacterial blight was important in Zones III, IV and V. Another potentially important disease, frog skin root disease, was identified in Zone I. Although this disease was found on a relatively small number of farms, yields were severely affected.

Thrips, gall midges (Cecidomyiidae) and whiteflies (**Bemisia** sp.) were found on a large proportion of sample farms in all zones (Table 2). Other insects of local importance include mites and fruit flies (**Anastrepha** sp.).

Results of soil tests taken on sample farms are summarized in Table 3. Considerable differences were found among zones; however, it appears that cassava is most frequently cultivated on relatively heavy, inorganic, low-fertility soils with a low pH, low organic matter content and low phosphorus and potassium contents. Zone II had the highest yields and also the highest potassium content in the soil. Until further

Table 1. **Disease incidence in cassava on sample farm in five zones* (Percentage of farms and area affected).**

	I		II		III		IV		V	
	Farms	Area	Farms	Area	Farms	Area	Farms	Area	Farms	Area
Brown leaf spot	28	6.1	31	6.5	75	9.9	71	29.4	80	42.7
White leaf spot	70	39.9	92	48.3	24	2.0	29	3.7	57	21.7
Cercospora leaf blight	57	26.5	31	7.3	69	28.5	49	7.6	55	25.1
Cassava ash disease	46	17.4	16	31.1	52	5.3	9	1.2	9	3.0
Phoma leaf spot	41	13.0	42	9.3	0	0	0	0	0	0
Superelongation	2	0.5	0	0	63	7.3	24	3.9	0	0
Cassava bacterial blight	2	0.4	0	0	14	2.3	25	11.0	30	8.6
Root rot	2	0.3	3	0.6	0	0	0	0	0	0
Powdery mildew	2	0.1	0	0	24	3.3	5	0.8	0	0
Frog skin root disease**	11	—	0	0	0	0	0	0	0	0

* I. Cauca; II. Valle and Quindio; III. Tolima; IV. Meta; V. Magdalena

** Incidence measured at time of harvest

analysis has been made, however, it would be premature to conclude that the higher potassium content is an important reason for the higher yields in other zones as in Zone II.

Although the use of modern technology differs among zones, regional differences are less marked for cassava than for certain other crops such as beans. The most advanced cassava production, from a technological point of view, is found in Zone II; the most traditional systems are found in Zones I, III and V (Table 4). Many cassava producers in all zones use insecticides, but the use of chemical fertilizers, fungicides and herbicides is low. Machinery is used only for land preparation; its use is determined primarily by topography and farm size.

Table 2. **Insect incidence in cassava on sample farms in five zones (Percentage of farms and area affected).**

	I		II		III		IV		V	
	Farms	Area	Farms	Area	Farms	Area	Farms	Area	Farms	Area
Thrips	59	14.2	88	36.6	100	63.9	95	62.9	86	29.2
Gall midges	25	3.1	44	8.3	69	8.9	65	8.6	84	15.3
Whiteflies (**Bemisia** sp.)	70	34.3	14	1.7	37	16.7	25	13.2	70	15.5
Whiteflies spp.	48	14.4	5	0.3	12	3.8	0	0	5	0.9
Leaf-cutter ants	10	2.5	5	0.3	24	2.5	0	0	2	2.6
Shoot flies	8	1.3	30	8.1	3	0.7	24	8.6	0	0
Fruit flies (in stems)	7	2.0	75	25.6	14	6.3	5	0.6	9	10.2
Leafhoppers	2	0.2	2	0.8	0	0	0	0	18	1.6
Hornworms	0	0	2	0.6	0	0	0	0	11	2.3
Chrysomelids (leaf beetles)	5	0.3	6	1.9	0	0	0	0	5	0.6
Tingids (lace bugs)	16	2.6	3	0.4	7	0.5	7	1.6	0	0
Mites	7	1.6	8	1.0	41	11.4	9	2.7	43	34.3

Table 3. **Selected soil characteristics on sample farms (average by zone).**

	I	II	III	IV	V
Organic matter (%)	5.22	3.69	5.33	3.53	1.93
Less than 4%*	26.20	75.00	32.20	60.00	97.70
Phosphorus (ppm)	1.78	32.89	2.62	21.36	69.66
Less than 15 ppm*	100.00	35.90	100.00	72.70	31.80
Potassium (meq|100 g)	0.21	0.45	0.26	0.12	0.22
Less than 0.30 meq|100 g*	80.30	37.50	76.30	94.60	81.80
Aluminum (meq|100g)	4.37	0.06	0.84	2.84	0.06
pH	4.69	5.73	5.21	4.75	6.59
Less than 5.5*	100.00	12.50	83.10	89.10	6.80
Sodium saturation (%)	1.46	0.46	0.18	0.48	5.16
Calcium|magnesium	1.66	5.42	2.67	2.65	4.37
Exchange capacity (meq|100 g)	20.33	15.26	24.08	11.80	9.75

* Percentage of farms

Cassava yields were extremely low in Zones I, III and V. Quantitative analysis is presently being carried out to identify the principal factors determining yields. This analysis has been completed for an extended sample of farms in Zone II, where yields ranged from 0.5 to 43.3 tons|ha, with an average yield of 12.6 tons|ha.

Independent of cropping system, rainfall and soil potassium content were identified as the most important factors affecting yield in Zone II. Rainfall pattern and quantity during the crop cycle were classified for each farm as normal, excessive or deficient, according to the farmer's perception. Sixty percent of the

Table 4. **Farm size, yields and selected technology characteristics of cassava production on sample farms (average by zone).**

	I	II	III	IV	V
Average farm size (ha)	7.2	37.5	16.5	61.3	18.0
Cassava acreage (ha)	2.9	6.4	2.0	9.4	5.3
Input use (% of farms)					
Fertilizers	18.0	35.9	8.5	21.8	13.5
Insecticides	96.7	60.9	79.7	85.5	36.4
Fungicides	0	3.1	0	1.8	0
Herbicides	0	10.9	0	3.6	0
Purchased seed	41.0	23.4	0	12.7	27.3
Credit	29.5	12.5	10.2	23.6	20.5
Technical assistance	8.2	6.3	27.1	1.8	9.1
Mechanical land preparation (% of farms)	0	81.3	3.4	80.0	52.3
Monocropping (% of farms)	77.1	48.4	71.2	74.6	36.4
Cassava yields (tons|ha)	4.2	12.6	3.0	6.2	3.7

farmers reported excessive rainfall while the rest said rainfall had been normal. A simple comparison of yields under these two different conditions showed a highly significant difference of about 12,000 kg|ha. Average yields on excess rainfall lots were 8,238 kg|ha, as compared with 20,509 kg|ha on lots with normal rainfall.

On the basis of soil tests made on the sample farms, lots were classified into two groups according to their potassium content; the level of 30 meq|100 g was used as the minimum acceptable level. About 45 percent of the lots contained less than this level. Average yields on these lots were estimated at 7,388 kg|ha and 19,812 kg|ha for excessive and normal rainfall, respectively. Yields on lots with 30 meq|100 g or above were 9,259 kg|ha and 20,857 kg|ha for each of the rainfall conditions, respectively. Hence a simple yield comparison indicated that low potassium content reduced yields by 1 to 2 tons|ha.

A more complete analysis of the impact of rainfall and potassium content on yields, using a production function approach, showed that the impact of rainfall was 11,800 kg|ha and that of potassium, 1,700 kg|ha, supporting the results of the simple comparisons.

Analyses aimed at identifying the principal factors causing low yields in the other zones are yet to be carried out; but it appears that in addition to the aforementioned factors, frog skin root disease in Zone I, superelongation in Zone III and cassava bacterial blight in Zones III, IV and V may also be causes of the low yields.

Economic analysis of selected cropping systems

In approximately 30 percent of the area dedicated to cassava in Colombia, some 40 percent of the growers mix cassava with other crops (1974 Annual Report, p.106). Because of the importance of mixed cropping in cassava production and because of the lack of information on the relative economic behavior of such systems, an economic analysis of selected cropping systems was carried out in Zone II. The objectives were (1) to estimate relative yields, labor use, costs and net returns for each of the systems and (2) to identify factors—other than relative net returns—influencing the farmer's choice of cropping system for cassava in Colombia: cassava alone, cassava and maize, and cassava and beans.

Zone II (Valle and Quindío) was chosen for the analysis because of its importance in cassava production and because of the large number of farmers with each of the three cropping systems within a small region. Slightly more than one half of the cassava producers in the region grew cassava alone. Cassava mixed with maize or beans was found on 34 percent (17 percent each) of the farms while the rest of the farmers grew cassava mixed with other crops.

Farm size, area planted to cassava and use of modern technology on sample farms by cropping system are shown in Table 5. There is a very strong correlation between the level of technology and cropping system. The highest level of technology was found among farmers growing cassava alone; monocropping was basically found on the larger, more progressive farms while the small farmer tended to use mixed cropping. The larger producer's preference for monocropping is based partly on the expressed belief that net returns per unit of land are higher, which in turn appears to be based more on the influence of the extension agent than actual experience and partly on the fact that credit is easier to obtain for monocropping. Hence, institutions providing credit and technical assistance seem to play an important part in promoting monocropping among the more progressive farmers; i.e., those that need credit and receive technical assistance.

Table 5. **Farm size and use of modern technology by cropping system in Zone II.**

	Cassava alone	Cassava and beans	Cassava and maize
Farm size (ha)	65.0	34.9	18.7
Cassava acreage (ha)	13.3	4.9	4.0
Percentage of farmers using			
Chemical fertilizers	52.2	28.6	16.7
Insecticides	67.4	38.1	41.7
Fungicides	4.3	0.0	0.0
Herbicides	17.4	4.8	0.0
Machinery	82.6	81.0	58.3
Credit	45.7	23.8	8.3
Technical assistance	50.0	19.0	0.0

The main reasons for maintaining a mixed cropping system, as expressed by the producers, were (1) to maintain a supply of beans and|or maize, as well as cassava, for home consumption, (2) to provide for cash incomes during the cassava growing cycle, and (3) to obtain a higher net return per unit of land. Many farmers felt that cassava yields would not be greatly affected by the presence of maize and|or beans, hence the land would be more efficiently exploited by intercropping. The present economic analysis does not disprove the validity of this; however, it should be noted that bean and maize yields are extremely low. Furthermore, cassava yields are far below those obtained by the best farmers in the region.

Survey farmers seemed quite willing to change from one system to another. From 1972 to 1974, more than half of them (53.2 percent) changed from one system to another. The primary reasons for changing from mixed to monocropping were that (1) the previous crop had failed and the farmer was experimenting to identify a better system, (2) the farmer was told that monocropping was better, and (3) no bean and|or maize seed—or funds to pay for it—were available at planting time. On the other hand, farmers changing from mono to mixed cropping did so because they wanted to grow maize and|or beans for home consumption.

A slightly tendency toward increased monocropping was found among the survey farmers during this three-year period. This trend was not represented by an increase in the number of farmers using monocropping exclusively, but rather by an increase in the number of farmers having both cassava alone and intercropped simultaneously and the resulting reduction in the number of farmers having only a mixed cropping system. The primary reason for this tendency seems to be the desire to try monocropping initially on a limited scale while maintaining the more traditional mixed cropping systems.

Estimated labor and production costs by cropping system are shown in Tables 6 and 7. A considerable difference in labor requirements was found. The higher total labor requirements for mixed cropping systems are a result of higher requirements for planting, vigilance and harvesting. The differences in labor needs for land preparation and input application can be attributed to the differences in the level of

Table 6. **Labor use by production activity and cropping system (man-days|growing season) in Zone II.**

	Cassava alone	Cassava and beans	Cassava and maize
Land preparation	7.4	8.6	14.7
Planting	9.9	17.3	11.9
Replanting	0.7	0.6	0.5
Input application	5.6	3.8	1.7
Weed control	62.1	77.3	60.8
Vigilance	10.4	14.7	26.8
Harvesting	14.3	20.2	31.4
Seed collection	2.7	3.3	3.2
Other activities	1.4	1.2	1.1
Total	114.5	147.0	152.1

technology (mechanized land preparation) mentioned earlier and not to the cropping system per se.

Although total variable costs differ among systems, these differences were not statistically significant, basically because the variation was great among farms within each system. Principal cost differences were found in (1) seed—because of the high cost of bean seed; (2) fertilizers, insecticides and fungicides—because of the difference in use; and (3) harvesting—because of the higher costs of harvesting beans and maize.

Cassava yields were equal when cassava was grown alone or with beans (Table 8). When grown with maize, yields were lower. Although the yield difference was about 2,000 kg|ha, it was not statistically significant, primarily because of a high

Table 7. **Variable costs (US$|ha)* by production activity and cropping system in Zone II.**

	Cassava alone	Cassava and beans	Cassava and maize
Land preparation	44.66	46.71	41.44
Seed, planting and replanting	24.53	56.97	26.15
Fertilizers, insecticides, fungicides and application	32.22	21.29	6.38
Weed control	84.73	103.07	81.07
Harvesting	7.46	10.70	14.48
Other variable costs	8.93	4.51	2.49
Total variable costs	202.53	243.25	172.01

* Exchange rate used: Col $30 = US$1

Table 8. **Yields, value of production and margin for fixed costs and net returns by cropping system in Zone II.**

	Cassava alone	Cassava and beans	Cassava and maize
Yields (tons|ha): Cassava	12.9	13.2	11.0
Beans	-	0.16	-
Maize	-	-	-
Value of production (US$|ha)*	869	984	815
Total variable costs (US$|ha)	203	243.25	172
Margin for fixed costs and net returns	667	742	643

* Average prices received on sample farms, cassava, US$67.33\|ton; beans, US$612.70\|ton, maize, US$107.73\|ton

variation in yields within the cropping system. Furthermore, a production function analysis did not reveal any significant difference among cassava yields for the different systems. The data provide strong evidence that the presence of beans and maize intercropped with cassava did not reduce cassava yields on the sample farms. Since no significant difference was found among total variable costs, it may be concluded that net returns per unit of land from cassava alone are below those obtained from cassava mixed with maize or beans unless yields or prices of the latter crops are zero. Relative net returns from the mixed cropping systems depend on the relative prices of maize and beans. At the current price ratio of $\frac{\text{P (Maize)}}{\text{P (Beans)}} = 0.18$, cassava and beans provide the highest net returns. Net returns from the two systems would be equal at a price ratio of 0.23.

On the basis of the findings from this study, it appears that net returns from the cropping systems are slightly above those from cassava monocropping among the sample farms. In addition to relative net returns, it appears that farmers favor mixed cropping because they want to produce maize and beans for home consumption and they need cash income during the cassava crop cycle. On the other hand, certain institutional pressures favor monocropping. The survey farmers seemed quite willing to experiment with cropping systems other than the one they were currently using so they would probably shift rapidly toward whichever system offered relatively higher yield potentials.

PHYSIOLOGY

Efforts to define a plant ideotype for cassava have continued. Last year the importance of having a leaf area index (LAI) of about 3 during the root bulking period, coupled with a long leaf life, was stressed mainly through a study based on a hypothetical model. This year the experimental data confirmed this hypothesis more directly.

M Colombia 113 was planted in a systematic density design to give different leaf area indices. Two harvests were taken at a six-week interval, during which time all fallen leaves were collected. Leaf life was quite short at about seven weeks (Fig. 1). Crop growth rate increased with LAI to about 110 g $m^{-2}wk^{-1}$ at LAI 4; above this level it declined rapidly (Fig. 2). The reason for this decline is not apparent but may be due to high respiration rates at higher plant populations or the large proportion of very

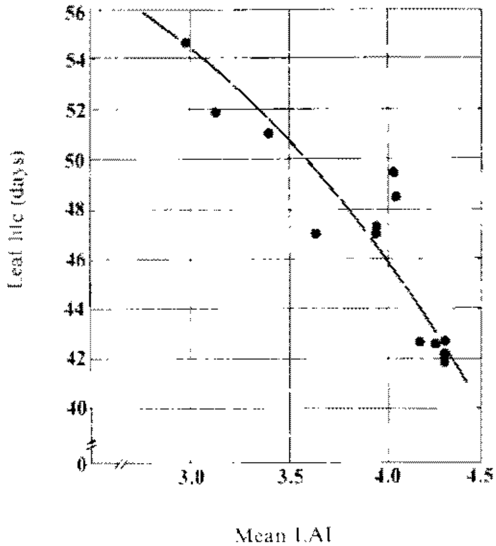


Figure 1. **Leaf life as a function of mean LAI during the six weeks after leaf formation in M Colombia 113.**

young leaves at high populations. In many crops photosynthesis increases with leaf age and then declines slowly; at high populations with a leaf life of only 42 days, it is probable that average photosynthesis is quite low. Root growth rate showed a marked decline from 45 g $m^{-2}wk^{-1}$ at a LAI of 3 to 3.5 to less than 20 g $m^{-2}wk^{-1}$ at a LAI of 4.2 (Fig. 3). These data confirm the hypothesis that the optimum LAI for root growth in cassava is 3 to 3.5 during the bulking period.

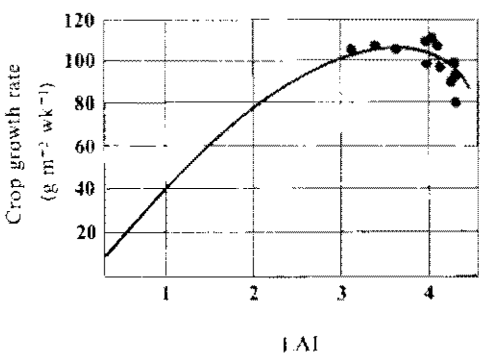


Figure 2. **Crop growth rate of M Colombia 113 as a function of LAI.**

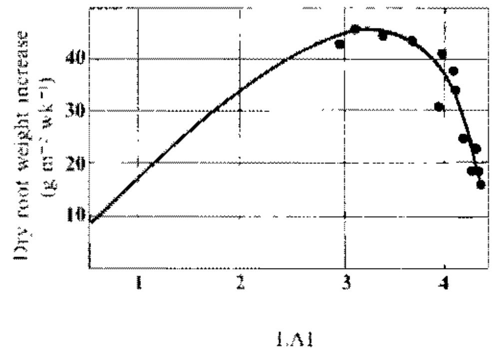


Figure 3. **Root weight increase as a function of LAI in M Colombia 113.**

M Colombia 113 and M Colombia 22 were grown at 1 x 1 m spacing. In the treated plots, half the young leaves were removed as they formed at different growth stages. In M Colombia 22 yields decreased markedly when LAI was reduced at all stages (Fig. 4). As maximum LAI was always less than 2, this result was consistent with the idea of an optimum LAI of 3 to 3.5. In M Colombia 113 the control plots had LAI's below the optimum at 100 and 300 days but above the optimum at 200 days; plots with leaves removed at 100 to 200 days had LAI's similar to the control at 100 and 300 days but below the optimum at 2.1 at 200 days. The treated plants yielded 97 percent as much as the controls; thus it appears that the control plots exceeded the optimum whereas treated plots were below, once again placing the optimum between 3 to 4 (Fig. 4). In plots clipped at 0 to 100 days and at 200 to 300 days, LAI's were considerably lower for long periods and yields were substantially reduced (Fig. 4).

Leaf area index is a function of individual leaf size, rate of leaf formation per apex, branching habit and leaf life. In CMC-84 plots planted and harvested at different times, there was an increase in leaf size up to three to four months after planting, after which time, it decreased (Fig. 5). Similar data were found for CMC-9 grown in entomology plots (Fig. 6). Both varieties branch (CMC-9 profusely and

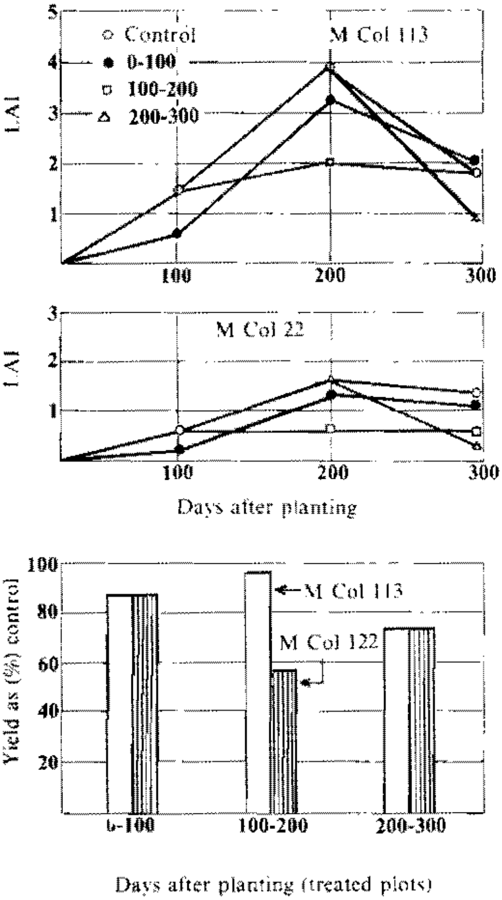


Figure 4. **Effects of removing 50% of the leaves as they form at different growth stages on yield and LAI of M Colombia 113 and 22.**

CMC-84 less profusely), and it was thought that this decrease in leaf size might be related to changes in branch number. However, the same trend was noted in M Colombia 1120, a nonbranching variety (Fig. 6); thus leaf size tends to decline with time after about four months although great variability exists among varieties.

The number of leaves formed per continuous branch was measured on spaced plants. The cumulative number formed per apex increased with time from 10 to 40 weeks after planting; however, the rate of increase declined (Fig. 7). There was little difference among varieties; i.e., about

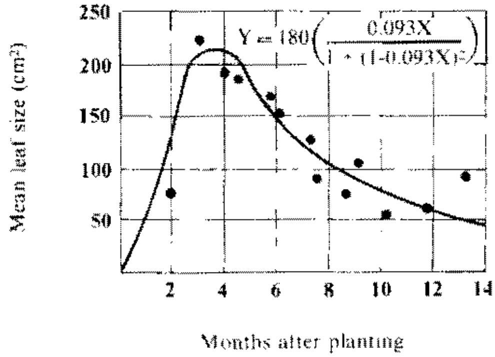


Figure 5. **Leaf size of CMC-84 at different times after planting.**

10 percent. M Colombia 22 and M Colombia 113 were grown at 1 x 1 m spacing. Once again little difference between the two varieties was found; furthermore the increase from 10 to 40 weeks was similar to that found in the other trial. The number of leaves formed per branch could be very precisely described by the equation $Y = 2.85 \tan^{-1} (0.0296t)$ in the case of M Colombia 113 (Fig. 8). From these data it is concluded that little varietal difference exists in the number of leaves formed per apex.

Shading was found previously to reduce leaf life. M Colombia 113 was planted in a

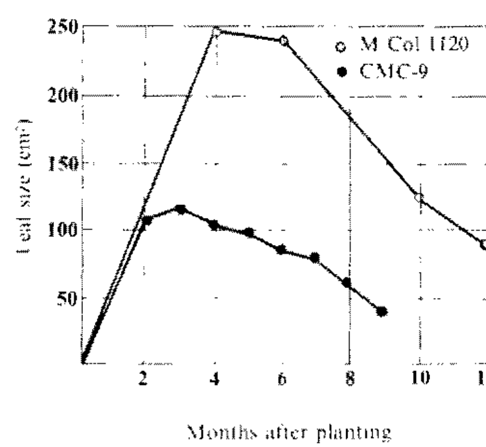


Figure 6. **Leaf area per leaf of CMC-9, a highly branched variety, and M Colombia 1120, a nonbranching type.**

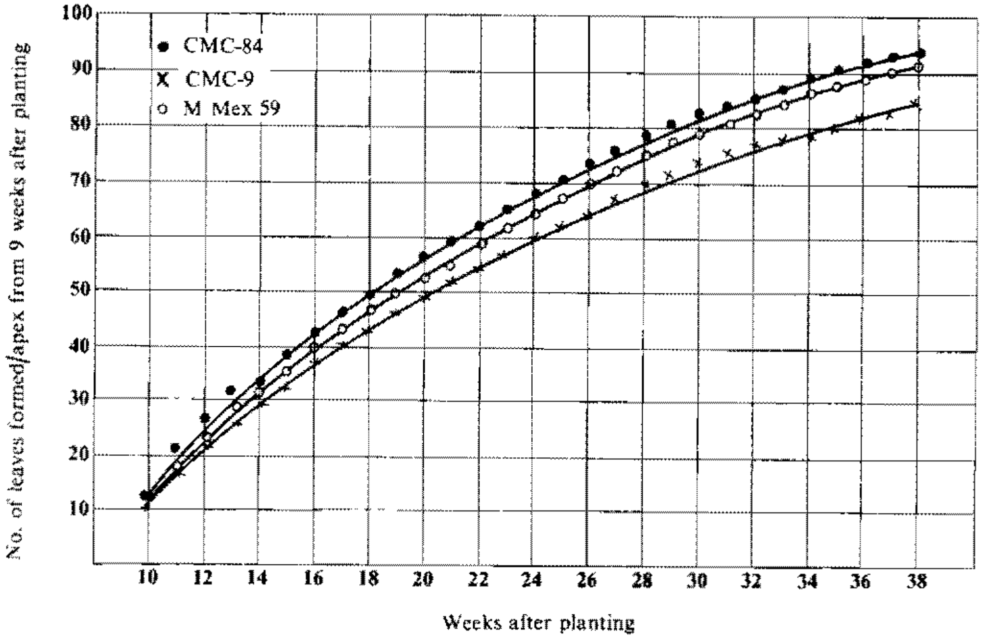


Figure 7. **Total number of leaves produced per apex from nine weeks after planting (spaced plants).**

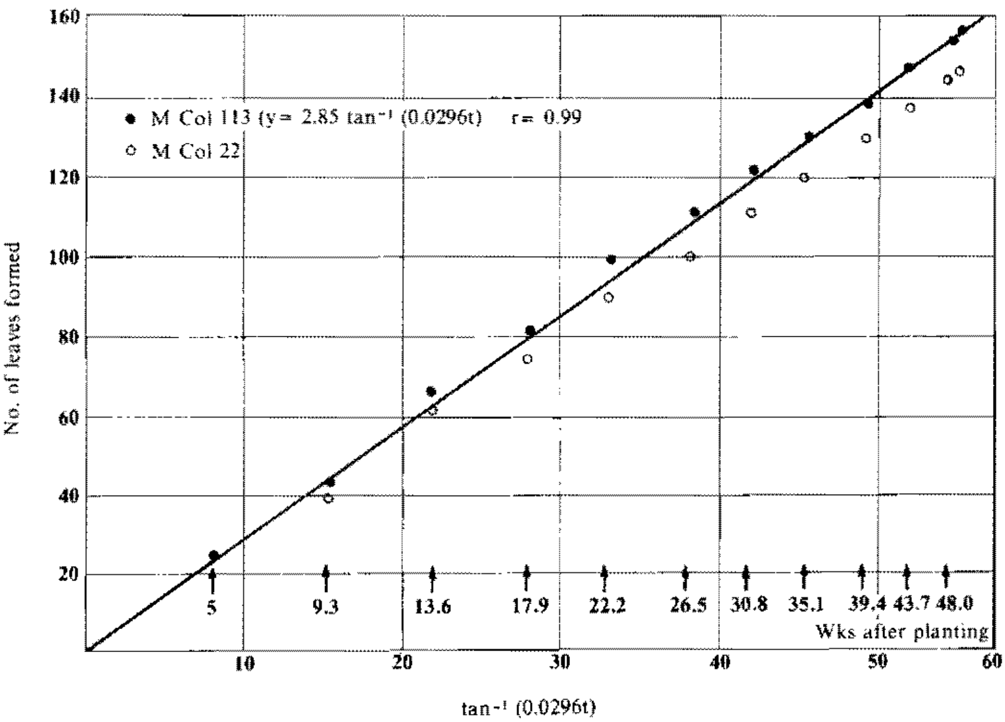


Figure 8. **Number of leaves produced per apex in M Colombia 113 and M Colombia 22.**

systematic density trial and leaf life was measured. Leaf life decreased in proportion to the LAI at the time the leaves formed (Fig. 1). These data suggest that it will be difficult to obtain LAI's above 4 as leaf life drops very rapidly above this level. The low efficiency of maintaining high LAI's for root growth (Fig. 3) is not only explained by mutual shading and reduced crop growth rate but also by the extra energy used for producing a large number of short-lived leaves whose efficiency is low in terms of energy produced per unit of energy expended in formation.

Leaf life of spaced plants was measured for leaves formed 10 to 23 weeks after planting. Leaf life did not apparently change with plant age (Fig. 9). Consistent varietal differences were found: The variety CMC-9 (Llanera) had a consistently long leaf life (94-114 days) in comparison to the other four varieties (66-98 days). This difference is not likely due to shading because the plants were widely spaced (2,500 plants|ha) and CMC-84 (with a short leaf life) is of about the same vigor as CMC-9. It is therefore concluded that large and useful differences in leaf life exist among varieties.

These data suggest that the key to high root yields in cassava is to maintain LAI at the optimum level for as long as possible during the root bulking phase. There appears to be little genetic variation in rate of leaf formation per apex and the tendency for leaf size to decrease after four months; hence manipulation of these characters to maintain optimum LAI does not appear possible. On the other hand, variation does exist for leaf life and branching habit so these can be manipulated to maintain the optimum LAI. At present the interaction between these characters and the environment is not known.

The model to describe the existence of an optimum LAI and the overall growth of

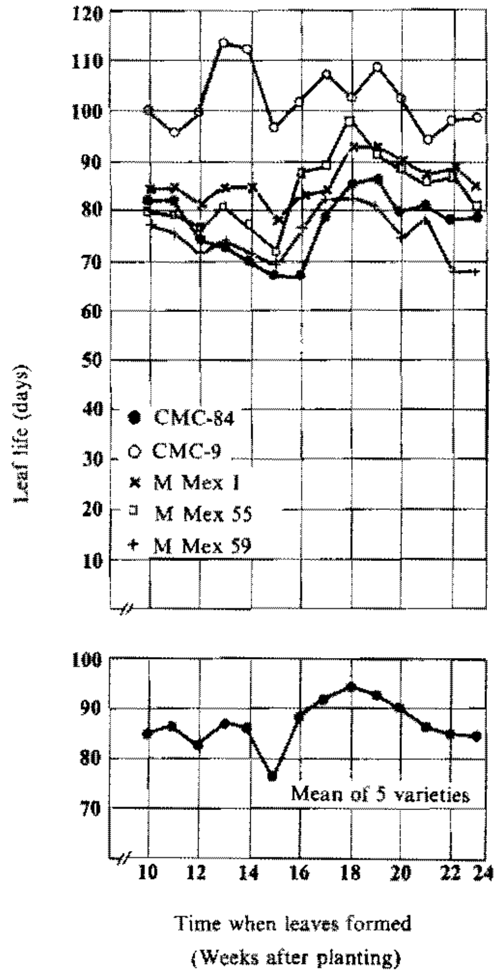


Figure 9. **Leaf life of five varieties as a function of time after planting (spaced plants).**

cassava was based on the fact that top growth takes precedence over root growth and that roots accept the excess carbohydrate produced by the tops. Shading five-month-old plants of M Colombia 22 reduced the number of new leaves formed per apex by 15 percent, increased leaf size by 6 percent and reduced stem weight changes by 8 percent. Therefore, the effects of reduced carbohydrate supply on top growth are minimal at a level of 50 percent shading. On the other hand, shading reduced root dry weight increase by 35 percent, confirming that top growth has preference (not complete) over root growth.

Many varieties of cassava flower and fruit readily; however, little is known of the effects of flowers and fruit production on root yield. Five varieties were grown as spaced plants and flowers were removed as they formed. This was quite easy to do up to about seven months after planting, when it became difficult without damaging plants and several flowers could not be removed. Ten months after planting, the roots and tops were harvested. There was no relationship between yield and number of fruits per plant; therefore, it was concluded that flowering, at least at moderate levels, had no adverse effect on root yield.

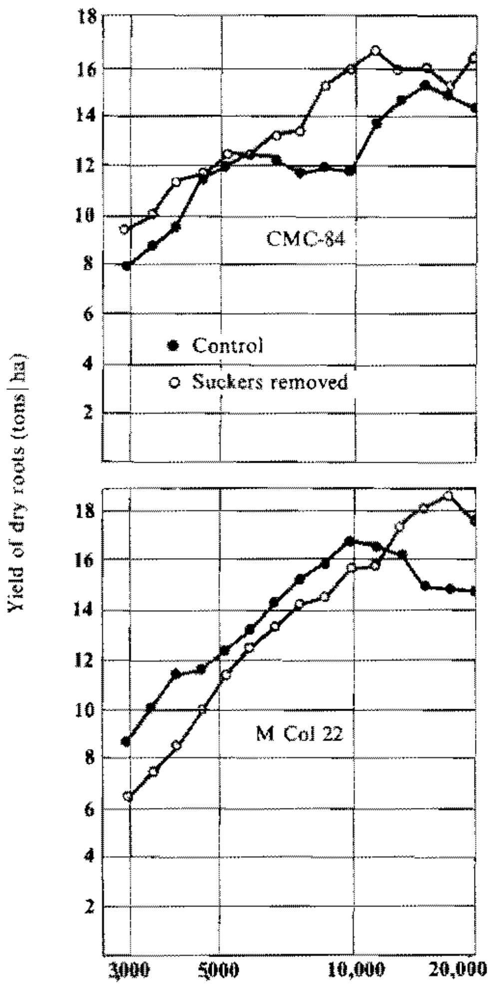


Figure 10. **Yield of two cassava varieties at different plant densities with removal of suckers.**

Many farmers in Colombia remove side or sucker branches. At CIAT it was found that these suckers generally have long internodes and very small leaves. This suggests that leaf production per unit of stem weight is small and that these suckers would be rather inefficient in producing excess carbohydrate to meet their own needs. M Colombia 22 and CMC-84, a low- and a medium-vigor variety, were planted in a systematic density design. On treated plants the suckers were removed every month. In CMC-84, treated plants yielded slightly more at all plant populations; the mean increase was approximately 1.5 tons|ha of dry roots (Fig. 10). The less vigorous M Colombia 22 yielded about 2 tons|ha less when suckers were removed at low plant populations but about 3 tons|ha more at high plant populations. Maximum yields were about 16.5 tons|ha with suckers and about 18 tons|ha without suckers. It appears that suckers are useful only at low populations with low vigor types; otherwise they are inefficient and reduce yields.

PROPAGATION

In the 1973 Annual Report a propagation method was described. Small green shoots were rooted in peat pots filled with sterilized soil and placed in a propagation frame; after rooting they were transplanted in the field. This system was costly because of the need to sterilize soil and purchase peat pots.

Recently it was found that young green shoots rooted in sterile water satisfactorily. Green shoots (8 cm tall) are placed in small flasks containing boiled water (Fig. 11).

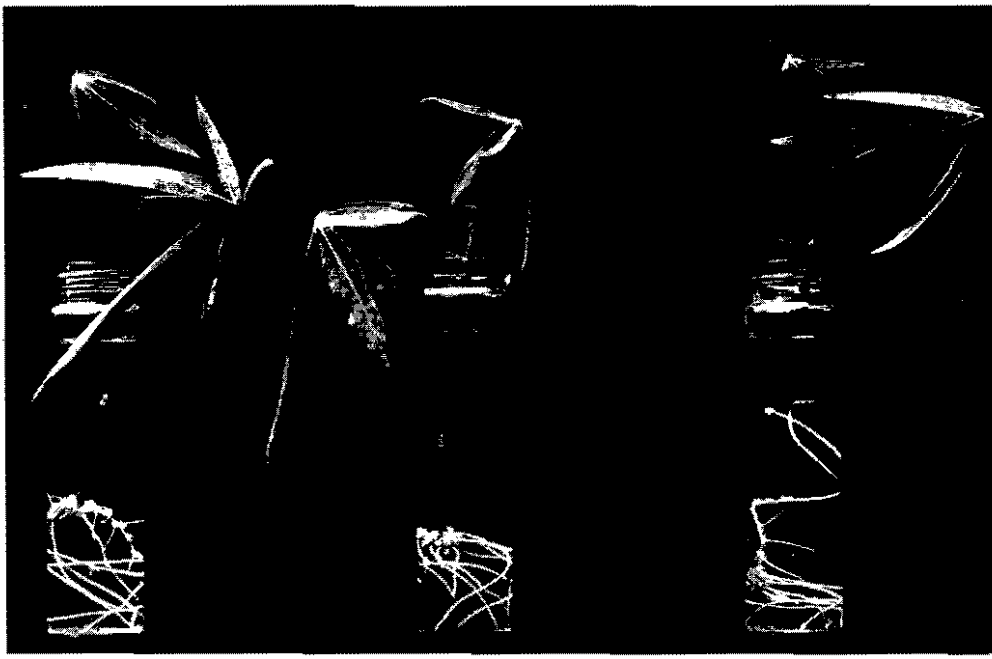


Figure 11. Shoots rooted in water. These plants have passed the stage when they should be planted.

After about one week, a callus forms on the base of the shoots and very shortly afterwards small roots appear. When these roots appear, the plantlets can be transplanted directly to the field if it is well prepared. The plantlets must be planted deep enough (up to the lowest leaf) so they do not dry out.

PATHOLOGY

During 1975 emphasis was placed on the identification of cultivars and the testing of F_1 lines for resistance to the major diseases of cassava in America: cassava bacterial blight (CBB), Cercospora leaf spots (*Cercospora henningsii* and *C. vicosae*), Phoma leaf spot and the superelongation disease. Several etiological aspects of the causal agent of the superelongation disease and of an unknown bacterial disease of cassava (bacterial stem rot) were investigated, as well as methods for screening for resistance to the major cassava diseases. The survival of CBB in plant tissues and exudates is being investigated under controlled environmental conditions. Assessments for disease losses (some of which are still under way) were established by planting in localities where the severity of each particular disease was great.

Cassava bacterial blight

Screening for resistance

Although screening for resistance under field conditions has given consistent results, final evaluations are possible only after a rainy season, thus requiring extensive time after inoculation to obtain results. A simple method for rapid screening under greenhouse conditions was developed. Six to ten cuttings per hybrid or cultivar are grown in pots inside a greenhouse with about 83 percent relative humidity (maximum, 99 percent; minimum, 65 percent) and a temperature of 24°C (maximum, 34°C; minimum,

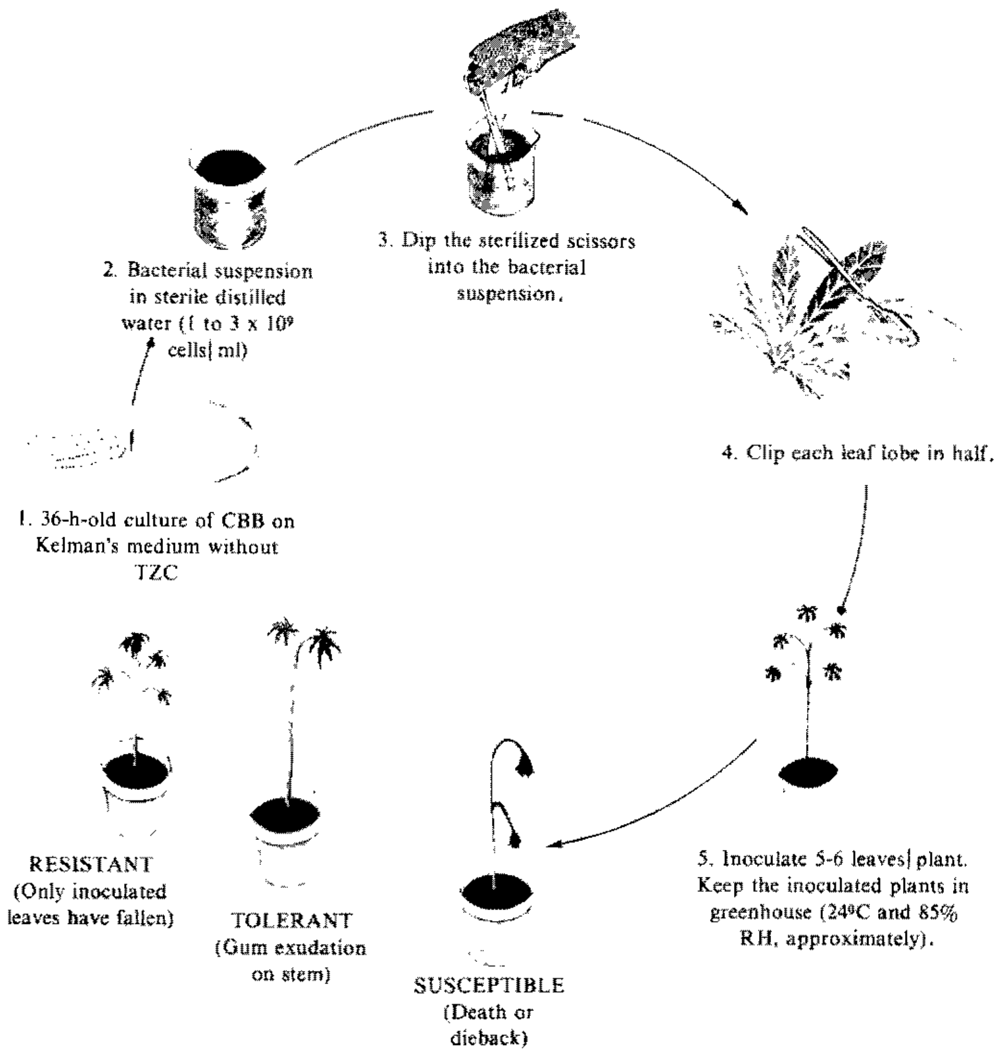


Figure 12. **Clipping method for screening for resistance to CBB.**

19°C). When plants are 30 to 35 days old, five to seven leaves are clipped with scissors infested by dipping into a bacterial suspension of 1.5 to 3.0 x 10^9 cells| ml. The first leaf symptoms occur seven days after inoculation; 19 to 24 days later, gum exudation is observed along the stem on the susceptible genotypes. Resistance is evaluated 40 to 45 days after inoculation. (Fig. 12).

Interactions between bacterial concentrations, serial inoculations, plant and inoculum ages were also investigated. Best results were obtained when one-month-old plants were clip inoculated with 36-hour-old cultures at a concentration of 1 to 3 x 10^9 cells| ml. A high relative humidity (more than 80 percent and a moderate temperature (around 24°C) gave best results.

Disease evaluation for resistance

An evaluation of 870 F_1 lines obtained from different crosses was made for resistance to CBB under greenhouse conditions by inoculating six to ten plants/line (Table 9). A higher percentage of resistant lines appeared when CBB-resistant cultivars, which had been identified after screening the entire germplasm collection, were used for controlled hybridizations. This stresses the importance of using CBB-resistant sources and controlled pollinations for a high breeding efficiency for resistance to CBB.

Simultaneous to the screening of hybrids, several well-known cultivars such as Llanera, M Colombia 22, M Colombia 113 and M Colombia 647, were also tested by using the clip inoculation method for CBB reaction. Results were in complete accordance with those obtained in repeated field trials. Cultivars like M Colombia 22 and M Colombia 113 were very susceptible, both in the field and by using the new inoculation method under greenhouse conditions. M Colombia 647, which had always shown resistance to CBB under field conditions, showed high resistance with clip inoculation. These results confirm the efficiency of the clip inoculation technique; moreover, a considerably larger amount of material can be tested in a short time with this method.

Disease losses

Data taken by the cassava soil group at Carimagua show that CBB could reduce yields of the tolerant cultivar Llanera from 50 to 90 percent when the disease appeared during the first four months of growth. This obviously suggests that CBB seriously affects yield in cassava plantations in areas where there are prolonged periods of rainfall, such as in the Llanos Orientales of Colombia. When infection occurred immediately after germination, yield was more severely reduced than when it appeared four months after planting. N (as urea) or K (as KCl) applications did not correlate with CBB severity, but Mg applications (as MgO) increase its severity and reduced yield.

CBB survival

The survival of CBB in soil was studied during 1974. During 1975, CBB survival in exudates and plant tissues was investigated. Results up to October, 1975 showed that CBB may survive for more than four months and at high concentrations (1×10^7 cells/ml) in plant exudates stored at room temperature (around 24°C and 70% RH) or in a controlled dry environment by using $CaCl_2$ (24°C and 20% RH). CBB also appears to survive for the same period in plant tissues but at lower concentrations than in

Table 9. **Evaluation of resistance to CBB of F_1 crosses among cultivars with different degrees of resistance.**

Cross type	Total no. of F_1 crosses	Disease rating * 1	2	3
Open pollinated lines	59	1 (1.6%)**	9 (15.3%)	49 (83.1%)
Control pollinated lines (Susceptible x Susceptible)	267	3 (1.1%)	64 (23.9%)	200 (75.0%)
Control pollinated lines (Susceptible x Resistant)	544	30 (5.5%)	178 (32.7%)	336 (61.8%)

* Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

** Percentage related to the total number of lines tested per cross type exudates. CBB survival in necrosed stem tissue is longer than in necrosed petiole and leaf tissues. These results stress the importance of our previous suggestions for a careful elimination of all cassava debris and volunteer plants by burning in order to eradicate CBB from infected plantations.

Cercospora leaf spots

Work on Cercospora leaf spots was concentrated on *C. henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot), the most serious and widespread pathogens in cassava plantations located below 1200 m.

Screening methods

Cercospora henningsii and *C. vicosae* are prevalent and endemic at CIAT, possibly because of the continuous planting of cassava and the favorable environmental conditions for disease development. Field evaluation was possible throughout the year, giving consistent results when readings were taken on seven- to eight-month-old plants spaced 1 x 1 m apart. Disease rating was evaluated on hybrids and cultivars by calculating the percentage of infection of the leaves for each pathogen. Resistant hybrids or cultivars were those which showed narrower leaf lesions and less than 10 percent of the total leaves infected.

Checking 454 and 449 leaves of two susceptible cultivars (M Ecuador 150 and M Panama 64) from their emergence to leaf drop, it was found that only 13 and 11 percent, respectively, of their leaves remained healthy. Of 325 leaves of CMC-84, a cultivar resistant to *C. henningsii* but susceptible to *C. vicosae*, 27 percent were healthy. In contrast, 90 percent of the leaves of M Mexico 59, a cultivar resistant to both **Cercospora** spp., remained healthy. It was also found that healthy leaves of the susceptible cultivars (M Ecuador 150 and M Panama 64) fell about 17 percent later than the diseased ones.

It appears that the environmental conditions at CIAT are good for the occurrence of these two diseases; therefore, field evaluation for *C. henningsii* and *C. vicosae* resistance could be successfully done in areas located at around 1000 m altitude with steady rainfall distribution throughout the year. Evaluation must be taken seven months after planting. It appears that high plant density per area increases disease severity and therefore the efficiency of screening.

Evaluation for resistance

The evaluation of resistance to *C. henningsii* and *C. vicosae* in CIAT's cassava germplasm is presented in Table 10. Resistance to *C. henningsii* (58 percent) was higher than to *C. vicosae* (11 percent). This suggests that resistance to *C. henningsii* is more commonly found and easier to incorporate.

Table 10. **Field evaluation of resistance to *Cercospora henningsii* and *C. vicosae* in CIAT's cassava germplasm collection (2,061 cultivars).**

	Disease rating *		
	1	2	3
C. henningsii	1,192 (58%)**	555 (27%)	314 (15%)
C. vicosae	221 (11%)	1,134 (55%)	706 (34%)
Evaluation for both pathogens	175 (8%)	1,157 (56%)	729 (36%)

* Disease rating, 1 = resistant, 2 = tolerant, 3 = susceptible

** Percentage related to the total number of evaluated cultivars

Many of the cultivars resistant to *C. vicosae* were also resistant to *C. henningsii*, but the resistance to these two pathogens does not appear to be linked in any way because there were cultivars with resistance to either one. A relatively satisfactory percentage (8 percent) of resistance to both pathogens exists in CIAT's cassava germplasm.

The evaluation of resistance to *C. henningsii* and *C. vicosae* of F_1 hybrids among cultivars with different degrees of resistance is presented in Tables 11, 12 and 13. As was found in the evaluation of the germplasm (Table 10), resistance to *C. henningsii* among F_1 hybrids was much more frequent than resistance to *C. vicosae* (Tables 11 and 12).

For both *C. henningsii* and *C. vicosae*, higher percentages of resistant lines were obtained when resistant cultivars were used as the cross parents (Table 13). There seems to be no apparent barrier to incorporating resistance to the two **Cercospora** spp. into one genotype; hence the resistance to Cercospora can be incorporated into any favorable genotype by using resistant parents in hybridization programs.

The superelongation disease

Etiological studies

The identification of the causal agent of the superelongation disease of cassava was confirmed as a species of the fungal genus **Sphaceloma**; the pathogen may well be *Sphaceloma manihoticola*, which was previously reported causing a somewhat similar disease on *Manihot esculenta* and *M. glaziovii* in Brazil in 1950. A host range study of the superelongation pathogen was made, using a number of available **Manihot** and related species including *M. esculenta, M. glaziovii, M. carthagenensis, M. faetida, M. silvestre, Ricinus communis, Jatropha gossypifolia* and *Euphorbia pulcherrima* (poinsettia). Only *M. esculenta* and *M. glaziovii* were

Table 11. **Field evaluation of resistance to** *Cercospora henningsii* **(brown leaf spot) of F_1 crosses among cultivars with different degrees of resistance.**

Pollination system	Total no. of F_1 crosses	Disease rating *		
		1	2	3
Self-pollinated				
Resistant	30	12 (40%)**	8 (27%)	10 (33%)
Tolerant	52	15 (29%)	23 (44%)	14 (27%)
Susceptible	7	2 (29%)	5 (71%)	0 (0%)
Controlled pollination				
Resistant x Resistant	259	160 (62%)	69 (27%)	30 (11%)
Resistant x Tolerant	78	27 (35%)	42 (54%)	9 (11%)
Resistant x Susceptible	235	40 (17%)	92 (39%)	103 (44%)
Tolerant x Tolerant	1,240	159 (13%)	337 (27%)	744 (60%)
Tolerant x Susceptible	1,331	269 (20%)	265 (20%)	804 (60%)
Tolerant x Resistant	3,967	2,192 (55%)	664 (17%)	1,111 (28%)
Susceptible x Tolerant	46	9 (21%)	16 (37%)	18 (42%)
Susceptible x Resistant	76	30 (39%)	25 (33%)	21 (28%)
Total	7,321			

* Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

** Percentage related to the total number of F_1 lines evaluated/cross type

Table 12. **Field evaluation of resistance to *Cercospora vicosae* (blight leaf spot) of F_1 crosses among cultivars with different degrees of resistance.**

Pollination system	Total no. of F_1 crosses	Disease rating *		
		1	2	3
Self-pollinated Tolerant	89	15 (17%)**	25 (28%)	49 (55%)
Controlled pollination				
Resistant x Tolerant	44	23 (52%)	14 (32%)	7 (16%)
Tolerant x Tolerant	2,233	275 (12%)	555 (24%)	1,403 (64%)
Tolerant x Susceptible	3,797	212 (6%)	836 (22%)	2,749 (72%)
Tolerant x Resistant	911	359 (39%)	253 (28%)	299 (33%)
Susceptible x Susceptible	178	5 (3%)	70 (39%)	103 (58%)
Susceptible x Tolerant	60	5 (8%)	25 (42%)	30 (50%)
Susceptible x Resistant	6	0 (0%)?	0 (0%)?	6 (100%)
Total	7,318			

* Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

** Percentage related to the total number of F_1 lines evaluated/cross type

infected by the pathogen, and the pathogen was isolated from naturally infected plants belonging to these two species. However, a **Sphaceloma** sp. previously reported as *S. poinsettiae*, isolated from infected poinsettia plants, induced symptoms on cassava similar to those induced by **Sphaceloma** sp. on cassava. Until further evidence can prove otherwise, it is suggested that the superelongation pathogen may be the same fungus as reported by Bitancourt and Jenkins as *Sphaceloma manihoticola*.

The conidia of the superelongation causal agent are produced on phialides and are small (averaging 5.3 x 2.7 µ), oblong to oblong-elliptical. The conidia swell greatly prior to germination. The effects of temperature, moisture, light, spore concentration and age of colony upon conidial germination were tested. Free moisture was shown to be essential for germination, and optimum germination occurred at approximately 28.5°C. Light and spore concentration had little or no effect upon germination, but the percentage of germination decreased with increased colony age.

The aforementioned data were necessary to establish a successful system for

Table 13. **Field evaluation of resistance to both *Cercospora henningsii* and *C. vicosae* of F_1 crosses among cultivars with different degrees of resistance.**

Pollination system	Parental reaction	Resistant lines / No. of lines evaluated	% of resistance
Self-pollinated	Tolerant	11/82	13.4
Self-pollinated	Susceptible	0/8	0.0
Control pollinated	Resistant x Susceptible*	225/976	23.6
Control pollinated	Tolerant x Susceptible*	238/6,075	3.9
Control pollinated	Susceptible x Susceptible*	2/198	1.0
Total		476/7,318	6.5

* Including some reciprocal combinations

Table 14. **Yields of two resistant (R) and one susceptible (S) cassava clone when the superelongation disease occurred five months after planting.**

	Yield (tons/ha)		
Replicate	Llanera (R)	M Col 22 (R)	M Col 113 (S)
1	29.13	25.57	33.27
2	23.23	31.06	27.87
3	32.90	37.67	35.53
Average*	28.42	31.43	32.22

* The difference between means of the above three yields was not significant at the 1% level (F test)

artificially inoculating young cassava plants. A minimum of approximately eight hours of free moisture was necessary for infection to occur. Increased disease incidence and severity occurred as the number of hours under free moisture increased. No conclusive evidence of pathogenic races of the fungus has been observed yet. Histological studies of inoculated leaves showed that the fungus directly penetrates the host.

Disease losses

Yields can be greatly reduced in heavily infected fields. Two resistant cultivars, Llanera and M Colombia 22, and the susceptible cultivar M Colombia 113 were inoculated one month after planting; in a second trial, inoculation was made five months after planting. Where infection occurred early, yield losses were approximately 80 percent. After the fifth month after planting, no significant loss was recorded (Tables 14 and 15 and Fig. 13).

Dissemination

Disease dissemination and reduction in plant establishment by the use of infected planting material was studied with the susceptible cultivar M Colombia 113. Cuttings (144) taken from healthy and diseased plantations were planted in an isolated locality. After 25 days germination

Table 15. **Yields of two resistant (R)and one susceptible (S) cassava clone when the superelongation disease occurred one month after planting.**

	Yield (tons/ha)		
Replicate	Llanera (R)	M Col 22 (R)	M Col 113 (S)
1	19.08	18.05	3.75
2	17.32	15.45	3.75
3	19.17	17.43	3.25
Average	18.52*	16.98	3.58

* LSD between mean yields at the 1% level is 3.04.

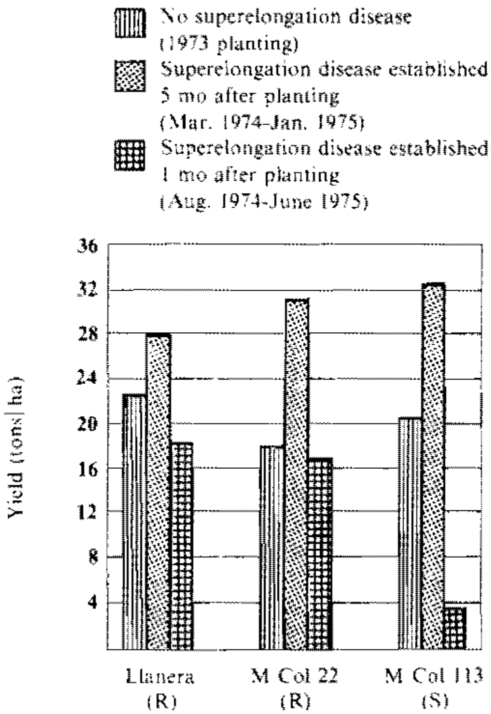


Figure 13. **Mean yield of two resistant (R) and one susceptible (S) cassava clone under three different superelongation disease situations.**

was reduced about 3 percent; 26 percent of the plants obtained from diseased cuttings were infected and the weight of leaves and stems was reduced by about 41 percent.

Phoma leaf spot

The correlation between disease reaction and yield of more than 348 cultivars was determined 15 months after planting. A group of 113 cultivars was harvested at the end of the rainy season, and another group of 235 cultivars was harvested immediately after the dry season. The cultivars were planted in rows (1 m apart) of 11 plants|cultivar (0.50 m apart) with two replications.

Fresh root yields in the area (Popayán) average 6 tons|ha. When cultivars were harvested at the end of the rainy season, 100 percent of the very susceptible and 84 percent of the susceptible cultivars yielded less than the regional average. In contrast, 70 and 100 percent of the tolerant and resistant cultivars, respectively, produced more than the regional average. When harvested at the end of the dry season, 93 and 68 percent of the very susceptible and susceptible cultivars, respectively, yielded less than 6 tons|ha; but 92 and 100 percent of the tolerant and resistant cultivars yielded more. To increase yields in areas above 1300 m, where Phoma leaf spot disease is more severe and endemic, it is necessary to incorporate resistance to this disease into high-yielding cultivars.

By grouping cultivars in accordance with their disease rating (Figs. 14 and 15), it can be seen that yields increase when resistance to Phoma leaf spot increases. Some of the resistant cultivars yielded only as much as the tolerant ones (Fig. 15), which could be related to genetic yield ability per se.

To verify the resistance shown by cultivars previously evaluated in the

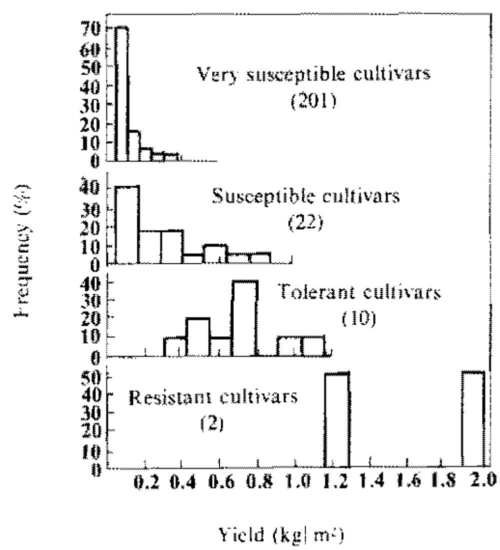


Figure 14. **Yield of 235 cultivars grouped according to their reaction to Phoma leaf spot. Cultivars were harvested 15 months after planting and at the end of the rainy season.**

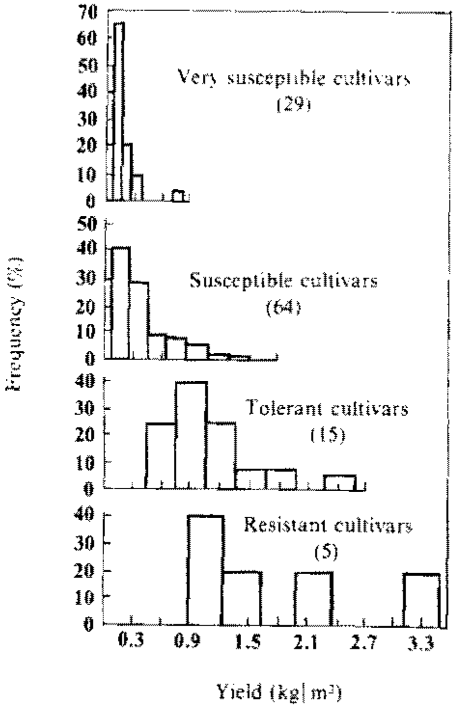


Figure 15. **Yield of 113 cultivars grouped according to their reaction to Phoma leaf spot. Cultivars were harvested 15 months after planting and at the end of the dry season.**

Popayán area, nine highly resistant cultivars were planted in El Darién (1430 m), where the disease occurs with greater severity. In both localities, the susceptible cultivars showed complete defoliation, dieback and, in many cases, death; consequently, total plant weight was considerably reduced. The resistant cultivars grew normally, producing a high total weight of fresh matter according to the intrinsic vigor of each cultivar (Table 16). It was concluded that these highly resistant cultivars could be used successfully in any breeding program for resistance to this disease.

Bacterial stem rot

A bacterial species pathogenic to cassava was isolated from rotted stem samples taken from three different cassava-growing areas. Preliminary cultural, morphological, physiological and biochemical tests, as well as disease symptomatology, showed that this bacterial species and the disease it induces are far different from the cassava blight bacterium.

Tests suggest that the species belongs to the genus **Erwinia.** It is a Gram-negative, rod-shaped peritrichous organism that grows well on several sugar media, producing round, white and entire colonies. It produces gelatinase; causes soft rot in potatoes, carrots and cassava slides; liquefies pectate gel and does not use sorbitol.

Bacterial penetration and establishment occur through wounds, which in nature may be caused by insects. Infected plants were always damaged by **Anastrepha** sp. (fruit flies), but not all Anastrepha-infected plants showed bacterial infection. The relationship between insects and this bacterium to pathogenesis is still

Table 16. **Total plant weight of cultivars resistant (R), tolerant (T) and susceptible (S) to Phoma leaf spot, 12 months after planting in El Darién.**

Cultivar collection no.	Disease reaction	% of defoliation	Total weight* (tons/ha)
CMC-92	R	20	54.4
M Col 340	R	25	14.3
M Col 230	R	22	19.1
M Col 276	R	18	29.4
M Col 80	R	24	25.7
M Col 235	R	22	23.3
M Col 291	R	21	15.9
M Col 2	R	17	15.1
M Col 307	T	53	13.0
CMC-39	T	58	12.4
Valluna	S	98	3.6
M Col 22	S	100	0.17

* Total plant weight was calculated from three randomized plots of 9 plants; plot borders were eliminated.

unknown; the insect damage is further discussed in the entomology section.

Pathogenic tests showed that the organism is restricted to stem tissues. Infected plants show blackish necrosis, then wilting and finally dieback. Buds located along infected stem portions are first invaded and necrosed; thus the infected stem parts may be lost for planting purposes. Even though its effect on cassava production is unknown, it appears that the most important factor is related to the damage to buds, which could be reflected in germination and crop establishment when planting material is taken from infected plants.

Cassava rust

Cassava rust was first reported in 1887. Six different species belonging to the Uredinal order are reported, but neither their taxonomic status nor their geographic distribution had been defined. A cooperative study between the Instituto Colombiano Agropecuario| Universidad Nacional and CIAT was initiated this year.

The characteristic taxonomic features for each pathogenic species were determined. Keys for their taxonomic identification are being produced with descriptions and illustrative diagrams based on samples obtained from different herbaria.

ENTOMOLOGY

An extensive program to evaluate the cassava germplasm bank for resistance to several mite species was initiated this year. A procedure was developed to evaluate resistance to mites. Continued emphasis was placed on determining yield losses associated with thrips, mites, fruit flies and shoot flies. Studies were undertaken on the biology, ecology and importance of whiteflies and fruit flies. Control practices were investigated for insects attacking planting material and germinating plants.

Insect and mite population fluctuations

A two-year study of the factors influencing insect populations in cassava was completed at CIAT during 1975. This insect complex includes mites, thrips, the cassava hornworm, the shoot fly (*Silba pendula*) and the cassava lace bug *(Vatiga manihoti)*. Three cuttings in two replications of 90 cassava varieties were planted on May 1, August 1 and November 1, 1973. Fifty varieties were planted on February 1 and May 1, 1974. Monthly evaluations were made of the aforementioned insects.

Mite populations were measured by sampling the central part of the plant and counting the number of mites found in a 20-cm^2 leaf area. Thrips populations were determined by evaluating the damage using a visual scale of 0 to 5 (0 = no damage, 5 = apical and lateral buds dead). The number of parasitized and nonparasitized cassava hornworm eggs were sampled weekly and larvae were counted on 75 randomly chosen plants. In addition a monthly evaluation by variety was made. Shoot fly populations were measured by monthly counts of the total number of growing tips per plant and the number of attacked tips. The percentage of infestation per variety and per planting was thereby determined. Populations of the cassava lace bug (nymphs and adults) were sampled by inspecting three leaves from each of the upper, central and lower parts of the plant.

During the first three months afte planting, attack by thrips, shoot flies hornworms and the cassava lace bug wer the most severe. The mite populations however, increased with the age of th plant (Fig. 16). The dry period wa especially favorable for higher population of thrips (Fig. 17), mites, lace bugs, shoo flies and oviposition by the hornworm.

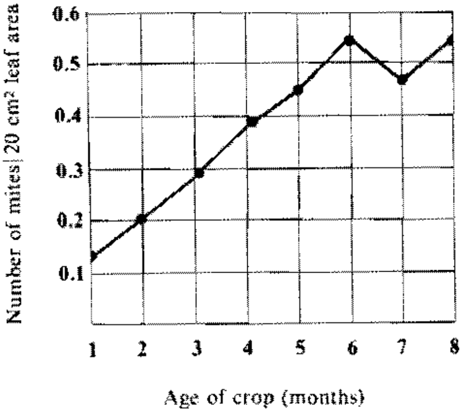


Figure 16. **Monthly evaluations of *Mononychellus mcgregori, Tetranychus urticae* and *Oligonychus peruvianus* mite populations measured on several cassava varieties.**

Mites

Four species of mites have been identified as attacking cassava in Colombia. All belong to the family Tetranychidae and include *Mononychellus tanajoa, M. mcgregori, Tetranychus urticae* and *Oligonychus peruvianus. M. tanajoa* and *T. urticae* appear to be the most important species on a global basis. *O. peruvianus* is of limited importance while *M. mcgregori* has been reported in limited regions of Colombia and Venezuela.

The **Mononychellus** mite is usually found around the growing points of the plant on buds, young leaves and stems; lower leaves are less affected. The leaves emerge from the bud marked with yellow spots, lose their normal green color and become deformed. The attacked shoots lose their green color, turning rough and brown. The stems and leaves die progressively from top to bottom (Fig. 18).

Damage from the **Tetranychus** mite first appears on the lower leaves of the plant. Damage first shows as yellow dots along

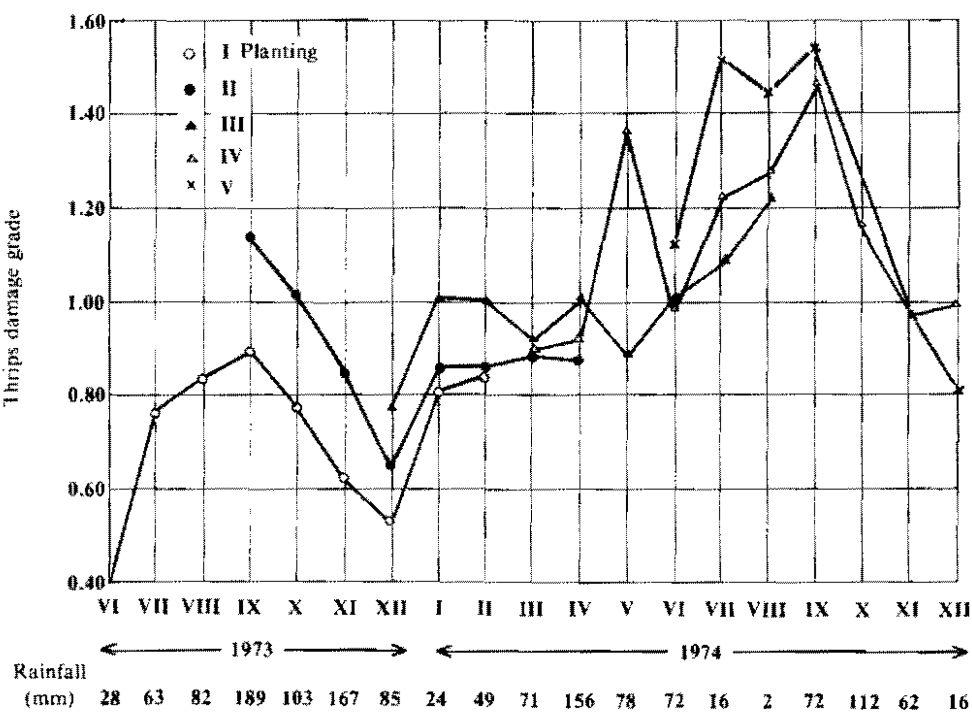


Figure 17. **Monthly evaluation of thrips damage for five plantings on several cassava varieties.**

Figure 18. Typical damage caused by *Mononychellus* sp. on the growing points of the cassava plant.

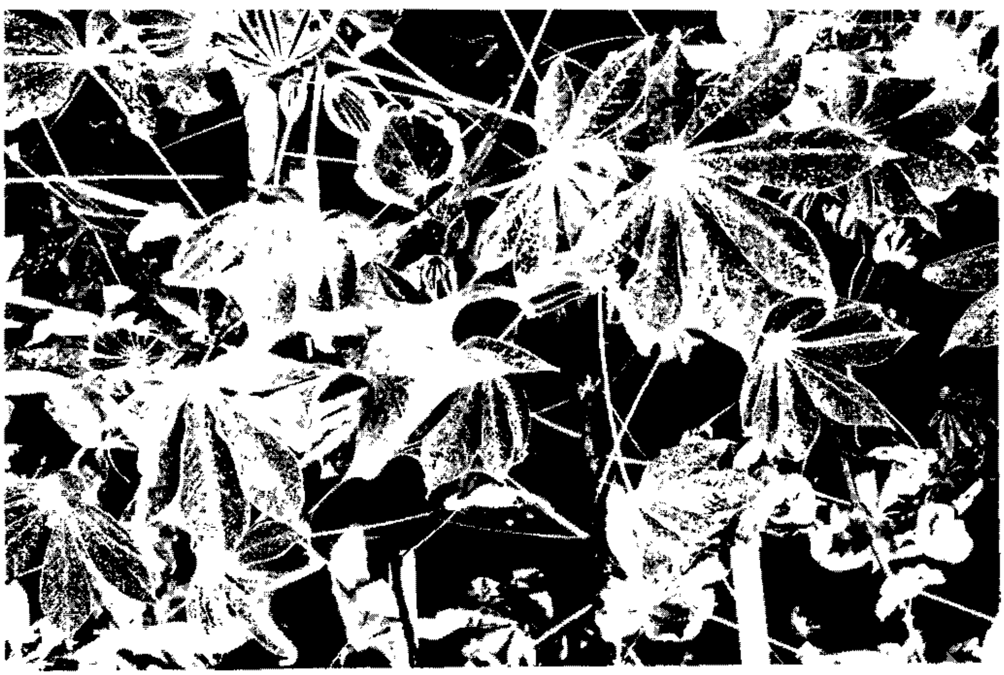


Figure 19. Severe leaf damage and webbing caused by *Tetranychus urticae* under controlled environmental conditions.

the main leaf vein and eventually spreads over the whole leaf, which turns reddish brown or rusty in color. Beginning with the basal leaves, severely infested leaves dry and drop; under severe attack plants may die (Fig. 19).

Presence of the **Oligonychus** mite is characterized by a small whitish web that the female spreads on the undersides of the leaves, commonly along the center and lateral leaf veins. Yellow to brown dots form on the leaf's upper surface. Damage is more pronounced on the lower leaves.

A procedure was developed to evaluate the cassava germplasm bank for resistance to the **Tetranychus** and **Mononychellus** mites under screenhouse conditions since natural infestations in Colombia are neither high enough nor sufficiently uniform for field screening. Cassava varieties are planted in floor beds or pots in a screenhouse and are surrounded with plastic to raise the temperature to 34°C. Leaves infested with mites are placed on one-month-old plants to inoculate them. Resistance is evaluated at weekly intervals from two to six weeks after inoculation; second and third inoculations are made if the initial one was not successful.

Screening for **Oligonychus** resistance was done on 1,884 varieties in the germplasm bank during a natural outbreak on the CIAT farm.

Preliminary results indicate that there are only low levels of resistance to the **Tetranychus** mite but intermediate resistance to both the **Mononychellus** and **Oligonychus** mites. Of the 427 varieties screened for resistance to the **Tetranychus** mite, only one variety (M Colombia 114) was selected as having a moderate level of resistance. Several varieties, however, have

Table 17. **Resistance of cassava varieties to three species of mites.**

Mite	No. of varieties evaluated	Resistance evaluation scale***	No. of varieties in each resistance class		
Tetranychus urticae	427*	0 - 5	5.0 = 370 var.		
			4.5 = 46 var.		
			4.0 = 10 var.		
			3.5 = 1 var.		
Mononychellus mcgregori	45*	0 - 5	5.0 = 4 var.		
			4.5 = 12 var.		
			4.0 = 44 var.		
			3.5 = 9 var.		
			3.0 = 8 var.		
			2.0 = 2 var.		
Oligonychus peruvianus	1,884**	No. of mite colonies/leaf	0 - 10	72	3.82%
			10 - 50	591	31.36%
			50 - 100	454	24.09%
			100 - 200	421	22.34%
			200 - 500	319	16.93%
			500 - 1000	27	1.43%

* Artificial infestation in screenhouse

** Natural infestation in the field

*** Damage rating: 0-1 = resistant; 2-3 = intermediate resistance; 4-5 = susceptible been selected as promising for future testing. Only 45 varieties have been evaluated for resistance to the **Mononychellus** mite, but several lines appear to have good intermediate resistance. On the varieties screened for resistance to **Oligonychus,** 0.5 to 1,205 webs per leaf were found. Seventy-two varieties had less than 10 webs per leaf (Table 17) and 16 varieties less than 5.

Thrips

Five species of thrips have been identified as attacking cassava: *Corynothrips stenopterus, Scirtothrips manihoti, Euthrips manihoti, Frankliniella williamsi* and **Frankliniella** sp.

Yield reductions induced by thrips attack were studied in two trials on the CIAT farm. In the first trial thrips attack was heavy during the dry season, and losses were up to 15.4 percent in susceptible cultivars and 11 percent for intermediate resistant cultivars (Table 18). Yield reduction in thrips-susceptible cultivars was attributed to all insects attacking cassava; in resistant cultivars it was

Table 18. **Cassava yields of thrips-susceptible (S), intermediate resistant (I) and resistant (R) cultivars, ten months after planting, with and without insecticidal application.**

Cultivar	Thrips resistance evaluation	Yield (tons/ha) Without insecticides	Yield (tons/ha) With insecticides*	% yield reduction
Trial 1				
M Col 890	R	17.3	18.0	3.9
M Col 113	R	23.9	25.8	7.4
M Col 65	R	25.5	27.9	8.6
Average		22.2	23.9	6.6
M Col 22	I	28.1	33.1	15.1
M Col 1438	I	34.0	42.5	20.0
Average		31.0	37.8	17.6
M Col 1703	S	21.5	25.7	16.3
M Mex 34	S	14.3	18.9	24.3
M Col 248	S	18.0	24.1	25.3
Average		17.9	22.9	22.0
Trial 2				
M Col 1696	S	20.2	21.4	5.6
M Col 1745	S	21.9	24.0	8.8
M Col 1670	S	20.2	22.4	9.8
M Col 1765	S	20.8	24.3	14.4
M Col 1703	S	21.5	27.1	20.7
M Col 1777	S	19.5	25.3	22.9
M Col 1701	S	16.8	22.5	25.3
M Col 1767	S	16.9	23.6	28.4
Average		19.7	23.8	17.2

* Dimethoate applied every month at 0.75 liters a.i./ha

attributed to all insects except thrips. Assuming that insects other than thrips attack cultivars equally, the greater yield reduction in susceptible cultivars can be attributed to thrips damage.

In the second trial, yield reduction due to thrips was estimated by the reduction in yields of plots without insecticidal protection as compared to protected plots. Yield reduction ranged from 5.6 percent for M. Colombia 1696 to 28.4 percent for M. Colombia 1767, with an average reduction for all varieties of 4.1 tons|ha or 17.2 percent (Table 18).

White grubs

White grubs, the larval stage of a beetle (Scarabaeidae) feed on the roots of young plants, causing considerable damage. Grubs feed on the bark and buds of recently planted cuttings, reducing germination. Attacks are more severe in fields that were in pasture prior to the planting of cassava.

Two control methods of insecticidal application were studied: Soil applications of a granular or dust insecticide were made at the time of planting, or cuttings were submerged in an insecticidal solution for 20 minutes before planting. Two varieties (CMC-59 and 57) were treated with eight insecticides and one herbicide; stake germination was recorded 15, 25 and 35 days after planting. In another experiment using the insecticides carbofuran and disulfoton, three methods of application were studied: incorporation in the soil, placed below the cutting or around the cutting.

Results in the first experiment show that white grubs can reduce germination markedly unless controlled. Of 160 cuttings planted in the four control replicates, 153 (95.6 percent) did not germinate due to white grub damage (Table 19). Aldrin and carbofuran (granulated form only) gave the best control with 80.6 and 73.1 percent germination, respectively. Disulfoton (50.6

Table 19. **Effects of the application of several insecticides on the germination of cassava cuttings in the presence of white grubs (Scarabaeidae).**

Insecticide treatment	Dosage	No. germinated*	% germination**
toxaphene—DDT	1.2 liters| 100 liters H_2O	34.0	21.3
carbofuran (granulated)	3 g| m^2	117.0	73.1
carbofuran (dip)	100 cc| 100 liters H_2O	17.0	10.6
Herbicide (alachlor + diuron)	2 liters + 2 kg| ha	17.0	10.6
methamidophos	100 cc| 100 liters H_2O	15.0	9.4
fenthion	75 cc| 100 liters H_2O	48.0	30.0
disulfoton	3 g| plant	81.0	50.6
aldrin	60 kg| ha	129.0	80.6
diazinon	70 cc| 100 liters H_2O	14.0	12.5
Control		7.0	4.4

* Randomized block of 4 plots of 40 cuttings per plot

** Significant at 1 percent level

Table 20. **The effectiveness of the distribution of the placement of the granulated insecticides carbofuran and disulfoton for the control of white grubs (Scarabaeidae).**

Insecticide	Method of soil application	No. germinated*	% germinated
carbofuran	Incorporated in 20 m^2	65	81.3
carbofuran	Below the cutting	74	92.5
carbofuran	Around cutting	66	82.5
disulfoton	Incorporated in 20 m^2	62	77.5
disulfoton	Below cutting	66	82.5
disulfoton	Around cutting	57	71.3
Control	———	58	72.5

* Randomized block of plots of 20 cuttings per plot

percent germination) gave moderate control, but the remainder of the insecticides gave little or no grub control. The dip method of application was not effective.

In the second experiment, carbofuran (granular) applied below the cutting gave the best results (Table 20). This resulted in only a 7.5 percent reduction in germination as compared to a 27.5 percent reduction in the control.

Cassava fruit flies

Cassava fruit flies have become one of the most serious pests of cassava in the coffee-growing region of Colombia. Originally believed to be only a pest of the cassava fruit, two species of fruit flies, *Anastrepha pickeli* and *A.manihoti* (Tephritidae) have now been identified as also attacking the stem. The female prefers to oviposit in the fruit but frequently oviposits in the soft tissue of the stem of the young cassava plant about 10 to 20 cm below the growing point. The young larva hatches and bores its way into the pith region of the stem and tunnels downward. This tunneling is a point of entry for a bacterial pathogen that can cause extensive rotting of the stem (See pathology section).

During their initial stages, the larvae are white, turning yellow later. The presence of the larvae within the stem can often be noted by the white liquid exudate that flows from the larval wound down the stem. This extensive rotting often causes death of the growing point of young plants (Fig. 20). On one field 84 percent of the plants were observed with this damage, while in another field about 75 percent of the plants had collapsed 20 to 30 cm below the growing point.

Figure 20. **Extensive rotting and death of the growing point caused by a bacterial pathogen in association with the larvae of the cassava fruit fly (Anastrepha sp.).**

Table 21. **Fecundity, egg viability and longevity of the whitefly *Trialeurodes variabilis* under caged conditions in the field (based on 10 pairs of adults).**

Developmental stage	Minimum	Maximum	Average	Standard deviation
No. of eggs per female	134	178	161.1	± 14.50
Eggs hatched (%)	89.9	100	95.2	± 3.59
Pupae formed (%)	59.3	96.1	79.7	± 11.64
Adults emerged (%)	86.2	98.4	95.3	± 3.28
Survival egg to adult (%)	55.1	90.3	72.4	± 10.50
Longevity of female (days)	14	22	19.2	± 2.31
Longevity of male (days)	5	15	8.8	± 3.12

Whiteflies

Whiteflies (Aleyrodidae) are distributed over many of the cassava-growing areas of the world. Several species have been identified as attacking cassava: these include *Trialeurodes variabilis, Bemisia tabaci, B. tuberculata,* **Aleurotrachelus** sp. and **Aleurothrixus** sp. Although indications are that whiteflies may not cause direct damage due to feeding, they are of particular importance because of their ability to transmit mosaic disease in Africa. In addition a sooty mold growing on their excretions may have an adverse effect on plant photosynthesis.

The biology of the whitefly *I. variabilis,* commonly found in Colombia, was studied under field conditions in screened cages (Table 21).

An evaluation for resistance to the whitefly **Aleurotrachelus** sp. was made on 189 cassava cultivars during a heavy field infestation. The oblong pupal stage of this whitefly is black with a white waxy excretion around the outer edge, making it easy to detect on the leaf undersurface. Several varieties were identified with very low levels of infestation (Table 22), indicating that resistance to **Aleurotrachelus** sp. is available in the cassava germplasm bank. Infestation was uniform, but only one evaluation was made and therefore needs to be repeated.

Cassava hornworm

A system for biological control of the cassava hornworm *(Erinnyis ello)* was described in the 1974 Annual Report. The combination of egg parasitism by *Trichogramma fasciatum* and larval predation by the paper wasp *Polistes erytrocephalus* supressed the hornworm population at CIAT throughout the year. There has been no outbreak at the CIAT farm since these biological control agents were introduced in 1973.

Hornworm outbreaks were studied on two nearby farms. In both cases an insecticide had been applied to the cassava crop for insect (thrips and fruit fly) control

Table 22. **Evaluation of 189 cassava cultivars for resistance to the whitefly** Aleurotrachelus **sp.**

Total no. of cultivars	Damage rating*					
	0	1	2	3	4	5
189	2	36	42	72	33	4

* 0 = no whitefly infestation, 1 = less than 20% of leaves infested, 2 = 20 to 40% of leaves infested, 3 = 40 to 60% of leaves infested; 4 = 60 to 80% of leaves infested; and 5 = 80 to 100% of leaves infested

prior to the outbreak. Egg parasitism by **Trichogramma** was between 50 and 60 percent. The **Polistes** wasp was introduced into both fields. In the first field there has been no further outbreak for six months; the second field is still being studied.

VARIETAL IMPROVEMENT

During the past three years a substantial amount of basic data on germplasm and genetic behavior and selection efficiency of the cassava plant was accumulated. Evaluation of more than 2,000 entries in the germplasm collection was completed. Hybridization and seedling selection techniques were established. Selection based on harvest index of the plant proved to be efficient, both genetically and physiologically.

During the year, approximately 230 cultivars, 3,000 hybrid lines and 8,000 hybrid plants were evaluated and harvested in a replicated yield trial, an observational yield trial and a hybrid selection field, respectively. About 160 hybrids lines, 1,200 hybrid lines and 25,000 hybrid seeds were planted in the replicated yield trial, the observational yield trial and the selection field, respectively. Approximately 30,000 hybrid seeds were produced from about 250 cross combinations. A major part of these seeds are sown at CIAT within six months of harvest; some are sent to breeders in many countries of America, Asia and Africa.

A yield of more than 60 tons|ha|year was obtained in a replicated yield trial. The highest yielding cultivars at CIAT are outperforming the local cultivars not only at CIAT but also outside CIAT; thus yield improvement through modifying the cultivars seems a forthcoming reality.

Germplasm collection

The present status of the CIAT germplasm collection is presented in Table 23. Useful genotypes have been identified for all the major diseases and insect problems.

Table 23. **Present status of the CIAT cassava germplasm collection.**

Country of origin	No. of cultivars maintained at present	No. of cultivars evaluated
Colombia	1,676	1,646
Venezuela	269	255
Ecuador	134	134
Mexico	68	65
Brazil	22	5
Panama	20	20
Puerto Rico	16	15
Costa Rica	16	0
Dominican Republic	5	0
Peru	2	2
Paraguay	2	2
Total	2230	2,142

Yield trials

Selected mainly on the basis of harvest index and root yield when grown in single rows, 232 cultivars were harvested in replicated yield trials at CIAT. The experiments had two replications and all harvested plants had two border rows. The nine central plants were harvested 12 months after planting in each replicate. No fertilizer, fungicide or insecticide was applied to the experiment.

Data on the best-yielding cultivars are presented in Table 24. One cultivar yielded more than 60 tons|ha, eleven cultivars yielded more than 50, and three gave a dry matter yield of more than 20 tons|ha. Llanera, a local cultivar, yielded 26.7 tons|ha of fresh root or 8.7 tons of root dry matter. These results suggest the possibility

Table 24. **Twenty best yielding cultivars.**

	Root yield (tons/ha/year)	Dry matter content of roots	Root dry matter yield (tons/ha/year)	Total plant weight (tons/ha/year)	Harvest index
M Ven 218	60.6	.359	21.7	96.7	.626
M Mex 17	54.2	.368	19.9	83.9	.646
M Col 946	53.6	.394	21.1	106.1	.505
M Pan 70	52.8	.376	19.8	79.4	.664
M Col 1686	52.5	.306	16.1	99.2	.529
M Col 1292	52.2	.387	20.2	118.6	.440
M PTR 26	52.2	.368	19.2	79.4	.657
M Col 803	51.4	.365	18.8	106.7	.482
M Col 1684	50.8	.331	16.8	78.3	.649
M Mex 59	50.6	.358	18.1	100.3	.504
M Ven 77	50.0	.334	16.7	88.6	.564
M Ven 168	49.4	.369	18.2	86.9	.550
M Mex 16	49.2	.353	17.4	83.9	.590
M Pan 114	49.2	.375	18.4	76.2	.645
M Col 638	48.6	.351	17.1	106.9	.454
M Col 655A	46.7	.385	18.0	105.6	.442
M Col 1468	46.1	.327	15.1	94.7	.487
M Ecu 47	46.1	.371	17.1	93.1	.495
M Ven 270	45.8	.395	17.9	108.9	.421
M Mex 52	44.1	.390	17.4	107.6	.416
Llanera (Local cultivar)	26.7	.325	8.7	53.1	.503
M Col 22 (Control)	26.7	.398	10.6	41.4	.644
M Col 113 (Control)	38.1	.354	13.5	85.3	.446

of immediate yield increase by varietal selection. Considering that the eleven cultivars that yielded more than 50 tons/ha compose the upper 0.5 percent selection from the original collection, it is obviously important to start a selection program with a very broad variability of germplasm.

High total plant weight and harvest index are very important in obtaining high yields (Figs. 21 and 22). There seems no way of obtaining high yields when the harvest index is less than 0.40. Harvest index was negatively correlated with leaf and stem weight (Fig. 23), thus confirming that the top and roots are competing sinks. The types with too vigorous top growth have a very low harvest index; and the types with a very high harvest index cannot maintain a reasonable level of top growth and hence leaves, resulting in a low total dry matter accumulation.

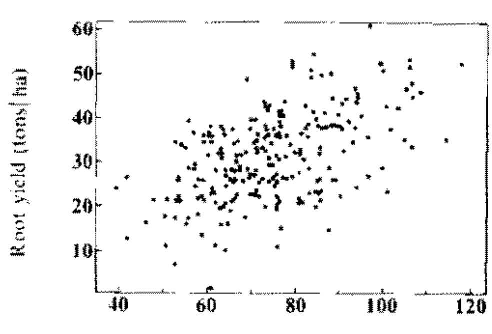


Figure 21. **Relationship between total plant weight and root yield (fresh weight).**

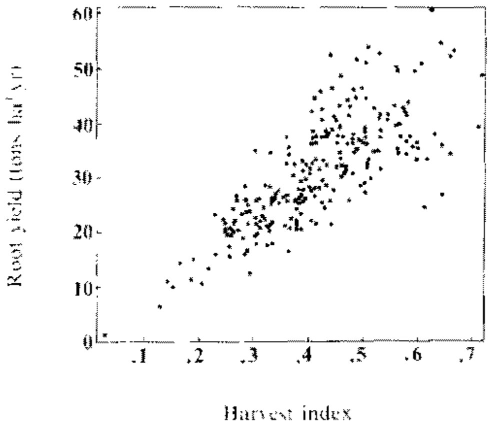


Figure 22. **Relationship between harvest index and root yield in population trial.**

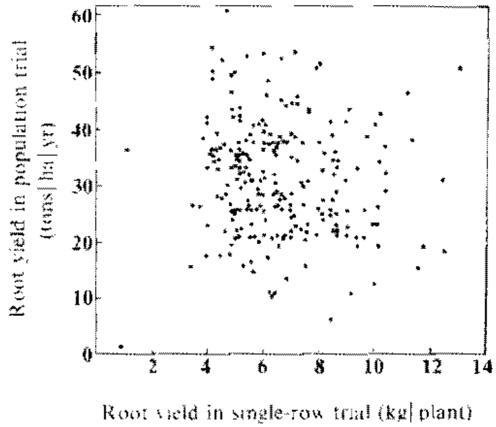


Figure 24. **Relationship between root yield data in single-row and population trials.**

The correlation between yield data in the single-row and population trials was surprisingly low (Fig. 24), probably because of intensive intergenotypic competition. The correlation between harvest index in the single-row and population trials (Fig. 25) was high. As a result, the harvest index in the single-row trial was highly correlated with the yield in the population trial (Fig. 26); this indicates that harvest index as a selection trait is even better than yield itself when genotypes are tested at the observational yield trial level.

A remarkable varietal variation was observed in initial vegetative vigor. Initial vigor was highly correlated with leaf and stem weight at harvest and negatively correlated with harvest index; however, it was not significantly related to yield (Table 25). Under CIAT conditions, which are regarded as nearly ideal for obtaining high yields, the yield of more than 50 tons/ha was obtained with a rather wide range of initial vigor. However, when considering less favorable conditions for cassava growth that are more representative of vast cassava-growing areas in the tropics, the

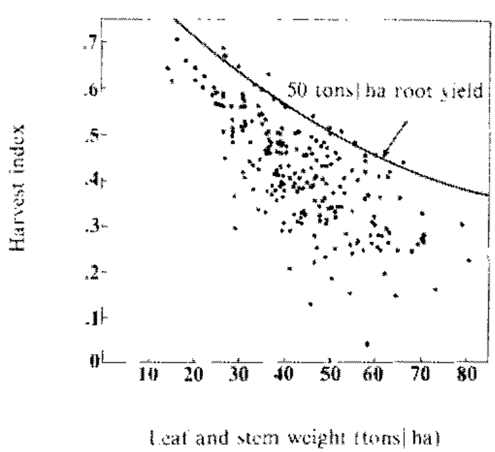


Figure 23. **Relationship between top growth and harvest index in population trial.**

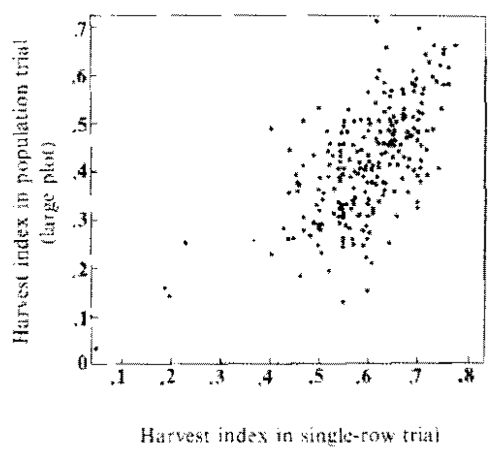


Figure 25. **Relationship between harvest indexes in single-row and population trials.**

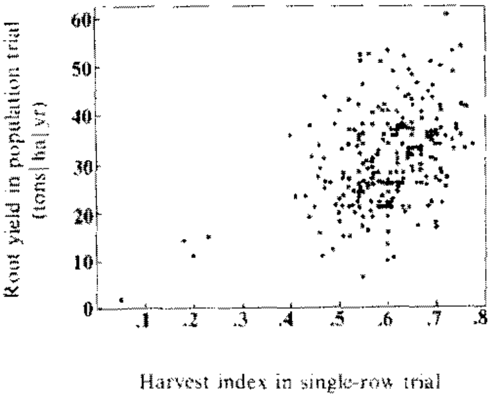


Figure 26. **Relationship between harvest index in single-row trial and root yield in population trial.**

Table 26. **Effect of lodging on yield and harvest index.**

Lodging*	Number of plots	Root yield (tons | ha)	Harvest index
0	177	37.6	.499
1	88	31.2	.434
2	55	28.8	.378
3	52	30.0	.357
4	43	28.0	.317
5	39	18.7	.238

* Evaluated at ten months after planting. 0= no lodging. 5= complete lodging

types with high initial vigor may be given more importance than those with a high harvest index and low vigor.

Yields decreased parallel to the degree of lodging index (Table 26). Like almost any other crop, lodging is fatal to cassava yields and should be avoided at all cost.

Trials outside CIAT

A number of selected cultivars and hybrid lines were planted in Carimagua (Llanos Orientales), Caribia (Northern Coast) and Popayán (mountain zone). In Caribia, the center of cassava production in Colombia, M Mexico 59, M Colombia 638, M Colombia 1468 (CMC-40, ICA selection) and M Colombia 1684 were among 15 best yielders in 300 lines evaluated. This suggests that there are high-yield selections adapted at least to the altitude range from 0 m in Caribia to 1,000 m at CIAT.

Selection

From a total of approximately 8,000 F_1 hybrid plants, about 1,200 were selected on the basis of harvest index and root yield (Table 27). These materials were forwarded to the observational yield trials, and some are also being observed in Carimagua and Caribia.

The high correlation of yield data—i.e., harvest index, root yield and total plant weight—between the seedling and the stake-planted generations has been

Table 25. **Effect of initial vigor on yield characters.**

Initial vigor*	Number of cultivars	Root yield (tons | ha)	Harvest index	Total plant wt (tons | ha)	Leaf and stem wt (tons | ha)
1	4	27.5	.523	53.2	25.7
2	49	32.0	.473	67.8	35.8
3	90	32.5	.439	74.1	41.6
4	80	29.0	.363	79.2	50.2
5	7	32.9	.338	96.0	63.2

* Evaluated at two months after planting: 1= very low vigor; 5= very high vigor

Table 27. Data on selection of F_1 hybrids.

Cross	Parents	Total no. of hybrids	No. hybrids selected	Average yield of all hybrids*	Average yield of selected hybrids (kg/plant)	Average harvest index of all hybrids	Average harvest index of selected hybrids
CM 305	M Col 113 x M Col 22	150	40	5.9	7.1	.69	.69
CM 307	M COL 22 x M Col 340	254	13	5.0	7.7	.58	.64
CM 309	M Col 22 x M Col 647	737	193	5.2	7.1	.62	.65
CM 310	M Col 22 x M Col 667	310	17	3.7	7.6	.55	.61
CM 314	M Col 22 x M Col 1292	74	12	5.2	8.2	.66	.67
CM 321	M Col 22 x M Ven 270	423	69	4.4	7.0	.64	.69
CM 323	M Col 22 x M Mex 59	680	140	4.6	8.1	.62	.64
CM 334	M Mex 55 x M Col 647	35	10	5.2	10.3	.61	.66
CM 342	M Col 22 x M Col 1468	178	17	-	7.6	-	.64
CM 345	M Col 113 x M Mex 59	100	8	-	10.6	-	.59
CM 356	M Col 647 x M Mex 55	35	11	-	8.2	-	.61

* Planted at 1 x 2 m spacing and harvested ten months after transplanting

confirmed. This high correlation or high efficiency of selection with seedling plants exists as early as seven months after transplanting them (Fig. 27). Even if the seedling plants are kept until 15 months, these correlations do not improve (Fig. 28).

Since only a few planting stakes can be obtained with seedling plants less than seven months old, it is unlikely that the breeder will practice selection with seedling plants before the plants reach this age. The results do, however, suggest that very efficient seedling selection is guaranteed whenever the planting stakes can be cut from the seedling plants as long as they are widely spaced to avoid intergenetypic competition in a reasonably uniform field.

Hybridization

Results of the yield trial were significant, not only because quite a few cultivars yielded well but also because many of these high-yielding cultivars had been actively utilized in our hybridization program for two years. Of 20 of the best yielders, eight had been used quite actively in hybridization and several hundred selections from these hybridizations are already being evaluated in observational trials in and outside CIAT. There is a good chance of perfecting such cultivars as M Mexico 59 and M Colombia 1468, which easily outyield local cultivars in and outside CIAT, by selecting from the hybrid lines which exist in the order of tens of thousands if the problem is high yield potential and wide adaptability. Thus, the emphasis in our hybridization program has shifted to disease resistance and some other characteristics such as long root durability after harvest or high starch content.

Additions to the hybridization program are given in Table 28. M Colombia 638 is of particular interest because it seems to combine yielding ability with high resistance to cassava bacterial blight. As a result of one initial cycle of hybridization and selection, several hybrid lines with a high harvest index and resistance to CBB

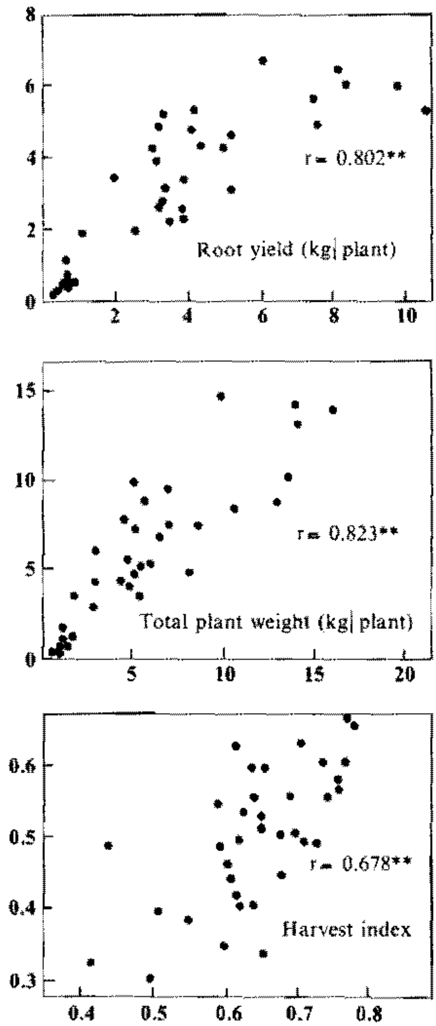


Figure 27. **Correlation of data for seedling plants (horizontal axis) harvested at seven months compared to that of the stake-planted plants (vertical axis) of the same genotype.**

were identified; thus hybrids such as CM 309-41, CM 309-56 and CM 309-206 are actively used in hybridization.

Using the data with seedling plants, a highly significant regression of parental average on F_1 hybrids average in harvest index had already been shown. The same type of analysis was made with both the parents and the F_1 hybrids, using the data

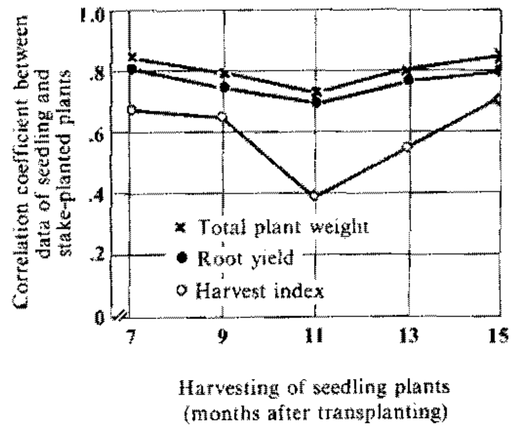


Figure 28. **Harvesting time of seedling plants and the efficiency of selection.**

of stake-planted plants. By nature, this type of analysis is more accurate and practical than the former. A highly significant regression was obtained not only in harvest index but also total plant weight. The regression in root yield itself was not as high as in harvest index and total plant weight; nevertheless, it was also significant (Figs. 29, 30 and 31). This encourages breeders to believe that almost any character with practical meaning can be inherited, thereby justifying the fact that a large part of our hybridizations are by controlled pollinizations.

Disease resistance

The pathology group has shown that there are at least five major diseases to be taken into account when breeding for resistance. Highly resistant genotypes for cassava bacterial blight and Cercospora leaf spots were identified (See pathology section and Table 28). The data suggest that this resistance can be readily incorporated into agronomically desirable types. Highly resistant genotypes for Phoma leaf spot, a disease prevailing in temperate climates, were also identified; but it is not yet known whether this is easily incorporated into high-yielding types at low temperatures. Several moderately resistant types for superelongation disease

Table 28. **Characteristics of cultivars or hybrid lines frequently used in hybridization programs.**

								Resistance to			
	Harvest index	Vigor	Leaf area retention	Early maturity	Easy to harvest	Root durability	Starch content	CBB	Super-elongation disease	***Cercospora*** spp.	***Phoma*** sp.
Llanera	+							+	+		
M Col 22	++			++	++		++				
M Col 113			++								
M Col 197								++			
M Col 340											++
M Col 638	+							++	+		
M Col 647								++			
M Col 655A		++					+				
M Col 667								++			
M Col 1292		++					+				
M Col 1468	+										
M Col 1684	++										
M Mex 55	+										
M Mex 59	+	++								++	
M Ven 270		+					++				
M Pan 114	++										
CM 309-41	++							++			
CM 309-56	++							++			
CM 309-206	++							++			
CM 321-15	++					+					
CM 327-12	++					+					

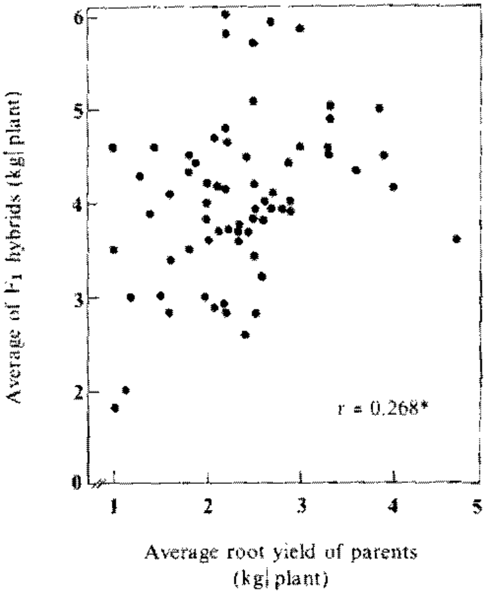


Figure 29. **Relationship between average root yields of parents and the respective F_1 hybrids.**

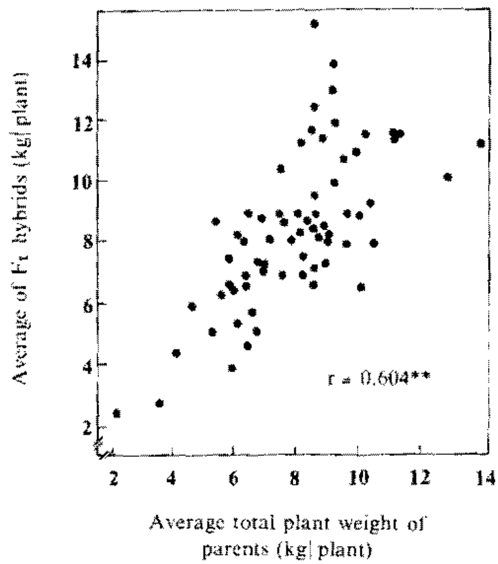


Figure 31. **Relationship between average total plant weight of parents and the respective F_1 hybrids.**

were identified; however, it is not known how effective the resistance of these types will be and how long the resistance will last. Needless to say, all resistant types are actively hybridized with high-yielding types and among themselves.

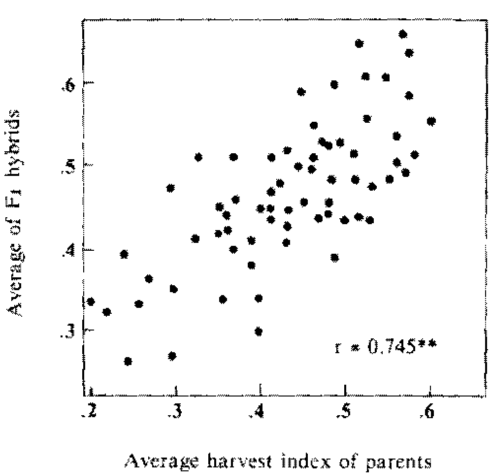


Figure 30. **Relationship between average harvest indexes of parents and the respective F_1 hybrids.**

The observational yield trial at Caribia was infected by CBB, and a clear varietal difference in the reaction to this disease was observed. The observational yield trial at CIAT was free from CBB. The varietal yields of the two locations were compared at each level of the CBB attack in Caribia (Table 29). The yield difference of about 3.5 kg between CIAT and Caribia with resistant and tolerant cultivars (CBB, grades 1 and 2) represents the general yield difference between the two trials. With highly susceptible cultivars (grade 5), the yield difference was 6.4 kg. Results indicate that even under a moderate level of CBB attack, resistant cultivars are highly desirable, moderately susceptible cultivars give a significant yield reduction, and susceptible cultivars will give disastrous results. Thus, the first cultivar to be recommended should possess at least a moderate level of CBB resistance, if not a high one, in addition to high yielding ability with wide adaptability.

The observational yield trial at Carimagua was heavily infected by CBB and superelongation disease. Practically

Table 29. **Comparison of root yields at Caribia and CIAT at different levels of varietal CBB reaction.**

CBB attack in Caribia*	Number of cultivars	Yield at Caribia (kg/plant)**	Yield at CIAT (kg/plant)***	Difference
1	6	2.23	5.85	3.62
2	52	2.18	6.05	3.27
3	76	2.47	6.71	4.24
4	37	1.87	6.52	4.65
5	25	1.09	7.54	6.45

* 1 = no symptoms; 5 = heavy CBB infection

** Planted at 1 x 1 m spacing and harvested at nine months

*** Planted at 1 x 1.4 m spacing and harvested at ten months

all the plants were wiped out, and only M Colombia 638 gave roots of edible size. The results simply indicate that under extraordinarily heavy attacks of CBB and superelongation, an extremely high level of resistance to these diseases is required; and in the long run, this level of resistance should be incorporated into high-yielding types.

Starch content and root durability

Since a significant portion of cassava production is expected to go for animal feeding and starch extraction in the future, yield should be expressed in terms of root dry matter or starch yield, as well as root fresh yield. Varietal variation in root dry matter content was great, even among the 20 cultivars selected on the basis of fresh weight yield (Table 24). This suggests that the yield ceiling level has not been reached as regards dry matter yield per area per time.

The correlations between root specific gravity and root dry matter content and between root specific gravity and root starch content were very high. Conversion diagrams from specific gravity to dry matter content and starch content in the peeled root are presented (Figs. 32 and 33). The proportion of root peel fresh weight to whole root fresh weight and the starch content of root peel varies according to cultivars. Assuming 20 percent as a rough average for both, conversion diagrams from root specific gravity to starch content of (1) the whole root and (2) of the peeled root over the whole root are also presented (Fig. 34).

One of the biggest shortcomings of cassava is its extremely rapid root decay after harvest. Some genetic difference in

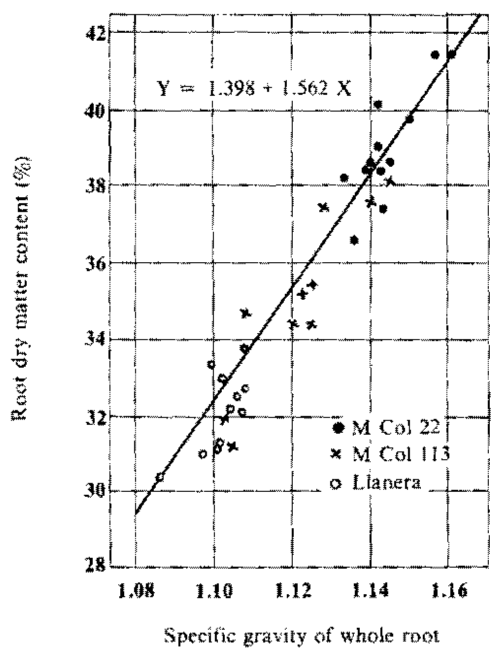


Figure 32. **Regression of root specific gravity on dry matter content (roots harvested at 11 months).**

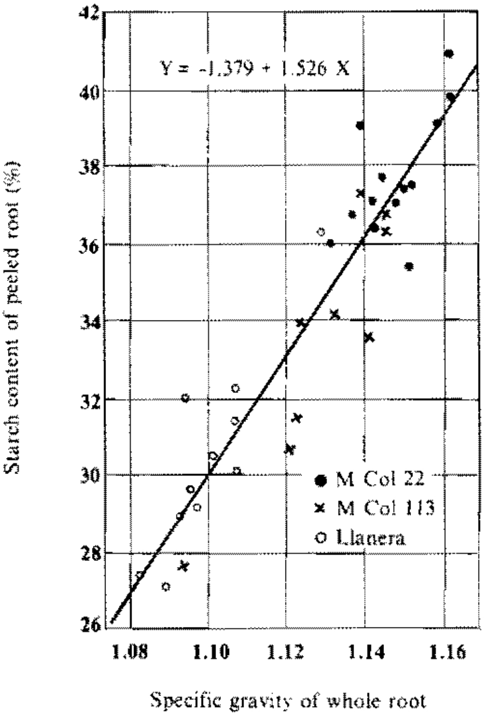


Figure 33. **Regression of root specific gravity on starch content of peeled root (roots harvested at 11 months).**

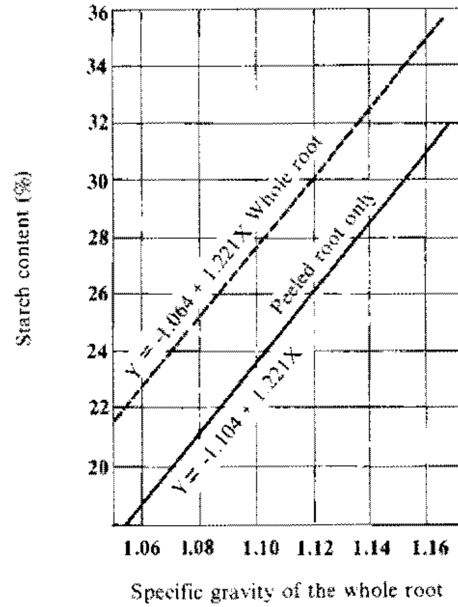


Figure 34. **Regression of the specific gravity of the whole root on the starch content of the whole root and the proportion of starch in the peeled root as compared to the whole fresh root.**

root durability after harvest has been observed. Two methods representing two extremes of conditions to which cassava is subjected before marketing or processing, were devised to evaluate this characteristic. In the field evaluation, 15 randomly selected roots were left in the field for two weeks and then evaluated by chopping them. In the laboratory evaluation, 15 randomly selected roots were kept inside a room at a normal temperature of about 24ºC. After one week, all the roots were chopped and the degree of streaking on the root was evaluated. In this way, the fitness of stored roots for human consumption, animal feeds and starch extraction can be more objectively evaluated.

In the great majority of cultivars, roots simply decayed after three or four days whether they were kept in the field or in the laboratory. However, roots of some cultivars of hybrid lines were occasionally found edible even at two weeks after harvest. There is a large margin of error associated with the two methods. The correlation between the field and the laboratory evaluations was not high but acceptably useful. After eliminating all the cultivars or lines which showed unacceptable decay in any evaluation, there were still a certain number of cultivars and hybrid lines that survived all evaluations. There seems to be no association between root durability and yielding ability. The selected materials are being utilized in the hybridization program, and the genetic behavior of this character is being studied.

AGRONOMY

During 1975, 90 percent of the work was done outside CIAT, principally in collaboration with farmers and national agencies such as the Instituto Colombiano Agropecuario (ICA), the Federación

Nacional de Cafeteros and regional departments (secretarías) of agriculture. Although work was done on cultural practices, major emphasis was placed on regional trials.

Regional trials

Cassava shows great variability. To select a variety based on marked differences in character is easy, but to select compatible genetic characteristics that react favorably to several environments and produce optimal yields under intensive growing conditions is difficult. For this reason, yield evaluations in the field must still be made.

From the 14 trials planted in different regions of Colombia (Table 30), nine have been harvested. Five trials were planted in cooperation with ICA, three with the Federación Nacional de Cafeteros and one with the Department of Agriculture in Santander del Sur.

Multiplying promising varieties

The rapid propagation method (see section on propagation) was used to multiply 22 promising varieties in sufficient number to plant 21 regional trials. Asexual "seeds" (cuttings) from these varieties were distributed to the Philippines, Australia, Guyana, Ecuador, Venezuela and Mexico.

Objectives

As Colombia is a relatively small country that offers a wide gamut of climatic and edaphic conditions, it is ideal for evaluating promising varieties for their productivity and adaptation. The trials have two main objectives: (1) to measure the components that have the most influence on yield under different environmental conditions in order to extrapolate results to other regions, both within and outside Colombia; and (2) to replace local varieties with improved varieties that not only give higher yields but that are also disease and insect resistant, tolerate poor soils, are easy to harvest and are of superior quality for human consumption and industrial uses.

Technology and methodology used

The same technology was applied to all trials; the use of modern, expensive inputs was avoided. Planting was done on ridges when the soil was heavy and on the flat when soils were very permeable or sandy. A randomized block design with four replications was used. The soil was analyzed in each replication, and a pluviometer was installed at each site. The regional variety or varieties were used as controls. The harvested area was always surrounded by at least two border rows, either of the same variety or at least one of the harvested variety and others of the neighboring line. Stakes (20 cm) were planted vertically at a population density of 10,000 plants/ha.

Cuttings were dipped in a 5 percent arazan solution for five minutes to prevent the rotting of cuttings and the death of seedlings at the time of germination. Toxaphene-DDT 40-20 was applied at a rate of 1 gal/ha to control soil insects that are not specific to cassava but that could hinder normal germination and good plant development during the initial stage.

A mixture of preemergence herbicides (diuron and alachlor) was applied immediately after planting in variable dosages according to soil texture (Table 31). Diuron was used to control broadleaf weeds and alachlor, grasses. Weedings were carried out in accordance with the rainfall pattern of each region. Carimagua was the only site where fertilizers were used. Insects attacking the aerial portion of the plant and diseases were not controlled in order to determine the true potential of the promising varieties under the conditions found on the majority of cassava-growing farms.

Table 30. **Sites where the first group of promising ICA/CIAT varieties were planted and the main soil and climatic characteristics.**

	Altitude (m)	Mean Temperature (°C)	Rainfall (mm/yr)	RH (%)	Soil type	pH	Organic matter (%)	P (Bray II) (ppm)	K (meq/100 g)
Media Luna	10	27.2	1,486	77.6	Sandy	6.28 (N)	0.7 (L)	8.2 (L)	0.6 (L)
Carimagua	200	26.1	2,031	75.2	Clay loam	4.7 (VA)	0.6 (L)	1.0 (L)	0.1 (L)
Nataima	430	27.8	1,479	69.0	Sandy	6.2 (N)	1.3 (M)	24.7 (M)	0.2 (M)
Villavicencio	450	26.3	4,306	75.6	Clay loam	4.3 (VA)	2.8 (M)	4.1 (L)	0.1 (L)
Florencia	450	25.0	3,475	85.0	Sandy loam	5.5 (A)	2.3 (M)	18.9 (M)	0.2 (M)
El Nus	847	23.7	1,875	63.6	Loam	5.0 (A)	3.8 (M)	4.3 (L)	0.1 (L)
Rionegro	480	26.6	1,594	79.5	Silt loam	5.1 (A)	1.5 (M)	3.9 (L)	0.7 (M)
CIAT	1,000	23.5	1,055	74.5	Clay	6.4 (N)	3.6 (M)	25.0 (M)	0.4 (H)
Caicedonia	1,100	22.2	1,900	80.7	Silt loam	5.5 (A)	5.3 (H)	70.0 (H)	0.7 (H)
La Zapata	1,100	22.7	1,219	75.2	Clay loam	5.2 (A)	6.8 (H)	5.0 (L)	0.1 (L)
Darién	1,450	19.5	1,500	83.0	Silt loam	5.1 (A)	15.0 (H)	1.9 (L)	0.1 (L)
Pereira	1,480	19.0	2,000	80.0	Silty clay	5.1 (A)	8.3 (H)	8.3 (L)	0.1 (L)
Popayán	1,760	18.0	2,500	85.0	Clay loam	5.0 (A)	7.6 (H)	2.4 (L)	0.4 (H)
La Unión	1,800	17.0	1,844	70.0	Clay loam	5.7 (A)	12.3 (H)	6.1 (L)	0.4 (H)

N = Neutral, A = Acid, VA = Very acid, L = Low, M = Medium, H = High

Table 31. **Preemergence herbicide mixture recommended according to soil texture.**

Clay	2.0 kg diuron	+	3.0 liters alachlor
Silt loam	1.5 kg diuron	+	2.5 liters alachlor
Clay loam	1.5 kg diuron	+	2.0 liters alachlor
Sandy	1.0 kg diuron	+	2.0 liters alachlor

The recommendation of varieties in each country corresponds to the respective national agency; however, CIAT and the local agency conduct a field day at harvest time to inform farmers about the results and let them select the varieties that best suit their needs. They then receive seed to make their own evaluations. A register is kept of the farmers and the places where the varieties are to be planted. So far, the criteria for selecting varieties for the second or third year of trial have been flexible, depending mainly upon the zone and the behavior of the control. At Rionegro, for example, those varieties that outyielded the best regional one by 50 percent were selected. At Media Luna, the percentage was 25; at Caicedona, 20; and at CIAT, 34. Rejected varieties are replaced yearly with new ones being tested for the first time. This is a continuous, dynamic process in which excellence is the criterion for selection.

Each site was visited eight times to check the development of the trial, collect data and order the necessary weedings.

Results

As regards diseases, there was a severe outbreak of bacteriosis at Carimagua and a moderate outbreak at Media Luna, La Zapata and Nataima. Although clean material was taken to all sites, it is difficult to prevent contamination where the disease already exists.

Superelongation disease was also found at Carimagua. Phoma leaf spot decimated the majority of varieties at Darién, which explains the low yields obtained at this site (Table 32). All three types of Cercospora were found at all sites, but *C. vicosae* was

Table 32. **Principal characteristics of the promising cassava varieties planted at the 1974-1975 regional trials.**

			Resistance to					
	Plant height (m)	Easy to harvest	Thrips	Bacteriosis	Superelongation disease	**Phoma** sp.	*C. henningsii*	*C. vicosae*
M Col 22	1.50*	Easy	R**	S	R	S	R	T
M Col 113	1.98	Difficult	R	S	S	S	T	S
M Col 673	2.00	Moderate	T	S	-	S	R	S
M Mex 23	2.23	Difficult	R	S	-	S	T	S
M Mex 55	1.70	Easy	T	S	-	S	S	S
M Mex 59	1.85	Moderate	S	S	-	S	R	R
CMC-9 (M Col 1438)	2.00	Moderate	S	T	R	S	S	S
CMC-40 (M Col 1468)	2.35	Easy	S	S	-	S	R	T
CMC-76 (M Col 1505)	2.25	Easy	S	-***	-	S	R	T
CMC-84 (M Col 1513)	2.35	Easy	T	S	-	S	R	T

* Plant height for ICA/CIAT promising varieties is given for conditions at CIAT.
** R = resistant, S = susceptible, T = tolerant
*** Not evaluated

Table 33. **Fresh weight (tons|ha) and dry matter yield (kg|ha|ha) of cassava varieties at nine sites in Colombia, harvested at 11 months.**

	Rio Negro		Media Luna		Darien	La Zapata		Caicedonia		Nataima		El Nus		CIAT		Carimagua
	F.W.	D.M.	F.W.	D.M.	F.W.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W.
Trial varieties																
M Mex 59	34.7*	20.5	28.7*	22.0	2.4	29.2*	30.5	40.0*	49.0	43.6*	44.0	14.6*	16.9	33.1	35.6	-
CMC-40**	28.6*	21.6	29.3*	25.8	5.3*	18.3	17.6	32.0	35.7	45.3*	40.9	15.0*	17.3	42.2*	42.3	-
CMC-84**	26.0*	26.1	17.8*	15.6	4.0	26.6	29.3	27.1	31.9	33.6*	36.3	26.0*	33.2	40.3*	44.7	7.3*
CMC-76**	25.8*	25.9	18.2	19.5	1.4	17.7	17.5	32.4	35.3	26.7	29.8	20.0*	24.9	36.0*	39.2	-
M Col 113	22.9	16.4	13.4	10.8	2.5	38.9*	43.9	31.2	35.2	23.8	18.5	15.6*	18.0	26.8*	29.0	1.6
CMC-9**	20.2	21.4	8.0	7.8	0.1	20.7	21.2	24.4	28.8	17.7	16.7	7.8*	9.0	31.7	31.9	-
M Col 22	19.8	17.4	22.3*	24.0	0.0	20.0	22.2	27.7	35.8	34.5*	34.4	13.6*	18.2	39.4*	46.2	4.1
M Mex 23	14.5	12.0	11.8	12.6	1.0	35.6*	41.5	39.6*	43.6	24.5	24.8	4.5	5.6	34.3*	36.3	5.8*
M Col 673	25.1*	19.0	10.5	10.8	-	32.8*	38.2	-	-	-	-	-	-	25.0	28.8	4.7
M Mex 55	12.8	8.1	18.8	20.1	-	-	-	-	-	-	-	-	-	28.8	32.4	-
Regional varieties																
Colombiana	15.7	12.0														
Torrana Negrita	11.9	8.4														

* Varieties approved for a second-year trial

** Promising ICA varieties

Table 33. (Continuation)

	Rio Negro		Media Luna		Darien	La Zapata		Caicedonia		Nataima		El Nus		CIAT		Carimagua
	F.W.	D.M.	F.W	D.M.	F.W.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W.	D.M.	F.W
Blanca Mona			17.7	21.2												
Secundina			11.0	12.8												
Nativa					6.3											
Tolima						28.1	32.3							19.5	20.0	
Chiroza Gallinaza								32.3	33.0							
Varasanta										22.3	21.6					
Aguabajo										18.3	19.3					
Palmireña												7.7	9.6			
M Col 113														26.8	29.0	
Chiroza Acacias																3.8
Average including regional varieties	21.5	17.4	17.3	16.9	2.5	26.7	29.4	31.8	41.9	29.0	28.6	13.9	17.0	32.5	35.1	4.3
Average without regional varieties	23.0	18.7	17.9	16.8	2.0	26.6	29.1	31.8	43.0	31.2	30.7	14.7	17.9	33.0	35.7	4.4
Best regional average	15.7	12.0	17.7	21.2	6.3	28.1	32.3	32.3	33.0	22.3	21.6	7.7	9.6	26.8	29.0	3.8

most frequent at Rionegro and Media Luna.

As for insects, La Zapata was severely attacked by thrips, which were also reported at Caicedonia, although in smaller numbers.

In relation to dry matter, there was a great deal of variation, as can be seen in Table 33. Taking into account only the four most outstanding varieties, it can be seen that as fertility increases so does dry matter content (Table 34). It was interesting to find that in areas of low soil fertility such as Media Luna, there were varieties so efficient as CMC-84 (13 percent more dry matter than M Mexico 59). These data are especially important for the starch and pelletizing industries and should be taken into account in the final evaluation of varieties.

The principal characteristics of the outstanding promising varieties are given in Table 32. Data on fresh weight and dry matter content are given in Table 33. The general average yield for the best regional varieties at the nine sites in Colombia was 17.8 tons|ha. In comparison to the estimated national average (8 tons|ha), there is a difference of 9.8 tons|ha. Results from the agro-economic survey carried out on 300 Colombian cassava farms suggest that this difference is even greater. Therefore, the national average was surpassed 122 percent through such simple agronomic practices as planting clean, treated seed; incorporating insecticides in the soil at planting; and keeping the crop weed free. The best CIAT|ICA line in each region gave an average yield of about 30 tons|ha, suggesting the enormous yield potential through using not only improved, low-input technology but also improved varieties.

Cultural practices

Planting systems

A trial to determine the effect of planting system (on ridges or on the flat) on yield was carried out in collaboration with cassava growers from the region of Caicedonia, where the majority of farmers plant cassava on ridges, even on the slopes. The farmers do this to reduce root rot, which occurs when the soil is very moist. Since some farmers had found that this system produced fewer roots in comparison to planting on the flat, a trial was designed to determine whether this was true. The local variety Chiroza was used with a fixed population of 10,000 plants|ha. Weed control was practiced; it was not necessary to apply either fertilizers or insecticides.

Table 34. **Variation in dry matter content (percentage) of four outstanding varieties, according to site and soil fertility.**

	M Mex 59	CMC-40 (M Col 1468)	CMC-84 (M Col 1513)	M Col 22
Media Luna				
Low NPK levels	19.5	24.9	33.0	29.0
Nataima				
Medium NPK levels	33.0	29.8	35.7	32.9
Caicedonia				
High NPK levels	40.4	36.8	38.9	42.7
La Zapata				
High N, low P and K levels	34.5	31.8	36.3	36.6

Table 35: **Yields, harvest index, percentage of commercial roots and weight of commercial roots for the different plant populations of the variety Chiroza, taken at 340 days.**

Plants/ha	Fresh weight yield total roots (tons/ha)	Harvest index*	Commercial roots (%)	Fresh weight commercial roots (tons/ha)
4,000	20.5	0.50	100	20.5
7,000	30.9	0.51	100	30.9
11,000	31.4	0.49	91	28.5
14,000	27.8	0.46	91	25.2
17,000	35.7	0.49	84	29.9

* Data taken from 20 plants selected at random

Harvesting was done at 341 days. Average yield on ridges was 28.4 tons/ha whereas on the flat it was 32.2 tons. Nevertheless, planting cassava on the flat is not advisable in all cases; soil texture must be taken into account. On sandy soil, planting should be done on the flat; and on heavy soils, ridges should be used to avoid

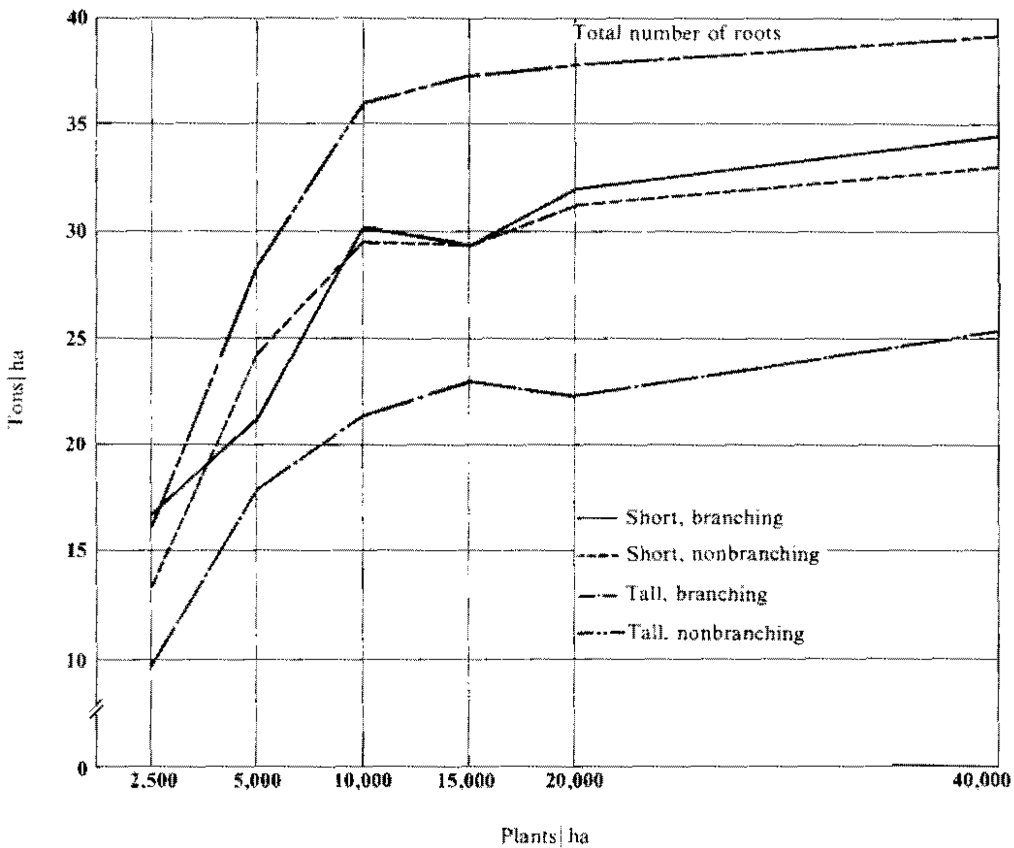


Figure 35. **Effect of plant population on fresh weight yield of total number of roots from four different plant types.**

the danger of rotting. Although yields are lower when cassava is planted on ridges, harvesting is easier. This is not evident in the case of Caicedonia because of the special soil conditions of this region. When planting on ridges, an average of 1,070 kg|man was harvested during a seven-hour day, as compared to 896 kg for the other system. In a similar trial at CIAT, it was found that planting on ridges required 12.6 tractor hrs|ha, whereas planting on the flat required only 8.4; therefore, the latter system is recommended on soils where rotting is not a serious risk.

Optimal plant populations on ridges

In order to determine the optimal plant population for the medium-height variety Chiroza, a trial was designed using low and high populations in contrast to the 7,000 plants|ha commonly used in the region. Populations ranging from 4,000 to 17,000 plants|ha were used.

Between the 7,000 and 17,000 plant population, there was a difference of 4,790 kg|ha, significant at 5 percent with the Duncan test (Table 35). Nevertheless, this higher weight is not profitable because as the population increases, the percentage of commercial roots decreases. Consequently, a population of 7,000 plants|ha is adequate for the conditions in Caicedonia, where the roots are destined for fresh consumption.

Plant type versus population

In cassava, optimal plant population depends upon the height of the variety. The fan-shaped trials have provided a great deal of information, but further study is needed in relation to the different plant types.

Two short and two tall varieties with different branching habits were selected. Populations ranging from 2,500 to 40,000

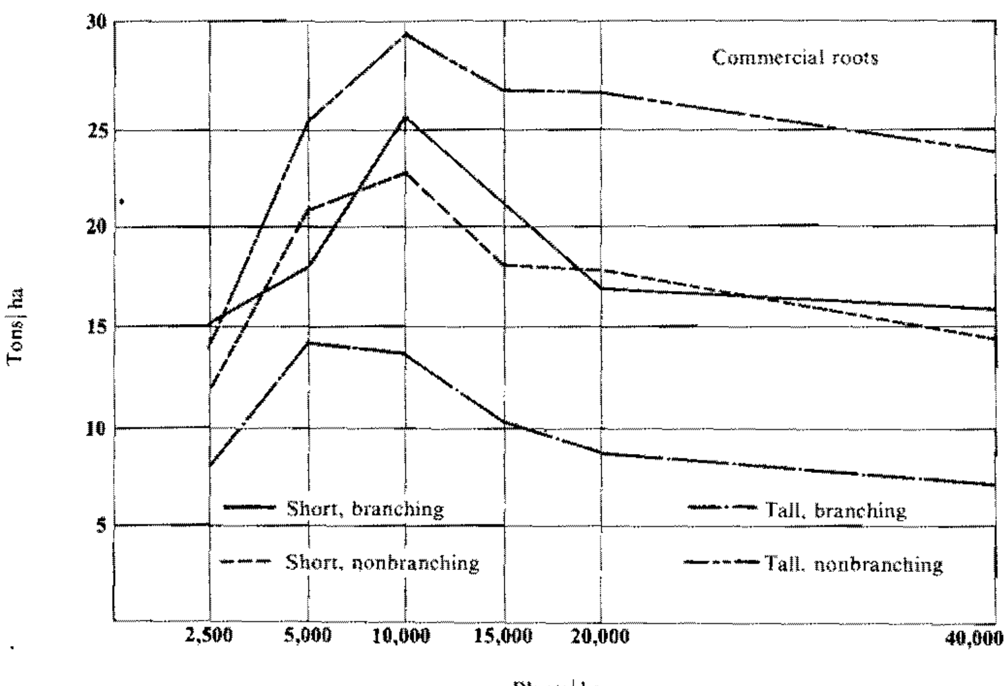


Figure 36. **Effect of plant population on fresh weight yield of commercial roots from four different plant types.**

plants/ha were used. The trial was harvested at 367 days.

Figure 35 shows the trend for total root production; that is, as plant population increases, cassava production increases. This would be the ideal case for countries like Brazil and Thailand, where cassava is processed before being marketed. In the 1974 Annual Report (physiology section), population curves tended to descend at 40,000 plants/ha. In this case, however, these curves do not descend at this level because weeding was done only three times and weed populations were lower at higher densities, whereas in the physiology trials, weeding was done throughout the trial.

In areas where cassava is consumed fresh, it is necessary to find an optimal plant population for commercial root production (roots longer than 25 cm and more than 5 cm in diameter). For the short varieties and the tall, nonbranching varieties, this was 10,000 plants/ha; whereas for the tall, branching variety, the optimal population was 5,000 (Fig. 36). Each variety must be analyzed separately and cannot be compared, as each has a different genetic nature that determines its potential yield. It was also found that as plant populations increase, the number of weeds decreases. Branching varieties let less light through than nonbranching ones, thus exercising better weed control.

SOILS

At the beginning of 1974 various experiments were planted in the acid soils in Carimagua (Llanos Orientales) to study the response of cassava to fertilization and to determine the best agronomic practices for this type of soil. A severe attack of CBB eliminated several experiments and affected plant growth to a lesser extent in others. In October, 1974 several experiments were repeated in Tranquero, a few kilometers from Carimagua; and these remained free of CBB until harvest. The results of the Tranquero and the least affected Carimagua experiments are reported below. Except for the element(s) under study, the trials received a uniform fertilizer application of 1/2 ton lime/ha with a Ca/Mg ratio of 10:1;100 kg N/ha as urea; 100 kg P_2O_5/ha as triple superphosphate; 200 kg K_2O/ha, half as KCl and half as K_2SO_4; and 10 kg Zn/ha as zinc sulfate. The variety Llanera was used; all experiments were harvested at 9 1/2 or 10 months of age.

Fertilization

Potassium*

In last year's report it was indicated that K is the element that most limits cassava yields in many soils. The importance of K was again demonstrated in Carimagua and Tranquero, as well as in Jamundí, on an acid, but relatively high base-status soil (1974 Annual Report, Table 26, p.91). Studying the effect of three sources of K(KCl, KCl + S and K_2SO_4) in Tranquero, it was found that plants with the KCl treatments had severe yellowing of bottom leaves, indicative of S deficiency, at three months of age while those with KCl + S and K_2SO_4 applications remained green and showed better plant growth. Sulfur content of leaves, averaged over three levels of application, was 0.29, 0.30 and 0.37 percent for KCl, KCl + S and K_2SO_4 treatments, respectively. The S contents were above the 0.2-0.25 percent level, given as the criticals content for most crops; but cassava may have an unusually high S requirement as it was the only crop showing clear S-deficiency symptoms in Carimagua.

Figure 37 shows the yield response to K applications in Jamundí and Tranquero. In Jamundi there was a significant response to the application of 120 kg K_2O/ha, but no significant differences were observed between KCl and K_2SO_4. In

* This and the next two experiments were part of a PhD thesis project.

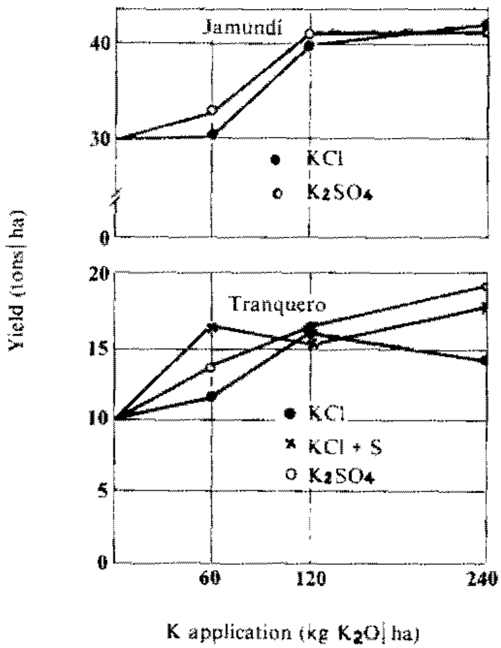


Figure 37. **Response of cassava to the application of several levels and sources of K in Jamundí and Tranquero; harvest at 10 and 9 1|2 months, respectively.**

Tranquero cassava showed a large response to applications of 120 kg K_2O|ha as KCl and 240 kg K_2O|ha as KCl + S or K_2SO_4. The negative response to high KCl applications could be due to a high leaf N|S ratio of 17.2, as compared to 15.1 and 14.8 for comparable KCl + S and K_2SO_4 treatments. In other crops N|S ratios over 15 are generally indicative of S deficiency. Also, the high chloride application reduced the uptake of sulfate by anion competition, intensifying the S deficiency even more. A direct toxicity of the chloride anion (as observed in potatoes) is also a possible explanation since the high KCl treatment had a chloride content of 0.11 percent in the roots as compared to 0.09 percent for KCl + S and 0.06 percent for K_2SO_4 treatments. The lack of significant differences between K sources in Jamundi was mainly due to a lack of S response, which is due to the higher S status of these volcanic-ash influenced soils (7.8 ppm available sulfate S) compared with the Llanos soils (4.0-4.5 ppm). Yields in both trials were high, particularly for the Llanos, where a yield of just under 20 tons|ha was obtained.

NxK interaction

A complete factorial trial of three levels of N by three levels of K was established in Tranquero to study the interaction of these important plant nutrients. There was no response to N in the absence of K, but there was a strong positive response to K in the absence of N (Fig. 38). Cassava yields with no N and 300 K_2O were nearly double those obtained with no K and 200 N. In the presence of K there was a positive response to the application of 100 kg N|ha but a subsequent negative response to 200 kg. In the presence of N there was a strong positive response to the application of 150 kg K_2O|ha (as KCl), but there was no additional yield increase with 300 kg K_2O|ha.

It appears that K is the main element limiting yields, but once the K requirement is satisfied, plants respond to a moderate

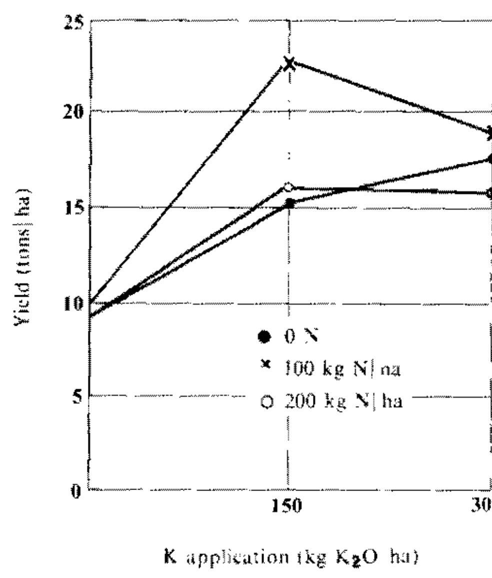


Figure 38. **Response of cassava to the application of several levels of K and N in Tranquero; harvest at 9 1|2 months.**

but not too high application of N. Information in literature indicating that high N applications increase leaf growth but decrease root growth was not corroborated in this experiment since leaf area as well as yield were depressed by high N applications in the presence of K. Root dry matter production was highly correlated (r = 0.97) with total dry matter production.

Although yields increased, K fertilization reduced the N content and thus the protein content of roots significantly; nevertheless, protein yield|ha was increased. The application of K reduced the Mg content of leaf blades and petioles, possibly inducing Mg deficiency, resulting in a yield reduction with the high K treatments.

Magnesium

Since cassava plants grown in Carimagua generally have a very low Mg content in the leaves, a trial was established to determine the significance of Mg fertilization, using two sources and five levels of Mg. Figure 39 shows that cassava yields can be increased by 10 tons|ha, applying 50 kg|ha of Mg as $MgSO_4$. Higher levels of $MgSO_4$ were detrimental, possibly due to induced Ca deficiency. Ca levels in petioles at 3 1|2 months decreased

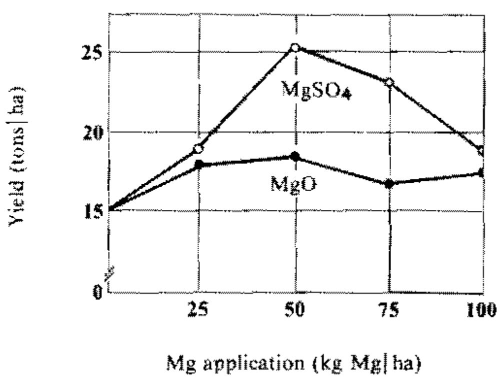


Figure 39. **Response of cassava to several levels of applied magnesium using two different Mg sources in Tranquero; harvest at 9 1|2 months.**

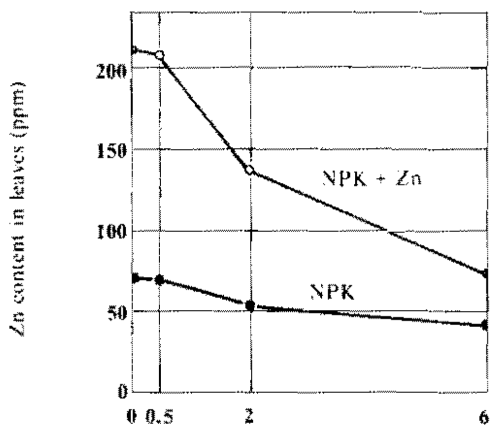
from 2.95 to 1.38 percent by high $MgSO_4$ applications. $MgSO_4$ was a more effective source than MgO because of its higher solubility and the presence of sulfate, which apparently is essential for optimum cassava production in these soils. The yield of 25 tons|ha, the highest obtained to date in the Llanos, is very promising in view of the fact that it was achieved after 9 1|2 months.

Lime x minor element interactions

During a previous evaluation it was observed that most cassava cultivars produced highest yields with applications of 1|2 or 2 tons|ha of lime but showed a strong negative response to higher lime applications. At the 6 tons|ha lime level, many varieties showed severe chlorosis and deformation of the growing points, which was attributed to a possible deficiency of minor elements. Although the problem was thought to be due mainly to Zn deficiency, an experiment was planted to study the interaction of lime with all minor elements except Fe, which is abundant in these soils. Within main plots with applications of 0, 1|2, 2 and 6 tons|ha of lime, subplots of minor elements (added individually and in complete combination) were established.

The effect of liming on pH and Al has been reported before (1973 Annual Report, p.211). The Chirosa variety used was intermediately affected by CBB; the attack was less severe at high levels of lime application. During the entire growth cycle, plants did not show deficiency symptoms, and there appeared to be a positive response to the application of 2 and 6 tons|ha of lime.

Foliar analyses at two months (Fig. 40) indicated that without Zn applications the Zn content decreased from 72 to 38 ppm with the application of 6 tons lime|ha. With applications of 20 kg Zn|ha, the Zn content decreased from 212 to 71 ppm. As compared to other varieties, Chirosa had a



Lime application (tons|ha)

Figure 40. **The effect of lime application on the zinc content of cassava leaves with and without soil-applied zinc.**

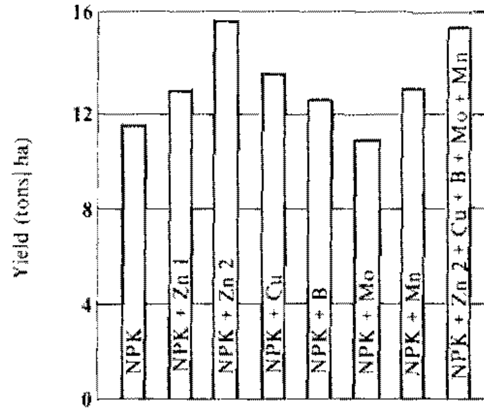
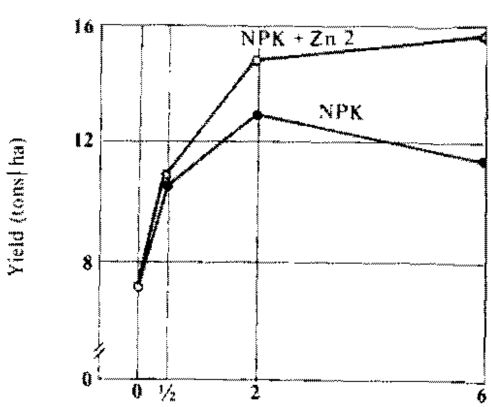


Figure 42. **Response of cassava to minor element applications at a lime level of 6 tons|ha in Carimagua; harvest at ten months.**

high Zn content; but without Zn applications its Zn content (38 ppm) was deficient although it was not low enough to produce deficiency symptoms, which generally appear below 20 ppm.

Figure 41 shows yield responses to lime applications with and without added Zn. It is clear that without Zn there is a negative response to the high lime application whereas with Zn the variety responded positively up to 6 tons lime|ha. This was the only minor element treatment without a yield reduction at the high lime level. Thus, the negative response of cassava to even moderate lime applications, not observed in any other crop studied, is due to induced Zn deficiency, to which cassava is apparently very susceptible. Figure 42 shows the yield response to all minor elements at the 6 tons|ha lime level, indicating the relative importance of Zn and, to a lesser extent, Cu and Mn. At the lower lime levels, the response to minor elements was smaller.



Lime application (tons|ha)

Figure 41. **Response of cassava to lime applications with and without soil-applied zinc in Carimagua; harvest at ten months.**

Nutrient content of plant parts

Table 36 shows the nutrient contents of leaf blades, petioles and roots at various times during the growth cycle. These nutrient contents correspond to near maximum yields in Carimagua; they give an indication of what may be considered to be "normal" nutrient contents although these may vary to some degree according to soils, varieties, climatic conditions and fertilization.

N, P and S contents were higher in the leaf blades than in the petioles while levels of K, Ca and Mg were much higher in the petioles. The petioles also showed a wider

Table 36 **Nutrient content of leaf blades and petioles in upper canopy and roots at various times during the growth cycle of cassava plants grown in Carimagua.**

	Leaf blades			Petioles			Roots
Months	2	4	6	2	4	6	10
N(%)	5.60	4.90	5.00	1.60	1.50	1.40	0.50
P(%)	0.27	0.25	0.25	0.13	0.12	0.12	0.05
K (%)	1.80	1.60	1.50	3.30	2.80	2.20	0.80
Ca (%)	0.60	0.60	0.70	1.20	1.50	1.50	0.04
Mg(%)	0.23	0.23	0.22	0.37	0.30	0.41	0.05
S (%)	—	0.37	0.34	—	0.14	0.13	0.05
Zn (ppm)	60	60		—	—		-

range for the latter group of elements and thus were more indicative of their nutrient status. Roots had a much lower nutrient content than either leaf blades or petioles. Most elemental contents decreased slightly during the growth cycle with the exception of Ca. Ca and Mg contents in Carimagua were low compared to those on many other soils and may have resulted in relatively high K contents.

Economics of fertilization

Without fertilizer application, cassava yields in the Llanos soils are extremely low (5-10 tons|ha). An adequate level of fertilization would be the application of 500 kg|ha of dolomitic lime; 100 kg N|ha as urea, band applied at seeding and 60 days; 100 kg P_2O_5|ha, band applied as basic slag at seeding; 200 kg K_2O, band applied as KCl; 25 kg|ha of elemental sulfur; and two foliar applications of Zn as 2 percent zinc sulfate.

At current fertilizer and transport costs, this amounts to about $4,500 in fertilizer and $1,500 in transport costs or a total of $6,000|ha. At current prices for cassava ($3|kg), the cost of fertilization can be paid for by producing an extra 2 tons of cassava|ha. With a potential yield increase (due to fertilization) of at least 15 to 20 tons|ha, the application of fertilizers seems economically justified.

Agronomic practices

Methods of fertilization

Comparing various methods of application of a complete fertilizer (broadcoast, band, circle and spot placed), it was found that broadcast applications were entirely ineffective in supplying nutrients to recently planted cassava, inducing excessive weed growth only. Among the localized placement methods, spot placement either in the stake hole or 15 cm from the stake, as well as the single- or double-interrupted band placement, looked most promising at the early growth stage. At two months of age, plants had heights of 31 to 36 cm with localized fertilization, as compared with 19 and 20 cm for the broadcast and check plots, respectively.

Time and method of seeding

In areas with a pronounced dry season, it is important to determine the best time of seeding in relation to the dry season. Monthly seedings were carried out between October and June, when the trial had to be terminated because of CBB. In

Table 37. **Yields of cassava planted in Carimagua at monthly intervals on ridges or on the flat; harvest at ten months.**

Month of planting	Yield (tons/ha)	
	Ridge	Flat
October	17.1	18.1
November	8.6**	17.5
December	12.0	12.3
January*	17.7	14.4
February*	18.9	20.2
March*	14.5	12.8
April	9.0	5.3
May	10.5	9.1
June	12.8	11.7

* One initial irrigation at seeding

** Low yield due to damage by pigs

Carimagua the dry season extends from December to March, with highest precipitation in June and July. The January, February and March seedings received one irrigation at time of seeding since soils moisture was entirely inadequate for germination.

Best yields were obtained by seeding one to three months before the onset of the dry season or during the dry season when irrigation was possible. Lowest yields were obtained seeding two to three months before the wettest months when high rainfall coincides with a period of high plant susceptibility to diseases and root formation coincides with a period of soil moisture stress. Seeding on ridges was better during the wet season plantings whereas seeding on the flat was better during the dry season plantings (Table 37).

WEED CONTROL

In the agro-economic survey conducted last year, bracken fern (*Pteridium aquilinum*) was found to be an important weed in several cassava-growing regions. None of the herbicides recommended for cassava give effective control of this rhizomatous weed. As a postemergence herbicide, asulam is reported to control bracken fern; a trial was conducted to determine its selectivity in two cassava varieties. Applications of 2 and 4 kg/ha were made over the top of 45-day-old cassava or to the lower half of the plants.

The over-the-top application caused severe initial injury to both varieties at the high rate but only to M Colombia 137 at the low rate (Table 38). There was partial recovery from the initial effects when the entire plant was treated. Spraying the

Table 38. **Tolerance of two cassava varieties to postemergence applications of asulam.**

Asulam rate	Part of plant treated	Injury rating*			
		M Col 137		M Pan 64	
		30 DAA**	60 DAA	30 DAA	60 DAA
2	Lower half	1.0	1.2	0.8	1.3
2	Entire	5.2	3.5	3.3	3.0
4	Lower half	2.3	1.6	1.3	1.0
4	Entire	7.3	6.6	7.0	6.6
Check	–	0	0	0	0

* Visual scale where 0 = no injury; 10 = crop killed

** DAA = days after application

Table 39. **Summary of three years' research on selective herbicides in cassava.**[1]

Highly selective[2]	Marginally selective[3]	Nonselective[4]
alachlor	butylate	ametryn
benthiocarb	chlorbromuron	amitrole (post)[5]
bifenox	CIPC + naptalam	atrazine
butachlor	diuron	bentazon (post)
chloramben	fluometuron	bromacil
cyanazine	linuron	dalapon (post)
dinitramine	methabenzithiazuron	DNBP (post)
DNBP	metribuzin	DPX-1108 (post)
DPX-6774	oxadiazon	DPX-3674
fluorodifen		EPTC
FMC-25213		glyphosate (post)
H-22234		karbutilate
IT-5914		MSMA (post)
methazole		paraquat (post)
napropamide		prometryn
nitralin		tebuthiuron
nitrofen		terbutryn
norea		2, 4-D (post)
perfluidone		vernolate
pronamide		
prinachlor		
S-2846		
trifluralin		

1 All herbicides applied as preplant incorporated or preemergence treatments unless otherwise noted

2 No injury to cassava even at four times the normal rate

3 No injury at the normal rate but serious injury at double and quadruple rates

4 Serious injury even at the recommended rates

5 Postemergence treatments were applied over the top of young cassava plants

lower half caused only slight injury at either rate. Therefore, where bracken fern is a serious problem, directed applications of asulam should be tested as a possible control measure.

As a conclusion to the intensive herbicide screening activities in cassava which began in 1972, a large selectivity trial was carried out. The recommended rate and four times this rate were applied preemergence in a medium-textured soil to the variety M Colombia 113. Injury observations were taken during the first three months, and foliage and root yields were taken ten months after planting. Based on these and all previous trials, a summary of the relative selectivity of herbicides in cassava is presented in Table 39.

Twenty-three compounds were found to be highly selective. These products applied singly or in combination would provide effective treatments for nearly all weed species commonly found in cassava-growing regions. In addition, the marginally selective compounds could also be recommended under most conditions if applied correctly.

PUBLICATIONS *

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COCK, J.H., WHOLEY, D.W. and **GUTIERREZ DE LAS CASAS, O.** The spacing response of cassava. (In press).

COCK, J.H. Some physiological aspects of yield in cassava. (In press).

COCK, J.H. Characteristics of high yielding cassava varieties. (In press).

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LOZANO, J.C. y **van SCHOONHOVEN, A.** El peligro de diseminar enfermedades y pestes por la introducción de material de propagación de yuca (*Manihot esculenta* Crantz). Cali, Colombia, CIAT. 12 p.

LOZANO, J.C. y **van SCHOONHOVEN, A.** Danger of dissemination of diseases and pests through the introduction of material for the propagation of cassava. **In:** The international exchange and testing of cassava germplasm. Workshop. Palmira, Colombia pp.41-44.

LOZANO, J.C. Algunas consideraciones fisiológicas y biológicas sobre enfermedades de plantas. Noticias Fitopatológicas 4(1):104-111.

TAKATSU, A. y **LOZANO, J.C.** Translocación del agente causal del añublo bacterial de la yuca (*Manihot esculenta* Crantz) en los tejidos del hospedero. Fitopatología 10(1):13-22.

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* This list includes only journal articles published outside CIAT's series.

Bean production systems

HIGHLIGHTS IN 1975

The Bean Program continued to develop and consolidate in 1975, its second full year of operation. Priorities established after an in-depth analysis of bean production problems in Latin America emphasize: germplasm characterization and supply to national programs; assistance in documentation and training for Latin American scientists; and development of bean production systems which minimize the need for costly fertilizers and chemicals. Staff appointments in physiology and systems agronomy have allowed considerable progress in these areas in 1975. Following are some major highlights for the year.

In the first full year of bean hybridization, 85 parents were used in an intensive crossing program. A total of 4,530 pollinizations representing 1, 266 different hybridizations were made, with 35,400 F_1 and F_2 progeny field tested.

High experimental yields were obtained in both bush and climbing beans, giving promise of farm yields previously thought to be unobtainable in this species. In bush beans, the maximum yield in replicated plots was 4.26 tons|ha; in climbing beans under monoculture, yields consistently ranged between 4.5 and 5.5 tons|ha.

Varietal trials for bush beans continued in 1975, and high yields were again common. Scientists attending the Bean Breeding and Germplasm Workshop helped develop and approved plans to establish an international series of variety trials in 1976.

Nitrogen fixation studies at Popayán showed rates of fixation similar to those reported for soybean. The ten varieties studied fixed an average of 25 kg N|ha over a 120-day period.

An agro-economic study of major Colombian bean growing areas was carried out giving important information on disease incidence and severity, production problems and seed storage and quality.

As part of its new responsibility for coordinating Latin American bean research, the program organized conferences in 1975 to discuss bean breeding, germplasm and disease problems. The Bean Advisory Committee also met to review program activities. Twenty-six trainees, including two PhD and three MS candidates, received training at CIAT.

There were additionally some changes in research emphasis within the program. Germplasm evaluation played a lesser role than in previous years while work with climbing beans and maize-bean associations received more emphasis. Work on spider mites—previously throught to be of major importance in Latin America— was replaced by studies on the **Tarsomenis** mite.

ECONOMICS

An analysis of bean production processes in four regions of Colombia was begun in 1974 (1974 Annual Report). The primary purpose of the analysis is to provide details of the bean production process that will be useful for establishing priorities in agricultural research and public policy. The data collection for three regions, or departamentos,* was completed in 1975 and is being analyzed. While some of the results presented here are for all four regions, the discussion emphasizes the Valle region —for which the data analysis is most advanced.

Agronomic factors of bean production in Colombia

Technology levels and bean yields

The 177 farmers surveyed are located as follows: Valle, 31; Huila, 105; Antioquia, 22 and Nariño, 19. Beans are usually grown as a monocrop in the Valle region, while in Huila, Antioquia and Nariño, they are predominantly grown with maize. In Huila, some area is also planted to beans alone. Other cropping systems include potatoes, peas or peanuts. Table 1 shows the farm size, use of modern technology and yields for the four regions. Valle is characterized by relatively large commercial farms, extensive use of modern technology, monocropping and relatively high bean yields. Nariño, on other hand, consists mainly of small farms, with very limited use of modern technology, mixed cropping and relatively low bean yields. In Valle yields on small farms were only slightly more than half the yields on large farms. Table 2 shows that even within one region, wide differences exist among cropping systems and technology levels employed for bean production. Differences are particularly marked in the use of irrigation, certified seed, herbicides, credit and technical assistance.

These findings would indicate that research efforts to expand and improve

* A departamento is a political sub-division similar to a state or province.

Table 1. **Characteristics of bean production in four regions of Colombia.**

	Valle	Huila	Antioquia	Nariño
Average farm size (ha)	48.0	25.2	4.5	4.0
Area in beans (ha)	22.6	5.9	1.5	1.8
Percentage of farms using:				
Irrigation	45	3	0	0
Certified seed	52	7	0	5
Fertilizers	94	24	100	0
Herbicides	33	0	0	0
Insecticides	87	23	64	10
Fungicides	97	10	59	0
Credit	87	53	54	58
Technical assistance	71	30	32	32
Mixed cropping	0	74	100	95
Machinery	100	44	5	0
Bean yield (kg/ha)	906	683	509	447
Bean equivalent yield (kg/ha)	906	n.a.*	919	703

* n.a.=not available

Table 2. **Selected characters for bean production farms of three sizes in Valle.**

	Farm size		
	small	medium	large
Average farm size (ha)	2.8	21.0	115.0
Area in beans (ha)	2.4	17.0	47.5
Percentage of farms using:			
Irrigation	18	44	73
Certified seed	18	22	64
Fertilizers	90	100	100
In soil	40	66	64
On leaves	60	78	100
Herbicides	20	33	45
Insecticides	91	78	91
(applied by:)			
airplane	0	22	64
tractor	0	22	27
backpack sprayer	100	89	64
Fungicides	100	100	100
Credit	73	89	100
Technical assistance	27	89	100
Mixed cropping	0	0	0
Mechanization	100	100	100
Bean yield (kg/ha)	683	896	1,118

productivity must consider the specific production system and region toward which the efforts are focused. New technology for large-scale monocropping is likely to be adopted rapidly by the larger, more progressive farmers characterized by the Valle region. Special efforts may be needed to design and diffuse technology to benefit small farmers typical of Nariño and Antioquia.

Diseases and insects

Angular leaf spot, rust and bacterial blight were common in all regions. Other diseases were important for some but not all the regions (Table 3). The yield impact of some of these diseases is discussed in a later section.

A large number of insect species were found in the bean fields under observation with **Empoasca** and thrips among those most frequently found. The percentage of farms affected by each insect species differed greatly among regions (Table 4).

Soils

To assist in understanding fertilizer use and yields, soil samples were collected on each farm of the survey. These samples are being analyzed for organic matter, pH and levels of calcium, magnesium, phosphorus and potassium.

Plant population and seed loss

The average plant population 30 days after planting was estimated to be 387,000 plants|ha in Valle. Plant population per hectare tended to be higher on large farms. A considerable loss of seed or seedlings occurred during the first 30 days after planting. Establishment losses of 50 and 32 percent were found on small and large farms, respectively. The causes of such large losses are being studied.

Using production function analysis and with current seed prices at US $700|ton, the optimum plant population was estimated at 419,500 plants|ha, and max-

Table 3. **Percentage of bean farms in four regions of Colombia where diseases were observed during either of two visits.**

	Region							
	Valle[1]		Huila[2]		Antioquia[3]		Nariño[4]	
Visits:	I	II	I	II	I	II	I	II
Angular leaf spot	74	100	30	78	91	91	32	79
Rust	94	94	63	71	41	68	26	16
Bacterial blight	55	84	40	77	0	9	53	79
Gray spots	0	3	44	63	68	82	63	53
Anthracnose	0	0	50	51	86	100	37	42
Flowery spots	0	0	11	72	73	64	10	47
Powdery mildew	0	0	6	28	50	68	0	0
Virus	10	19	21	6	0	0	21	11
Root rot	39	13	19	1	5	9	37	5
Leaf spot	0	0	21	11	14	9	16	5

1 Crop season: 80-100 days. Visit I, 20-30 days after planting, II, 50-60 days after planting

2 Crop season: 80-120 days. Visit I, 30-50 days after planting; II, 70-90 days after planting

3 Crop season: 120-160 days. Visit I, 60-80 days after planting; II, 90-100 days after planting

4 Crop season: 90-110 days. Visit I, 30-40 days after planting; II, 60-70 days after planting.

Table 4. **Percentage of bean farms in four regions of Colombia where insects were observed during either of two visits.**

	Region							
	Valle		Huila		Antioquia		Nariño	
Visits:	I	II	I	II	I	II	I	II
Insects attacking seedlings:								
Cutworms	13	0	14	4	0	0	0	0
Crickets	13	0	11	0	0	0	0	0
Sucking insects:								
Aphids	32	6	56	77	18	14	37	53
Thrips	39	36	79	70	36	36	68	63
Stinkbug (**Nezara** sp.)	0	6	0	2	9	0	5	0
Empoasca sp. (adults)	61	97	87	85	68	64	68	79
(nymphs)	36	87	78	83	64	77	63	95
Whitefly	62	26	42	38	36	0	47	26
Gargaphia sp.	0	0	14	30	0	0	0	0
Leaf miners:								
Agromyza sp., **Liriomyza** sp.	26	42	60	57	0	0	58	32
Hemichalepus sp.	0	43	55	30	68	55	47	5
Leaf feeders:								
Estigmene sp.	13	13	3	6	-	5	0	0
Trichoplusia sp.	0	55	16	39	14	45	5	0
Hedylepta sp.	6	16	7	32	0	0	0	0
Urbanus sp.	0	3	9	4	0	0	0	0
Spodoptera sp.	3	3	0	0	0	0	0	0
Chrysomelidae	36	52	12	7	32	0	53	16
Pod damaging insects:								
Heliothis sp.	0	16	0	10	0	0	0	16
Trichoplusia sp.	0	32	0	30	0	0	0	16
Maruca sp., **Epinotia** sp.	0	48	0	52	0	59	0	5
Dipterons	0	0	0	8	0	23	0	26
Stemborers:	0	0	1	0	82	59	0	0
Mites:								
Tetranychus sp.	0	0	16	48	0	0	0	0

imum production was estimated to be obtained at 486,600 plants|ha. Increasing the plant population to the economic optimum level at current seed prices was estimated to add 14 kg|ha to yields.

Labor use

Figure 1 shows estimated labor use in bean production in Valle by production activity and farm size. Bean production in

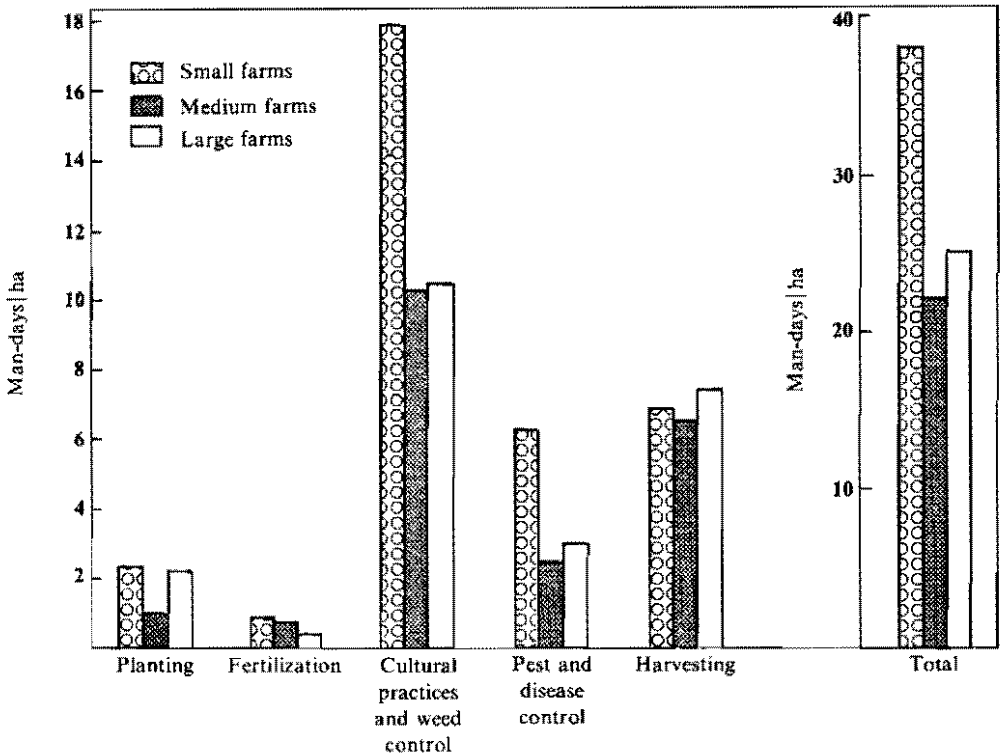

Figure 1. **Labor use in bean production by activity and farm size, Valle, Colombia, 1975.**

the region is highly mechanized, hence labor use is low relative to other regions. Weed control and cultural practices account for about half of the total labor use. The amount of labor used in the production process is higher for small than for large farms and is particularly pronounced for weeding and cultural practices because fewer small farmers use herbicides. Labor use for pest and disease control also differs because large farmers use tractors to apply insecticides and fungicides while small farmers tend to use backpack sprayers.

Economic factors of bean production in Colombia

Production costs and returns

Table 5 shows estimated variable costs by production activity and farm size. The cost of seed and planting accounts for about 25 percent of total variable costs, followed by disease and pest control (20%) and land preparation (15%). A considerable cost difference was found among size groups of farms. Total variable costs on small farms were estimated to be US $233|ha and for large farms, US $328|ha. The cost differentials among farm size groups were due primarily to the quantity of fertilizers, insecticides, herbicides and fungicides applied, and to a lesser extent, to differences in harvesting costs caused by yield differences.

Table 6 shows estimated gross and net returns from bean production in Valle during the survey period. As farm size increased, yields, total costs and net returns increased. The benefit|cost ratio increased from 1.15 for small farms to 1.45 for large farms.

Table 5. **Estimated variable costs of bean production on three farm sizes, Valle region, Colombia, 1974-75.**

	Farm size					
	small		medium		large	
	(US\$|ha)	(%)	(US\$|ha)	(%)	(US\$|ha)	(%)
Land preparation	33.87	14.5	46.57	17.0	42.70	13.0
Seed and planting	67.57	29.0	61.00	22.2	67.57	20.6
Fertilizer and application	17.37	7.5	22.93	8.3	24.40	7.4
Irrigation, drainage	-	-	3.47	1.3	5.57	1.7
Cultural practices and weed control	36.67	15.8	30.63	11.2	30.70	9.4
Disease and pest control	38.33	16.5	57.50	21.0	74.23	22.6
Harvesting	15.83	6.8	21.67	7.9	45.27	13.8
Other costs	23.23	9.9	30.47	11.1	37.80	11.5
Total	232.87	100.0	274.24	100.0	328.24	100.0

A production function analysis was conducted to determine the optimum levels for variable costs (excluding harvesting costs) and yields per unit of land*. It was found that the current level of variable costs, (US $251.77|ha) was optimum for a product price of US $533|ton. At the average price received by farmers of US $550|ton, net returns would be maximized at a variable cost of US $260|ha, which in return would increase yields by 18 kg|ha and net returns by US $1.27|ha.

* Harvesting costs were excluded from variable costs in the production function analysis because they are determined by the quantity produced and not **vice versa**. Hence, since harvesting costs are fixed per unit of output in the region, these costs were subtracted from the product price in the marginal analysis.

Prices received by the survey farmers ranged from US $400 to $720|ton. At these prices, net returns would be maximized at variable costs of US $152 and US $326|ha, respectively. Before planting, reputable private companies offered the farmers contracts with a guaranteed price of US $583|ton. Less than one-fourth of the farmers accepted such contracts. Apparently at the time of planting, farmers expected future prices for beans to be equal

Table 6. **Estimated economic results of bean production on three farm sizes, Valle region, Colombia, 1974-75.**

	Farm size		
	small	medium	large
Yield (kg|ha)	683	896	1,118
Value of production (US\$|ha)	366	508	626
Total costs (US\$|ha)	317	352	432
Net profit (US\$|ha)	49	156	194
Benefit|cost ratio	-1.15	1.44	1.45

to or greater than the contract price, and that this price would form the basis for decisions on minimum levels of input use and variable costs. At the contract price, the optimum variable costs were estimated to be US $277|ha. Hence, it may be concluded that the survey farmers invested slightly less than the optimum amount, whether the actual average or expected minimum prices are considered. However, given the risk and uncertainty associated with bean yields and prices, it appears that the farmers were as close to optimum investment levels as could possibly be expected.

Sources of yield losses

A production function analysis was carried out to estimate yield losses caused by selected factors. Table 7 shows the estimated yield loss from eight factors assuming a totally affected lot. Also shown is the percentage of the total bean area affected and the total loss to the region. Assuming constant prices, i.e. an infinitely elastic demand, and using average prices received by the survey farmers (US $550|ton), the loss to the region due to adverse rainfall conditions and lack of water control was estimated to have been almost US $1.2 million for the crop cycle beginning in October, 1974.* The loss caused by rust was estimated at slightly less than this. The presence of bacterial blight reduced average regional yields by 137 kg|ha and total regional production by about 1,700 tons. Other important factors limiting yields were the presence of **Empoasca** and angular leaf spot. Certified seed was used on 59 percent of the area. The potential gain from using certified seed on the remainder of the area was estimated to be US $0.5 million. The potential gains from optimizing variable costs and plant populations were quite small.

The estimates presented in Table 7 are gross rather than net losses. To obtain net losses, costs and secondary benefits associated with reducing or eliminating losses need to be estimated. Finally, the estimates in Table 4 should be interpreted with caution because of their preliminary nature, the small number of observations

* Since almost all the black beans produced in Valle are exported and since the quantity accounts for a small proportion of total supplies in the markets to where it is exported, the assumption of infinitely elastic demand is probably valid for the limits considered here.

Table 7. **Estimated losses in bean production from selected factors, Valle region, Colombia, 1974-75.**

Factor	Est. loss in totally affected lot (kg|ha)	Est. loss in totally affected lot (%)*	Area affected (%)	Est. loss, Valle (kg|ha)	Est. loss, Valle (%)	Est. loss, Valle (tons)	Est. loss, Valle Value (US$1,000)**
Adverse rainfall	416	31.5	42	175	16.2	2,168	1,192
Rust	307	25.3	56	172	16.0	2,130	1,171
Bacterial blight	Total	100.0	12	137	13.1	1,697	933
Empoasca	315	25.8	35	110	10.8	1,362	749
Angular leaf spot	538	37.5	15	81	8.2	1,003	552
Certified seed	186	17.0	41	76	7.7	941	517
Variable costs	-	-	-	18	1.9	223	123
Plant population	-	-	-	14	1.5	173	95

* Percentage based on estimated average yield plus estimated loss due to the particular factor

** Estimated value of regional loss at constant prices of US$550|ton.

and the severe difficulty in separating the effects of the various factors influencing yields.

BREEDING

Hybridization program

Hybridization among promising selections in the bean germplasm bank began in 1974 using ten progenitors (1974 Annual Report). In 1975, the number of progenitors was increased to 85, widening the number of characteristics being sought and greatly accelerating the hybridization program. By October of this year, 4,530 pollinations representing 1,266 different hybridizations had been completed. During this program, the overall efficiency of pollination rose from the 31.5 percent reported last year to more than 50 percent. This is discussed more in the next section.

Two cycles of intensive crossings have been completed. From the original ten progenitor materials, 23 F_2 single crosses and 51 F_1 double cross populations were developed. These materials were field grown this year and 27 bulked populations and more than 450 individual plant selections made. While it is premature to talk of firm yield figures based on low density plantings, two results deserve comment. (1) P459 proved an excellent parent. All outstanding F_1 double cross materials included this selection as a parent, as did eight of nine F_2 mass selections from single crosses. (2). Preliminary yields in the double cross progeny were, in general, considerably higher than in those from single crosses.

Table 8 shows the parental materials and characteristics sought in the second group of crosses. Emphasis here was on establishing base populations which united different sources of genes for quantitatively inherited characteristics, i.e. rust resistance, common bacterial blight resistance and yield. Combining simply inherited features such as common mosaic resistance in prominent commercial varieties is also stressed. Further crossing and evaluation of hybrids will continue in 1976.

The bean team as a whole, aided by discussions at the breeding workshop in October, devoted much time to developing

Table 8. **Breeding groups and crosses made for genetic improvement in *P. vulgaris*, CIAT, 1975.**

No. of crosses	Groups of desirable factors under breeding
160	Sources of tolerance (5) to common bacterial blight (*Xanthomonas phaseoli*) and high yield potential
183	Sources of tolerance (6) to web blight (*Thanatephorus cucumeris*) and high yield potential
143	Sources of resistance (5) to common mosaic virus (*Marmor phaseoli*), high yield potential and commercial varieties of Latin America
118	Sources of tolerance (14) to leaf hopper (*Empoasca kraemeri*) and high yield potential
96	Sources of resistance (6) to rust (*Uromyces phaseoli*) and high yield potential
13	Sources of resistance (2) to yellow mosaic and commercial varieties of Chile
37	Sources of tolerance (2) to golden mosaic and commercial varieties of Honduras
31	Sources of resistance (1) to angular leaf spot (*Isariopsis griseola*) and high yield potential
485	Combination of physiologic characters: late flowering (3), insensibility to photoperiod (3), stability in growth habit (3) and high yield potential.

a methodology for improving and distributing new lines of *P. vulgaris*. It would appear that in the short term, much can be achieved stressing simply inherited characters such as resistance to common mosaic and anthracnose, and combining these into better commercial varieties. This should be achievable by single cross hybridization to incorporate disease resistance coupled to a backcross program to recover desirable seed characteristics. Improving quantitatively inherited characteristics, for example tolerances to common bacterial blight, leafhoppers or golden mosaic virus, and incorporating these into high yield backgrounds will prove much more difficult. Recurrent selection procedures like those shown in Figure 2 for **Empoasca** seem highly appropriate. Here intermating and selfing would both be practiced, with siblines tested first of all for **Empoasca** tolerance (A-factor) and later on for yield (B-factor). Even here, individual disciplines will have to give high priority to developing screening procedures which permit distinction of relatively small differences in resistance or yield levels.

Hybridization techniques

As stated earlier, pollination efficiency was only about 32 percent in 1974. To improve this rate, a study to evaluate crossing methodology was begun this year. Crosses were made in a screenhouse without environmental control using P4 and P5 as female and male parents, respectively. Among the factors studied were: (1) use of p.4-chlorophenoxyacetic acid to prevent abscission of pollinated flowers; (2) placement of wet cotton around the pollinated flowers; (3) time of pollination during the day; (4) removal of all flowers not to be pollinated; (5) the need for repollination; and (6) time of emasculation relative to pollination.

The results are shown in Table 9. Maximum efficiency of 81 percent was achieved using the hormonal applications, making the crosses up to midday, pollinating only one flower per raceme, and removing all flowers not being pollinated. Using the wet cotton around the flower increased flower abscission, as did any situation which permitted competition for nutritients between the fertilized flower and other flowers on the plant. The non-significant increase in efficiency from repollinating does not appear to be practical.

Inheritance studies

Bean breeding trainees are directly participating in a series of studies to obtain information on the inheritance of main limiting production factors.

In rust resistance studies, two independent F_2 populations were evaluated in the field by the use of a local inoculum. The sources of resistance were PR-5 (P568) and Cacahuate 72 (P569). As shown in Table 10, both studies indicated that resistance was dominant and simply inherited.

A genetic study of common bacterial blight tolerance was done in the greenhouse with the resistant line Tara (P567) and CIAT's C-6 inoculum. The average reaction of the foliage to the bacteria is shown in Table 10. The nature of the disease reaction was quantitatively inherited and showed additive gene effects.

GERMPLASM

Evaluation and documentation of the CIAT holdings of *P. vulgaris* and related species continued in 1975. Major activities have been in four areas of work.

(1) The germplasm bank includes approximately 1,800 accessions for which only very limited numbers of seeds were supplied. These materials have been planted in the screenhouse to minimize loss of individual accessions, and will be field screened in 1976.

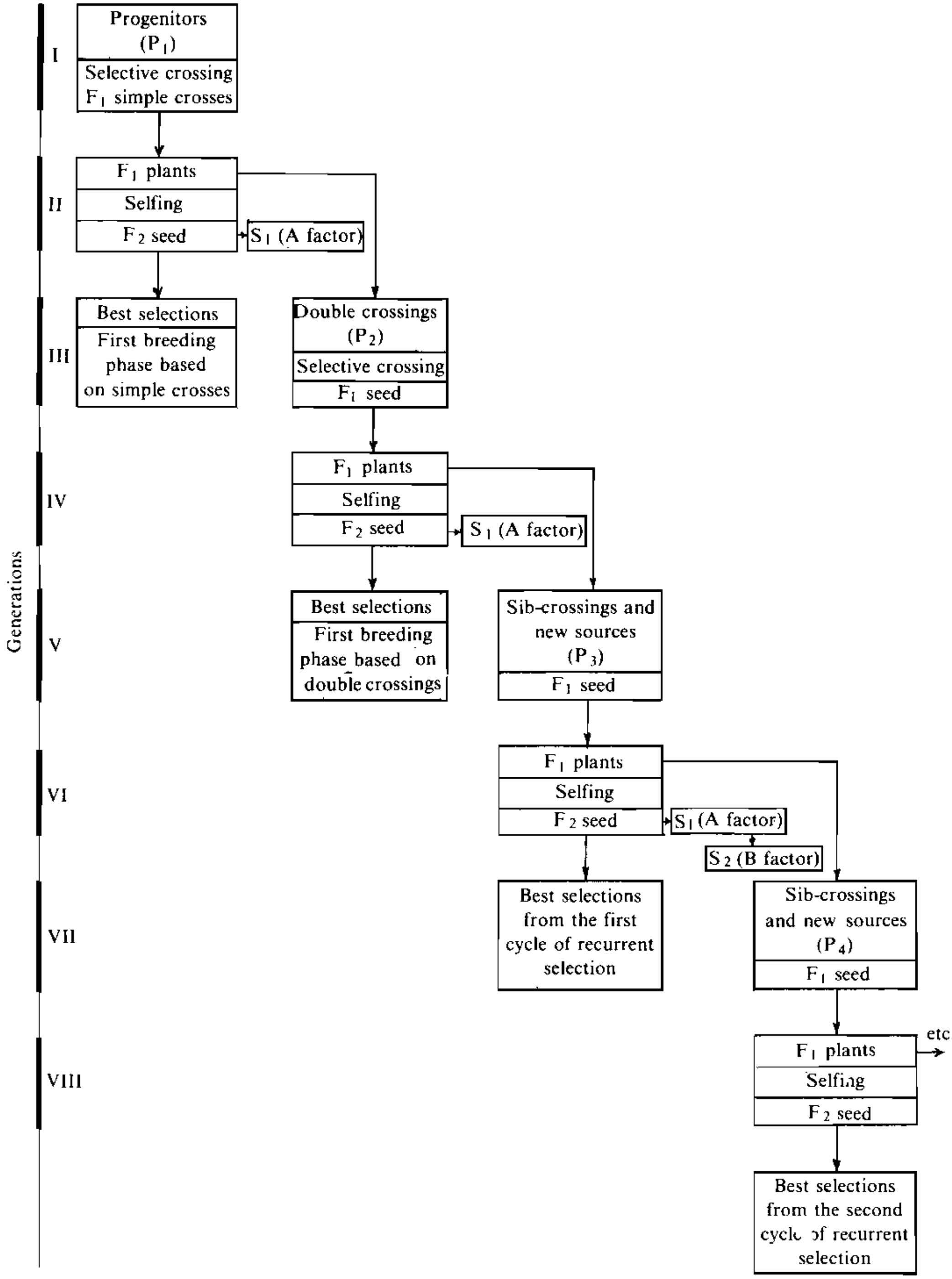

Figure 2. **Recurrent selection process for genetic improvement of *P. vulgaris* to obtain combinations among two polygenic factors from an initial 10-15 progenitors, CIAT, 1975.**

Table 9 **Effects of several treatments for increasing the crossing efficiency in *P. vulgaris*, CIAT, 1975.**

Treatment	Efficiency (%)	Mean temperature (°C)	Mean rel. hum. (%)
Hormone*	81.0	31.0	54.5
Hormone + wet cotton wool	71.0	30.0	53.6
Wet cotton wool	62.0	29.4	52.4
Check	74.0	29.1	57.4
Single pollination (with no competition effects)	63.3	24.6	98.2
Repollination after 24 hr	66.6	24.6	98.2
Presence of other flowers at pollination	40.0	24.0	98.2
Two pollinated flowers per raceme	38.3	29.8	85.1
Emasculation and then pollination after 24 hr	31.4	25.3	96.1

* p.4-chlorophenoxyacetic acid

Table 10. **Inheritance studies of resistance to rust, *Uromyces phaseoli*, and tolerance to common bacterial blight, *Xanthomonas phaseoli*, in *P. vulgaris*, CIAT, 1975.**

	Observed data		Calculated (3:1)			
Generation	Resist.	Susc.	Resist.	Susc.	X^2	P
			Rust inheritance			
P_1 (P459)		20				
P_2 (P569)	20	-				
F_1	4	-				
F_2	126	49	131	44	0.840	.50-.30
P_1 (P568)	20	-				
P_2 (P459)	-	20				
F_1	4	-				
F_2	171	73	183	61	3.147	.10-.05

Blight inheritance

Generation	Disease reaction 1	2	3	4	No. of plants	Mean reaction to the disease
P_1 (P459)	-	-	-	8	8	4.00
P_2 (P567)	8	-	-	-	8	1.00
F_1	1	-	-	3	4	3.25
F_2	33	38	45	23	139	2.41

Table 11. **Characteristics determined for *P. vulgaris* germplasm, CIAT.**

1. Days to emergence	19. No. branches with pods	36. Root rots
2. Plant vigor	20. Branch angle	37. Common mosaic virus
3. Hypocotyl length	21. Seeds/pod	38. Golden mosaic virus
4. Hypocotyl color	22. Seed shape	39. Chlorotic mottle virus
5. Leaf size	23. Major seed color	40. Bacterial blight
6. L.A.I.	24. Secondary seed color	41. **Empoasca**
7. Effective plant height	25. Seed gloss	42. Apion
8. Node number at flowering	26. Seed weight	43. White fly
9. Node number at maturity	27. Yield/plant	44. Red spider mite
10. Days to flower initiation	28. Harvest index	45. Tropical mites
11. Duration of flowering	29. Total dry matter	46. **Zabrotes**
12. Flower color	30. Degree of lodging	47. Bean weevils
13. Sensitivity to photoperiod	31. Yield trial ranking	**Other characters:**
14. Growth habit	**Resistance to:**	48. **Rhizobium** efficiency
15. Plant height	32. Rust	49. Other references to accession
16. Stem width	33. Angular leaf spot	50. Mixed seed
17. No. racemes per plant	34. Web blight	51. Clean seed
18. No. pods per plant	35. Anthracnose	52. Species

(2) In 1975 it was decided to increase the number of descriptor terms used for the germplasm collection from 26 to 52. The complete list of descriptor terms is shown in Table 11. The additional data needed is being collected from new field plantings of 2,000 accessions per semester. Data for the accessions in now maintained on tape, and is being adapted for use with both the EXIR and SAS data retrieval and analysis systems.

Table 12. **Variation of specified characteristics among 2,216 accessions of *P. vulgaris* evaluated at CIAT, 1975.**

Days to emergence	5 - 12 days
Days to flowering	29 - 72 days
Plant height	22 - 220 cm
Racemes per plant	1 - 29
Pods per raceme	1 - 5
Pods per plant	3 - 47
Seeds per pod	2 - 10
Seed weight	12 - 58 g/100 seeds
Seed weight per plant	1 - 37 g
Days to harvest	61 - 110

(3) To date more than 700 selections have been made which show promise in one or more attributes. A catalogue describing these promising materials is being prepared and will be available early in 1976. In addition, the catalogue will describe the frequency and variation for particular characteristics in the total germplasm collection. The ranges for certain characters are shown in Table 12.

(4) The germplasm bank is continually receiving and shipping seed. In 1975, 1,105 new accessions were received, principally from Mexico and Central America, while samples of 2,832 accessions were forwarded to other centers.

PHYSIOLOGY

Growth and development studies

The varieties ICA Gualí, Porrillo Sintético and PI 310740, representing plant types I, II and III, respectively, were analyzed exhaustively in 1975 to better understand *P. vulgaris* growth and development processes under tropical conditions. The experiments were conducted at Palmira at a density of 30 plants|m² with furrow irrigation and adequate protection from insects and diseases.

Key growth parameters for Porrillo Sintético are shown in Figures 3 and 4. Dry matter production reached a maximum of

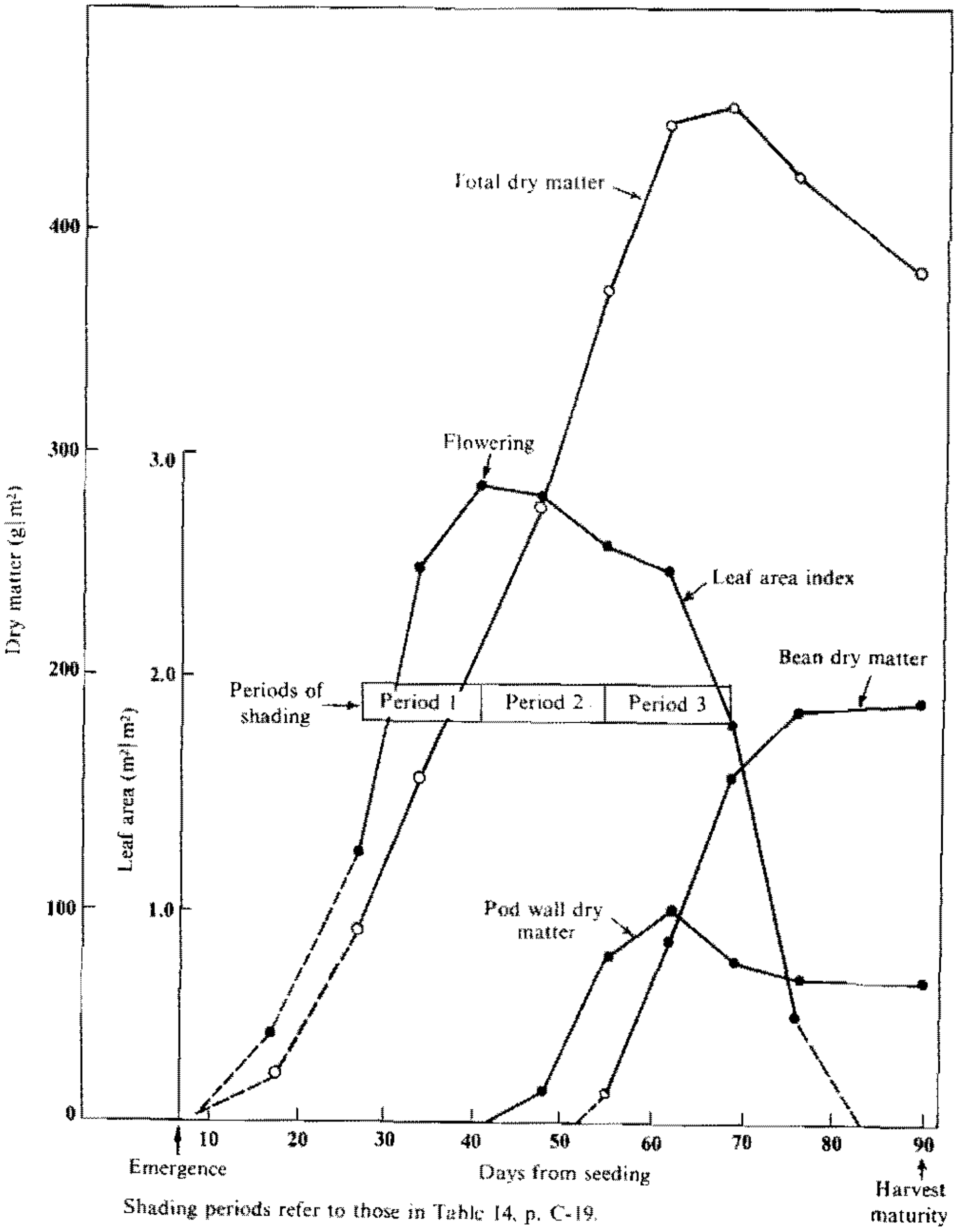

Figure 3. **Key growth parameters for cv. Porrillo Sintético at a density of 40 plants|m², under fertilized, irrigated and protected conditions at CIAT, 1975A.**

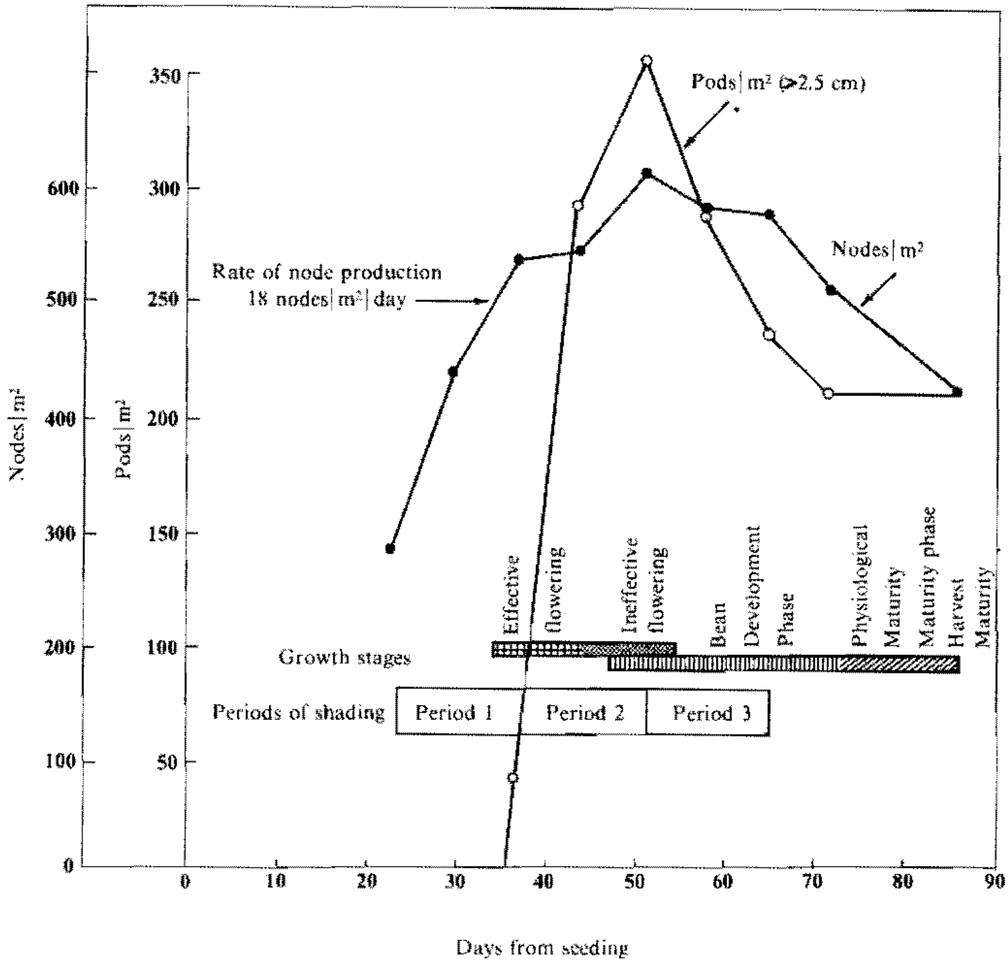

Figure 4. **Node and pod density variations in relation to growth stages for cv. Porrillo Sintético for same crop shown in Figure 3.**

450 g/m² and declined as leaf fall accelerated after a maximum green leaf area of 3.0 m²/m². Crop growth rate was virtually linear from 20 to 60 days from seeding with flowering occurring at 38 days and physiological maturity at about 80 days. Node production continued well into the flowering phase and reached a maximum rate at preflowering of 18 vegetative nodes produced/m²/day. Pod abscission, even under the excellent growing conditions at CIAT, was severe during the bean development phase.

Flower production and subsequent development was mapped on representative plants of each variety as shown in Figure 5. The pattern of "flower" (pods $<$ 3 cm) and "pod" ($>$ 3 cm) abscission is summarized in Table 13. In the determinate variety ICA Gualí, with a maximum of eight nodes on the main stem at flowering, flowers borne directly on nodes 7 and 8 all abscissed as did flowers which formed late in the flowering process on lower branches. The same pattern of abscission was evident in the indeterminate

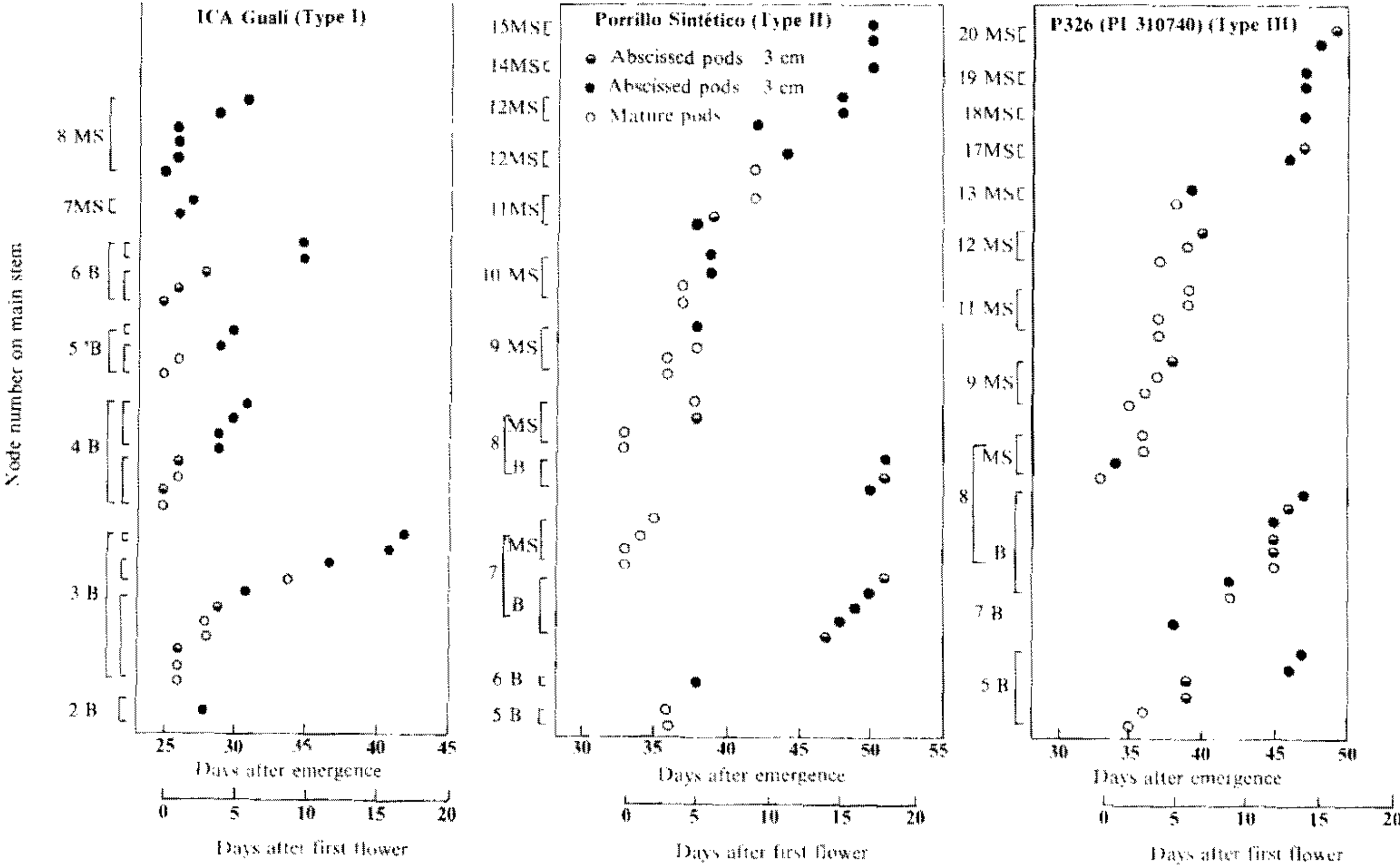

Figure 5. **Abscission patterns of "flowers" (pods< 3 cm) and pods (pods>3 cm), location of mature pods in relation to the time each bud opened, and pod location on main stem (MS) or branches (B) for three varieties of bean with three growth habits. CIAT (1975A).**

Table 13. **Summary of flowering and pod abscission data for three varieties of *P. vulgaris*, CIAT, 1975A.**

Variety	ICA Guali	Porrillo Sintético	PI 31074
Growth habit	I	II	III
Total number of flowers/plant	37	39	39
Pods abscissed < 3 cm	21	20	13
Pods abscissed > 3 cm	7	5	9
Mature pods/plant	9	14	17
Pod set efficiency (%)	24	36	44
Flowering period (days)	18	19	17
Period (A) for first 60% flowers (days)	4	10	10
Pod set efficiency during A (%)	36	60	70
Period (B) for final 40% flowers (days)	14	9	7
Pod set efficiency during B (%)	7	0	6

varieties but in addition, abscission was evident on main stem nodes produced after flowering. Pod set for all varieties was significantly higher in the first-formed flowers, the extreme case being Porrillo Sintético where flowers that formed during the last 16 days produced no pods at all. Clearly, flower and pod abscission is an area needing major research emphasis.

Analysis of the total soluble carbohydrates in the main stem is shown in Figure 6. The pattern of carbohydrate storage was strongly related to growth habit with ICA Guali showing more than 12 percent total carbohydrates (starch plus sugars) during the postflowering phase. By contrast, Trujillo 3 (a Type IV variety included in this analysis) showed a relative-

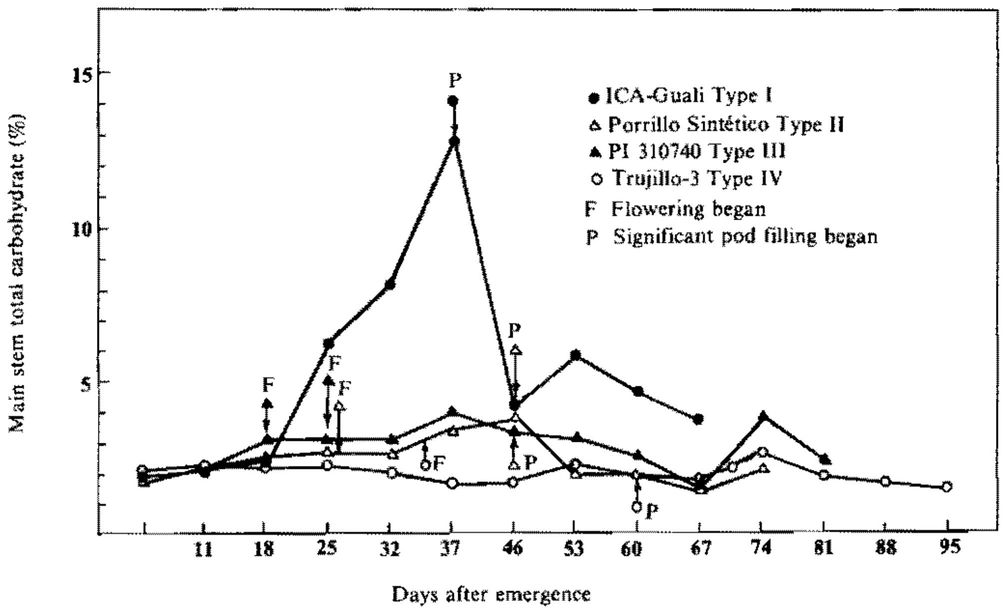

Figure 6. **Total main stem carbohydrate (anthrone method) in four varieties of *P. vulgaris* (Types I-IV) in relation to days from emergence at CIAT (1975A). Initiation of flowering and significant pod filling shown for each variety.**

ly constant and very low carbohydrate level at all growth stages. Carbohydrates decreased rapidly in the determinate variety only when significant bean filling had commenced. It is unlikely that photosynthate stress per se is the direct cause of flower abscission in this variety.

Source-sink manipulation

A series of experiments with Porrillo Sintético involving shading (48% interception); carbon dioxide fertilization, leaf thinning and photoperiodically induced extension of the preflowering phase, were used to alter the development pattern for the different growth stages shown in Figures 3 and 4. Shading (Table 14) reduced yields in the preflowering (-14 to 0 days before flowering) and flowering (0 to +14 days) phases equally. Yield reduction during preflowering was associated with reduced node density and a subsequent decrease in the number of potential racemes. Shading during flowering did not affect node production but was associated with a lower number of racemes. Yield was not reduced by the postflowering (+14 to +28 days) treatment indicating that preflower node production and pod set efficiency in the flowering phase were the main factors controlling yield potential in this crop-environment situation.

Leaf thinning (Table 15) in the late-flowering (+13 days from flowering) and bean filling (+22 days) periods reduced yields significantly, but considering the severity of the treatment, yield reduction was not great. In this case, yield reduction was associated with lower mean bean weight, as would be expected when a major proportion of the leaf system is removed during the period of active bean filling.

Applying carbon dioxide to field canopies to alter source sink balance has proved an excellent physiological tool in other crops. Preliminary studies in which CO_2 was applied preflowering increased yields 19 percent. This will be further studied in 1976.

When the photoperiod sensitive variety Porrillo Sintético was grown at photoperiods ranging from 13-19 hours, flowering was delayed by up to 6 days with a consequent 71 percent yield increase, to 3,388 kg|ha (Table 16). This increased yield was associated with a 26 percent increase in node density|m² at flowering and a 58 percent increase in final bean

Table 14. **Effect of shading (48% interception) during three growth stages on yield and associated parameters of cv. Porrillo Sintético, CIAT, 1975A.***

Parameter	Growth stage: Preflowering (-14 to 0)**	Flowering (0 to + 14)	Postflowering (+ 14 to + 28)
Grain yield	78.2	74.3	91.2
Total dry matter	79.7	79.3	93.7
Harvest index	97.1	92.4	96.9
Racemes | m²	80.4	78.0	88.4
Pods | m²	81.2	81.1	101.2
Beans | pod	95.2	90.1	94.0
Bean weight (mg | bean)	99.5	99.0	96.5
Nodes | m²	79.0	98.0	92.0
Racemes | m²	80.0	78.0	88.4

* Data expressed as percentage of nonshaded control plot; mean control yield was 205 g|m² (14 percent moisture)

** On day 0, 50 percent of plants have at least one flower

Table 15. **Effect of leaf thinning at three growth stages on yield and associated parameters of cv. Porrillo Sintético, CIAT.***

Time of thinning	Bean yield (g/m²)	No. of pods/m²	Bean wt. (g/pod)	Bean wt. (mg/bean)
Control	274 (100)	236	1.16	228 (100)
Day 0**	222 (81)	213	1.03	205 (90)
Day 13	152 (55)	174	0.80	182 (80)
Day 22***	181 (66)	220	0.82	172 (75)

* Mean of treatments with 33, 66 and 100 percent of leaves removed at growth stage.

** On day 0, 50 percent of plants have at least one flower.

*** Bean filling commenced on day 14.

density per m^2. Total dry matter production and bean size also increased. The rate of vegetative node production during the extra six days before flowering was 19.3 nodes/m^2/day, a rate similar to that for the normal preflowering development phase. The increased pod set appears to be due to decreased abscission, particularly on those nodes (on main stem and branches) which normally would have been produced after flowering. The results of three treatments applied during the preflowering phase are summarized in Table 17. These data confirm the importance of increased node structure by the time flowering commences. An increase in the length of the preflowering phase could be the most rapid means to achieve improvement.

Yield potential in a wide range of genotypes

Physiological data was taken on 193 genotypes representing all four growth habits (Type IV varieties supported on 2-meter trellis). A correlation matrix show-

Table 16. **Effect of photoperiod control of the preflowering phase on yield and other parameters of cv. Porrillo Sintético, CIAT, 1975A.**

Parameter	Photoperiod 16 hr 30 min. (1-4 m)[1]	Photoperiod 16 hr 30 min (4-8 m)[1]	Control 12 hr 30 min[2]
Yield (kg/ha, 14% moisture)	3,388 (171)	3,053 (154)	1,978 (100)
Days to flowering[3]	39	35	33
Days to physiological maturity[3]	75	71	68
Days of postflowering	36	36	35
No. of nodes/m² at flowering	560 (126)	473 (106)	444 (100)
Bean weight (mg/bean)[4]	172 (107)	168 (105)	160 (100)
Bean no./m²	1,693 (158)	1,560 (145)	1,070 (100)
Dry matter/m², at maturity[5]	498	488	377
Harvest index	0.58	0.54	0.45
Bean yield efficiency (g/m²·day)	3.88	3.69	2.50

1 Distance from line of illumination.

2 Normal daylength, Palmira, 3°N.

3 Days from emergence (planting to emergence was 7 days).

4 Dry matter basis.

5 Excluding petioles and leaves at maturity.

Table 17. **Effect of three preflowering treatments on yield and associated parameters of cv. Porrillo Sintético at plant density of 30-40 plants|m², CIAT, 1975A[1].**

Treatment	Yield (g|m²) Control		Yield (g|m²) Treatment		Nodes|m² (% of control)	Pods|m² (% of control)
CO_2 fertilization[2]	217	(100)	258	(119)	97	117
Shading[3]	222	(100)	171	(78)	79	81
Extension of period[4]	198	(100)	339	(171)	126	158

1 Preflowering period: 38 days emergence to flowering

2 700 ppm applied for 2 weeks prior to flowering

3 Shading (48%) for 2 weeks prior to flowering

4 16 hr 30 min photoperiod applied in preflowering period only

ing the interrelations of a wide range of characters is shown in Table 18. These results are further evidence that node density (in this case measured at maturity) is the first sequential determinant of yield. The positive correlations of node density with raceme density and bean density and the nonsignificant relationship between node density and other pod characters, i.e. pods|raceme and bean number|pod.

Table 18. **Correlation matrix of bean yield and other parameters for 193 varieties of four growth habits CIAT, 1974B[1, 2, 3].**

	Pod density|m²	Bean density|m²	Bean weight (mg|bean)	Node density|m²	Raceme density|m²	Pod no.|raceme	Bean yield|raceme	Bean no.|pod	Pod wall weight|pod	Pod wall ratio	Total dry matter (g|m²)	Harvest index
Bean yield|m²	.70	.64	.21	.42	.63	.04	.46	.18	.32	-.18	.94	.36
Pod density|m²		.80	-.29	.51	.78	.29	-.28	.17	-.19	-.02	.70	.14
Bean density|m²			-.56	.41	.53	.32	-.15	.66	-.04	.01	.69	.06
Bean weight (mg|bean)				-.09	-.04	-.36	.70	-.63	.45	-.16	.13	.26
Node density|m²					.58	-.15	-.09	.04	-.08	-.02	.48	-.11
Raceme density|m²						-.30	-.11	-.06	-.13	-.08	.59	.20
Pod number|raceme							-.27	.20	-.13	.19	.11	-.15
Bean yield|pod								.07	.69	-.23	.39	.34
Bean number|pod									.14	.02	.28	-.01
Pod wall weight|pod										.47	.40	-.14
Pod wall ratio[4]											.02	-.66
Total dry matter|m²												.07

1 Mean of two replications, plot size 1 x 2 meters

2 Type IV varieties supported on 2-meter trellis

3 Values underlined are significant at P = 0.05

4 Pod wall weight/total pod weight

suggest that node numbers can be increased without negative compensations in other yield components formed later in the sequence. The negative correlation between bean density and weight (-0.56) or pod density and bean yield per pod (-0.28) suggest that postflowering photosynthate limitations could be limiting yield potential in those varieties with high sink size, i.e. pod density|m².

The strong positive correlation of total dry matter with yield (0.94) and the rather poorer correlations with harvest index were also apparent last year. Increased node structure and leaf area obviously lead to increased dry matter production.

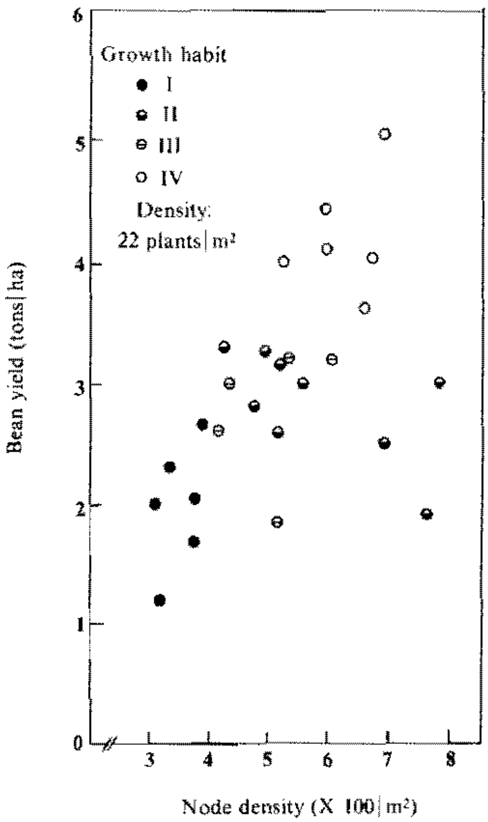

Figure 7. **Bean yield of 26 varieties of *P. vulgaris* in relation to vegetative node density (main stem plus branches) at flowering.**

When yields of 26 varieties were compared there was a strong relationship between node density at flowering and bean yield (Figure 7). Only three bush varieties with high node density did not follow this trend. In this experiment, yields were high with climbing beans producing up to 5 tons|ha and bush beans 3 tons|ha. Further studies with climbing beans, either in monoculture or associated with maize, are reported on page C-53.

Photoperiod insensitivity

One hundred seventy-three promising accessions from types I, II and III were screened for photoperiod sensitivity in the first semester of 1975 using an illumination system previously described (1973 Annual Report). Thirty-nine percent were insensitive to the 18-hour photoperiod regime in the field at CIAT (Table 19). No correlation is evident between photoperiod response and growth habit or maturity group. Insensitive varieties occurred in each growth habit group and in material with a wide range in number of days to flowering.

Table 19. **Number of photoperiod insensitive varieties indentified in 18-hour photoperiod from among 173 promising *P. vulgaris* varieties, in relation to growth habit and days to flowering, CIAT, 1975A.**

Days to flowering**	Growth habit I	II	III	Total
30-34	5	2	2	9
35-39	5	1	-	6
40-44	4	30	3	37
45-49	2	6	3	11
50-54	1	2	-	3
55	-	2	-	2
Total	17	43	8	68
Total screened	40	98	35	173
Percent insensitive	42	40	22	39

* Mean temperature 23.8°C, normal daylength 12 hr 20 min.

** Days from sowing.

Photoperiod insensitivity has contributed to wide adaptation and has been a feature of international research in wheat, rice and other crops. The wide range of potential sources of insensitivity identified in this study will allow breeders considerable flexibility in ensuring that elite materials produced at CIAT will be insensitive. The existence of late-flowering, insensitive accessions could lead to high yielding materials with high node density and wide adaptation to photoperiod.

The influence of temperature, particularly night temperature, in altering the photoperiod is being considered in a collaborative study at Cornell University.

Drought tolerance screening

An experiment similar to one described in 1974 was conducted at La Molina, Peru. Twenty genotypes were tested. Two irrigation regimes were imposed: (a) one irrigation approximately 13 days after flowering commenced, and (b) four irrigations over the 80 to 110-day growth cycle. In general, stress plot yields were lower in 1975 (Table 20). Lower overall yields were associated with a low plant density due to the irrigation system used which required planting in wide furrows.

Of those showing reasonable resistance in 1975, P750 appeared to escape the stress by having an extended flowering period and producing pods on later formed flowers. P729, P730 and CIAT G-03836 apparently can withstand stress during the flowering period since they did not have an extended flowering period.

Stability of growth habit

Results obtained in 1974 demonstrated the importance of growth habit stability in promising materials grown in a range of climatic conditions. In 1975, in collabora-

Table 20. **Field evaluation of drought tolerance (1975A), and stress: control yield ratios (1974A), La Molina, Peru.**

Identification		Control yield (tons/ha)	Stress: control yield ratio *	
CIAT No.	Promising No.	1975A	1975A	1974A
G 00073	-	0.61	0.49	0.69
G 01643	P 748	0.66	0.50	1.02
G 01951	P 729	1.13	0.61	0.74
G 02206	P 730	0.91	0.57	1.16
G 03790	P 747	1.22	0.36	0.90
G 03836	-	0.52	0.63	0.87
G 05704	P 689	1.03	0.52	-
G 04109	P 735	0.82	0.51	0.58
G 04115	-	1.34	0.45	1.08
G 04498	P 392	0.91	0.36	-
G 02409	P 359	0.65	0.53	0.49
G 03241	P 734	0.66	0.28	-
G 04118	-	0.92	0.27	1.04
G 04128	P 750	0.84	0.62	0.89
G 04198	-	1.21	0.38	-

* Ratio of stressed yield to irrigated control yield.

tion with Cornell University, five type II selections showing stable growth habits across widely differing conditions in Colombia and Ecuador have been compared with five varieties showing unstable growth habits (variable expression of apical dominance). Eight regimes of temperature, daylength and light intensity were utilized. The results support the field evaluations for stability. Further studies on this character are in progress.

MICROBIOLOGY

Variety-strain interaction

Microbiology studies during 1975 again emphasized varietal response to inoculation, rather than strain testing.

Preliminary experiments at Popayán compared 60 accessions of *P. vulgaris*, either inoculated with the strain CIAT 57, or uninoculated. Differences between accessions varied widely in nodule number, nodule dry weight, yield and percent N (Table 21). In addition, some accessions, for example 72 Vul 26549, appeared to nodulate more easily with soil- or seed-borne rhizobia than did others. Plant nitrogen increased up to eight-fold in some accessions after inoculation (Fig. 8), while overall, yield increased 10 percent.

Ten accessions, including the most promising selections from the above experiment, were then compared at Popayán. The accessions differed in growth habit, nodulation characteristics, flowering and maturity times and maximum LAI. Two blocks of each line were sown, one inoculated with the strain CIAT 57 and lime pelleted; the other pelleted but not inoculated. Replicate samples were taken from each block at weekly intervals through most of the growing season and were tested for reduction of acetylene, nodule number and dry weight, leaf and stem dry weight, seed weight and percentage nitrogen and carbohydrate. The method for measuring acetylene reduction is shown in Figure 9.

Fixation rates of up to 20 μM C_2H_4 produced|plant|hour were achieved (Fig. 10). This level is comparable to fixation rates found in other grain legumes. The maximum levels of specific nodule activity (SNA) obtained, 100-120 uM C_2H_4 produced|g nodule dry weight|hr, also compare favorably with levels reported elsewhere. The duration of fixation was, however, much shorter than has been reported for peanut and soybean with most lines fixing little nitrogen before day 39, or at day 74. Despite this, fixation gains for the ten varieties averaged more than 25 kilograms N_2 fixed|ha, during the 120-day growth period, and inoculated plots

Table 21 **Response of selected lines of *P. vulgaris* to Rhizobium inoculation.**

Line	Uninoculated				Inoculated			
	Nodules|plant	Nodule dry wt. (mg|plant)	Yield (g|plant)	N (%)	Nodules|plant	Nodule dry wt. (mg|plant)	Yield (g|plant)	N (%)
2097.	40.1	91.0	7.55	4.21	105.0	340.0	13.02	4.50
25093	10.5	20.0	3.02	3.67	223.0	627.0	5.36	3.61
25146	1.8	34.0	3.92	3.68	26.3	30.0	1.26	4.99
26259	49.3	29.4	0.67	3.17	47.5	70.0	1.42	4.53
26549	70.9	118.0	4.44	3.13	112.0	396.0	8.38	4.93
26689	4.3	11.0	12.07	3.53	61.5	228.0	16.09	4.71

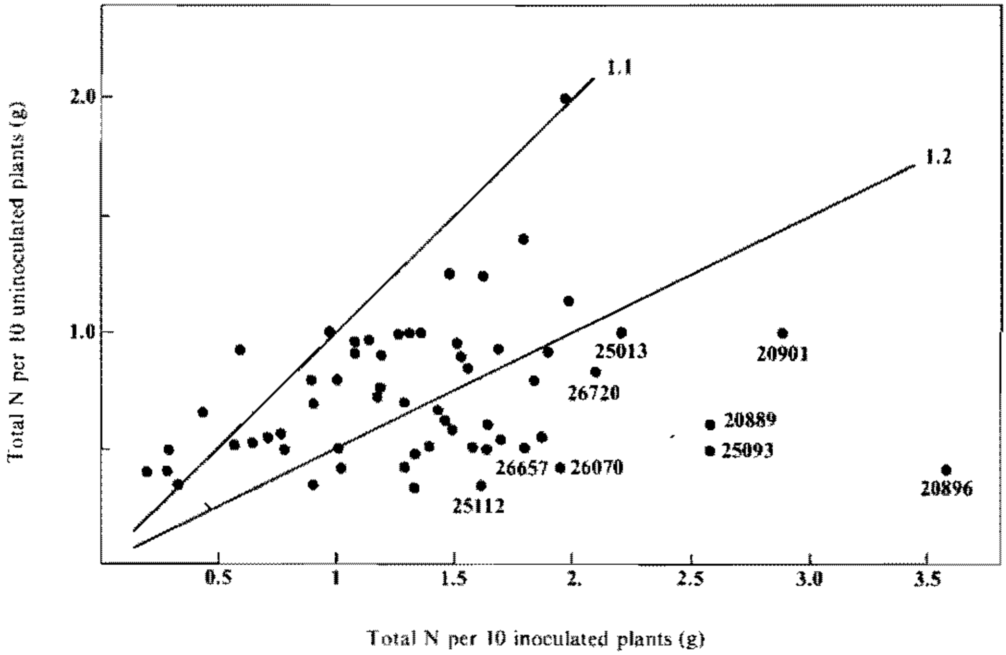

Figure 8. **Increase in total N among 60 accessions of *P. vulgaris* as a result of inoculation. Each dot represents the response of a single accession. Accessions below the 1:2 line more than doubled total N after inoculation and are the most promising for increasing N fixation. Exceptional accessions are named.**

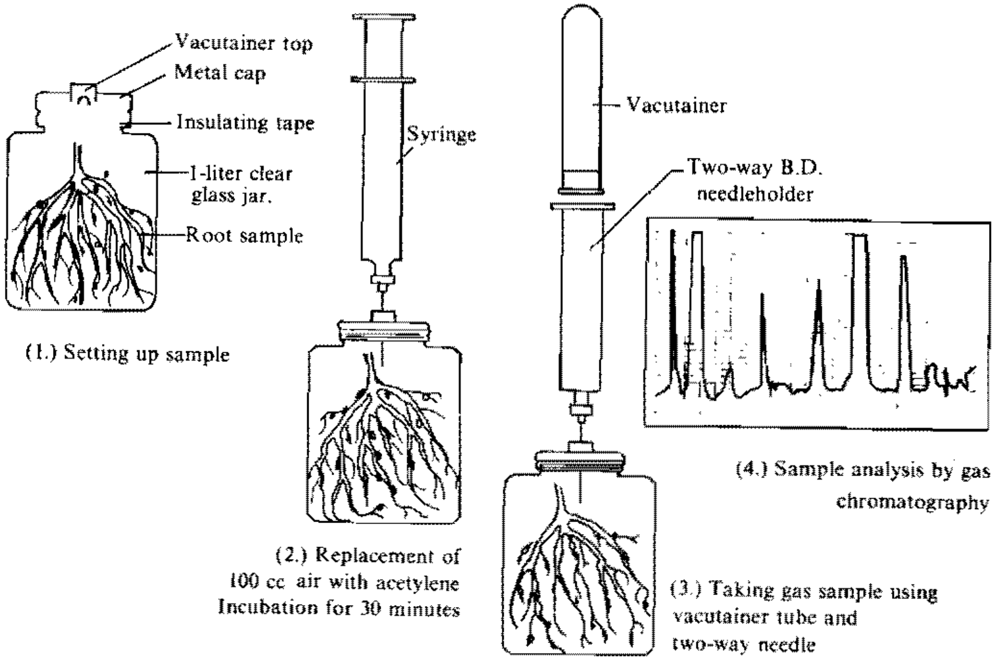

Figure 9. **Measuring N fixation by acetylene reduction.**

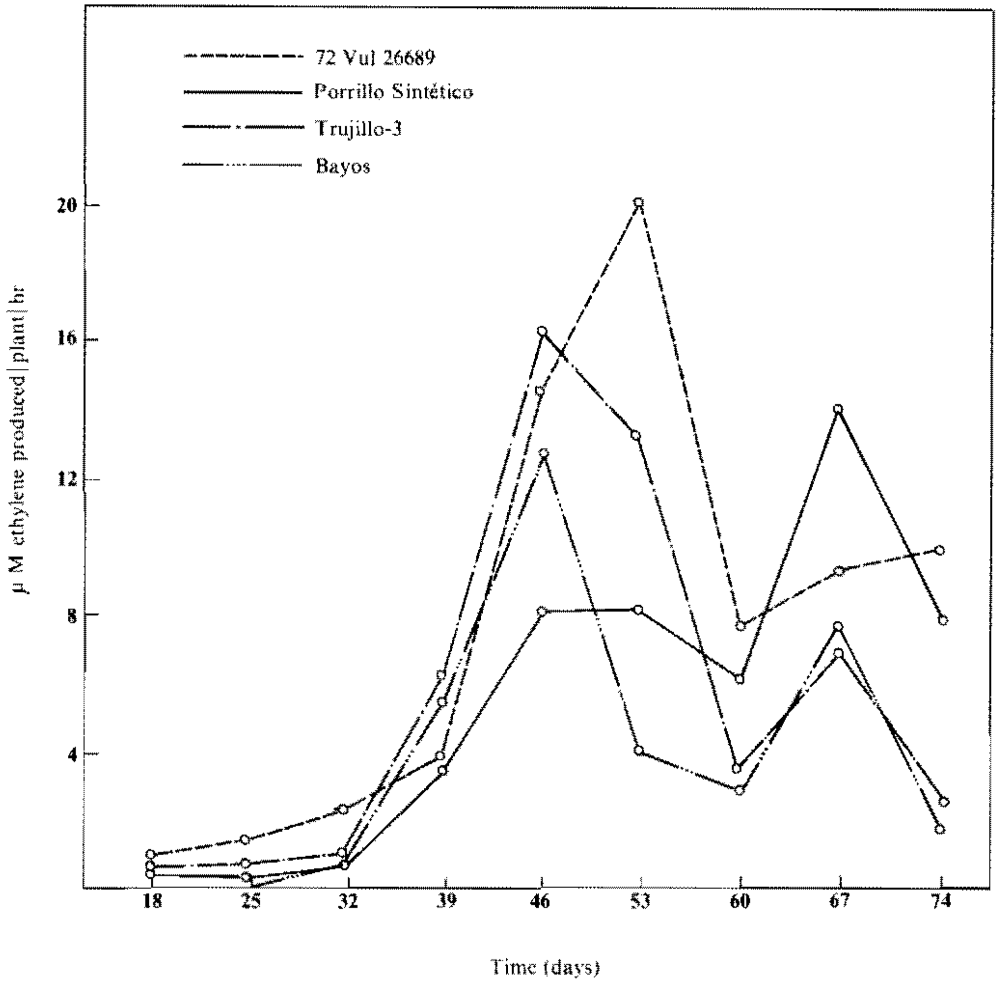

Figure 10. **Acetylene reduction in four varieties of *P. vulgaris* at different stages in the growing season.**

outyielded those without inoculation by 20 percent. Total N accumulation rates, averaged for the 10 accessions, are shown in Figure 11.

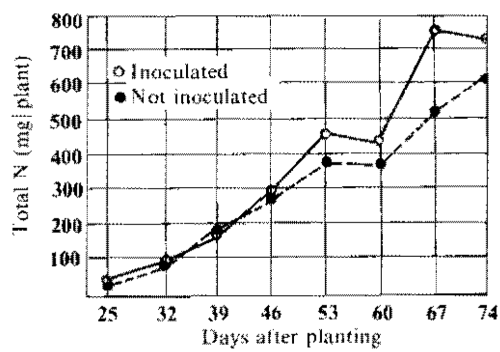

Figure 11. **N accumulation per plant in *P. vulgaris* as a result of inoculation, (averaged for 10 varieties studied).**

The balance and movement of energy in the plant clearly influenced nitrogen fixation by the ten accessions. Thus, (a) fixation | plant and per unit nodule weight dropped near flowering, the decline in specific nodule activity being most dramatic (Fig. 12); (b) accessions which flowered early (i.e. Bayos) fixed much less nitrogen than did late-maturing selections,

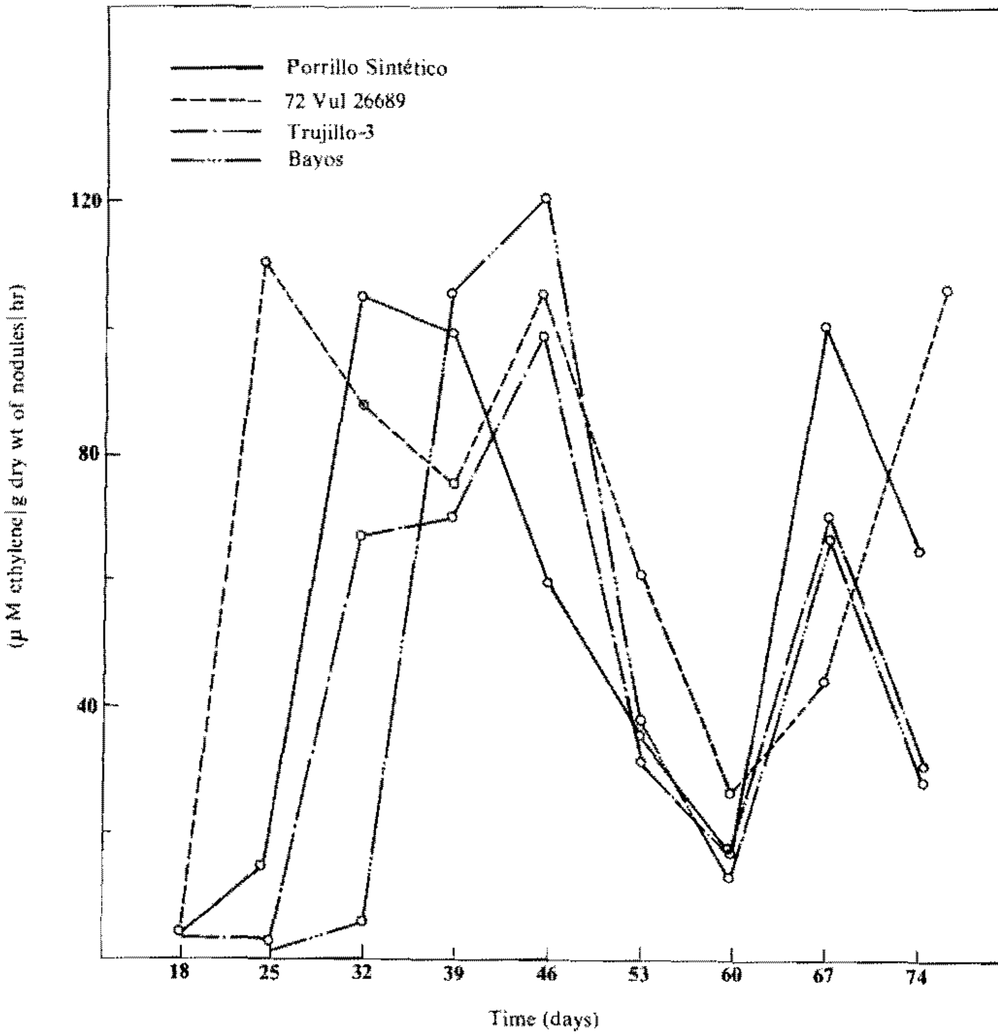

Figure 12. **Change in specific nodule activity (μ M ethylene produced|g dry weight of nodules|hr) during the growing season for four common *P. vulgaris* varieties.**

for example 72 Vul 26689 (Fig. 13); (c) in the preflowering phase nitrogen fixation levels correlated with leaf weight; and (d) levels of fixation|unit leaf weight also differed considerably between varieties with P 566A being low in efficiency of energy utilization for nitrogen fixation (Fig. 14).

Shading (Table 14) and time to maturity studies in beans have demonstrated the importance of sink-source relationships to final yield. Similar balances appear to control nitrogen fixation. Studies in progress are concentrating on the translocation of energy from leaves to roots, and on how growing habits, flowering patterns, and maturity characteristics affect the energy available for fixation. It is of note that CHO levels obtained in these experiments were very similar to those reported in Figure 6.

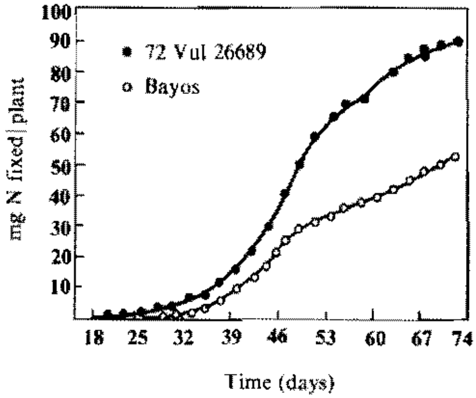

Figure 13. **Cummulative N fixation curves for precocious (Bayos) and later flowering (72 Vul 26689) accessions.**

Results obtained in the glasshouse correlate flowering time to nodule development in *P. vulgaris* (Fig. 15). The microbiology and physiology groups will collaborate in furthering these studies.

Comparison of nitrogen fixation in beans and soybeans

Since *P. vulgaris* is generally considered inferior to soybean in symbiotic nitrogen fixation, an experiment was undertaken at CIAT, to compare fixation in the bean varieties Trujillo 3 (Type IV) and Porrillo Sintético (Type II) with that in the soybean variety Pelikan. Plants were grown in a soil-sand bed and sampled every ten days. Characteristics considered were the same as reported in the experiment on page C-24.

Although Pelikan nodulated slowly, by the 38th day after planting it had developed

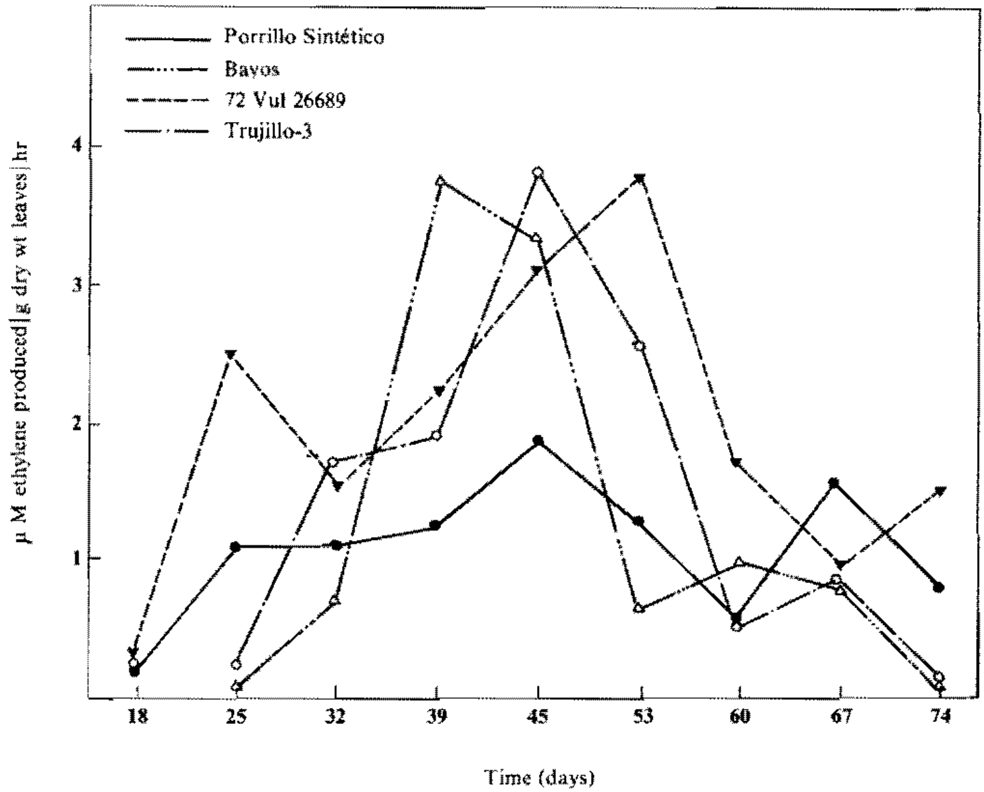

Figure 14. **Acetylene reduction per unit leaf weight in four varieties of *P. vulgaris* during different stages of the growing season.**

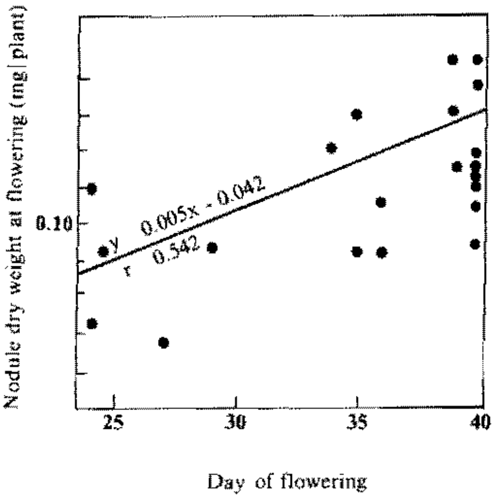

Figure 15. **Relation between days until flowering and nodule dry weight in *P. vulgaris*.**

significantly more nodule tissue than either bean variety, finally producing more than twice the weight of nodules found in Porrillo Sintético or Trujillo 3. Nitrogen fixation also was considerably greater in the soybean (Fig. 16), both bean varieties responding poorly to inoculation under CIAT conditions. Experiments are in progress to determine if this was due to high temperatures. In view of the probable dependence of small farmers on climbing varieties with limited nitrogen applied as

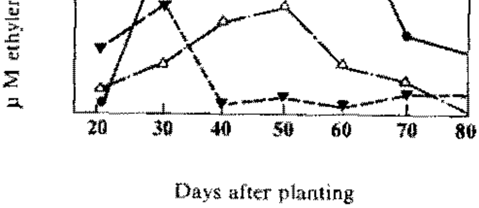

Figure 16. **Levels of acetylene reduction in two bean varieties and one soybean variety during the growing season.**

fertilizer, the poor performance of Trujillo 3 at both Palmira and Popayán is worrying. Studies are continuing to determine whether other Type IV plants respond similarly to inoculation.

Strain trials

Strain trials using the host variety ICA-Pijao were repeated in 1975, the strain CIAT 57 again being most efficient in nitrogen fixation as measured by acetylene reduction. Yield differences were, however, not significantly different.

Inoculant supply

As in previous years the soil microbiology group continued to supply a wide range of **Rhizobium** cultures to both scientists and farmers in Latin America.

ENTOMOLOGY

Empoasca kraemeri

Resistance selection

Screening of accessions in the germplasm bank for leafhopper (*Empoasca kraemeri*) resistance continued to have high priority; screening of all materials for which seed was available was completed this year. About 1,000 lines were selected for further testing. Of those, 395 will also be screened for nymphal populations in the hope of detecting resistance mechanisms other than tolerance. The 14 most promising lines have been selected for diallel crossing to raise resistance levels and measure which parents form the best combinations for this. The lines are P6C, P231, P346, P458A, P478, P511A, P512A, P560B, P680A, P681A, P682A, P722, P723A and PI 200-974.

Resistance levels of 54 varieties were measured in the wet season to compare with results from last year's dry season (Table 22). The yield reduction in wet

Table 22. **Levels of resistance of selected accessions of *P. vulgaris* to *E. kraemeri*, as determined by yield increases resulting from pesticide protection (wet season planting).**

Accession	Yield per plant (g) Not Protected	Protected	Increase (%)
73 Vul 3624	10.88	9.76	-11
PI 200-974	9.03	9.28	3
72 Vul 25221-1	9.58	10.60	11
PI 208-769	7.99	10.42	30
Bunzi	7.95	10.59	34
Line 32	10.06	14.61	45
Brazil 1059	7.19	11.30	57
Brazil 1074	5.52	9.37	70
Brazil 1089	9.98	17.15	72
72 Vul 25299 M	7.89	14.71	86
Brazil 1031	2.34	7.41	217

season plantings was much less, and selection 73 Vul 3624 actually yielded more without pesticide treatments. This suggests that the resistance level found in some lines thus far may be sufficient for a low intensity of **Empoasca** attack. Some lines, however, ranked among the best in the dry season, but performed poorly in the wet season. Specific adaptations probably play a role in these types of experiments.

No high level of resistance to *E. kraemeri* has been found so far within *P. vulgaris*. For this reason other species were tested for resistance in the hope that interspecific crossing might incorporate this resistance into common beans. In preliminary screening higher levels of resistance were found in other species, i.e., in *P. mungo* (Table 23), but the variation in resistance levels in these species also was large. Other

Table 23. **Resistance range expressed in nymphal counts in selections of** Phaseolus **species to** *E. kraemeri.*

Species	Selection no.	No. of nymphs/10 leaves at days after planting: 20	35	50	Avg.
P. acutifolius	1	3	5	4	4.0
	2	17	54	13	28.0
P. lunatus	1	5	11	2	6.0
	2	14	102	37	51.0
P. aureus	1	0	0	1	0.3
(V. radiata)	2	1	2	3	2.0
P. mungo	1	0	0	0	0.0
(V. mungo)	2	0	0	0	0.0
Controls					
Calima	(Susc.)	17	54	18	30.3
73 Vul 299	(Resist.)	3	19	9	10.3

Table 24. **Average number of *E. kraemeri* nymphs emerging per entry in free-choice oviposition tests, and number of males in feeding preference test.**

	Oviposition test		
Accession	Free-choice	No-choice	Feeding test (no. of males)
Diacol-Calima	71.7 a*	75.0	4.6 a
P 680	54.3 ab	58.7	3.3 ab
Brazil 1087	50.0 ab	81.0	2.3 b
ICA-Pijao	46.3 b	53.7	3.6 ab
Brazil 343	36.3 b	67.7	3.3 ab
ICA-Tui	30.3 b	60.0	1.3 c

* Data within columns followed by the same letter are not significantly different at 5 percent level

materials of species crossable with *P. vulgaris* are being evaluated.

Resistance mechanism against E. kraemeri

More detailed studies were made on the resistance mechanism of six bean varieties with different resistance levels. In free-choice oviposition and feeding tests (the latter with males only), a significant oviposition and feeding preference existed for Diacol-Calima, a susceptible variety, compared to ICA-Tui, a tolerant variety and the least preferred (Table 24). However, the nonpreference disappeared when the leafhoppers were confined to one variety only, and equal numbers of nymphs emerged per variety. This indicates that the level of nonpreference is low. Antibiosis was not found in these six varieties (Table 25), nor in 54 additional accessions tested. Tolerance, although found in field screening, could not be measured accurately in laboratory trials.

In trials with excised leaves in nutrient solution, seven adults on each excised leaf caused grade 5.0 damage on Diacol-Calima, after 3 days, and 3.1 on ICA-Tui (scored on a 1-9 scale). Although the observed variation in response was too great for this technique to be used in screening for increases in resistance on individual plants in segregating populations, further studies are in progress to obtain a more precise screening methodology (see also page C-33).

Table 25. **Test for antibiosis in six *P. vulgaris* accessions.**

Accessions	Duration of nymphal stage (days)	Adult survival in 6 days (%)	Avg. weight (μ g)
Diacol-Calima	11.0	94	144
Brazil 343	10.7	79	140
Brazil 1087	11.2	86	133
ICA-Pijao	10.7	94	144
P 680	11.0	92	141
ICA-Tui	10.6	92	141

Table 26. **Life cycle and reproduction of *E. kraemeri* under laboratory conditions on Diacol-Calima plants.**

Development stage	No. of days		
	Min	Max	Avg.
Egg	9	10	9.1
First instar	1	2	1.9
Second instar	1	2	1.8
Third instar	1	2	1.2
Fourth instar	2	2	2.0
Fifth instar	3	3	3.0
Preoviposition period	4	7	5.2
Lifespan	13	86	64.8
	14	80	58.2
No. of eggs	13	168	107.2

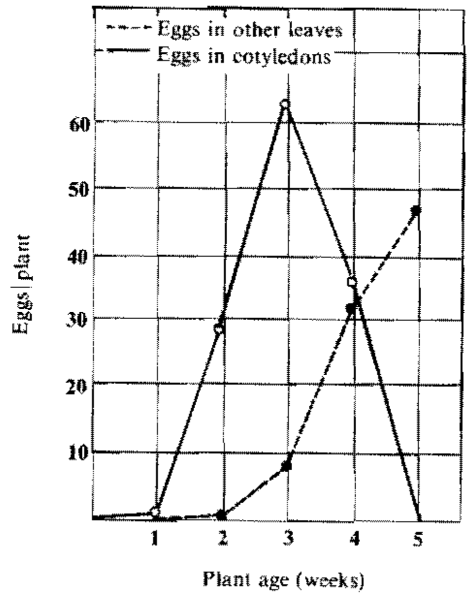

Figure 17. **Distribution of eggs on leaves of Diacol Calima plants during the first five weeks.**

Biology of E. kraemeri

Because bean entomology literature lacks much information on the biology of *E. kraemeri*, a study was made on some aspects of its biology, using the susceptible variety Diacol-Calima as the host. The egg stage lasted almost as long as the nymphal period (Table 26). The period from egg to egg lasted 24.2 days and adults lived an average of two months. The adults preferred the petioles over the leaves as oviposition sites. On line 73 Vul 3624, 82 percent of the eggs were found in petioles and only 18 percent in the leaf blades. A remarkably high percentage of the total eggs per plant were found in the cotyledons. During the first four weeks, more than half the eggs per plant were found in these leaves(Fig. 17). Egg counts were made under the microscope after clearing the leaf tissue with lactophenol.

A relatively high level of egg parasitism by **Anagrus** sp. (Myrmaridae) was found. When plant samples were cleared of insects and subsequent numbers of newly emerged nymphs and parasites were recorded, 60 to 66 percent egg parasitism was found (Table 27). These may be overestimates as some of

Table 27. **Level of egg parasitism of *E. kraemeri* by** Anagrus **sp. (Myrmaridae).**

Treatment	Avg. no. of emerged insects		Parasitism (%)
	E. kraemeri nymphs	**Anagrus** adults	
Field collected plants	11.6	28.5	66
Field exposed plants (4 days)	9.2	14.2	60

the eggs are infertile and newly emerged parasites may oviposit in developing eggs.

The relative damage caused by different developmental stages of *E. kraemeri* was also studied using excised leaves in nutrient solutions. Ten insects in each developmental stage were caged on the leaf, and the number of days until leaves started to curl and dry along the margins was recorded.

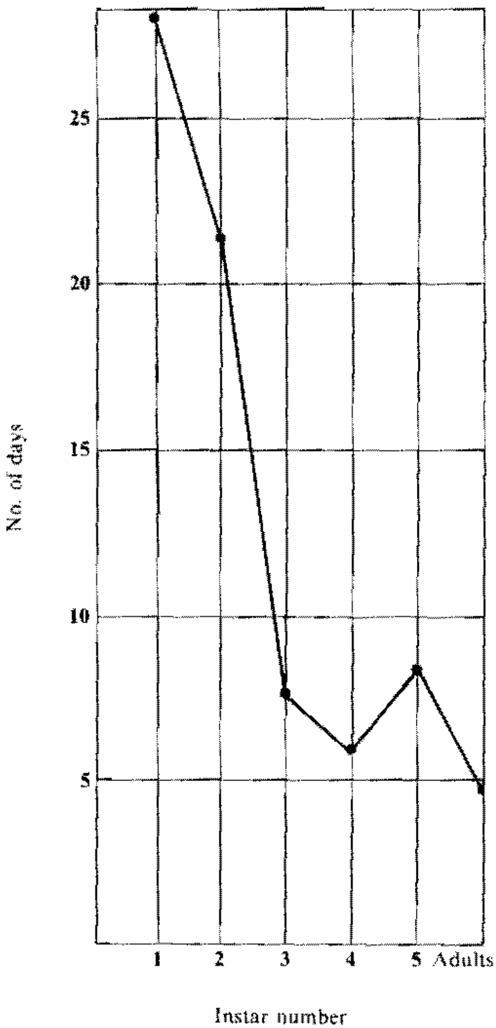

Figure 18. **Days required by 10 insects of each of the six developmental stages to cause a leaf of Diacol Calima to curl and fold along the leaf margins (by Boyliantes).**

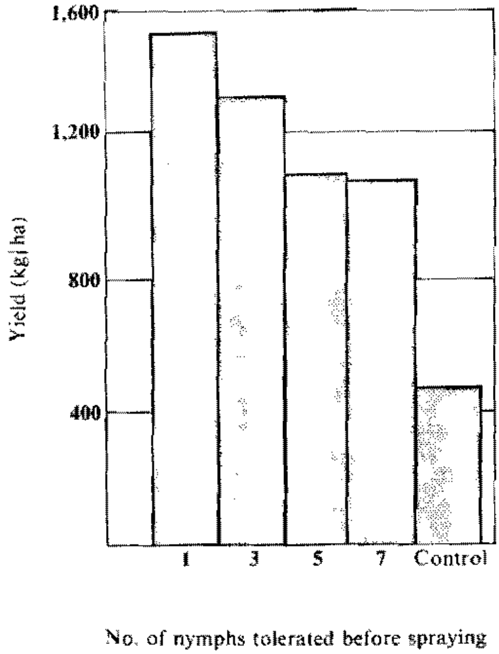

Figure 19. **Yield (kg|ha) of Diacol Calima when azodrin (0.35 liter a.i.|ha) was sprayed when the nymphal population had reached one, three, five or seven insects per leaf (avg. of three replications).**

Preliminary results indicate that adults are more damaging than nymphs and that the fourth nymphal instar is more damaging than the fifth (Fig. 18). In the field there was a close correlation between damage caused by **Empoasca** and the number of nymphs per leaf (Fig. 19). In this experiment monocrotophos (0.35 liter|ha) was applied each time the nymphal population reached one, three, five or seven nymphs per leaf. The frequency of sprays in the treatments with five or seven nymphs per leaf was the same, as after the first application the population did not reach seven per leaf again. These data indicate that for each additional nymph per leaf, yields are reduced by 7 percent. However, the relationship appears non-linear at high nymphal populations.

The plant growth stage most susceptible to **Empoasca** attack was determined by not controlling the insects during one of the following growth stages: planting to first trifoliate formed; first trifoliate formed to 15 days thereafter; from that stage to flowering; from flowering to pod-filling; and from pod-filling to harvest. It appears that beans are most susceptible to **Empoasca** damage from the time the first trifoliate is formed until 15 days thereafter. Control of **Empoasca** up to flowering is essential if yields are to be maintained (Fig. 20). These results are similar to those recorded in Tables 14 and 15. These studies will be used to better define control treatments that are timely and effective against **Empoasca.**

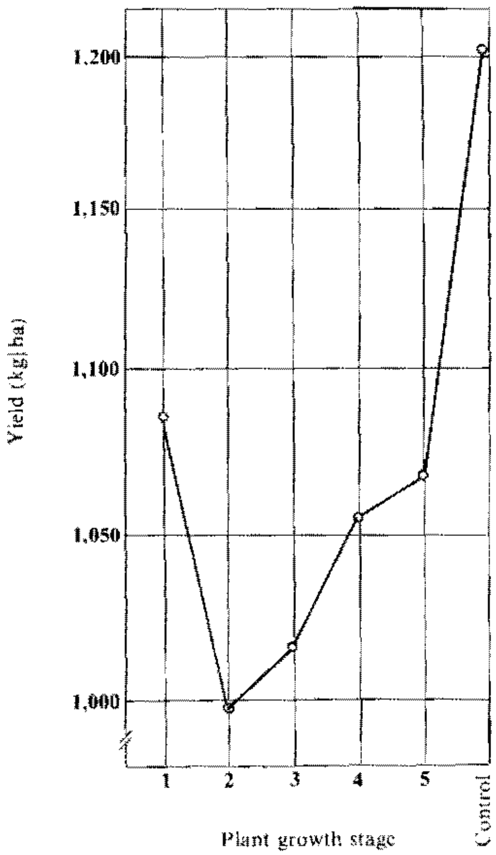

Figure 20. **Yield (kg|ha) on an average of four bean varieties when no insecticides were applied during one of each of five growth stages of the plant.**

Table 28. **Yield reduction by *P. latus* on selected infested and uninfested plants of Diacol-Calima beans.**

No. of plants	No. of pods/plant	Seed/plant (g)
86 uninfested	10.1	13.1
93 infested	5.6	5.8

Mites

Emphasis this year was on the Tarsonemid mite, *Polyphagotarsonemus latus*. Studies of its importance on an individual plant basis showed 56 percent yield loss following mite attack (Table 28). Damage caused by the mite is severe and is often mistaken for virus attack.

The mite multiplies extremely rapidly, passing from egg to egg in only five days under laboratory conditions (Table 29). Each female produces an average of 48.3 eggs (Fig. 21). Chemical control of the mite was effective with carbaryl and monocrotophos.

Whitegrubs

Whitegrubs, Phyllophaga sp., sometimes cause problems on newly cultivated land. A chemical control study showed that carbofuran (3% granular), furrow applied under the seed, and incorporation of disulfoton, aldrin or toxaphene-DDT, in that order, were most

Table 29. **Average length of developmental stages of *P. latus*.***

Stage		Duration range (days)	Avg. duration (days)
Egg		2 - 3	2.03 ± 0.1
Larvae		1 - 2	1.03 ± 0.1
Pseudopupa		1	1.00
Adult	♀	7 - 18	15.06 ± 3.1
	♂	11 - 14	12.50 ± 2.1

* On variety ICA-Pijao in the laboratory (22-28°C)

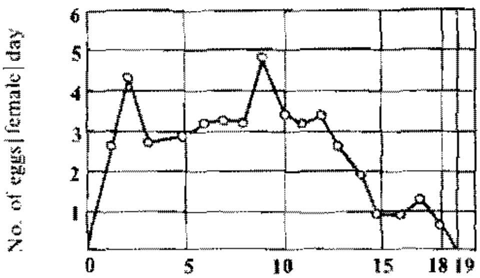

Figure 21. **Oviposition curve of *P. latus* in the laboratory on leaves of ICA Pijao.**

effective in reducing losses of seedlings from whitegrubs (Table 30). While carbofuran was more effective applied in the furrow, endosulfan gave better control when incorporated.

Stored bean insects

The search for resistance to *Zabrotes subfasciatus* was continued because some promising sources like PI 309-709 lost resistance when seed was planted, harvested and retested. From 296 additional lines tested in 1975, 70 were selected as showing promise of resistance expressed as either a low oviposition rate, low percentage adult emergence or slow development. Some examples are presented in Table 31.

Z. subfasciatus can be controlled by storing beans in the pods. Eggs were found on pod walls and larvae penetrated the pods, but died inside without entering the bean seeds (Table 32). The artificial damage to the pods consisted of cutting the pod tips to allow adults to enter at one end.

Chemical control studies were continued with pyrethrin compounds. Dosages of 1.5 ppm gave 120 days protection, while 2.5 and 4 ppm provide longer protection.

Malathion powder (4%) and the fungicide thiram formulated as a mixture of thiram (70%) and methoxychlor (2%) gave good control of **Zabrotes** (Table 33). The critical dosage of thiram for preventing oviposition is around 50 ppm while the commercial dosage for prevention of damping-off is about 638 ppm. Studies are continuing on the use of thiram without the methoxychlor addition.

Table 30. **Number of seedlings killed by whitegrubs following insecticidal treatments. Avg. 4 replicates. CIAT, 1975.**

Material	Rate a.i./ha	Type of application	Avg. no. seedlings killed
carbofuran 3 g	0.9 kg	furrow, underseed	7.3 a*
carbofuran 3 g	0.9 kg	incorporated	27.3 abc
disulfoton 5 g	0.9 kg	incorporated	19.0 ab
aldrin 2.5	1.25 kg	incorporated	20.0 a
toxaphene-DDT (40-20)	1.6 0.8	surface spray	24.5 abc
Cebotox	40.0 kg	incorporated	27.3 abc
endosulfan 3 g	0.9 kg	furrow, underseed	40.0 cd
endosulfan 3 g	0.9 kg	incorporated	29.8 bc
fensulfothion 5 g	2.0 kg	incorporated	26.8 abc
Dotan 5 g	0.5 kg	incorporated	35.3 bc
Check	–	–	68.3 d

* Values followed by the same letter are not significantly different at the 5 percent level.

Table 31. **Examples of selections expressing different degrees of resistance in preliminary tests to *Z. subfasciatus*.***

Selection	Selected for:	No. of eggs	Emergence (%)	Developm[ent] period
Brazil 1034	Low oviposition	9.0	38.8	46.7
P 364 B	Low % emergence	41.5	20.5	52.2
P 514	Slow development	95.0	47.4	51.2
Diacol-Calima (Susc. check)		100.0	84.0	48.8

* Average of two replications, 50 seeds infested with four pairs of adults | replication.

Table 32. **Infestation of *Z. subfasciatus* after exposing undamaged and damaged pods and shelled seed.***

Treatment	No. of eggs | replication	No. of adults | replication
Undamanged pods	0.8	0.8
Damaged pods	162.0	111.7
Shelled beans	203.7	162.8

* 100 seeds of Diacol-Calima per replication seven pairs of adults in each replication.

PLANT PATHOLOGY

Common bacterial blight

Screening for resistance

Field screening for tolerance to common bacterial blight was continued. During the first semester, 366 varieties from CIAT and Michigan State University were tested by inoculating with *Xanthomonas phaseoli*,

Table 33. **Control of *Z. subfasciatus* with malathion and thiram | methoxychlor.***

Treatment level (ppm a.i.)	Mortality at five days (%)	No. of eggs | replication	No. of adults | replication	Emergence (%)
malathion powder (4%)				
0	27.8	259.0	131.8	50.9
5	91.4	12.0	2.4	20.0
10	100.0	9.4	0.0	0.0
20	100.0	5.8	0.0	0.0
40	100.0	6.8	0.0	0.0
thiram powder (75%) and methoxychlor powder (2%)				
0	2.9	236.4	100.4	42.5
113	50.0	3.2	0.0	0.0
375	85.7	0.0	0.0	0.0
638	98.6	0.0	0.0	0.0
900	100.0	0.0	0.0	0.0

* Average of five replications, seven pairs of adults | replication, on Diacol-Calima.

isolate C6, using methods similar to those reported in 1974. Tolerance of the varieties Jules, Tara and PI 207-262, which were screened previously, was confirmed (Table 34). P561 and seven MSU lines were highly tolerant to common bacterial blight. Some question remains, however, as to the virulence of the C6 isolate.

Screening method using excised leaves

A rapid method for screening tolerance to common bacterial blight was sought. Trifoliate leaves of nine varieties were excised and petioles inserted in distilled water in Erlenmeyer flasks. The leaves were inoculated with *Xanthomonas phaseoli*, isolate C6, by the water soaking method and maintained in a humid chamber. Symptoms appeared at seven days and observations were made ten days after inoculation. The same reactions as in the field were observed in all varieties tested, with the exception of Duva (Table 35). Further work needs to be done on aspects such as inoculum level, leaf age and medium for maintaining leaves, but the method seems valuable in detecting foliage reactions to the disease.

Table 34. **Foliage reaction of bean varieties and lines to *Xanthomonas phaseoli*, isolate C 6, at CIAT.**

Variety or line	Reaction
Jules	1.5*
Tara	1.5
P561	1.5
P458	1.5
MSU 42.772	1.5
MSU 42.842	1.5
MSU 42.935	1.5
MSU 42.950	1.5
MSU 42.954	1.5
MSU 42.964	1.5
MSU 43.009	1.0
Seafarer (susceptible check)	4.0
Vigna sinensis (cowpea)	0.0

* Rating: 0 = no visual symptoms; 1 = highly tolerant; 2 = tolerant; 3 = slightly susceptible, 4 = susceptible; and 5 = highly susceptible.

Table 35. **Foliage reaction of field-grown plants and excised leaves of bean varieties to *Xanthomonas phaseoli*, isolate C 6.**

	Foliage reaction	
Varieties	Field	Excised leaves
Tara	T*	T
Jules	T	T
G.N. # Sel. 27	T	T
PI 207-262	T	T
Red Kidney	I	I
Sanilac	S	S
Gratiot	S	S
Seafarer	S	S
Duva	S	I

* Rating: T = tolerant; I = moderately susceptible; S = susceptible.

Rust

Screening for resistance

In 1975 an evaluation was made of 1,500 accessions from the germplasm bank; 196 were resistant and will be incorporated into an International Bean Rust Nursery (IBRN) to be tested against races of the fungus not found at CIAT.

An IBRN of 108 entries, resistant to rust in various countries, was sent to 14 cooperating institutions during the year. Twenty sets were shipped, and results are already available for six. The accessions Ecuador 299 and Compuesto Chimaltenango 2 were resistant in all six countries.

In the IBRN planted at CIAT, 13 races of *Uromyces phaseoli* var. **typica** were reported. The evolution of races of the fungus was studied in a continuous screening nursery. Races 3,8, 10, 28, 29, 32 and 33 were found, the most prevalent being 29 and 33. Based on their reaction with the differential variety US 814, two biotypes were identified, one corresponding to race 3 and the other to 29.

Losses due to rust

In an experiment similar to that described in the 1974 Annual Report, ICA Tui and ICA Pijao, susceptible and tolerant varieties, were infected with rust spores at different stages of plant development.

The yield of the susceptible variety Tui was reduced 85 percent when the infection occurred the first week after emergence and 82, 80, 77, 24, 18 and 11 percent, respectively, during successive weeks, as compared to the tolerant Pijao, which was reduced 34 and 31, 28, 21, 14, 10 and 4 percent, respectively.

Chemical control

To determine the best chemical control for rust, the variety ICA Tui was planted and then sprayed with various protectants 15, 25 and 35 days after emergence. A preliminary evaluation was made five days after the last application. Plots protected with maneb (3 kg|ha) yielded 100 percent more than the control. Chlorothalonil (2.5 kg|ha) and fentin acetate (0.8 kg|ha) increased yields 85 percent, whereas triforine (1.5 liters|ha), pyracarbolid (3.0 liters|ha), carbendazim (1 kg|ha) and oxycarboxin (1 kg|ha) yielded 55, 52, 40 and 30 percent, respectively, more than the control. In one of the two semesters in which the experiment was carried out, benodanil performed as well as triforine, pyracarbolid and oxycarboxin.

Mixtures of the best fungicides were tested. Oxycarboxin plus captafol increased the yields of Porrillo Sintético 64 percent, as compared to increases of 48 percent in mixtures of oxycarboxin with chlorothalonil, fentin acetate and maneb or tridemorph with fentin acetate.

Anthracnose

Screening for resistance

Using a screening technique similar to that for rust, 100 accessions, selected from among accessions reported to be resistant in other countries, were tested at Popayán (1,600 m) and Bogotá (2,600 m). Preliminary results indicated that Cornell 49,242, Widusa, Preto 141 and 145 and P459 were resistant at both sites. The reaction of some accessions differed from one site to another, suggesting the presence of different races of the fungus *Colletotrichum lindemuthianum*.

Losses due to anthracnose at Popayán

Diacol Nima and Diacol Andino were used as susceptible and tolerant varieties, respectively. The plots, replicated four times, were inoculated weekly for seven weeks after emergence. The absolute control was protected with benomyl (0.5 kg|ha), applied weekly. The inoculated plots were also protected up to 15 days before the inoculation. The inoculum (50,000 conidia|ml in distilled water) was applied as a low-pressure spray, late in the afternoon when the relative humidity was about 100 percent.

Yields of the susceptible variety Diacol Nima were reduced 95 percent when infection occurred one week after emergence. During the next four weeks, losses remained constant at around 88 percent and then declined to 38 and 27 percent after the sixth and seventh weeks. This pathogen causes serious losses during the whole growing period, not only due to foliar infections but also to stem and grain infections. In the tolerant variety Diacol Andino, the weekly losses were 10 percent less than in the susceptible Nima. When the environmental conditions for infection were not particularly suitable, loss patterns were similar to those for rust.

Chemical control

As shown in the agronomy section (p. C-50), more careful chemical control of anthracnose is required for second-semester plantings in Popayán than for those of the drier first semester (Table 36).

Table 36. **Chemical control of anthracnose in the variety Diacol Nima (Popayán, 1974B, 1975A).**

Fungicides	Dose (kg/ha)	Yield (kg/ha)		% of increase over the control	
		1974B	1975A	1974B	1975A
captafol	3.5	1,157	1,602	2,471	393
benomyl	0.5	960	1,283	2,033	295
carbendazim	0.5	871	1,845	1,936	468
maneb + zinc ion	3.0	724	1,406	1,509	333
carbendazim	1.0	711	1,617	1,480	398
chlorothalonil	2.5	595	1,003	1,222	209
fentin acetate	0.8	523	1,539	1,062	374
captan	3.5	279	1,287	520	296
thiabendazole	0.5	175	632	289	94
sulfur	3.0	126	331	180	2
copper hydroxide	2.0	115	641	155	97
oxycarboxin	1.0	41	491	9	52
quintozene	4.0	37	561	18	73
Control	-	45	325	0	0

The increases obtained were spectacular. Captafol, benomyl and carbendazim raised yields to 2,471, 2,033 and 1,936 percent for the second-semester crop and 468 percent for the first semester. This pathogen is the major yield-limiting factor at Popayán

Common bean mosaic virus (CBMV)

Seed contamination

Because CBMV is transmissible through seed, the use of virus-free seed makes it possible for farmers to raise their yields significantly (1974 Annual Report). However, the reproduction of this seed requires special care, which is difficult for farmers to do themselves. Experiments were therefore designed to establish the recontamination of seed under field conditions. When plots were planted with clean seed, away from sources of contamination, the harvested seed remained free of virus. However, in plots planted close to contaminated plants, transmission was 16 and 15 percent for the susceptible varieties ICA Gualí and ICA Duva and 8 and 6 percent for the tolerant ICA Tui and P459, when the few aphids present in the field were not controlled. When the vector was chemically controlled, the level of contamination was significantly reduced.

Seed transmission in various promising materials observed varied from 10 to 60 percent.

Screening for resistance

Some accessions resistant and tolerant to CBMV were retested with various strains of the virus. The varieties Top Crop, Monroe, Jubila, Widusa, Amanda, Pinto 114 and the CIAT accessions P393, P323, Perú 0257 and PI 146-800 were selected as sources of resistance to be incorporated into the breeding program.

Losses due to CBMV

The long-term study of economic losses resulting from CBMV was concluded this year; the methods used are given in the 1974 Annual Report. Yield reductions of 94, 95, 85, 68, 43 and 20 percent were determined for the two red varieties, ICA Gualí and ICA Duva, as compared with 89, 79, 36, 34, 29 and 16 percent for the two black varieties, ICA Tui and Jamapa, for the plots artificially inoculated with the virus every week for seven weeks after germination.

Bean golden mosaic virus (BGMV)

Screening for resistance

No source of resistance to BGMV has been identified in the 3,700 accessions studied to date. An International BGMV Nursery has been established to test further tolerant collections selected in collaboration with the Instituto de Ciencias y Tecnología Agrícola (ICTA) in Guatemala. Seed multiplication is being carried out for the 144 collections included. The IBGMN will be planted in several locations in Brazil, Puerto Rico, Jamaica, Guatemala, El Salvador, Costa Rica, Colombia, the Dominican Republic, Nigeria, Kenya and India. The first IBGMN was planted only in Guatemala, and some materials with apparently higher tolerance than Turrialba 1 and Porrillo 1 were selected. These materials were CIAT P747, P474, G-02689, P516, P657, P675, P544, P-5 and Guatemala 417.

Identification and purification of BGMV

CIAT is attempting to develop a means of identifying the numerous viruslike diseases of beans in Latin America, which would not involve carrying living material from one country to another. A bank of antisera is being built up for this purpose for those viruses found in Latin America and the Caribbean islands.

Bean golden mosaic, isolated from El Espinal (Colombia) and Santa Tecla (El Salvador), was studied in 1975. Mechanical transmission was highly improved, and 100 percent infectivity was obtained by grinding 15- to 20-day-old infected leaves in phosphate buffer, 0.1M, pH 7.5, plus 1 percent 2-mercaptoethanol. The plants were inoculated in both primary leaves, which had been previously dusted with 600-mesh carborundum. The concentration of the virus in the plant dropped dramatically 40 days after inoculation; the molarity of the buffer also played an important role in its stability.

The virus was kept viable in dessicated tissue over $CaCl_2$ at 4°C for up to three months. It was found to have a thermal death point of 55°C, a dilution end point of 1:128 and an aging in vitro at 23°C of 72 hours. The virus was stable in the buffers phosphate, herpes and borate at 0.1 M, pH 7.5; less so in Tris. HCl; and not at all in EDTA.

The virus was purified by treatment with 7 percent n-butanol, precipitation with Baker polyethylene glycol 6000 plus NaCl (6 and 1 percent, respectively), and centrifugation on sucrose density-gradient columns. A zone formed at 2.3 cm from the meniscus contained the causal agent of the bean mosaic disease, as shown by repeated infectivity assays. Samples from healthy extracts taken at the same depth did not show any infectivity.

The particles of the BGMV have a special morphological structure; they appear in dimers, and the bonded sides of the paired particles have a flattened appearance (Fig. 22). Almost no single particles were seen (100:1). The bonded particle measured about 32 x 19 mm.

Antiserum prpared against the Colombian form of BGMV will be used to compare the virus forms present in the different countries of Latin America and the Caribbean islands.

Bean chlorotic mottle virus (BCMV)

This virus is transmitted by *Bemisia tabaci*. The natural host is *Rhinchosia minima*, a common tropical weed. In

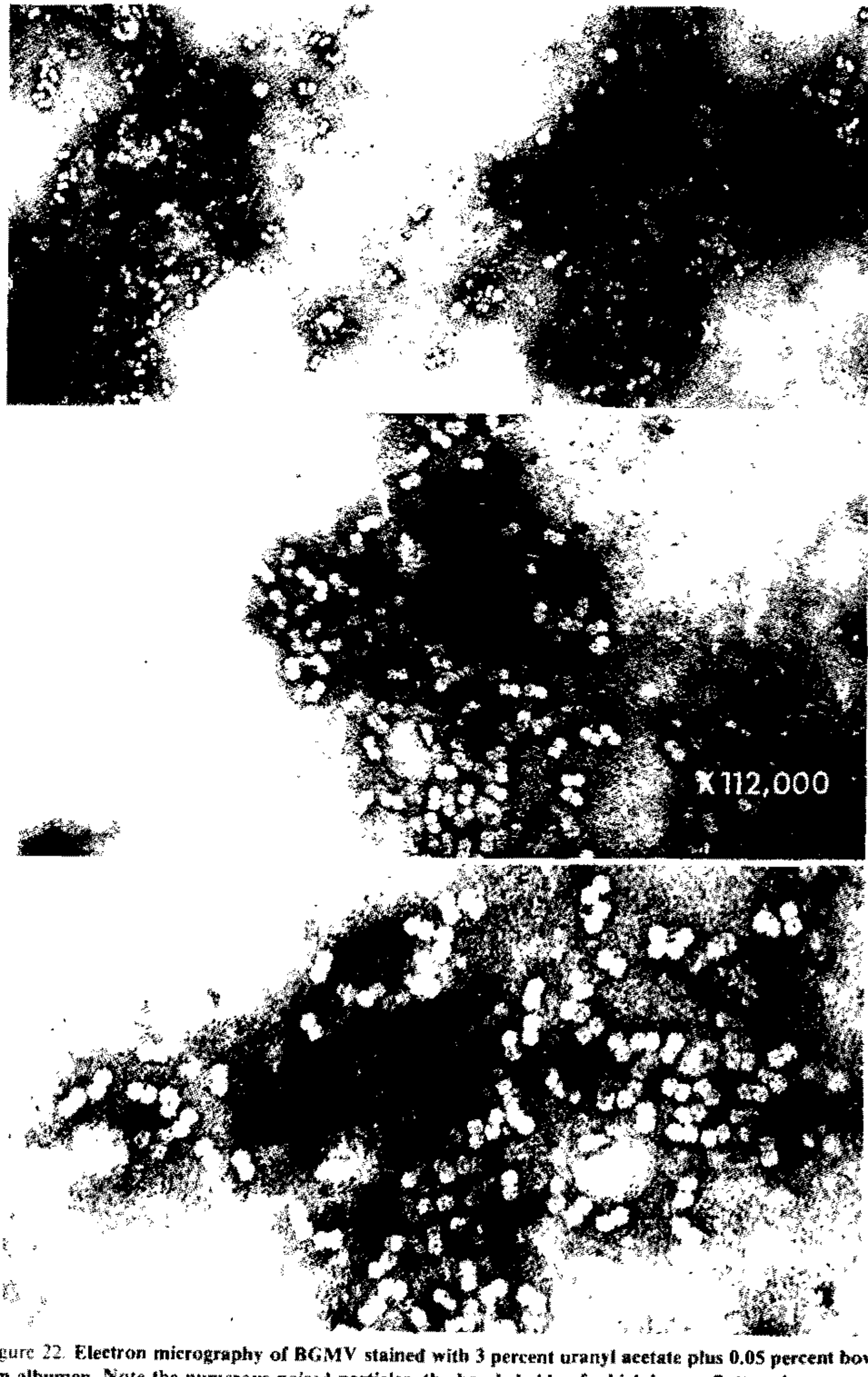

Figure 22. **Electron micrography of BGMV stained with 3 percent uranyl acetate plus 0.05 percent bovine serum albumen. Note the numerous paired particles, the bonded side of which have a flattened appearance.**

soybeans, it causes a disease with symptoms similar to those of BGMV in beans. The symptoms of the virus on beans are chlorotic mottled patches and some curling and deformation of the leaves. In some varieties it causes witches'-broom and severe stunting symptoms. Studies are under way to determine whether chlorotic mottle, Rhincosia mosaic, mottled dwarf, crumpling, Abutilon mosaic, Euphorbia mosaic and Sida mosaic diseases are caused by the same virus. An International Uniform Host Nursery, ready to be sent to different collaborators in Latin America, the Caribbean islands, Africa and Asia, will help in the identification of this complex in the near future.

Screening for resistance

Resistance to chlorotic mottle was not difficult to find. The CIAT collections P-6, P458, P527, P225 and P457 are highly resistant to this virus; Panamito 27R and ICA Duva are highly susceptible.

Rugose mosaic (RMV) and swelling mosaic (SMV) viruses

The RMV and the SMV, transmitted by several beetles, are increasing in importance in Guatemala and El Salvador. The 1974 studies on identification and characterization have been continued by trainees from El Salvador and Mexico. The two diseases belong to the same group of multicomponent viruses, and antisera against all the strains found in Guatemala, El Salvador, Costa Rica and Colombia have been prepared. They show that all these diseases may be caused by the same virus, consisting of several strains. There are several sources of resistance that could be incorporated into new varieties.

Artificial defoliation to estimate disease losses

Percentage of defoliation versus time of defoliation

These experiments, started in 1973, were concluded this year. The results (Fig. 23) confirmed previous observations on the varieties ICA Gualí (red) and Porrillo Sintético (black). It is clear that the most critical stages are initiation of flowering and the pod-filling period, following the seedling stage. After the initiation of the physiological maturity, defoliation has little effect on yield. These results fully support those obtained in physiological studies (p. C-19).

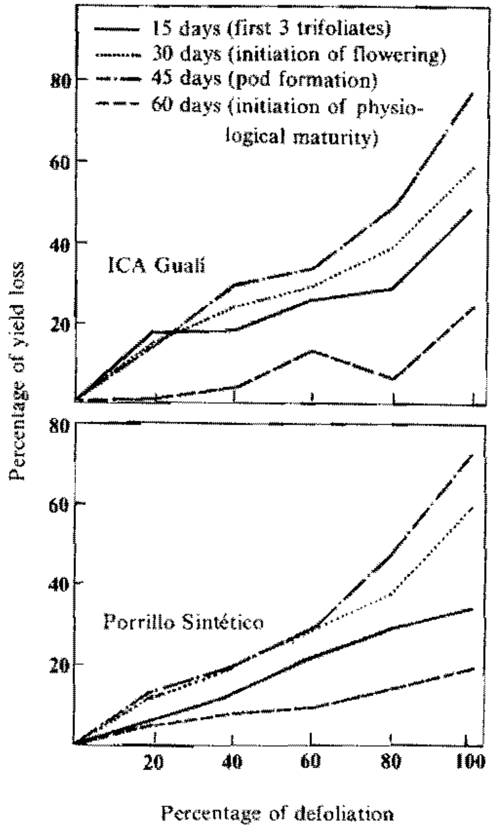

Figure 23. **Losses due to artificial defoliation in the varieties ICA Guali and Porrillo Sintético at CIAT, (1975).**

Seed pathology

Production of seed free from pathogens

The rationale and benefits from the use of clean seed have been presented in previous annual reports. Cleaning seed of seed-borne pathogens continued as a priority project. A total of 1,453 varieties and collections were cleaned in the screenhouse. Included were promising materials for the breeding program, differential varieties of several pathogens, the IBRN, as well as varieties from Colombia, Guatemala, Peru, Honduras, Ecuador, Mexico and Chile. A total of 1,008 were further increased in field plantings.

The search for areas to produce clean seed continued, and cooperative projects are under way in Brazil, Peru, Guatemala, Ecuador and Colombia. Studies are also considering the possibility of producing seed of certain varieties in regions unfavorable to particular pathogens rather than to send it back to the original location.

Internally seed-borne fungi

Seed collected as part of the agro-economic survey reported on page C-3 was assayed for percentage of germination and internally seed-borne fungi. An assay was made of 100 seeds from each of nine seed lots per departamento.* Internally seed-borne fungi representing the following genera and species were recovered from the seeds: *Aspergillus niger*, **Aspergillus** spp., **Penicillium** spp., *Fusarium oxysporum*, **Fusarium** spp., *Rhizoctonia solani*, *Colletotrichum lindemuthianum*, **Phomopsis** spp., **Alternaria** sp., **Rhizopus** sp., **Monilia** sp., **Cladosporium** sp., **Peyronellaea** sp., *Isariopsis griseola*, *Macrophima phaseoli*, **Botrytis** sp., **Acrostalogmus** sp., *Sclerotinia sclerotiorum*, **Pestalotia** sp. and several other unidentified fungi.

Of the 3,600 seeds assayed in this study, 1,154 (32 percent) contained internally seed-borne fungi. Of the seed that contained fungi, 823 (71 percent) did not germinate. **Fusarium** spp. were isolated from 32 percent of the nongerminated seeds, followed by **Phomopsis** sp. (13 percent), *Colletotrichum lindemuthianum* (9 percent) and *Rhizoctonia solani* (8 percent). A typical screening for internal seed-borne fungi is shown in Figure 24, which compares seed from Huila with CIAT clean seed.

Seed from Huila had more internally seed-borne fungi and less germination than seeds from the other three departamentos (Table 37). Of 900 seeds assayed from Huila, 737 (81 percent) contained fungi and 536 (60 percent) did not germinate. Seed lots from Huila had as much as 100 percent infection by fungi and only 8 percent germination. This study indicates that internally seed-borne fungi are an important factor in reducing seed quality and germination.

Fungicide seed treatment

Movement of fungicides into seeds and their effect on internally seed-borne fungi and bean germination

Poor-quality commercial seed of the variety Tui was studied in detail. The percentage of seeds with internally seed-borne fungi and the percentage of germination were 88 and 41, respectively. Fungi representing seven genera were located within the seed coat (testa) tissues and occasionally in embryo tissues (cotyledons). When captan and thiram were applied to the seeds, they penetrated the seed coat tissues and occasionally the embryo; they effectively controlled fungi within the seed coat (Table 38). Benomyl (a systemic fungicide) also penetrated the seed coat and the embryo and was effective against fungi. Fungicide seed treatment significantly increased the percentage of germination on PDA and emergence in sterile soil and in the field and significantly reduced the percentage of fungi in seeds. The use of fungicides for seed treatment would be beneficial where poor-quality seeds must be used for planting.

* A Colombian political division similar to a state or province

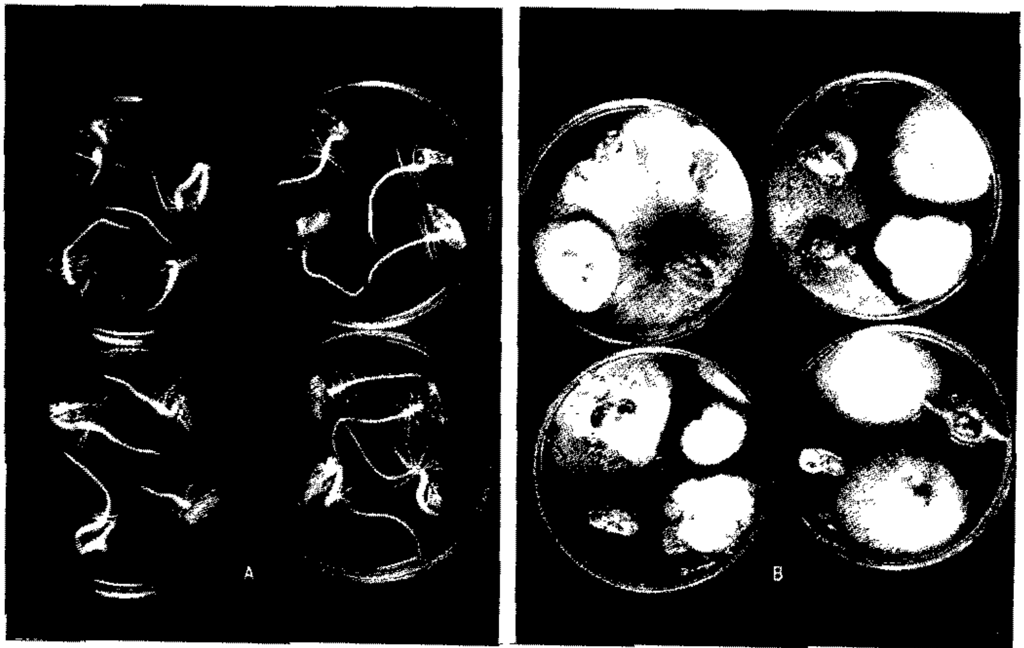

Figure 24. CIAT clean seed (a) and diseased seed (b) from Huila. Notice the amount of seed-borne fungi in the Huila lot.

When high-quality, disease-free seeds were treated with various fungicides, there were no benefits; however, when low-quality, diseased seeds were treated with the same fungicide, significant increases in percentage of emergence and stand were obtained.

AGRONOMY

Varietal trials

The testing of accessions for yield potential under experimental conditions was intensified during 1975 with 14 yield trials sown to date. Three levels of testing have been used:

(1) In Preliminary Variety Trials large numbers of materials are screened at CIAT, then sometimes screened a second time at the higher altitude location of Popayán. Accessions are grown under competitive conditions with replications.

Of the 750 promising selections the bean team has identified to date, 331 were

Table 37. **Mean percentage of germination in vitro, total fungi and seeds with fungi that did not germinate from seeds from four departamentos in Colombia.***

Departamento	% of germination	% of total fungi	% of nongerminated seeds with fungi
Huila	40	82	60
Valle	91	10	7
Antioquia	88	17	10
Nariño	86	19	11

* Based on 100 seeds per each of nine seed lots per departamento.

Table 38. **Percentage of internally seed-borne fungi, germination in vitro (PDA), and emergence in sterile soil (greenhouse) and in the field of poor-quality seed (*P. vulgaris* cv. Tui), either nontreated or treated with captan, thiram, or benomyl.**

	Germination in vitro (PDA)	Emergence		Total fungi
		Sterile soil	Field	
captan	73	68	53	14
thiram	72	66	52	15
benomyl	73	65	47	12
Control	41	33	35	88
LSD 5%	19	18	8	13
1%	29	28	12	21

selected for high yield potential and are of the non-climbing type. One hundred twenty-six of these have passed through Preliminary Variety Trials. Seed of the remaining materials is being cleaned and|or multiplied for testing during 1976. Most high yielding varieties are black seeded, but some promising accessions of other colors have also been identified. Evaluation for common bean mosaic virus, rust and bacterial blight are included in these trials.

(2) Uniform Variety Trials, using the same 40 high yielding varieties in each, have been planted at CIAT, Popayán, and Montería in Colombia and at Boliche, Ecuador. The major aim of these trials is to test adaption of promising materials to different environmental conditions.

The Uniform Variety Trials from CIAT, Popayán and Boliche have been harvested; the highest yielding varieties from each location are shown in Table 39. Four of the best five varieties from 1974 trials (five locations) are again among the highest yielding varieties this year. The highest yielding varieties with the best adaptation were P459 (Jamapa), P302 (PI 309-804), and P511 (S-182-R), while P675 (ICA-Pijao) and P560 (Var 51051) were high yielders in only some of the locations. The variety P566 (Porrillo Sintético), the highest yielder in the 1974 trials, suffered severely from bacterial blight and ranked only tenth in 1975.

(3) International Variety Trials are intended as a collaborative activity in which promising lines from CIAT or national bean breeding programs would be tested over many locations.

During the second semester, five trials were seeded in various locations in Colombia and Ecuador to determine the most appropiate methodology for these trials. The format used is shown in Table 40. This experimental methodology as proposed by the CIAT bean team, was discussed during the Bean Plant Breeding Workshop in October. Suggestions from workshop participants will be taken into consideration, with the modified International Variety Trials to be sent to collaborating institutions in early 1976.

Bean fertilization studies

Boron fertilization

Earlier studies on boron deficiency, a major problem on the CIAT farm are reported in the 1973 and 1974 Annual Reports. In 1975 a few additional studies were undertaken, mainly to determine residual effects of B applications and varietal differences. Figure 25 shows the effect of B applications on yields of three

Table 39. **Highest yielding bean accessions in three Uniform Yield Trials in 1975, compared with 1974 trials.**

Location	CIAT accession no.	Name	Yield (tons/ha)	Growth type	Color
CIAT (1975B)	P-459*	Jamapa V.	3.32	II	black
	P-737	Jamapa CR.	3.09	I	black
	P-511*	S-182-R	3.07	II	black
	P-302*	PI 309-804	2.98	II	black
	P-560*	Var 51051	2.96	II	black
	P-506	73 Vul 6542	2.95	II	white
Popayan	P-498	Puebla 152	3.09	III	black
	P-302*	PI 309-804	3.04	II	black
	P-512	S-166-A-N	2.84	II	black
	P-588	ICA-Huasano	2.82	II	black
	P-326	PI 310-740	2.80	III	black
	P-459*	Jamapa V.	2.78	II	black
Boliche	P-302*	PI 309-804	2.56	II	black
	P-459*	Jamapa V.	2.52	II	black
	P-445	Guat. 2226	2.47	II	black
	P-675*	ICA-Pijao	2.46	II	black
	P-418	Col. 12-E	2.42	II	black
	P-511*	S-182-R	2.37	II	black
1974 Trials**	P-566	Porrillo Sint.	2.3 - 2.8	II	black
	P-675*	ICA-Pijao	2.3 - 3.1	II	black
	P-737*	Jamapa CR.	1.9 - 2.7	I	black
	P-459*	Jamapa V.	1.8 - 2.6	II	black
	P-560*	Var. 51051	2.1 - 2.5	II	black

* Among best materials in at least two trials

** Yields are the range for trials at the three above locations

Table 40. **Proposed experimental methodology for International Bean Variety Trials.**

Number of entries: 25, of which 20 are common to all sites and 5 are local varieties or selections; of the 20 common varieties, 10 are black and 10 are of other colors.

Design: Triple lattice, with three replications.

Plot size: 3 x 5 = 15 m², consisting of 6 rows of 5 meter length with 50 cm between rows; the area to be harvested is 2 x 4 = 8 m².

Plant Population: By thinning adjusted to 250.000 plants/ha.

Insect and disease control: As locally recommended for good bean production; one additional replication or two split replications can be planted without insect and/or disease control for local observations on disease and insect resistance.

Fertilization, weed control, and irrigation: As locally recommended for good bean production.

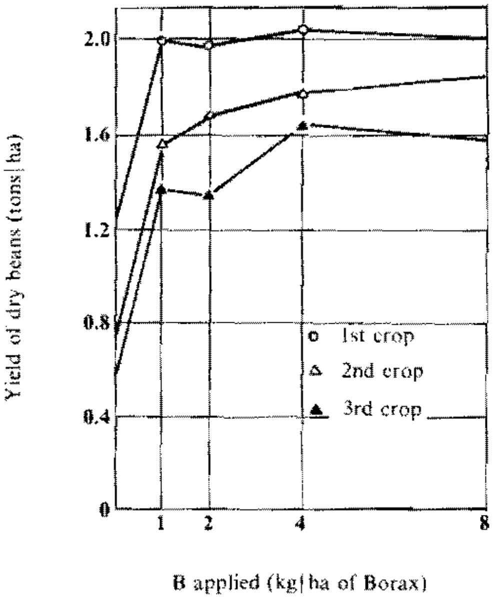

Figure 25. **Effects of one soil application of various rates of B on yields of ICA-Tui beans in three subsequent seedings, CIAT.**

subsequent crops of the variety Tui. During the initial seeding, 1 kg B|ha was sufficient to attain maximum yields. However, in later seedings the residual effect of this application was insufficient and maximum yields were attained only from the initial application of 2-4 kg B|ha. Since symptoms of B toxicity have been observed at the seedling stage in several fields at CIAT following applications of 2-3 kg B|ha, especially during dry weather, it is recommended to apply only 1-2 kg of B|ha, and if necessary, to repeat the application the following semester.

To determine the need for B fertilization, critical levels of B in leaf tissue and soil must be established. Correlations between bean yield and B content of leaves and soil showed that yield increases may be expected from B applications if the B content of the upper leaves at flowering is less than 25 ppm and if the hot-water soluble B content of the soil is less than 0.4 ppm.

The seeding of 14 promising varieties with three levels of applied B revealed greater susceptibility to B deficiency in 11 black-seeded varieties than in the two red-seeded varieties tested (Fig. 26). Mung bean (*Phaseolus mungo*) actually showed a negative response to B fertilization. The critical B level of 20-25 ppm in leaf tissue was confirmed for the 11 black bean varieties.

When B deficiency is not severe enough to inhibit initial growth, foliar applications may be a more economical alternative to soil application. In one trial highest yields were obtained with three foliar applications of 0.1 percent B in solution, equivalent to about 1 percent Borax or 0.5 percent Solubor. Concentrations of 0.2 and 0.4 percent B resulted in severe toxicity symptoms and yield reductions.

Phosphorus fertilization

Phosphorus is the main element limiting bean production in many soils of Latin America. Figure 27 shows the response of

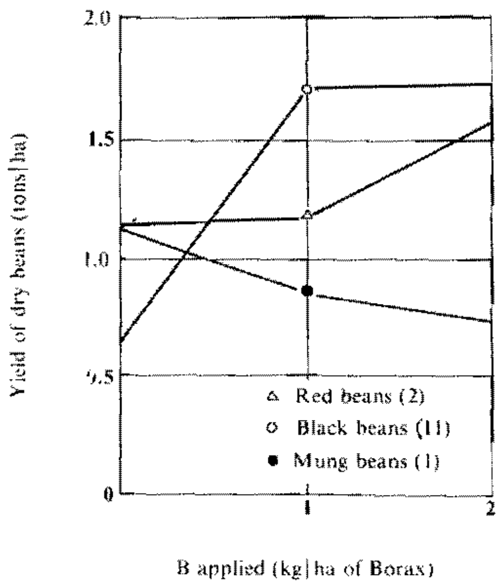

Figure 26. **Effects of soil applications of B on yields of two red and 11 black bean varieties (*Phaseolus vulgaris*) and one mung bean (*Phaseolus mungo*).**

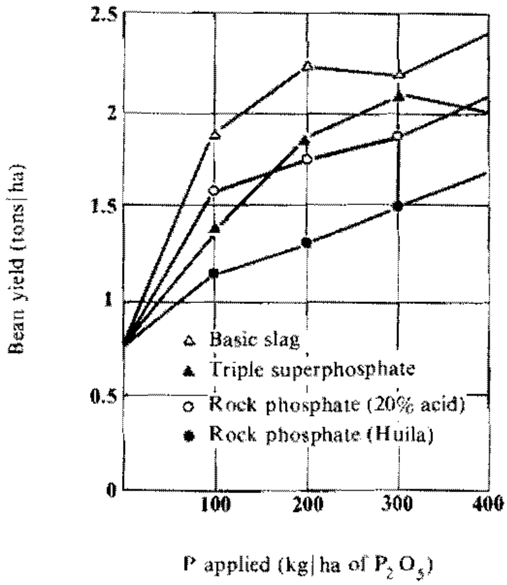

Figure 27. **Response of Porrillo Sintético bean to several levels of P from four sources, Popayán (1975A).**

beans to P in the extremely P-deficient volcanic ash soil of Popayan. Using the soluble source triple superphosphate (TSP), highest yields were obtained with 300 kg P_2O_5/ha. With less soluble sources such as basic slag, rock phosphate and rock phosphate 20 percent acidulated with sulphuric acid, beans responded to up to 400 kg P_2O_5/ha. Basic slag was the most effective source when all sources were broadcast and incorporated. Band placement of TSP would probably have improved its efficiency. Rock phosphate from Huila was the least effective source, but at high rates, it was definitely beneficial and economical. The partial acidulation of rock phosphate increased its efficiency to that of TSP. This treatment, which can be done on the farm, increases the cost of the fertilizer from Col. $4.6 to Col $9.5/kg P_2O_5 but makes it a very attractive P source in comparison with TSP which presently costs as much as Col $24.5/kg P_2O_5 (Figure 28). Basic slag, being extremely effective as well as cheap (Col $4/kg P_2O_5) is the most economical source, but its production is limited and can't satisfy the present fertilizer P requirements.

Two additional sources, fused magnesium phosphate and rock phosphate plus sulfur were studied. Yields with fused magnesium phosphate were not significantly different from those with TSP, and the rock phosphate + S mixture was not much different from rock phosphate alone. These two sources are thus not shown. A correlation between bean yield and percentage of P in the upper leaves at time of flowering showed a critical P content in the leaves of 0.35 percent.

Nitrogen fertilization

Previous trials by INIAP established that nitrogen is the major limiting element for beans in Boliche. A cooperative trial

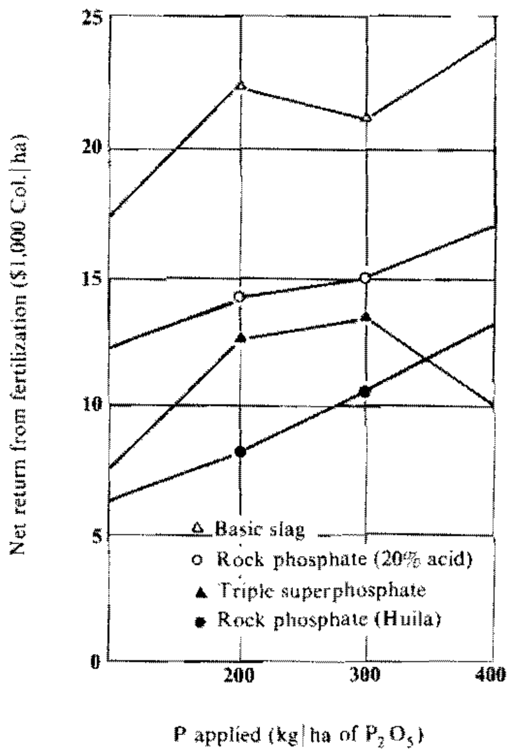

Figure 28. **Net return (Col.$) from bean fertilization with various sources and levels of P, Popayán (1975A).**

was established to study levels, sources, times and methods for applying N. Levels as high as 800 kg N|ha were used to determine possible negative effects on yield as well as to determine the true yield potential of Porrillo Sintético under the favorable climatic conditions of this station. Figure 29 shows that a maximum yield of 3.76 tons|ha was obtained with this bush bean variety, and that N fractionation had no positive effect on yield. This corroborates results reported in the 1974 Annual Report. Figure 30 shows no significant differences between urea and ammonium sulphate, but indicates that band placement was considerably inferior to broadcast applications at all N levels. Beans responded positively to rates as high as 200-400 kg N|ha, with no negative response up to 800 kg N|ha.

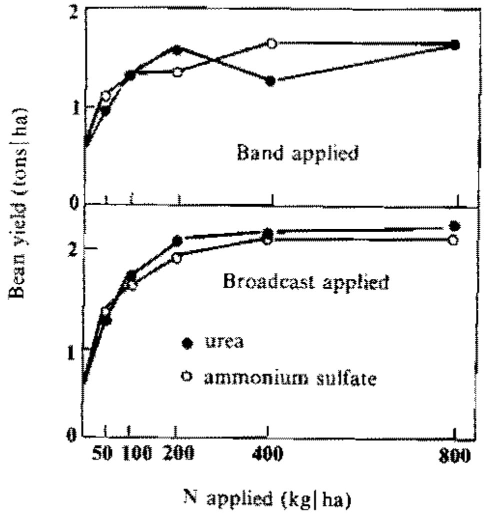

Figure 30. **Response of Porrillo Sintético bean to several levels of N as urea or ammonium sulfate and applied by banding or broadcasting, Boliche, Ecuador (1975A).**

N x P interaction

The effect of N and P fertilization on yield and protein quality of three bean varieties was studied in four locations during two semesters. The yield responses of the variety Tui in Popayán, La Zapata, and Carimagua are shown in Figure 31. In the high organic matter, volcanic ash soil of Popayán beans responded principally to P and only when the P-need was satisfied was there a clear response to N. In the highly infertile oxisols of Carimagua beans responded principally to N, and only when the N-need was satisfied was there a response to P. In the volcanic ash-influenced soil of La Zapata, with intermediate organic matter and low P content, beans responded equally well to N and P. In all locations, maximum response to P was obtained at the high N level and maximum response to N was obtained on the high P level.

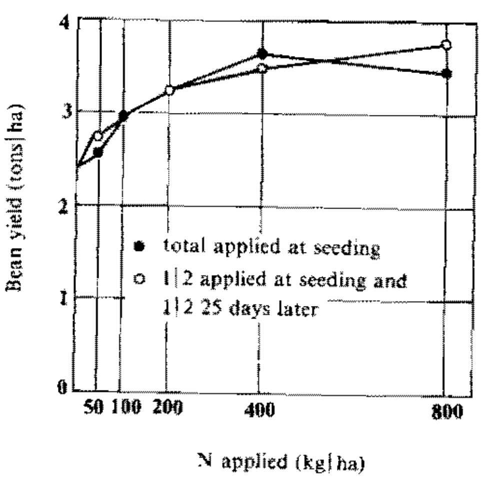

Figure 29. **Response of Porrillo Sintético bean to several levels of N applied at seeding or as split applications, Boliche, Ecuador (1975A).**

Agronomic practices

Time of seeding

The time of seeding trial in Popayán reported in the 1974 Annual Report was continued. Figure 32 shows that with insect and disease control, excellent yields can be obtained seeding beans from December through March when monthly precipitation is about 150-200 millimeters. Extremely poor yields were obtained with seedings from May through October,

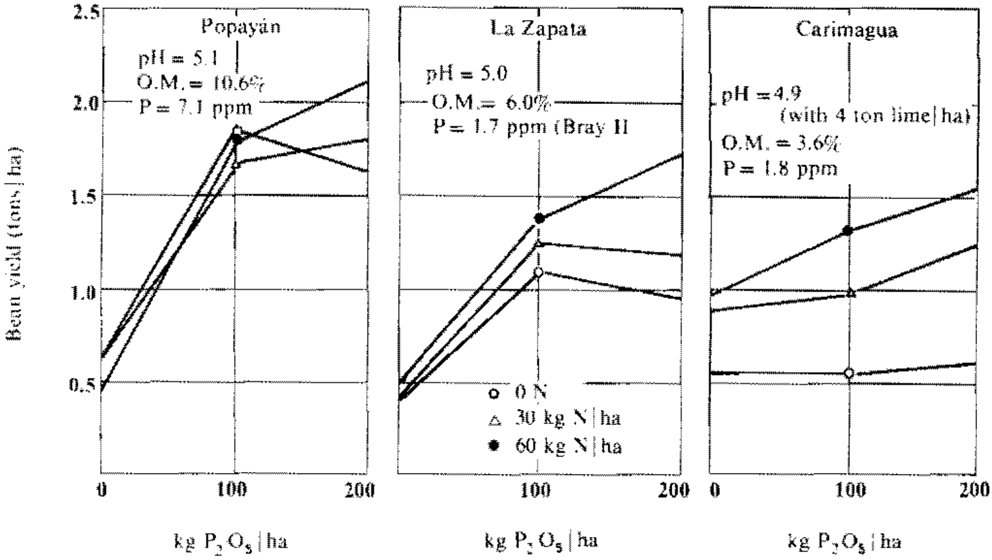

Figure 31. **Response of bean variety ICA Tui to N and P at Popayán, La Zapata and Carimagua.**

because rainfall was limited from May to August but excessive from October to December. With the exception of seedings in March and April, insect and disease control was essential for reasonable yields. In the second semester, high rainfall increased anthracnose to the extent that practically no grain could be harvested. It is possible that insect populations and disease infections built up more severely in this experiment than is normally encountered when beans are seeded only once or twice a year. The results may thus represent an extreme situation. They do indicate, however, that commercial bean production is most likely to be successful during first semester plantings.

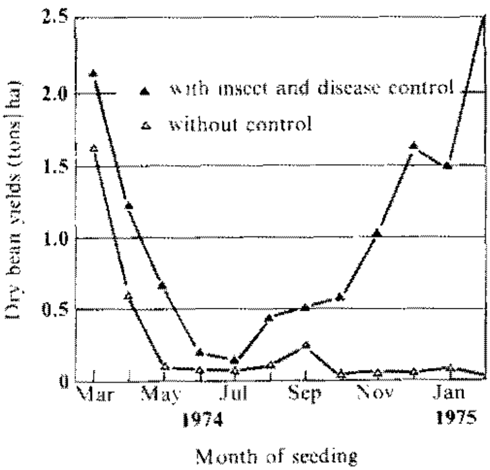

Figure 32. **Effect of month of seeding on yields of bean variety ICA Tui grown with or without control of insects and diseases, Popayán (1974-75).**

Mulching

Two trials were seeded at CIAT to study the effects of mulching with crop residues on weeds, soil temperature, humidity, fertility and yields of beans. Table 41 shows that highest yields were obtained with a soil cover of maize residues, rice straw, and dead **Amaranthus** weeds. The latter significantly increased the soil P and K levels, possibly eliminating P deficiency (critical P-level in soil is about 15 ppm). All mulch treatments greatly reduced weed growth, plantain leaves being most and **Amaranthus** least effective. The treatments decreased soil temperature about 2-2.5°C but had little effect on humidity.

Table 41. **Effect of soil cover on production of beans, weed growth and soil characteristics.**

Treatment	Bean yield (tons|ha)	Weeds[1] (g|m²)	Soil temp.[2] (°C)	Soil humidity (%)[3]	Soil analyses[4] (ppm P)	(meq K|100 gm)
Weedy check	1.80	948	26.7	20.8	12.6	0.44
Weed-free check	1.92	292	26.2	20.3	-	-
Maize residues	2.06	208	24.2	21.1	11.8	0.44
Rice straw	2.05	336	24.6	20.8	14.4	0.49
Plantain leaves	1.94	184	24.0	20.6	13.8	0.46
Sugarcane leaves	1.95	304	24.5	20.7	12.7	0.71
Dead weeds **(Amaranthus)**	2.23	728	25.2	21.7	23.1	0.71

1 Weeds collected at time of harvest
2 Average of four determination at 10-cm depth
3 Average of three determinations at 20-cm depth
4 Soil analyses after harvest.

Contact herbicides for hastening maturity

High rainfall during maturation can cause plants to resprout and reflower at a time when previously formed pods are drying. The newly formed leaves prevent the proper drying of these pods and pod rotting may result. Under these conditions the application of a contact herbicide like paraquat can increase defoliation and hasten maturity. One application of paraquat (1.5%) 10-20 days before harvest was the most beneficial of several treatments and had no detrimental effects on seed germination of the two varieties tested.

Weed control in beans

Maize or beans grown alone were compared to maize and beans grown in association, to determine whether weed control inputs were equivalent in the three systems.

Maize and beans were planted on the same day in beds 1.8 meters wide with either two rows of maize and three rows of beans or two rows of maize and one row of beans per bed. A brachytic maize and bush bean variety were used. Treatments included no weeding, one or two hand weedings and use of a pre-emergence herbicide.

Twenty days after planting there were fewer weeds in the monoculture bean plots than in the maize or maize and bean plots, reflecting the competitive ability of a dense population of beans (240,000 plants|ha). This relationship persisted until harvest (Table 42). Intercropped maize likewise had fewer weeds than maize alone. For the weed species present, one hand weeding gave adquate control in all systems. On this basis, there was no advantage to intercropping.

Bean yields were reduced 83 percent both for beans alone and associated with maize, when no weeding was performed. Yields of monocropped maize were reduced 68 percent when not weeded, while in association with beans, the loss was only 47 percent. This suggests that maize is more tolerant of competition from beans than from weeds.

Another trial was conducted to determine which herbicides can be used safely in a maize-bean association. Maize (hybrid H-253) was planted and nine herbicides

Table 42. **Effects of weed control method on weed numbers and control and crop yields in maize and beans alone or intercropped.**

Weed control system	Population* (no./m²)			Yield (tons/ha)			
						Intercropped	
	Maize	Beans	Intercropped	Maize	Beans	Maize	Beans
One hand weeding	43	12	30	5.4	1.77	2.7	0.94
Two hand weedings	29	16	20	5.5	1.77	3.0	1.03
Herbicides	20	4	9	5.6	1.80	3.4	0.96
Weedy check	120	52	68	1.8	0.30	1.6	0.16

* Weed population at harvest time

were applied. Beans (variety Calima) were planted two weeks later. All treatments except DNBP gave acceptable grass control, while broadleaf control was less effective (Table 43). No herbicide caused any observable injury to either maize or beans.

Plant density studies

Bush beans

In experiments on appropriate planting densities for bush beans, yield plateaus were observed for densities above 200,000 plants/ha. This plateau was independent of plant type and planting system (Fig. 33), row distance (Fig. 34), and bean variety (Table 44). Yields from 2 to more than 3 tons/ha were obtained. The results confirm information presented in the 1974 Annual Report. Again, only limited variety/density interactions were found among the varieties and systems tested. Populations losses during the growing season complicated the evaluation of response to planting density in bush beans. In one trial, established densities of 20, 40,

Table 43. **Effect of nine pre-emergence herbicides on percentage weed control and yield of maize and beans grown in association.**

Herbicide	Rate (kg/ha)	Grass control* (%)	Broadleaf control** (%)	Yield (tons/ha)	
				Beans	Maize
fluorodifen	3.5	85	75	.910	3.4
linuron	1.0	90	40	.886	2.7
cloramben	3.0	80	60	.775	3.8
DNBP	3.0	20	90	.770	1.9
trifluralin	1.5	90	70	.850	3.2
dinitramine	0.75	70	70	.935	3.2
butralin	1.5	90	80	.885	2.8
penoxalin	1.5	85	60	.825	3.3
H-22234	3.0	80	60	.940	3.2
Weedy check	-	0	0	.165	0.7

* 40 days after application. Predominant species were *Eleusine indica, Echinochloa colonum* and *Leptochloa filiformis*

** 40 days after application. Predominant species were: *Amaranthus dubius, Momordica charantia, Portulaca oleracea, Euphorbia hirta.*

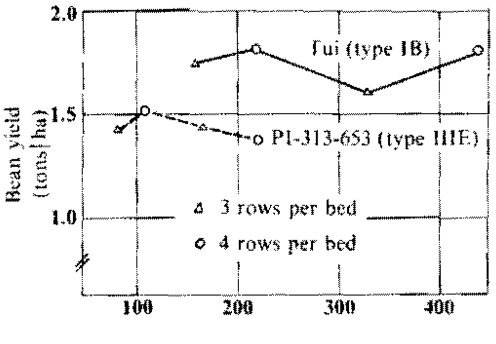

Figure 33. **Yields of two bean varieties at four densities in two planting systems, CIAT.**

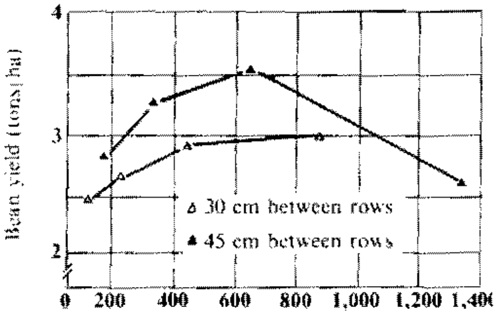

Figure 34. **Yields of Porrillo Sintético at two row spacings and four plant densities, Boliche, Ecuador, (1974B).**

60 and 80 plants|m² were reduced to approximately 14, 26, 36 and 46 plants|m², respectively, at harvest.

Climbing beans

The need for more detailed evaluation of planting density in climbing beans was stressed in the 1974 Annual Report. Results this year confirm the need for plant densities higher than those conventionally used, but suggest that desirable planting densities are less than the 40 to 80 plants|m² originally considered. Under farmers' conditions, it is common to plant both maize and beans at a maximum of 40,000 plants|ha. To evaluate this practice, maize was planted at a constant density of 40,000 plants|ha with bean densities ranging from 40,000 to 320,000 plants|ha. These treatments were compared to monocrop beans planted on a trellis support system of bamboo, wire and twine, over the same range in densities. In this system there was one meter between trellises and two rows per trellis. Figure 35 shows a reduction in maize yield with increasing bean population, as well as an increase in maize yield when both crops were planted at 40,000 plants|ha in

Table 44. **Effect of plant population on the yield of beans of nine promising varieties, CIAT.**

	Yield (tons|ha)			
Plants|ha:	200,000	300,000	400,000	Avg.
ICA-Pijao	3.18	3.12	3.08	3.13
73 Vul 6586	3.25	3.02	3.04	3.10
141-M-1	3.27	3.12	2.92	3.10
Tui	2.58	2.52	2.54	2.55
Porrillo Sintético	2.66	2.29	2.70	2.55
6530 var. 51052	2.70	2.41	2.24	2.45
73 Vul 6589	2.71	2.66	2.05	2.47
Porrillo # 1	2.21	2.42	2.39	2.35
150-1-1	1.94	1.77	1.65	1.79
Avg. all varieties	2.72	2.59	2.51	

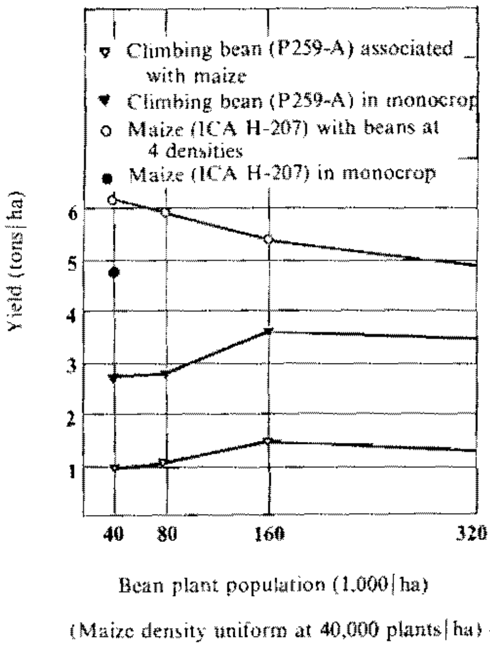

Figure 35. **Yields of bean and maize in monocrop and in association at four bean densities.**

association. There is no apparent system|density interaction, as the bean yields in both monocrop and associated crop systems were highest at 160,000 bean plants|ha. The difference in bean yields between the two systems was significant at all densities. Figure 36 compares yields for maize and beans when four maize types were used as supports for the Chilen variety P259-A. Yields of this variety in monocrop leveled at 2.0 tons|ha.

In agronomic trials comparing maize versus trellis or stake support systems, total crop value of beans or beans plus maize increased appreciably at higher plant densities, and were almost independent of the crop system (Fig. 37). Maximum crop values were obtained from the monoculture system at bean densities over 80,000 plants|ha, and from the maize|-bean association at bean densities over 60,000 plants|ha. Net profit from these systems is a function of costs of the initial installation (monocrop climbing beans), seed (varies with density), planting and crop protection, and harvest (partially a function of yield). The number of crops per year depends on availability of irrigation water and labor to install the system. It is probable that small farmers with limited resources could profitably utilize either monocrop beans on artificial supports or associated maize and high-density beans to achieve high returns from family labor on a small area. The early harvest of maize as green ears would facilitate more than the normal two crops each year.

Multiple cropping

Research on the bean|maize system produced tentative conclusions on relative planting dates, densities, spatial orientation of plants, and design of the system.

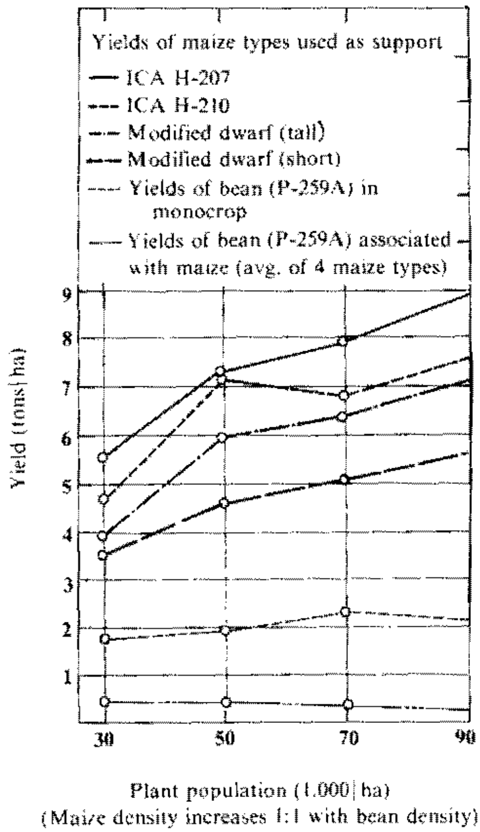

Figure 36. **Monocrop yields of beans and yields of intercropped beans and maize at four plant densities.**

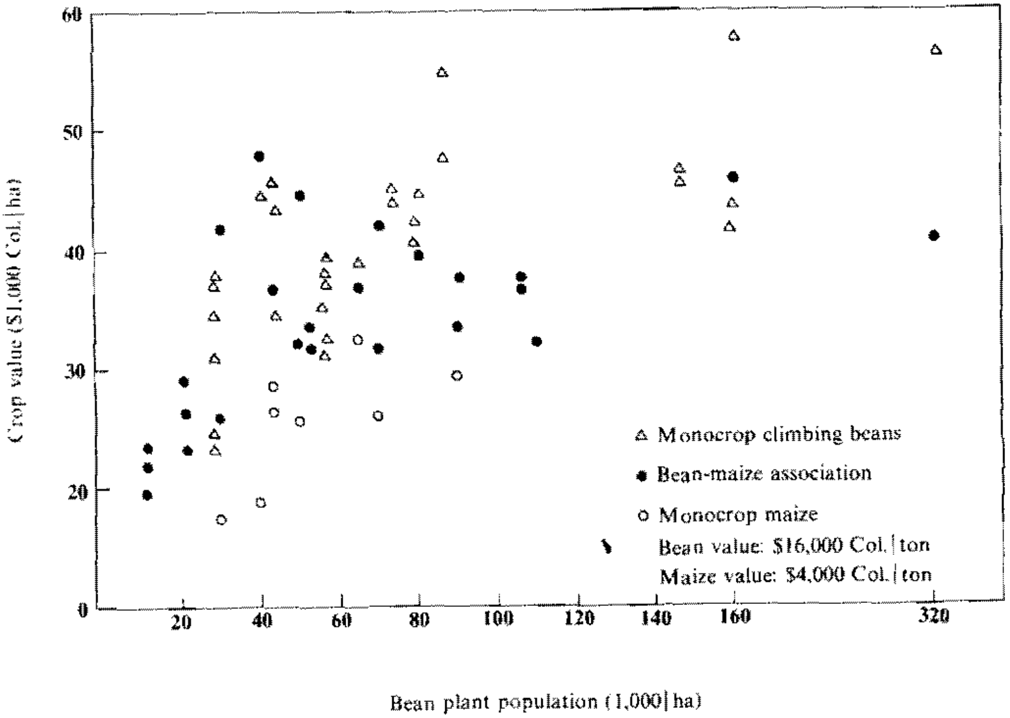

Figure 37. **Value of maize and beans monocropped and in association for several plant densities.**

The optimum planting date for bush beans (200,000|ha) is 15 days before maize (40,000|ha), at CIAT. In this association, bean yields were not reduced significantly from the monocrop level, nor was maize yield affected. This relationship must be tested at higher plant densities and yield levels. Preliminary observations of climbing beans with maize indicate that simultaneous planting is optimum for bean production, with only a minimum effect of competition on maize yields.

At a given density, maize planting system and spatial row arrangement were shown to affect bean yields (1974 Annual Report). To further reduce the effect of maize competition for light, trials are in progress to intercrop paired rows of maize with four rows of beans. Climbing beans still have an adequate support system, being at the most only 40 centimeters from the maize rows.

The effects of crop association of fall army worm (*Spodoptera frugiperda*) attack in maize are illustrated in Figure 38. The association of maize with bush beans planted six days before the maize retarded infestation, compared to the monocrop maize check. With a climbing bean planted seven days after the maize, this difference was drastically reduced. This same pattern of differential infestation persisted over three consecutive observation dates, and even after the **Spodoptera** infestations had been chemically treated. This reduced incidence of a principal maize insect may be one of the reasons small farmers use these multiple cropping systems to assure a harvest and minimize risk at low levels of technology.

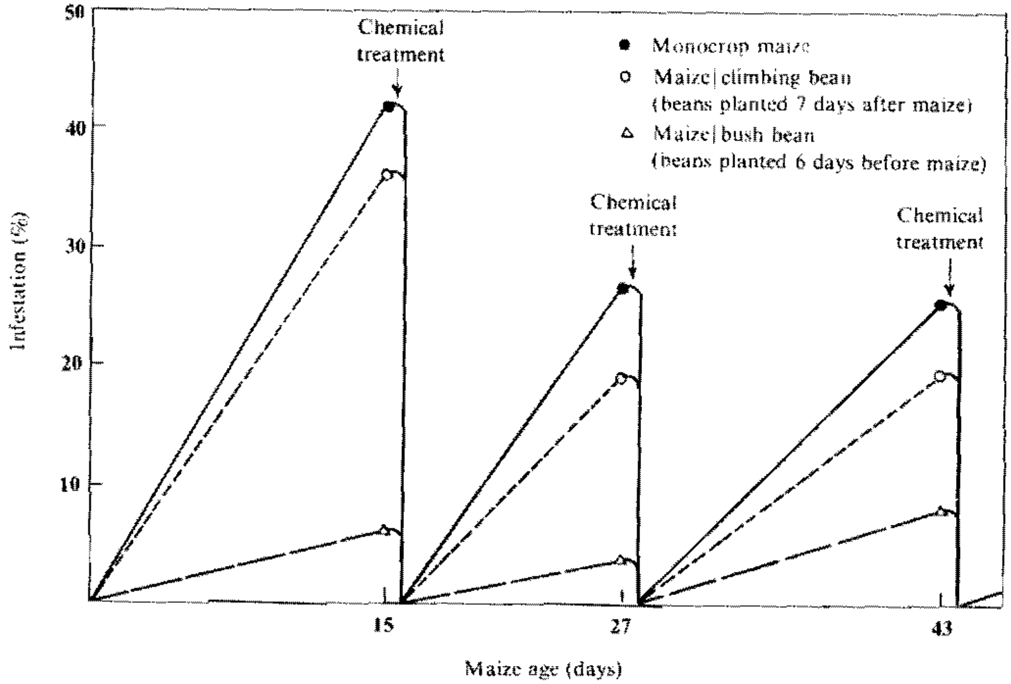

Figure 38. **Fall armyworm infestation in maize at three ages, in three cropping systems, CIAT.**

COLLABORATIVE ACTIVITIES

During 1975 the CIAT Board of Trustees agreed to the proposal by the Technical Advisory Committee of the Consultative Group for International Agricultural Research that the CIAT Bean Program coordinate the establishment of a Latin American Bean Research Network. With this goal in mind, the Bean Program has accelerated its collaborative experimental program and has established firm contacts with most national bean research programs in Latin America. Activities during 1975 have been in five areas.

(1) **Training:** During the year, the program received three post- and two predoctoral students, three students for the MS degree, and a total of 18 other postgraduate becarios. For the first time, five becarios from the same country were trained at CIAT as a multidisciplinary group. An intensive one-month training course in bean production for experimental studies, is planned for 1976.

(2) **Documentation.** Documentation of available bean literature was again emphasized in 1975 with more than 1,000 cards distributed to over 320 scientists in the bean research field. Literature on symbiotic nitrogen fixation continued to be distributed by the microbiologist.

(3) **Conferences.** Two conferences were organized during the year, the first on bean breeding and germplasm, the other on aspects of plant protection. A major result of the breeding-germplasm workshop was a better definition of how CIAT should manage its breeding program to satisfy a multiplicity of demands from national programs (see page C-11). Details for an international series of variety trials were

also presented at this meeting, and accepted in principle (see Table 40). This will begin when sufficient clean seed becomes available in 1976.

(4) **Review meeting.** An external review of the Bean Program was held from Oct. 21-23, 1975. Current research, research trends and staffing pattern and requirements were reviewed by a committee in which Latin Americans predominated, and where the major question to be answered was the relevance of the CIAT program to other areas of South and Central America.

(5) **Collaborative research** is under way in several countries of South and Central America, and referred to frequently in the preceeding text. Major activities have been the varietial evaluations in Ecuador; rust resistance nursery screening in 14 countries; the evaluation of golden mosaic tolerance in Guatemala; and **Rhizobium** and fertilizer studies in several parts of Colombia. ICA and the Secretaria de Agricultura del Cauca both were prominent in these studies. The agro-economic study reported on page C-3, depended heavily upon support from several collaborating institutions.

Additional collaborative projects with several developed country institutions are under way, generally, in areas where the CIAT program has insuffucient equipment or expertise to undertake the studies. Thus students at Cornell University are studying stability of growth habit in beans (1974 Annual Report) and photoperiod-temperature interactions. Michigan State University and Hokkaido University are also involved in this program.

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WILDE, G. and **SCHOONHOVEN, A. VAN.** Mechanisms of resistance of *Empoasca kraemeri* in *Phaseolus vulgaris* L. J. of Econ. Ent. (in press).

——————; **SCHOONHOVEN, A. VAN;** and **LAVERDE, L. G.** The biology of *Empoasca kraemeri* on *Phaseolus vulgaris*. Ann. of Ent. Soc. of Am. (in press).

Multiple Cropping

FRANCIS, C.A.; FLOR, C.A. and **TEMPLE, S.R.** Adapting varieties for intercropped systems in the tropics. Cali, Colombia. CIAT. 1975. 36p.

Paper presented in Multiple Cropping Seminar. Annual Meeting of the American Society of Agronomy, Knoxville, Tenn., U.S.A. 1975.

* This list includes only journal articles published outside CIAT's series.

FLOR, C.A.; HOWELER, R.H. y GONZALEZ, C.A. Zinc y boro: dos microelementos limitativos para la producción de arroz y frijol en algunas regiones cálidas de Colombia. **In** Reunión Anual del PCCMCA, 21st., San Salvador, El Salvador, 1975. Proceedings 1:213-230.

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GALVEZ, G.E. and CASTAÑO, M. Purification of the whitefly-transmitted bean golden mosaic virus. Turrialba (in press).

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__________ y **DIAZ, A.** Purificación y caracterizacion parcial del mosaico ampollado del frijol. **In** Reunión Anual del PCCMCA, 21st., San Salvador, El Salvador, 1975. Proceedings 1:235-236.

__________ ; **GALINDO, J.** and **ALVAREZ, G.** Artificial defoliation for estimating losses due to foliar damage. **In** Annual Meeting of the American Phytopathological Society, Caribbean Division, Cali, Colombia, 1975. Proceedings (in press.

__________ ; **GALINDO, J.** y **ALVAREZ, G.** Defoliación artificial para estimar pérdidas por daños foliares. **In** Reunión Anual del PCCMCA, 21st., San Salvador, El Salvador, 1975. Proceedings 1:355-357.

YOSHII, K. and GALVEZ, G.E. The effect of rust on yield components of dry beans *(Phaseolus vulgaris)*. **In** Annual Meeting of the American Phytopathological Society, Caribbean Division, Cali, Colombia, 1975. Proceedings (in press).

__________ and **GALVEZ, G.E.** The therapeutic effect of fungicides for control of bean rust. **In** Annual Meeting of the American Phytopathological Society, Caribbean Division, Cali, Colombia, 1975. Proceedings (in press).

Physiology

LAING, D.R. International nurseries for yield and adaptation of dry beans *(Phaseolus vulgaris)*. Cali, Colombia, CIAT, 1975. 16p.

Paper presented at Workshop on Genetic Improvement of Dry Beans *(Phaseolus vulgaris)* and Germplasm Resources, Centro Internacional de Agricultura Tropical, Cali, Colombia, 1975.

Plant Breeding

HERNANDEZ-BRAVO, G.; HIDALGO, R. y BRUGA, C. Selección por tolerancia a sequía en frijol, *Phaseolus vulgaris*. **In** Reunión Anual del PCCMCA, 21st., San Salvador, El Salvador, 1975. Proceedings 1:105-110.

Swine production systems

HIGHLIGHTS IN 1975

During 1975 there was a basic change in the orientation of CIAT's Swine Program towards a new philosophy emphasizing training and international cooperation activities. The basis of research activities in the program's experimental farm unit has been the study of the major limiting factors in relation to the efficient utilization of potentially available feedstuffs for swine production in Latin America. Nutritional research on the utilization of cassava, rice meal or polishings and opaque-2 maize in swine feeding systems has received priority. The practical evaluation of these feedstuffs has continued to be oriented towards the development of integrated life-cycle feeding systems. This year experimental data on the use of cassava meal and opaque-2 maize have been completed through one life cycle.

Upon terminating the long-term research on the performance of native pigs, an improved breed (Duroc), and their respective crosses in tropical zones, information has been completed on the performance of two consecutive litters and on the evaluation of the carcass quality of the animals reaching marketing weight. In both litters, the performance of native pigs was lower than that of either improved breeds or crossbred pigs.

In animal health the main objective was the economic evaluation of health problems affecting swine production. In addition, the Animal Health Unit continued to build up basic information on the main diseases affecting swine production in different areas of Latin America in order to establish priorities for future research prior to the development of economic preventive and/or control methods.

The Swine Program has strongly supported close collaboration with national programs in Central and South America, where the potential of swine production is being evaluated. Training activities have been directed mainly at training professionals from CIAT's cooperative programs in Latin America; eight professionals received training in swine production in 1975.

SWINE NUTRITION

Cassava

When fresh cassava is fed free choice to growing pigs, its consumption is limited; this is one aspect of swine nutrition that has not been satisfactorily solved. Palatability has been mentioned as one of the possible causes for the low consumption of fresh cassava. In the 1973 Annual Report, mention was made of the marked differences in consumption of fresh sweet and bitter cassava by finishing pigs. Hydrocyanic acid (HCN), present in small quantities (50 to 100 ppm) even in sweet cassava roots, could affect palatability. In recent studies with growing-finishing pigs fed fresh cassava mixed with 15 percent sugar or molasses, it was found that palatability was slightly better than for fresh cassava (Table 1). The intake of protein supplement was less (0.85 vs 1.02 kg|animal|day) when cassava was mixed with sugar. Although there was still an excess in protein intake, the sugar- or molasses-cassava mixtures provided a better energy|protein balance than the fresh cassava alone.

In addition to its effect on palatability, the presence of HCN or cyanogenic compounds in cassava rations may have a toxic effect on animal nutrition. Trials with laboratory rats fed bitter cassava meal-based diets (600 mg HCN|kg dry matter) showed that during the gestation period the placental barrier protects the fetuses from high levels of cyanide or its principal detoxification products, thiocyanates (1974 Annual Report). In order to study the possible toxic effect of high levels of cyanide in diets for gestating sows, an experiment was carried out using fresh sweet cassava plus a protein supplement, to which increasing levels of HCN (0, 250 and 500 ppm) were added in the form of potassium cyanide. There were slight metabolic alterations; nevertheless, no adverse effects on fetus viability were observed. Further observations made during the lactation period of these sows did not show the presence of residual effects from these treatments made during gestation that could affect the later

Table 1. **Performance of growing-finishing pigs fed a protein supplement free choice and cassava mixed with 15 percent molasses or sugar.**

Parameters*	Cassava alone	Cassava + molasses	Cassava + sugar
Daily gain (kg)	0.69	0.72	0.74
Daily feed intake (kg)			
Cassava	2.99	3.37	3.11
Supplement (40% protein)	1.02	0.92	0.85
Total Dry matter	2.03	2.27	2.17
Feed/gain	2.97	3.16	2.93
Daily protein intake (kg)	0.54	0.51	0.46
Daily digestible energy intake (kcal)	8,273.10	8,850.50	8,767.30
Percentage of protein intake**	23.45	20.44	18.98

* Mean of 12 pigs per treatment, 91-day trial, av initial weight, 21.9 kg; av final weight 87.1 kg for the control group

** Based on dry matter

performance of either the sows or their litters.

Because of their high HCN or cyanogenic glucoside content, care must be taken when using bitter cassava varieties because of their possible toxic effect. The preparation of cassava meal reduces the HCN content and thus considerably diminishes the limitations found when using fresh bitter cassava. Nevertheless, pigs fed diets based on meal made from the bitter cassava variety CMC-84 (73.8 percent) had a lower rate of gain (0.50 vs 0.59 kg/day), consumed less feed (1.47 vs 1.67 kg/day), and had a lower rate of feed efficiency (1.32 vs 1.51 feed/gain) than pigs fed diets based on meal prepared from the sweet cassava variety Llanera (73.8 percent). Judging from the analytical results of these meals, lower performance could be partially due to the higher HCN or cyanogenic glucoside content of the bitter cassava meal.

Experimental results obtained thus far suggest that palatability factors and aspects of nonlethal toxicity from residual HCN could be responsible for the lower performance on bitter cassava meal-based diets. In order to detoxify the cyanide ion, it is necessary to have a dietary source of sulfur that will permit the conversion of cyanides into thiocyanates ($^{-}CN + S \longrightarrow {}^{-}SCN$).

In order to assess the efficiency of several sulfur compounds, a trial was carried out with growing pigs fed diets based on bitter cassava meal (70 percent), supplemented with methionine (0.2 percent), sodium thiosulfate (0.79 percent) or elemental sulfur (0.2 percent). Supplementation with methionine gave the best weight gains, with a daily feed intake similar to that of the control (Table 2). The other two sources of sulfur gave slightly lower results as regards weight gains; but the feed conversion for pigs on the diet supplemented with elemental sulfur was similar to those supplemented with methionine. These results confirm previous experiments (1973 Annual Report), in which the addition of methionine improved the quality of the protein in cassava meal-based diets since cassava is most deficient in this amino acid; besides it permits the adequate detoxification of the cyanide or cyanogenic glucoside still present in the meal. The addition of elemental sulfur apparently gives similar results—at least as far as feed conversion is

Table 2. **Effect of the addition of sulfur compounds to a bitter cassava meal-based diet on the performance of growing-finishing pigs.**

	Bitter cassava meal-based diets			
Parameters*	Control	+ 0.2% methionine	+ 0.79% sodium thiosulfate	+ 0.2% elemental sulfur
Daily gain (kg)	0.67	0.70	0.61	0.65
Daily feed intake (kg)**	1.81	1.77	1.58	1.64
Feed/gain**	2.43	2.29	2.32	2.29

* Mean of five pigs per treatment, fed individually; **42-day trial**; av. initial weight, 19.5 kg; av. final weight, 47.1 kg

** Based on air-dried feed

concerned—under the conditions of the experiment.

CIAT's Cassava Production Systems Program has conducted a series of experimental trials designed to study cassava storage and its effects on the biochemical and biophysical changes that occur during storage in field clamps or in storage boxes (1974 Annual Report). In cooperation with the Swine Program, a nutritive evaluation was made of the roots stored in field clamps for a minimum of two weeks before being fed to the pigs. The stored roots were chopped daily and given to the pigs in open feeders. A protein supplement (40 percent crude protein) was available in a separate, automatic feeder. Although the results obtained were from a reduced number of animals during a short experimental period (28 days) and must be confirmed on a large scale, there are certain tendencies that should be considered for future research. There was less consumption of stored cassava than fresh, and less bitter cassava (either fresh or stored) was consumed (Table 3). This limited consumption of cassava was compensated for

Table 3. **Effect of field clamp storage on the nutritive value of sweet and bitter cassava for growing pigs.**

	Experimental variables			
	Sweet cassava (M Col 22)		Bitter cassava (CMC-84)	
Parameters*	Fresh	Stored	Fresh	Stored
Dry matter content in roots (%)**	40.0	38.7	30.5	31.7
Average daily intake (kg)				
Cassava	1.90	1.68	1.61	1.43
Protein supplement***	0.51	0.91	0.81	0.87
Total dry matter	1.27	1.56	1.30	1.33
Daily gain (kg)	0.57	0.75	0.63	0.66
Feed/gain (based on dry matter)	2.23	2.06	2.07	2.03

* Mean of three pigs; **28-day trial**

** Dry matter content was calculated daily in samples of chopped cassava during the third week of the trial.

*** The protein supplement contained 40 percent crude protein and 88.2 percent dry matter by a greater intake of protein supplement so that the total dry matter intake was similar for all groups. The performance of the growing pigs was acceptable in all groups; however, pigs fed stored sweet cassava had the best gains, partly because they consumed more of the protein supplement. The differences in texture and the poorer organoleptic quality of the stored roots apparently affected acceptability. It is necessary to add that as the feed conversion data on the basis of dry matter refer to a short experimental period (only four weeks), they do not reflect the results that could be obtained during the growing-finishing period (weaning to 90 kg liveweight).

Samples of sweet (M Colombia 1148) and bitter cassava (CMC-84) varieties, stored in field clamps or storage boxes for a two-week period, were sliced, oven dried at 65°C, and then ground into meal. In an experiment with laboratory rats, it was found that storage in either system did not affect meal palatability, growth performance, feed intake or efficiency.

Whole grain maize and sorghum

Several experiments were conducted to test the utilization of whole grain maize and sorghum in order to eliminate the problem and cost of grinding, which is one of the most limiting factors on small farms.

In the first experiment, a mixture was used of 80 percent whole grain maize and 20 percent protein supplement based on either soybean, cottonseed, sesame seed, meat or fish meals (Table 4). The growing pigs responded better when the maize was ground and mixed with the other ingredients (control diet). Intake of whole grain maize was consistently lower, and the animals wasted a lot of food trying to separate the grain from the supplement in order to consume more of the latter.

To eliminate some of the problems encountered, another experiment was carried out, in which the whole grain maize was soaked in water for 24 hours in one of the treatments. In addition, the protein supplement was fed free choice in separate feeders (Table 5). There was a greater consumption of the soaked maize, but there was an excess of protein intake in both cases, especially by the pigs fed the dry grain. Performance improved when the whole grain maize was soaked, but it was not equal to that of ground maize, especially when it was mixed with the other ingredients in the control diet.

Table 4. **Effect of whole grain maize-based diets with different protein supplements* on the performance of growing pigs.**

Treatments**	Daily average		
	Gain (kg)	Feed (kg)	Feed/gain
Ground maize - soybeans	0.72	1.92	2.67
Whole grain corn plus			
Cottonseed - meat - fish	0.55	1.48	2.69
Cottonseed - sesame seed - meat	0.39	1.34	3.43
Cottonseed - sesame seed - meat - soybeans	0.47	1.54	3.28
Sesame seed - soybeans - meat	0.52	1.76	3.38
Cottonseed - soybeans	0.56	1.70	3.03

* These supplements were fed in the form of meal or cake, in different proportions, according to the supplement used

** Mean of eight pigs per treatment, **49-day trial;** av initial weight, 19.9 kg; av final weight, 55.4 kg for the control group

Table 5. **Effect of feeding dry and soaked whole grain maize plus a protein supplement* on the performance of growing pigs.**

Parameters**	Control (Maize + SBM)	Ground maize	Whole grain maize	
			Soaked***	Dry
Daily gain (kg)	0.82	0.76	0.72	0.68
Daily feed intake (kg)				
Maize	-	2.02	1.66	1.31
Supplement	-	0.43	0.51	0.66
Total	2.42	2.45	2.17	1.97
Feed | gain	2.95	3.22	3.01	2.90

* The protein supplement, which contained 40 percent crude protein, was fed free choice in separate feeders.

** Mean of 14 pigs per treatment; **28-day trial**; av initial weight, 33.8 kg; av final weight, 56.6 kg

*** Based on air-dried feed

On the other hand, there was not so much difference in pig performance on whole or ground sorghum. Besides, protein consumption and feed waste were lower in the sorghum-based diets (Tables 6 and 7). Gains, as well as feed efficiency, were comparable. There was a slight excess of protein supplement intake by the pigs fed the dry grain; but in the other treatments, the consumption of the supplement was within the normal range for pigs of that age.

Rice meal (bran and|or polishings)

During the last few years, rice production has increased considerably in most Latin American countries; consequently, the availability of its by-products (meal, bran and|or polishings) has grown apace. In many regions, the prices of rice and its by-products compete favorably with the cereal grains (especially maize and sorghum) traditionally used in animal nutrition. However, the utilization of rice

Table 6. **Effect of feeding dry and soaked whole grain sorghum on performance of growing pigs.***

Treatments	Daily average		Feed | gain
	Gain (kg)	Feed (kg)	
Ground sorghum + protein supplement	0.68	2.03	2.99
Whole grain sorghum + protein supplement			
Dry - fed separately - ad libitum	0.66	1.93	2.93
Dry - mixed - controlled	0.60	1.97	3.28
Dry - mixed - ad libitum	0.61	1.92	3.15
Soaked - fed separately - ad libitum	0.65	1.88	2.90
Soaked - mixed - controlled	0.54	1.82	3.38
Soaked - mixed - ad libitum	0.66	2.24	3.40

* Mean of eight pigs per treatment; **49-day trial**; av initial weight, 18.5 kg; av final weight, 50.9 kg for the control group

Table 7. **Effect of feeding whole grain sorghum plus a protein supplement* on the performance of growing pigs.**

Parameters**	Control (Sorghum + SBM)	Whole grain sorghum		
		Ground sorghum	Soaked***	Dry
Daily gain (kg)	0.66	0.69	0.66	0.66
Daily feed intake (kg)				
Sorghum	-	1.58	1.55	1.37
Supplement	-	0.49	0.48	0.53
Total	2.04	2.07	2.03	1.90
Feed/gain	3.09	3.00	3.07	2.88

* The protein supplement, which contained 40 percent crude protein, was fed free choice in separate feeders.

** Mean of 14 pigs per treatment; **49-day trial**; av initial weight, 18.5 kg; av final weight, 51.0 kg.

*** Based on air-dried feed.

does not generally give the results expected since high levels of rice meal in diets adversely affect weight gains and feed efficiency in growing-finishing pigs. Among the possible causes for this limited performance are the level of fiber content (hulls), the availability and balance of amino acids (protein quality), the interaction of minerals, and the effect of prolonged storage (rancidity).

The effect of fiber content had been studied previously (1974 Annual Report). In the earlier experiments the amount of protein in the experimental diets was variable; but in the present experiment, the content of soybean meal (SBM) was adjusted to obtain isoproteic diets (N x 6.25), thus eliminating the factor of protein quantity as a possible variable. Gains were practically identical for all groups, but pigs fed rice meal with ground hulls added needed to consume a greater quantity of feed daily to obtain the same weight gains (Table 8). The reduction of the digestible energy content of the diets containing rice hulls can be seen even when small percentages were added.

These results and those previously reported (1974 Annual Report) suggest that the quantity of supplementary protein (SBM) in diets with 60 percent rice meal is apparently not a factor of prime impor-

Table 8. **Performance of growing pigs fed isoproteic diets based on rice meal containing different levels of hulls.***

Rice meal (%)	60	54	48	42	36
Rice hulls (%)	-	6	12	18	24
Daily gain (kg)	0.64	0.64	0.64	0.64	0.64
Daily feed intake (kg)	1.81	1.87	2.05	1.97	2.05
Feed/gain	2.84	2.91	3.17	3.07	3.35
Digestible energy (kcal/kg DM)	3,504	3,233	2,971	2,849	2,586

* Mean of ten pigs per treatment; av initial weight, 17.1 kg; av final weight, 52.8 kg.

Table 9. **Performance of growing-finishing pigs fed rice meal-based diets with different protein supplements.**

Dietary treatments	Daily average Gain (kg)	Feed intake (kg)	Feed/gain
Control: maize + soybean meal	0.70	2.29	3.11
Rice meal (60%) plus			
Soybean meal	0.57	1.89	3.16
Fish meal	0.67	2.11	3.03
Meat meal	0.60	1.93	3.08
Fish meal + cottonseed meal	0.61	2.04	3.19

* Mean of ten pigs per treatment; av initial weight, 18.5 kg, av final weight, 91.8 kg for the control group

tance in the depression in performance observed in growing pigs. In recent experiments, the combination of rice meal with protein sources other than soybean meal were studied in growing-finishing pigs in order to assess the possible effect of the supplementary protein quality. In spite of the fact that performance with the protein sources other than SBM was better, it was not equal to the control diet of common maize plus SBM (Table 9). Diets supplemented with animal protein were consumed at levels that were comparable to the control diet and feed efficiency was similar. These data suggest that protein quality may be one of the limiting factors in the efficient use of rice meal. On the other hand, it has been found in rice meal-based diets (except for studies on the effect of adding hulls) that the consumption of feed is consistently lower than for the control.

In order to study further the possible effect of protein quality, an experiment was carried out with growing pigs fed a basal diet composed of 60 percent rice meal and SBM, supplemented with the amino acids lysine and methionine (Table 10). Lysine supplementation produced an adverse effect, whereas the addition of methionine produced gains similar to those

Table 10. **Effect of lysine and methionine supplementation on the utilization of rice-based diets for growing pigs.***

Treatment**	Daily average Gain (kg)	Feed intake (kg)	Feed/gain
Control: maize + soybean meal	0.65	1.82	2.81
60% rice meal + soybean meal +	0.61	1.70	2.81
0.15% lysine	0.58	1.66	2.86
0.15% methionine	0.63	1.71	2.72
0.15% lysine + 0.15% methionine	0.61	1.76	2.89
60% rice meal + fish meal	0.62	1.61	2.61

* Mean of six animals per treatment; **49-day trial**; av initial weight, 17.7 kg; av final weight, 49.2 kg for the control group

** Isoproteic diets calculated to supply 16 percent crude protein of the control animals and to those animals fed the rice meal-based diet supplemented with fish meal. Feed efficiency with methionine or with fish meal as a source of protein was better than that of the control and of the other treatments. This suggests that with rice meal-based diets, greater emphasis should be placed on the quality of the supplementary protein than on the total quantity of protein supplied.

Another factor to be considered is the quantity and quality of phosphorus in rice meal and its possible effect on the calcium phosphorus relationship in the diets. In rice meal, as in the majority of products of plant origin, most of the phosphorus is found in the form of phytic phosphorous which is, in the majority of cases, unavailable to monogastric animals. Diets with high levels of phytic phosphorous tend to interact with other mineral elements, especially zinc, producing insoluble zinc phytates, thereby reducing the availability of this minor element. Nevertheless, in a factorial experiment designed to study different ratios of total Ca/total P and their interactions with two levels of zinc (50 and 100 ppm) in the form of zinc oxide, no improvements in growth gains were observed. In comparison to the control group, feed intake on the rice-based diets did not increase.

The experimental results obtained to date suggest that the nutritive quality of rice meal depends to a great extent on its crude fiber content, which increases with the addition of hulls. Good-quality rice meals (i.e., low crude fiber content) can be used at relatively high levels (40 to 60 percent) as a principal source of energy in diets if good-quality protein sources are used. Further studies need to be done to clear up certain aspects of interaction between amino acids in order to find a practical solution to this problem, especially in regard to the supplementation of methionine, which is apparently the limiting amino acid. The reduced intake of rice meal-based diets suggests that certain physical aspects such as consistency, density and palatability should be considered to obtain the efficient utilization of rice by-products in swine feeding.

Opaque-2 maize

Most of the studies conducted previously with opaque-2 maize have concentrated on evaluating this product during the growing-finishing phases (1972 and 1973 Annual Reports). Nevertheless, its nutritive value had not been determined for the lactation period when the protein needs are most critical because of the additional requirements for milk production.

In a series of studies with pigs and rats, it was found that when opaque-2 maize was used as the only energy source, it was not sufficient for pig performance during lactation. In lactating sows, the negative effect was mainly reflected in weight losses (Table 11), whereas in rats the mother, as well as her offspring, was affected.

In these experiments five treatments were used with different combinations of opaque-2 maize and three protein levels. In two of these treatments, the diet was changed at 28 days in order to evaluate different feeding systems during the first half of the lactation period (56 days) because of the difference in milk production during these two phases. As can be seen in Table 11, there was a clear nutritional advantage for sows that consumed opaque-2 maize (9.5 percent protein) during the first phase and opaque-2 maize plus soybean meal (13 percent protein) until weaning. Performance in terms of weight gain for the sow and performance for the litters were equal or better than the other opaque-2 maize treatments in spite of the fact that total protein consumption during lactation was less, except for the group that consumed only opaque-2 maize during the whole pe

Table 11 Performance of lactating sows fed different combinations of opaque-2 maize and prote[illegible]

Parameter	Control	Op-2 [illegible]	O_2 + SBM	[illegible] SBM	[illegible]
Lactation [illegible]					
No. of sows [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Daily feed intake [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Farrowing [illegible]					
No. pigs [illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Individual [illegible]	[illegible]		[illegible]		[illegible]
Litter [illegible]	[illegible]			[illegible]	[illegible]
Weaning [illegible]					
No. pigs/litter	[illegible]			[illegible]	[illegible]
Individual weight [illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Litter [illegible] (kg)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* Indicates [illegible]
[illegible]
** There [illegible]

Cassava meal and opaque-2 maize in life cycle swine feeding

The evaluation of these feeds in integrated life-cycle swine feeding was continued this year. Descriptions of the sequence of the experimental diets for each of the different periods of the life cycle of the pigs as well as results for the growing-finishing periods, were presented in the 1974 Annual Report. During this year the complete cycle, which also includes pregestation, gestation and lactation was completed.

The results of these first litters obtained from this experiment are given in Table 12. The larger number of births corresponded to the group fed cassava meal, however this can be attributed to aspects of management or individual variations in animals rather than to the experimental treatments. Some gilts were eliminated in the final selection of the breeding stock before the mating period; others had delayed estrus and were therefore not considered at the same time as the others. For this reason there is a difference in the number of gilts at [illegible].

The number of pigs per litter was similar for all groups although gilts on cassava meal diets tended to have smaller litters. In addition, the weights of these pigs at birth were consistently lower than for the other groups. The average number of pigs at weaning was significantly lower for the cassava meal group, so the small differences observed at birth were more significant at weaning. Although the average weights per pig at weaning were not appreciably different for the three groups, the interaction of weight and number of pigs per litter, expressed as total weight per litter at weaning was considerably lower for the cassava meal group, especially when compared to the control group (103.6 and 145.4 kg, respectively). The performance of litters from the opaque-2 maize group was intermediate.

Table 12. **Reproductive performance of gilts fed diets based on cassava meal, opaque-2 maize, or common maize during one life cycle.***

	Experimental variable		
Parameter	Common maize	Opaque-2 maize	Cassava meal
No. of gilts	10	12	14
Farrowing data			
No pigs/litter	10.0	9.0	8.4
Individual pig wt (kg)	1.09	1.10	0.97
Weaning data			
No. pigs/litter	9.4	7.5	6.6
Individual pig wt (kg)	15.87	15.42	15.70
Litter wt (kg)	145.4	111.1	103.6

* Life-cycle swine nutrition performance of Yorkshire gilts fed the experimental diets during the growing, finishing, pregestation, gestation and lactation periods.

Total feed intake per gilt during the life cycle, including the starter diet for the suckling pigs, was similar (approximately 1 ton|animal) for all groups. (Table 13). The most noticeable differences correspond to the supplementary protein needs, in this case, soybean meal. Because of the high-quality protein of opaque-2 maize, animals fed these diets required only 36 percent of the quantity of SBM (53.7 vs 149.1 kg) needed by the animals fed the common maize-based diets. On the other hand, the reduced quantity of crude protein present in cassava meal and its poor quality led to the high SBM requirements (269.0 kg), as compared to 149.1 and 53.7 kg for the common maize and opaque-2 maize-based diets, respectively. Therefore, in order to balance the experimental diet based on cassava meal, animals needed 80 percent

Table 13. **Intake data for gilts fed diets based on cassava meal, opaque-2 maize, or common maize during one life cycle.***

	Experimental variable		
Parameter	Common maize	Opaque-2 maize	Cassava meal
Total intake (kg)			
Diet	1,001.4	977.9	1,079.6
Maizes	796.4	870.2	-
Cassava meal	-	-	754.1
Soybean meal	149.1	53.7	269.0
Proportional intake of SBM (%)	100.0	36.0	180.4

* Figures indicate total intake of diet and basic ingredients consumed by a gilt during the growing, finishing, pregestation, gestation and lactation periods, including the diet for the litter.

Table 14. **...econd litter of Zungo (Z) and Duroc (D) sows.**

Parameter	Z x Z*	D x Z	Z x D	D x D
No. of litters	7	4	3	4
Farrowing data				
No. of pigs | litter	8.6	9.0	9.0	9.0
Individual pig wt (kg)	0.96	1.08	1.22	1.31
Litter wt (kg)	8.2	9.8	11.0	11.8
Weaning data (56 days)				
No. of pigs | litter	5.9	6.8	6.0	5.5
Individual pig wt (kg)	10.53	13.10	13.56	13.15
Litter wt (kg)	61.7	88.4	81.3	72.3

* Parent designation: boar x sow

more SBM than the control group. The lower performances in the cassava meal group can be partially explained by the effect of the protein quality, possibly due to the methionine deficiency in both the cassava and the SBM.

Experimental observations confirm the theoretical estimates of protein saving or protein supplementation derived from the use of high-lysine maize, such as opaque-2. On the other hand, when cassava meal is used, there is a need for greater nutritional and economic considerations in order to obtain results as satisfactory as those of the control diet.

The performance of native and improved swine in tropical zones

Studies measuring the performance of native and improved swine (Duroc) and their respective crosses were continued in collaboration with the Instituto Colombiano Agropecuario (ICA) at the Turipaná Experimental Station in Montería. Part of this research constituted doctoral thesis work of a research associate from the Technical University in Berlin. A brief description of the techniques and experimental design used is given in the 1974 Annual Report.

Table 14 gives the results obtained with the second litters from the foundation breeding stock used in the experiment. The number of pigs in the second litter of the Zungo sows was similar to that of the Durocs, although their average weight (as was also true of both their first litters) was slightly less. The total number of weaned pigs in the second litter was slightly lower than for the first litter; nevertheless, their

Table 15. **Performance of Zungo, Duroc and crossbred pigs during the growing-finishing periods.***

Parameter	Z x Z**	D x Z	Z x D	D x D
Duration (days)	182	131	128	126
No. of animals	16	19	14	12
Daily gain (kg)	0.44	0.61	0.61	0.63
Daily feed intake (kg)	1.93	2.42	2.38	2.44
Feed | gain	4.38	3.99	3.92	3.90

* Period from weaning to approximately 90 kg liveweight

** Parent designation: boar x sow

weights were higher. As can be seen, the performance at weaning of the D x Z offspring was similar to that of purebred Durocs or Z x D crosses.

Performance indices of the offspring during the growing-finishing periods indicate that Zungo pigs grow more slowly, consume less feed and have a lower feed efficiency than pure Duroc or crossbreds (Table 15).

These data suggest that under intensive management conditions, native pigs should be submitted to a rigorous genetic selection plan to bring their level of performance up to that of the improved breeds. The simple cross considerably improved the performance of native swine under the experimental conditions used.

At the end of the growing-finishing period the pigs were slaughtered to study their carcass quality. The results were quite similar for both the first and second litters; Table 16 gives data on the latter. Carcasses from Zungo pigs had more backfat, a greater quantity of total fat and a lower percentage of lean parts than the pure Durocs. The carcasses of the crossbred animals showed intermediate characteristics. Although the demand for animal fat in general, that of pork, still seems to be important in many Latin American countries, there is a growing tendency towards greater consumption of fats and oils of plant origin. This would mean that greater emphasis should be placed on the selection of native pigs that would produce more meat and less fat.

ANIMAL HEALTH

The major objective this year was animal disease economics; that is, the measurement of economic impact and the cost-benefit ratio of control. Secondly, work was carried out to identify areas where further investigation or research was required before economic methods of prevention or control could be devised. These activities were based on the knowledge accumulated on the spectrum of swine diseases in the Latin American tropics, enumerated in previous reports.

Disease impact at the farm level

The collection of data on foot-and-mouth disease has continued. In addition, information was gathered on brucellosis, leptospirosis, transmissible gastroenteritis and swine dysentery; however, the economic analyses of these data have not been completed.

Foot-and-mouth disease

In the absence of an adequate vaccine, swine producers normally attempt to control foot-and-mouth disease outbreaks through sanitary methods and treatment of clinical cases. There was an opportunity to

Table 16. Carcass characteristics of Zungo, Duroc and crossbred pigs (second litter).

Parameter	Z x Z	D x Z	Z x D	D x D
Liveweight (kg)	90.1	91.5	91.1	91.6
Carcass yield	83.0	82.8	81.[illegible]	82.6
Backfat thickness (cm)	5.2	4.7	[illegible]	4.1
Total fat (%)	32.[illegible]	30.4	[illegible]	26.9
Ham (%)	26.1	27.4	27.0	[illegible]
Lean parts (%)	33.6	37.6	[illegible]	41.[illegible]
Carcass length (cm)	88.4	[illegible]	92.8	[illegible]

* [illegible]

make an evaluation of the sick and in-contact animals slaughtered as a complementary control to sanitary measures. The control of the outbreak (Type A virus) was striking. Of 709 animals, seven were found with lesions; there were 14 contacts. All 21 animals were slaughtered. The value of these animals was US$3,900 whereas the value of all animals on the farm at the time of the outbreak was US$36,000. The quarantine was lifted one month after the first case was detected, and the farm resumed normal operations.

Brucellosis

Sufficient information is now available for analyzing brucellosis, another disease that can seriously affect the profitability of swine production, as well as being transmissible to man. The control method being evaluated consists primarily in isolating infected animals, which are then eliminated from the farm. Possible contacts and animals giving weak serological titers were submitted to two more tests two months apart, in addition to other complementary techniques. Data for economic analysis include morbidity, mortality, pregnancy and birth rates; sales of animals, costs of bleeding the animals, testing and elimination. It was found that progenies from brucellosis-positive sows could be utilized as replacement breeding stock; this is a very important economic development for swine producers.

Having established an improved methodology for the control and eradication of this disease, it is necessary to establish the cost-benefit ratio in relation to the different types of swine operations. Given this kind of analysis, a national government can design area or country-wide eradication policies.

Disease investigation and research

Leptospirosis

This is another disease known to cause important production losses, as well as being a zoonosis. Evidence of infection was found on most farms visited in the Valle del Cauca, but epidemiological studies were necessary to determine optimal control methods. *L. pomona* is known to be the most important of these pathogens for swine; the three isolations made to data from aborted pig fetuses have been of this serotype.

The rodent population was examined on four infected farms. Cultures were made from the kidneys of 111 brown rats (*Rattus norvegicus*) (Table 17). To date, eight isolations representing seven strains of *L. icterohaemorrhagiae* and one of *L. pomona* have been obtained.* The latter report is significant as few reports exist of

* Typing was confirmed at the Centro Panamericano de Zoonosis (CEPANZO), Buenos Aires, Argentina.

Table 17. **Isolation of two types of Leptospira from kidneys of *Rattus norvegicus* trapped on infected pig farms.**

Farm	No. of kidneys cultivated*	No. isolations	Types of **Leptospira**
A	8	1	*L. pomona*
B	27	0	
C	30	2	*L. icterohaemorrhagiae*
D	46	5	*L. icterohaemorrhagiae*
Totals	111	8	

* Media used: Fletcher, Korthof and Ellinghausen

Table 18. **Kidney histological lesions and [illegible] of leptospirosis found [illegible] *Rattus norvegicus* trapped on infected pig farms.**

Farm	No. of animals examined	No. with lesions	% with lesions
A	8	0	0
B	27	11	40.7
C	30	13	43.3
D	46	30	60.5
Totals	111	54	48.6

rats acting as carriers of this serotype. Histological examinations of all the kidneys collected showed that 48 percent of them had lesions compatible with subacute or chronic leptospirosis (Table 18). These are strong indications of the rat's role in the epidemiology of the disease. The results are even more important in relation to human health as *L. icterohaeorrhagiae* and *L. pomona* are the two serotypes most commonly found infecting man.

The importance of *L. icterohaemorrhagiae* infections in pigs was checked by experimental infections with isolates from rats. There was no mortality; but in all cases, interstitial nephritis was found in the autopsies.

Eradication by slaughter is not feasible because of the high prevalence of infection on the farms. Methods of control and eradication using antibiotics and rodent control are being studied on individual farms, particularly in areas where there are leptospiral abortions.

Porcine enteroviruses

Serum samples sent to the Plum Island Animal Disease Center in 1974 gave strongly positive reactions to this group of viruses. When this evidence was considered together with the clinical and histological findings in a herd of pigs where cases of a central nervous system disorder were occurring, there was a strong likelihood that it was Teschen disease. Final confirmation depended on the isolation and characterization of the virus. This has been done and sent to Plum Island. There is very little information available in Latin America concerning this group of viruses; whereas in countries with highly developed swine industries, the enteroviruses have an important economic impact.

Swine dysentery

After identifying swine dysentery due to *Treponema hyodysenteriae* for the first time in Latin America, information on diagnostic and control methods was distributed to veterinarians working in both public and private institutions. The disease is probably widespread on commercial pig farms. New outbreaks were rapidly controlled using broad spectrum antibiotics.

A trial was carried out to determine the relative importance and interrelationship between **Treponema** and two other causal agents of dysentery, *Vibrio coli* and *Balantidium coli*.

INTERNATIONAL COOPERATION AND TRAINING

In 1975 contacts were extended with some national institutions that develop training, research and swine production programs in Latin America. Visits were made to those institutions and professionals developing national swine production programs. Their projects were studied as a basis for evaluating priorities in future training and technical cooperation programs. Maps of Central and South America, locating these institutions, are presented in Figures 1 and 2. The type of cooperation has been classified into three categories in accordance with the following criteria:

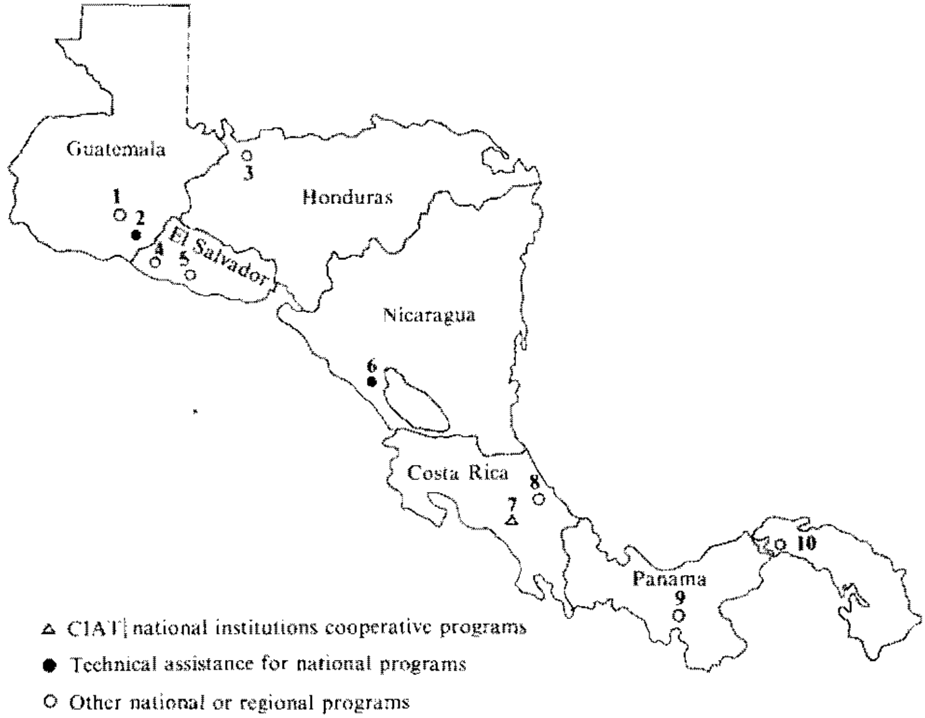

Figure 1. **Swine production projects in Central America.**

1. **CIAT|national institutions cooperative programs.** This category includes those sites where CIAT has participated most directly on the basis of agreements and priorities established by the IDRC|CIAT Project. In these cases there has been greater collaboration in technical assistance, in the training of professionals, and in the financing of some installations for the swine unit. CIAT has participated in these projects from the beginning, including the selection of the site, planning and supervision of the infrastructure and the projection of immediate activities. On the basis of these agreements, the cooperative projects should place emphasis on the training of professionals and swine producers, the transfer of technology, the development of swine production at a regional and national level, and the conducting of applied research oriented to solve local problems.

2. **Technical assistance for national programs that are already established.** This category includes those national programs where CIAT has provided indirect cooperation sporadically, especially in the areas of research, training and technical assistance. Each of these projects has been visited several times during the year as a starting point for greater international cooperation in the future.

3. **Other programs where there are possibilities of future cooperative projects.** This covers national or regional projects visited and evaluated by CIAT staff, where there has been only an exchange of information. CIAT cooperation, especially in training and technical assistance, can be increased in many of these sites in the future.

The principal activities related to international cooperation and training

Figure 2. **Swine production projects in South America.**

programs in swine production are given by country.

Bolivia

The construction of a swine unit for the cooperative Universidad Gabriel René Moreno|Proyecto Heifer|CIAT program in Santa Cruz (16)* was finished during the present year, with the technical and financial cooperation of the IDRC|CIAT Project. Facilities include buildings for lactating sows, growing-finishing pigs, postweaning corrals, and office and warehouse facilities. The equipment and the foundation breeding stock arrived by midyear, and the unit is presently functioning. The production of breeding stock for promoting development projects and for carrying out local research activities

* The number in parentheses refers to the one used to locate the sites in Figures 1 and 2.

will be initiated during the first months of 1976. A coordinating committee, made up of representatives from the aforementioned cooperating entities, was created with the purpose of formulating a work plan and providing technical assistance for those professionals doing research, teaching and extension work. These professionals participated in training activities of the Swine Program at CIAT.

Other contacts have been established with the Comité de Obras Públicas in Santa Cruz and Chuquisaca (17), in an attempt to integrate activities such as the production of breeding stock, swine development and transfer of technology to swine producers through the Cooperative Project. A preselection of possible candidates for the 1976 training course at CIAT was made of professionals from both institutions.

Costa Rica

Construction of the buildings that will house the swine unit forming part of the cooperative Universidad de Costa Rica, UCR |CIAT program in Atenas (7) has not yet begun. Through the IDRC|CIAT Project, technical and financial assistance was given in 1975 to begin activities for promoting the development of swine production. The site, plans and budget for construction are ready; only a few legal requisites need to be fulfilled before the university will permit construction to begin.

As part of this program, a CIAT swine specialist went to Costa Rica for six months as an instructor of the swine production course at the UCR Departamento de Zootecnia. Several research projects were begun on local nutritional problems as topics for graduete degree theses. Other complementary activities carried out by this professional included several conferences for swine producers and the organization of a Central American swine production course programmed for 1976.

In 1975 two Costa Ricans participated in CIAT's training program. One of them is on the staff at UCR and the other at the Ministerio de Agricultura y Ganadería in Guápiles (8). Foundations have been laid for a more effective integration between these two entities in the promotion and development of swine production in Costa Rica. A preselection was made of two technicians from the ministry for attending CIAT's 1976 training program.

Peru

Cooperation with this country has continued, mainly through the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) in Pucallpa (15). The construction of facilities for a swine production unit housing 20 to 30 breeding sows was begun and should be finished at the beginning of 1976.

The professional in charge of IVITA's cooperative swine program participated in the training program at CIAT. At the same time, he received technical assistance for the initial phase of the project (building the installations for the animals, training programs, immediate plans for local experiments, etc.).

Contacts have also been made with other institutions, especially the Sociedad Agrícola de Interés Social (SAIS) and the Ministerio de Alimentación, with the purpose of selecting candidates for future CIAT training programs.

Colombia and Ecuador

Most of the cooperative work in these countries has been carried out through ICA in Colombia (11, 12) and the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Santo Domingo and Quito, Ecuador (13, 14). The activities developed this year were related to specific research projects and the training of professionals.

Cooperative ICA|CIAT work on the evaluation of the native breed (Zungo) has continued; results are presented in the section of this report on the performance of native and improved swine in tropical zones. Two Ecuadorians were trained at CIAT during 1975. One of them returned to INIAP after one year. A research associate returned after finishing his thesis work at CIAT on the utilization of opaque-2 maize in diets for lactating sows.

Other countries

The most important activities developed in other countries are related to training programs for professionals belonging to national institutions and technical assistance for swine programs through periodic consultations and visits. This group includes the Instituto de Ciencia y Tecnología Agrícolas (ICTA) and the Instituto Técnico Agrícola (ITA) in Guatemala (1, 2); the Banco Nacional de Fomento in Honduras (3); the Centro de Desarrollo Agropecuario (CEDA) of the Ministerio de Agricultura y Ganadería in Sonsonate and San Salvador, Salvador (4, 5); the Banco Nacional (6) and the Ministerio de Agricultura y Ganadería in Nicaragua; the Universidad de Panamá (10) and the Ministerio de Desarrollo Agropecuario in Veraguas, Panama (9); and the Ministerio de Agricultura y Ganadería in Asunción, Paraguay (18).

Two professionals from Nicaragua and one from Panama participated in CIAT's training programs. Also during 1975, two research fellows returned to Nigeria after finishing work for their doctoral theses as part of the IDRC|CIAT|University of Ibadan Project.

PUBLICATIONS*

BUITRAGO, J., MANER, J.H. y GOMEZ, G. Producción de cerdos en América Latina. **In:** Proteínas y América Latina. Instituto de Nutrición de Centro América y Panamá, INCAP, Guatemala. (In press).

CLAWSON, A.J., MANER, J.H., GOMEZ, G., MEJIA, O., FLORES, Z. and BUITRAGO, J. Unextracted cottonseed in diets for monogastric animals. I. The effect of ferrous sulfate and calcium hydroxide in reducing gossypol toxicity. Journal of Animal Science 40(4):640-647.

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GOMEZ, G., MANER, J.H., FLORES, Z. and FRANCIS, C.A. A comparison of vitreous and soft endosperm high-lysine and common maize in diets for growing rats and pigs. Journal of Animal Science 41(6):1638-1644.

* This list includes only the journal articles published outside CIAT's series.

Maize production systems

HIGHLIGHTS OF 1975

Activities of the CIAT Maize Program have shifted from a Palmira-based, research-oriented program to one of collaborative services with the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) in Mexico. This program will principally support national programs in the Andean Zone and in tropical Brazil. An excellent spirit of cooperation exists among maize scientists of these countries and the two international centers involved.

During 1975, materials from CIAT's breeding program were tested in on-farm trials and recombined into basic genetic sources (populations), which may be useful to national programs and conveniently combined into existing CIMMYT materials. In breeding, emphasis has been placed on developing short materials that resist lodging, a major cause of yield reductions in the region.

International trials consisting of 30 CIMMYT experimental varieties and six local checks were planted in cooperation with the Instituto Colombiano Agropecuario (ICA) at several locations in Colombia.

Thirteen on-farm trials were conducted near Montería. Average yields of almost 5 tons|ha indicate that reasonable yields are possible for this traditional maize area. Establishing and maintaining a favorable plant density appears to be a major factor in the improvement of maize yields in this and similar areas.

The CIMMYT|CIAT collaborative services program has assembled and distributed national program materials to be tested in highland and lowland regional trials at 18 locations in six tropical countries.

PLANT IMPROVEMENT

Reduced plant height

Maize breeding work has concentrated on genotypes with reduced height and a stable plant type. The tendency of traditionally tall maize types to lodge is apparent in Table 1.

The program focused on full-sib family selection in materials homozygous for the brachytic-2 gene. As illustrated in the 1974 Annual Report, there are many variants of the "original" brachytic, with its thick stalk, wide leaves and very compact internodes. Such a plant type is not acceptable for intercropping with climbing beans or yams, as climbing and vegetative development are inhibited by a maize plant with compact internodes. Thus plants were sib-pollinated within rows that were reasonably uniform as to the plant types described in Table 2.

It was hypothesized that Type II would possess optimal support characteristics for association with climbing beans and yams and that Type III would not only have a better distribution of dry matter but would also be more responsive to higher densities in monoculture. This hypothesis was tested in collaborative studies with the Bean Program. Modified types II and III were compared with the new ICA brachytic hybrid H-210 (comparable to Type I) and the popular normal hybrid H-207. The value of a maize genotype as support was determined by the production of climbing beans. Preliminary results showed no significant differences among different maize types as supports for climbing beans (Table 3). These insignificant differences in the fall-off point for bean yields as maize densities increase will be studied in greater detail, using methods that will reduce the confounding of maize and bean densities and that will have more appropriate planting dates and systems for these associations. Under optimal conditions at Palmira, the ICA normal and brachytic hybrids outyielded CIAT's open-pollinated brachytics. Maize yields were high, averaging more than 6 tons|ha.

Table 1. **Results of 13 on-farm tests conducted near Montería (1975A).**

Plant type and variety	Origin	Grain	Average lodging (%)	Average yield (kg/ha)	No. of trials
Normal					
La Posta C_2	CIMMYT	Normal white dent	27	6,861	1
YHE	CIMMYT	Hard yellow opaque	34	5,036	2
WHE	CIMMYT	Hard white opaque	40	5,737	2
Comp. K	CIMMYT	Hard yellow opaque	39	5,295	2
ICA VE-21	ICA	Hard yellow opaque	33	5,273	2
ICA V-106	ICA	Normal yellow flint	53	3,948	6
ICA H-207	ICA	Normal yellow flint	46	4,969	5
ICA H-208	ICA	Soft yellow opaque	10	5,311	1
ICA H-154	ICA	Normal white flint	50	5,525	5
Brachytic					
Br I (Bl)	CIAT	Normal white flint	6	4,440	4
Br II (Bl)	CIAT	Normal white flint	8	5,029	2
Br III (Bl)	CIAT	Normal white flint	3	5,284	2
Br II (Am)	CIAT	Normal yellow flint	12	2,783	2
Br III (Am)	CIAT	Normal yellow flint	10	3,140	2
		Average (all materials over all locations)	26	4,902	

A second collaborative maize-bean experiment studied the importance of variety by system interaction in the selection of maize plant types adapted for both monoculture and intercropping (Table 4). Bean densities were significantly higher than in the previous experiment and in fact reduced the maize yields, which nonetheless were high in all systems. There were no significant differences among maize families in each of the three systems in the first maize trial. Correlations for maize yield and rank order were variable among the systems tested. Correlations for rank order ($r = 0.72^{**}$) and yield ($r = 0.66^{**}$) between the two maize-bean systems were highly significant, suggesting that maize selections made under one associated cropping system would be very successful in the other system as well. Similar studies of variety by system interaction are being conducted by the CIAT Bean Program to establish reasonable and inexpensive screening and

Table 2. **Characteristics of three different types of brachytic maize.**

	Height (m)	Stalk	Leaves	Internode compaction
Brachytic I	1.2	Thick	Wide, large	Extreme
Brachytic II	1.5.-2.0	Thick	Wide, large	Reduced
Brachytic III	1.5-2.0	Thin	Narrow, reduced	None

Table 3. **Yield of a climbing bean (P-259A) associated with four maize varieties, planted at four densities (CIAT, Palmira, 1975A).**

	Bean yield (kg|ha)				
	Maize and bean density*				
Maize variety	30	50	70	90	Average
ICA H-210 (brach.)	476.2d**	440.8de	334.2defg	204.4gh	363.9x
Brach. II Bl.	466.0d	459.4d	334.4defg	202.0gh	365.4x
Brach. III Bl.	491.0d	451.2de	241.0efgh	238.8efgh	355.5x
ICA H-207 (normal)	411.0def	281.6defgh	218.0fgh	177.8h	272.1x
Bean monoculture	1,754.8c	1,954.0bc	2,290.4a	2,083.8b	2,020.8y
Average	719.8m	717.4m	683.6m	581.4m	675.4

* Thousands of plants|ha of maize and beans

** Mean values in the same column, followed by the same letter, do not differ significantly at the 5 percent level.

Table 4. **Yield (kg|ha) and rank order of 15 maize genotypes planted alone and in association with bush and climbing beans (CIAT, Palmira, 1975A).***

	System A		System B		System C	Maize rank by system			
Maize variety or family	Maize	Bush bean**	Maize	Climbing bean***	Maize monoculture	A	B	C	Av maize yield
1188	3,853	455	3,403	424	4,643	13	14	11	3,966
1577	3,629	519	3,584	411	4,668	14	13	10	3,960
1768	4,207	422	4,581	450	5,437	9	5	1	4,742
1389	4,470	405	4,441	445	4,015	4	8	14	4,309
1464	4,106	479	3,308	402	4,167	11	15	13	3,860
1443	4,228	372	4,437	361	4,961	8	9	6	4,542
1101	4,630	325	4,924	372	4,934	3	3	7	4,829
1030	4,248	483	4,393	344	4,815	7	10	8	4,485
1599	4,880	337	5,076	383	5,003	1	2	4	4,986
1586	3,064	435	3,923	413	4,717	15	11	9	3,901
1449	4,181	323	4,603	520	3,855	10	4	15	4,213
4004	3,926	437	3,849	528	4,503	12	12	12	4,093
ICA H-207	4,866	372	4,470	341	4,992	2	7	5	4,776
ICA H-210	4,310	362	4,533	335	5,334	6	6	3	4,725
Tuxpeño Caribe-2	4,445	310	5,331	449	5,367	5	1	2	5,048
Average	4,203	402	4,324	412	4,761				4,429

* Yield correlations: $r_{AB} = 0.66^{**}$; $r_{AC} = 0.23$; $r_{BC} = 0.46$. Rank correlations $r_{AB} = 0.72^{**}$; $r_{AC} = 0.45$, $r_{BC} = 0.56^{*}$

** Variety ICA Pijao, 300,000 plants|ha, yield in monoculture, 942 kg|ha

*** Variety P-259A, 300,000 plants|ha, yield in monoculture, 2,532 kg|ha

Table 5. **Yields (kg|ha) of maize selections in brachytic and planta baja populations (CIAT, Palmira, 1974B, 1975A).***

Population	Average yield		
	1974B		1975A
	All families	Selected families	All families
White brachytic	3,092	4,276	7,550
Yellow brachytic	2,582	3,518	8,229
White planta baja	3,676	5,477	8,479
Yellow planta baja	4,714	5,008	7,378

* Average of two replications

selection methods for crops grown in association, using as prototypes the bean-maize systems, which are extremely important in Latin America.

Two cycles of full-sib selection and crossing of selected families have produced open-pollinated populations of white and yellow modified brachytics that are 1.5 to 2.0 meters tall, resistant to lodging and with yields near those of normal hybrids (Tables 1 and 5). Since preliminary results indicated little or no variety by system interaction, current plans are to combine types II and III during the present selection and crossing cycle. A high density replication (66,000 plants/ha) has been planted to eliminate genotypes that respond poorly to increased plant populations.

Shorter plant height is also the principal criterion in half-sib selections of white and yellow "plantas bajas."* An attempt has been made to improve the adaptation of these materials, originally from CIMMYT, to Andean Zone growing conditions. A better flint grain texture is also being selected to improve its acceptability to the local or small farm sector. As in the brachytic selections, a replication of plantas bajas has been planted at 66,000 plants/ha to evaluate density response.

* The term planta baja refers to the reduced plant height attributed to many genes, each with a small effect; in contrast, the reduced height of brachytic materials is attributable to a single gene with a large effect.

Materials for poorly drained areas

In 1974 a CIMMYT material (La Posta C_2) was found to be highly tolerant to high pH and poor drainage at CIAT. ICA and CIAT plant breeders collaborated in the selection of the best ears from the best families. The resulting composite was divided for planting at several locations, including the same poorly drained CIAT lot and a farm near Montería, where it yielded almost 6.9 tons (Table 1). La Posta has been mass selected for still another cycle to study its response to conditions of excess soil moisture; it should also be compared to other materials in several poorly drained locations.

Protein quality

As CIMMYT is emphasizing the conversion of high-yielding normals to hard endosperm opaque-2, CIAT's role in breeding for protein quality has been limited to testing promising CIMMYT populations and recombining opaque-2 with brachytic-2.

Recent cycles of white and yellow, hard endosperm opaques have performed much better than earlier counterparts. This can be seen in Table 1, where yields of all opaques tested near Montería averaged more than 5 tons|ha. The 1974 average for these materials was only 2.4 tons. Yields of 2.6 and 3.7 tons have been obtained with Composite K and ICA VE-21, respectively, in a farm trial in Cundinamarca. It is apparent that shorter opaque materials would be desirable to reduce the high rate of lodging. Therefore, CIAT has limited further breeding of opaque materials to recombining hard endosperm opaque-2 with brachytic-2 into a high-yielding, open-pollinated yellow variety. These materials are nearly ready for initial farm testing.

Six opaque varieties, including five with a hard endosperm, have been multiplied for rat and swine feeding trials under way in CIAT's Swine Program. One of these varieties (ICA's experimental variety VE-21), an ICA|CIAT selection from CIMMYT's Vera Cruz x Antigua x Venezuela opaque population, has been increased for more extensive farmer testing.

Resistance to Diatraea

The stalk borer **Diatraea** spp. is found throughout tropical Latin America. Principal damage is yield reduction and lodging, which makes the maize crop more difficult to harvest and of little value as a support for other crops. Chemicals for controlling this insect effectively are expensive, and their distribution from one area to another is uncertain. Therefore, genetic resistance must be sought.

CIMMYT and Cornell University have collaborated for several years in developing and testing an Insect and Disease Resistant Nuersery (IDRN), which includes artificial infestation and selection for resistance to **Diatraea** in Mexico. From 287 maize families (1974A cycle) that were sent to CIAT, 32 were selected, representing a range in plant maturity and combinations of damage to leaves and stalks. ICA H-207 was included as the local check variety. Plants were artificially infested at 55 and 60 days, with four larvae two to three days old. Damage, evaluated at harvest by splitting the stalks, was heavy; and there was a highly significant negative correlation between damage and grain yield (r= -0.5681**). Stalk damage ratings at CIMMYT and either stalk damage or grain yield at CIAT were not significantly correlated. The results do not necessarily mean that materials selected for resistance to **Diatraea** in Mexico are not resistant in Colombia. They do suggest that materials selected for borer resistance should be screened under natural or preferably artificial infestation in a number of localities with different combinations of insects, plant genotypes and environments. Results from this trial, which should be repeated in another season, suggest that CIAT would be a good location for such testing.

VARIETAL TESTING

International trials

Yields in 11 CIMMYT progeny and experimental variety trials (Table 6), planted in 1974B and 1975A, were excellent. These experimental yields are for two replications of single 5-meter rows. Open-pollinated experimental varieties are produced by CIMMYT from reserve seed of families selected for yield (Table 6), reduced height, and resistance to lodging and ear rot. A replicated trial of 30 CIMMYT experimental varieties and six local checks produced average yields of 5 tons|ha. A hard endosperm, yellow opaque population gave the highest average yield (6.6 tons). This same experimental variety trial has been planted at three other locations in Colombia in cooperation with ICA and is planned for another two locations in order to study varietal stability from near sea level to 1,400 meters on diverse soils, from the

Table 6. **Yield (kg|ha) from international CIMMYT trials (two replications) planted at CIAT (Palmira 1974B, 1975A).**

Trial	Varieties	Yield of families		Yield of checks	
		Trial (Av)	Selected (Av)	Best	(Av
La Posta C_2	256	3.152	4.610	3.744	2.536
Cogollero	256	3.122	5.148	3,619	2.942
IDRN	256	4.196	5.842	5.188	3.435
Blanco Subtropical	256	3.489	5.044	3.297	2.610
Amarillo Subtropical	256	3,329	5.138	3.387	2.330
Braquiticos	256	8.514	10.925	7.859	6.203
Tuxpeño Caribe 2	256	8.534	10.799	6.086	4.641
(Mix 1 x Col. Gp 1) ETO	256	7,105	9.201	6.277	5.058
Blanco Cristalino	256	7,400	8.956	5.603	4.339
Mez. Trop Blanco	256	9,312	11.339	6.327	5.486
Experimental varieties*	36	5,004	6.602	6.550	3.884

* Four replications

fertile soils of the Valle del Cauca to the highly infertile soils of the Llanos Orientales. Additional progeny and experimental variety trials were planted in 1975B.

Key activities of the CIMMYT|CIAT collaborative services program are regional trials of national program materials. Trials for eight highland and ten lowland locations are being sent to the six collaborating countries.

On-farm trials

A number of farm trials were conducted at Montería in collaboration with the weed control and small farm groups. The principal objectives of these trials were (1) to evaluate CIAT brachytic materials and local varieties and hybrids in monoculture and associated with yams, (2) to determine optimal plant densities for the maize varieties, and (3) to evaluate several weed control alternatives for maize production on small farms.

Interesting conclusions may be drawn from the 13 trials; the most important is that reasonable maize yields are possible for this area (Table 1). In spite of delayed rainfall and subsequent flooding in some zones, 1975A was an excellent season for maize. All ICA, CIAT and CIMMYT materials produced several times the traditional average yields (approximately 1.2 tons|ha) reported for the Andean Zone. Furthermore, all hard endosperm opaque varieties were equal or nearly equal to normal hybrids and varieties at comparable plant densities.

Plant density was the principal limiting factor in varietal performance across all locations. A typical example of density effects on maize yields for the ICA hybrid H-207 is illustrated in Figure 1. Results were similar for all locations and for all 14 materials tested. The importance of adequate population density may apply to a large part of the Andean Zone. Estimates are that 70 percent increases in yields of unimproved Bolivian native varieties could be obtained if higher plant densities could be implemented.

Over all locations and varieties, 68 percent of the seed planted produced

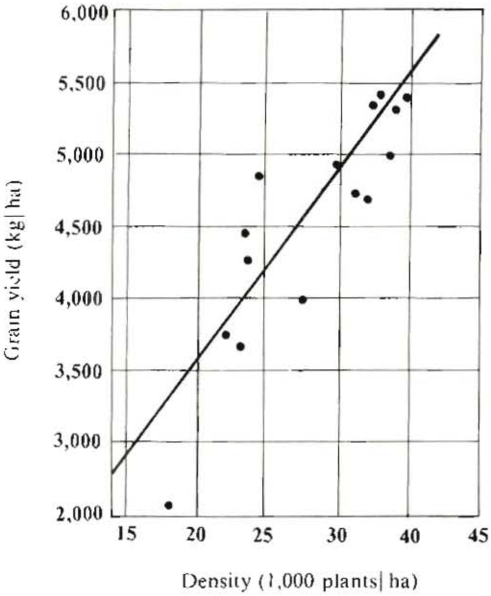


Figure 1. **On-farm yield of maize hybrid ICA H-207 as a function of plant density, Montería, Colombia (1975A) (r = 0.852).**

plants for harvest. Obtaining and maintaining high-quality planting seed from harvested opaque maizes stored under traditional farming conditions is a potentially serious limitation to a more extensive distribution of such materials, and must be examined.

La Posta C_2, selected from a 1974B CIMMYT progeny trial for its performance under adverse conditions of high pH and poorly drained soils, yielded extremely well under similar conditions in a field near Montería. An additional cycle of selection has been completed at CIAT. The acceptability of a soft, white, dent grain type is limited but can be improved by recombination with more desirable types.

Lodging data (Table 1) indicate that brachytic varieties should have distinct advantages over normal plant types as support for yams. Among the three selected brachytic plant types, no differences were observed in the relative growth and climbing ability of the yams. Variations in yields of yams supported on normal and brachytic maizes should show the importance of the lodging observed.

A number of the on-farm maize trials included weed control treatments, particularly the use of preemergence herbicides. Previous studies have shown that farmers have a labor shortage during the maize-growing seasons; an effective herbicide treatment plan could alleviate this situation.

Atrazine or linuron, alone or in combination, or atrazine and alachlor gave slightly higher yields than the farmers' usual system of two or three hand weedings. Since rainfall was light during the first 30 to 50 days of these trials, weeds were not as abundant or competitive as they would normally be.

The labor-saving potential of herbicides was also tested in nontillage systems on three farms. The nonselective, nonresidual compounds paraquat and glyphosate were applied alone or in combination with preemergence herbicides to the weeds present at planting time. These treatments were compared with the farmers' traditional land preparation methods. Results were promising for both products; when used in combination with a preemergence herbicide, they gave better control than when used alone.

These farm trials have demonstrated that at adequate plant densities, yields of a number of normal, brachytic and opaque varieties are high enough to justify inputs such as fertilizers, insecticides and herbicides.

REGIONAL ACTIVITIES

CIMMYT and CIAT acted as hosts of the 1975 meeting of Andean Zone maize researchers in Mexico. Participants explored ways in which the collaborative services of the two centers could best support national program efforts to increase maize production. CIMMYT provided an in-depth look at its materials, population development scheme and farm testing methodology. National program leaders presented current maize production data for their respective countries, as well as short- and long-term objectives for improving production. National program activities for reaching these goals were presented, followed by discussions of how CIMMYT and CIAT, through their collaborative services program, could best support national program activities in research, varietal development and testing, and the training of scientists and production agronomists. A number of the participants made a brief visit to Palmira on their return in order to see CIAT programs and services.

As a result of the Mexico meetings, guidelines were established for the regional program, which will encompass the five Andean countries and tropical Brazil. The key areas of support include:

1. A more liberal and rapid exchange of genetic materials at all stages of development among national programs and between national programs and CIMMYT.

2. The formation of national maize training programs at the production agronomist level, encouraging professionals from several countries to participate in the course presentation. Such a course has been planned by the Bolivian national program for the 1975B season in the state of Santa Cruz.

3. The facilitation of field-level interaction among scientists from different countries to broaden the exchange of ideas and germplasm on a regional basis.

4. The establishment of uniform variety trials of national program materials for both the highland and lowland tropical areas. The agronomic practices for these trials were developed at the conference in Mexico, and the materials have been distributed for planting during the next season.

Rice production systems

HIGHLIGHTS IN 1975

Extensive testing of 14 promising rice lines was completed and six were selected for further evaluation, purification and multiplication. It is expected that one or two of the most promising lines will be named and released as varieties in 1976.

Breeding to develop a large quantity of germplasm with resistance to the rice blast disease has progressed along two approaches. One approach attempts to combine multiple sources of resistance into new varieties. A total of 587 multiple crosses were produced and from these, resistant plants were selected and transplanted in the field to provide an enormous source of resistance. In the second approach, a modified, multiline procedure is being employed to combine blast resistance with favorable agronomic characteristics.

Progress has been made in the chemical control of weeds and volunteer and red rice. The problem is especially difficult as selective herbicides are not effective against the volunteer rice as a weed. Combinations of herbicides were tested and some effectively controlled pest plants while not harming the later seeded rice.

Knotgrass, another important weed in rice, propagates both by seed and stolons and a two-stage program is necessary to achieve proper control. Stolons must be eliminated before planting the crop, then standard herbicides for controlling germinating grass seeds can be used.

An irrigation pump was developed which combines low production and operating costs with a simple method of installation in a concrete culvert. The pump is powered from the PTO of a tractor. Final design plans will be released in 1976.

Theoretical work was done to improve machine mobility in soft fields and the results successfully applied at the Palmira station. When lugs are removed from large tires and the tires inflated to a low pressure the increased deflection and surface contact area provides improved traction and superior mobility.

Various CIAT units have cooperated to develop a continuous rice production system for the Palmira station. The system will facilitate research and training functions by providing fields at various stages of rice production throughout the year.

ECONOMICS

Economics research in the Rice Program has been directed to documenting and analyzing the impact of new rice varieties in Latin America. The study is composed of two major parts: (a) a general review of rice areas, yields, production and trade in Latin America and the Caribbean, with emphasis on measuring the contribution to output of the new high-yielding varieties (HYV's); and (b) a detailed analysis of the economic benefits from the new varieties in Colombia with attention to the distribution of the benefits.

The first part of the study involves a survey of all major rice producing countries in the region, to obtain the data for estimating the contribution of the new varieties to production. This survey, now being conducted in collaboration with national and international agencies, will provide data to up-date the information provided in the 1972 Annual Report.

Table 1 has been constructed from preliminary survey data. The results are shown by region in Latin America. Brazil has been excluded from the analysis. While she produces about one-half of Latin America's rice, the majority comes from the upland sector, where yields are very low. Inclusion of Brazil would mask the impact of the HYV's in other regions. For Latin America (excluding Brazil), the preliminary estimate is that rice production was 40 percent higher in 1974 than it would have been in the absence of HYV's. This figure could be overstated due to some confounding with irrigation (especially in the data shown for South America), but conversely no allowance is made for the fact that some of the expansion in areas may not have taken place in the absence of HYV's.

It would be incorrect to attribute all increased production solely to the improved genetic potential of the HYV's. Expanded use of inputs, improved cultural practices and the roles of national and grower organizations are all important complementary inputs.

Rice production in Colombia has doubled since 1968, due entirely to expanded area and yields in the irrigated

F-1

Table 1. **Estimated contribution of high yielding varieties (HYV's) of rice to total yields in regions of Latin America, 1974.**

		Mexico and Caribbean	Central America	South America (excl. Brazil)	Colombia (irrigated)	Latin America (excl. Brazil)
1. Total area	(1,000 ha)	452.0	257.1	1,088.0	273.0	1,797.0
2. Total production	(1,000 tons)	1,022.0	472.2	3,647.1	1,420.1	5,141.4
3. Yield	(tons/ha)	2.261	1.837	3.352	5.203	2.861
4. HYV's area	(1,000 ha)	200.4	157.9	386.6	279.2	744.9
5. Traditional area	(1,000 ha)	251.6	99.2	701.4	2.7	1,052.1
6. Traditional yield	(tons/ha)	1.779	1.284	2.399	3.100	2.040
7. Traditional production	(1,000 tons)	447.6	127.4	1,682.6	8.5	2,146.4
8. HYV's production	(1,000 tons)	574.4	344.9	1,964.5	1,411.7	2,995.0
9. HYV's yield	(tons/ha)	2.866	2.184	5.082	5.224	4.021
10. Yield margin	(tons/ha)	1.087	0.900	2.683	2.124	1.981
11. Additional production	(1,000 tons)	217.9	142.1	1,037.2	573.9	1,475.6
12. Additional production	(%)	27.1	43.0	39.7	67.8	40.3

Sources and derivations: (1), (2): U.S. Dept. of Agri. (4): CIAT, HYV's surveys, 1972 and 1974. (5) (1) - (4). (6): Average yield 1960-64. (7). (5) x (6). (8) (2) - (7). (10): (9) - (6). (11): (10) x (4).

(12) $\frac{(11)}{(2) - (11)} \times 100$

sector. The competitive position of the upland sector, where yields have been constant at 1.5 tons|ha, was reduced and the proportion of national output from the upland sector fell from 32 to 10 percent. Irrigated yields rose from about 3 tons|ha when Bluebonnet 50 was the major variety to almost 5.5 tons|ha with the new dwarf rices (1974 Annual Report). The sowings of dwarf rices rose from 5.5 percent of the irrigated area in 1969 to almost 100 percent in 1974. The estimated yields of Bluebonnet 50 and the HYV's at the farm level are shown in Table 2.

As a result of rapidly expanded production in Colombia, real prices received by producers in 1972 were almost half the 1965 level, recovering somewhat by 1974 (Table 2). This has meant that Colombian consumers have benefitted from the technological change. Net incomes of producers (after meeting variable costs) would have been higher without the new varieties.

This pattern of the distribution of the benefits has resulted because the extra production was very largely sold on the domestic market, where the demand for rice is moderately inelastic. Rice exports have been indirectly discouraged because of the tariff policies favoring the manufacturing sector. With these tariffs, the exchange rate can be maintained at a level lower than would apply in their absence, thereby making exporting less attractive.

The retail price of rice in Colombia has not tended to cheapen as has farm price (Table 2). As a result, the rice marketing margin has risen very substantially. This margin is the difference between the retail price and the farm price expressed as a percentage of the farm price. Prior to 1968 it had been constant or falling. With greatly expanded production, the milling, transport and distribution activities had to handle almost twice the volume of rice between 1968 and 1973. However, preliminary analyses suggest that an increase in the margin from 115 percent (in 1968) to 218 percent (in 1973) was much greater than could be accounted for by rising costs in these activities. Thus, some benefits attributed to consumers may have

Table 2. **Yields and prices for Bluebonnet 50 and high yielding varieties (HYV's) of rice in Colombia, 1964-74.**

	Estimated yield, Bluebonnet 50 (tons|ha)	Estimated yield, HYV's (tons|ha)	Producer price, paddy ($Col|ton)*	Retail price, milled ($Col|ton)*	Marketing margin**
1964	3.09	3.25	1,347	3,480	158
1965	3.01	3.85	1,592	3,850	142
1966	3.02	-***	1,507	3,568	137
1967	3.29	5.84	1,418	3,259	130
1968	3.16	5.65	1,452	3,117	115
1969	3.04	5.51	1,217	2,877	136
1970	3.34	6.07	1,121	2,727	143
1971	3.42	6.29	1,044	2,735	162
1972	3.02	5.49	893	2,493	170
1973	2.94	5.37	978	3,113	218
1974	2.84	5.22	1,151	3,321	188

* Expressed in 1964 $(Col.)

** 100 (Retail Price - Producer Price)|Producer Price

*** Less than 2 percent of the area was sown to HYV's.

accrued as returns to factors in this sector. While not altering the total benefits from new rice varieties, this aspect has important distributional implications, and future work will examine the components of this increase.

BREEDING

Potential new varieties

In 1975, the CIAT Rice Program continued cooperation with the Instituto Colombiano Agropecuario (ICA) in developing, testing and multiplying promising lines for future varieties. Fourteen lines were tested at 21 locations with irrigation and at three locations without irrigation in major rice areas of Colombia. These regional trials were financed by the Federación Nacional de Arroceros (FEDEARROZ), conducted by personnel of FEDEARROZ and ICA, and evaluated by staff of those groups and CIAT.

Table 3 shows average yields for the 14 lines and the five commercial varieties in five major climatic and rice producing regions of Colombia. Nursery and field trials were also conducted in Guatemala, Panama and Costa Rica and information

Table 3. **Average rice yields (kg|ha)* of 14 lines and 5 varieties in 21 irrigated regional trials in Colombia (1975A).**

	Valle and Cauca(4)**	Tolima and Huila(6)	Atlantic Coast(4)	Northeast Zone(3)	Meta (4)	Average, all locations
Lines						
4403	6,337	8,914	6,676	6,853	5,307	7,029
4418	5,745	7,715	7,110	6,690	4,875	6,559
4419	7,736	8,000	6,461	5,613	4,886	6,805
4421	7,096	8,956	6,878	6,398	4,902	7,065
4422	7,884	9,221	6,326	6,573	4,509	7,128
4436	5,499	6,910	5,963	5,373	3,715	5,644
4438	7,216	6,625	5,981	6,250	4,437	5,681
4440	8,870	8,725	7,563	7,456	5,445	7,579
4444	7,459	8,451	7,020	6,983	4,943	6,981
4461	5,960	6,696	6,535	6,180	3,444	5,880
4462	5,874	7,290	7,201	7,166	4,525	6,475
4467	7,771	7,496	6,086	6,513	4,466	6,521
4468	8,515	8,095	7,266	8,270	4,876	7,372
4469	7,175	7,890	6,140	7,316	2,637	6,334
Commercial varieties						
CICA 6	5,725	7,296	6,183	6,070	2,827	5,835
CICA 4	6,496	7,091	6,711	6,173	3,298	6,088
IR 8	6,881	7,061	6,223	5,743	2,096	5,828
IR 22	5,710	6,218	6,315	5,290	3,068	5,481
Bluebonnet 50	4,222	4,254	4,698	4,446	2,586	4,107

* Yields are for dry paddy rice

** Number of trial locations in each zone collected on resistance to rice blast disease caused by *Pyricularia oryzae*. Six lines were selected from the 14 based upon their yields and observations of blast resistance, lodging, **Sogatodes** reaction, growth cycle, plant height, shattering rate and milling and grain quality. Table 4 compares reactions to rice blast and the milling quality of the six lines with commercial varieties. After another season of regional trials, one or two of the lines will be named as varieties and basic seed will be released in 1976 for certified seed production. Figure 1 compares the quality and length of grains of the six promising lines.

Seed multiplication

Extensive purification and multiplication of the 14 advanced genetic lines were accomplished during 1975. Two-hundred-fifty panicle selections of each line were planted in seedbeds and material of each panicle was then transplanted into a single row to observe uniformity of plant type and yield. Eight lines were rejected because of undesirable plant characteristics or because of reported susceptibility to rice blast in the regional trials.

Because of the seriousness of the rice blast disease on commercial varieties, seed multiplication of the six remaining blast resistant lines was accelerated by pulling young plants, separating their tillers and retransplanting. Table 5 shows the pedigrees and amount of seed produced for these lines. The resistant lines 4440 and 4444 were segregating for grain type and will be repurified and multiplied again in 1976.

A new system of continuous rice production discussed later in this report will be used for multiplying seed as necessary.

Table 4. **Reaction to *Pyricularia oryzae* and grain quality characteristics of 6 lines and 5 varieties of rice (1975A).***

	P. oryzae		Grain characteristics	
	Leaf reaction	Damage to neck (%)	Milling index (%)	Milled grain length (mm)**
Lines				
4421	Resistant	5	61.0	7.2
4422	Resistant	8	59.4	7.2
4440	Resistant	2	49.8	7.2
4444	Resistant	3	50.3	7.6
4461	Resistant	3	[illegible]	[illegible]
4462	Resistant	3	[illegible]	[illegible]
Varieties				
CICA 4	Susceptible	[illegible]	[illegible]	[illegible]
CICA [illegible]	Moderately susceptible	16	[illegible]	[illegible]
IR 8	Susceptible	[illegible]	[illegible]	[illegible]
IR 22	Susceptible	[illegible]	[illegible]	[illegible]
Bluebonnet 50	Moderately susceptible	13	[illegible]	[illegible]

* [illegible]

** [illegible]

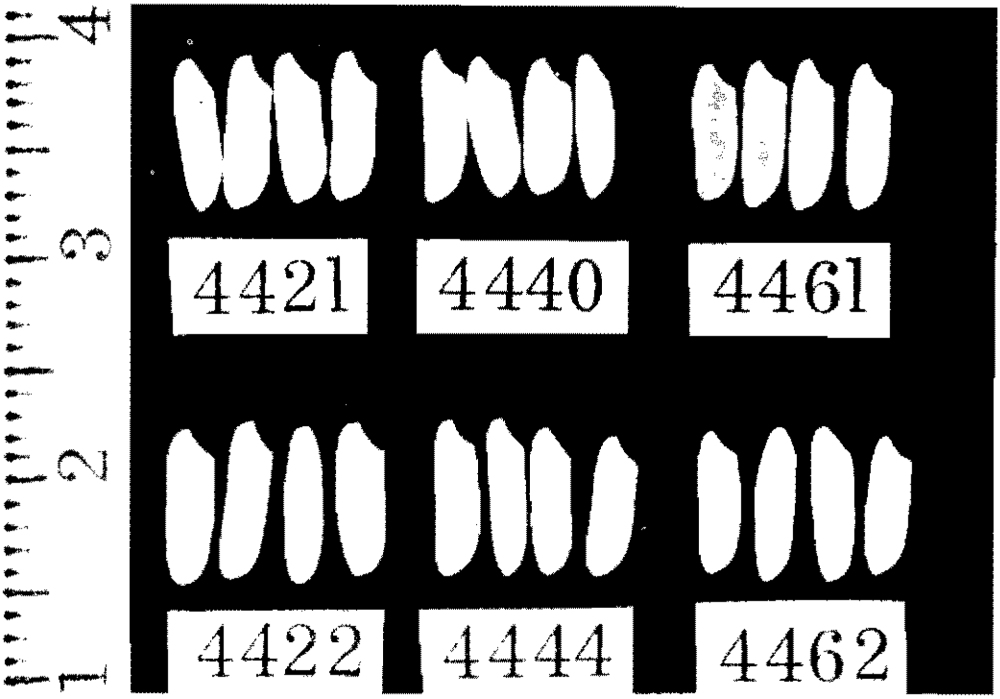


Figure 1. **Comparison of lengths and physical appearances of seed of six advanced rice lines at CIAT.**

Table 5 **Parentages of advanced lines of rice purified and multiplied by CIAT (1975).**

Line	Cross	Pedigree	Seed produced (kg)
4421	IR665-23-3-1 x F1 (IR841-63-5-104-1B x C46-15)	P901-22-11-2 6-1-1B	1,300
4422	IR665-23-3-1 x F1 (IR841-63-5-104-1B x C46-15)	P901-22-11-5 3-2-1B	1,333
4440	CICA 4 x F1 (IR665-23-2-1 x Tetep)	P918-25-1-4-2 3-1B	18
4444	CICA 4 x F1 (IR665-23-3-1 x Tetep)	P918-25-15-2 3-2-1B	360
4461	IR22 x F1 (IR930-147-8 x Col. 1)	P881-19-22-12 1B-6-1B	420
4462	IR22 x F1 (IR930-147-8 x Col. 1)	P881-19-22-12 1B-7-1B	1,000

Blast resistance

A small group of elite sources of blast resistance has been identified in the world collection of rice by the International Rice Research Institute (IRRI) and cooperating national programs. These sources have demonstrated broad resistance after several years of evaluation in many countries. The CIAT Rice Program has transferred resistance from four of these sources — Tetep, Dissi Hatif, C46-15 and Colombia 1 — into agronomically acceptable plant types. Breeder seed of superior resistant lines selected from these crosses was produced in 1975 for seed multiplication, regional testing and the release of new varieties in 1976. These new varieties carry resistance derived from only one parent. Experience indicates that single-source resistance breaks down after a few cycles of commercial plantings.

Two new approaches to blast breeding were initiated in 1975 to prolong resistance. The first method attempts to combine multiple sources of resistance in new varieties. To achieve this, ten blast-resistant, advanced lines were selected from yield trials. These lines carry different levels of resistance from Tetep, Dissi Hatif, C46-15 and Colombia 1. They were intercrossed to give 45 single crosses that were planted in March, 1975 only to produce the new crosses and not to be advanced to the field. A total of 587 multiple crosses were harvested in August, 1975.

The multiple crosses were produced by selectively combining the F_1 single crosses and crossing them with an additional line having the blast resistance of the variety Carreon, another source of broad resistance. Over 12,220 seeds were produced from these multiple crosses which recombine three or four distinct sources of resistance in each combination. Fifteen crossed seeds of each multiple cross were germinated, the seedlines exposed to blast disease, and the resistant ones transplanted in the field in October, 1975, providing an enormous source of resistance and other germplasm for selection.

The second approach to blast resistance breeding is a modified multiline procedure featuring two highly productive lines well-adapted in the Americas. The lines 4417 and 4421 were each crossed with a series of sources of broad resistance having good to excellent agronomic characters. F_1 combinations will be backcrossed in 1976 to lines 4417 and 4421 to recover their plant and grain types. Resistant selections from these backcrosses will be carried through the segregating generations while selecting for the phenotypes of the recurrent parents. By the F_7 generation a large number of phenotypically similar lines having distinct genes for resistance will be available for international evaluation. National programs can bulk seed of several similar lines carrying distinct resistance factors to produce their own multiline varieties.

International regional trials

The Rice Program has trained 68 rice technicians from 13 Latin American and Caribbean countries. Upon returning to their home countries, some of these persons continue to work closely with CIAT in evaluating genetic material developed at both IRRI and CIAT. Observations from these cooperative tests provide valuable information on the adaptation of certain genetic lines or varieties over a broad area and under many climatic and soil conditions. In recent years, CIAT has sent seed of promising lines and varieties to every rice-producing country in Latin America for evaluation. The rice agronomist has made annual visits to most of these national research sites to assist in evaluating the material, to assess the reliability of research results and to try to advise on ways of strengthening and improving the program.

In general, practically all the CIAT-IRRI lines are resistant to the races of blast in Central and Southern Brazil, Uruguay, Argentina, Paraguay and Bolivia. Lines and varieties that are susceptible to blast in Colombia are also usually susceptible in Guyana, Venezuela, Ecuador, Peru, and in Central American and Caribbean countries. Wherever the varieties are resistant and good cultural practices are used, the better dwarf plant, adapted material is yielding from one to two tons more per hectare than traditional local varieties.

AGRONOMY

Weed and volunteer rice control

Mechanical land preparation can destroy weeds and volunteer rice, however, this practice also brings up more weed seed to germinate later. Certain herbicides can control weeds during germination while others control established weeds. The objective is to select single herbicides or combinations which control weeds and which can also be applied in a manner to control volunteer and red rice. Control of the two rice weeds is urgently needed, especially in direct-seeded rice areas where two or more crops per year are possible. The dual control of weeds and volunteer or red rice rules out the use of selective herbicides.

Mechanical land preparation was compared to two applications of paraquat after rice and weeds had germinated. Three successive weed crops were killed by rotary tilling in dry soil in one treatment while paraquat was applied twice at ten-day intervals (0.5 kg|ha a.i. each time) in another treatment. Pregerminated seed was broadcast over the entire area. No additional weed control measures were made after seeding, however, had they been applied, it is possible that yields would not have differed. Results of these exploratory trials show that two applications of paraquat may be superior to dry land preparation. Much higher weed and volunteer rice infestations occurred in the rotary tilled plots due to bringing up weed seed from lower depths. Results with paraquat indicated that applying non-selective herbicides may effectively control weeds and volunteer rice before planting the main crop.

A series of experiments followed, one in which herbicides were applied to the soil before germination of weeds and volunteer rice, while in the second, herbicides were applied to the growing weeds and volunteer rice 18 to 25 days after germination.

Although some rice herbicides in the first experiment considerably reduced weed infestation, none was sufficiently effective in controlling volunteer rice germination. Only atrazine, a corn herbicide used as a check at 1 kg|ha active ingredient, effectively controlled germinating volunteer rice and weeds. In the second experiment, growing weeds and volunteer rice were best controlled by two applications of paraquat (0.5 kg|ha, each application) at 18 and 25 days after germination, although glyphosate at the same rates and times was almost as effective. A mixture of 4 kg|ha of MSMA + 1 kg|ha of 2,4-D also gave good control when applied 18 days after weeds and volunteer rice germinated.

Residual herbicide effects

Atrazine, which controlled volunteer rice, grasses and broadleaf weeds best, normally has a residual effect in the soil for several months. Preliminary tests in 1974 with different flooding periods indicated that flooding nullified the residual effect of atrazine and several other herbicides. Additional herbicide trials with atrazine, metribuzin, alachlor, 2,4-D, terbutryn and RH2512 were made in 1975. After flooding for 30 days the areas were drained and seeded with pregerminated rice. Figure 2 illustrates good control of volunteer rice and weeds with a mixture of alachlor and

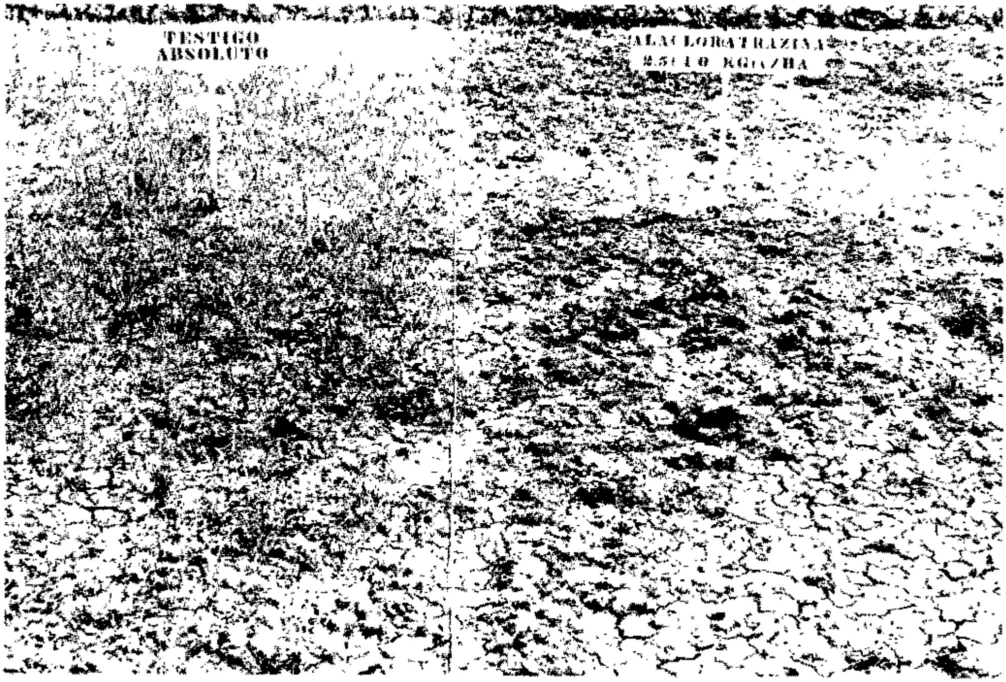


Figure 2. **A combination of alachlor and atrazine effectively controls volunteer rice and weeds in rice paddies.**

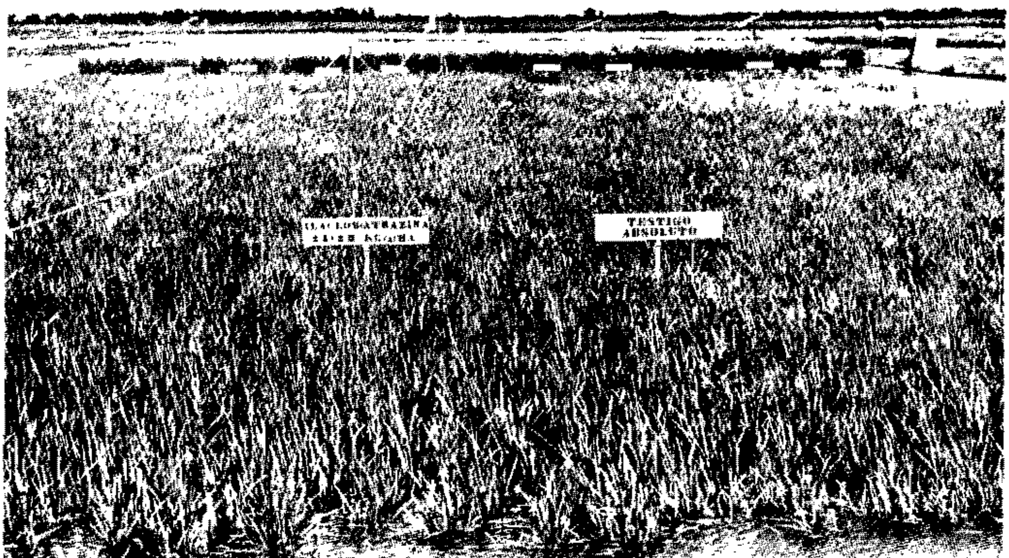


Figure 3. **No residual effects from herbicides are evident if the paddy is flooded for 30 days before planting.**

atrazine while Figure 3 shows no residual effect on growth of rice seeded after flooding for 30 days.

Three herbicides, atrazine, metribuzin and lunuron, were applied at recommended, double, triple and|or quadruple rates. Volunteer rice and weed control and the residual effect on rice planted after one month of flooding were evaluated with the results shown in Table 6. Atrazine controlled volunteer rice and weeds best but also killed from 16 to 40 percent of the rice planted after 30 days of flooding. Metribuzin and linuron controlled both rice and weeds well and also had little or no residual effect on reseeded rice after the flooding period, although the 2.0 kg|ha rate of metribuzin did retard growth of a few of the rice plants. Further experiments are in progress to better define the herbicide, rate and time of flooding and other cultural practices before recommending residual herbicides to control volunteer rice and weeds.

The knotgrass problem

The grassy weed *Paspalum distichum* (knotgrass) is spreading rapidly in rice growing areas. It usually encroaches from the edge of the field and bunds by means of stolons but it also is a prolific seed producer. In the screenhouse, six herbicides were evaluated for control of knotgrass established by seed or stolons.

None of the herbicides tested was effective against stolons while several were excellent in killing germinating seeds. Propanil was most effective when applied at the 2-3 leaf stage since knotgrass hadn't completely emerged when the application was made at the single leaf stage. Oxadizon and butachlor also controlled germinating seeds well. No herbicide seriously injured the rice.

If knotgrass arises from stolons, no effective pre- or postemergence treatments can be recommended for use in rice. Stolons should be eliminated before planting rice by mechanical or chemical means, then germinating seeds may be controlled by standard herbicide applications for control of germinating grass seed and grasses in the 1-3 leaf stage.

The "hoja blanca" threat

"Hoja blanca" is an important disease occurring in cycles, the last epidemic being

Table 6. **Residual effects of three herbicides in the soil after flooding for one month before planting rice.**

	Application rate (kg|ha) a.i.)	Volunteer rice and weed control (%)	Rice damaged from residual effects (%)
atrazine	2.0	90	16.66*
atraz	4.0	98	30.00*
atrazin	6.0	98	40.00*
metri	0.5	80	0
metribuz	1.0	85	0
metribuzin	2.0	90	6.66**
linuron	1.5	80	0
linuron	3.0	85	0
linuron	4.0	90	0

* Dead plants

** Retarded growth

in 1957-64. The vector of the virus is the plant hopper, *Sogatodes oryzicola*, which can also destroy rice crops through direct feeding. CIAT's Rice Program has emphasized resistance to **Sogatodes** and all the newer varieties are resistant to this vector. Only CICA 4 is also resistant to the virus but field observations indicate that resistance to **Sogatodes** protects the variety from virus attack. No hoja blanca outbreak or **Sogatodes** damage has been confirmed through 1974, since the release of the new dwarf varieties.

Anticipating a possible new cycle of hoja blanca or the appearance of a new race of the insect vector, CIAT has requested cooperating national programs to report virus or insect damage in commercial dwarf varieties. Two reports of problems with the IR 8 variety in Colombia were investigated this year. In one instance a field was severely damaged by hoja blanca and **Sogatodes**. Insects were collected at both of the locations, multiplied at CIAT and evaluated on a set of varieties of known reaction to direct feeding injury. None of the insects collected were found to be from a new race.

In Peru a report of virus damage in IR 8 and local varieties was investigated and severe hoja blanca attack was confirmed although few insects were present. The affected fields were all transplanted crops. It is apparent that virus infection occurred in the seedbeds before transplanting, an early growth stage when no variety is resistant to the virus. An insecticide application in the seedbeds was recommended to control **Sogatodes**, and thus the virus, in future crops. No evidence suggests the presence of a new race of **Sogatodes** in Peru.

A report of heavy virus and insect damage in IR 8 and other varieties was also received from Cuba. A set of differental varieties was sent to Cuba to clarify varietal reactions. A reciprocal set of Cuban varieties was requested for evaluation at CIAT but has not yet been received.

ENGINEERING STUDIES

Water control

A 24-inch diameter, axial flow pump was completed, installed and tested during 1975. This pump, when driven at 540 rpm from the power takeoff of a tractor, delivered 55 to 63 cubic meters per minute against a variable head from 0 to 180 centimeters. The pump is designed for ease of local manufacture and low cost — both of the pump and its installation and operation. Design changes are being made before release of the designs in 1976. The most interesting feature is the simple mounting of the pump in a horizontal, concrete pipe culvert installed in a drain crossing under a road or protective levee.

Machine mobility

Since tractor mobility in saturated fields in an important factor in rice production for enabling efficient water leveling, wetland preparation and transport of harvested grain from fields, the agricultural engineer worked on this problem while on study leave at Louisiana State University. Prediction equations were developed for torque, traction, rolling resistance, and sinkage of pneumatic tires in soft clay soils. These equations combine the variables of tire width, diameter, deflection, weight on tire and soil cone index values. Figure 4 illustrates the relationship between measured pull and predicted pull. In a practical application of the theory at CIAT, worn-out lugs were removed from a used 23.1 x 26-inch rice and cane tire to permit the tire to fit within the limited space of a combine made for smaller tires. The smooth tires were inflated to about 3 psi or less allowing a large deflection on the soil surface. This deflection provided better mobility.

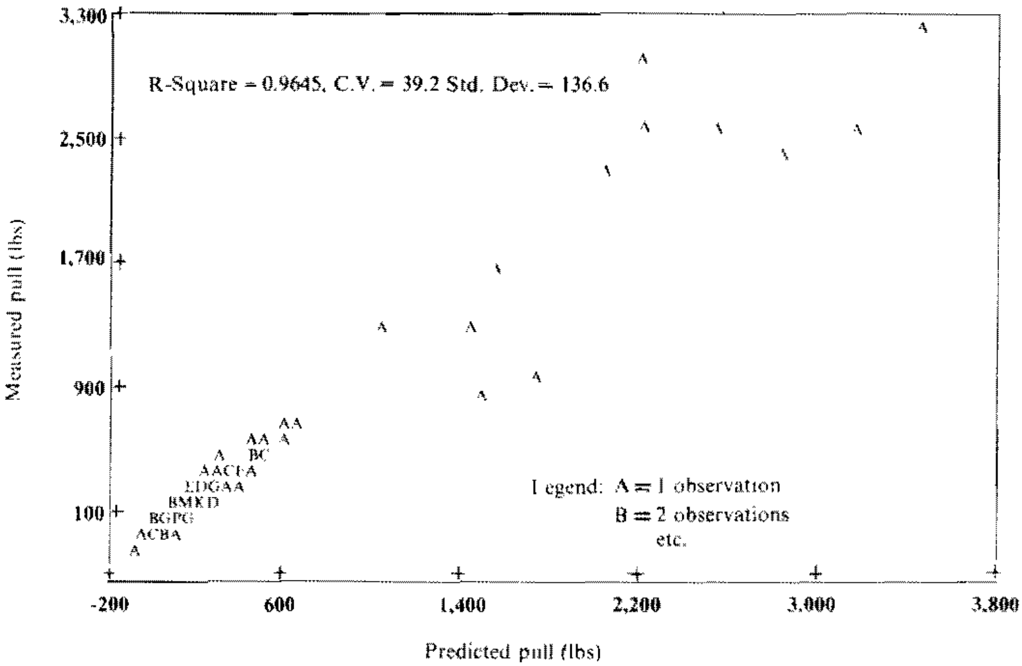


Figure 4. **Measured versus predicted net traction or pull for implement tires of various sizes.**

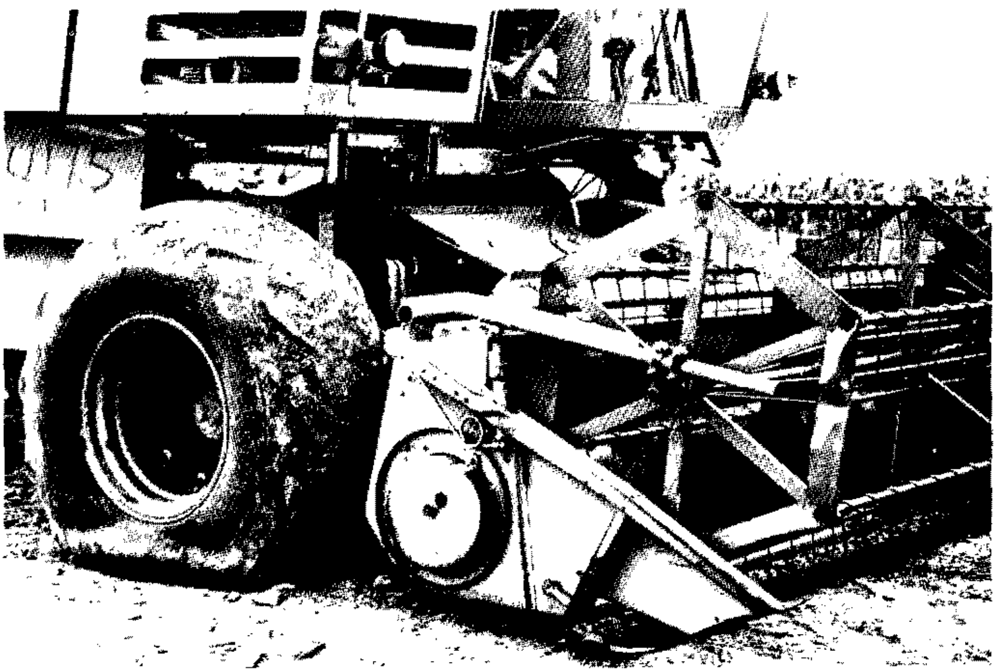


Figure 5. **A smooth tire inflated to a low pressure provides improved mobility for this combine in soft soils at CIAT.**

CONTINUOUS RICE PRODUCTION

CIAT's Experiment Station Operations unit and the Training and Conferences and Rice Programs have initiated a project to develop an intensive and continuous rice production system on the Palmira station. The objective is to modify and integrate the best of Asian technology to Latin American conditions and to fully utilize the land, labor, water, and other resources at all times.

Fields are prepared and puddled in water to achieve soil conditions typical of Asia, then pregerminated rice is broadcast seeded. Two to five hectares of rice have been planted each week since August, 1975. Prior to August a similar program existed but with only periodic plantings as time and conditions permitted. Although these occasional plantings were largely made to level and leach soils, and to improve irrigation and soil uniformity for later cropping, valuable experience, practical training and a cash crop were obtained. Good stable yields are possible during all seasons. Since 1972, almost 1,300 tons of rice have been produced with an average yield of 5.8 tons/ha.

TRAINING

This year four trainees – from Brazil, Paraguay, the Dominican Republic and Guatemala – were trained in the Rice Program, and 17 others in crop production training spent part of their time in rice production.

The continuous rice production scheme mentioned earlier will strengthen training for rice production specialists in the future by providing fields at all stages of production, at all times. The availability of rice at all growth stages will permit trainees to participate in all operations and see problems without waiting, as would be the case with only one planting per season. The training time can be condensed by moving the trainee through all phases of rice production, and at the same time, the trainee can return or progress to any phase where more concentration is necessary.

Combining seed production into the program will form a complete package of rice technology: land development, land preparation, irrigation, planting, fertilizing, weed and insect control, problem identification, harvesting, drying, processing, marketing, and management of labor, machines and money. This integrated training will be on a field scale where the best practices are used and new technology or modifications are field tested before being recommended to farmers. Cost data will be obtained; most budget costs will be met from sales of seed and commercial rice. The effort is expected to serve as a pilot project for possible within-country production, demonstration and training centers.

Extensive travel to all rice-growing countries in Latin America has enabled program staff to collect photographs of almost every problem that might be found in growing rice. An identification manual containing color photographs of the most important insect, disease and other rice production problems of the region was published this year. The booklet is expected to be of great value to rice technicians and producers in identifying production problems.

PUBLICATIONS*

CHEANEY, R.L. El control de arroz rojo con herbicidas de acción residual. Cali, Colombia, CIAT, 1975. 14p.

Paper presented in Reunión Anual del Programa Nacional de Arroz, Instituto Colombiano Agropecuario, Santa Marta, Colombia, 1975.

____________. El manejo del agua en sistemas de fangueo. Cali, Colombia, CIAT, 1975. 14p.

Paper presented in training course for agronomists of the Federación Nacional de Arroceros of Colombia, 1975.

____________. El manejo del cultivo de arroz. Cali, Colombia, CIAT, 1975. 14p.

Paper presented at postgraduate course for soil technicians, Centro Interamericano de Desarrollo Integral de Aguas y Tierras, Universidad de los Andes, Mérida, Venezuela, 1975.

____________. El manejo de suelos para el cultivo de arroz. Cali, Colombia, CIAT, 1975. 12p.

Paper presented at postgraduate course for soil technicians, Centro Interamericano de Desarrollo Integral de Aguas y Tierras, Universidad de los Andes, Mérida Venezuela, 1975.

JOHNSON, L. Mobility equations for pneumatic tire performance in soft clay soils. Cali, Colombia, CIAT, 1975. 31p.

Paper presented at Annual Meeting of American Society of Agricultural Engineers, University of California, Davis, 1975. (Paper No. 75-1013).

* This list includes only journal articles published outside CIAT's series.

Training and Conferences

Postgraduate training and conference activities at CIAT continued to expand in 1975 at a pace closely related to (1) the progress in structuring the staff and strategies of the research programs; (2) the new technologies they are generating; and, (3) the recognition by national institutions of the role of CIAT and of the opportunities it offers for the transfer, adaptation and adoption of scientific advances in the commodities for which it has responsibility.

Expansion of training and conference activities and those of the Information Services Unit justified a reorganization of the former Training and Communications Program. Information services functions were merged with those of the library and documentation center and are reported in the next chapter.

TRAINING

During 1975, 201 professionals from 27 countries were trained at CIAT. Approximately one-half of these were postgraduate interns, of which 58 were research interns and 45 were production interns. Table 1 summarizes the distribution of trainees by categories and by commodity or field of specialization. Table 2 lists the countries from which various categories of trainees came. A complete list of trainees at CIAT in 1975 is at the end of the Training section.

The number of trainees (201) at CIAT during 1975 represents an 8 percent increase over the previous year. The increase in numbers of professionals trained at CIAT in the six years since training activities began is shown in Figure

Table 1. **Trainees processed by CIAT in 1975 classified by major field of specialization and training category.**

Field	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short courses
Beans	20	(10)*	5	5	5	-
Cassava	17	-	3	2	3	-
Rice	3	(7)*	2	-	2	-
Crop production	-	24*	-	-	-	-
Beef	9	21	4	10	13	-
Swine	6	-	2	3	-	-
Small farm systems	1	-	1	-	-	-
Others	2	-	3	1	4	30
Total	58	45	20	21	27	30

* Of the 24 trainees in Crop Production, 10 specialized in Beans, 7 specialized in Rice and 7 trained in general crop production

Table 2. **Trainees processed by CIAT in 1975 classified by country of origin.**

Country	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short courses	Total
Argentina						2	2
Bolivia	2	2			1	3	8
Brazil	8				3	6	17
Cameroon				1			1
Canada				1			1
Chile	2	5	1	1			9
Colombia	10	13	13	2	3	6	47
Costa Rica	3					1	4
Dominican Republic	1				2		3
Ecuador	3	3	1		1	2	10
El Salvador	5			1			6
Guatemala	4	7	2	1		1	15
Honduras	1					1	2
Indonesia				1			1
Mexico	8		1		2		11
Netherlands						5	5
Nicaragua	2	1					3
Nigeria	1			2			3
Panama	1					1	2
Paraguay		12			2		14
Perú	3	1	2			5	11
Thailand	3						3
United Kingdom				1			1
Uruguay					1		1
USA		1		6	3		10
Venezuela	1				4	2	7
West Germany				4			4
Total	58	45	20	21	27	30	201

1. Worthy of notice is the proportional increase in trainees classified as research scholars (MSA candidates) and visiting research associates (MSA level professionals and PhD candidates), a trend which is favored by CIAT's staff.

The CIAT staff has acquired a more definite awareness of the extremely important role CIAT-trained young scientists from national institutions can play in the local validation and transfer of new technologies generated by the Center's commodity research programs.

Training in commodities

The distribution of trainees by commodity programs, disciplines and categories of training is given in Table 3. CIAT's primary programs —beef, beans and cassava —are doing the largest proportion of the total training at the Center.

Training activities specific to each commodity are reported in the respective program sections. These activities mostly involve research training in one discipline

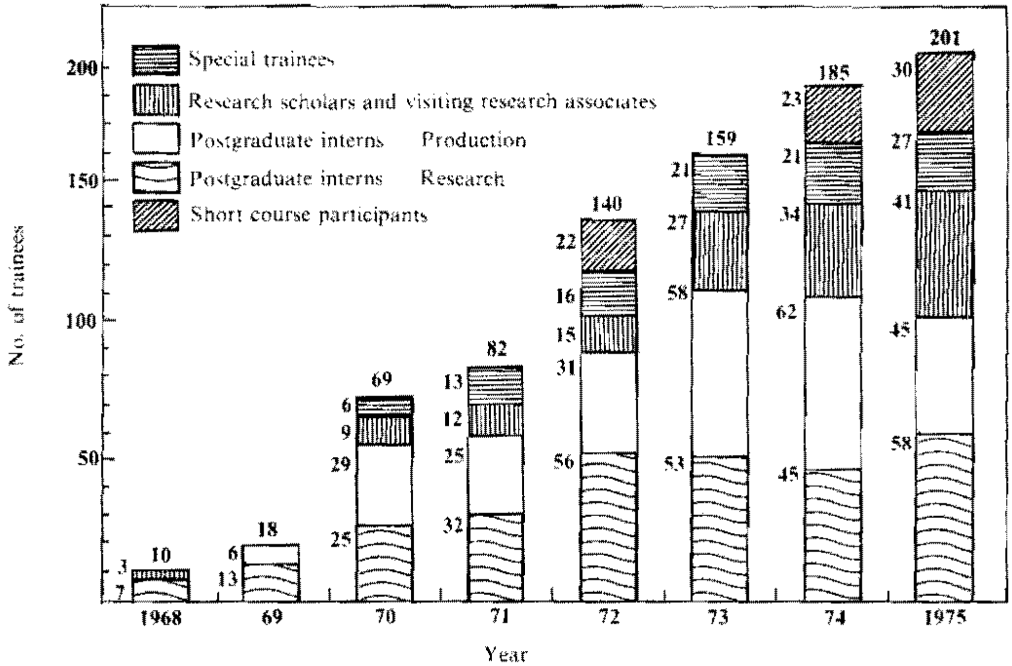


Figure 1. **Numbers of trainees at CIAT, 1968-75**

of a commodity program. In the case of the Beef Program, these activities also include the structured Livestock Production Specialist Training Program (LPSTP), fourth in a series of ten to 12-month courses that began in 1970.

The team approach

A notable development in training for commodity research in 1975 is the simultaneous training of "commodity research teams" or "research-production commodity teams." This approach seeks to bring three or more young scientists from the same institution to CIAT for training in a single commodity, at the same time. Each trainee should specialize in a discipline of critical importance to the production of that species in his country. In the case of a production specialist trainee, he should concentrate on one commodity. In this way it is possible to equip interested countries with a self-reinforcing team of at least three scientists centered on one commodity, i.e. a breeder, a pathologist and an agronomist or a production specialist. This approach has been tried by the Bean Program, for Chile and for Guatemala, and in the Cassava Program, for Thailand and for Mexico. Although results remain to be seen, this tactic appears to have a greater chance of success for the rapid transfer of CIAT's technology and for national commodity research than the traditional one-at-a-time approach to training scientists from national institutions. In the future this approach will be encouraged as much as possible.

Training in management of experimental stations

Earlier effors in station management training have evolved this year into a comprehensive training plan encompassing the various aspects of this important operation in research institutions. There is an apparent need to assure adequate administrative and technical support, at the experimental station level, to national research programs in beans, cassava, rice, maize, beef and swine. This need, together with the comparative

Table 3. **CIAT trainees appointed and | or completing training during 1975, by specialization in commodity program and training category.**

Field of specialization	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short course	Total in sub-program	Grand total
BEANS | agronomy	3			2			5	
biometrics	2						2	
breeding	4						4	
economics	3			1			4	
ag. engineering	1						1	
entomology	4		1		1		6	
pathology	1		1	1			3	
physiology	2		2				4	
soil microbiology			1	1	4		6	
Beans - total	20	(10)*	**5**	**5**	**5**			45**
CASSAVA | agronomy	8						8	
biometrics	1						1	
breeding	3						3	
economics			1		2		3	
entomology	1						1	
pathology	4		2	1			7	
physiology				1			1	
soils					1		1	
Cassava - total	**17**		**3**	**2**	**3**			**25**
RICE | agronomy	1				2		3	
breeding	1						1	
pathology			1				1	
weed control	1		1				2	
Rice - total	**3**	**(7)***	**2**		**2**			**14***
Crop production		**24***						**24**

* Of the 24 trainees in Crop Production, 10 specialized in Beans, 7 specialized in Rice and 7 trained in general crop production

** Includes 10 Crop Production trainees.

Table 3. Continued

Field of specialization	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short course	Total in sub-program	Grand total
BEEF|				3			3	
animal health	5		2	4	7		18	
economics			2	1			3	
pastures & forages	2			2	6		10	
pastures & forages microbiology	1						1	
weed control	1						1	
Livestock Production Specialist Training Course		21					21	
Beef - total	**9**	**21**	**4**	**10**	**13**			**57**
SWINE|nutrition			2				2	
production	6			3			9	
Swine - total	6		2	3			11	
Small farm systems	**1**		**1**				**2**	
OTHER FIELDS|								
Crop production (MSA)			2				2	
Food and housing					1		1	
Library and documentation					1		1	
Rural sociology					2		2	
Soil phosphate				1			1	
Station operations	2		1				3	
Weed Control Short Course						30	30	
Other fields - total	**2**		**3**	**1**	**4**	**30**		**40**
Total	**58**	**45**	**20**	**21**	**27**	**30**		**201**

advantage CIAT has in station operations, justifies the Center's involvement in this type of training, on a limited basis. Two experimental station managers, one each from Guatemala and Venezuela, each received three months of training as postgraduate interns in 1975. Five more plan to come to CIAT in 1976 for stays of four to six months.

Training in crop production

Since 1970, CIAT has conducted six Crop Production Specialist Training Programs (CPSTP) with support from the Interamerican Development Bank (IDB) and other donors. These seven to 12-month events averaged 18 participants and simultaneously covered rice, beans, maize and cassava. These courses were integrated for efficiency of instruction, taking advantage of agronomic commodities among them. Such an approach was desirable while most of CIAT's commodity programs were still in the early stages of development.

After five years of trying various structural alternatives for the CPSTP, a seven-month course has been developed with components that make it flexible enough to be used for individual commodities but complete in terms of content needed for a comprehensive, yet in-depth coverage of subject matter.

During the fifth CPSTP this year, the postgraduate interns were encouraged to specialize in one crop of priority importance to their respective countries. Out of 20 participants (six from Guatemala, five from Chile, three from Ecuador, four from Colombia and one each from Nicaragua and Paraguay), ten chose to specialize in beans, seven chose rice and three preferred to simultaneously study two crops that are components of a rotation or are grown in association. Besides providing technology on the production of crops, the course also offered an opportunity to increase functional knowledge and skills on (1) field experiments for validating technology; (2) specific production economics-farm management activities applied to the crops studied with particular emphasis on cost analysis; and, (3) communication skills and strategies for transfer of technology, including how to organize and conduct within-country training. Seventy-five percent of course time was devoted to practical learning directly on production fields, experimental plots and small farms in the Cauca Valley. The other 25 percent of the time was invested in programmed conference-discussion sessions, cost analysis, reporting and independent reading.

Short course by programmed planting

As part of the fifth CPSTP, interested participants received special training in the practice of organization and teaching of a two-week practical short course using a methodology of "programmed planting," first developed at the International Rice Research Institute for rice and later adapted to beans at CIAT. A special 14-day short course on bean production was organized for professors and final year students of the College of Agriculture of the National University at Palmira.

The method consists of ten plots of any size with each one planted at intervals of approximately seven to ten days, beginning 76 days (or a full growing cycle length minus the number of days duration of the course) before the start of the 14-day event.

In this way, the ten standard plant growth stages are available sequentially from land preparation, seeding and emergence through vegetative growth, flowering and grain development up to maturity and harvest. All of the stages are present in the field during the 14 days (or 30 days) duration of the short course. By these means, the traditional classroom short courses of limited value given in many national institutions may be replaced by practical opportunities to grow a crop with new technology and acquire problem diagnostic abilities, and associated cost analyses under a real situation.

It should be noted that this method depends on the availability of irrigation and should be conducted during the dry season or at least during a mild rainy season to avoid problems in land preparation and early stages of plant growth.

Utilization of training by CPSTP participants

A survey of the activities of the 20 participants in the fifth CPSTP after they returned to their home countries revealed that 14 of them were actively working in research and development of commodities they were trained on at CIAT. Two are involved full-time with university education; three are in charge of organizing crop production training courses in national research institutions (in Chile, Ecuador and Guatemala) and one is managing his own farm.

Within-country training

The major in-depth involvement of CIAT this year in regard to assisting within-country training took place in the form of the six-month within-country field phases of the LPSTP for beef. Eleven participants from Paraguay did their field work portion of the course on ranches in that country, in association with the University of Asunción and the Ministry of Agriculture (see page A-57).

By the end of this course, a meaningful impact had already been made at the university there, resulting in a decision to add one more year of supervised, in-field training to the required curriculum for veterinary medicine.

Other successful efforts of CIAT in support of within-country training included (1) limited but productive assistance to the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador, through instructional inputs to its two-year-old Crop Production Program, organized and conducted by former trainees in CIAT's CPSTP; and, (2) preliminary assistance to the Instituto de Ciencias y Tecnología Agrícola (ICTA), in Guatemala in collaboration with former CIAT trainees to organize a six-month training program in crop production, to begin in March 1976 and planned to continue as a long-term program.

Short courses

A four-week Short Course on Weed Control was co-sponsored by the International Plant Protection Center of Oregon State University and CIAT and held in June and July. Thirty participants came from the following countries: Argentina (2); Bolivia (3); Brazil (6); Colombia (6); Costa Rica (1); Ecuador (2); Guatemala (1); Honduras (1); Panama (1); Peru (5) and Venezuela (2).

CIAT's Biometric Unit taught a two-week course on Experimental Design for Field Experimentation in mid-1975 for the benefit of trainees and research associates and assistants. Emphasis was on proper planning and design of field experiments, rather than on statistical analysis procedures that can better be handled by central biometric services.

Financing of training

Interest from outside donors to sponsor training at CIAT continued at a relatively high level in 1975. Only 82 of 201 trainees were financed from CIAT's core budget this year. Twenty-nine other sponsors provided funds for 110 others and nine trainees were self-supported (Table 4). The IDB has generally been the primary source of funds for production training courses. A series of six courses —three in crops and three in livestock— was completed in 1975 with IDB financing. These courses, three more crop courses financed from other sources and the other training courses conducted or assisted with by CIAT are shown in Figure 2.

Table 4. **Trainees processed by CIAT in 1975 classified by source of support.**

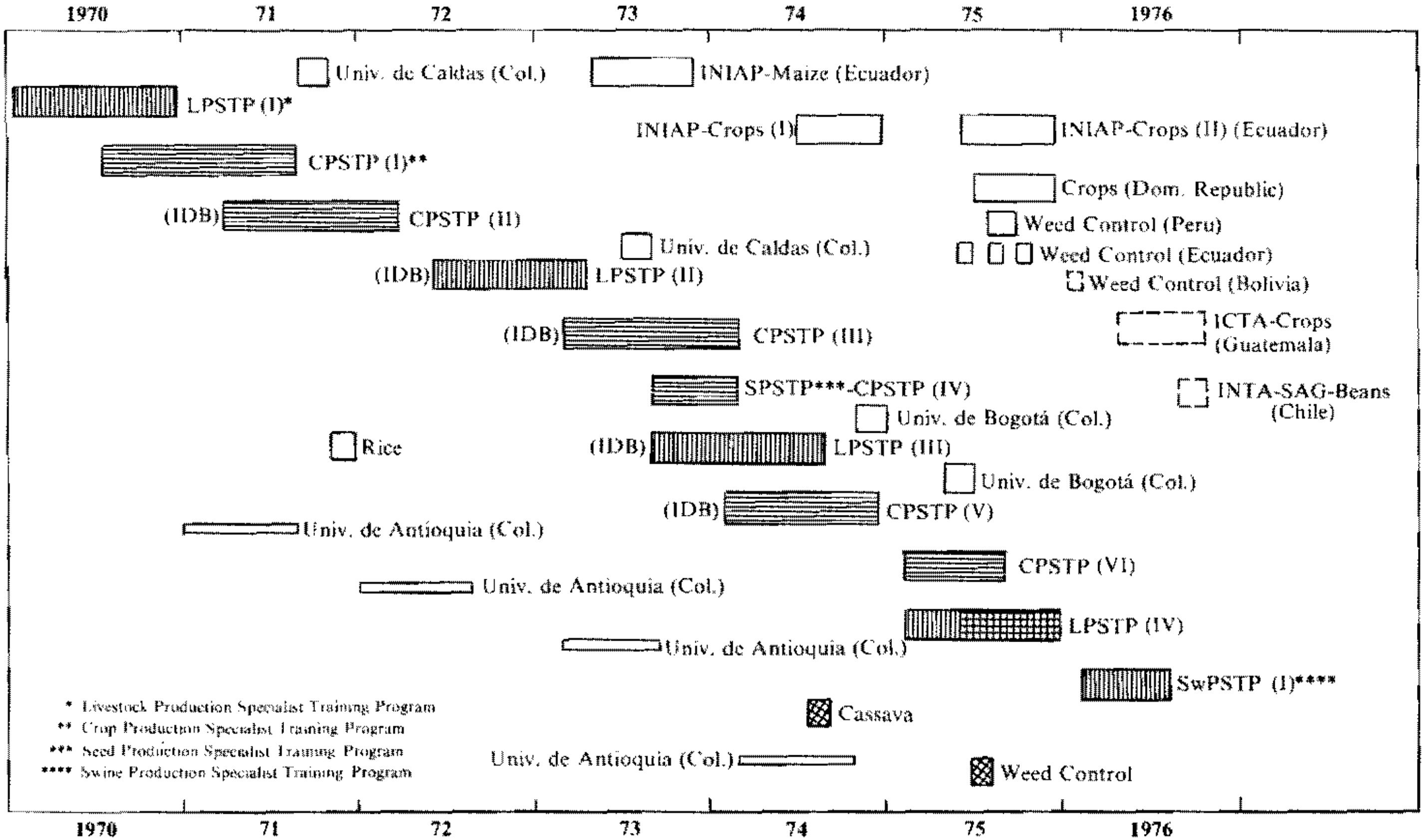
Source of support*	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short courses	Total
National and international interests:							
Agency for International Development (AID) USA	1	2					3
AID and Oregon State University, USA						30	30
Banco Central de Guatemala, Guatemala			1				1
Banco Nacional de Crédito Rural, Mexico	1						1
Centro Internacional de Agricultura Tropical (CIAT)	51	12	13	3	3		82
Centro Panamericano de Zoonosis, Argentina					5		5
Cornell University, USA				2			2
Corporación Autónoma Regional del Valle del Cauca (CVC), Colombia		1					1
Ecumenical Scholarship Program, West Germany		1					1
Federación Nacional de Arroceros (FEDEARROZ), Colombia	1						1
Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), Venezuela	1				1		2
Food and Agriculture Organization (FAO) of the United Nations		1			2		3
Ford Foundation, USA				1			1
Interamerican Development Bank (IDB)		23	4	1	1		29
International Development Research Centre (IDRC), Canada				2			2

* All or bulk of financial support provided by or through organization indicated

Table 4. Continued

Source of support*	Postgrad. research interns	Postgrad. production interns	Research scholars	Visiting research associates	Special trainees	Short courses	Total
International Fertilizer Development Center (IFDC)				1			1
Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala	2	4	1				7
Instituto Colombiano Agropecuario (ICA), Colombia			1		2		3
Instituto Superior de Agricultura (ISA), Dominican Republic					1		1
Midwest Universities Consortium for International Activities (MUCIA), USA				1			1
Peace Corps, USA		1					1
Promoción Agropecuaria, S. A., Paraguay					1		1
Rockefeller Foundation, USA				3			3
Secretaría de Estado de Agricultura, Dominican Republic					1		1
Technical University of Berlin, West Germany				1			1
Tulane University, USA				2			2
Universidad Central de Venezuela, Venezuela					1		1
Universidad del Tolima, Colombia	1						1
University of Illinois, USA				1			1
West Germany, Government of				3			3
Self-supported:					9		9
Total	58	45	20	21	27	30	201

* All or bulk of financial support provided by or through organization indicated



1976 courses are planned.

Figure 2. **Production training and other courses conducted by or assisted with by CIAT and within-country training courses conducted by former CIAT trainees.**

Table 5. **CIAT trainees appointed and | or completing training during 1975.**

Name	Country	Area of Study	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Postgraduate Research Interns:				
Acosta, Jesús	Mexico	Cassava | plant breeding	3.5	C
Aguilar, José W.	El Salvador	Beans | ag. engineering	5	C
Aguilar, Roberto	Costa Rica	Cassava | beans | plt. pathology	2	C
Alonso, Freddy	Guatemala	Beans | entomology	4.5	C
Alvarado, Fabián	Ecuador	Swine | production systems	6	C
Bacaro, Manuel	Guatemala	— | station operations	4	C
Bandeira, Coracy	Brazil	Rice | agronomy	3	C
Bazalar, Hernando	Peru	Animal health | hemoparasitology	2	-
Calderón, Guillermo	Peru	Animal health | hemoparasitology	12	-
Carrizo, Vicente	Panama	Swine | production systems	12	-
Concha, Alfredo	Colombia	— | weed control	5	C
Cortés, René	El Salvador	Beans | plant pathology	5	C
Cuevas, Federico	Dominican Republic	Rice | plant breeding	10	C
Chavez, Jesús Aurelio	Colombia	Beans | agronomy	6	C
Del Valle, Ricardo	Guatemala	- | agricultural systems	3.5	C
Deras, Carlos	El Salvador	Beans | entomology	5	C
Dos Santos, María Auxiliadora	Brazil	Cassava | agronomy	1	C
Erives, Marcelo	Mexico	Cassava | agronomy	3	C
Farfán, Carlos	Ecuador	Beef | pastures & forages	8	C
Figueroa, Carlos Enrique	Guatemala	Beans | physiology	7	C
Freire, Wania, María	Brazil	Cassava | plant breeding	5	-
Fukuda, Chigeru	Brazil	Cassava | plant pathology	3.5	-
García, Carlos Mario	El Salvador	Beans | agronomy	5	C
Gastao, Orival	Brazil	Beans | plant breeding	3	C
Giraldo, Hernán	Colombia	Beans | ag. economics	9	C
González, Víctor	Mexico	Cassava | agronomy	3.5	C
Gutiérrez, John	Colombia	Beans | ag. economics	8	C
Hurtado, Erwin	Bolivia	Beef | pastures & forages	3.5	C

Table 5. Continued

Name	Country	Area of Study	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Ibe, Donatus	Nigeria	Cassava | biometrics	1	C
Jarupat, Thanakorn	Thailand	Cassava | plant pathology	7	-
López, Gustavo	Colombia	Animal health | hemoparasitology	4	-
Madruga, Claudio Roberto	Brazil	Beef | animal health | microbiology	3	C
Morales, César Guillermo	Peru	Beans | agronomy	3	C
Moreno, María Teresa	Colombia	Beans | physiology	12	-
Muñoz, Jaime Eduardo	Colombia	Beans | biometrics	4	-
Musmani, Miguel	Costa Rica	Swine | production systems	6	C
Nobre, Adilson	Brazil	Cassava | agronomy	7	C
Nuñez, José Ignacio	Mexico	Cassava | entomology	3.5	-
Orta, César Guillermo	Venezuela	— | station operations	5	C
Prager, Martín	Colombia	Beans | ag. economics	9	C
Quintero, Manuel	Mexico	Beef | pastures & forages | microbiology	8	C
Quiroz, Carlos	Chile	Beans | entomology	9	C
Ramos, Federico	Honduras	Beans | plant breeding	6	C
Rodríguez, Roberto	Brazil	Cassava | agronomy	5	-
Rojanaridpiched, Chareinsuk	Thailand	Cassava | plant breeding	7	-
Ruiz, José Adán	Nicaragua	Swine | production systems	4	-
Salazar, Luis Carlos	Colombia	Beans | biometrics	3	C
Saldivar, Anacarsis	Mexico	Cassava | agronomy	3.5	C
Tay, Juán	Chile	Beans | plant breeding	10	C
Teruya, Rosa Mercedes	Bolivia	Beef | animal health | clin. path.	8.5	C
Toro, José Zacarías	Ecuador	Beef | weed control	1	C
Vargas, Héctor Armando	Colombia	Beans | entomology	3	-
Vega, Julio Alejandro	Nicaragua	Swine | production systems	4	-
Vichukit, Vichan	Thailand	Cassava | agronomy	7	-
Villa, René	El Salvador	Beans | plant breeding	5	C
Villalobos, José	Mexico	Cassava | agronomy	3.5	C
Wood, Rogelio	Mexico	Cassava | plant pathology	3.5	-
Yee, Mario Gerardo	Costa Rica	Swine | production systems	6.5	C

Table 5. Continued

Name	Country	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Postgraduate Production Interns			
Crop Production			
Agurto, Luis Aurelio	Nicaragua	7	C
Amézquita, Mario	Guatemala	7	C
Ayres, Alejandro	Chile	7	C
Ayres, Clara Luz de	Chile	7	C
Benítez, Daniel	Paraguay	7	C
Caicedo, Marino	Colombia	7	C
Ceballos, Luis Fernando	Colombia	7	C
Cuadra, Pedro	Chile	7	C
Delgado, José Leonardo	Colombia	7	C
Florez, Orestes	Perú	2	C
Freire, Efrén	Ecuador	6	C
González, Danilo	Guatemala	7	C
González, Leopoldo	Guatemala	7	C
Hernández, Carlos	Guatemala	7	C
La Torre, Vicente	Bolivia	2.5	C
Lara, José Rolando	Guatemala	7	C
Licuona, Mario	Bolivia	2	C
López, Javier	Colombia	7	C
Maldonado, Marco A.	Guatemala	2	C
Matheu, Raúl	Guatemala	7	C
Paladines, Carlos	Ecuador	6	C
Seeman, Peter	Chile	6	C
Suing, Gerardo	Ecuador	6	C
Tiska, Vicente	Chile	7	C
Livestock Production			
Acosta, Sabino	Paraguay	10	C
Alvarado, Jairo	Colombia	10	C
Arciniegas, Fabio	Colombia	10	C
Beltrán, Luz Stella	Colombia	10	C
Boyd, Charles	USA	3	C
Caballero, Luis	Paraguay	10	C
Cabral, Severiano	Paraguay	10	C
Espinola, José María	Paraguay	10	C
Fernández, Armando	Colombia	10	C
González, Braulio	Paraguay	10	C
Jiménez, José J.	Colombia	10	C
Maciel, Adalberto	Paraguay	10	C
Ortiz, Flavio	Colombia	10	C
Piedrahita, Francisco	Colombia	10	C
Regúnega, Celso	Paraguay	10	C
Romero, Celedonio	Paraguay	10	C
Rubio, Jaime	Colombia	10	C
Ruiz, Miguel Angel	Paraguay	10	C
Segovia, Tranquilino	Paraguay	10	C
Trinidad, Juán A.	Paraguay	10	C
Villamil, Luis Carlos	Colombia	10	C

Table 5. Continued

Name	Country	Area of Study	Institution where enrolled	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Visiting Research Associates					
Betancourt, Jesús A.	Colombia	Animal health | parasitology	Texas A&M University, USA	6	-
Ellis, Michael	USA	Beans | plant pathology	U. of Illinois, USA	4	-
Evans, David Eric	U. Kingdom	Animal health	U. of London, England	12	-
Hammond, Lawrence	USA	Soils | phosphate rock	Michigan State University, USA	3.5	-
Hudgens, Robert	USA	Beans | agronomy	U. of Florida, USA	4	-
Job, Titus	Nigeria	Swine	U. of Ibadan, Nigeria	6	C
Kleemann, Gunter	West Germany	Swine	Technical Univ. Berlin, West Germany	8	C
Kloter, Kirby	USA	Animal health	Tulane University, USA	1	C
Krausz, Joseph	USA	Cassava | plant pathology	Cornell University, USA	6.5	C
Martínez, Romeo	Guatemala	Beans | nitrogen fixation	Michigan State University, USA	5	-
Ngongi, Amos	Cameroon	Cassava | physiology	Cornell University, USA	8	C
Pervis, Dennis	Canada	Beans | economics	Michigan State University, USA	3.5	-
Rubinstein de, Eugenia	Chile	Economics | animal health	U. of Minnesota, USA	12	-
Salazar, Mauricio	El Salvador	Beef | pastures & forages	U. of Florida, USA	3.5	-
Schellenberg, Rupprecht	West Germany	Beef	Technical Univ. Berlin, West Germany	12	-
Schultze-Kraft, Rainer	West Germany	Beef | pastures & forages	J. Liebeg Univ. Giessen, Germany	12	C
Serrano, Alfredo	Colombia	Beef	U. of Minnesota, USA	3	C
Soekanto, Lebdosoekojo	Indonesia	Beef cattle production	U. of Florida, USA	8	-
Stolberg, Alexander	West Germany	Beans | production	J. Liebeg Univ. Giessen, Germany	8	C
Tewe, Olumide	Nigeria	Swine	U. of Ibadan, Nigeria	6	C
Yates, Juanito	USA	Animal health	Tulane University, USA	1	C

Table 5. Continued

Name	Country	Area of Study	Institution where enrolled	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Research Scholars					
Acuña, Luis G.	Colombia	— | crop production	U. of Guelph, Canada	12	-
Altieri, Miguel Angel	Chile	| physiology | w. control	Esc. Graduados, ICA, Colombia	3	-
Alvarez, Camilo	Colombia	Cassava | ag. economics	U. Católica de Chile	8	C
Cárdenas, Moisés	Mexico	Beans | plant pathology	Esc. Graduados, ICA, Colombia	6	-
Castaño, Jairo	Colombia	Rice | plant pathology	Esc. Nal. Agricultura, Mexico	3	C
Celleri, Walter H.	Ecuador	Swine | nutrition	Esc. Graduados, ICA, Colombia	11	C
Domínguez, Carlos	Colombia	— | crop production	U. of Guelph, Canada	12	-
Garcés, Carlos	Colombia	| ag. engineering	Esc. Graduados, ICA, Colombia	12	-
Hidalgo, Rigoberto	Colombia	Beans | physiology	Cornell University, USA	5	-
Laberry, Rafael	Peru	Cassava | plant pathology	Esc. Graduados, ICA, Colombia	3	-
Mattos, Luz Leonor	Peru	Cassava | plant pathology	U. Nal. Agraria, Perú	3	-
Morales, Leopoldo	Colombia	— | weed control	Esc. Graduados, ICA, Colombia	4	C
Morales, Víctor	Colombia	— | soil microbiology	U. of Florida, USA	10	-
Ramírez, Luis E.	Colombia	Beef | animal microbiology	U. Antioquia, Colombia	12	-
Rivas, Libardo	Colombia	Beef | ag. economics	U. Católica de Chile	7	C
Rueda, Camilo	Colombia	Beef | animal health	Esc. Graduados, ICA, Colombia	11	C
Samayoa, Otto	Guatemala	— | ag. economics	U. Católica de Chile	12	-
Santa María, Gilberto	Guatemala	— | ag. economics	Esc. Graduados, ICA, Colombia	3	C
Santos, Jorge	Colombia	Swine | nutrition	U. of Guelph, Canada	11	C
Vargas, Octavio	Colombia	— | entomology	Cornell University, USA	6	-

Table 5. Continued

Name	Country	Area of Study	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C = completed)
Special Trainees				
Alvarez, Olga Lucía	Mexico	Food and housing	2	C
Caicedo, Elizabeth	Colombia	Agricultural economics	0.5	C
Cetrangolo, Roberto	Uruguay	Animal health	2	C
Cortez, Miguel	Bolivia	Beef | pastures & forages	0.1	C
D'Jesús, Francisco	Venezuela	Beef | pastures & forages	1.5	C
Da Silva, Amadeo	Brazil	Animal health	2	C
De Figueiredo, Marcio	Brazil	Animal health	2	C
Docal, Digna María	USA	Animal health | biology	1	C
Docal, María Victoria	USA	Animal health | zoology	1	C
Dorresteijn, Hans	Netherlands	Rural sociology	5	-
Fernández de, Thisbe	Venezuela	Beans | microbiology	2	C
Galeano, Antonio	Paraguay	Rice | agronomy	2	C
García, Alvaro	Colombia	- | soils microbiology	2.5	-
Keim, David	USA	Beef | pastures & forages	2	C
Luzuriaga, Hugo	Ecuador	Cassava | ag. economics	3	C
Munevar, Fernando	Colombia	— | soils microbiology	3	C
Naujenis, Romualdo	Venezuela	Beef | pastures & forages	2	C
Orozco, Luis	Mexico	Animal health	2	C
Pereira, Luis Gonzaga	Brazil	Animal health	2	C
Rewinkel, Bernardus	Netherlands	Beef | pastures & forages	3	-
Rewinkel, Margaretha	Netherlands	Beef | pastures & forages	3	-
Rodas, Jorge E.	Paraguay	Rice | agronomy	2	C
Strobosch, Peter	Netherlands	Rural sociology	5	-
Taveras de, Dulce María	Dominican Rep.	Library & documentation	2	C
Taveras, Pedro	Dominican Rep.	Cassava | beans | soils	2	C
Tesoro, de Delia	Venezuela	Beans | microbiology	2	C
Van Dam, Wim	Netherlands	Beans | entomology	5	C

Table 5. Continued

Name	Country	Area of Study	Mo. of training completed as of Dec., 1975	Status as of Dec., 1975 (C= completed)
Alvarez, Guillermo	Colombia	Weed Control Short Course	1	C
Andrade, Voni	Brazil	Weed Control Short Course	1	C
Atencio, Filiberto	Perú	Weed Control Short Course	1	C
Bohórquez, José Gabriel	Ecuador	Weed Control Short Course	1	C
Clement, Achilles	Brazil	Weed Control Short Course	1	C
Cortez, Miguel	Brazil	Weed Control Short Course	1	C
Covolo, Lorenzo	Brazil	Weed Control Short Course	1	C
Chaquilla, Oscar	Perú	Weed Control Short Course	1	C
Dell'Agostino, Eduardo	Argentina	Weed Control Short Course	1	C
Filho, Ricardo	Brazil	Weed Control Short Course	1	C
Garrido, Juan	Venezuela	Weed Control Short Course	1	C
Huanca, Félix	Perú	Weed Control Short Course	1	C
Jaramillo, Hernando	Colombia	Weed Control Short Course	1	C
Larrea, Nelson Eduardo	Perú	Weed Control Short Course	1	C
López, Ricardo Luis	Argentina	Weed Control Short Course	1	C
López, Luis Orlando	Panamá	Weed Control Short Course	1	C
Mago, Enrique Gonzalo	Venezuela	Weed Control Short Course	1	C
Martínez, Enrique	Colombia	Weed Control Short Course	1	C
Muñoz, José Alvaro	Guatemala	Weed Control Short Course	1	C
Odeñana, Otto Rafael	Ecuador	Weed Control Short Course	1	C
Orrego, Diego	Colombia	Weed Control Short Course	1	C
Raigoza, Juan	Colombia	Weed Control Short Course	1	C
Restrepo, Manuel	Colombia	Weed Control Short Course	1	C
Rodríguez, Rolando	Bolivia	Weed Control Short Course	1	C
Silva, Elquin	Perú	Weed Control Short Course	1	C
Soto, Adolfo	Costa Rica	Weed Control Short Course	1	C
Urbina, Norberto	Honduras	Weed Control Short Course	1	C
Velasco, Francisco	Bolivia	Weed Control Short Course	1	C
Wassano, Ioshio	Brazil	Weed Control Short Course	1	C
Lake, Clive	Brazil	Weed Control Short Course	1	C

Postdoctoral appointments

CIAT has now formalized fellowship opportunities for postdoctoral research projects within the commodity programs. The Training and Conferences Program now administers these fellowships. The postdoctoral program is primarily intended to initiate young scientists with outstanding academic records into research in tropical agriculture and into commodity production orientation. However, it is also a means for providing additional research manpower, on a short-term basis, for certain priority or temporary problem areas of the commodity programs.

Three postdoctoral fellows were appointed to this program in 1975 to conduct research projects within the Bean Program. The fellows and their research interests are: Dr. F. Eskafi (entomology); Dr. Y. Hayakawa (physiology); and Dr. K. Yoshii (plant pathology). The three fellowships are funded by the Rockefeller Foundation.

CONFERENCES

An improved pattern of planning and execution of conferences has emerged during 1975 as experience has been acquired in selecting participants and in setting up meeting programs.

There has been a definite trend towards limiting workshops and seminars to groups of 30 to 40 participants and CIAT events have rarely had more than 60 participants. Apart from the logistical advantage derived from more limited numbers, there has been a noticeable increase of interaction among participants and greater coherence of results.

Pre-meeting planning has also been tightened. Whereas wide organizing responsibility has been given the Manager of Conferences and Symposia, final decision-making responsibility has been narrowed to one, or at most, two persons within a steering committee. This step has also increased fluidity and reduced duplications and gaps in logistical aspects of meetings.

With regards to conference proceedings or even just reproductions of authors' versions, plans have been made to include the Information Services Unit in the first phase of organizing a workshop or seminar. This should force planners to make an earlier decision on what to do about invited papers, and will insure a quick publication of the kind of document required, within the norms of CIAT's standards.

The year 1975 has been a very busy one with a very high rate of conference room occupancy. For the first time, on six occasions this year, records showed 100 percent conference facility occupancy.

Fifteen events were organized, sponsored or co-sponsored by CIAT and attended by 650 invited participants and about 300 observers (Table 6). Four CIAT training courses also utilized various conference facilities from time to time, while throughout the year, the commodity programs frequently use one or more conference rooms for internal meetings. In addition, CIAT hosted 33 other events which were sponsored by numerous institutions and which involved more than 1,300 persons.

Table 6. **Events held in CIAT conference facilities in 1975.**

Date	Event	No. of participants
CIAT sponsored:		
Jan. 29 - Feb. 6	Cassava Advisory Committee and Testing Program	30
Feb. 1-6	CIAT Program Reviews	60
Mar. 17-22	The epidemiology and control of anaplasmosis and babesiosis in Latin America.	70
Apr. 7-12	Potential of the Latin American Tropics, IICA-Trópicos	20
Apr. 14-15	Workshop on Nature and Organization, CIAT Agricultural Systems Program	20
May 22-24	CIAT Presentation Days	40
Aug. 25-30	The ecology and control of external parasites of cattle of economic importance in Latin America.	75
Sept. 1-2	Review of Animal Health Unit at CIAT	10
Oct. 13-16	Workshop on Genetic Improvement of Dry Beans and Germplasm Resources	60
Oct. 20-22	Bean Program Advisory Committee	12
Nov. 17-18	Characterization of the cattle industry in selected countries.	15
Nov. 26-28	Economic analysis in the design of new technology for the small farmer.	35
Nov. 29	Meeting of agricultural economists from International Centers	8
Dec. 1-3	Bean Protection Workshop	100
Dec. 9-12	CIAT Program Reviews	60
CIAT sponsored training courses:		
Feb. 3-July 30	Livestock Production Specialists	21
Mar. 3-May 30	Crop Production Specialists	25
May 19-31	Experimental Design Course	10
Dec. 1-19	Livestock Production Specialists	25
Sponsored by other institutions:		
Monthly	SENA regional representatives meetings (14 events)	480
Feb. 10-15	Marketing Management - INCOLDA	35
Apr. 11	Meeting of Latin American Ministers of Agriculture	35
Apr. 12-14	Meeting of Colombian Ministers of Agriculture and managers of related institutions	30
May 13-15	Universidad Nacional (Colombia), briefing on CIAT	110
May 25-30	Production Management - INCOLDA	45
June 2-13	Seminar on Nutrition - Catholic Relief Services	40

Table 6. Continued

Date	Event	No. of participants
June 16-21	Meeting of regional representatives, Friedrich Naumann Foundation	30
June 18-20	Meeting of ICA regional managers	15
June 24	Management in Maize and Sorghum - FENALCE	30
June 27	Meeting of Colombian Regional Agricultural Secretaries	20
July 2-5	Meeting of Banco de la República branch managers	12
Sept. 15-19	AID regional representatives meeting	60
Oct. 6-8	Catholic Relief Services—USCC Representatives	25
Oct. 25	COOMEVA General Assembly	100
Nov. 12-15	Seed Production Management - ACOSEMILLAS	16
Nov. 28-29	Meeting of the Federación de Asociaciones de Odontólogos	25
Dec. 4-6	American Phytopathological Society—Caribbean Division	150
Dec. 18	Meeting of the Asociación de Médicos del Valle	100
Non-CIAT sponsored training courses:		
Apr. 8-11	ICA Pastures and Forages course	30

Library and Information Services

The Library and Information Services Program is dedicated mainly to diffusing to scientists throughout the world, technical information related to the commodities on which CIAT does research. It is also responsible for the institution's public image. Thus, the program was reorganized at the beginning of 1975 into three subprograms or units: Library and Documentation, Information Services and Public Information Office.

Library and Documentation Center

The library's collection stands at 35,000 volumes (including bound journals) and receives 1,284 scientific journals regularly. In addition to the normal activities of a specialized library, there is a documentation center providing abstract cards on cassava, beans, animal health and Latin American agricultural economics. This center had about 2,000 subscribers during 1975. Some 2,500 documents were processed in the four areas mentioned, and a compilation of 2,000 abstracts on cassava was published in book form.

The Tables of Contents service, whereby scientists may request photocopies of articles from scientific journals received by CIAT, was modified, grouping the journals into three categories: animal sciences, plant sciences, and agricultural economics and development (CEDEAL).

In this way it was possible to extend the service to all agricultural scientists on CIAT's mailing list for Latin America. An estimated 2,000 scientists were receiving this service as of January 1976. To facilitate payment of photocopies internationally, a system of coupons was designed.

Short bibliographies, containing as many abstracts as available, were produced by the library on specific topics by special request; these were included as a CIAT publication series for further diffusion, available on request.

Public Information Office

A total of 3,000 visitors (including groups) were handled by this office during 1975. In addition, the policy of regularly informing the public on the development of certain conferences and symposia held at CIAT was initiated, stimulating relations with the media. Technical articles on CIAT appeared not only in the agricultural sections of the Cali and Bogotá newspapers but also in some national and international magazines.

Information Services

The addition of staff and equipment made it possible to publish and distribute 33 CIAT publications. A major change in the format for the Annual Report is also being implemented for this year. Separate commodity reports are being issued for distribution to individuals according to their special interests. The comprehensive report has a more limited distribution to research centers and libraries only. In addition, a summary report emphasizing accomplishments in 1975 is intended for the general public.

The following publications were issued in 1975:

AS- 9 Noti-CIAT. Noviembre-Diciembre, 1975. 4 p.

AE- 9 Noti-CIAT. November-December, 1975. 4 p.

BS- 6 Informe Anual. 1975. 286 p.

BE- 6 Annual Report. 1974. 260 p.

CS- 2 El potencial del fríjol y de otras leguminosas de grano comestible en América Latina. 272 p.

CE- 2 Potential of field beans and other food legumes in Latin America. 388 p.

CE- 7 The potential of the lowland tropics. 100 p.

CE-9 Horizontal resistance to the blast disease of rice. 246 p.

CS-10 El potencial para la producción de ganado de carne en América tropical. 307 p.

CE-10 Potential to increase beef production in tropical America. 328 p.

CE-11 Methods for allocating resources in applied agricultural research in Latin America. 65 p.

CS-11 Métodos para la asignación de recursos en la investigación agrícola aplicada en América Latina. 68 p.

DS- 5 **LOZANO, J.C.** y **BOOTH, R.H.** Enfermedades de la yuca (*Manihot esculenta* Crantz). 1974. 48 p. (Reprinted).

ES- 5 **DIAZ, R.O., PINSTRUP-ANDERSEN, P.** y **ESTRADA, R.D.** Costos y utilización de insumos en la producción de yuca en Colombia. 36 p.

ES- 6 **CLAVIJO, H.** y **MANER, J.H.** El empleo del banano de rechazo en la alimentación porcina. INIAP-CIAT. 20 p.

ES- 8 **LOZANO, J.C.** El añublo bacterial de la yuca (CBB). 12 p.

ES-16 **DOLL, J.** Control de malezas en cultivos de clima cálido. 12 p.

EE-17 **BOOTH, R.H.** Cassava storage. 20 p.

ES-18 **RUIZ DE LONDOÑO, N.** y **PINSTRUP-ANDERSEN, P.** Descripción de factores asociados con bajos rendimientos de maíz en fincas pequeñas de tres departamentos de Colombia. 44 p.

ES-19 **GUTIERREZ, U., INFANTE, M.** y **PINCHINAT, A.** Situación del cultivo del fríjol en América Latina. 36 p.

FE- 2 ICA-CIAT herd systems project Carimagua. 8 p.

FS- 3 Información sobre los programas del CIAT (gúia para visitantes). 8 p.

FE- 3 Information on CIAT's programs (a guide for visitors). 8 p.

FS- 4 CEDEAL. 6 p.

FS- 5 Programa de sistemas de producción de fríjol. 42 p.

FE- 5 Bean production systems program. 38 p.

FS-11 Lista de publicaciones del CIAT. 33 p.

GS- 2 **CARDENAS, J., FRANCO, O.** y **ROMERO, C.** Clasificación de herbicidas. ICA-CIAT. 44 p. (Reprinted).

GS- 6 Guía para la preparación de compendios, IICA-CIAT. 74 p.

GS-15 **CHEANEY, R.L.** y **JENNINGS, P.** Problemas en cultivos de arroz en América Latina. 96 p.

GE-15 **CHEANEY, R.L.** and **JENNINGS, P.** Field problems of rice in Latin America. 96 p.

HE-26 2,000 abstracts on cassava (*Manihot esculenta* Crantz). Vol. 1. 584 p.

Research support groups

BIOMETRICS

The Biometrics Unit at CIAT is a service group whose responsibilities are the following: to give assistance in the planning and design of experiments and to render consulting and data analyses services to all research and training programs at CIAT.

Basic Functions

Consultations and statistical analyses

The Unit offers consultant services prior to the initiation of an experiment. After having established the hypotheses that a researcher wants to test with his experiment, Biometrics collaborates in the planning of this research, in the decision as to the type and size of the sample, and in the selection of the experimental design to be used. Once the experiment has been carried out, the Unit is responsible for making the statistical analyses of the data obtained on the basis of the experimental design used.

These services have been rendered to all CIAT programs and to some collaborating institutions such as ICTA in Guatemala, INIAP in Ecuador, EMBRAPA in Brazil and ICA in Colombia.

Evaluation of technology

The Biometrics Unit collaborates with research programs in order to measure the impact of new technology that CIAT is testing. A classic example is its collaboration in the design and analysis of regional field trials for new bean or cassava varieties; another example is the support given to the analysis of beef cattle and crop production systems experiments. However, the most relevant is the design of mathematical models that permit the evaluation of different technological alternatives to improve agricultural and livestock production.

Research to improve statistical techniques

During 1975, the Unit placed emphasis on the study of designs and the analysis of more complicated models that arose out of research program needs, such as

1. Models for unbalanced designs and analytical techniques for each type of design.

2. Experimental designs with mixed models (models where fixed and random factors are used simultaneously).

3. Mathematical models to represent biological phenomena. In addition to the common regression models, the Unit has worked with models based on Liebig's law of limits.

4. The introduction of two-stage least squares techniques for simultaneous equations models.

In order to render services efficiently and rapidly, the Unit has installed an IBM 3780 terminal for direct communication with the IBM 370|145 computer of the Departamento Administrativo Nacional de Estadística (DANE) in Bogotá. CIAT receives valuable assistance from DANE through a collaborative agreement on information services. The Unit uses the Statistical Analysis System (SAS) of North Carolina State University as a principal means of statistical computation.

Collaboration with Commodity Programs

The Bean Production Systems Program

An information system has been designed to handle data for the germplasm collection of *Phaseolus vulgaris*. For this project the Unit has continued using SAS as a data management system, and most of the objectives stated initially have been accomplished. Specifically, the Unit has created a computer-based file for the bean germplasm collections and selections, which will be the basis for publishing a catalog of all existing information on the most promising materials.

The Unit has also provided experimental design and analyses services for the physiology, breeding, pathology, entomology and agronomy sections of the Bean Program. At the same time, it has collaborated in the data management and analysis of the agro-economic survey on bean production in Colombia, which is in the process of being analyzed.

Determination of the optimal size, shape and number of replicates

The Unit conducted a bean yield trial in collaboration with the program's entomology group to determine the most adequate size, shape of plot and number of replicates in order to minimize experimental error. Several methods for calculating yield per plot were also evaluated. The trial was conducted on the experimental farm at CIAT, Palmira. Línea 32 was chosen from a total of 12 materials because of its high yielding ability and its use, not only at the experimental but also at the commercial level.

In the trial a split plot design with eight replicates was used with whole plots (number of beds: 1, 2 or 3; each bed was 1 meter wide); subplots were formed by the lengths of the beds (1, 3, 5, 7, 9 and 11 meters), thus making a total of 18 plot configurations per replicate.

In order to determine optimal plot size, the coefficient of variation (CV) was computed for each plot size and charted against plot size ($\underline{X}$) (Fig. 1). The following model ($CV = 34.84\ X^{-0.547}$) was estimated, using least squares.

To find the optimal X, the first derivate was set equal to one corresponding to an optimal plot size of 6.72 m^2, which for practical purposes should be said to be 7 m^2.

In the determination of the most adequate plot shape, several selection critiera were used:

1. Optimum number of beds was selected on the basis of the one with the lowest coefficient of variation, which corresponded to two beds with a CV of 14.46 percent. Combining this criterion with that of optimal size, a length of 3 **meters** was chosen, which gives an area close to 6 m^2.

2. Taking into account optimal plot size, variances were taken of plots that had

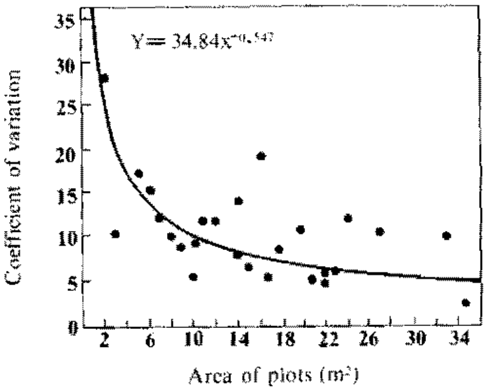


Figure 1. **The coefficient of variation as compared to plot size in the determination of optimal size.**

the same area or one close to 7 m^2. Using this criterion, the size with the least variance was as follows:

$$s^2 = 56{,}900 \left(\frac{kg}{ha}\right)^2$$

For two beds, each 1 meter wide and 3 meters long,

$$s^2 = 96{,}822 \left(\frac{kg}{ha}\right)^2$$

but considering the smaller size of the borders in plots with two 3-meter-long beds, this dimension is recommended as a useful area.

In order to calculate the optimal number of replicates, the methodology used was that proposed by S. Romero, E. Carney and B. Rojas.* It was found that this number was equal to three.

Therefore, for research on beans done at CIAT, where it is necessary to estimate yield, it is recommended to use plots with two seed beds 90 to 100 cm wide and a minimum of 3 meters long and that the basic arrangement be replicated at least three times.

The evaluation of several methods for estimating yield in experimental plots

Bias was evaluated for various methods used in estimating yield. One method that has been used to evaluate germplasm when there is little seed available consists of estimating yield from the average of five plants in competition, taken at random from the experimental plot. Bias was estimated as follows:

$$\text{Bias} = P_{(5)} - P_t$$

$P_{(5)}$ = Produccion (kg|ha), based on a sample of 5 plants

P_t = Total production per plot

* ROMERO, CH.S., CARNEY, E.J. y ROJAS, B. La potencia de la prueba en los diseños experimentales: Agrociencia 1(1):31-50. 1966.

The overestimates found were surprising; on the average, they ranged from 1,757 to 3,029 kg|ha for the 18 proposed arrangements; that is, overestimates between 93.8 and 177.3 percent. There does not seem to be any clear relationship between bed length and the size of the bias.

Although technical articles often mention "the taking of representative samples," serious limitations arise in practice as far as representativity is concerned. This is even more serious in situations where there has been no clear definition of the population being sampled. Even in populations using a smaller number of elements, which as a whole can be observed previously by the sampler, the taking of representative samples has its difficulties as can be seen in several experiments, which also proves true in the case at hand where there was a systematic overestimation of yields.

In addition to bias, yield variability is taken into account, using standard deviation to measure this factor. There was great variation in yields, which were based on a sampling of five plants.

Although an estimator may be biased, this method can be used in practice if there is a way of learning the size of the bias in order to make the necessary corrections. In order to find the degree of association between P_t and $P_{(5)}$, the coefficient of correlation between these two elements was calculated at the plot level, resulting in a very low value (0.0969).

In spite of this being a simple, economic system from a practical point of view, the method for estimating production on the basis of five plants is not satisfactory from a statistical point of view due to the great variability, the bias and the low degree of association found between the production measured and total plot production (Fig. 2).

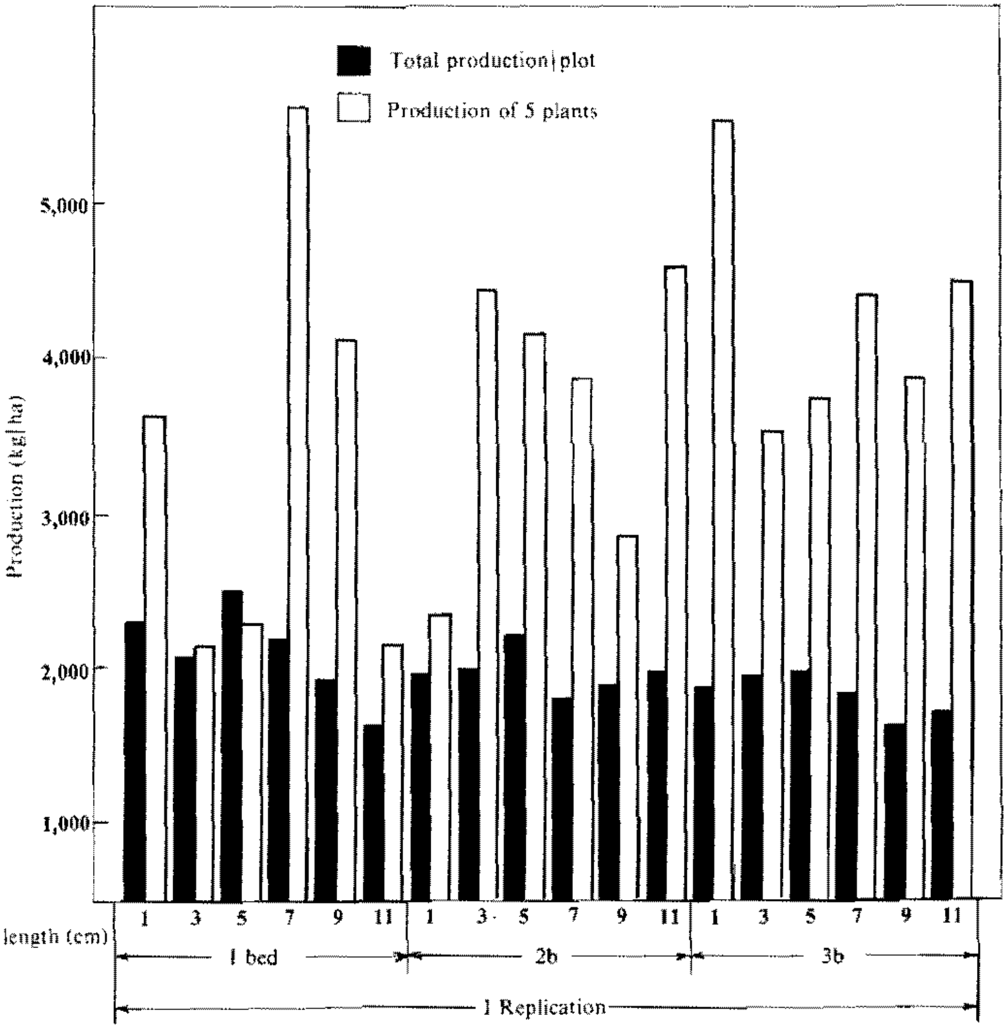


Figure 2. **Contrast in yield estimates for total plots and for 5 plants only (one replicate).**

The Beef Production Systems Program

The Unit has also lent assistance to the "Herd Systems I" project, which was begun in July of 1972 and which will be continued at least until the end of 1977. Because of the large volume of information generated by this project, it was necessary to design a data management system for the data. So far these objectives have been accomplished through the creation, maintenance and reorganization of the file of data used for reference and analysis, as well as through the analysis of all the information obtained as of July, 1975.

The Herd Systems I project has been of great interest to the Biometrics Unit from a statistical point of view. Due to the size of the experiment, to the great number of factors and interactions that are to be studied simultaneously, and to the alterations that have had to be made to the original project, this experiment does not follow a traditional experimental design; it has a number of confounded factors, and some combinations of factors are not included in the treatments. In addition, there are an unequal number of observations per treatment.

In order to carry out the analysis, the experiment was divided into three stages according to chronological order: grazing, reproduction and calving. Independent analyses were made of each of these stages, studying the effect of diverse relevant factors. In each case the model corresponded to an incomplete, unbalanced factorial design. The statistical computations needed for the respective analyses of variance and covariance were made using the so-called Harvey's program,* which is an adaptation for computer use of analysis techniques for unbalanced designs developed by Henderson.**

The Unit also collaborated with the Beef Production Systems Program in the "Early weaning on commercial farms in the Colombian Piedmont" project in the selection of the experimental design to be followed and in the carrying out of the statistical analysis.

Economic aspects of beef cattle production

Collaboration was extended to the Economics Unit of the Beef Production Systems Program in establishing a computer-based simulation for the evaluation of beef production technologies. This simulation is used to aid CIAT research through the testing of technical coefficients in herd development.

Trainees doing research on economics of beef also received assistance as regards statistical models and analyses required for the preparation of their theses, particularly with supply and demand models for beef in Colombia.

Animal health

Data analyses have been done for studies on animal health, nutrition and herd management, especially in what refers to the epidemiology for beef cattle diseases in the Llanos Orientales. In addition, the Biometrics Unit participated in the planning and design of the cooperative CIAT|Texas A&M University|ICA project, "Economic aspects of the immunization of cattle against anaplasmosis and babesiosis," as well as in the general development of methods for epidemiological studies.

Pastures and forages

Methodological research was conducted to adapt a certain kind of experimental design and analysis to experiments related to pastures and forages evaluation. The nature of the experiments is characterized by limitations in operational costs and different types of herd or pasture management and by the biological barriers that are found implicitly within the structure of the experimental treatments.

The Cassava Production Program

A mathematical model was designed to simulate the physiological behavior of the cassava plant as regards the process of leaf and root formation. The results are presented in the respective section of the cassava program.

A methodology of analysis was developed for the cassava regional trials to learn the factors that influence the performance of the materials being studied. It is hoped that this analysis, based on linear models, will contribute to strengthening the model of the development of the cassava plant, particularly with respect to factors such as soil, climate, diseases and pests.

* HARVEY, W.R. Least-squares analysis of data with unequal subclass numbers. USDA, Washington. 1960.

** HENDERSON, C.R. Estimation of variance and covariance components. Biometrics: 226-252, 1953.

The Unit is conducting a joint experiment with the Cassava Program, the purposes of which are:

1. To determine the response of leaf area index to fertilization with N and K and its relationship to yield.

2. To establish a new methodology for conducting trials to determine the response surfaces. This research is being done specifically in relation to this crop since traditional designs require very extensive experimental areas, which are costly with a large plant like cassava.

3. To utilize the response surface as a variable in the simulation of the mathematical model developed to describe the behavior of the cassava plant.

Training

A short course was given on "Experimental Designs and Methods for Research at CIAT." Participants included research associates, assistants and trainees from the different CIAT programs and personnel from ICA. The course included nine sessions (two hours daily each) on the following topics: experimental methods in agriculture and livestock sciences; the methods for managing an experiment in the field to isolate the hypotheses to be tested; characteristics of experimental designs and their respective field techniques; appropriate designs for experiments with animals; fundamental concepts of statistical analysis; linear models as a basis for experimental design; examples of analyses for different designs in crop experiments and in the animal sciences; pastures and forages; and systems for handling data obtained in the experimental process.

In addition to these services rendered principally in the field of statistics, the Unit has assumed responsibility for maintaining and developing quantitative methods for evaluating technology within the content of the farmer's situation. This is being done through the use of simulation models using computers. With these methods, work on experiments will be integrated with regional trials to evaluate the technology generated by the CIAT commodity programs.

WEED CONTROL

Control of purple nutsedge

Research was continued to learn more of glyphosate's behavior in the tubers of purple nutsedge (*Cyperus rotundus*). Glyphosate is a postemergence, translocated herbicide known to control perennial weeds. Since purple nutsedge is a prolific tuber producer (up to 45 million|ha) precise information of glyphosate's action on the tubers is needed.

The first trial compared effects of various rates of glyphosate and 2,4-D (reported by several authors to be effective on purple nutsedge) on the inibition of sprouting by tubers produced from a single tuber planted in pots 90 days previously. At the time of application an average of 70 new tubers had been produced, all forming part of the same plant, and being able to receive the translocated herbicide. Ten days after application, the foliage was removed from the parent plant, the tubers were dug, counted and planted and observations made on the number of tubers sprouting during 180 days after planting (Fig. 1).

Both rates of 2,4-D failed to inhibit sprouting and neither 0.5 nor 1 kg|ha of glyphosate gave significant reductions. Only half the tubers sprouted after foliage treatment with 2 kg|ha of glyphosate while the 4 kg|ha rate almost totally inhibited sprouting. This is very significant as it suggests that eradication may be possible if all tubers in the soils could be made to

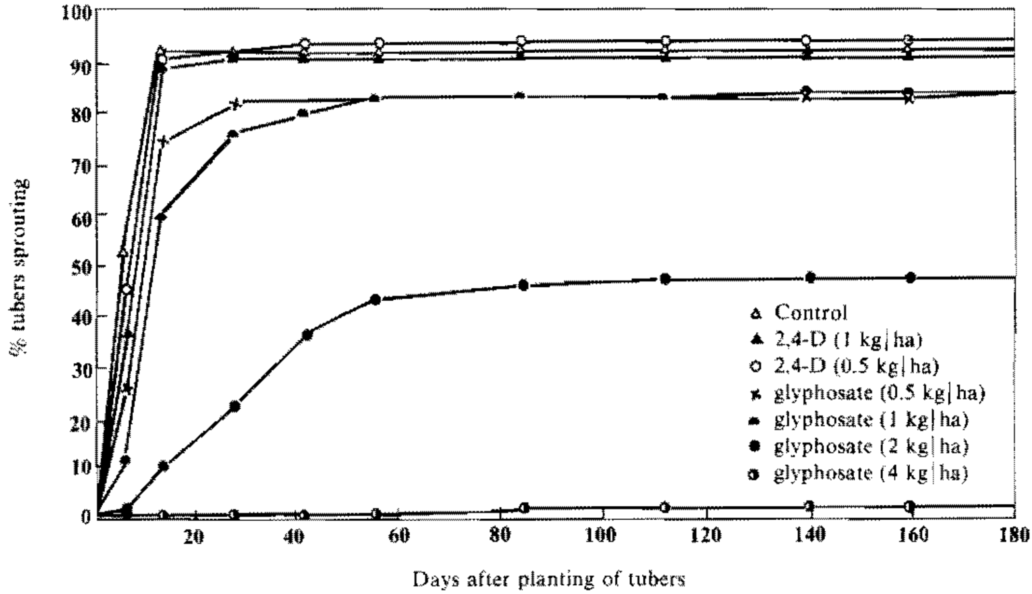


Figure 1. **Effects of glyphosate and 2,4-D applied to foliage of parent plants on the sprouting of *Cyperus rotundus* tubers.**

sprout and the foliage then treated with glyphosate. It was also apparent that most sprouting occurred within 60 days after planting. Nevertheless, after 180 days the nonsprouted tubers were removed from the soil and appeared to be intact. Tubers were solid and the flesh was generally white but washing them with water for various days did not cause sprouting. Testing dissected tubers with a tetrazolium solution indicated that most were no longer viable. Why they remained firm and whether they will ever sprout are being investigated.

Two trials were done to determine the time needed between the application and the accumulation of sufficient glyphosate in the tuber to prevent sprouting. Two rates of glyphosate were applied to the foliage of 90-day-old purple nutsedge in pots. At specific times after application, the leaves were removed to prevent further translocation into the tubers. The tubers were immediately cut from the rhizomes, counted and planted in fresh soil. Periodic observations on the number of sprouted tubers were taken (Tables 1 and 2).

The time allowed for translocation in the first trial was too long to find the minimum. Less than seven days were sufficient to give excellent sprout inhibition, especially at the higher rate. In the second trial, shorter translocation times and lower rates were employed. At the 1 kg|ha rate, 72 hours were needed to give excellent inhibition. With 2 kg|ha, 36 hours were adequate. Thus, there is an interaction between rate and time such that at higher rates less time is needed for a sufficient quantity of glyphosate to reach the tuber and prevent sprouting, while at lower rates, more time is required. To obtain nearly total inhibition, at least 2 kg|ha of glyphosate must be applied. In both trials there was little difference between the number of tubers sprouted at 56 and 95 or 100 days after planting. Observations were taken for 180 days after planting but essentially no more tubers sprouted after 56 days.

Since glyphosate is translocated from the aerial to the root portion of the plants, light intensity could be important in this process. In crops such as banana, coffee,

Table 1. **Effect of time for translocation of two rates of glyphosate on sprouting of *Cyperus rotundus* tubers (Expt. I).**

Glyphosate applied (kg|ha)	Translocation time (days after application)	% of tubers sprouting		
		28 days after planting	56 days after planting	95 days after planting
0	7	94	94	94
	14	93	94	94
	28	94	94	94
1.5	7	2	3	8
	14	17	28	32
	28	7	11	13
3.0	7	0	0	0
	14	0	0	0
	28	0	0	0

cassava and citrus, considerable shading can occur at gound level and may in turn reduce translocation since the weeds will be photosynthesizing less. This hypothesis was tested by applying 1.5 kg|ha glyphosate to purple nutsedge plants growing under shades providing from zero to 92 percent light interception. Twenty-

Table 2. **Effect of time for translocation of two rates of glyphosate on sprouting of *Cyperus rotundus* tubers (Expt. II).**

Glyphosate applied (kg|ha)	Translocation time (hours after application)	% of tubers sprouting		
		28 days after planting	56 days after planting	95 days after planting
0	12	90	91	91
	24	90	91	91
	36	90	91	91
	48	90	91	91
	72	90	91	91
	120	90	91	91
1	12	86	87	87
	24	82	83	83
	36	52	69	72
	48	36	50	53
	72	6	17	22
	120	4	15	16
2	12	72	76	77
	24	37	54	59
	36	2	5	9
	48	1	2	2
	72	0	0	1
	120	0	0	0

Table 3. **Sprouting of *Cyperus rotundus* tubers after treatment of the parent plant with glyphosate* under shading.**

% shading of parent plants	% control of parent plants 28 days after planting	% tubers sprouting	
		28 days after planting	56 days after planting
0	94	11	22
30	94	2	6
49	94	3	6
63	96	2	6
73	91	0	3
92	60	0	4
Control	0	92	92

* 1.5 kg|ha of glyphosate applied to parent plants before shading

eight days later the percentage control was observed and the tubers were dug, counted and replanted to determine their sprouting capacity (Table 3).

Control of the foliage tended to decrease as the shade increased above 73 percent. However, glyphosate was equally effective at inhibiting the sprouting of tubers attached to the treated plant at all shades. In fact, the least effective treatment was the nonshaded one. This is attributed to the fact that these pots were exposed to full sunlight and even though the pots were watered daily, on hot days they tended to dry out. This very likely afffected translocation while the other pots were shaded and were not subject to such drying conditions. Apparently, glyphosate would be equally effective under the shades found in perennial crops.

The highly systemic nature of glyphosate means that perhaps not all of the plant need be treated to achieve maximum effects. In another trial, 25, 50, 75 or 100 percent of the foliage on 90-day-old purple nutsedge in pots was treated with 1 kg|ha glyphosate. Control ratings were taken 14 and 28 days later. Tubers were then dug, counted, planted and periodically observed for sprouting (Table 4)..

Purple nutsedge control increased both with time and as the percentage of the plant treated increased. Perhaps the glyphosate

Table 4. **Effects of glyphosate treatment* on control of parent plant and sprouting of tubers in *Cyperus rotundus*.**

% of parent plant treated	% control of parent plant		% of tubers sprouting	
	14 days after application	28 days after application	28 days after planting	56 days after planting
0	0	0	95	96
25	16	30	53	59
50	26	49	27	34
75	25	58	20	28
100	43	70	11	15

* 1 kg|ha of glyphosate

rate was too low to provide better control. Tuber sprouting was similarly affected, indicating that best results are obtained by treating the entire plant.

In addition to control studies with purple nutsedge, the effects of soil moisture and texture on four plant biotypes were investigated. Tubers were collected in four regions of Colombia (Valle, Tolima, Córdoba and Magdalena) and grown in soil at moisture levels of 25, 50, 75 or 100 percent field capacity or at the saturation point of the soil. Dry matter production increased as soil moisture increased up to 75 percent of field capacity (Fig.2). There were no differences among biotypes in

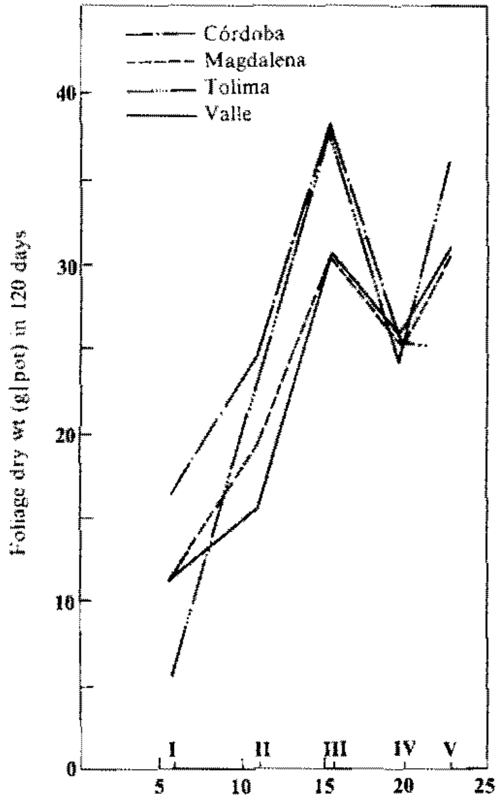


Figure 2. **Effect of 25, 50, 75 and 100 percent field capacity (I, II, III and IV, respectively) and soil saturation (V) on growth of four biotypes of** ***Cyperus rotundus*****.**

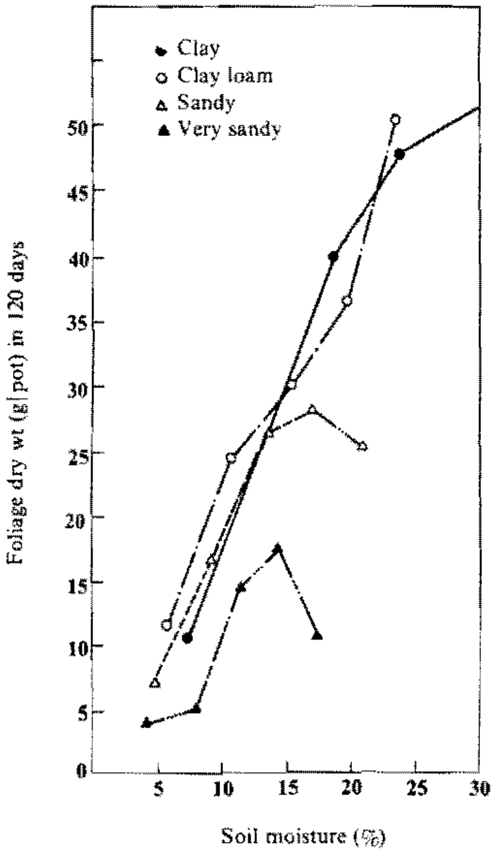


Figure 3. **Effect of soil moisture in four soil types on dry matter production of** ***Cyperus rotundus*** **from Valle, Colombia in 120 days.**

foliage dry matter production. The effects of soil moisture on tuber production were similar to those on dry matter production and even in saturated soils, many tubers were produced. The most prolific tuber producers were plants from Córdoba and Magdalena (143 and 141 tubers|pot, respectively), followed by those from Tolima (135|pot) and Valle (124|pot).

More marked differences were caused by changing soil texture (Fig. 3). The heavier soils produced more dry matter than lighter soils with maximum production coming at the point of moisture saturation. In contrast, sandy and very sandy textured soils gave three times less total dry matter production and less growth occurred at saturation that at field capacity. Nearly identical results were observed for the number of tubers produced.

Both trials indicate that nutsedge would be a more serious weed in heavy, wet soils than in lighter, well-drained soils. This partly accounts for the difficulty of controlling purple nutsedge, by whatever means, in heavier textured soils.

Many new promising herbicides for purple nutsedge control were tested in screenhouse and field trials. Excellent results were obtained in the screenhouse with preplant incorporated applications of K-1441 (5 kg|ha), U-44,078 and U-44,344 (1.5 kg|ha each) and H-25893 and H-26910 (4 kg|ha each). Perfluidone, AC-206,246 and AC-206,490, all at 4 kg|ha in pre-emergence, also gave excellent control. Poor control was obtained by K-223, cyperquat, bentazon, MBR-12325 and amitrol.

In the field, only U-44,078, U-44,343 and K-1441 have given acceptable control. Further trials will be conducted.

Weed seed germination

A two-year study was conducted on the germination of 20 weed species. Seeds were collected and germination tests conducted every two months to determine which species have a dormancy period and which ones would survive during the entire test period.

Cyperus esculentus and *C. rotundus* germinated poorly during the entire period, confirming that seed germination is not an important means of propagation for these perennial, tuber-producing weeds (Table 5). The grass seeds generally had low germination, with the exception of *Rottboellia exaltata*. For this species, removing the hull from the seed increased germination and decreased its dormancy.

The seeds of dicotyledonous species generally had high germination. The only species which were not viable after two years were *Andropogon bicornis* and *Eclipta alba*.

Control of raoul grass

Raoul grass (*Rottboellia exaltata*) is a rapidly spreading weed in many areas of Latin America. Its seeds float on water and are also often transported in crop seeds, especially sorghum, due to the similarity in size and weight. It is particularly troublesome in maize and sorghum since none of the herbicides currently available for these crops control it.

Raoul grass first appeared in lower areas of CIAT's farm in 1972. It is highly probable that seeds were carried in flood water during a previous year from a nearby farm which has a serious infestation of raoul grass. Since it was found, a methodical vigilance program was established. Infested areas were periodically checked and all raoul grass was pulled and removed from fields. In three years the grass has been eradicated from CIAT's fields, and in most locations, this was accomplished within 18 months. This practice should be followed by farmers immediately after discovering a new infestation on their land. If its removal is delayed, the likelihood of eradicating this serious weed is reduced.

Since raoul grass is spreading rapidly in many areas of Colombia, an educational campaign was conducted in cooperation with the Instituto Colombiano Agropecuario (ICA), the Sociedad Colombiana de Control de Malezas y Fisiología Vegetal (COMALFI) and several herbicide manufacturers. A total of 250 farmers, agronomists and extension agents from several areas attended a three-day program one day each in three locations to learn the identification and biology of the weed and how to prevent its spread and to eradicate or control it once it appears.

Table 5. **Germination of seeds of 20 weed species over 24 months.**

Group and species	Age at maximum germination (mo)	Avg. germination during 24 mo. (%)	Range in germination (%)
Cyperaceae:			
Cyperus esculentus	22	2.8	0 - 25
Cyperus rotundus	20	0.4	0 - 2
Gramineae:			
Andropogon bicornis	2	0.5	0 - 4
Digitaria sanguinalis	12	13.2	0 - 42
Echinochloa colonum	2 and 10	17.5	4 - 27
Eleusine indica	14	6.2	0 - 13
Leptochloa filiformis	12	3.5	0 - 26
Panicum fasciculatum	20	3.4	0 - 16
*Rottboellia exaltata**	6	66.5	39 - 89
*Rottboellia exaltata***	8	57.1	8 - 88
*Rottboellia exaltata****	12	42.2	0 - 92
Dicotyledons:			
Amaranthus dubius	10	31.0	6 - 55
Corchorus orinocensis	22	3.7	0 - 9
Crotalaria striata	20	34.0	24 - 50
Eclipta alba	10 and 12	5.8	0 - 16
Euphorbia hypericifolia	6	10.3	0 - 50
Hetheranthera reniformis	12	0.8	0 - 3
Ipomoea hederifolia	12	41.4	9 - 53
Leonotis hepetaefolia	0	9.7	2 - 51
Momordica charantia	6	53.2	18 - 80
Portulaca oleracea	8	54.9	39 - 66
Sida rhombifolia	6	2.8	1 - 6

* Dehulled seed stored and germinated

** Hulled seed stored and then germinated without the hull

*** Hulled seed stored and germinated

Trials were also done to study the effects of shade on the growth and development of raoul grass. Pots seeded with raoul grass were placed under shade chambers and weekly observations were made.

In total darkness, the seeds germinated but died two weeks after emergence (Table 6). Plant height increased as the shade increased and the differences were greater at 70 than at 35 days after planting. Shading delayed tillering but only 73 percent or more shade markedly reduced the number of tillers produced. Dry matter production by foliage was high up to 80 percent shade.

The seed production data show why raoul grass is so aggressive. Numbers of seeds per plant increased 46 percent when under 47 percent shading, compared to seeds produced on plants in full sunlight. Apparently, it becomes more prolific in the shade and this helps explain its competitive nature with all crops. Even under 92 percent shade, 35 seeds per plant were

Table 6. **Response of *Rottboellia exaltata* to shading.**

% shading of plants	Plant height (cm)		No. of tillers		Foliage dry wt. (g/plant)	No. of seeds/plant*
	35 days after planting	70 days after planting	35 days after planting	7 days after planting		
0	28	82	6	30	38	257
30	30	107	4	26	36	398
47	37	128	4	22	38	472
55	36	137	3	16	31	336
63	39	133	3	21	32	324
73	44	164	1	11	25	228
80	44	138	0	7	11	161
92	35	87	0	4	4	35
100**	-	-	-	-	-	-

* Harvested 77 days after planting.

** In total darkness, all plants died after two weeks.

produced. Thus, if raoul grass is allowed to germinate, it will survive under most crop canopies.

Weed control short course

An intensive, one-month weed control short course was held in mid-1975, with financing from the U.S. Agency for International Development (AID), the Oregon State International Plant Protection Center (IPPC) and CIAT. Thirty-one agronomists from 12 Latin American countries were selected to participate. Those chosen had weed control research responsibilities but limited experience. The objective was to provide participants with as much practical experience as possible and to bring them up to date with the latest principles and recommendations in weed control.

Participants were divided into six teams to facilitate field exercises and short-term research projects and also to stimulate intergroup competition. The course was a success from every point of view. Participants increased their test scores 31 percent from the initial to the final exam and rated the course highly in nearly every category during a final evaluation. In addition to increased competence acquired by participants, CIAT established valuable international contacts for future collaboration.

EXPERIMENT STATION OPERATIONS

The principal activities carried out at CIAT during 1975 by personnel from this unit were as follows:

- The needs of CIAT's research programs (preparation and maintenance of the experimental areas) and the Training and Conferences Program's crop production courses were attended to.

- New plots to be used for experiments, amounting to about 16 hectares, were leveled and leached.

- Problems relating to the maintenance of the station were taken care of as necessary.

- Three agricultural engineers from Central America and Venezuela were trained in planning, developing and operating an experimental station.

• A short training course on preparing and leveling of land under water was given to three officials from the Instituto Nacional de Colonización y Reforma Agraria de Colombia (INCORA) and one from the CARE mission in Colombia.

• A total of 432 hectares being cultivated by CIAT's research programs were irrigated.

• A total of 597 hectares were prepared for experimental plantings, training courses and commercial production.

• 1,840 meters of irrigation canals were designed and built; these were lined with a mixture of soil and cement (8:1); total area lined was 8,509 m^2. In addition, 41 concrete transitions and 9 boxes were incorporated into the concrete portion of CIAT's irrigation system.

• Maintenance was done on 37 kilometers of roads, 35 kilometers of drainage canals and 39 kilometers of irrigation canals.

• Six kilometers of fence were removed and 31 kilometers maintained.

• Maize, sorghum, beans and cassava were grown commercially in areas not being utilized by training and research activities.

• A continuous rice production program was begun, planting approximately 4 ha|week in cooperation with the Training and Conferences and Rice Production Systems programs.

PUBLICATION*

JOHNSON, L. Experiment station development training. Cali, Colombia, CIAT, 1975. 32p.

Paper presented at Bellagio Agricultural Education Conference, 2nd., The Rockefeller Foundation, Bellagio, Italy, 1975.

* This list includes only journal articles published outside CIAT's series.

FINANCE

Price Waterhouse & Co.

APARTADO AEREO 180 - CALI, COLOMBIA

April 17, 1976

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, 1975 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, 1975, 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 - Note 2)

	December 31 1975	1974	1973	1972
ASSETS (NOTE 3)				
CURRENT ASSETS:				
Cash	1,152	623	139	272
Accounts receivable:				
Donors (Note 4)	607	531	497	499
Employees	66	85	69	73
Others	311	718	289	287
	984	1,334	855	859
Inventories (Note 1)	250	199	100	54
Prepaid expenses	5	8	5	17
Total current assets	2,391	2,164	1,099	1,202
FIXED ASSETS (Note 1):				
Equipment	1,721	1,346	802	758
Vehicles	593	568	305	314
Vehicles (replacements) in transit	330			
Furnishings and office equipment	930	901	378	369
Buildings	4,495	4,429	3,950	2,359
Other	46	103	925	64
Total fixed assets	8,115	7,347	6,360	3,864
Total assets	10,506	9,511	7,459	5,066
LIABILITIES AND FUND BALANCES				
CURRENT LIABILITIES:				
Bank overdraft	14	317	137	7
Accounts payable	758	286	351	181
Payable to donors			25	25
Others		385	127	100
Total current liabilities	772	988	640	313
GRANTS RECEIVED IN ADVANCE	250	115	117	
FUND BALANCES:				
Invested in fixed assets	8,115	7,347	6,360	3,864
Unexpended funds (deficit):				
Core —				
Unrestricted	303	32	(37)	(12)
Working fund grant	600	100	100	
Capital grants	185	628	175	891
Special projects —				
Donors	340	301	144	35
Other	(59)		(40)	(25)
	1,369	1,061	342	889
Total fund balances	9,484	8,408	6,702	4,753
Total liabilities and fund balances	10,506	9,511	7,459	5,066

The notes on pages G-40 and G-41 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 - Note 2)

	Year ended December 31			
	1975	1974	1973	1972
Revenue:				
Core:				
Operating grants —				
Unrestricted	4,180	3,475	2,672	2,286
Restricted	1,090	1,030	790	433
Working fund grant	500		100	
Capital grants	257	1,365	1,779	1,614
Total Core	6,027	5,870	5,341	4,333
Special projects	593	631	404	98
Earned income	339	310	168	98
Total revenue	6,959	6,811	5,913	4,529
Expenditures:				
Core programs:				
Direct research —				
Beef	813	724	661	417
Swine	211	230	202	177
Cassava	413	399	330	309
Beans	517	374	262	114
Rice	201	133	135	240
Maize	78	83	121	150
Small farm systems	160	185	36	110
	2,393	2,128	1,747	1,517
Research support	328	342	230	45
Total research	2,721	2,470	1,977	1,562
Training and conferences	527	520	518	371
Library and information services	438	276	139	77
Administration expenses	598	559	340	314
General operating costs	986	678	656	567
Total Core programs	5,270	4,503	3,630	2,891
Special projects	613	602	305	166
Purchases of fixed assets	768	987	2,496	1,426
Total expenditures	6,651	6,092	6,431	4,483
Excess of revenue over expenditures:				
Operating grants	271	69		(89)
Working fund grant	500		100	
Capital grants	(443)	453	(717)	188
Special projects	(20)	197	99	(53)
	308	719	(518)	46
Unexpended funds at beginning of year	1,061	342	889	843
Grants receivable for prior years written off			(29)	
Unexpended funds at end of year (see balance sheet)	1,369	1,061	342	889

The notes on pages G-40 and G-41 are an integral part of the financial statements.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT) **SCHEDULE 1**

SUPPLEMENTARY INFORMATION

ANALYSIS OF GRANTS AND RELATED EXPENDITURES

FOR THE YEAR ENDED DECEMBER 31, 1975

(Expressed in thousands of U.S. dollars)

		Expenditures						% of library, administration and general operating to total research and training	
	Total funds available	Fixed assets	Total research	Training and conferences	Library and information services	Administration	General operating		Transfer to unexpended balance
Unrestricted Core:									
The Ford Foundation	625								
The Rockefeller Foundation	600								
United States Agency for International Development	1,230								
Interamerican Development Bank	1,645								
United Nations Environment Program	70								
World Rock Phosphate Institute	10								
Balance from previous year	32								
Income applied in year	271								
Total unrestricted Core	4,483		2,305	267	351	478	779	63	303
Restricted Core:									
The W. K. Kellogg Foundation	290			180	23	32	55	61	
Canadian International Development Agency	800		416	80	64	88	152	61	
Total restricted Core	1,090		416	260	87	120	207	61	
Working fund grants:									
Government of the Netherlands	175								
Government of Switzerland	115								
Government of the Federal Republic of Germany	210								
Balance from previous year	100								
Total working fund grants	600								600

	Total funds available	Expenditures: Fixed assets	Total research	Training and conferences	Library and information services	Adminis-tration	General operating	°/o of library, administration and general operating to total research and training	Transfer to unexpended balance
Capital grants:									
Government of the Federal Republic of Germany	134								
United Kingdom - Ministry of Overseas Development	23								
Interamerican Development Bank	100								
Balance from previous year	628								
Income applied in year	68								
Total capital grants	953	768							185
Special projects (1):									
The Ford Foundation	97		17		17			100	63
The Rockefeller Foundation	185		54	39		5	7	13	80
United States Agency for International Development	30			30					
Interamerican Development Bank	186		43	134	6	24	38	38	(59)
United Kingdom - Ministry of Overseas Development	126		41			4	7	27	74
International Development Research Centre (Canada)	123		67		13	2	4	28	37
International Board for Plant Genetic Resources	50		11						39
International Fertilizer Development Center	15		4						11
International Minerals & Chemical Corporation	25		3				1	33	21
Others	56			41					15
Total special projects	893		240	244	36	35	57	26	281
Total grants and expenditures	8,019	768	2,961	771	474	633	1,043		1,369

(1) Includes balance brought forward from previous year of US$300,000

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT) SCHEDULE 4

SUPPLEMENTARY INFORMATION

DATES OF RECEIPT OF GRANTS

FOR YEAR ENDED DECEMBER 31, 1975

(Expressed in thousands of U.S. dollars)

	Rec. at beg. of year	1975 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at yr. end	1976 rec. in adv.	Net 1975 grants
Unrestricted Core:																	
The Ford Foundation				157		52	52	52	52	52	52	52	52	52			625
The Rockefeller Foundation			305	18	18	28	31	19	16	21	9	17	104	14			600
United States Agency for International Development							500		500			230					1,230
Interamerican Development Bank											947		349		349		1,645
United Nations Environment Program							70										70
International Development Association					110											(110)	
World Rock Phosphate Institute										10							10
			305	175	128	80	653	71	568	83	1,008	299	505	66	349	(110)	4,180
Restricted Core:																	
The W.K. Kellogg Foundation							290										290
Canadian International Development Agency					420					380							800
					420		290			380							1,090
Capital grants:																	
The Rockefeller Foundation	(160)														160		
Government of the Netherlands									175								175
Government of Switzerland		115												140		(140)	115
Government of the Federal Republic of Germany			64			126				116		38					344
United Kingdom - Ministry of Overseas Development														23			23
Interamerican Development Bank											100						100
	(160)	115	64			126			175	116	100	38		163	160	(140)	757

	Rec. at beg. of year	1975 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at yr. end	1976 rec. in adv.	Net 1975 grants
Special projects:																	
The Ford Foundation				25							22						47
The Rockefeller Foundation	(12)					20			22				94		12		136
United States Agency for International Development															30		30
Interamerican Development Bank					90												90
United Kingdom - Ministry of Overseas Development						37				33				9			79
International Development Research Centre (Canada)									7		36				23		66
International Board for Plant Genetic Resources										50							50
International Fertilizer Development Center												15					15
International Minerals & Chemical Corporation				25													25
Others	(3)					3	11	2			2	6	1		33		55
	(15)			50	90	60	11	2	29	83	60	21	95	9	98		593
	(175)	115	369	225	638	266	954	73	772	662	1,168	358	600	238	607	(250)	6,620

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