Annual Report

1973

Centro Internacional de Agricultura Tropical, CIAT

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

Cables: CINATROP

CIAT is a non-profit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out mainly at its Experimental Centers at Turipaná and Carimagua. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research. In 1973, these donors were the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the Canadian International Development Agency (CIDA), the W. K. Kellogg Foundation, the International Bank for Reconstruction and Development (IBRD) through the International Development Agency (IDA), and the governments of the Netherlands, Switzerland, and the Federal Republic of Germany. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada and the Interamerican Development Bank (IDB). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations, or governments.

Contents

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* As of December 31, 1973

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(As of December 31, 1973)

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Assistant Entomologist

* Assignment divided between programs indicated

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Jerome H. Maner, Ph.D.
Animal Scientist; Coordinator

* Eduardo Aycardi, Ph.D.
Assistant Microbiologist

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* Alberto Valdés, Ph.D.
Associate Agricultural Economist

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Communication Scientist; Leader

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Assistant Scientist; Editor

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Photographer

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Associate Animal Scientist;
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Animal Scientist; Director Adjunto Instituto de Ciencia y Tecnología Agrícolas

Eugenio Martínez, Ph.D.
Plant Breeder; Director Técnico Instituto de Ciencia y Tecnología Agrícolas

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Hemoparasitology (Beef)

Thomas J. Galvin, D.V.M., Ph.D.
Hemoparasitology (Beef)

David Hopps, D.V.M.
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Dale Fisher, B.S.
Swine Management

Roger Sanstead, Ph.D.
Agronomy (Field Beans)

* Assignment divided between programs indicated

Foreword

Dedication of the new physical facilities of the Centro Internacional de Agricultura Tropical on October 12, 1973, served to climax some five years of intensive planning, designing, development, and construction.

During this same period, CIAT acquired most of its senior staff and several hundred local support employees. Cooperative programs with the Instituto Colombiano Agropecuario (ICA) had been under way in some commodities since 1968; crop and animal studies were begun on the CIAT farm in 1969; nearly 200 persons had been trained from some 20 countries, more than 1,000 persons had participated in six major international conferences and symposia, and staff members had conferred with agricultural, educational and policy leaders in most of the tropical countries of Latin America and the Caribbean.

Consequently, with its programs already well under way, most of its staff employed, increasing financial support from governments and agencies represented in the Consultative Group for International Agricultural Research, and growing interest among donors and countries for special outreach projects, the dedication represented a milestone in CIAT's progress, a recognition of accomplishment, thanks to those who made it possible, a preview of future challenges and opportunities, and a commitment to continued action.

More than 1,200 persons, in addition to the employees, participated in one or more of the five separate events undertaken incident to the inauguration of the new facilities. These events were:

Employees' Day, marking the first use of the new kitchen and dining facilities;

Neighbors' Day with some 300 members of the scientific and technical staffs of more than 30 institutions in the Cauca Valley attending;

Founders' Day, in which some 60 persons were recognized for their vision, dedication and cooperation in making CIAT possible;

Dedication Day, with some 700 persons hearing major addresses by Misael Pastrana Borrero, President of the Republic of Colombia; Francisco de Sola, Board Chairman; John H. Knowles, President of the Rockefeller Foundation; and U. J. Grant, Director General of CIAT, and the Inaugural Symposium, in which six internationally known leaders analyzed the potential of the lowland tropics before an audience of some 200 leaders in agricultural and economic development.

Staff and management continued efforts to sharpen the focus and to accelerate progress in the six commodity programs: beef, swine, cassava, field beans, maize and rice. This process was facilitated by active participation of the Board of Trustees and committees of the Board, as well as through informal discussions with present and prospective donors, representatives of the countries of the lowland tropics, and, in the case of beef, a formal review team which spent six weeks studying not only CIAT beef programs but also visited several of the major beef-producing areas of tropical America.

Another program development was the decision to change the focus of the agricultural systems program to concentrate more on small farms in the lowland tropics.

The following paragraphs represent a few highlights of accomplishments and activities in CIAT's major programs during 1973.

Beef. The beef team concentrated on identifying ways to provide adequate year-round feed supplies, establishing means of controlling diseases and parasites, and developing and demonstrating economical systems of production. The goal is to stimulate the beef cattle industry in the development of the lowland tropics of Latin America with approximately 150 million head of cattle, plus extensive grassland areas, many of which are understocked and have limited immediate or long-term potential for cultivated crops.

At Carimagua, an area representative of extensive latosol regions, the productivity of molasses grass (**Melinis minutiflora**) pasture has been four to five times that of native pasture in the rainy season. This advantage disappears, however, during the dry season, with weight losses that often cancel a large portion of the gains. Inter-seeding of the high protein forage legume **Stylosanthes guyanensis** in grass pastures along with protein supplementation are being studied as a means of curbing weight losses and their effects on fertility.

Although malnutrition is the main factor associated with low calving rates, breeding diseases are often important, and other diseases frequently

These six men presented the inaugural symposium on "The Potentials of the Lowland Tropics" in connection with the dedication of CIAT. Left to right: Paulo de T. Alvim, Director, Cacao Research Center, Itabuna, Bahia, Brazil; Lewis M. Roberts, Rockefeller Foundation (moderator); Galo Plaza, Secretary General, OAS; Raul Prebisch, Adviser to U.N. Secretary General; Benjamin Viel, Executive Director, Western Hemisphere Region, International Planned Parenthood Federation; and Armando Samper, Sub-Director General, FAO, and Chairman, CIAT Board of Trustees

Facsimile of the bronze plaque that was unveiled at CIAT's inaugural ceremonies on October 12, 1973, by the President of Colombia, Misael Pastrana Borrero

aggravate the problem. Surveys in the Eastern Plains of Colombia have identified significant incidence of infectious rhinotracheitis, leptospirosis and brucellosis, but other breeding diseases have not been found.

In collaboration with Texas A&M University, significant advances have been made in the epidemiology, immunization, antigen sources, diagnostic methods, chemical control and treatment of two hemoprotozoan diseases, anaplasmosis and babesiosis. Promising results have been obtained through partial immunization of cattle through vaccinations against some of the most serious blood parasites.

In life cycle beef production systems under study, near optimum inputs of a variety of management improvement are being compared with prevailing practices and conditions. Mineral supplementation has markedly increased conception and growth rates of cattle grazing on both native and molasses grass pastures.

Results of a study of cattle farms in the Eastern Plains indicate that these operations are typically small. On an average, a farm markets fewer than 12 head per year. Only 8 per cent of the cattle farms market 50 to 60 head annually.

International activities of the staff during the year included advisory and consultative work in Bolivia, Brazil, Colombia, Ecuador, Perú, Venezuela, and the Caribbean.

Swine. The network of institutions collaborating with the swine program was increased in 1973 by initiating programs with the Universidad de Bolivia and the Universidad de Costa Rica, both activities being under the supervision of scientists who recently completed postgraduate internships at CIAT. Similar programs already were under way in Ecuador and Colombia.

As 80 to 90 per cent of the total expense of producing pork in Latin America is associated with feed costs, the program continued to seek ways to utilize feedstuffs readily available in the tropics. These include cassava, maize, plantain, bananas, yams, and by-products of agricultural industries. In addition, special emphasis is placed on finding on-the-farm sources of protein. Tests this past year were made with cowpeas, field beans, cottonseeds and the forage legumes, **Desmodium** and **Stylosanthes.**

With 80 to 85 per cent of all swine produced in Latin America being grown on small farms, work continues on the small farm swine project at Cacaotal. Swine producers quickly adopted new practices in housing, management and parasite control, but acceptance of improved feeding systems, principally a protein-vitamin-mineral supplement, has been slow. Reasons for this are associated with lack of education, limited capital and lack of commercial availability and high cost of the supplement.

Animal health specialists, continuing their study of 20 collaborating swine farms in the Cauca Valley, have identified pig diarrhea, abortions, abscesses and arthritis as the most prevalent problems.

Cassava. Yields of more than 50 ton/ha per year were achieved in unreplicated yield trials, and more than 46 ton/ha on larger scale replicated plots. While the varieties with this yield potential do not have high disease and insect resistance, sources of resistance to most of the major diseases and pests have been found.

With development of breeding techniques, controlled crosses were made to combine useful characters. At the same time, the germplasm bank of some 2,100 entries was being evaluated for useful varieties and parents for future crosses.

Preliminary data from physiological studies suggest that a high-yielding variety will be associated with a short plant, one that has little stem and a high harvest index combined with the ability to retain a large leaf area index from six months up to harvest.

The rapid field method of propagation devised at CIAT will allow fast increase of promising varieties. This system also produces planting material free of the cassava bacterial blight.

A survey has shown that (a) weed control is one of the major labor-using operations in cassava production, (b) thrips are a major problem in cassava growing in Colombia, and (c) the majority of farmers grow cassava as a monoculture, not as a mixed crop.

Simple on-farm methods of storage are being developed, and cassava roots have been kept for up to eight weeks with little decline in quality.

The basic drying characteristics of cassava have been defined, and the design of practical equipment to facilitate the process on the farm is under way.

Of the some 3,000 documents collected, more than 1,500 have been fully processed. Abstracts are being distributed world wide.

Field Beans. CIAT's program in field beans was launched in February with an international seminar which explored the potentials of field beans and other food legumes in Latin America. Participants helped to identify production problems needing research as well as the individuals and institutions most qualified to conduct these studies. They placed major emphasis on finding practical means to form an informal cooperating network to the end that work on priority problems be accelerated efficiently.

By year's end, more than 9,000 bean varieties had been collected at CIAT and were being systematically screened for plants showing desirable characteristics (resistance to diseases and insects, superior performance on poor soils, and good yields). Inasmuch as many of the beans produced in Latin America are grown in association with maize, the research includes such cultivation situations.

Other aspects of the bean program receiving high priority attention were efficiency of nitrogen fixation by root nodule bacteria, and the production and distribution of disease-free seed to national programs.

Maize. This program cooperates with and supports national research and production programs in the Andean zone-- Colombia, Venezuela, Ecuador, Perú and Bolivia. As such, it serves as a link in an international network of national, regional and international centers under the general coordination of CIMMYT.

Most promising yields were found in trials of present commercial maize hybrids and the experimental materials from PCCMA and CIMMYT. In several trials, an introduced hybrid or selection produced more than locally developed double cross checks, indicating a potential for further advances in the Cauca Valley environment.

Results of studies of minimum tillage systems indicated there was no significant difference among the four treatments tested, and thus the most simple or lowest cost treatment would be most desirable. This experiment, now in its fourth continuous crop of maize after a single land preparation two years ago, demonstrates a tremendous potential for saving 2 to 3 weeks in time and about 25 per cent of production costs for land preparation.

Selection for enhanced protein quality through use of the opaque-2 gene has concentrated on hard endosperm types for direct human consumption. A yellow hard endosperm line introduced from CIMMYT was selected during three cycles for shorter plant height, prolificacy, and resistance to local diseases and insects. This variety has been distributed to programs in the zone.

Region-wide activities included testing of germplasm, uniform regional trials, a meeting of maize research workers in Bolivia, a plant protection workshop at CIAT, a newsletter, and support of training activities at CIAT and elsewhere.

Rice. Large percentages of the rice areas of Mexico, Cuba, Costa Rica and other Central American countries, Colombia, Venezuela, Ecuador and Perú are planted with CICA 4, IR22, IR8 and selections from materials provided by CIAT and IRRI. Yield increases have been excellent; in Colombia, for instance, the new technology has increased yields by about 2.2 ton/ha to more than 5 ton/ha over the entire irrigated area since 1966.

As expected, the rice blast disease is beginning to depress yields of the new varieties. The problem will increase with continued plantings. Consequently, resistance to blast is being urgently sought in new lines under study.

Soils studies emphasized work on upland rice, particularly under the extreme soil acidity conditions of high savanna soils. Results indicate the problems can be solved either through liming to increase pH or through varietal tolerance. Varieties differ markedly in tolerance to acid soil factors.

Results of field studies in areas that are alternately dry in the dry season but flood in the wet season indicate that naturally flooded soils and their surrounding areas have a great potential for rainfed rice as long as the water level does not rise above 50 cm, the land is prepared during the dry season, the rice is seeded at the onset of the rainy season, and varieties are used that are either tall or have floating rice characteristics.

Small Farm Systems. Experiences up to and including 1973 led CIAT, late in the year, to recast its agricultural systems program more specifically as a small farm system focus. As such, the program is concerned with small family farms as integrated systems; the whole farm unit will be studied.

With a planning session in October, 1973, including some 40 participants from the CIAT staff, Universidad del Valle, ICA, and interested international agencies and foundations, CIAT formulated its objectives and initial plan of action for this new approach. The underlying concern of the participants was to establish a research team to focus on the understanding of existing small farming systems in order that the relevance and impact of new technology on farm family welfare could be planned and predicted.

The staff, consisting initially of an agronomist, systems engineer and economist, had developed by year's end programs of cooperative activities with development activities and projects in Colombia and Guatemala as well as within CIAT.

Training and Communication. The widening international scope of CIAT involvement was directly reflected in numbers of trainees, participation in conferences and symposia and distribution of informational materials. During the year, 159 persons from 24 countries were enrolled in training, more than 150 persons from 20 countries in five continents registered for the seminar on field beans, and information materials were being circulated widely.

Administrative Developments

Increased program activities led to growth in financial needs, these being met in 1973 with three new donors joining the Ford, Rockefeller, and W. K. Kellogg Foundations, the United States Agency for International Development, the Canadian International Development Agency and the Government of the Netherlands. The new donors were the governments of Switzerland and the Federal Republic of Germany, plus the International Bank for Reconstruction and Development through the International Development Agency.

Funds for special projects and outreach activities came from the International Development Research Centre of Canada, the Interamerican Development Bank, and the W. K. Kellogg Foundation. In addition, the Rockefeller Foundation provided funds to enable CIAT to assign two staff members in residence in Guatemala as part of the cooperative program between CIAT and the Instituto de Ciencia y Tecnología Agrícolas (ICTA). Dr. Robert Waugh serves as assistant director to ICTA, while Dr. Eugenio Martínez is technical director.

ICTA presently is concerned with production and productivity of several commodities, including field beans, rice, maize, sorghum, wheat and vegetable crops. Selected professionals from ICTA will receive training at CIAT, and CIAT is helping ICTA establish assistance ties with other international centers and activities.

Mr. Francisco de Sola, a member of the original CIAT Board of Trustees and chairman for the past five years, completed two consecutive terms in 1973. The Board, management, staff and employees of CIAT, in a variety of ways, expressed their appreciation for the enthusiasm, dedication, and leadership which marked the years of his affiliation with CIAT.

At the October meeting, the Board installed Dr. Armando Samper as Chairman, Mr. Julián Rodríguez Adame as Vice Chairman and one newly elected member, Mr. Luis Crouch of the Dominican Republic.

The major staff change during the year was the departure in August of Dr. A. Colin McClung, deputy director general, to accept a position in the New York offices of the Rockefeller Foundation. The Board of Trustees, in October, named Dr. Eduardo Alvarez-Luna, director of Plant Sciences, CIAT, to the post of deputy director general.

Other appointments to the senior scientific and administrative staff were: Dr. Eduardo Aycardi, animal health; Mr. David Franklin, small farm systems and biometrics; Dr. Kazuo Kawano, cassava breeding; Dr. Grant Scobie, agricultural economics; Dr. Julio César Toro, cassava agronomy; Mr. Andrew Urquhart, comptroller, and Dr. Alberto Valdés, agricultural economics, plus Dr. Waugh and Dr. Martínez to their respective assignments in ICTA, Guatemala.

Special appointments as visiting scientists were made to Mr. Guido Delgadillo, agronomist in the beef program; Mr. Dale Fisher, swine management; and Dr. Roger Sanstead, bean agronomy. The Peace Corps assigned Mr. Timothy Lawler to CIAT as a full-time instructor in English and communication.

Others leaving the staff at the termination of their special appointments were Dr. Donald Bushman, ruminant nutritionist; Dr. Albert Clawson, visiting scientist in swine; Mr. Robert Etheredge, architectural consultant; Dr. Andries Jonkers, virologist in animal health; and Dr. Amador Villacorta, entomologist.

During the year, Dr. Donald Corrier, hemoparasitologist, and Mr. David Hopps, hemoparasitologist, joined the Texas A&M University project group.

Beef production systems

CIAT's beef program operates under the assumption that the beef cattle industry will continue to have a key role in the development of the lowland tropics of Latin America. There is a large resource base, including approximately 150,000,000 head of cattle, plus extensive grassland areas, many of which are under stocked and which have limited immediate or long-term potential for cultivated crops. In addition, productivity of many of these grasslands could be greatly increased through establishment of improved pastures.

Despite the potential, there are serious biological and socio-economic constraints to increasing beef production. Low fertility and slow growth rates are the principal reasons for low productivity. Socio-economic constraints, such as deficiencies in infrastructure and regional development programs, often are serious barriers to putting production technology to work.

The CIAT Beef Production Systems Program focuses on assembling production systems and training key production personnel as part of a strategy for developing the lowland tropics and increasing beef production. Research and training programs are under way at CIAT in Palmira, the ICA Carimagua station in the Llanos Orientales, and the ICA Turipaná station located on the north coast.

Research objectives are: 1) to identify ways of providing adequate feed supplies; 2) to establish means of controlling disease and parasitism; and 3) to develop and demonstrate economical systems of production.

Dietary deficiencies of protein, energy and minerals not only are the principal causes of low reproductive performance and slow growth, but increase susceptibility to disease and parasitism. As life cycle production systems on pasture predominate, CIAT places major emphasis on providing a nutritionally adequate pasture forage throughout the year, with supplementation as necessary to correct deficiencies of the grazed forage.

In Carimagua, which is representative of extensive latosol soil regions, the productivity of molasses grass (**Melinis minutiflora**) pasture has been four to five times that of native pastures during the rainy season. However, this advantage disappears during the dry season, with weight losses that often erase a fair portion of the weight gains achieved in the previous rainy season. Interseeding of the high protein forage legume **Stylosanthes guyanensis** in grass pastures along with protein supplementation are being tested as means of curbing these weight losses and their effects on fertility. Mineral supplementation has markedly increased conception and growth rates of cattle grazing both native and molasses grass pastures.

In animal health CIAT is placing emphasis on breeding diseases, hemoprotozoan diseases and involvement of wildlife in the epidemiology of diseases affecting cattle and man.

Although malnutrition is the main cause of low calving rates, breeding diseases are often primary causes, and other diseases further aggravate the problem. CIAT surveys conducted in the Llanos have encountered significant infections of IBR (infectious bovine rhinotraccheitis), leptospirosis and brucellosis, but other breeding diseases have not been found.

In collaboration with Texas A&M University, significant advances have been made in the epidemiology, immunization, antigen sources, diagnostic methods, chemical control and treatment of two hemoprotozoan diseases, anaplasmosis and babesiosis.

Another focus of the Beef Production Systems Program is economics, with the objective of determining the implications of technical changes in beef production at the micro and macro levels. This includes studies relating to the economics of beef production systems in savanna regions, a survey of the phosphate fertilizer market, and a pilot benchmark study of the Colombian livestock sector. Benchmark studies hopefully will be extended to other Latin American countries.

CIAT conducts various training programs for production specialists. Seventeen trainees completed the second livestock production specialist training course, and the third course was initiated in September with eighteen trainees. Nine trainees received in-service training in specific disciplinary areas. Two graduate students were engaged in doctoral research and two CIAT research fellows entered graduate school. Special training was provided for thirty-three trainees.

To complement Colombia-based work, CIAT's beef program outreach activities have included visits to Latin America and other areas to identify trainees, establish professional and institutional contacts and to collaborate in research and training projects.

FEED SUPPLY

Inadequate nutrient intake is the principal reason for low reproductive performance and growth rate of beef animals and increases their susceptibility to disease. Major emphasis is placed on providing a nutritionally adequate pasture forage throughout the year, with supplementation as necessary.

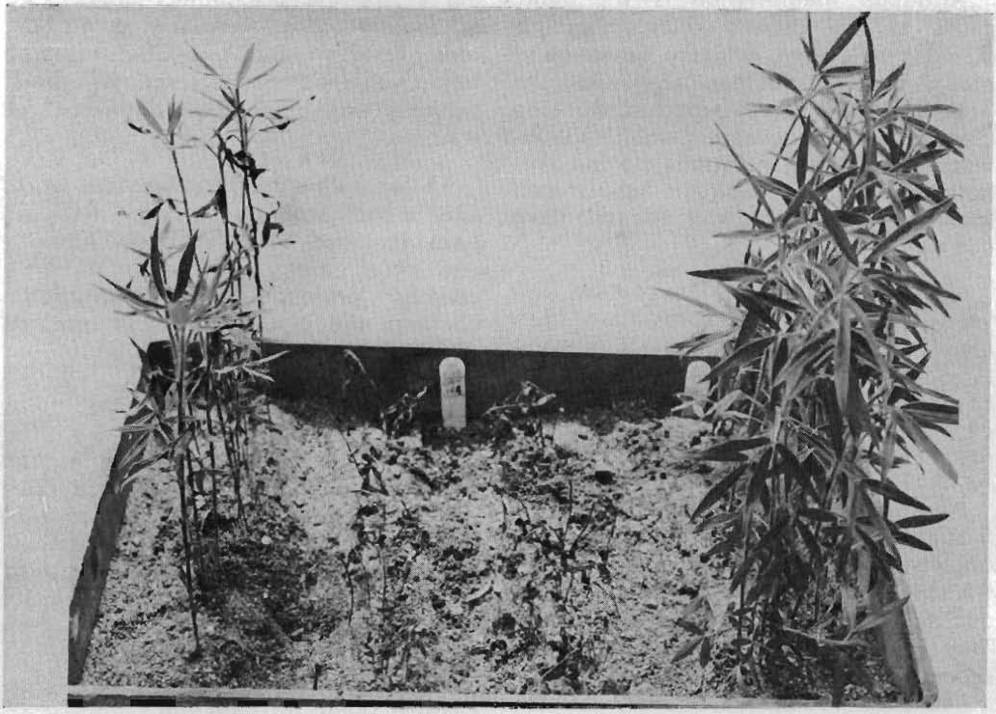
Pasture plant introduction

Some 600 accessions of tropical forage species are being evaluated, including 180 **Stylosanthes** species and ecotypes collected from lowland tropical areas of Colombia and Venezuela. Spaced plants of the new **Stylosanthes** accessions were screened in replicated nursery plots. Forage dry matter, seed yields and number of crown branches per plant showed a wide range of variation among the accessions (Tables 1, 2 and 3).

Table 1. Dry matter yield of S. guyanensis accessions

CIAT No.	Low yield (1.000 g/plant)	CIAT No.	Medium yield (1.000 g/plant)	CIAT No.	High yield (2.000 g/plant)
100	277	25	1,037	132	2,014
101	235	18 *	1,181	138	2,069
63	457	136	1,483	133	2,090
74	579	144	1,516	135	2,656
41	756	50	1,657	130	2,745
105	777	81	1,678		
68	820				

* La Libertad



Stylosanthes guyanensis **plants inoculated with anthracnose** (Colletotrichum gloeosporioides). **Left: susceptible Colombian variety; center: dead plants of IRI 1022; right: highly resistant variety from the Llanos Orientales of Colombia**

Selection for improved agronomic traits, dry matter yield, disease resistance and seed yield indicated that several lines of **S. guyanensis** possess better agronomic characteristics and anthracnose (**Colletotrichum gloeosporioides**) resistance than La Libertad used in preliminary studies.

Table 2. Number of crown branches per plant in S. guyanensis accessions

CIAT No.	Low (90 branches/plant)	CIAT No.	Medium (90-180 branches/plant)	CIAT No.	High (180 branches/plant)
126	68	133	96	74	189
100	71	151–A	98	130	198
101	77	138	106	25	205
64	78	50	117	191	212
43	74	135	120	105	250
18 *	87	136	125		
68	85	144	129		
		81	141		
		132	150		
		41	168		
		30	174		

* La Libertad

Table 3. **Seed yield of S. guyanensis accessions (Yield of dehulled seed)**

CIAT No.	Low yield (5 g/plant)	CIAT No.	Medium yield (5-15 g/plant)	CIAT No.	High yield (15 g/plant)
43	0.7	64	5.1	18 *	18.8
61	1.0	63	6.3	30	19.3
103	1.5	68	6.9	151-A	21.9
67	2.4	130	7.3	70	22.6
92	2.4	50	9.1	152	24.5
		191	9.7	144	28.9
		107	10.9		
		74	11.8		
		152-A	13.5		

* La Libertad

Of 18 varieties of **Stylosanthes guyanensis** planted in small plot experiments at Carimagua, three accessions out yielded the control, La Libertad. Also they were more resistant to anthracnose (Table 4).

In plant house tests at CIAT the four cultivars of stylo, which are available on the international market, were susceptible to anthracnose in this declining order: IRI 1022, Endeavour, Schofield and Cook. Anthracnose resistant plants were isolated from **S. guyanensis, S. hamata, S. humilis** and **S. subsericea.**

Table 4. **Establishment yield of** Stylosanthes guyanensis **varieties at Carimagua (July to December, 1973)**

CIAT No.	Yield (green) kg/ha
50	4,630
16	3,860
21	2,830
18 *	1,520
46	1,290
44	500

* La Libertad

Results indicate that rapid progress can be made in developing anthracnose resistant stylo cultivars by screening a large number of ecotypes of this normally self-pollinated, indigenous tropical forage legume.

Seed as well as forage yields of several **Desmodium** spp. are reduced by insect attack. A Colombian selection of **Desmodium** sp., probably a natural hybrid of **D. intortum** and **D. uncinatum,** displayed strong resistance to leaf-eating insects.

The forage plant potential of **Indigofera hirsuta** recently introduced from the Llanos of Venezuela is being investigated. This legume has desirable forage attributes such as rapid seedling establishment and early vigor. In the year of establishment it out yielded seven varieties of stylo but recovery was slow after cutting (Table 5). It is a heavy seed producer and the pods do not shatter.

Siratro, the commercial cultivar of **Macroptilium atropurpureum,** is severely affected by rhizoctonia (**R. solani**) and bean rust (**Uromyces phaseoli**) in high rainfall areas. This limits its use in the humid tropics. An indigenous ecotype

Table 5. **Establishment yield of stylo varieties and Indogofera hirsuta**

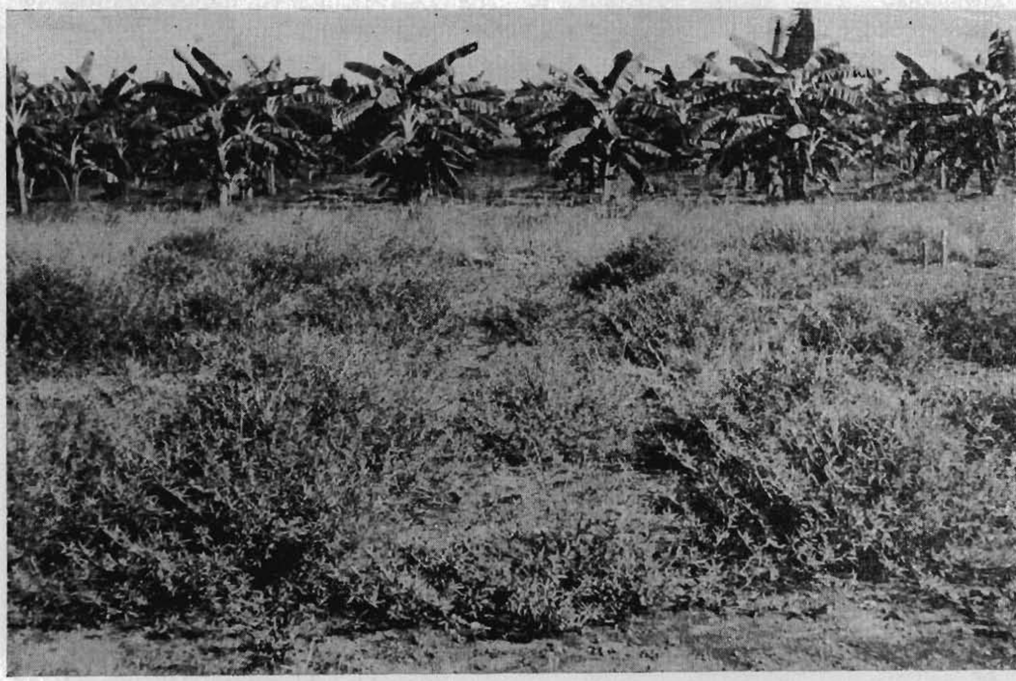
CIAT No.	Variety, origin	Yield, dry kg/ha	Crude protein %
700	*Indigofera hirsuta*, Venezuela	16,125	13.0
21	Santander, Colombia	9,108	13.6
18	La Libertad, Colombia	8,834	12.9
50	Castilla Nueva, Colombia	8,636	14.7
144	IRI 1022, Brazil	8,416	12.5
16	CPI 34,000,Costa Rica	7,578	13.8
41	David 217, Panama	7,226	14.5
45	Pance 2, Colombia	6,459	13.5

from the Caribbean coast was found highly resistant to both diseases. Seed production was initiated of this accession plus several other varieties from Colombia and Venezuela.

Soil microbiology

Strain selection and testing

Strain isolation and testing were continued with 254 strains of **Rhizobia**



Influence of inoculation growth of Stylosanthes guyanensis **var. La Libertad, at Carimagua Experiment Station. Plants in the center were not inoculated; others were inoculated with different Rhizobium strains** (Photo: P. H. Graham)

Table 6. Strain selection trials for pasture legumes, 1972 - 1973

Plant species	How tested	Strains tested	Dry weight/plant (grams) Average	Dry weight/plant (grams) Selected strains	Strains selected by CIAT
M. sativa var. Deputi	Pots	3	1.07	2.63	44
P. atropurpureus	Tubes	68	0.04	0.05	79, 111, 181, 188, 202, 230, 246, 265, 266, 270
D. uncinatum	Tubes	30	0.02	0.03	293, 282, 301, 303
S. guyanensis	Field trial, Leonard jars, Tubes	116	—	—	79, 111, 308, 315, 278, 292
C. pubescens	Leonard jars, Tubes	22	0.75	1.73	48, 193, 223, 225, 227, 243, 325
T. repens	Field trial, Tubes, Leonard jars	15	—	—	61, 62, 67, 70

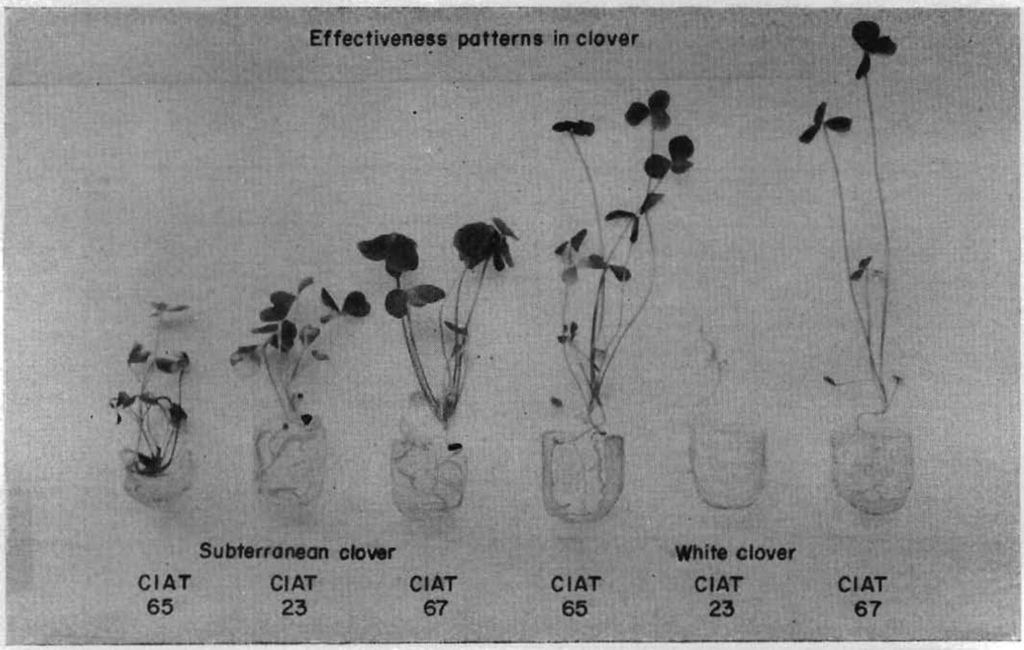
being examined for nodulation and nitrogen fixing ability. Strains selected from initial screenings were subsequently included in field evaluation (photo page 14) with promising cultures for the major pasture species being selected as shown in Table 6.

Several donor agencies and international bodies asked the microbiology group to develop germplasm capability for tropical pasture rhizobia. As a consequence, strain isolation, testing and distribution will be accelerated in 1974.

During strain testing a number of varietal strain interactions become evident, especially in **Stylosanthes** and **Trifolium** species. Differences in the response of white and subterranean clover to three inoculant strains are shown in photograph on page 16.

Organic carrier media for inoculants

During 1972 inoculants produced at CIAT were prepared in Sibundoy peat, in bagazo, or in mixtures of the two (see CIAT Annual Report, 1972). While excellent survival was obtained up to four weeks at 28°C, further studies showed rapid loss of viability in inoculants exposed to 37°C. Because of this, additional peat deposits were investigated and tested, and one, from the Rio Negro district of Antioquia, was selected as most suitable for inoculant usage. With this material, **Rhizobium** survival is excellent for up to 13 weeks at 28°C storage temperature (Figure 1). At 37°C survival of all strains was better than in Sibundoy peat with the strains CIAT 79 and CIAT 44 (for **Stylosanthes** and **Medicago,** respectively) surviving



Strain effectiveness differences in Subterranean and White clovers as influenced by the inoculant strain used (Photo: P. H. Graham)

better than does the clover organism CIAT 61. This is evident in Figure 2.

Pelleting of leguminous seed

Initial studies on pelleting of pasture legumes to improve nodulation were detailed in CIAT 1972 Annual Report. These studies were extended into four areas in 1973.

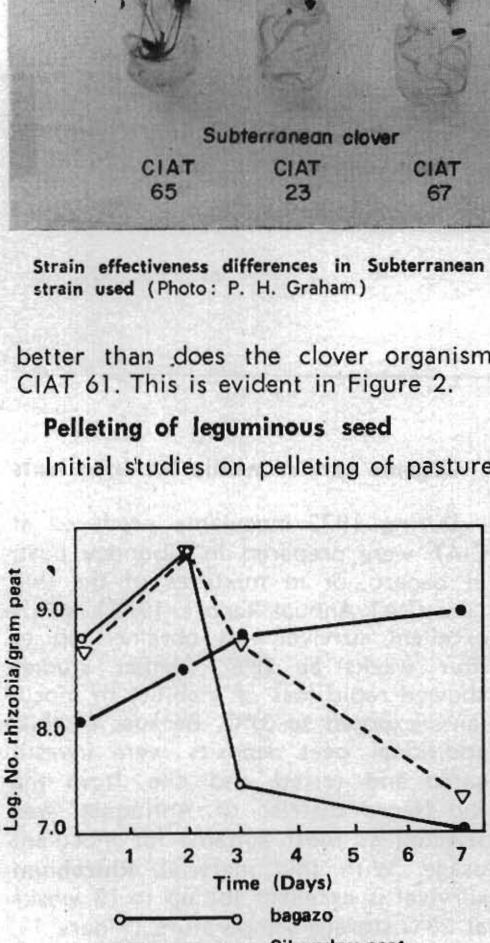


Figure 1. **Survival of** R. trifolii **strain CIAT 61 in three inoculant carriers at 28° C**

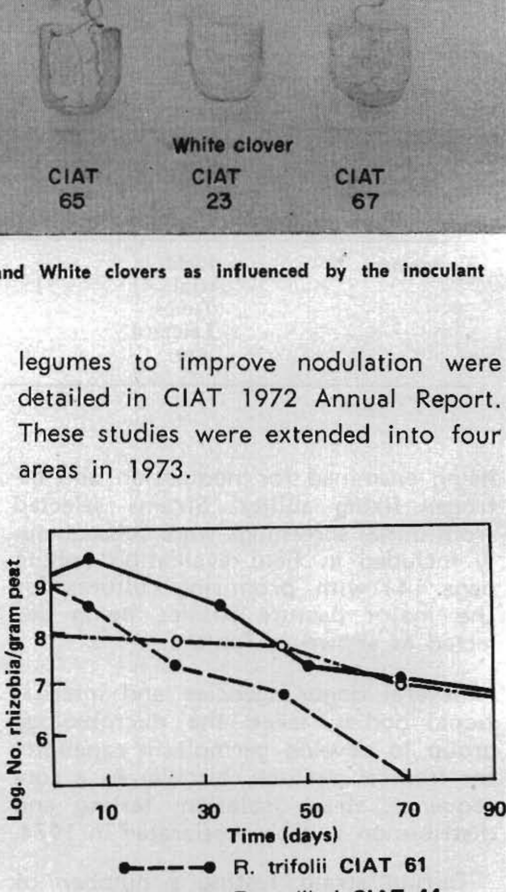


Figure 2. **Survival of three** Rhizobium **strains in peat from Río Negro, at 37° C.**

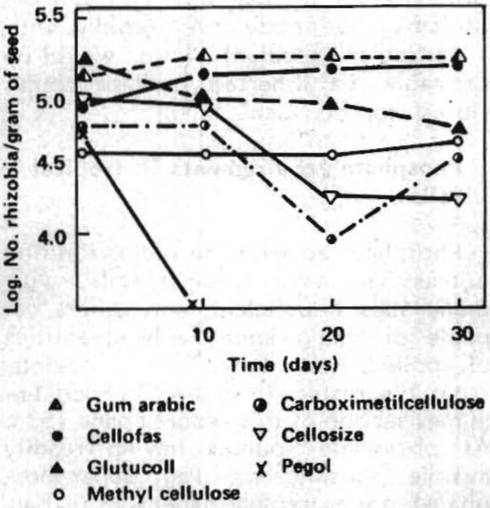


Figure 3. **Survival of** Rhizobium trifolii **CIAT 61 with $CaCO_3$ –covered seed, using different "sticker" substances**

Gum arabic and methyl ethyl cellulose are the most common "stickers" used in pelleting leguminous seeds. Unfortunately, these substances are either not available in many Latin American countries, or else are expensive and of variable quality. Locally available stickers were examined for their ability to support **Rhizobium** survival on the seed. The results are shown in Figure 3, with Glutocoll (hydroxymethyl-cellulose) being an apparently suitable and inexpensive alternative to gum arabic.

Investigation of rock phosphate deposits from the Huila and Boyacá regions in Colombia showed that these could be used in pelleting tropical pasture legumes.

As the extreme acidity encountered in many areas of the lowland tropics could influence Mo availability, the effect of incorporating various molybdenum salts into the pelleting material was investigated. While both sodium and ammonium molybdate proved detrimental to **Rhizobium** survival on **Stylosanthes guyanensis** seed, molybdic oxide applied at a rate of 50-100 grams/6 kg of seed did not influence survival (Figure 4).

Seed pelleting studies were repeated under field conditions. With **Stylosanthes guyanensis** (La Libertad) inoculation and rock phosphate pelleting again gave best nodulation responses and dry matter yields (Figure 5). Simple seed inoculation improved plant growth more than the use of lime-pelleted seed. Experiments are in progress to determine whether **Rhizobium** multiplication in the rhizosphere is the limiting factor in lime-pelleted seed.

Strain variety interaction in Stylosanthes cultivars

Because inoculant strains in soil can encounter highly acid conditions, and/or competition from native strains, studies were undertaken on some of the characteristics of nodulation in four **Stylosanthes** cultivars. Table 7 shows the time to first nodule formation when the four cultivars were tested against six promising inoculant strains. Strain

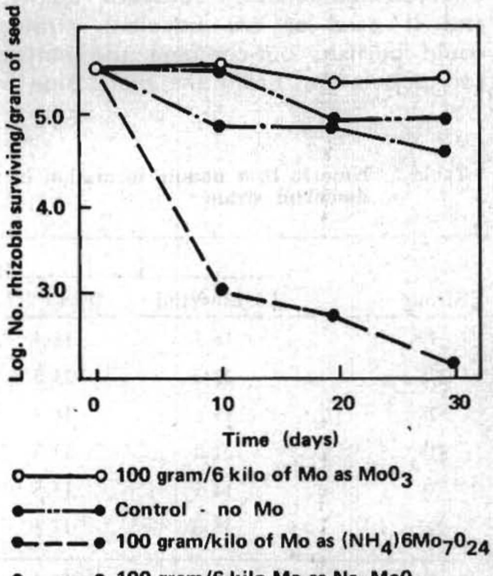


Figure 4. **Influence of form of molybdenum used on survival of** Rhizobium **in molybdenum-treated seeds of** Stylosanthes guyanensis.

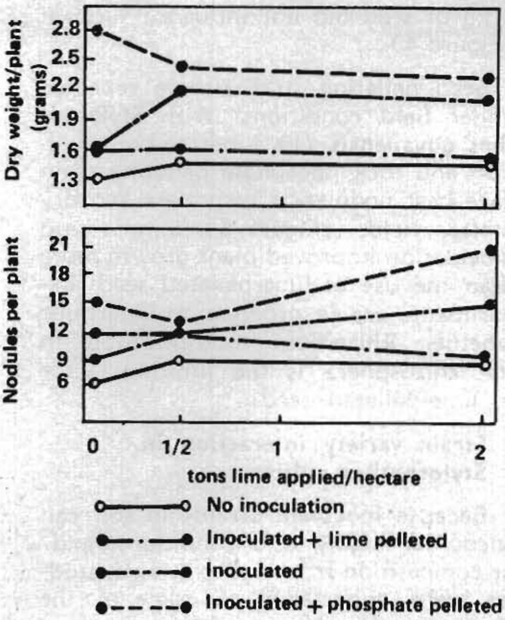


Figure 5. **Response of** *Stylosanthes guyanensis* **var. La Libertad to inoculation, pelleting and lime amendment at Carimagua.**

CIAT 56 nodulated all cultivars rapidly, and if used as an inoculant strain, could perhaps out-compete the native soil population. From the plant side a cultivar slow to nodulate with soil organisms, but nodulating rapidly with a particular inoculant strain, would be desirable. La Libertad perhaps comes closest to this ideal.

Phosphate requirements in tropical soils

Phosphate appears the major limiting nutrient in most tropical soils, with many soils P deficient, and others capable of fixing appreciable quantities of applied P fertilizer. This is obvious from the results in Figure 1, Food Legumes section of this report (page 153). As phosphate sources having readily avaible phosphorous (eg. superphosphate) are extremely expensive in Latin America, studies have been initiated on the vesicular-arbuscular fungus **Endogone,** and on its ability to influence phosphorous availability. In preliminary studies at Carimagua, spore counts from soil were consistently low. Spores recovered by wet sieving plant root systems have been used as inoculants in glasshouse experiments with P-limited soils, growth increases being obtained with both siratro (**Micropticulum atropurpureum**) and cassava.

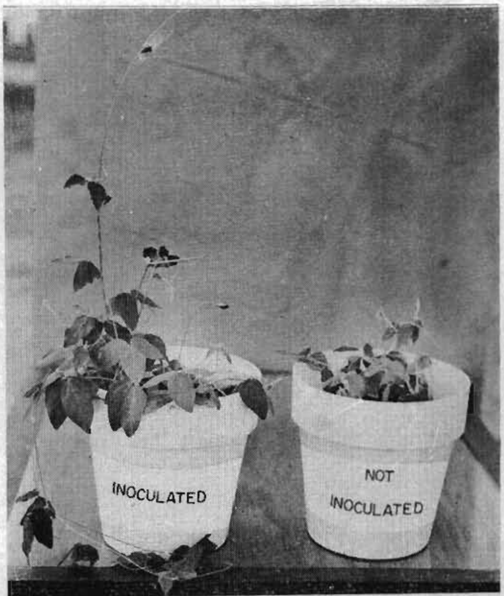
Table 7. **Time to first nodule formation in four varieties of** *Stylosanthes* **as influenced by inoculant strain** *

	Variety				
Strain	La Libertad	David 217	Subsericea	Hamata	Strain means
79	18.3	18.4	14.2	13.6	16.1
278	22.2	23.5	12.4	14.8	18.2
28	19.6	18.3	14.7	17.3	17.4
315	21.0	17.5	18.2	13.2	17.4
56	14.5	13.5	12.9	16.0	14.2
297	15.0	17.6	15.0	16.3	16.2
Variety mean	18.4	18.1	14.73	15.2	

* Mean of 15 replications

F (strains = 19.78 xxx F (varieties) = 42.80 xxx

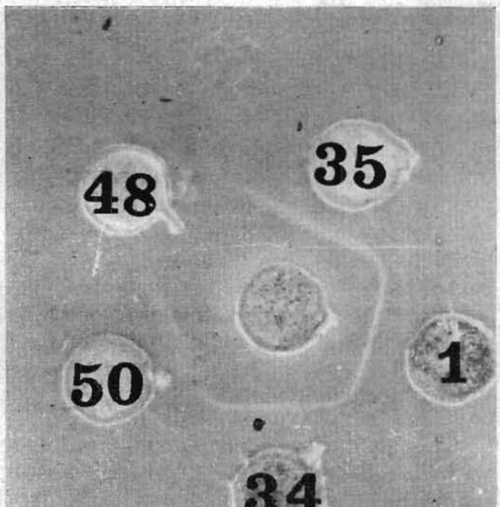
F (strans x varieties) = 1.14, n.s.



Response of siratro (Micropticulum atropurpureum) **to inoculation with strain of Endogene** (Photo: P. H. Graham)

Serology

Cultures of **Colletotrichum** sp. isolated from anthracnose lesions in **Stylosanthes** species have been typed serologically. At least one antigen was common to all the isolates tested, but additional and distinguishing antigens were found among the six strains tested. The strain 48 of **Colletotrichum,** most virulent of the anthracnose strains so far tested, was readily identifiable by its serological reactions.



Serological reactions of Colletotrichum **isolates from** Stylosanthes, **showing non identity of isolate 48** (Photo: P. H. Graham)

Forage plant improvement and breeding

Nine thousand F_5 hybrid derivatives of the cross **Centrosema brasilianum** x **C. virginianum** were evaluated as spaced plants. High yielding lines, not affected by segregation, were selected with a view to their commercial production. Selected F_5's of the hybrid out yielded indigenous varieties of **C. pubescens** from Ecuador and Colombia (Table 8). The high potential of the hybrid as a forage cultivar for low latitudes in tropical America was demonstrated.

Self and cross fertility determinations were conducted in **Brachiaria ruziziensis.** This species proved to be

Table 8. Dry matter yields of centrosema hybrids

F_5 Hybrid lines	Dry matter yield/plant, g (means of 20 plants per plot)
17-45	122.9
8-16	116.3
10-32	108.3
17-33	101.6
17-8	99.2
17-7	91.7
17-87	83.3
10-37	81.2
17-18	76.3
Control I *C. pubescens* (Colombia)	60.5
Control II *C. pubescens* (Ecuador)	55.0

Means connected by a single line are not different at the 1 per cent level of significance

Progeny test plots of Centrosema hybrids (F_5) at Palmira

highly cross fertilized, and it was successfully hybridized with **Brachiaria decumbens.**

Seed production

Field scale seed production of **S. guyanensis** (La Libertad) and **Paspalum plicatulum** was carried out. Seed increase of several species and ecotypes of **Stylosanthes, Desmodium** and **Indigofera hirsuta** is in progress.

A total of 813 kg, equivalent to 116 kg/ha of recleaned seed of native **Paspalum plicatulum,** was harvested at CIAT. The seed of this grass has a rather short period of dormancy and seed stored for six months gave high germination. Germination of fresh seed was substantially increased by acid scarification.

The 3.5 ha seed increase plot of La Libertad stylo yielded 166 kg or 47 kg/ha of recleaned seed.

Pasture establishment and maintenance

A number of greenhouse and field trials were conducted or initiated in an integrated program to develop efficient, low-cost means of establishing and maintaining tropical pasture species on allic soils. Research focuses on the determination of macro-and micronutrient and lime requirements for establishment and maintenance of legumes and grasses and on seedbed preparation and seeding methods.

Macronutrients

A greenhouse trial was conducted with La Libertad stylo grown in soil from the surface horizon of an oxisol at Carimagua in which nutrient levels of Ca + Mg, P, K and S were varied in a San Cristóbal (central composite) design. Calcium and magnesium were treated as one variable, maintaining a Ca:Mg ratio of 10:1.

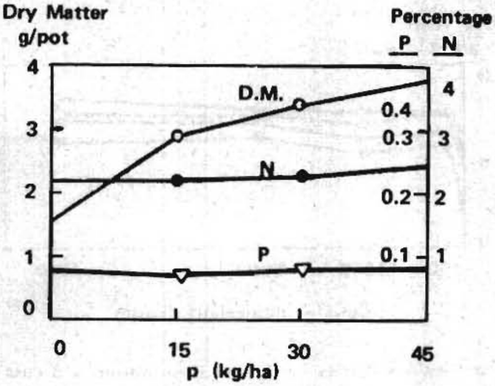


Figure 6. **Effect of phosphorus on dry matter production and forage content of nitrogen and phosphorus of** Stylosanthes guyanensis **var. La Libertad grown in a Carimagua oxisol. Results of first cutting.**

In the first cut, the only significant differences were those resulting from increasing P levels. There was an apparent response to the first level of Ca + Mg; (150 Kg $CaCO_3$ equivalent). The response to P is shown in Figure 6 along with P and N content of the forage. Forage levels of P remain low while dry matter production increases markedly with increasing P levels to 45 kg P/ha. It appears that grazing animals could be much more efficiently supplemented orally with P than through the forage if this response pattern is

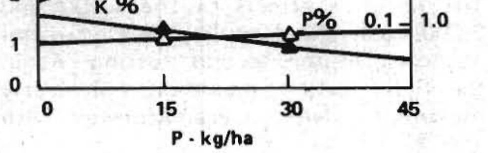


Figure 7. **Effect of phosphorus on dry matter production and forage content of nitrogen and phosphorus of** Stylosanthes guyanensis **var. La Libertad. Results of second cutting, including also potassium content**.

valid for field conditions. The results of the second cutting are shown in Figure 7. Forage content of potassium is included to indicate the dilution effect on K content, which drops below levels commonly considered critical for **Stylosanthes humilis.**

The same Ca + Mg x P x K x S experiment was initiated in the field at Carimagua with **Stylosanthes guyanensis** (La Libertad), **Centrosema pubescens, Desmodium intortum, Calopogonium muconoides, Hyperrhenia rufa, Melinis minutiflora, Paspalum plicatulum** and **Brachiaria decumbens.** In the one harvest to date, responses to P and Ca + Mg are similar to those observed in the greenhouse trial. In addition, there is an apparent response to sulphur.

A trial has just been initiated to study rates of P and methods of application, with the objective of improving fertilizer efficiency and reducing weed competition. Band placement should reduce weed problems at Carimagua where P applications have greatly stimulated weed competition in newly seeded pastures. The response of weeds to P which was broadcast is shown in Figure 8.

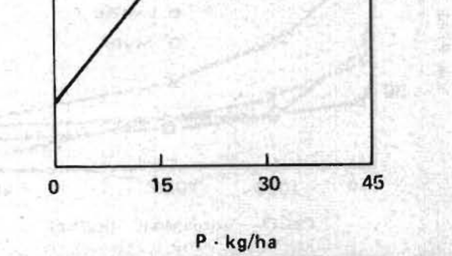


Figure 8. **Response of weeds to phosphorus in a pasture trial at Carimagua. Weed weights were taken at time of first harvest.**

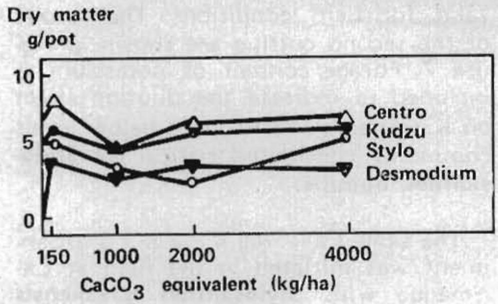


Figure 9. Effect of lime on dry matter production of four legumes grown in a Carimagua oxisol. First cutting

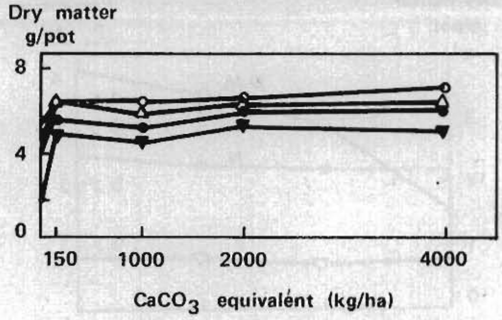


Figure 11. Effect of lime on dry matter production of four legumes in a Carimagua soil. Average of two and three cuts, as indicated

Micronutrients

A greenhouse trial similar to the macronutrient trial was conducted with Ca + Mg, B, Cu and Mo as variables. There were no significant nor apparent differences among treatments.

Lime

A series of greenhouse experiments was conducted to determine optimum levels of lime for four legumes and three grasses. Figure 9 shows the results of the first cut for the four legumes. Maximum yield was achieved for all four at 150 kg lime/ha. The shape of the curves is most unusual, probably reflecting various functions of lime. The first response is likely a nutrient response to Ca and/or Mg. The effects of lime treatments on the Mn and Zn content of the forage are shown in Figure 10. The effect of 150 kg equivalent of $CaCO_3$ on Zn and Mn is large. The depression in yield at 1,000 and in some cases 2,000 kg/ha is similar to results obtained on the same soil with cassava in 1972. The high yields at 4,000 kg/ha are difficult to explain.

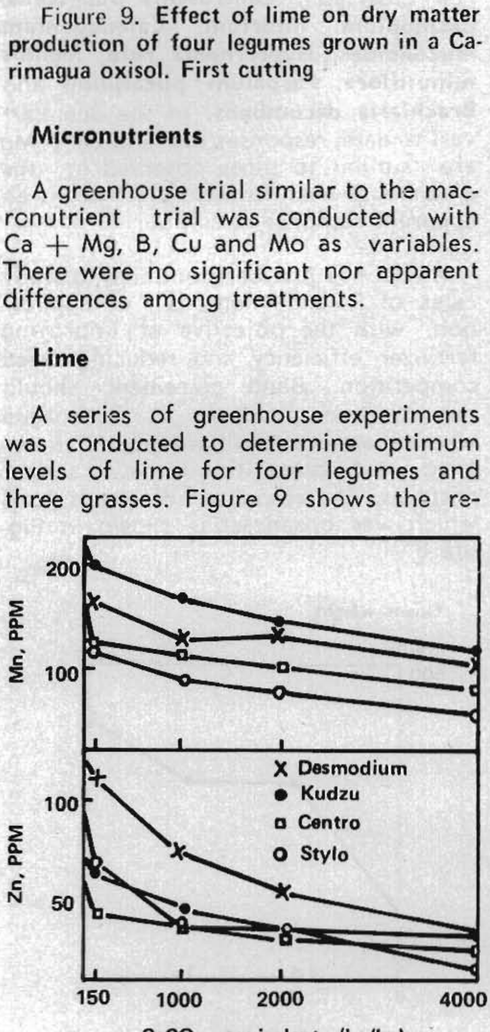


Fig. 10. Effect of lime on forage composition of four legumes grown in an oxisol from Carimagua. First cutting.

Figure 11 shows the effect of lime on dry matter yield of the four legumes averaged for the first three cuttings. The negative effects of the 1,000 and 2,000 kg/ha lime applications were not observed in the second cutting. As in the first cutting, maximum, or nearly maximum yields, were achieved with 150 kg/ha.

Response curves for grasses are quite different from those observed for legumes for the first cutting but quite similar for the subsequent cuttings (Figures 12 and 13).

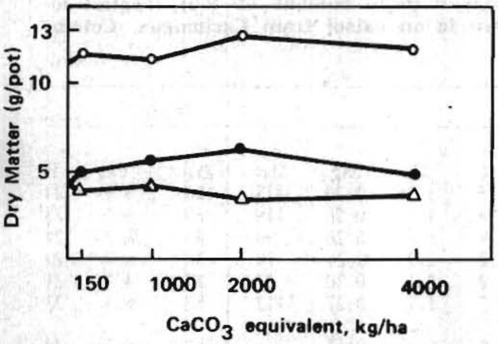


Figure 12. **Effect of lime on dry matter production of three grasses grown in a Carimagua oxisol. First cutting.**

It appears that lime is required primarily as a source of Ca and/or Mg for the tropical forages included in these trials with a very acid, highly aluminum-saturated oxisol. Many trials reported in the literature use one ton of lime as a first increment. It may be that the most beneficial range of lime applications has often been completely by-passed. In practice, sufficient calcium as nutrient may well be applied in the form of phosphate fertilizer. In

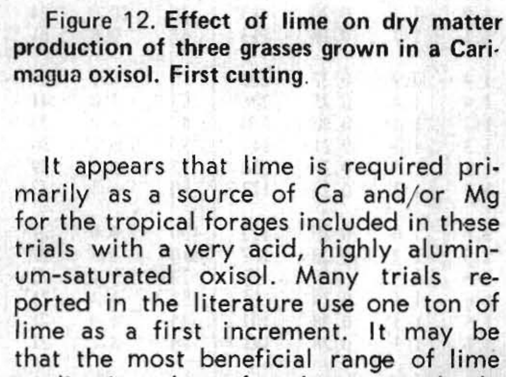


Figure 13. **Effect of lime on dry matter production of three grasses in a Carimagua soil. Average of two and three cuts, as indicated.**

all trials involving low levels of lime or calcium, a non calcium source of P has been used.

The effect of liming on the chemical composition of four legumes and three grasses is shown in Table 9. It is clear that the effect is less pronounced with the grasses than with the legumes included in these trials.

Seedbed preparation and methods of seeding

Most seeding has followed disking two or three times with an offset disc. This essentially destroys the native grasses and leaves a loose, rough seed bed 10-15 cm deep. The traditional way of seeding the very small seeded grasses such as molasses grass and yaragua (**H. rufa**) is to wait until several hard rains have fallen and then broadcast the seed by shaking it from loosely woven jute bags. If rains are frequent enough, stands are usually satisfactory. However, if there is a brief dry period just after the seed germinates, stands are usually poor, excepting in wheel tracks, indicating the need for firming the seedbed at planting to assure capillary flow of soil water from below to the seed at the surface.

A packer, using old tires, was built in 1972. Seedings have generally been successful when this packer has been used. It also favors germination of many weeds which are especially bad if P has been applied. Band seeding plus band application of fertilizer and firming of the seed row with a press wheel, leaving the rest of the surface loose and rough will likely maximize pasture germination and survival and minimize weed competition. Trials are presently under way to test a number of seeding methods.

A trial was initiated early in 1973 to test the feasibility of spontaneous seeding using natural agents for seed dispersal (wind, water, bird) from nar-

Table 9. The effect of lime applications on forage nutrient content of four tropical legumes and three tropical grasses, grown in an oxisol from Carimagua, Colombia, first harvest

Species	Lime level	(%) N	P	K	Ca	Mg	(ppm) Mn	Zn	Cu	B
Stylosanthes guyanensis La Libertad	0	2.6	0.13	1.5	1.2	0.29	213	103	5.0	24
	150	2.3	0.16	1.8	1.5	0.26	119	65	6.0	28
	1000	2.6	0.14	1.9	1.6	0.26	90	38	7.3	24
	2000	3.3	0.19	2.2	1.9	0.24	79	38	8.7	20
	4000	2.4	0.13	1.3	2.1	0.30	57	17	4.7	21
	x	2.6	0.15	1.7	1.7	0.27	112	52	6.3	23
Centrosema pubescens	0	2.3	0.12	1.0	0.8	0.17	136	63	5.7	16
	150	1.4	0.16	1.1	1.1	0.17	126	43	9.8	20
	1000	2.0	0.19	1.2	1.2	0.18	115	39	10.7	22
	2000	1.8	0.16	1.1	1.3	0.18	104	32	10.7	23
	4000	2.0	0.15	1.0	1.4	0.20	83	26	10.9	24
	x	1.9	0.15	1.1	1.2	0.18	113	41	9.6	21
Pueraria phaseoloides	0	2.6	0.16	1.4	0.9	0.22	222	70	6.7	33
	150	1.9	0.20	1.4	1.4	0.25	201	63	7.0	41
	1000	1.8	0.15	1.3	1.4	0.20	170	47	6.0	33
	2000	2.6	0.14	1.3	1.3	0.21	147	37	6.7	30
	4000	2.0	0.13	1.1	1.5	0.29	120	32	6.0	29
	x	2.2	0.15	1.3	1.3	0.23	172	50	6.5	33
Desmodium intortum	0	3.3	0.20	2.0	1.0	0.29	172	120	4.0	21
	150	2.2	0.14	1.3	1.3	0.28	167	110	3.3	22
	1000	2.6	0.15	1.6	1.3	0.29	127	72	3.7	21
	2000	2.5	0.16	1.6	1.4	0.26	134	52	3.3	21
	4000	2.7	0.17	1.5	1.5	0.28	107	35	4.0	21
	x	2.7	0.16	1.6	1.3	0.28	141	78	3.7	21
Hyperrhenia rufa	0	1.8	0.09	1.0	0.4	0.29	166	35	7.1	16
	150	1.8	0.10	1.4	0.4	0.19	115	28	7.6	14
	1000	1.5	0.08	1.3	0.5	0.24	136	23	6.6	16
	2000	1.9	0.10	1.4	0.6	0.21	126	21	8.0	12
	4000	2.1	0.10	1.1	0.6	0.22	114	19	8.0	11
	x	1.8	0.09	1.2	0.5	0.23	131	25	7.5	14
Melinis minutiflora (leaves only)	0	1.1	0.07	0.6	0.3	0.27	110	73	8.0	7
	150	0.9	0.07	0.7	0.3	0.30	108	58	6.9	7
	1000	1.0	0.07	0.6	0.3	0.34	113	49	6.7	7
	2000	1.0	0.07	0.7	0.3	0.33	97	47	6.0	7
	4000	1.0	0.07	0.6	0.4	0.45	106	48	5.0	8
	x	1.0	0.07	0.6	0.3	0.34	107	55	6.5	7
Brachiaria mutica	0	0.9	0.08	0.5	0.1	0.07	31	41	10.7	5
	150	0.7	0.08	0.4	0.2	0.08	33	44	10.0	5
	1000	0.7	0.08	0.5	0.2	0.11	42	38	9.3	5
	2000	0.7	0.09	0.6	0.2	0.12	44	34	9.3	2
	4000	0.8	0.08	0.5	0.3	0.15	34	35	10.7	5
	x	0.8	0.08	0.5	0.2	0.10	37	38	10.0	4

row-seeded strips with relatively wide intervening strips. Variables include land preparation and fertilization of the non seeded strips, and species (**Stylosanthes humilis, Hyperrhenia rufa** and **Paspalum plicatulum**). Spontaneous seeding will take place in late 1973 and early 1974 and population counts will be made with the beginning of the 1974 wet season in April.

WEED CONTROL

Pasture weed control research continued to seek solutions for the more serious problem species, including the undesirable grassy weed **Paspalum fasciculatum** (bullgrass) and several hard-to-kill brushy species.

Biological studies of bullgrass showed that its stolons can germinate from a depth of 10 cm below the surface but not from 15 or 20 cm in clay, sandy clay or sandy loam soils (Table 10). More shoots were produced and consequently there was greater aerial production in the clay or sandy clay soil than in the sandy loam, indicating a preference for heavier soil types.

Inflorescences were collected from various locations, and seed counts revealed that each one produces an average of 1,500 seeds. This, together with the high number of stolons produced, gives bullgrass an extremely high reproductive potential.

Bullgrass can be controlled with either dalapon or glyphosate (Figures 14 and 15) in both the dry and rainy seasons. The maximum effect of dalapon was obtained 90 days after in the rainy season. Control was more persistent in the dry than in the rainy season.

Glyphosate at two kg/ha in the dry season and one kg/ha in the rainy season gave excellent bullgrass control 60 days after application. As was observed for dalapon, the duration of control from glyphosate was also greater in the dry than in the rainy season. Thus, a desirable pasture grass should be

Table 10. **Effect of depth of stolon placement and soil type on days to emergence, shoot number, and fresh weight 60 days after planting**

Soil type	Depth of planting (cm)	Days to emergence*	Shoot: Number**	Shoot: Fr. wt*** (g)
Sandy loam	1	7	18	45
Sandy loam	5	12	11	36
Sandy loam	10	10	6	11
Sandy loam	15	—	—	—
Sandy loam	20	—	—	—
Sandy clay	1	7	48	107
Sandy clay	5	7	21	86
Sandy clay	10	19	6	21
Sandy clay	15	—	—	—
Sandy clay	20	—	—	—
Clay	1	10	33	88
Clay	5	9	11	60
Clay	10	21	6	26
Clay	15	—	—	—
Clay	20	—	—	—

* LSD (.05) for days to emergence = 6
** LSD (.05) for shoot number = 5
*** LSD (.05) for shoot fresh weight = 24

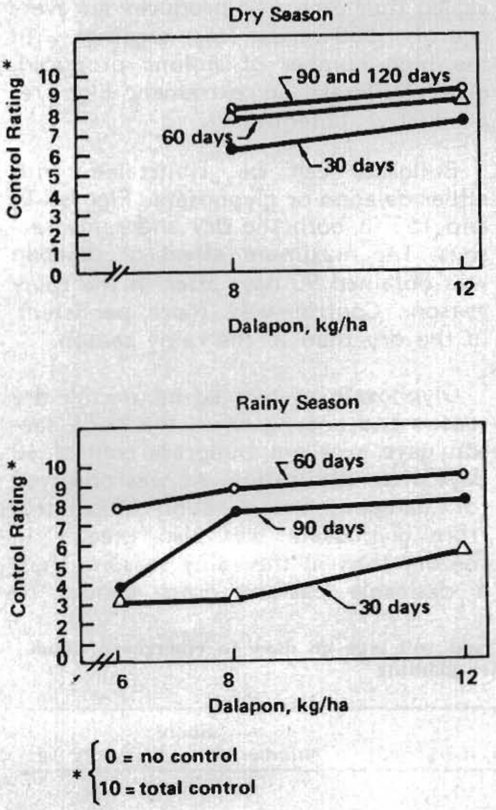


Figure 14. **Comparison of the effectiveness of dalapon to control bullgrass in the dry and rainy seasons.**

planted 40 to 60 days after applications made during the rainy season or at the initiation of the rainy season if herbicides were applied in the dry season.

Large demonstration plots were freed of bullgrass either by the use of herbicides alone or in combination with mechanical soil preparation. Pará grass (**Brachiaria mutica**) was vegetatively established by sprigging stem cuttings at 25 x 25 cm spacing 40 days after applying 10 kg/ha dalapon in a split application or 1.5 kg/ha glyphosate.

Dalapon and glyphosate reduced the bullgrass stand 83 and 96 per cent, respectively, in comparison to mechanical preparation without herbicides.

To determine if dalapon residues could affect the establishment of pasture species after controlling bullgrass or other grassy weeds, high rates were applied and Pará grass and **Hyparrhenia rufa** were to be planted 0, 10, 20, and 30 days later. Pará was seeded vegetatively while **Hyparrhenia** was established with seeds. The 20- and 30- day plantings were not necessary since no injury was observed in the Pará or **Hyparrhenia** planted immediately or 10 days after applying up to 40 kg/ha dalapon.

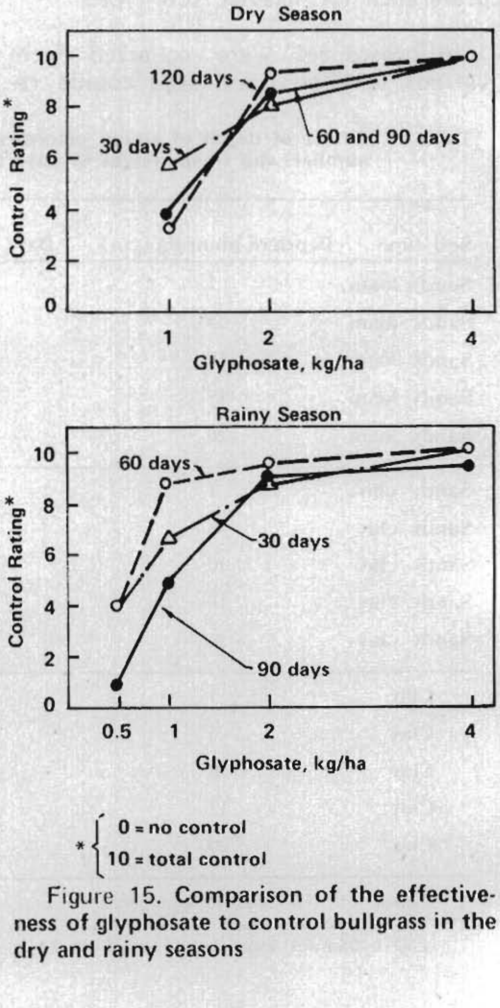


Figure 15. **Comparison of the effectiveness of glyphosate to control bullgrass in the dry and rainy seasons**

The high soil temperature and moisture of the region evidently result in a rapid degradation of dalapon in the soil, and there seems to be no residue problem which would affect pasture establishment.

Control measures for three problematic brush weeds were investigated. "Bálsamo", "Cerecillo" (species which have not been identified since they have never been found with flowers) and "Martín Moreno" (**Tetracera** sp.) abound on many ranches. Six brush herbicides were tested in various rates and combinations as foliar sprays. Control ratings were taken at 30-day intervals for five months after application. Bálsamo 1.5 m tall was completely defoliated within 15 days by all treatments. However, regrowth was occurring at 30 days. Tordon 101 in one per cent solution (picloram + 2,4-D amine) gave complete kill as did Tordon 225 (picloram + 2, 4, 5-T) at the same rate. Combination of 2,4-D with 2,4,5-T or dicamba was not effective.

Martín Moreno was also defoliated by all treatments 30 days after application. A two per cent solution of 2,4,5-T and a three-way combination of picloram + 2,4-D + 2,4,5-T killed one third of the treated shrubs. Cut stump treatments are difficult to do with this species as it produces a high number of trailing, weak stems, and higher rates or repeated applications may be necessary.

Cerecillo has a waxy leaf and was the most resistant of all species tested. Only Tordon 225 in a two per cent solution gave complete kill.

The brush species **Bactris minor** (lata) and **Chomelia spinosa** (fruta de pavo) are resistant to foliar herbicide application and cannot be easily controlled by mechanical means. Various herbicides were applied as cut stump treatments mixed in diesel fuel.

Lata was effectively killed by treating 15 to 20 cm of the cut stump with diesel fuel alone. Fruta de pavo was killed when one per cent (v/v) 2,4-D + 2,4, 5-T + 2,4-DP was mixed with diesel fuel and by four per cent 2,4,5-T; picloram + 2,4,5-T (Tordon 472); or 2,4-D + 2,4,5-T in diesel fuel.

The establishment of grass-legume mixtures in pastures often requires land preparation which allows weeds to germinate and compete with legume and grass seedlings. To find effective and selective herbicides to use during legume establishment, several products were applied after legumes had been seeded.

Linuron, chloramben, diuron, alachlor, and DNBP were applied at a single rate. Results indicate that single products are insufficient to give acceptable control and selectivity. Linuron and diuron at one kg/ha were toxic while giving fair weed control. The use of mixtures and further herbicide screening is indicated.

Herbariums of the common pasture weeds were started in both Cali and Montería. At present 56 species have been collected and mounted and more are being collected. They will be used to teach weed identification to trainees and to identify specimens sent in by ranchers, veterinarians, extensionists, and others.

A weed identification manual was completed and is now in press at ICA. It's 117 black and white pictures and descriptive texts will aid in the field identification of the common weed species in tropical pastures.

Pastures and Forages utilization

During 1973, work continued in the three ecological areas, allic soil areas, degraded alluvial soils and alluvial valleys of high fertility.

CIAT headquarters at Palmira

The two grazing trials established in 1971 to measure the beef production

Pangola grass is capable of producing more than one ton of beef weight gain per hectare, in one year, with nitrogen fertilizer, irrigation and adequate pasture rotation. This is a general view of a grazing trial at Palmira, in which intensive fattening of steers on Pangola grass is studied

potential of Pangola grass (**Digitaria decumbens**(and Pará grass (**Brachiaria mutica**) under nitrogen fertilization were continued.

In the Pangola grass trial, treatments include four levels of nitrogen (urea) fertilization, each with three stocking rates. The animals are rotationally grazed in six paddocks on a 30-day total rotation cycle. Figure 16 and Table 11 present the results obtained in 1972-1973.

Beef production per hectare appears to increase up to 500 kg of N/ha with no further increase at the highest level of nitrogen. As expected, the effect of stocking rate at every level of N was quadratic.

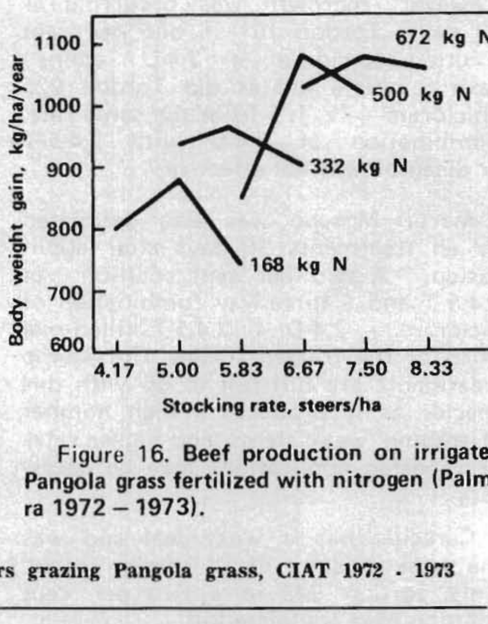


Figure 16. **Beef production on irrigated Pangola grass fertilized with nitrogen (Palmira 1972 – 1973).**

Table 11. **Average daily weight gain of steers grazing Pangola grass, CIAT 1972 - 1973**

Level of nitrogen kg/ha/year	Stocking rate, steers/ha					
	4.17	5.00	5.83	6.67	7.50	8.33
	g/day					
168	526	483	346			
332		517	456	365		
500			398	445	372	
672				425	395	348

Table 12. Increase in annual weight gain per kg of additional nitrogen applied to Pangola grass *

Level of nitrogen kg/ha/year	Stocking rate, steers/ha					
	4.17	5.00	5.83	6.67	7.50	8.33
	kg of gain/kg N applied					
168	3.0	3.5	2.4			
332		1.8	1.9	1.7		
500			1.0	1.5	1.4	
672				1.0	1.1	1.1

* Base of comparison is non-fertilized Pangola carrying two steers with average body weight gain of 450 g/day (330 kg/ha/year)

Table 12 presents the calculated utilization efficiency factors for the production of beef per kg of N applied/year and with irrigation. A weight gain of 330 kg/ha/year was estimated to be the productivity of unfertilized unirrigated Pangola grass, equivalent to two steers gaining 450 g/day. Efficiency factors are estimated taking unfertilized unirrigated Pangola as the base of comparison. At the lowest level of N, utilization efficiency is excellent, but decreases as the level of N increases. The same trends are shown in the economic analysis of the data.

For the period of 1971 to 1973 (from establishment to the end of 1973), the marginal internal rate of return increases at the lowest level of N, as the stocking rate goes from 4.17 to 5 steers/ha, reaching a maximum of 16 per cent. The best treatment combination was 168 kg N/year at a stocking rate of 5 steers/ha. An equal internal rate of return was obtained for 332 kg N and 5 steers/ha, but the total capital flow is higher in the latter case, making it less attractive for the producer (Table 13). Marginal rate of return is defined as that discount rate which

Table 13. Rate of return to the application of fertilizer nitrogen for beef production on irrigated Pangola grass * CIAT 1971, 1972 and 1973

Level of nitrogen kg/ha/year	Stocking rate, steers/ha					
	4.17	5.00	5.83	6.67	7.50	8.33
	Percentages					
168	12	16	11			
332		16	11	8		
500			5	9	6	
672				5	8	7

* Marginal internal rate of return, defined as that discount rate which equalizes the present value of changes in benefits with the present value of changes in cost and investments, relative to the traditional system (Pangola without fertilizers); in other words, the rate of return to that increment in expenditures, in consequence of using fertilizers and irrigation. It was assumed that there is no residual effect of the nitrogen. Estimation of cost and benefits using November 1973 prices. All calculations made on constant real prices, that is, adjusted for inflation. These results indicate that the most profitable system consists of using 168 kg/N/ha with a stocking rate of 5 steers/ha

Table 14. **Production of unselected commercial Zebu-type steers and crossbred Zebu-Charolais steers grazing Pangola grass *** **(1972-1973)**

Level of nitrogen kg/ha/year	Daily weight gain (g)		Weight gain/ha/year (kg)		Advantage of crossbreds over commercial Zebus (%)
	Commercial	Crossbred	Commercial	Crossbred	
168	390	570	692	1,030	46
332	379	638	793	1,352	70
500	375	507	910	1,237	36
672	367	473	998	1,286	29

* All animals were of approximately the same initial weight, but commercial Zebu type were about one year older

equalizes the present value of change in benefits with the present value of changes in cost and investments, relative to the traditional system (Pangola without fertilizer). It was assumed that there was no residual effect of the N applied. November, 1973 prices were used on estimating costs and benefits.

Table 14 compares weight gains obtained with unselected commercial Zebu-type animals and crossbred Charolais-Cebu steers and a projection of average productivity per hectare if animals of only one or the other type were used. The advantage of crossbreds is obvious and corresponds well with

The use of good quality young stock is one of the most important components of an intensive fattening system. The two animals on the right hand side are commercial Zebu-type steers, one year older, at equal weight, than the two Charolais x Zebu crossbreds on the left hand side

results of 1972 which indicated a 30 per cent improvement with crossbreds. This suggests a genetic advantage but is an effect obscured by a lack of specific pedigree and other background information. Crossbreds were younger and came, in part, from different herds than the commercial Zebus.

Internal rates of return were calculated for the 168 kg of N with five steers/ha treatment, using commercial and crossbred animals. The results indicate that returns of 12 and 31 per cent can be expected with commercial and crossbred cattle, when the purchasing and selling price of both types of cattle are the same. Actually, in most tropical Latin American countries, crossbred animals are at present not readily available and demand a premium price. An exploratory analysis indicates that the purchasing price of crossbred feeder cattle could be as much as 23 per cent higher than commercial Zebu-type animals for equal profit.

The partial components of an intensive fattening system under grazing in tropical alluvial soil areas of high fertility could then be described as follows:

1. Irrigated Pangola grass pastures
2. Six or more paddocks for rotational grazing
3. Rotation cycle of 30 days, 5 days of grazing and 25 of rest
4. Nitrogen fertilization at the rate of around 168 kg/ha/year, split into 12 applications, one after every grazing
5. Crossbred cattle, Zebu with native or European breed
6. All necessary measures of animal health prophylaxis.

Results of the Pará grass grazing trial for 1972-1973 are presented in Table 15. Pastures were not irrigated. Weight gain per kg of N applied was not as good as in Pangola, probably in part reflecting the lack of irrigation water.

Turipaná

A grazing trial was established at Turipaná to measure the productivity of Pará grass compared to a mixture of Pará and tropical legumes, including kudzu (**Pueraria phaseoloides**) which predominates, plus **Centrosema plumierii, Clitoria ternatea** and **Desmodium intortum**. Experimental grazing was started in December, 1973.

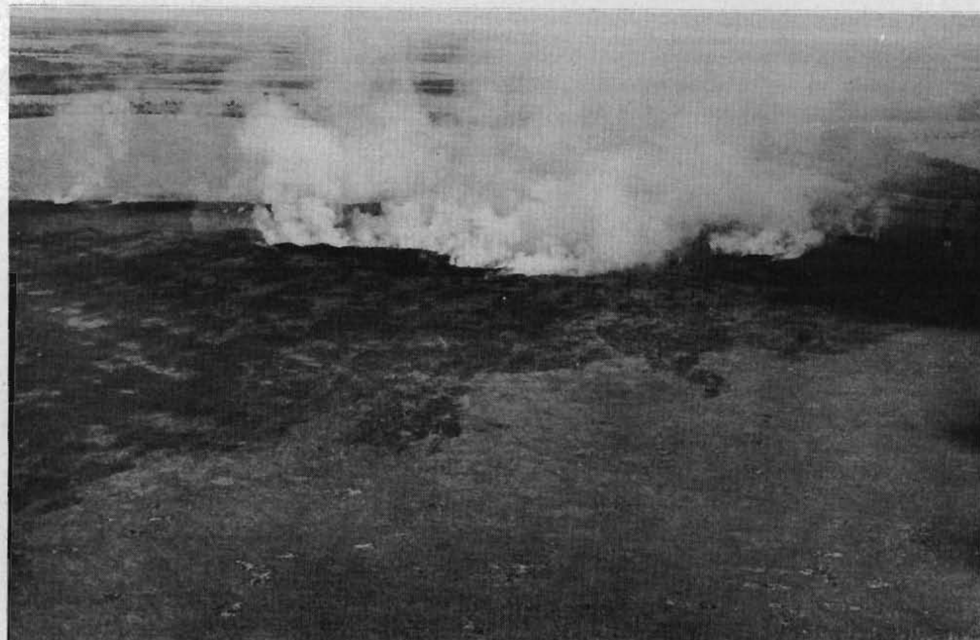
A series of 4-5 ha demonstration plots of **Hyparrhenia rufa, Centrosema pubescens, Macroptilium atropurpureum** and **Glycine wightii** were established in

Table 15. **Beef production on nitrogen fertilized Pará grass. Palmira, 1972-1973**

Nitrogen level kg/ha/year	Stocking * rate steer/ha	Average daily weight gain (g)	Average gain per hectare kg/year	Kg weight per kg of N applied**
200	4	393	596	1.7
400	5	354	666	1.0
600	6	346	777	0.9

* Stocking rate was increased from 4, 5 and 6 steers to 5, 6.1 and 7.1 steers in September 1973

** Base of comparison is unfertilized Pará grass carrying one and one - half steers gaining 450 g/day (250 kg/year)



Uncontrolled burning is a hazardous and wasteful method of managing the tropical savanna. However, with present level of technology and infrastructure, it is the only management tool available to get fresh and more nutritious forage (Photo: O. Paladines).

the rolling grazing areas of degraded alluvial soils near Turipaná. The objectives are to demonstrate methods of establishment and production potential of grass-legume mixtures to students in the Livestock Production Specialist Training Program and to producers of the area, and secondly, to obtain field production data.

Carimagua

In the trial established to measure the beef production potential of the native savanna in Carimagua and the effect of stacking rate (.5,.35 and .2 steers/ha), results obtained in 1971-1972 indicated that four paddock rotational grazing had no advantage over continuous grazing. The trial was modified to include the same three stocking rates, but comparing two burning schemes: 1) once-a-year burning of the total area at the end of the rainy season, and 2) once-a-year sequential burning, by which the savanna is divided into eight plots, separated by fireguards, and burned one plot at a time throughout the year. The first plot of the "sequential burning" was burned in November at the same time as the "total-area burning," the remaining seven plots were burned in December, January, February, March, May, July and September. Figure 17 shows weight changes in this trial.

It is interesting to observe the weight gain in the early dry season period (November to January) in the burned savanna (1972-1973) as compared to weight loss in the unburned savanna (1971-1972). In the latter part of the dry season (January to March) all animals in all treatments in both years lost weight, some of them at rates higher than 400 g/day. In the following rainy season (March to November), animals regained lost weight with average weight gains of 400 to 500 g/day. Over the whole year, weight gains per animal were satisfactory in all treatments.

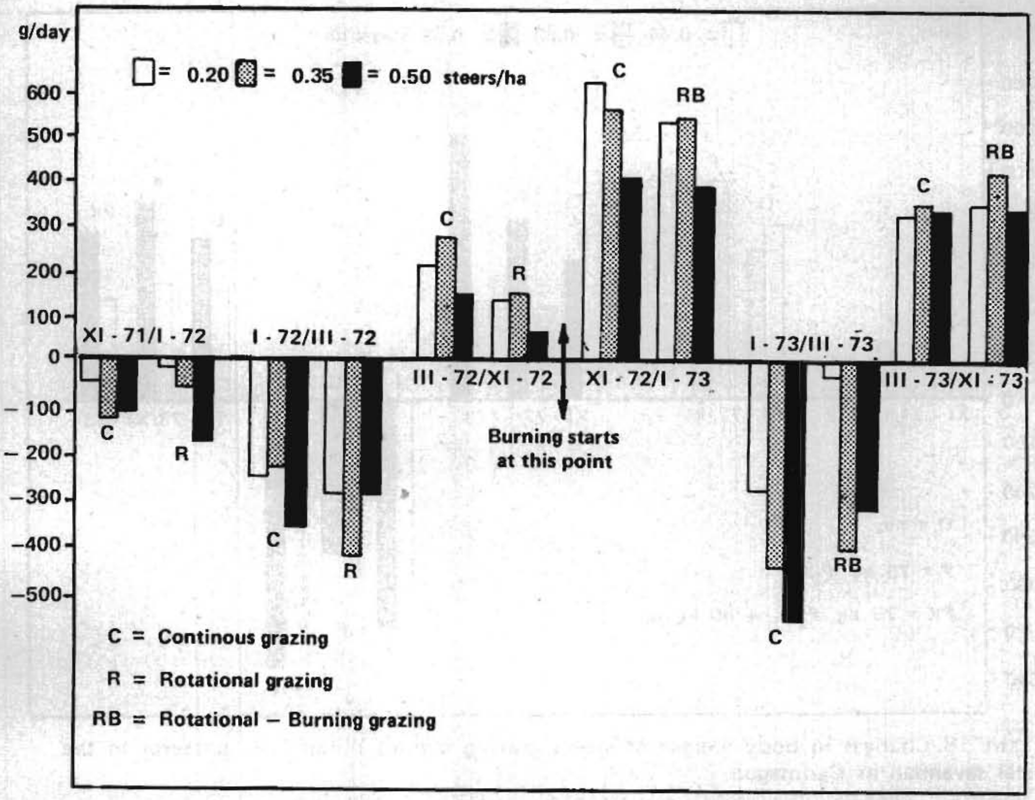


Figure 17. Changes in body weight of steers grazing the tropical savannah in Carimagua

Table 16 compares sequential-burning with the total area-burning treatment. A beneficial effect was found in favor of sequential burning, but this effect decreased with increasing stocking rate with no benefit at the highest rate. The 29 per cent benefit at the lowest stocking rate may prove to be economically important if the burning can be repeated year after year without

Table 16. **Productivity of the native savanna at Carimagua with two systems of burning (November 1972 - November 1973)**

Stocking rate Animals/ha	Average yearly weight gain per animal, (kg)		Advantage of sequential burning	
	One burning*	Sequential burning **	Kg/animal	Percentage
0.20	92	119	27	29
0.35	94	110	16	17
0.50	74	78	4	5

* All the area was burned in November 1972

** The area was divided by fireguards into eight plots with one plot burned at eight different times throughout the year, beginning November 1972 and ending September 1973

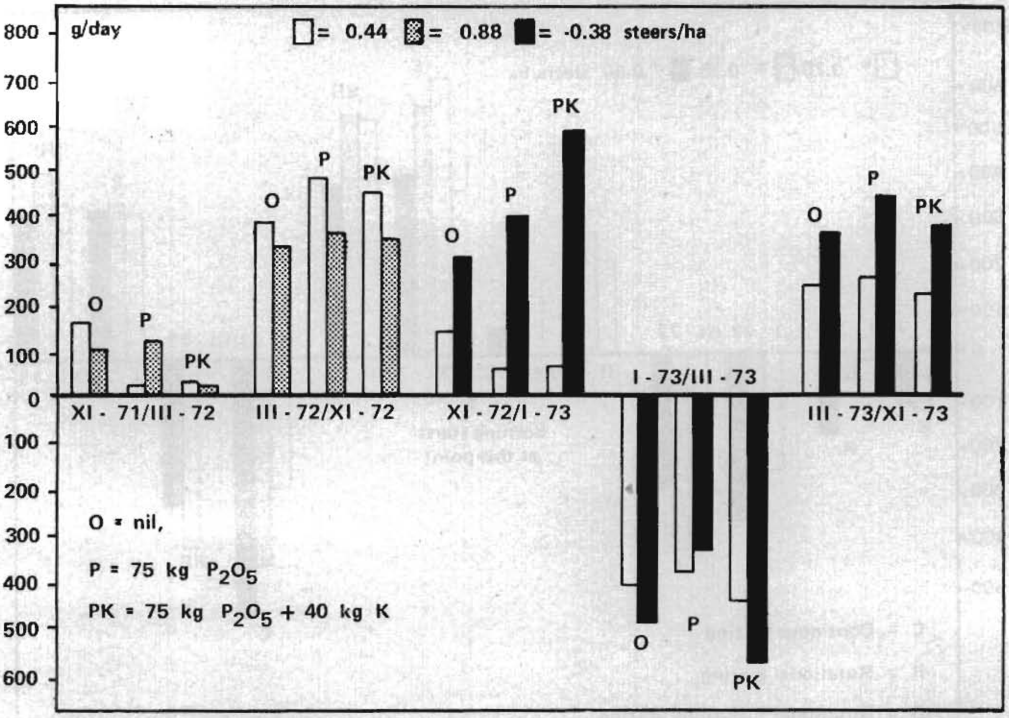


Figure 18. **Changes in body weight of steers grazing** Melinis minutiflora **pastures in the tropical savannah at Carimagua**

reducing productivity of the savanna. It remains to be seen if this is possible. In Eastern and Southern African savannas, burning can only be done every three or four years.

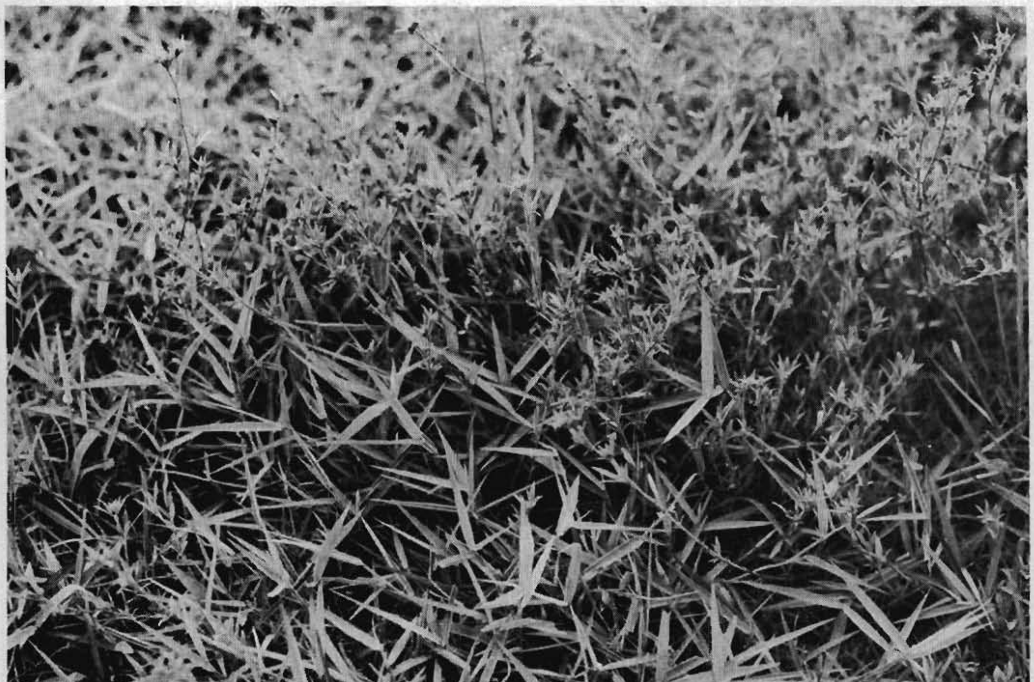
Burning in Africa is used in a somewhat different context than in Latin America. In Africa, fire is used to control bush and woody growth, representing the climax vegetation of these savannas. However, in some tropical Latin America savannas, tough, poor quality grass is often the stable climax vegetation, and where bush and woody growth is not only suppressed by fire but also by low fertility of the soil. Burning, in this case, is used to provide more nutritious and palatable regrowth of the grasses.

Figure 18 presents a summary of the daily per hectare weight gain obtained in the Molasses grass (**Melinis minutiflora**) trial from 1971 to 1973. Again in this grass, animals gained weight in the period of November to January and lost weight from January to March. Weight gains during the rainy period were good (March to November) in all treatments. Table 17 shows the weight gains obtained per hectare and per animal in the period 1972-73. Per hectare gains in the medium stocking rate treatments were superior to the lower stocking rates and far superior to the per hectare gain in native savanna (20 to 30 kg/ha/year).

The Molasses grass trial was initially established with three stocking rates; i. e, 0.44, 0.88 and 1.32 steers/ha for the rainy season and 0.44, 0.38 and 0.38 for the dry season. The highest stocking rate had to be spared both in 1972 and 1973 for varying periods of

Table 17. **Beef production on Molasses grass at Carimagua (November 1972 - November 1973)**

Fertilizer application at planting 1971		Stocking rate steers/ha	Number of grazing days	Average weight gain per animal kg/period	Weight gain/ hectare/year
No fertilizer	Low	0.44	365	113	49
	Medium	0.88	171	73	84
		0.38	194	53	
Phosphorus	Low	0.44	365	118	52
	Medium	0.88	171	93	114
		0.38	194	87	
Phosphorus + Potassium	Low	0.44	365	99	43
	Medium	0.88	171	71	95
		0.38	194	86	



Mixture of adapted grasses and legumes will provide the tropical savannas the necessary production and nutritive value needed, to bring in real changes in production. This close-up picture taken at Carimagua shows a Melinis minutiflora/Stylosanthes guyanensis **pasture which is under grazing** (Photo: O. Paladines)

Table 18. **Intake and digestibility of dry season** Melinis minutiflora **with and without a a supplement of** Stylosanthes guyanensis

Treatment	1	2	3
DM offered*			
M. minutiflora	100	80	
S. guyanensis		20	100
DM consumed*			
M. minutiflora	38.4	34.1	
S. guyanensis		18.5	63.3
Total	38.4	52.6	63.3
Dry matter digestibility (%)	40.7	48.7	65.3
Intake of digestible dry matter*	15.6	25.6	41.4

* In g/kg liveweight$^{.75}$/day

time to avoid complete destruction of the pasture; therefore, data has not been included in this report. Differences between fertilizer treatments were not statistically significant while stocking rate effects were highly significant.

Digestibility and Intake studies

Nutritive value of dry season Molasses grass

Molasses grass (**Melinis minutiflora**) has been introduced into the Llanos Orientales as an improved grass. CIAT studies demonstrate that on a yearly basis Molasses grass gives better performance than native pasture. However, the advantage of Molasses grass is only apparent in the rainy season. In the dry season, cattle on Molasses grass often suffer severe weight losses of 400 to 500 g per day.

A trial with crated sheep measured the intake and digestibility of dry season Molasses grass alone, Molasses grass supplemented with **Stylosanthes guyanensis,** and **Stylosanthes guyanensis** alone. The treatments and results are summarized in Table 18. Differences between the three treatments were large and in all cases significant ($P < 0.01$).

The poor quality of dry season Molasses grass is indicated by a low intake of this material. In treatment 1 only 38 per cent of the offered Molasses grass was consumed and 43 per cent in treatment 2. Leaf in the offered hay was 41 per cent but no leaf was encountered in the refused forage. Thus, the animals ate all the leaves and no stems of **M. minutiflora.** The digestibility of this selected part of Molasses grass was only 40 per cent, and intake of digestible dry matter was only 60 per cent of the estimated requirement for body maintenance. Animals in treatment 2 consumed more than 90 per cent of the offered Stylo, giving a higher total dry matter (DM) consumption, higher digestibility of the consumed DM and an intake of digestible DM which is estimated to be sufficient for maintenance of body weight. Animals receiving only Stylo had by far the highest intake of DM, digestibility of DM and intake of digestible DM.

Feeding value of Stylosanthes guyanensis

Enough **Stylosanthes guyanensis** (La Libertad) became available for more detailed trials with sheep. Three different cuts were tested:

Harvested	% Leaves	% Inflorescence	% Stem
5 months after planting	40	0	60
8 months after planting	25	16	59
3 months after cutting (regrowth)	49	0	51

Forages were fed at four levels, in order to measure the digestibilty of the total forage but also to determine how much sheep can improve their diet by selective consumption. Levels of feeding as well as the results are shown in Figure 19.

Intake of DM for the three months regrowth and the five months first growth reached a maximum at a feeding level of approximately 100 g DM/kg w^{75}. However, digestibility increased even at higher levels of feeding and so did intake of digestible DM. In the eight months-old first growth a linear response in intake of DM up to a feeding level of 140 g was obtained. Again this was accompanied by a significant increase in digestibility of DM and intake of digestible DM.

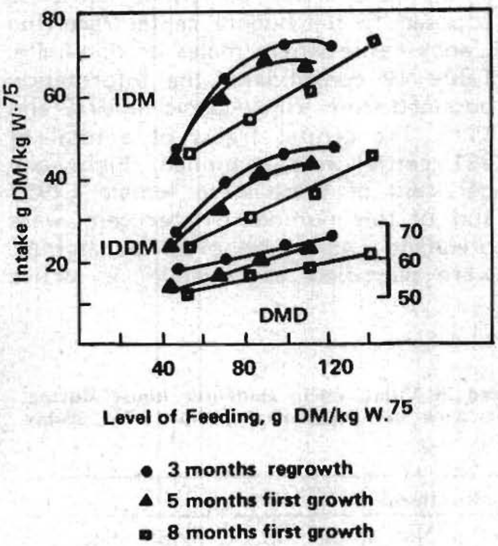


Figure 19. **Intake of Dry Matter (IDM) Dry Matter Digestibility (DMD) and Intake of Digestible Dry Matter (IDDM) of three cuts of** Stylosanthes guyanensis **var. La Libertad as affected by level of feeding.**

The strong increase in digestibility of consumed DM may be attributed to a strong selection for the leaves and inflorescence (Figure 20). When small amounts of feed were offered, the animals ate equal amounts of leaf and stem as present in the offered forage. However, with increasing levels of feeding, stem consumption decreased while leaf consumption sharply increased. Even after maximum total feed intake was reached, leaves further replaced stems in the consumed diet, thus further increasing digestibility.

The same process of replacing stems with leaves was also found in the five months first growth. The results from experiments with the eight months first growth indicate clearly that inflorescences also are well eaten by sheep and are highly preferred over stems.

Results show that **Stylosanthes guyanensis** is well accepted by sheep and has a high nutritive value. Also impor-

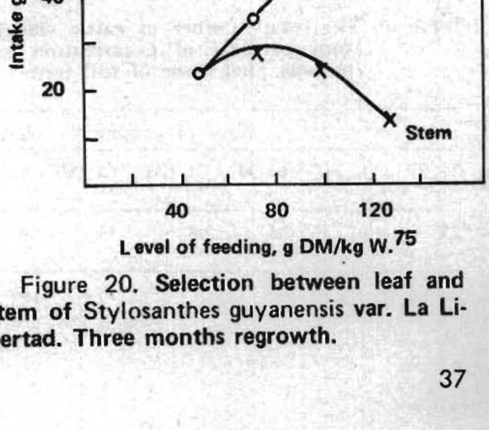


Figure 20. **Selection between leaf and stem of** Stylosanthes guyanensis **var. La Libertad. Three months regrowth.**

tant is the strong indication that even at advanced stages of maturity this species can provide a highly nutritive diet when selection is possible.

The strong selection for leaves indicates that the percentage of leaves may be an important factor in determining the nutritive value of the pasture species. Initial data show a great variability between varieties of **Stylosanthes** in leafiness; e.g., seven varieties had from 30 to 52 per cent leaves at the same time after planting. La Libertad ranked third in this group with 45 per cent leaves. The varieties Pance CV_2 and David 17 both had 52 per cent leaves and therefore are of particular interest.

Intensive systems of finishing cattle in confinement

An experiment is under way to determine the beef production potential of Elephant or Napier grass. Irrigation is provided as necessary; 800 kg N/ha is applied annually. Elephant grass is chopped and fed **ad lib** alone; fed **ad lib** with 500 g of cottonseed meal/head/day; fed **ad lib** with 500 g of cottonseed meal and two kg of molasses/head/day. Average daily gains are 440, 540 and 770 g, respectively. Carrying capacity approximates 14-16 animals/ha. Current beef production is approximately 2500-3000 kg/ha/yr and is expected to increase.

ANIMAL HEALTH

Principal emphasis was placed on breeding diseases, wildlife studies, hemoparasitic diseases, and ecto and endoparasites. New activities in the year were Library Documentation and the planning of an economics input.

Breeding diseases

All the findings in 1973 related to the Llanos Orientales where work was centered on the ICA/CIAT station at Carimagua and the Villavicencio slaughter house. The team working on the slaughter house floor included representatives from CIAT, the Instituto Colombiano Agropecuario (ICA), the Universidad Nacional and the Caja Agraria. At the end of the year, staff was allocated to the Costa Atlántica to carry out parallel observations in a contrasting ecological area of the lowland tropics.

Villavicencio slaughter house receives a high proportion of female cattle as opposed to the Bogotá center receiving Llanos cattle where males predominate. Table 19 consolidates the information obtained from Villavicencio in 1972 and 1973. The genital tracts of a total of 981 cattle were examined. Eighty-one per cent of these were female (795) and of this number 61 per cent were pregnant (484). Nonpregnant animals were classified as juvenile, in active

Table 19. The total number of cattle slaughtered in Villavicencio slaughter house during four periods of examination giving ages of pregnancy grouped in 30-day periods plus those of full term

Ages of pregnancy (days) plus those at full term										
0 - 30	to 60	to 90	to 120	to 150	to 180	to 210	to 240	to 270	Full term	Not recorded
23	61	64	68	53	45	43	37	34	34	22

Total males	186	Open females	311
Total females	795	Pregnant females	484

breeding life, or old. Old animals at the end of their breeding life were the exception.

The pregnancy rate is of obvious significance in the study of breeding diseases. A common story is that farmers send their female stock to the better grazing in the piedmont before slaughter and sell them at advanced pregnancy in order to obtain a higher price based on weight. The even distribution of ages of pregnancy (see Table 19) does not confirm this. Perhaps farmers find a necessity to sell breeding females in order to repay loans or perhaps they are merely taking advantage of high prices for beef. Whatever economic pressures are causing this phenomenon, it represents an important loss of breeding females from the national herd.

Information was collected on five diseases known to be important causes of abortion in other areas and circumstances in the world (brucellosis, trichomoniasis, vibriosis, leptospirosis and the infectious bovine rhinotracheitis /pustular vaginitis syndrome) and on one condition whose significance is ill-defined (granular vaginitis).

Brucellosis

An interesting phenomenon has been observed in the ICA/CIAT herd systems experiment at Carimagua. At the start of the experiment in early 1972 all heifers were checked for brucellosis using the tube agglutination test. Any animals showing any titer, irrespective of the interpretation, were culled. By July, 1973, however, 107 of the 320 selected animals were showing titers. Three of these were positive, confirmed on a second examination, and the animals were culled. Figures currently available from the ICA National Brucellosis Program give 0.9 per cent positive sera from the Meta section of the Llanos (3045 animals were tested). Brucella testing carried out on cattle on 39 farms included in the ICA/Fondo Ganadero/CIAT survey in 1973 gave 20 positive out of 2469 tested (4.1 per cent) but 7 of the positive animals were on a single farm. Enclosure and intensive management without culling positive animals can be expected to increase the incidence of infection, but the results at Carimagua have occurred even after vigorous culling and an explanation for the positive titers needs to be found.

Trichomoniasis and Vibriosis

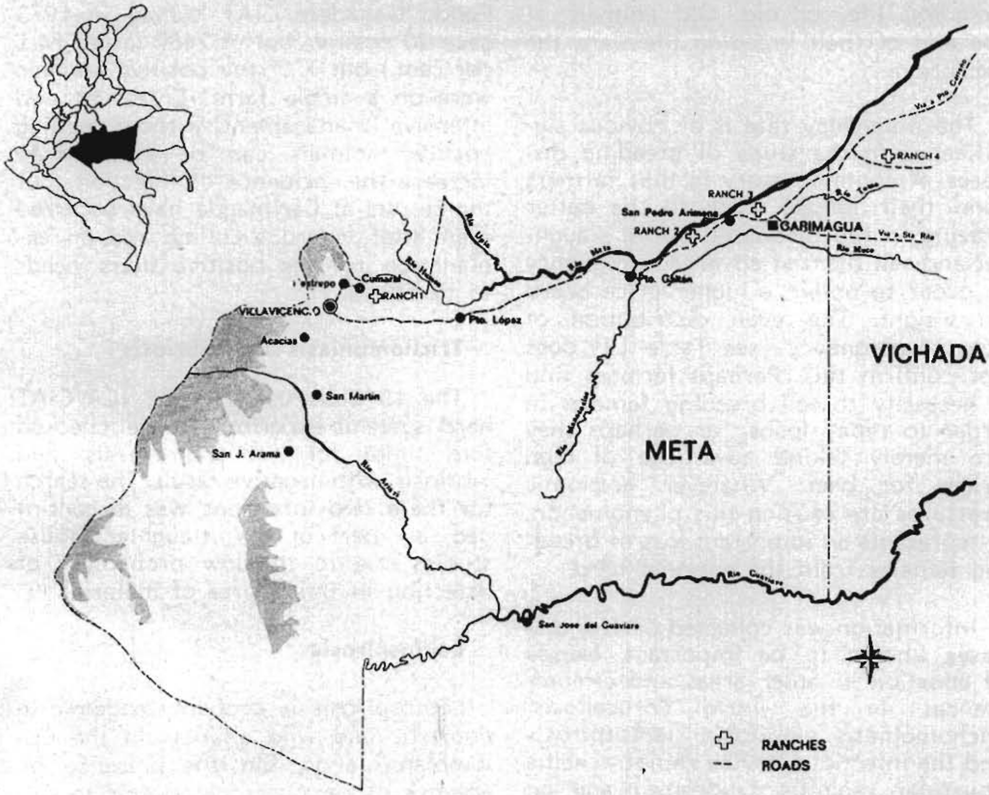
The 18 bulls used in the ICA/CIAT herd systems experiment were checked five times for trichomoniasis and vibriosis with negative result. The search for these two infections was discontinued as part of the slaughter house studies due to the low probability of detection in this source of material.

Leptospirosis

Leptospirosis is probably endemic in domestic and wild animals in the Colombian Llanos, but the presence or absence of serotypes pathogenic to cattle is unrecorded. The regional reference laboratory for leptospirosis is housed in the Pan American Zoonosis Center. One hundred and fifty-eight serum samples were submitted to the reference laboratory derived from two herds, 50 and 80 km, respectively, northeast of Puerto Gaitán. One hundred and fifteen samples gave positive reactions representing 11 serotypes. The three most prevalent were **hardjo, wolfii** and **sejroe.** These are important cattle pathogens and there is obvious need to define the situation. The Director of the Zoonosis Center has agreed to a collaborative study, and a project has been submitted to him to include sera from the CIAT wildlife studies.

Infectious Bovine Rhinotracheitis/ Pustular Vaginitis (IBR/IPV)

The three similar viruses isolated from the vaginal or cervical mucosa of



Isolation of the Infectious Bovine Rhinotracheitis virus (IBR). Map shows localization of ranches where cattle originated. Dark section in map of Colombia (left) shows area of study

cattle and reported in 1972 were identified as IBR virus on serum neutralization and histopathology. A fourth virus isolation made in 1973 was similarly identified. These were isolated from a total of 285 cattle in the Villavicencio slaughter house showing any lesion suspicious of pustular vaginitis. The infected cattle were traced back to their ranches of origin where serum samples were taken against further epidemiological investigations.

These four isolations are the first to be made from the Colombian Llanos. In addition, in 1973, ICA identified the virus in relation to an abortion syndrome in a dairy herd in the Sabana de Bogotá. The scattered distribution of the infected premises suggests that the virus is common and widespread (see map of Colombia). With prevailing extensive grazing systems the infection may not be of present importance, but it could represent an important hazard under more intensive management. A serological survey is required.

Granular vaginitis

Despite the high prevalence of the condition and the frequently obvious clinical signs, opinions on its etiology and importance show a diversity of opinion. The cattle in the herd systems experiment at Carimagua have given an excellent opportunity for clinical and epidemiological observation.

The cattle have been examined for this condition at intervals of 2-4 months through 1972 and 1973. In individual animals the clinical appearance varies widely from observation to observation but overall on a group basis there is a seasonal variation in incidence and intensity. The numbers of affected animals are greatest in July-August (280/320) and least in February-March before the start of the rainy season (200/317).

At present, there is no apparent correlation between this condition and fertility, but the animals that are not pregnant show the lesions of greatest intensity.

Examinations for granular vaginitis were also routinely carried out in Villavicencio slaugter house. These represent a wide range of age of female animals as opposed to the Carimagua group of first calf heifers. A lower proportion of animals was found in total to be affected (186/795).

Wildlife studies

The studies at Carimagua continued to investigate the actual and potential role of wildlife in the epidemiology of diseases of both man and cattle. There is need to understand the ecology of undeveloped areas preferably before the invasion of man and his domestic animals. Most of the animal collections were made in the gallery forests, and the main contact between cattle and wild animals is on the adjoining pastures.

Collaboration was maintained with the International Center for Medical Research and Training (ICMRT) and with the Biology and Microbiology Departments of the Universidad del Valle. Table 20 gives a check list and distribution of the mammals captured between September, 1972 and December, 1973. No numbers are given for bats as many were caught as part of bat control measures on the station. In addition, 53 reptiles were caught (**Iguana iguana,** 3; **Ameiva ameiva,** 3; and **Tupinambis** sp., 47), and binocular sittings were made of 89 bird species.

The following are notes on parasitisms, conditions or infections of significance to man and his domestic animals. Table 21 lists those detected in the period September 2, 1972 to December 20, 1973.

Trypanosomiasis

Specimens and cultures are routinely sent to the ICMRT where a graduate student is making serological studies of animal reservoirs for human trypanosomiasis. A total of 26 trypanosoma isolations have been made. From these, the pathogenic **Trypanosoma cruzi** and non-pathogenic **T. rangeli** have been identified on the basis of their behavior on inoculation into the hemolymph of **Rhodnius prolixus** and intracerebrally into suckling mice. The results indicate that the Carimagua area is endemic for these two trypanosomes infective to man.

Echinococcus

Six infections have been found in the 28 **Cuniculus paca** captured. The natural host of the adult worm is thought to be wild carnivores. Studies are being carried out to determine whether this particular species is one which is important to man.

Capillaria hepatica

Two cases have been found in **Didelphis marsupialis.** The eggs of this parasitic nematode are deposited in the liver causing a gross inflammation. Human cases have been suspected in Puerto Asís, Putumayo (communication from ICMRT).

Venezuelan Equine Encephalomyelitis (VEE)

Carimagua is or has been an endemic area for VEE. **Proechimys** sp., **Cebus apella** and **Ameiva ameiva** were serologically positive.

Table 20. **Check list of mammalian species captured in the wildlife studies in Carimagua in the period September 2, 1972 - December 20, 1973. Nomenclature after Morris (1965) ***

Mammalian order	Species	Common name	Number Of animals captured
Marsupials	*Didelphis marsupialis*	Common opossum	53
	Metachirus nudicaudatus	Rat-tailed opossum	7
	Lutreolina crassicaudata	Thick-tailed opossum	1
	Marmosa murina	Murine opossum	41
Bats	*Rhynconycteris naso*	Proboscis bat	
	Saccopteryx bilineata	White-lined bat	
	Noctilio labialis	Bulldog bat	
	Phyllostomus hastatus	Spear-nosed bat	
	Phyllostomus discolor	Spear-nosed bat	
	Phyllostomus elongatus	Spear-nosed bat	
	Mimon crenulatum	Spear-nosed bat	
	Glossophaga soricina	Long-tongued bat	
	Sturnira lilium	Yellow-shouldered bat	
	Carollia perspicillata	Short-tailed bat	
	Rhinophylla pumilio	Short-tailed bat	
	Uroderma bilobatum	Tent-making bat	
	Artibeus lituratus	American fruit-eating bat	
	Artibeus cinereus	American fruit-eating bat	
	Artibeus jamaicensis	American fruit-eating bat	
	Myotis nigricans	Common bat	
	Myotis sp.	Common bat	
	Eptesicus brasiliensis	Big brown bat	
	Lasiurus borealis	Hairy tailed bat	
	Molossus major	Velvety free-tailed bat	
	Eumops auripendulus	Mastiff bat	
	Eumops bonariensis	Mastiff bat	
	Molossops planirostris	Dog-faced bat	
Primates	*Cebus apella*	Brown capuchia	7
	Aotus trivirgatus	Douroucouli	2
Edentates	*Tamandua longicaudata*	Long-tailed tamandua	2
	Dasypus kapleri	Kappler's armadillo	2
	Dasypus novemcinctus	Nine-banded armadillo	1
	Dasypus sabanicola	Armadillo**	5
	Priodontes giganteus	Giant armadillo	1
Lagomorphs	*Sylvilagua floridianus*	Eastern cottontail	4
Rodents	*Hydrochoerus hydrochoeris*	Capybara	16
	Cuniculus paca	Paca	28
	(syn. *Agouti paca)*		2
	Dasyprocta fuliginosa	Agouti	
	Cavia porcellus	Cavie	2
	Coendou sp.	Tree porcupine	4
	Sciurus igniventris	Tree squirrel	1
	Proechimys sp.	Spiny rat	230
	Nectomys squamipes	Water rat	21
	Neacomys spinosus	Bristly mouse	9
	Zygodontomys brevicauda	Cane rat	25
	Sigmodon alstoni (syn. *Sigmodon sigmomys)*	Cotton rat	2
	Oryzomys concolor	Rice rat	23
	Oryzomys delicatus	Rice rat	3

* Morris, D. (1965) **The Mammals.** Hodder and Stoughton, London
** Species not listed by Morris

Mammalian order	Species	Common name	Number captured
Carnivores	*Cerdocyon thous*	Crab-eating fox	3
	Felis pardalis	Ocelot	1
	Felis jaguarondi (syn. *Herpailurus yagouaroundi)*	Jaguarondi	1
	Bassaricyon gabbii	Bushy tailed olingo	2
	Potos flavus	Kinkajou	1
Ungulates	*Odocoileus virginianus*	White-tailed deer	2

Table 21. Some parasitisms, conditions or infections of wildlife detected in Carimagua from September 2, 1972 to December 20, 1973

Parasitism	Condition or infection	Animal species
Hemoparasites	*Trypanosoma* spp.	*Proechimys* sp.
		Cuniculus paca
		Hydrochoerus hydrochoeris
		Didelphis marsupialis
		Cebus apella
		Potos flavus
		Odocoileus virginianus
		Tamandua longicaudata
		Molossus major
		Myotis sp.
		Myotis nigricans
		Carollia perspicillata
		Phyllostomus hastatus
		Sturnira lilium
		Glossophaga soricina
	*Trypanosoma rangeli***	*Didelphis marsupialis*
	*Trypanosoma cruzi***	*Didelphis marsupialis*
	Microfilaria	*Cebus apella*
		Aotus trivirgatus
		Myotis sp.
		Myotis nigricans
	Hemogregarina sp.	*Tupinambis* sp.
	Piroplasma spp.	*Felis pardalis*
		Molossus major
		Myotis nigricans
		Lasiurus borealis
	Plasmodia spp.	*Iguana iguana*
		Ameiva ameiva
		Myotis sp.
		Myotis nigricans
		Sturnira lilium
Ectoparasites	*Amblyomma auricularium*	*Sigmodon alstoni*
		Dasypus sabanicola
	Amblyomma longirostre	*Coendou* sp.
	Amblyomma goaeji	*Coendou* sp.
	*Amblyomma maculatum**	*Cerdocyon thous*
	Ixodes luciae	*Didelphis marsupialis*
Endoparasites	*Echinococcus* sp.***	*Cuniculus paca*
	*Capillaria hepatica****	*Didelphis marsupialis*
Viruses	Venezuelan Equine Encephalomyelitis***	*Proechimys* sp.
		Cebus apella
		Ameiva ameiva
Bacteria	*Brucella* ***	*Hydrochoerus hydrochoeris*
Neoplasms	*Basal cell tumor*	*Potos flavus*

* Of significance to domestic animals
** Of significance to man
*** Of significance to both man and domestic animals

Brucellosis

Not all sera have yet been checked for Brucellosis. The first 80 animals collected of various species contained no reactors, but a single capybara (**Hydrochoerus hydrochoeris**) separately and randomly tested was found positive. This latter result may be of significance relative to the positive cattle in the herd systems experiment.

Leptospirosis

Vigorous attempts were made to isolate leptospira with no success. Further attempts will be made relative to results from serological testing.

Basal cell tumor

A basal cell tumor in man is commonly called a rodent ulcer. The discovery of this kind of tumor on the leg of a **Potos flavus** is probably only of academic interest.

Hemoparasitic diseases (Texas A&M Group)

In contrast to the primarily epidemiological work in the other areas of the Animal Health program, the principal activity was the initiation and running of further long term field experiments in hemoparasitic diseases control. These were carried out in collaboration with ICA at Turipaná on the Costa Atlántica. The first field experiment was described in the 1972 Annual Report. Calves from a "clean" area for **Anaplasma marginale, Babesia argentina** and **B. bigemina** were introduced into the severe endemic challenge found at Turipaná. The groups compared were: premunition plus anthelmintics; chemoprophylaxis (imidocarb dipropionate) plus anthelmintics; anthelmintics alone, and control animals. Both premunition and chemoprophylaxis gave important degrees of protection. Following the experience gained from the logistics of this experiment, three further field experiments were designed and started, the total sequence now being designated Montería I, II, III, and IV.

Montería II was started in September, 1972 and is scheduled for completion in April, 1974. Comparison is being made of chemoprophylaxis (imidocarb dipropionate), chemotherapy (imidocarb dipropionate) and premunization for the control of hemoparasites in susceptible Normando calves introduced from a "clean" area (Sabana de Bogotá). The premunization was carried out before dispatch. The parameters being measured are: temperature, weight gain, haematocrit reading, complement fixation, parasitemia, tick counts and fecal parasite egg counts.

Because of some death losses during transportation by truck from Bogotá to Turipaná, a decision was made to complement Montería II with Montería III comparing only premunization, chemoprophylaxis and a control group of calves. In this instance, susceptible Holstein calves were chosen, premunization was carried out in a tick proof barn at CIAT Palmira, and the calves were transported by air to Turipaná. The parameters being measured are the same as for Montería II. The experiment started in December, 1972 and is scheduled for completion in April, 1974. Preliminary results from Montería II and III indicate that, based on weight gains, imidocarb dipropionate chemoprophylaxis is at least as effective as premunization in the control of hemoparasitic diseases in susceptible calves introduced into the Turipaná location.

Montería IV was designed to determine whether any advantage could be gained from immunizing calves born in the endemic Turipaná area. Comparison is being made of chemotherapy (imidocarb dipropionate) and two methods of "premunition" with both indigenous Romosinuano and Costeño con Cuernos calves. The same parameters are being measured as in Montería II and III. The experiment, started in February, 1973, is scheduled to end in April, 1975.

Montería IV is revealing much information on the epidemiology of hemoparasites in this area. Preparatory to the experiment, 51 calves were being routinely examined. Most of these were later incorporated into the experimental groups leaving 12 controls and 3 additional calves for extended studies on natural infections. Complementary epidemiological studies are being carried out on four ranches in the Montería-Turipaná-Sincelejo area. These ranches are four of those collaborating with the Livestock Production Specialist Training Program. Cows are being checked for complement fixing antibodies before and after parturition, and complement fixing antibodies and parasitemias are being checked routinely in the calves from birth.

The CIAT 1972 Annual Report commented on the apparently high percentage of cattle in the ICA/CIAT herd systems experiment at Carimagua which were probably susceptible to both anaplasmosis and babesiosis. The presence of complement fixing antibodies was again checked. The number of positive titers to **Babesia bigemina** continued to decline, but the number of positive titers to **Anaplasma marginale** showed a slight increase. **B. argentina** titers were not examined. An interpretation can be made that no transmission of babesiosis appears to be occurring within the area of the experiment, but there is some indication of the transmission of anaplasmosis.

Other activities within the hemoparasite group were, first, an experiment to compare the cross immunity to different strains of **Anaplasma marginale** in splenectomized Holstein calves; second, the identification of an organism resembling **Spirochaeta theileri** in the cattle under experimentation at Turipaná, and third, assistance to the ICMRT group at the Universidad del Valle in completing epidemiological studies on **Trypanosoma evansi** found in a vampire bat colony (**Desmodus rotundus**) near Cali.

The hemoparasite program now needs to identify and characterize epidemiological situations where control measures for hemoparasitic diseases may be required. The protection of susceptible breeding animals moving into endemic areas and the control of the disease within areas of heavy challenge are the more obvious situations. Opportunity exists to examine two others. The first is the Colombian Llanos where there is some indication of an uneven distribution of pathogens relative to the distribution of ticks. If confirmed, this would constitute a danger to a potentially expanding and intensifying industry. The second situation exists in the southern boundary of the distribution of **Boophilus** ticks in Brazil where all calves do not receive natural challenge followed by immunity, and field premunization of calves is routinely carried out annually by veterinary practitioners.

Ectoparasites

The natural history of the tick **Boophilus microplus** under Llanos conditions is being studied at Carimagua. This is an essential prerequisite to forming advice on the best strategy of control. A laboratory colony has also been established at CIAT, Palmira.

Three consignments of **B. microplus** were sent to the Wellcome Research Laboratories, England, to test resistance to acaricides. These contained a single sample from CIAT, Palmira, one sample from Turipaná from the cattle under hemoparasite experimentation, and two samples from Carimagua. Resistance was checked to Toxaphene, Delnav and Ethion. A degree of resistance to Toxaphene was found in one sample from Carimagua.

Observations are being made of the incidence of **Dermatobia hominis** (nuche) in the herd systems experiment at Carimagua. There appear to be specific foci within the total grazing area as if the parasite is of recent introduction and a slow colonization process is taking place.

Endoparasites

Helminths collected from autopsies both of cattle and wildlife at Carimagua are being stored against the appointment of a helminthologist in 1974.

Regular fecal examinations for helminth eggs are carried out by an ICA helminthologist on the cattle in the Carimagua herd systems experiment. Only one treatment with anthelmintics has been found necessary since the experiment started.

Other diseases diagnosed

Monitoring of diseases at Palmira and Carimagua revealed three conditions of particular interest. **Paratuberculosis** (Johnes disease) was diagnosed in a single Zebu animal at Palmira. Reports from this breed are rare. **Cerebral sarcosporidiosis** was diagnosed in another Zebu animal at Palmira which died suddenly. This may be the first description of sarcocystis infection not only in skeletal and heart muscle but also the brain. At Carimagua, bovine parainfluenza - P 1-3 (shipping fever syndrome) was diagnosed in a Zebu calf.

Library Documentation

The program has taken advantage of the CIAT library documentation system using the key-word list produced by the Commonwealth Bureau of Animal Health and a mechanized interior punch card system for retrieval. The only current literature stored at present is that relating to areas of work covered by the CIAT Animal Health program.

ECONOMICS

The objective of the Economics Program is to collaborate in identifying the implication of technical change in beef production both at the micro-and macroeconomic levels. This information will be useful to CIAT and also to national agencies in planning and designing economic policies. Research results should help to identify technical-economic restrictions as well as adjustments in research programs and policy.

Three research projects and the organization of an international workshop were emphasized in 1973.

Economics of Beef Production Systems in savanna regions.

Using a farm management approach, we are examining the effects on production and financial status of the cattle farm resulting from changing the system based on extensive grazing on savanna, traditional in the Colombian Llanos, to a more intensive system. This includes the introduction of improved species, particulary legumes. Effects of this technical change on capital and labor requirements, farm income profitability, debt repayment capacity and liquidity position of the farm through time, output and expenditures —all in a dynamic long-term contex— receive special emphasis. The effect of changing the size of the farm (acreage and cattle stock) and of alternative input and output prices is explicitly considered in the analysis.

A similar study is proposed for both the Venezuelan Llanos and the Campo Cerrado region in Brazil.

A technical note prepared by CIAT economists suggests that the calving rate commonly accepted as prevailing in the Llanos area implies that the cattle stock has been declining through time. This contradicts local statistics and casual observations. It is concluded that the calving rate today is probably above 50-55 per cent, instead of 42 per cent; and the mortality rate during the first year is probably less than 15 per cent.

As an integral part of this project, a farm management analysis of specific improved practices in the Llanos and in other areas is under way. For example, in 1973 the effect of nitrogen fertilization of grasses (under irrigation) in Palmira was examined; the results are shown in the pastures and forages utilization section.

Survey of the phosphate fertilizer market

A survey was undertaken in Colombia to anticipate difficulties in the supply of phosphate fertilizers and to evaluate the feasibility of a pasture establishment strategy that requires the application of small amounts of fertilizer per hectare, but on large areas. Similar studies have been proposed for other countries.

With respect to domestic consumption, supplies and prices, results suggest that:

The consumption of phosphate has increased at an average annual rate of 6.5 per cent between 1963-73, which is really not high, as compared to Brazil and Chile.

Most of the phosphates are offered in the form of mixed fertilizers (NPK), which is not the most appropriate combination for the allic soils prevailing in the Llanos Orientales.

Colombia now imports roughly 85 per cent of its total domestic consumption of phosphates.

The average export price (FOB) of superphosphates has risen from US$ 40 to US$ 90 per ton between 1971 and early 1973. It is urgent that studies be initiated on the long run projection of export prices.

Generally speaking, internal prices in Colombia have been approximately equivalent to world prices for the small proportion sold as phosphorous fertilizers alone. Mixed fertilizers and basic slag, subject to price controls, have been priced below the international price per unit of P_2O_5.

The Colombian Government, through the Caja Agraria which markets approximately one third of the total consumption of fertilizers, can indirectly control the fertilizer market.

Per unit of P_2O_5, the price of basic slag is approximately equivalent to one third of the price of superphosphate. One aspect that requires further study is the convenience of promoting consumption based on mixing phosphorus and sulphur, as an alternative to superphosphate, recognizing however that the latter has the fastest effect.

Proven phosphate reserves in Colombia for industrial exploitation would be consumed in approximately 12 years, if phosphate were applied on one half of the total acreage in the Llanos region, using 20 kilos of P_2O_5/ha/year, and on the assumption that no more than 60 per cent of the total supplies were consumed in that region.

At similar usage levels, latosol soils in Latin America would consume approximately 3.5 million tons of P_2O_5 annually, which is a high figure, relative to total current production.

Benchmark study of the livestock sector

A study is in progress to identify critical technical and socio-economic aspects influencing the livestock sector in Colombia. Based on available statistics and on other studies, the following are included:

— Evolution of cattle population by age and sex, classified by regions. Special emphasis is given to the measurement of the calving and mortality rates.

— Sources of change in cattle production between 1950-1970 and evolution of domestic consumption and beef exports.

— Description of public policy and legislation concerning the cattle industry.

— Land tenure, income distribution and economics of the small ranch.

— Design of a model to project the evolution of the stock, output and slaughter.

A similar study is proposed for other Latin American countries, in collaboration with national agencies.

Development of a collaborative research program.

A workshop was organized to be held in Cali in January, 1974 to: a) review existing research, both completed and in progress; b) identify substantive areas for priority work; and c) identify personnel and institutions capable of participating in a collaborative research effort

In addition to continued work on the aforementioned projects, research has been initiated in the area of the economics of animal health, with special emphasis to foot-and-mouth disease.

PRODUCTION SYSTEMS

All CIAT beef cattle research projects are aimed toward contributing technology for the development of complete beef cattle production systems in the tropics. An integrated multidisciplinary team of agronomists, animal husbandrymen, veterinarians, economists and training specialists is engaged in developing production techniques and systems that will be broadly applicable throughout the lowland tropics in whatever size and type of beef cattle enterprise. Production systems research concentrates on the development of life cycle beef cattle production systems and family farm systems where beef cattle are a principal component of the farm enterprise.

Food crop production

Cultivars of numerous food crop species have been screened for tolerance to soil acidity and general adaptation to the humid, hot tropical environment as represented at Carimagua.

A number of species are generally well adapted to the environment, while others which are not normally considered to be tolerant to acid soils are surprisingly variable genetically, providing adapted cultivars for immediate use and sources of germplasm for crop improvement and breeding programs. Examples of the latter are given in the sections on rice beans and corn in this publication.

Food crop production trials and a prototype food production unit of two ha have demonstrated the feasibility of supplying most if not all of the food needed for a balanced family diet in oxisol areas where lack of infrastructure makes prohibitive the use of sufficient lime to completely neutralize soil acidity.

The role of lime is more as a fertilizer than as a soil amendment; i.e., a source of calcium and magnesium as nutrients. In fact, some crops which have evolved in the tropical allic soil environment are extremely sensitive to over liming. Two tons/ha of lime severely depressed yields of many cassava cultivars in a 1972-1973 screening of 138 entries, and six ton/ha applications depressed yields of almost all of the cultivars. It has been observed that liming of cashew trees is very detrimental at rates as low as one ton/ha. But there is almost always a response to small (nutrient level) applications (Figure 13). Cassava responded to a 500 kg/ha application of lime in Carimagua (Figure 10). The same response could have probably been obtained with an even smaller application, as in the case of the forage legumes. Calcium requirements of many cultivars may be satisfied by the calcium contained in phosphorous fertilizers; e.g., simple superphosphate contains about 20 per cent Ca; triple superphosphate about 15 per cent and basic slag (Colombian) from 18-24 per cent Ca.

Crops tolerant to soil acidity also are likely to be more efficient at recovering

Table 22. **Food crops suitable for allic soils with minimum lime requirement (Lime requirement figures are for acid soil tolerant cultivars)**

Crop	Lime requirement	Planting season
Upland rice**	1/4–1/2 T	April-May
Cassava	1/4–1/2 T	April-November
Plantain (topocho)	1/2–2 T*	April-November
Cowpeas (vegetable)**	1/2–1 T	April-September
Cowpeas (grain)**	1/2–1 T	August-September
Peanuts	1/2–2 T	July-August
Corn (vegetable)**	1—2 T	April-September
Corn (grain)**	1—2 T	July-August
Black beans**	2 T	August-September
Sesame	2 T*	July-August
Sorghum	1—2 T	August-September
Fruits and tree crops		
Mango	1/4–1/2 T*	April-July*
Cashew	1/4–1/2 T*	April-July*
Citrus	1/4–1/2 T*	April-July*
Pineapple	1/4–1/2 T*	April-July*

* Tentative

** See commodity chapters for further information

applied as well as native plant nutrients than susceptible crops even when the latter are grown on limed soils. Tolerant crops can develop wider and deeper root systems and thus exploit a larger volume of soil for needed nutrients and moisture. It is almost impossible to lime the subsoil effectively; as a result, susceptible crop roots are often limited to the plow layer even after liming.

Table 22 lists some food crops suitable for allic soils, along with lime requirements for the more tolerant cultivars and indicated time of planting. All indications are based on experience at Carimagua on an oxisol with the characteristics shown in Table 23. The rainfall distribution is shown in Figure 21. Mean annual temperature is estimated at 27°C; elevation is 150-175 meters

Table 23. **Characteristics of an oxisol from Carimagua, Llanos Orientales, Colombia**

pH	4.3	P.C.*	meq/100 g	4.5
O. M. % (0-20 cm)	5	Al+++	meq/100 g	3.5
P ppm (BRAY II)	3	Ca++	meq/100 g	0.5
Texture Clay loam		Mg++	meq/100 g	0.3
		K	meq/100 g	0.08

* P. C. = Permanent charge

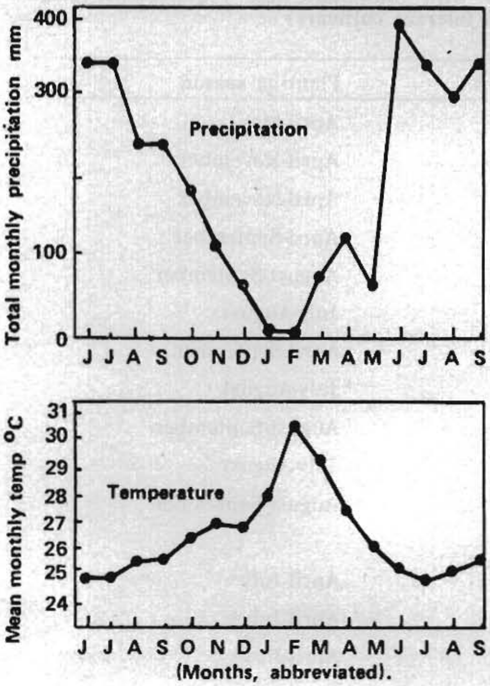


Figure 21. **Precipitation and temperature in Carimagua from June 1972 to September 1973.**

above sea level. The station is located at 4°30′ North and 71°30′ West.

Crops for grain, including legumes, oil seeds and cereals, should be planted late enough in the rainy season for maturity and harvest at the beginning of the dry season.

Farm structures

Carimagua windmill

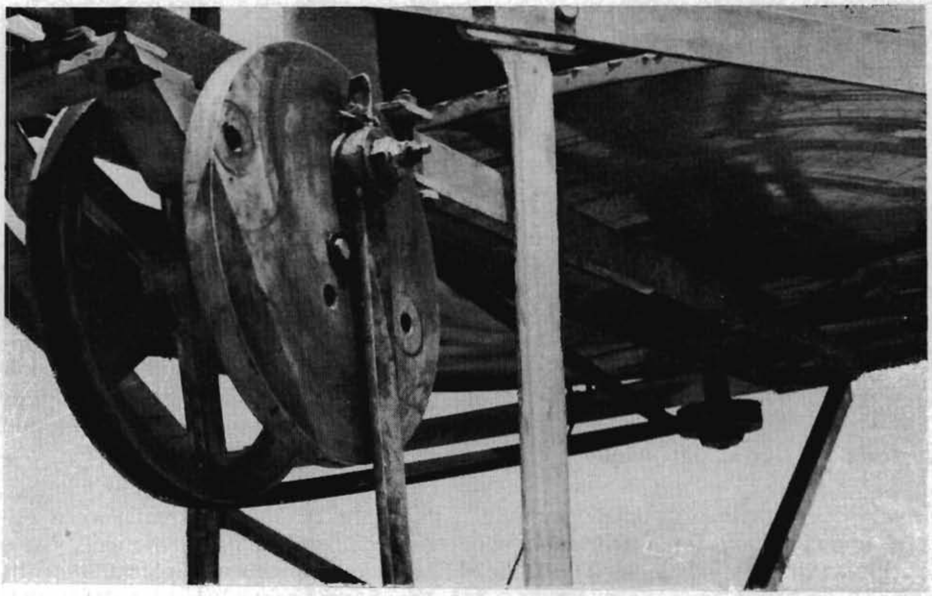
Improving the Carimagua windmill design, a modification of a wind machine (based on the Savonius rotor) developed by the Brace Research Institute of McGill University in Canada, has received limited attention. Included photographs show the mill and its power train as presently built by a Cali manufacturer. The tower was designed by the manufacturer.

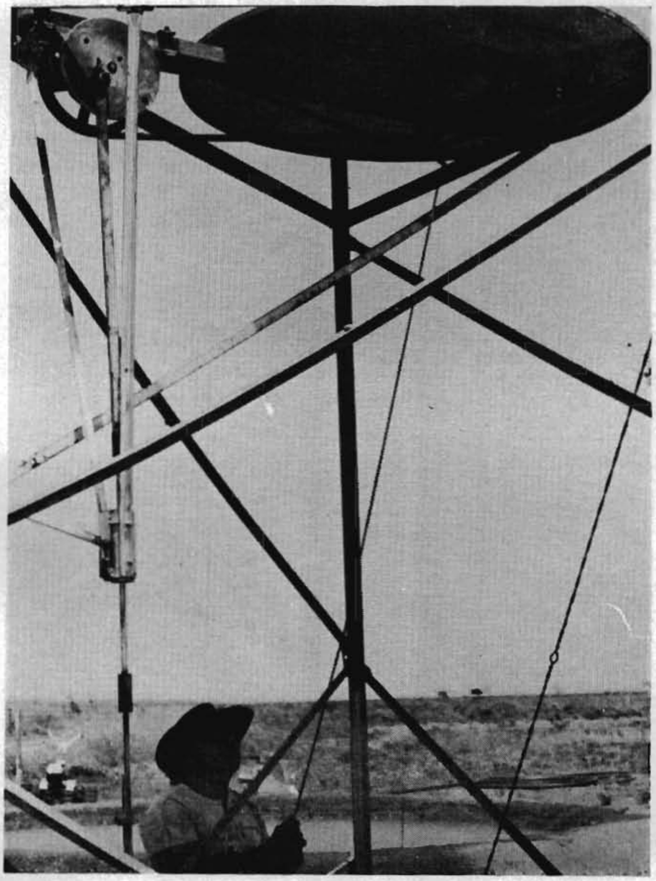
Experience with earlier models installed at Carimagua indicate a number of problem areas, such as:

1. Lack of dimensional stability, rigidity and durability of wooden cross members, leading to excessive vibration and wear of rotor bearing and power transmission train.
2. Excessive pumping frequency for windmill type piston pump, resulting in failure of lower check valve.
3. Need for automatic braking device to protect windmill from excessive wind speeds.

A prototype has been built using a v-belt twisting 90° from a small pulley (3½″) on the lower end of the rotor shaft to a large (10″) pulley on a short shaft to which an 8″ diameter eccentric is attached. The eccentric is centered over the well pipe and connects to the sucker rod with an articulated connecting rod. The upper end of the sucker rod passes through a guide to eliminate

Carimagua windmill mounted on 5.5 meter galvanized steel tower. Reservoir in foreground is formed using soil from well excavation





Eccentric is mounted on 6" jackshaft with 10 1/2" pulley. Rotor shaft is fitted with 3½" pulley. V belt is 5/8" (B), 96" long

V-belt is used to transmit power from rotor to eccentric, with three to one speed reduction. Plastic bushings are used as guides for upper end of sucker rod lateral movement. It is hoped that this system will reduce vibration greatly. If successful, it will reduce the pumping frequency by a factor of three and allow a much longer stroke.

The potential advantages of the windmill are low cost, design simplicity, ready availability of parts, simple construction and installation, and low-cost maintenance. The disadvantages are its relatively low efficiency in converting potential energy into usable energy and lack of standardized, tested, commercial models.

Herd systems project at Carimagua

Life cycle beef cattle production systems are under study in Carimagua. Near optimum inputs of a variety of management improvements are being compared with prevailing practices and conditions. These inputs will be evaluated singly and in combinations in an attempt to find a method to greatly increase reproductive rate at a feasible cost. Variables under investigation include: Molasses grass **vs** native pasture; complete mineral supplementation **vs** salt; crossbreeding with San Martinero **vs** continual backcrossing to Zebu; molasses-urea supplementation during the dry season; and early **vs** normal weaning.

Complete data are taken on production, physiological and disease parameters, including those necessary for economic analysis.

Complete mineral supplementation

Large growth responses were obtained by complete mineral supplementation but only in the rainy season. In the dry season there was no difference between the supplemented and nonsupplemented herds.

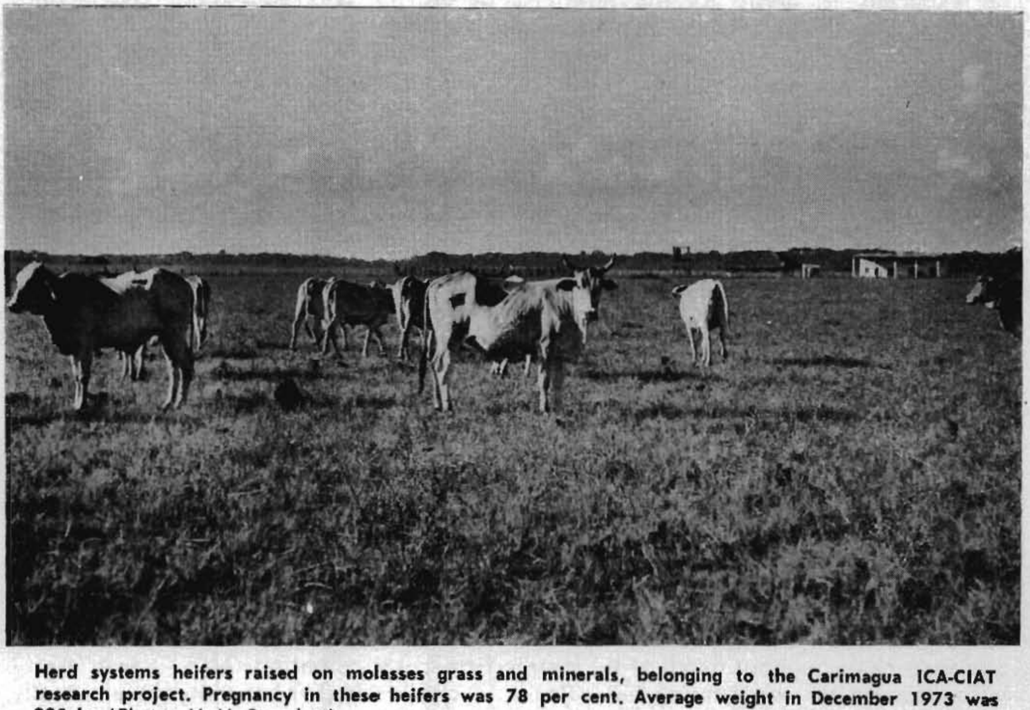
The more dramatic effects were apparent in breeding performance (Table 24). Average conception in four months for the herds receiving complete mineral supplementation was 70 per cent whereas it was 24 per cent for the herds not receiving minerals. A control herd which received the same treatment as the "salt only" herds had a conception rate of about 63 per cent almost equal that in the mineralized salt herds. The reason is not clear, but this latter herd had access to twice the area of native savanna (12.5 ha/

Table 24. **Preliminary results from ICA/CIAT herd systems project in 1972 - 1973 (as of December 11, 1973)**

Treatments	Herd	Heifer weight (kg)	Pregnancy in % (Oct., 73)	
Control*	1	307	63	
Native savanna-salt	2	289	31	) 24
Native savanna-salt	3	270	17	
Native savanna-minerals	4	334	68	) 70
Native savanna-minerals	5	332	71	
Native savanna-Molasses grass-minerals	6	325	58	) 60
Native savanna-Molasses grass Minerals	7	326	63	
Molasses grass-minerals	8	328	78	) 80
Molasses grass-minerals	9	335	81	

* Native savanna without improved management practices of cattle

Herd systems heifers on native savanna and salt, belonging to the Carimagua ICA-CIAT research project. Pregnancy in the heifers was 31 per cent after four months breeding. Average weight in December 1973 was 289 kg (Photo H. H. Stonaker)



Herd systems heifers raised on molasses grass and minerals, belonging to the Carimagua ICA-CIAT research project. Pregnancy in these heifers was 78 per cent. Average weight in December 1973 was 328 kg (Photo: H. H. Stonaker)

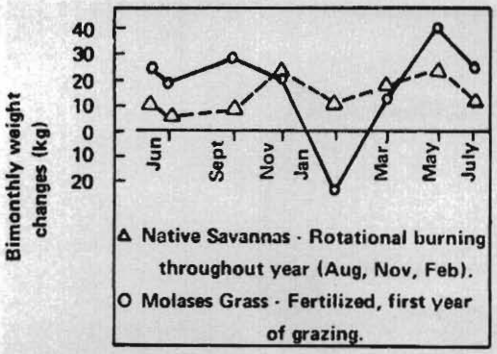


Figure 22.**Seasonal variations in available nutrition as measured by weight changes in heifers at Carimagua, calculated bimonthly from base zero (1972 – 1973).**

heifer) as did the experimental herds. Thus, there may be a response to having had access to greater areas of savanna than were provided for the other herds.

The response from providing minerals to virgin heifers cannot necessarily be expected to apply to the nursing cow, for the stress of milk production may uncover nutritional deficiencies other than minerals.

Native pasture vs. **Molasses grass**

In the first year, the large interactions between type of pasture and seasons indicate that Molasses grass pastures would be best used by the cow herd in the rainy season. Supplementation with urea-molasses hopefully might be an economical solution to avert the losses encountered on Molasses grass in the dry season.

Nutrition available during different seasons at Carimagua is reflected in weight changes as shown in Figure 22.

Supplemental feeding of the breeding herd

Marginal nutrition provided by native pasture throughout much of the year is inadequate for the nursing cow. Possible methods of ameliorating this situation are: 1) through use of lower wetter areas during the dry season, 2) provision for tropical forage legume based pastures which often provide a more nutritious forage than grasses, and 3) supplementation.

To this end, a short-term nutritional flushing of heifers was conducted; 56 heifers received molasses-urea supplement three times weekly, 56 others received cottonseed meal supplement. Preliminary analysis indicated little influence on pregnancy rate. The slight response is probably explained by the fact that supplementation occurred largely during the beginning of the rainy season when pastures were growing rapidly. Also, it is to be noted that a positive response might have been obtained in nursing cows which are under greater production and nutrition stress.

In followup of this and other work, provision has been made to determine the effects of urea-molasses supplementation during the dry season (December-April) on rebreeding and weight loss. Previous experience at Carimagua has indicated that body weight loss on molasses grass pasture is particularly great at this time. Urea supplementation may be a relatively low cost means for averting this problem so that the great advantage of molasses grass in the rainy season may be fully exploited.

Reproduction—Physiology

ICA personnel have monitored the reproductive status of the herds. Bulls in use were tested for satisfactory semen quality. Heifers were palpated at intervals of about six months to chart the status of ovarian development.

Breeding performance of Zebu and San Martinero bulls was observed daily for four months, using chin ball harnesses. This was a useful mechanism for early indicating the large differences in pregnancy subsequently confirmed by palpation. Also, it was useful to check whether all bulls were actually serving the cows.

Survey on small Llanos cattle farms

Llanos cattle farms are typically small. On an average, a farm markets fewer than 12 head per year. This would provide a gross cash annual income per family equivalent to about two laborers, assuming little or no out-of-pocket cost for the cattle enterprise. Only 8 per cent of the cattle farms would have 50 to 60 cattle to market annually, a gross product equivalent to the annual earnings of one Colombian Government professional at the doctoral level.

In collaboration with the Fondo Ganadero del Meta and ICA, a survey was conducted of 39 farms where cattle were leased to these farmers by the mentioned Fondo. Some of the preliminary findings indicate that estimated calving rate of 53 to 55 per cent was somewhat higher than generally reported (40 per cent). It was not appreciably higher in the Piedmont area than in the Llanos area, between Puerto López and Puerto Gaitán, even though pastures are distinctly different in species and carrying capacity. The distinct nature of the farms from the two areas is indicated in Table 25.

Preliminary information indicates a surprising similarity in cow productivity of the two areas. Distintive breeding seasons occur for the cattle even though bulls are not separated from the cows. Perhaps the most important failure in the production cycle is associated with the inability of the cows to rebreed while nursing calves. This narrows the focus on fertility and rebreeding in herd systems research at Carimagua.

At present, there is little wealth being produced from this vast area either for the country or for the inhabitants. Such fact provides an enormous challenge in increasing productivity and reflects on production potential.

TRAINING

Four research interns completed intensive training in pastures and forages. The main emphasis was in seed production. A fifth post-graduate intern received training in beef cattle production. Another postgraduate intern received training in pasture weed control while participating in the Livestock Production Specialist Training Program.

Two special trainees from the University of Wageningen, Netherlands, two from U.S.A., one from France and one from Colombia received training in tropical beef cattle production.

Table 25. **Data obtained on farms in which Fondo-ICA-CIAT collaborated (1973)**

Items studied	Piedmont	Meta
Contracts	20	19
Years occupancy	9.8 years	8.7 years
Owners in residence	16	10
Hectares	456	1,816
Cattle (Fondo)	98	95
Heifers and cows palpated	999	787
Nursing	43% (87% open) (13% pregnant)	37% (91% open) (9% pregnant)
Dry	57% (46% open) (54% pregnant)	63% (49% open) (51% pregnant)
Total pregnancy	36%	35%
Annual estimated calving rate	55%	52%
Modal breeding season:	Late February-May	November-January

Three students received postgraduate training in soil microbiology. Two of these (from Ecuador and Guatemala) will be the first from their respective countries to specialize in soil microbiology. A fourth student, from Ghana, will shortly complete the research work necessary for the doctoral degree.

Late in 1973, two research scholars from the animal health section entered the graduate school at the Universidad Nacional in Bogotá.

One research fellow completed his doctoral research in pastures and forages early in the year and now has the doctoral degree from Cornell University. A second research fellow, from Germany, began his doctoral research program in September, also in pastures and forages.

Animal health specialists established a collection of teaching material. Study sets of the histopathology of 22 diseases found in Latin America have been prepared and will eventually become available for issue to teaching institutions. The pathology section also has near completion a book in Spanish on histotechniques which may fill a need in Latin American laboratories. The color transparency collection now numbers some 2,000 photographs.

Livestock Production Specialist Training Program

The second Livestock Production Specialist Training Program was divided into five phases as follows:

1) An orientation-precourse examination period which served to establish a general academic level to which instructors could direct their lectures.

2) A two-month period of theoretical classes and laboratory exercises in preparation for the ranch phase. These classes were taught by the CIAT staff when the subject matter related to their field of work. Only in cases where subject matter was outside the realm of CIAT staff members were instructors from other institutions used.

The total number of course hours spent during the second phase was 328 hours, with approximately 30 per cent of the time devoted to field practices.

Just before going to the North Coast, the students spent one week in Buga, in the Departamento del Valle, attending a specialized farm machinery course in cooperation with SENA, * Massey Ferguson, and FAO.

3) The third phase (ranch phase) had a duration of eight months during which time the students lived on cooperating commercial ranches on the North Coast of Colombia (Departamento de Córdoba) with assignment of the following duties to perform:

a) A general description of the ranch

b) An evaluation of the ranch and preparation of a proposal for improving productivity (To be approved by training staff and ranch owner)

c) To attend semimonthly round table discussions and seminars at the ICA-CIAT Turipaná research station near Montería

d) To organize and carry out a Field Day at the end of the eight months with neighboring ranchers and other interested people of the area invited.

The eight cooperating ranches varied in size from 200 to 3,000 hectares. Seven of the ranches were located outside of the Sinú Valley since livestock operations in the valley are mainly fattening operations and not cow-calf operations and consequently are more desirable for training purposes. In five of these ranches, two students were assigned to each ranch (one veterinarian and one agronomist). This assignment proved to be successful as the two pro-

* SENA: Servicio Nacional de Aprendizaje, a Colombian vocational training institution.

fessions were complementary, and each learned many practices from the other's profession.

The Field Days were also successful as they provided the opportunity for the students to prepare visual aids and present the results of their work on the ranch to others, plus it forced them to review their experiences on the ranch and summarize their activities.

4) Course evaluation phase. Each student spent approximately one month at CIAT presenting a written report of his activities on the coast and participating in round-table discussions (by subject matter) with the CIAT staff members. A one-week trip was taken to Los Llanos Orientales of Colombia to visit a different ecological area where beef cattle production is also the main farm enterprise.

5) Home country phase. After receiving their certificates, the students returned to their respective countries to gather information and prepare a report which would be useful to them in developing ways to use their training. A copy of this report is forwarded to CIAT and will assist staff members in planning appropriate activities for supporting training within the home institution and country of each trainee.

The ranch reports prepared by the trainees living on each ranch have been reproduced, and copies were sent to all of the trainees for future reference. Also, a set of pertinent slides (which were taken during the year of training) have been sent to each trainee to be used as a teaching aid. Copies of all given lectures were also provided to each trainee as well as other printed reference material from various institutions in the Americas.

At the beginning of September, the third Livestock Production Specialist Training Program was started with 18 trainees from the following countries: Bolivia (3), Colombia (3), Dominican Republic (3), Ecuador (2), El Salvador (1), Paraguay (3) and Perú (3).

The third livestock production course is patterned after the second; however, the theoretical portion was expanded 15 days to allow more time for field training and research experience while still at CIAT headquarters.

During April and May, 11 senior-year students from the Universidad Nacional School of Veterinary Medicine, Bogotá, received two months of in-field training from the CIAT livestock production training staff. These students lived on the same ranches used for the production specialist course during this time. In August and September, 16 more senior-year students from the Universidad Nacional received similar training for the same period of time. This additional training amounted to 54 man-months of training in addition to the Livestock Production Specialist Training Program.

OUTREACH

Outreach activities have included visits to Latin America and other areas to identify trainees, establish professional and institutional contacts and to collaborate in research and training projects.

CIAT continues to participate in the collaborative pastures and forages introduction and evaluation project including pastures and forages programs from Bolivia, Brazil, Colombia, Ecuador, Perú, Venezuela, IICA and CIAT.

The beef cattle team acts in an advisory capacity to the INIAP Beef Cattle Program; the Forage Legume Program of the University of the West Indies in the Caribbean; certain aspects of the IVITA program in Pucallpa, Perú; pastures and forages program of the Bolivian Ministry of Agriculture in Santa Cruz; and to other agencies as assistance is requested.

The soil microbiology group has sent inoculants for legumes to Colombia, Belize, Costa Rica, Ecuador, Perú and Bolivia. Also, this group continues to publish a listing of current research articles and of training courses and seminars which is now distributed to 46 Latin American scientists.

Collaborative research and training projects are carried out with the Instituto Colombiano Agropecuario (ICA), Texas A&M University/USAID in hemoparasite diseases and Wageningen University, in tropical animal husbandry.

Papers were presented at meetings of the American Society of Animal Science; Latin American Association of Animal Production; American Society of Agronomy; Third Colloquium on Soils, Colombian Soil Science Society; Pan American Veterinary Congress; Peruvian Society of Forage Specialists and Researchers; International Symposium on Animal Production in the Tropics at Ibadan, Nigeria.

Visiting scientists have come to CIAT from Texas A&M (veterinary medicine), Wageningen (tropical animal husbandry), Bolivian Ministry of Agriculture (pastures and forages) and INIA in Chile (animal husbandry).

Cassava

production systems

Yields above 50 ton/ha per year have been achieved in unreplicated yield trials and more than 46 ton/ha on larger scale replicated plots. The varieties capable of these levels do not have high disease and insect resistance; however, sources of resistance to most of the major diseases and pests have been found.

Breeding techniques have to a large extent been worked out, and controlled crosses are being made so as to combine useful characters. At the same time, the germ plasm bank is being evaluated for useful varieties and parents for future crosses.

The devised rapid field method of propagation will allow prompt increase of promising varieties. This system also produces planting material free of the cassava bacterial blight which is spread from area to area by infected cuttings.

In economics, a survey has shown that weed control is one of the major labor-using operations in cassava production. Weed control trials have shown that at higher plant populations, less intense weed control may be needed or when weed control is intense, lower densities can be planted.

The economics survey also shows that, as anticipated, thrips are a major problem in cassava growing in Colombia and that the majority of farmers grow cassava as a monoculture, not as a mixed crop.

Simple on-farm methods of storage are being developed, and cassava roots have been kept for up to eight weeks with little decline in quality.

The basic drying characteristics of cassava have been defined, and design of practical equipment to facilitate the process on the farm is under way.'

The cassava documentation center has now collected about 3,000 documents and more than 1,500 have been fully processed. Abstracts are being distributed world wide.

Joint projects were set up with several universities and other institutes to study such items as protein enrichment using microbial fermentation (University of Guelph), world cassava market prospects (University of Guelph), chemotaxonomy of cassava (McGill University), and tissue culture (National Research Council, Saskatoon). These joint projects utilize specialized skills present at these locations, that CIAT does not possess.

The program had trainees from Africa and South America.

PLANT PHYSIOLOGY

Growth cycle of the plant

CMC 84 was planted at 1 x 1 m and left to grow as if it were a commercial crop. Harvests were taken at intervals to describe the growth pattern of the crop. Total root yield increased rapidly from 3 months to about 12 months and then increased at a slower rate. Thick root number was rather variable but remained between seven through nine thick roots per plant from 3 months to 20 months. Hence, the plant does not apparently produce more thick roots with time, but increases the size of those present (Figure 1).

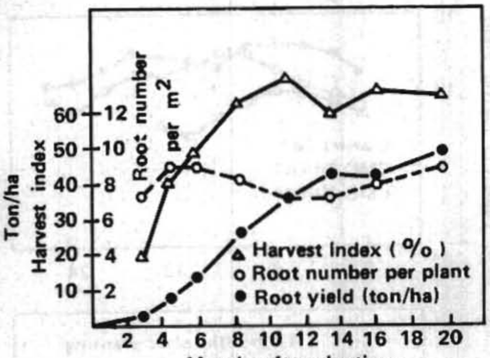


Figure 1. **Growth pattern of CMC 84 with time (cooperative work with ICA)**

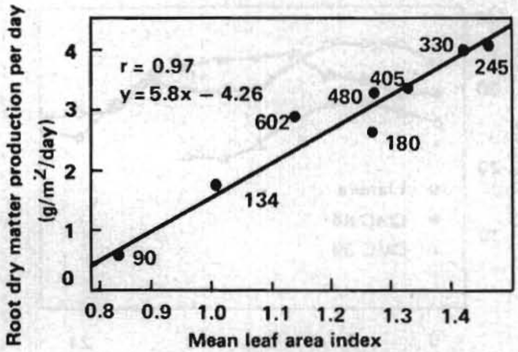


Figure 3. **Root dry matter productions per day as a function of mean leaf area index; numbers refer to days from planting to harvest (cooperative research work with ICA)**

Leaf area increased up to six months after planting (Figure 2). The small drop in leaf area index at 4½ months was due to sudden defoliation by a hailstorm. After six months, leaf area index (LAI) declined rapidly and during the last nine months of growth was between 0.6 and 1.2. This is far below the ceiling LAI of cassava.

Total dry matter production increased rapidly from three to eight months while LAI was large (Figure 2) and less slowly afterwards. Harvest index increased up to about eight months and then remained constant (Figure 1); hence, increases in root dry matter yield were similar to those in total dry matter production after eight months (Figure 2).

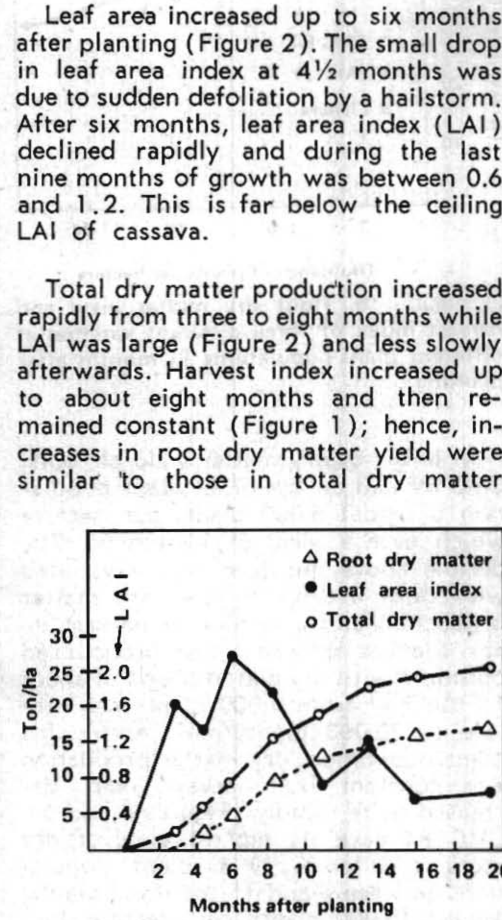


Figure 2. **Growth pattern with time of CMC 84 (cooperative work with ICA).**

The efficiency of dry root yield production in terms of time (i. e., root dry matter production per day) was extremely closely correlated with the mean leaf area index during the growth period (Figure 3). This suggests that in this particular variety the major factor limiting root yield was a lack of sufficient leaf area index.

Plant population studies

CIAT's 1972 Annual Report details spacing trials of the varieties CMC 84, Llanera, and CMC 39 up to seven months after planting. Since then, a final harvest after eleven months was made. After seven months, there was a pronounced optimum plant density in all varieties. By 11 months after planting, the optimum was less pronounced and plant population was higher than at seven months, CMC 84, a medium-height type with few branches, had a higher optimum plant population (about 10,000 plant ha^{-1}) than Llanera – a medium-height, very branched type– and CMC 39 –a tall type– which had an optimum population of about 5,000 plants (Figure 4). CMC 39 lodged severely at higher plant populations, and this undoubtedly contributed to the extremely rapid yield drop.

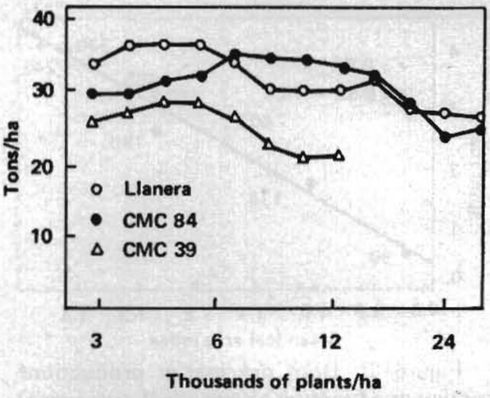


Figure 4. **Fresh root yield of three varieties at different plant populations.**

Total dry matter production varied, but that of CMC 84 and Llanera increased with increasing plant population (Figure 5), and then reached a plateau. CMC 39 had an optimum plant population for dry matter production of about 6,000 plants ha^{-1}.

Harvest index declined as plant population increased. The decrease was most marked in CMC 39; it only occurred in CMC 84 above a plant population of about 15,000 plants per hectare (Figure 6). The results from Llanera were somewhat variable but showed the same trend.

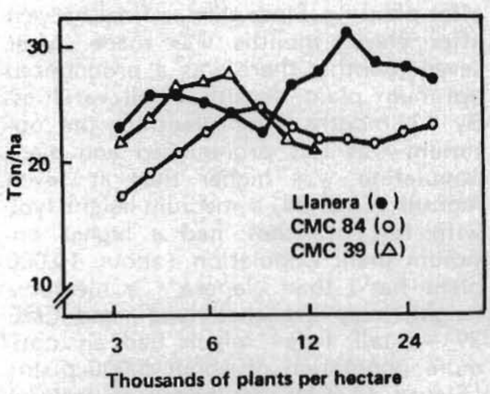


Figure 5. **Total dry matter yield of three varieties of cassava after 11 months at different plant populations.**

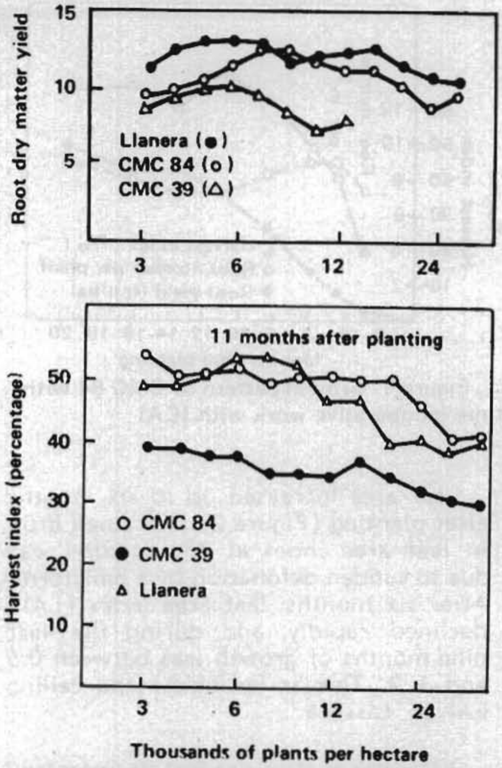


Figure 6. **Root dry matter yield and harvest index of three different varieties at different plant populations 11 months after planting.**

In terms of dry matter yield of roots, CMC 39 had an optimum plant population of about 6,000 plants per hectare which gave a yield of 11 ton/ha. The decline above this level was associated with both a drop in total dry matter production and a decline in harvest index. Llanera showed a less pronounced optimum with dry matter yields of about 13 ton/ha^{-1} from 4,000 plants per hectare to 20,000 plants/ha^{-1}. Above this plant population, dry matter production was constant but harvest index decreased quite rapidly (Figures 5 and 6). CMC 84 gave its highest yield of dry roots (12 ton/ha^{-1}) at plant populations between 6 and 15 thousand plants. Above 15,000 plants per hectare, ha^{-1} harvest index declined rapidly decreasing root dry matter yield.

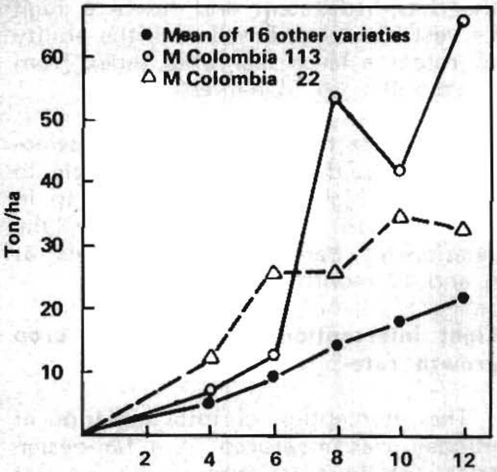


Figure 7. **Root fresh weight of M Colombia 113, M Colombia 22 and mean of 16 other varieties.**

As plant population increased, root number increased in a similar manner for all varieties, while weight per root decreased. Thus, if a particular root size is required, plant density can be manipulated to give the required size.

Varietal characteristics

Forty-four varieties were planted in unreplicated plots at 0.7 x 0.7 m using two-node cuttings for rapid multiplica-

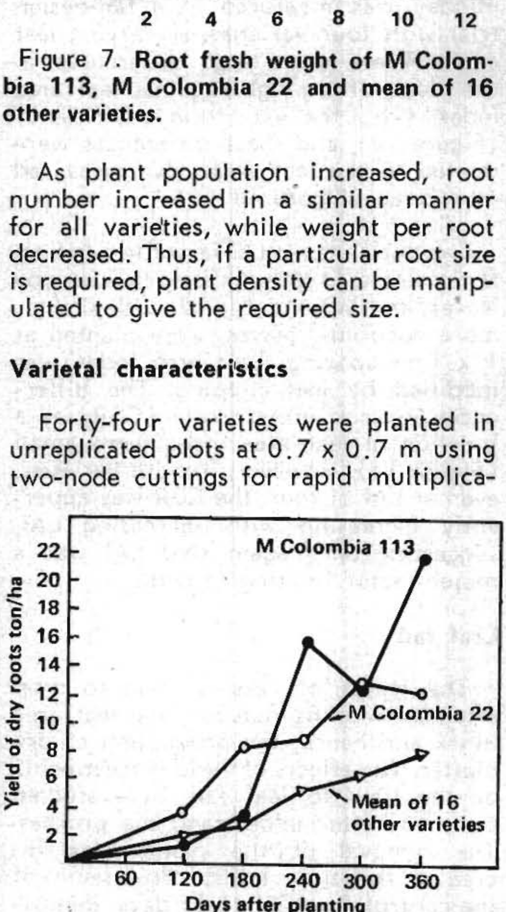


Figure 8. **Changes in root dry matter with time of M Colombia 113 and M Colombia 22 compared with the mean of 16 other varieties**

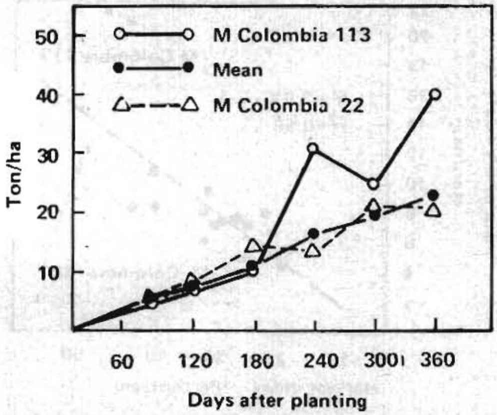


Figure 9. **Changes in total dry matter of M Colombia 113, M Colombia 22 and the mean of 16 other varieties.**

tion. Harvests were taken at four, six, eight, ten and twelve months from 20 plots (Llanera was repeated three times). The two highest yielding varieties, M Colombia 113 (66 ton/ha/year) and M Colombia 22 (32 ton/ha/year), were compared with the mean results of the other 16 varieties.

M Colombia 22 produced a high early yield (26 ton/ha) after six months while M Colombia 113 (12½ ton/ha) was only slightly better than the mean of 9½ ton/ha (Figure 7). However, from 6 through 12 months, M Colombia 22 showed a small yield increase (6.4 ton/ha) while M Colombia 113 increased by 53.2 ton/ha in comparison with the mean of 12.5 ton/ha for the other 16 varieties.

The dry matter yield showed a somewhat similar trend (Figure 8) to that of fresh roots reaching a level of 21.6 ton/ha of dry matter in the case of M Colombia 113 in one year.

M Colombia 22 produced no more total dry matter than the mean of the other varieties at any stage (Figure 9). Hence, it produced a high yield because of a higher harvest index (57 per cent) as opposed to 36 per cent for the mean. From Figure 9 it can be seen that there

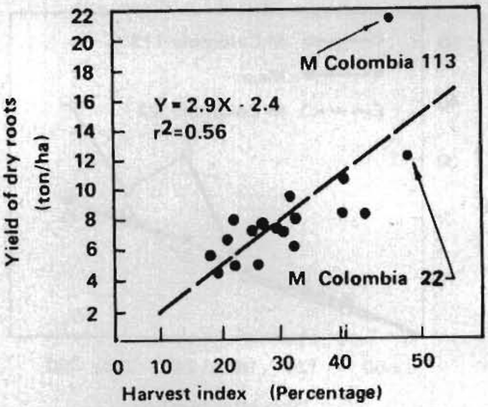


Figure 10. **Relationship between yield of dry roots and harvest index 360 days after planting.**

is a loose relation between yield and harvest index. The high yield of M Colombia 113 is due to a combination of a high harvest index with a high total dry matter production (Figure 10). Up to six months, both dry matter yield and leaf area index for M Colombia 113 and the mean were similar (Figure 11). However, in the other varieties, after six months, there was a large amount of leaf fall, whereas M Colombia 113 had very good leaf retention (Figure 11).

It appears that to obtain a high yielding type we need a short variety, one that has little stem and hence a high harvest index combined with the ability to retain a large leaf area index from six months up to harvest.

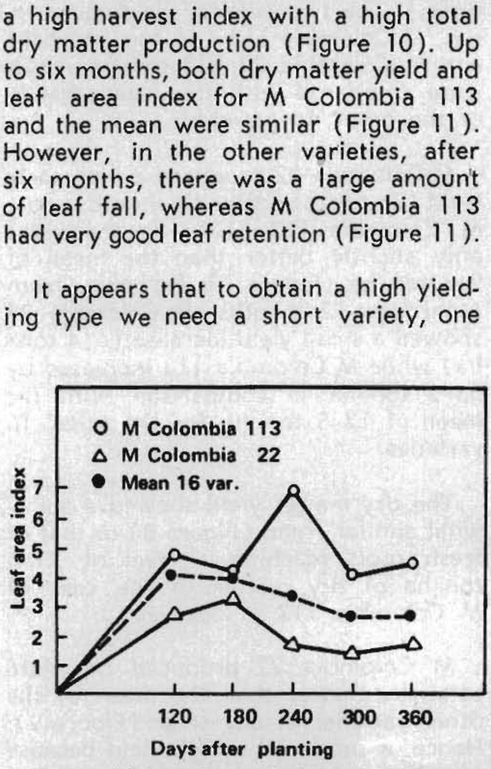


Figure 11. **Leaf area index of M Colombia 113 and 22 compared with the mean of sixteen varieties.**

To reduce the time devoted to selection, it would be useful to be able to select for high yielding types early in their growth cycle. Unfortunately, the relationship between dry root yield at 6 and 12 months is very low.

Light interception leaf angle and crop growth rate

The interception of total radiation at midday was measured in a fan-design trial with four varieties of varying leaf angle. There were large differences in the slope of log light against leaf area index (i.e., the extinction coefficient) (Figure 12), and these differences were related to the leaf angle also measured at midday (Figure 13).

Two varieties with different leaf habits, M Colombia 1148, with long thin droopy leaves, and M Colombia 12, with shorter more horizontal leaves, were planted at 1 x 1 m spacing. Leaf area index was modified by leaf clipping. The differences in crop growth rate (CGR) as a function of leaf area index were small (Figure 14). However, in both varieties, even at LAI of four, the CGR was apparently increasing with increasing LAI, suggesting once again that LAI was a major factor limiting growth.

Leaf fall

The leaves of cassava tend to drop after six months reducing the leaf area index and hence, the production of dry matter. The effects of various treatments on the time to leaf fall were studied so as to better understand the process. The removal of the plant apex increased the time to leaf abscission of the controls from 38 to 55 days. Removal of the apex in other species frequently delays senescence. Covering leaves with silver paper to prevent reception of light hastened leaf fall. Similarly,

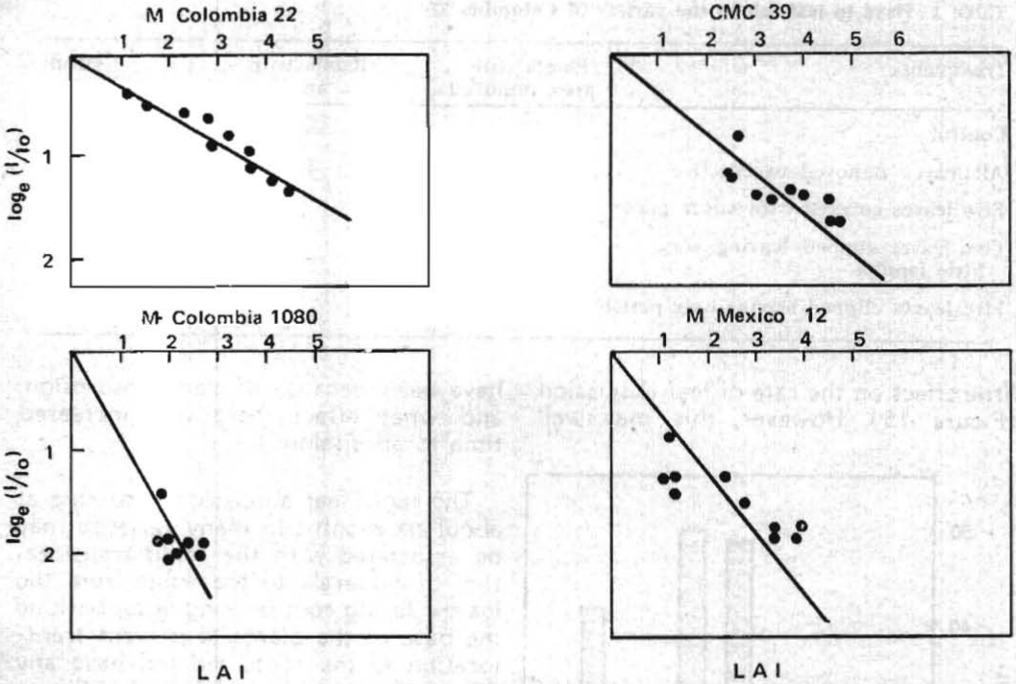


Figure 12. The relation between light interception and leaf area index (LAI) for four varieties of cassava (Io is radiation above crop, I is radiation below crop)

removing the laminae or a part of them increased rate of leaf fall. However, clipping all the upper leaves to allow the entry of more light to the remaining leaves had no effect on rate of leaf abscission (Table 1).

When different areas of leaf were left uncovered, the time to leaf abscission increased with increasing area uncovered (Figure 15). Application of 1,000 ppm of IBA in lanolin to the petiole had very

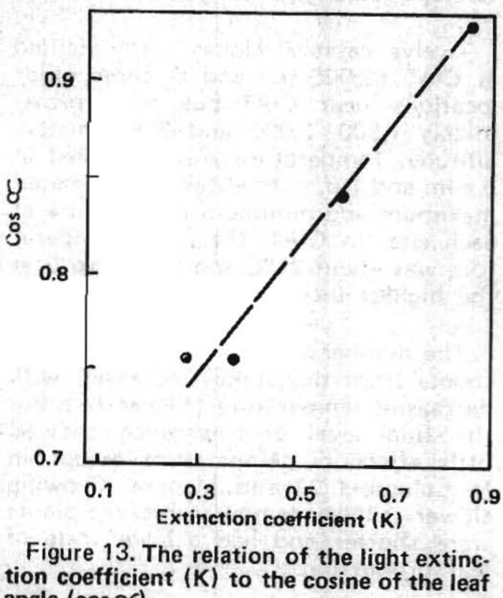


Figure 13. The relation of the light extinction coefficient (K) to the cosine of the leaf angle (cos ∝).

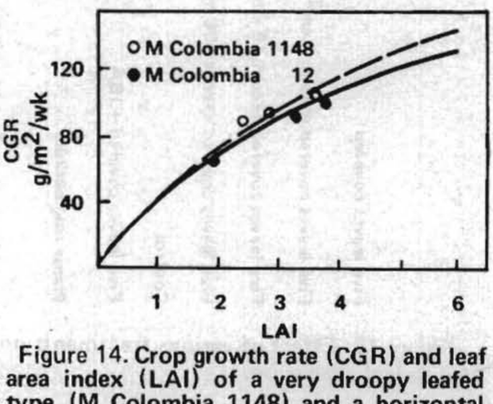


Figure 14. Crop growth rate (CGR) and leaf area index (LAI) of a very droopy leafed type (M Colombia 1148) and a horizontal leaf type (M Colombia 12).

Table 1. **Days to leaf fall in the variety M Colombia 32**

Treatments	Plants with apex removed	Plants with apex	Mean
Control	55	38	46.5
All leaves removed except five	58	32	45.0
Five leaves covered with silver paper	9	8	8.5
Five leaves clipped leaving very little lamina	18	17	17.5
Five leaves clipped leaving only petioles	7	7	7.0

little effect on the rate of leaf abscission (Figure 15). However, this may well have been because of poor absorption, and what effect there was increased time to abscission.

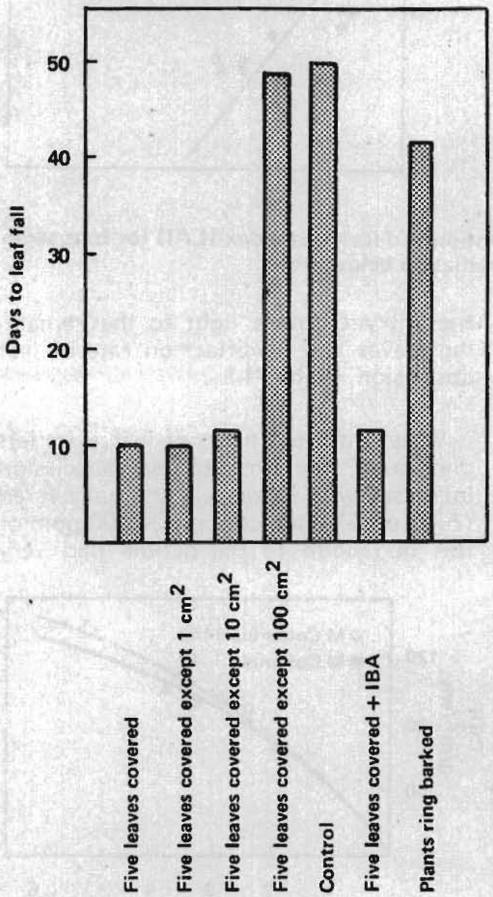


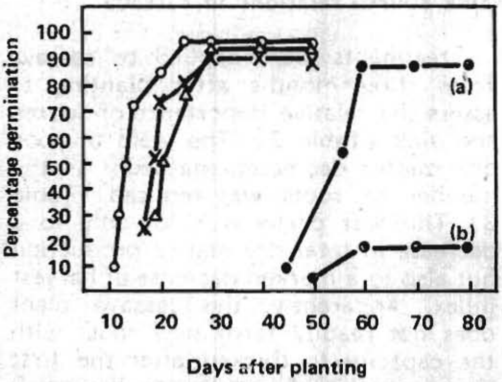
Figure 15. **Effect of various treatments on time to leaf abscission.**

The rapid leaf abscission occurring at about six months in many varieties may be associated with the rapid translocation of minerals to the roots from the leaves during root bulking. Ring barking the base of the plants to prevent translocation to the roots did not have any effect on rate of leaf abscission (Figure 15), suggesting that leaf fall is not directly caused by a sudden translocation of minerals from the leaves to the roots.

Photoperiodic and temperature effects

Twelve cassava clones were planted at CIAT (1,000 m) and at three other locations near CIAT but at approximately 1,500, 2,000 and 2,300 meters altitude. Temperature was measured at 6 a.m. and 1 p.m. to obtain an estimated maximum and minimum temperature at each site. In CIAT, the mean temperature was about 26°C and fell to 16°C at the highest location.

The number of days to emergence of shoots from the stakes increased with decreasing temperature (Figure 16), but the final level of emergence showed little effect of temperature except in M Colombia 22 and Llanera. Growing slower at lower temperatures, the plants were shorter and had a lower rate of leaf production.



a) Average of 10 clones;
b) Average of M Colombia 22 and Llanera

* Meters above mean sea level:

o 1.000	△ 2.000
×1.500	• 2.300

Figure 16. **Germination of cassava at four different altitudes.**

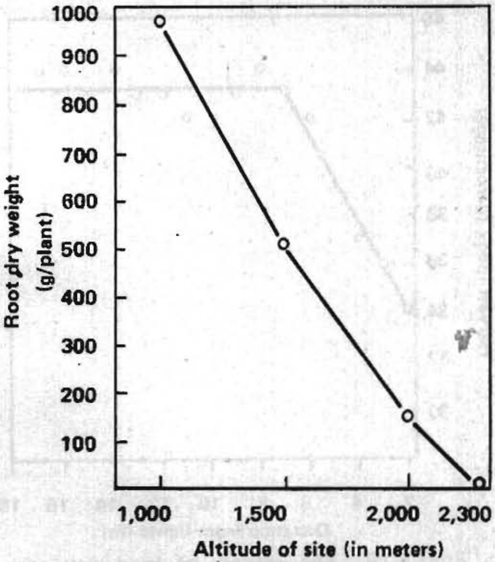
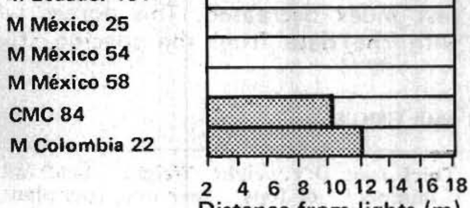


Figure 17 **Effects of temperature on cassava yield. Mean of 12 varieties.**

The final yield of roots after nine months showed a marked decline with decreasing temperature. With mean temperature below 20°C, the value of cassava as a crop must be limited (Figure 17).



Shaded areas indicate flowers present. (Order of varieties is for clarity only. In the field, there was no obvious pattern to the flowering response).

Figure 18. **Flowering response of twelve varieties as affected by the distance from lights giving a 15 hour/day exposure (plants were nine months old)**.

The same twelve clones were grown under a 15-hour day at CIAT to observe general effects of long days on cassava. Cassava flower initials are produced in the axils of branches on the main stem. These flower initials frequently abort very early in their growth. Time to flower initiation (measured by number of nodes to the first and second branches) was not affected by the long days. However, the number of fruits formed was markedly affected by photoperiod, some varieties producing more and others less fruits on long days (Fig. 18). Hence, in a breeding program, changes of day length may be useful to increase fruiting in certain varieties; however, it does not change time to floral initiation.

Past work in the greenhouse had indicated that cassava produced less root yield on long days. This was confirmed in the field by our results (Figure 19). The decrease in yield was not due to a decrease in root number, but rather to a decrease in their size. Varieties to be grown in the more extreme latitudes of the tropics should be tested for photoperiod response.

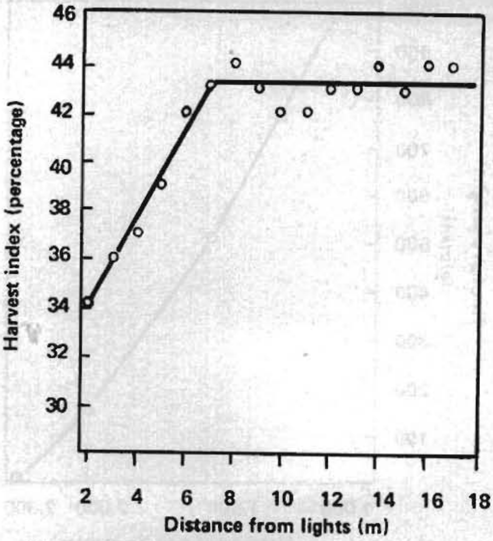


Figure 19. **The effects of long days on harvest index. Mean of 12 varieties (nine months after planting).**

Table 2. Treatments used with CMC 84

1. Control
2. One half of thickened roots cut at three months
3. One half of thickened roots cut at three months and the other half at 3 ½ months
4. Apex repeatedly cut from three months until final harvest
5. Half of leaves removed from three months onwards
6. Plant shaded to 50 per cent natural light from three months to harvest.

Sink source relations in cassava

Treatments were applied to cassava from three months after planting to assess the relative importance of source and sink (Table 2). The yield of root dry matter decreased markedly as the number of roots was reduced (Table 3). This was partly due not only to a decrease in total dry matter production but also to a marked decrease in harvest index. Apparently, the cassava plant does not readily form new roots with the capacity to thicken after the first three months of growth as the small number of roots (two per plant) in the "all roots cut" treatment shows. Also, the apparent lack of effect of the other treatments on final thick root number suggests that this number is fixed early and that, if there are not sufficient large roots, yield will decline.

Both the shading treatment and the leaf clipping treatments decreased yield showing that not only is sink important but also the source. The relatively small yield decrease as a result of leaf clipping is probably due to less leaf fall in this treatment. This suggests that the main problem in increasing leaf area index in cassava may not be one of leaf production but rather of leaf retention.

When plants were shaded, the top weight was not decreased, but the harvest index decreased. This agrees well with the data from the spacing study

Table 3. Yield components of sink source trial with CMC 84

	Yield of dry roots (ton/ha)	Harvest index	Thick root number/ plant	Dry weight of tops (g/plant)	Weight per dry root (g)	Leaf fall (per plant/ week)
1. Control	14.0	49	9.4	1,420	152	18
2 ½ roots cut	8.6	43	6.6	1,090	129	11
3. All roots cut	1.6	14	2.0	780	63	22
4. Apex cut	10.6	54	8.4	900	125	8
5. ½ leaves cut	11.9	56	8.1	950	150	5
6. 50 per cent shade	8.4	39	9.1	1,350	96	13

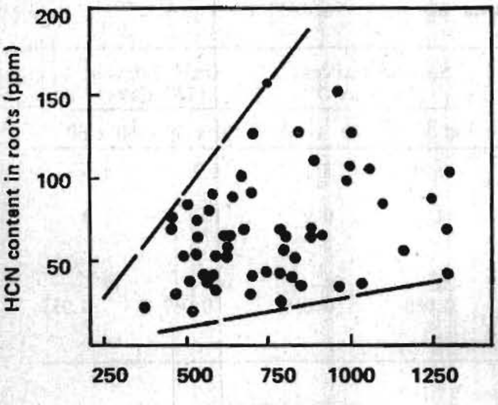


Figure 20. Relation between leaf and root cyanide content of 61 clones

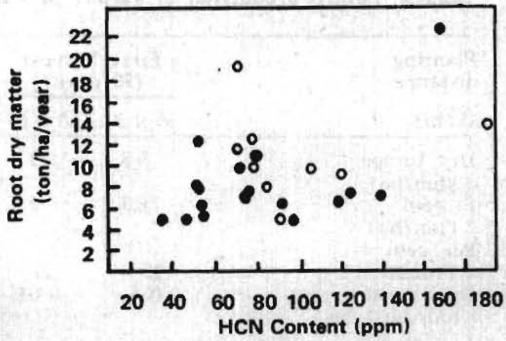


Figure 21. Relationship between root yield (dry matter) and cyanide content of different clones. Data from two separate trials.

showing that with more competition there is a less favorable dry matter distribution.

Cyanide content

During the year 1973, the germ plasm bank was screened for zero cyanide levels. No zero types were found. To screen for low cyanide levels, it is much easier to test the leaf content than the root content of seedlings; however, the relationship between leaf cyanide content and root cyanide content is rather loose, suggesting that this method may allow a large number of escapes (Figure 20). Nevertheless, from the 61 clones tested the lowest in leaf cyanide (380 ppm) was third lowest in root cyanide (23 ppm), and the second lowest in leaf cyanide (410 ppm) was lowest in root cyanide (10 ppm).

It is frequently suggested that sweet low cyanide types yield less than the bitter types. The results from two trials are presented in Figure 21 and show that apparently there are varieties that have both high yields and low cyanide content.

Yield trial

Nine varieties were planted in a replicated yield trial. Results are presented in Table 4. As was mentioned in

Table 4. Results of variety trial after one year

Variety	Yield (ton/ha)	Dry yield (ton/ha)	Per cent dry matter	Cyanide content (ppm)
M Colombia 22	46.4	19.1	40.8	62
CMC 84	40.8	14.3	35.1	194
Llanera	35.0	12.1	34.4	69
Llanera roja	28.8	9.9	34.2	70
M Colombia 65	29.0	11.6	40.0	62
M Colombia 645	25.8	9.6	36.3	96
Extranjera	24.6	8.0	32.5	76
M Colomba 463	23.3	9.1	39.0	110
M Panama 64	16.5	5.0	37.9	82

Table 5. Forage production of variety M Panama 31

Planting distance	First harvest (90 days)		Second harvest (163 days)		Only harvest (120 days)	
(cm)	30 x 30	60 x 60	30 x 30	60 x 60	30 x 30	60 x 60
Dry forage (ton/ha)	5.8	3.1	6.0	5.1	8.2	6.6
Protein (ton/ha)	1.3	0.7	1.2	0.9	1.3	1.3
Per cent Protein	22	22	20	18	16	19
Dry matter $ton/day^{-1}/ha^{-1}$	0.065	0.035	0.080	0.068	0.069	0.055

CIAT's 1972 Annual Report, M Colombia 22 appears to be a promising variety, with many useful characteristics. This variety is easy to harvest, has a high dry matter content and a low cyanide level. The dry yield of more than 19 ton/ha in a year shows that cassava is an efficient producer of carbohydrates.

Forage production

Cassava tops are used in some countries as food (e.g., Zaire and Brazil) and in Brazil, as animal nourishment. A preliminary trial to investigate the potential productivity of cassava tops was planted at two spacings 0.3 x 0.3 and 0.6 x 0.6 m using the variety M Panama 31. The whole top portion was collected for each harvest. Samples were taken in some plots after 90 and again 173 days after planting, when regrowth had occurred. Another set of plots were harvested at 120 days.

Yield data are presented in Table 5. The yields of protein are high, particularly at 0.3 x 0.3 m with two harvests. It is apparent that by delaying the first harvest there is no increase in protein yield because of a decrease in protein level. Closer spacings consistently gave the highest yields of dry matter and protein.

Cassava may have a potential as a forage production crop, but more studies are required to determine the nutritive value.

PROPAGATION*

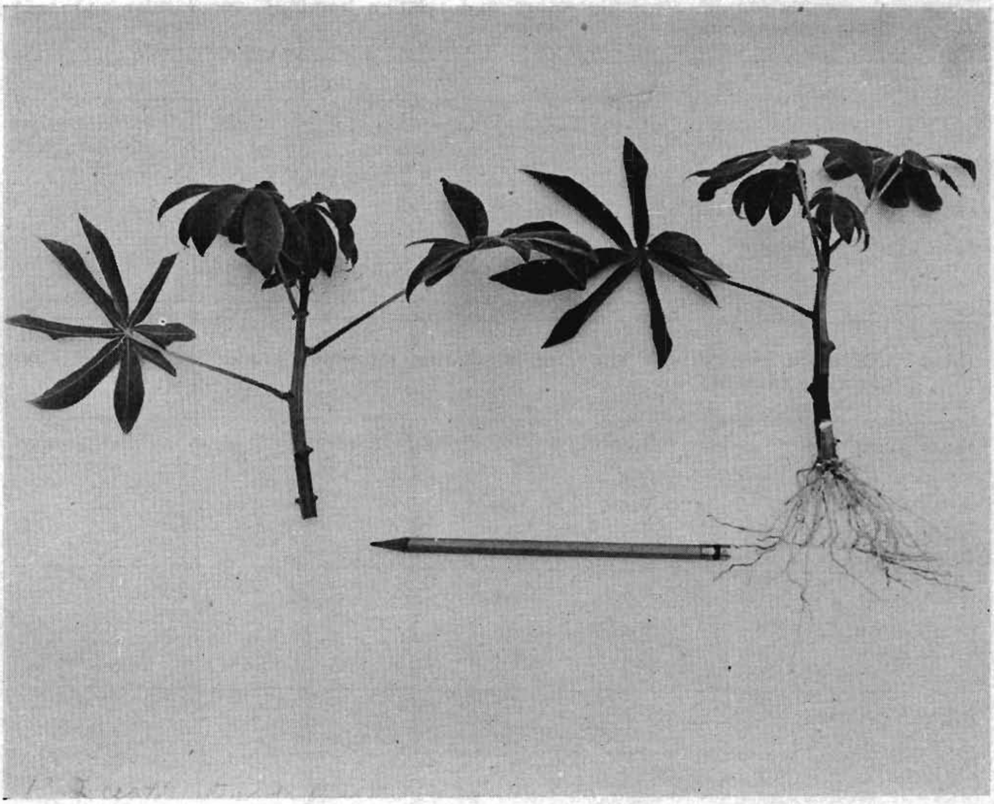
Green shoot cuttings

A system for the rapid propagation of cassava using green shoots as cutting has been developed. Experiments performed under automatic intermittent mist showed that 8-cm green shoots produced from horizontally planted mature stem cuttings rooted easily (Photo page 71). Although under these humid conditions a high proportion of the nodal buds developed into shoots, apical dominance prevented the growth of many of these into shoots large enough to use for cuttings. Experiments showed that the best way of overcoming this problem was to use short sections of stem, each with two nodes. In this way, the greatest efficiency in terms of green shoots per nodal bud was obtained.

Shoot regrowth

The green shoots were removed with a razor blade sterilized in 3 per cent hypochlorite leaving a stump 1 cm long. From this stump, regrowth occurred producing further green shoots. This process of cut and regrowth could be repeated until the reserves of the stem were exhausted. Investigations using two-node stem cuttings showed that suf-

* These studies are part of a PhD thesis to be submitted to the University of the West Indies, Trinidad and Tobago, by D. W. Wholey, a CIAT research fellow.



Cutting before and after rooting under mist

ficient major nutrients (N, P, and K) occur in the stem tissue to support green shoot production at a constant rate of one shoot per node every three weeks. After sixteen weeks, an efficiency of more than four green shoots per node was attained.

Propagation environment

Mist propagation facilities are expensive to install and require a reliable supply of electricity and water. The quality of the water is important as high salt concentrations kill cuttings. A propagation frame was developed incorporating a polyethylene roof over a bed, walled in with hollow water-filled concrete blocks (See photo page 72). The humidity within the frame was similar to that under mist (Table 6). The temperature was higher, but 45°C at midday did not damage the plants. Faster shoot production occurred in the propagation frame (Table 7).

Rooting green shoot cuttings

Under mist, roots appear from the basal end of green shoot cuttings 10-12 days after planting. After seven days, the root development is sufficient to allow transfer into soil-filled peat pots (See photo page 73). Ten days later the rooted cuttings can be transplanted into the field.

Green shoot cuttings root easily in the propagation frame. Sterilized sand or soil with good aggregate structure which

Table 6. **A comparison of air temperature and relative humidity under mist and in a propagation frame**

	Air temp °C		Relative humidity (%)		
	Max	Min	Max	Min	Hours/day with R. H. 80%
Mist	32.3	20.2	96.0	42.5	14.0
Propagation Frame	45.1	22.8	99.0	39.5	15.5

Table 7. **Effect of environment and size of cutting on shoot production after 40 days (variety Llanera)**

Cutting size	Intermittent mist	Propagation frame	Mean of environment
1 node	0.9*	1.1	1.1
2 node	0.7	1.4	1.1
10-cm long	0.5	0.9	0.7
20-cm long	0.5	0.9	0.7
Mean	0.6	1.1	0.9
L S D (P=0.05)	Between cuttings = 0.22 Between environment = 0.15		

* Shoots per node

The cassava propagation system being used at CIAT

Shoot cutting ready to be planted in the field

allows sufficient aeration provides adequate rooting media. It is easier to plant directly into sand-filled peat pots; the cuttings root rapidly and the roots perforate the peat pots after 15 days. These can then be transferred directly to the field.

Field establishment of rooted cuttings

Experience has shown that if the cuttings have adequate moisture during the two weeks after planting in the field, more than 90 per cent survive. This system is used at CIAT for the rapid propagation of cultivars from the germ plasm bank to provide planting material. It is not recommended to use shoot cuttings directly for yield, but rather for production of planting material.

Propagation rate

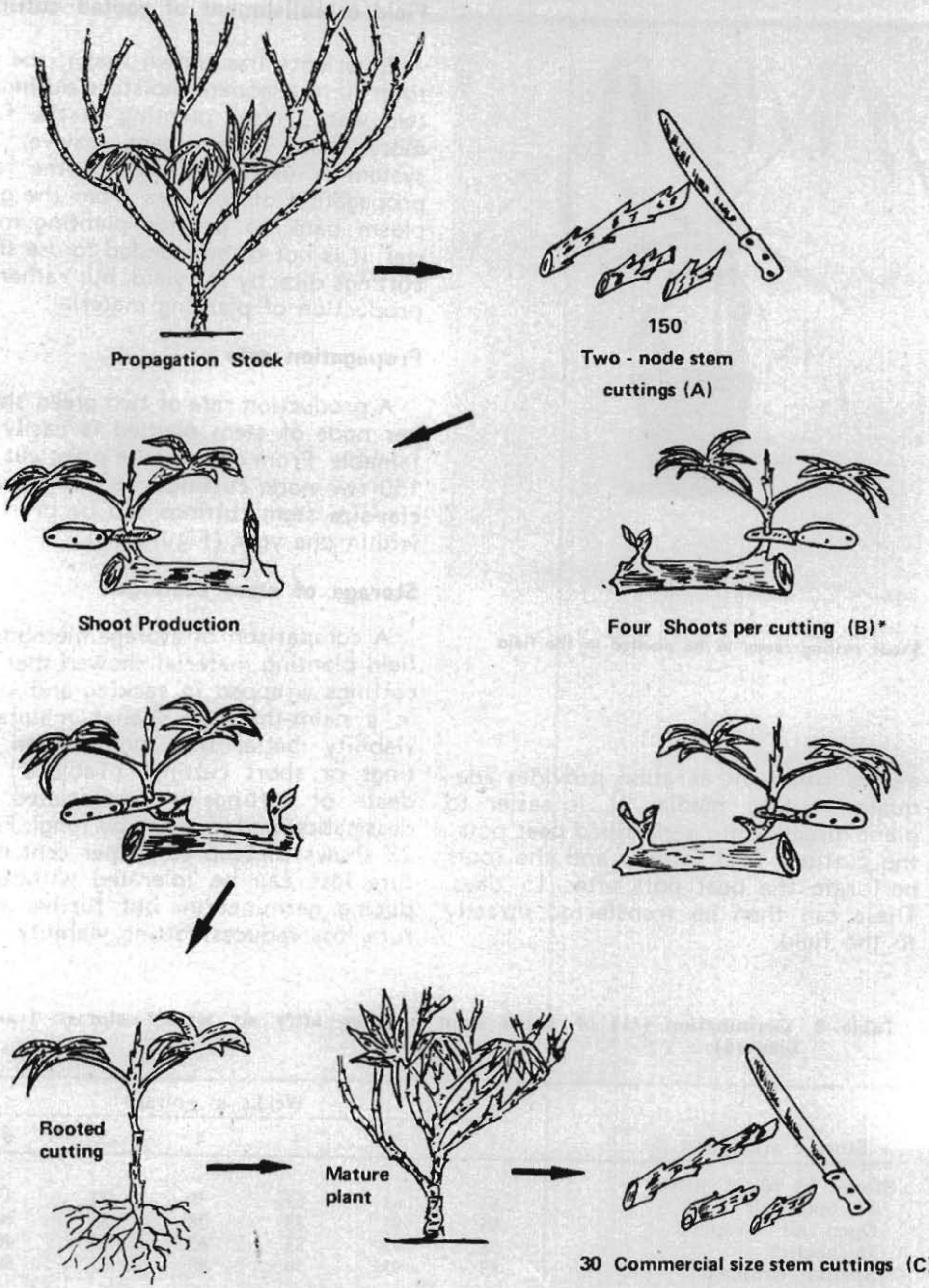
A production rate of two green shoots per node of stem planted is easily obtainable. From one mature plant cut into 150 two-node cuttings, 18,000 commercial-size stem cuttings can be produced within one year (Figure 22).

Storage of stem cuttings

A comparison of storage methods for field planting material showed that long cuttings wrapped in sacking and stored in a palm-thatched shelter maintained viability better than unprotected cuttings or short cuttings (Table 8). The death of cuttings was associated with dessication and invasion by fungi. Figure 23 shows that up to 10 per cent moisture loss can be tolerated without reducing germination, but further moisture loss reduces cutting viability.

Table 8. **Germination (%) of 15-cm stem cuttings after six weeks' storage (variety Llanera)**

	Weeks in storage					
Storage treatment	1	2	3	4	5	6
Stored as 60-cm pieces						
In open air	83	63	63	58	33	45
Open air wrapped	95	98	83	78	53	60
In shelter	98	75	83	65	50	40
Shelter wrapped	85	93	70	80	65	68
Stored as 15-cm pieces						
In open air	93	53	18	13	3	0
Open air wrapped	90	75	43	38	15	13
In shelter	95	75	45	38	33	15
Shelter wrapped	98	80	60	60	33	40



Multiplication rate (A x B x C)= (150 x 4 x 30) = 18,000

* Two shoots per node (data from current experiment)

Figure 22. Diagram of CIAT's propagation system of cassava using stem cuttings.

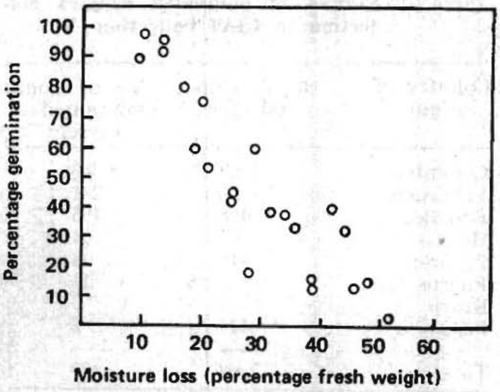


Figure 23. **Relationship between moisture loss and germination of 15 cm stem cuttings in variety Llanera.**

Dessication of the cutting begins from the apex, moving down until all the cutting is dead.

After two weeks, shoots appear from the apical end of the cuttings. When long cuttings are stored, shoots often appear also from the basal end. These shoots grow, exhausting the carbohydrate reserves of the cutting as well as transpiring water. Experiments using a commercial sprout depressant (CIPC) show that dipping cuttings for five minutes in a 1,000 ppm aqueous solution suppressed shoot elongation over a four-week period. The cuttings were maintained in polyethylene bags to prevent the loss of effect due to volatilization.

Field production of commercial planting material

Experiments using systematic spacing designs show that the production of commercial planting material falls from 97 cuttings of 15-cm per plant at 2.38 thousand plants/ha to 10 cuttings per plant at 55.9 thousand plants/ha (variety Llanera). An investigation of the effect of plant age on production and viability of stem cuttings showed that the number of cuttings per plant increases up to 10½ months of age (variety Llanera).

For field production of planting material from a small quantity of cuttings, plants should be widely spaced and allowed to grow for one year before they are cut for planting material. If maximum production is not essential, the plants may be cut for planting material after six months' growth. After this age, all the leafless portion of the stems are similar in germination ability, with the exception of the basal cutting from 12-month-old plants which shows reduced germination (Table 9).

Table 9. **Number of cuttings and their viability from plants of different age (variety Llanera)**

Age of plant (months)	Number of cuttings per plant	Germination (%)
12	25*	97+
10½	25	99
9	19	100
7½	16	99
6	16	97
4½	7	88

* Mean of five replicates + Mean of four replicates

VARIETAL IMPROVEMENT

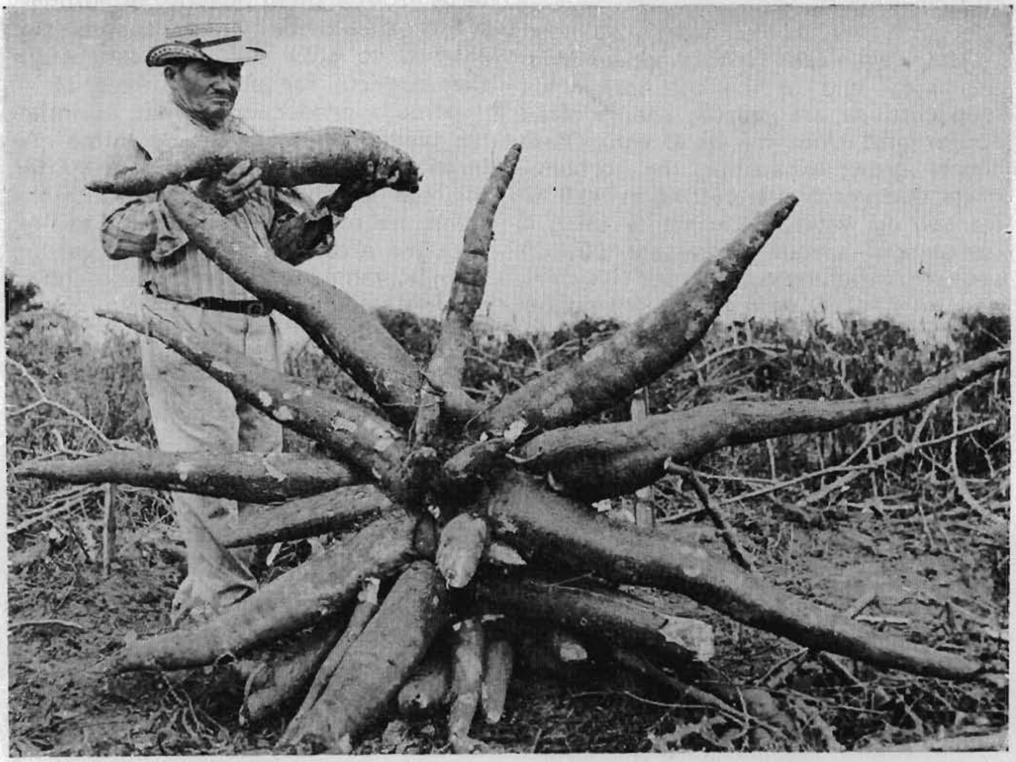
Cassava breeding work began formally early this year. The objectives of the breeding program are: 1) to select varieties with a high starch yield per unit-time, low HCN content, disease and insect resistance, easy harvesting, and a wide adaptability; 2) to supply genetic material for other cassava breeding programs; and 3) to design efficient breeding methods for cassava.

Germplasm collection

Early in CIAT's history, about 2,700 clones of cultivated cassava were collected from Colombia, Venezuela, Ecuador, México, Panamá, Puerto Rico, Brazil, and Perú (Table 10). The majority of the Perivian collection was eliminated because of the presence of the Brazilian mosaic virus. A significant number of Colombian, Panamian and Puerto Rican collections were lost because of salt spots in the field and an outbreak of bacterial blight (CBB) during the maintenance period. The total number of entries now is 2,129. The number of Brazilian collections is small in contrast to the ample

Table 10. **Entries of cultivated cassava collection in CIAT collection**

Country of origin	No. of clones collected	No. of clones maintained at present
Colombia	1,830	1,580
Venezuela	241	241
Ecuador	196	195
Mexico	67	63
Panama	118	19
Puerto Rico	60	16
Brazil	9	9
Perú	175	2
Total	2,696	2,129



In CIAT's germplasm collection there are several types of cassava plants with enormous roots but their practical agronomic value is much in question as yield per plant decreases very rapidly when planted close together

Table 11. **List of characteristics recorded in germplasm evaluation**

Growing period (month)	Agronomic characteristics observed
0-3	Germination, vegetative vigor, flowering
4-6	Thrips, shootfly, flowering
6	Root yield, top weight, harvest index, height, No. of total and commercial roots, root specific gravity
6-10	Branching habit, leaf size, leaf retention, spider mite, flowering
10	Root yield, top weight, harvest index, height, No. of total and commercial roots, root specific gravity, ease of harvest, root length, root stalk length, HCN and N content, root perishability

supply of material that was expected to be obtained from Brazil because of the vast genetic variability that occurs in this country. This deficiency exists because of plant quarantine regulations; however, a continuous effort is made to introduce more genetic variation from Brazil in the form of true seeds.

Germplasm evaluation

Ten propagules of every germ plasm entry were planted at CIAT with a 1.4 m distance between entries and 1 m among propagules (7,000 plants per ha). Various agronomic data, including root yield and top weight at 6 and 10 months after planting, are being collected (Table 11). A preliminary analysis was made on root yield, total plant weight, and harvest index at six months, with 630 entries.

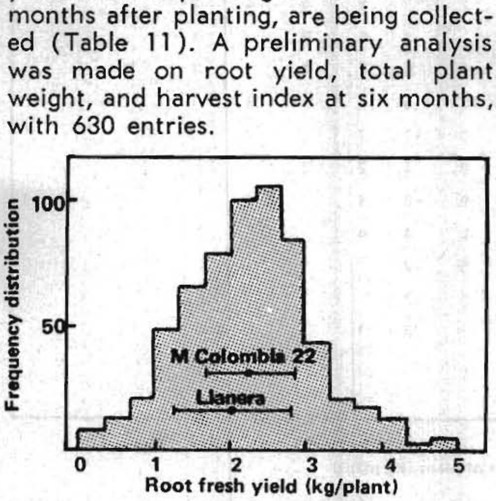


Figure 24. Frequency distribution of 630 clones in root yield at six months after planting

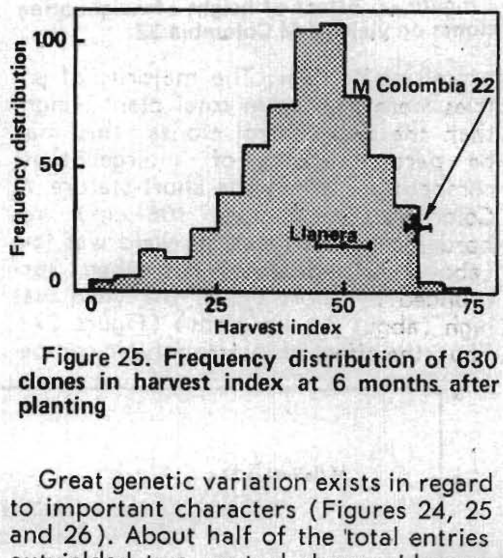


Figure 25. Frequency distribution of 630 clones in harvest index at 6 months after planting

Great genetic variation exists in regard to important characters (Figures 24, 25 and 26). About half of the total entries outyielded two control clones: Llanera, a local check, and M Colombia 22, a

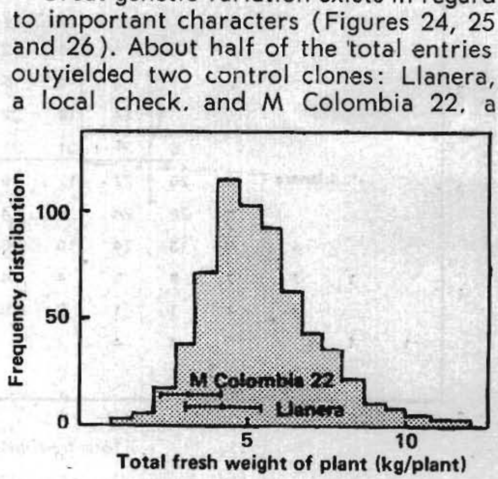


Figure 26. Frequency distribution of 630 clones in total plant weight at six months after planting

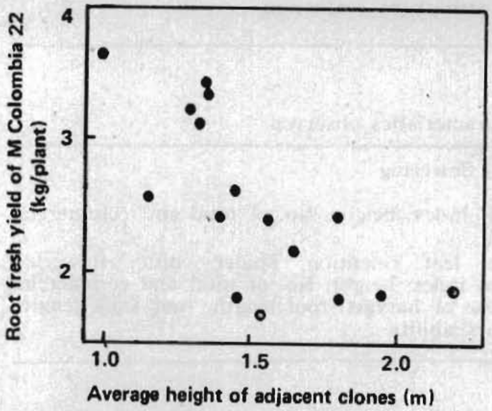


Figure 27. **Effect of height of neighboring clones on yield of M Colombia 22.**

promising cultivar. The majority of entries were heavier in total plant weight than the two control clones. This may be partly because of intergenotypic competition. When the short-stature M Colombia 22 (average 106 cm) was bordered by tall types, its yield was low (about 1.7 kg/plant) but when surrounded by short types, the yield was high (about 3.6 kg/plant) (Figure 27). Thus, the effect of intergenotypic competition is highly significant at six months after planting even with 1.4 m between rows.

Experimental error **per se** and the effects of intergenotypic competition combined resulted in considerable variation of the control clones in root yield and total plant weight (Figures 24 and 26). Yet, experimental error and the competition effect were relatively small in harvest index (Figure 25). This confirms that harvest index is an excellent selection criterion for cassava breeding.

As expected, both total plant weight and harvest index contributed significantly to the root yield (Figures 28 and 29). The relationship between total plant weight and harvest index appeared to be fairly independent (Figure 30). As harvest index is at least partly associated with dry matter production, a completely independent genetic recombination is unlikely to occur between harvest index and total plant weight, especially when the selection for root yield reaches a high level. Nevertheless, the rather independent relationship between harvest

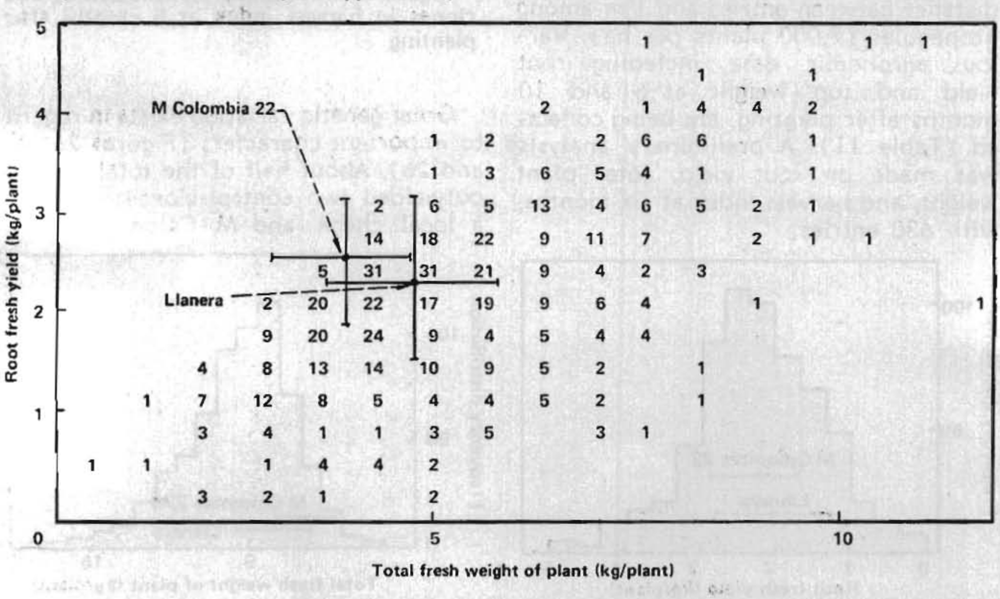


Figure 28. **Relationship between total plant weight and root yield in 630 clones at 6 months after planting**

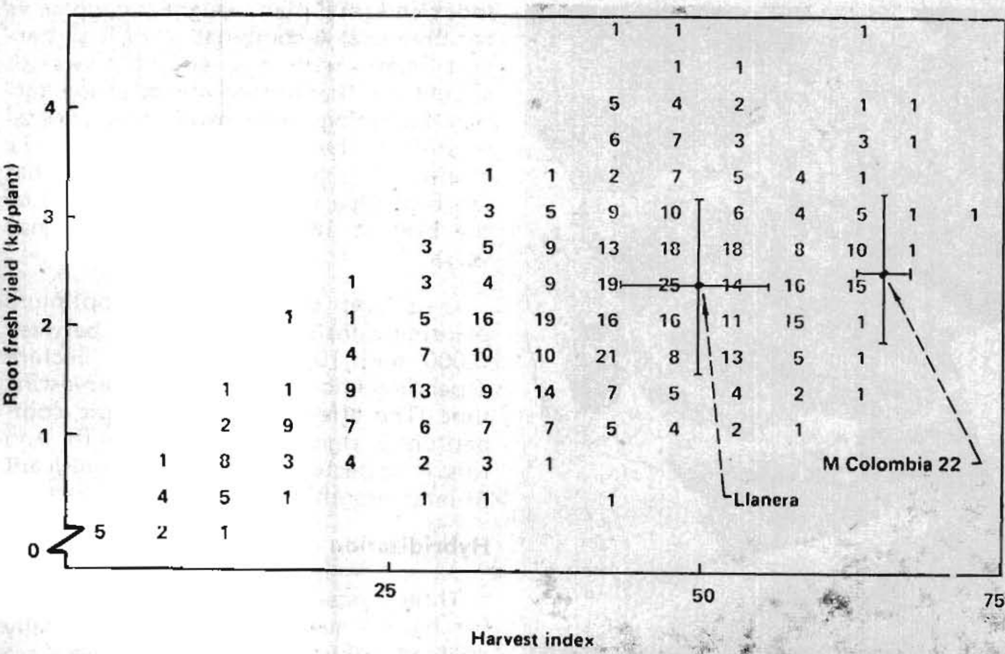


Figure 29. Relationship between harvest index and root yield in 630 clones at 6 months after planting

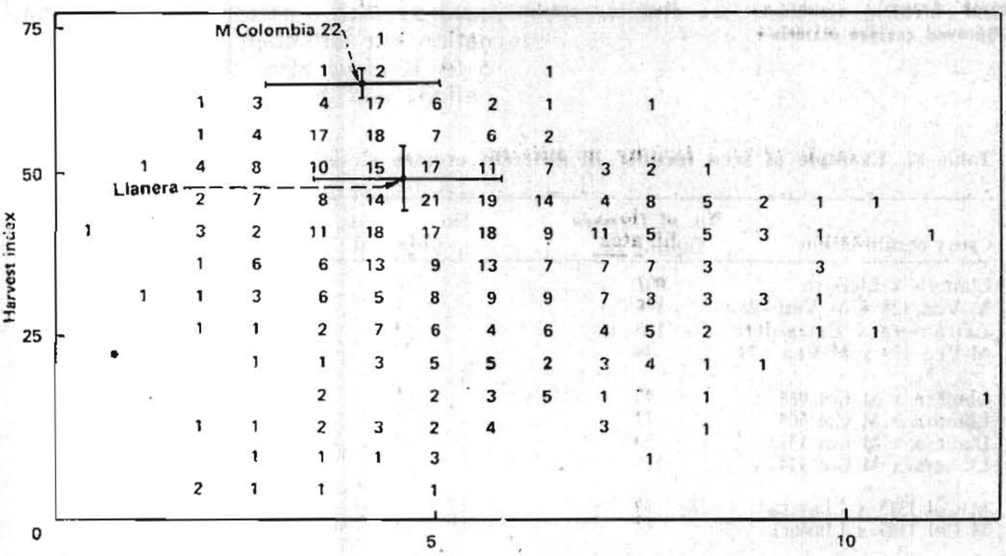


Figure 30. Relationship between total plant weight and harvest index in 630 clones at 6 months after planting

Plant breeding techniques are used to obtain improved cassava materials

index and total plant weight is good news for breeders. A combination of high harvest index with heavier plant weight should be the immediate selection tactics. Physiology data reveal that varietal interaction between yield at 6 and 12 months is significant. This means that the best type at six months may not be the best at 10 or 12 months and vice versa.

It is also shown that the optimum planting density is somewhere between 5,000 and 10,000 plants per hectare depending upon genotypes and harvesting time. The effect of intergenotypic competiton is significant at six month, and this is expected to be more significant in later months.

Hybridization

Three systems of pollination are used for hybrid seed production: 1) totally covered pollination; female flowers are covered with a cotton bag before and after artificial pollination; 2) partly covered pollination; female flowers are covered with a cotton bag before pollination but left open without cover for 6 to 10 days after the artificial pollination; and 3) open pollination.

Table 12. **Example of seed fertility in different crosses (totally covered pollination**

Cross combination	No. of flowers pollinated	No. of seeds obtained	Average seed set per flower*
Llanera x Llanera	602	18	0.030
M Ven 128 x M Ven 128+	146	1	0.007
Extranjera x Extranjera	116	82	0.707
M Ven 179 x M Ven 179	28	32	1.143
Llanera x M Col 988	45	0	0.000
Llanera x M Col 508	73	8	0.110
Llanera x M Col 1313	50	21	0.420
Llanera x M Col 1147	125	65	0.520
M Col 1313 x Llanera	39	7	0.180
M Col 1147 x Llanera	83	74	0.892
M Ven 179 x Extranjera	75	73	0.973
M Col 1313 x M Col 1147	62	66	1.065
M Col 1147 x Extranjera	54	70	1.296

\+ Abbreviations used in tables: Ven = Venezuela; Col = Colombia
* Each female flower has a capacity to produce up to three seeds

The adventage of method two over method one is that seed setting is much better when female flowers are not covered with a bag directly after pollination. The disadvantage is that it is impossible to be 100 per cent sure of parentage with this method because of the possibility of outside pollen contamination after the moment of artificial pollination.

Since the primary objective of hybridization work was to establish and get accustomed to the hybridization method, about 8,000 F_1 seeds out of some 500 cross combinations were produced using method one. A preliminary analysis of seed fertility in different crosses suggests that there are both hard and easy genotypes for making F_1 seeds. There is no genetic or physiological barrier to self-pollination (Table 12).

More recently, hybridizations were made with selected parents to produce more F_1 seeds per cross using method two. Some of the more frequently used parents are shown in Table 13.

Seedlings

Seeds of some cultivars (e.g., Llanera) germinate in the field without any special treatment but there are varietal differences in germination. Rupturing the testa and covering the seed bed with transparent plastic film for two days enhanced germination rate significantly in many cultivars. Seedlings are extremely susceptible to several pests such as anthracnose and thrips during the first two months after germination.

About 4,000 seedlings are growing in the field; half from controlled pollinated seeds and the rest from open-pollinated ones. Efficiency of selection at the seedling stage and the effect of parents on the performance of F_1 and following populations are to be studied before establishing a method of pedigree selection.

PLANT PATHOLOGY

Cassava bacterial blight

Studies of cassava bacterial blight (CBB) were directed towards the etiology of its causal agents in Africa and America. Other studies on dissemination, survival, control and estimation of losses due to the American strain of the disease were also carried out.

Table 13. Characteristics of representative cross parents

	Harvest index	Total plant weight	Early harvest	Easy harvest	Bacterial blight resistance	Thrips resistance
M Colombia 22	+ +		+	+		
M México 55	+ +		+	+		
M Colombia 914	+ +					
M Colombia 113	+	+				
M Venezuela 307	+	+				
M México 59		+	+			
M Colombia 9		+				+
M Colombia 340		+				+
M Colombia 348		+				+
M Colombia 1313		+ +				
M Colombia 1879		+ +				
M México 25		+ +				
M Colombia 647					++	
M Colombia 667					++	

Comparative studies of causal organisms of CBB*

A bacterial blight, recently reported in Africa, considerably damages cassava in some areas. Disease symptoms are similar to those found in America suggesting that they are a result of the same causal agent. A study was undertaken using seven American isolates (Brazil, Colombia and Venezuela), seven African isolates (Nigeria, Zaire, Malawi, and Mauritius), the type cultures of **Xanthomonas manihotis** (Arthand-Berthet) Starr and the type culture of **X. cassavae** Wieche and Dowson.

Cultural characteristics in 22 different media revealed that all isolates formed similar colony types, except for **X. cassavae.** Physiological studies and the preliminary serological results strongly suggest that CBB isolates from Africa and America belong to the same bacterial species, except for **X. cassavae.**

Dissemination

When insecticides were applied to uninfected plots close to a source of infection, the rate of infection was reduced. On the other hand, the use of attractants increased the infection by 14 per cent. This suggests that insects play a minor role in the dissemination of CBB; the major dissemination (78 per cent) is by rain splash. Preliminary results suggest that the unidentified insects merely act as mechanical carriers of the pathogen.

Bacterial survival

Studies of CBB survival in plant debris showed that this bacterial species could survive for more than seven months in necrosed stem pieces stored at 24°C and 80-87 per cent of RH. No bacterial cells were isolated from infected leaf tissues or petioles after 35 and 70 days, respectively, under the same environmental conditions. A relatively high concentration of bacterial cells (3.5×10^8 cells/g) were found in plant debris on the soil surface of infected plantations, but a lower concentration (1.9×10^7 cells/g) was found in the first 5 cm of this soil layer. From deeper soil samples it was not possible to isolate any CBB bacterial cells.

* This work is part of the PhD thesis of Tunde Ikotun, to be presented at the Imperial College of Science and Technology, London

Table 14. **CBB in plowed soil. The effect of length of time between plowing and planting on CBB apperance**

Time between plowing and planting (days)	Per cent of diseased plants Lot. 1	Lot. 2	Lot. 3
0	30*	35	28.5
30	6.5	18.5	3.5
60	6.5	6.5	0
90	0	0	0

* Mean of three replicates, 20 plants per plot

In heavily infected plantations the debris was burned and the land plowed. Roots were incorporated into the soil by plowing, and volunteer plants eliminated. Ninety days later no trace of CBB was found (Table 14).

Control

Seed Certification. Dissemination of CBB from one area to another by the use of infected cuttings was demonstrated previously (CIAT's Annual Report, 1972). This method of spread is also largely responsible for the dissemination of the disease from one growing season to another.

A method of rooting shoot tips is described in this publication whereby plants free from CBB can be produced (CIAT's Annual Report, 1972). The use of this method in addition to cultural practices is proposed for producing pathogen-free foundation stock for a planting material certification program. It is proposed that the method of producing CBB-free plants from shoot tips could provide the basis for a cassava seed certification program as oulined in Figure 31. CBB-free plants could be readily propagated from existing desirable varieties, even from those varieties which are infected with the disease.

Eradication of CBB from infected plantations. CBB was eradicated from the CIAT farm by producing bacteria-free planting stocks of cassava in addition to cultural practices and sanitation. Based on this experience and general results of investigations related to CBB ecological behavior, the following suggestions are presented as guidelines:

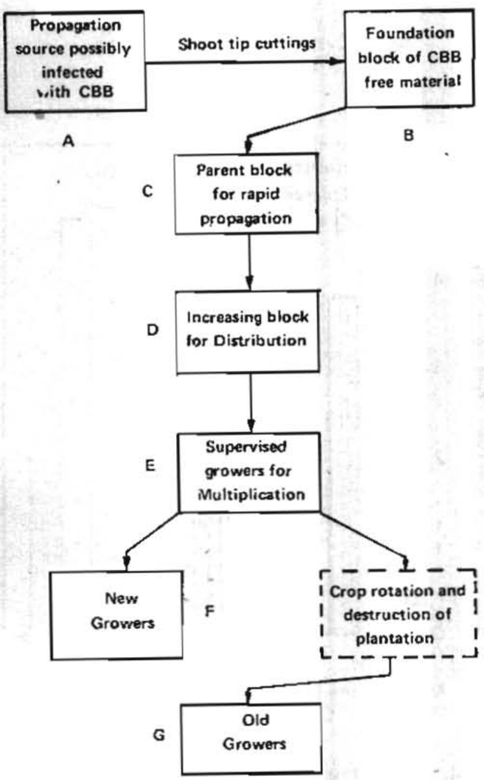


Figure 31. **Suggested scheme for eradication of CBB**

1) If certified CBB-free material is to be introduced to a farm, it is recommended that all plantations which may harbor CBB be eradicated, unless the distance between the suspect and the new planting is greater than one kilometer. Some varieties are tolerant but not immune to CBB. Although these tolerant varieties may not show characteristic symptoms, they may harbor the disease and thereby constitute a hazard.

2) To prevent the spread of disease from infected to non infected plantations, it is necessary to use non infected tools and implements. Tools, boots and other potential carriers of the pathogen such as tractor wheels and implements should be surface-sterilized using 5 per cent commercial formaldehyde.

3) Surface litter from an infected cassava plantation can be a source of CBB in the soil, potentially capable of transferring the infection to new plantings. Therefore, avoid planting clean material immediately after CBB infected cassava (Table 14). CBB is a poor competitor with other microorganisms in the soil and can be eliminated by crop rotation or a fallow free of cassava for six months. Destroy all infected cassava residues by burning.

4) It is recommended that large distances be maintained between clean and infected plantations because of danger from infection through wind-borne rain-splash, irrigation or drainage water or other methods. Insects are also agents for the dissemination of CBB (by mechanical means) within short distance.

Resistant varieties and estimation of disease losses. The response of a further 150 cassava cultivars to CBB has been determined using artificial inoculation with Colombian isolates. Disease indices ranged from susceptible to very susceptible.

A yield evaluation of three resistant, two tolerant and four susceptible cultivars was made under field conditions. Cassava cultivars were spray-inoculated

Table 15. **Yield of some CBB-susceptible and CBB-resistant cassava cultivars after artificial spray-inoculation with a bacterial suspension of 1.3 x 10^9 cells/ml. Inoculation was made three months after planting and yield was evaluated seven months after inoculation**

Cultivar	Disease rating	Yield of fresh roots/plant (kg)		Yield reduction (percentage)
		Noninoculated	Inoculated	
Valluna	S*	4.74	2.61	44.94
M Colombia 22	S	2.90	1.67	42.41
M Colombia 1073	S	2.77	1.19	57.04
M Mex 25	S	4.36	2.87	34.17
M Colombia 808	T	3.48	2.53	27.30
Llanera	T	4.17	3.23	22.54
M Colombia 1184	R	4.33	3.87	10.62
M Colombia 667	R	4.45	3.81	14.38
M Colombia 647	R	4.10	3.79	7.56

* S = susceptible; T = tolerant; R = resistant
LSD (1%): 4.7

with a bacterial suspension of 1.3 x 10^9 cells/ml three months after planting. (Table 15 and Figure 32). Yield after seven months in the resistant cultivars was reduced by 7.6 to 14.4 per cent; in the tolerant, from 22.5 to 27.3 per cent; in the susceptible ones, from 34.2 to 57.0 (Table 15 and Figure 32). These results suggest that the use of CBB-resistant cultivars can be recommended for heavily infected areas where the disease is endemic and its eradication would require a massive and coordinated program.

Experiments carried out to evaluate yield (fresh roots) of a CBB-susceptible cultivar ("Valluna") from healthy and CBB-infected planting material, showed that yield was 46 per cent reduced from 47 to 25 tons/ha by using infected planting material. These results stress the necessity of using certified cassava "seed" for propagation and the potential losses from the disease when environmental conditions favor disease dissemination within plantations.

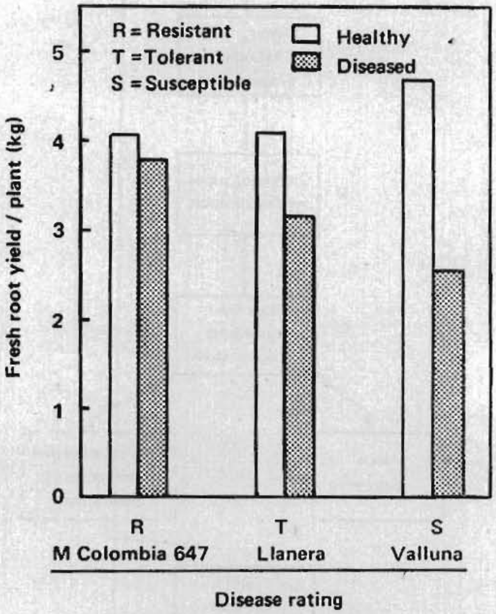


Figure 32. Yield reduction by CBB in cultivars of different susceptibility

Phyllosticta leaf-spot

This disease is commonly found in the cooler cassava growing areas of Colombia, Brazil, Asia and Africa. During the rainy season and when the temperature is below 25°C, this disease may severely defoliate susceptible cultivars, finally resulting in die-back of the plants.

The disease is characterized by the presence of large brown leaf spots, usually with indefinite margins. These lesions are commonly found at the tips or edges of the leaf lobes or along the midrib or main veins. The upper surface of the lesions initially shows concentric rings formed by brown pycnidia. These rings are frequently absent from older lesions as mature pycnidia are washed off by rain drops. In these cases, the uniformly brown lesions may resemble those caused by **Cercospora.** On the lower surface few pycnidia are produced so that the lesions are uniformly brown.

Under conditions of high relative humidity, the lesions may be covered with a greyish brown hyphal web. Also, on the under side of the leaves, the veins and veinlets around the lesions become necrosed, thus forming black strings radiating out from the lesions. These lesions grow, causing a leaf blight, and finally the whole leaf and petiole, which become darkbrown, necrose. At this stage the leaves wilt and then drop, in some cases causing extensive defoliation. In severe infections the fungus also attacks the young shoots causing a die-back. Diseased stems turn brown and are also frequently covered with pycnidia.

Field observations suggest that the older lower leaves may be more resistant than younger upper leaves. However, young leaves, fully expanded mature leaves, and green stem parts have all been observed with severe disease symptoms.

Pycnidia production on different artificial media is relatively low or nil, but on lima bean-agar mixture they formed profusely in a concentric rings pattern. These pycnidia are dark brown, globose, and borne singly or in small clusters. Pycniospores are short and hyaline, one celled, ovoid to elongate in shape.

Table 16. **Effect of temperature on germination of pycniospores of** Phyllostica **sp.**

Temperature (°C)	Germination* (%)
15	38.4
20	95.9
25	97.1
26	91.7
28	77.4
30	0

* Average of three replications with more than 300 spores each

Pycniospore germination is related to temperature (Table 16). No germination of spores occurred at temperatures above 28°C; the optimum temperature for germination was between 20-25°C. Similarly, artificial infection succeeded only when plants were inoculated and maintained during the first two days at temperatures below 22°C. When plants were maintained at 26°C or above no infection was obtained. The first symptoms appeared 10 days after inoculation at 15 to 22°C. Lesions were bigger when plants were maintained at 25°C than when they were at 15 and 20°C.

The concentration of pycniospores also seems to affect their germination (Table 17), possibly because of the production of self-inhibitory compounds. This is particularly important for pathogenesis, since for better results inoculum concentration has to be adjusted before inoculation. Moreover, spore concentration was correlated significatively with the number of lesions per lobe (Table 18).

Table 17. **Effect of concentration on germination of pycniospores of** Phyllostica **sp.**

Concentration (spores/ml)	Germination (%)
9×10^4	48*
5×10^4	83
2×10^4	91
1×10^4	97
6×10^3	97
3×10^3	95
1.5×10^3	93
7×10^2	97

* Average of five replications with more than 80 spores each

The highest number of lesions were obtained when the inoculum had 3×10^4 spores/ml.

In cooperation with the Plant Pathology Program of ICA, at the Palmira research station, screening for resistance is underway at Popayan (where nights are cool). Forty-four cultivars have been evaluated; two have shown acceptable resistance to this disease.

Table 18. **Correlation between the number of lesions per leaf-lobe and the spore concentration in** Phyllostica **sp.**

Concentration (spores/ml)	Number of lesions per lobe
5×10^4	6*
4×10^4	13
3×10^4	14
1.6×10^4	13
8×10^3	11
4×10^3	6
2×10^3	0

* Average of three replications with seven lobes each

The superelongation disease

The superelongation disease of cassava was discovered causing epidemics in Colombia during 1972. Although as yet little is known about this disease, growers and extension officers in several areas of Colombia report that the problem has existed in certain growing areas for many years.

Symptoms

The disease is characterized by exaggerated elongation of the internodes of young stems and petioles, by distortion or leaf-curl of young leaves, and by cankers on infected stems, petioles, and leaf lamina. Infected plants are considerably taller and appear weaker and thinner than healthy ones. The youngest part of stems, petioles of young leaves and leaf midribs are frequently deformed. Young leaf lamina are frequently slightly chlorotic and have numerous irregular whitish spots. They are rarely fully developed or expanded and show typical leaf-curl symptoms. These distortions are associated with cankers. These are usually lens shaped and form along the veins and midribs of leaves, on young petioles and stems. They vary in size, usually being larger on the petioles and stems where they may be more diffuse and, in appearance, can be confused with damage by thrips. During severe attacks, the leaves may become so completely deformed as to result in partial or total necrosis of the leaf lamina and premature leaf drop (See photo page 87).

Symptoms are most marked during the rainy season; at the onset of dry seasons, infected plants resume normal growth During prolonged dry periods, infected plants may look healthy, but a region of elongated internodes bearing cankers may still be observed. This elongated stem portion may still bear deformed leaves, but these commonly drop prematurely. The disease reappears rapidly after rains begin.

Superelongation disease in cassava

Experiments to estimate the effect of this disease on final root yields are under way; observations indicate that heavy infections reduce yield severely.

Causal agent

A fungus, tentatively identified as a lower Ascomycete (Commonwealth Mycological Institute, private communication), is the causal agent.

Histological studies have shown that the fungus initially grows over the epidermis of the host and, following penetration, grows within the intercellular spaces of the epidermal and cortical tissues. No infection of vascular or medullary tissues has been observed. Following infection, mycelial aggregates are formed in the cortex; these grow and push up the surrounding cells forming blister-like structures on the surface of infected stems, petioles, or leaf veins. These blisters grow and burst to form the lens-shaped cankers from which the fungus can be isolated. Most cells around such cankers have been observed to be abnormally large and to show considerable hypertrophy.

Dissemination

The disease is disseminated from one growing season to another or from one growing area to another by planting canker-bearing stem cuttings. The primary foci of infection are also frequently formed by rogue or volunteer plants growing among plantations, or more frequently, growing from old plant debris left around the edges of field after the previous cassava crop. From such primary foci the disease spreads rapidly during the rainy season. For example, in one growing area with a long humid season, the disease spread from an infected area of 1.5 hectares to 200 hectares within six months. Similarly, in another area, the disease spread from plots of a single infected variety throughout plots of 200 varieties and to another nearby experiment within six weeks. This rapid dissemination is believed to be by means of rain-or wind-borne spores produced in the cankers of infected plants.

Tests in humidity chambers confirm that high relative humidities are required for infection. When plants grown in these chambers were sprayed with a spore suspension, symptoms developed in 6-10 days. However, if infected plants are removed from the chambers and placed in a dry environment, they resume normal growth.

Control

Field observations of more than 200 cultivars of **M. esculenta** indicate that varietal resistance to this disease does exist. Seven resistant cultivars have been recently identified and screening for resistance under controlled conditions is under way. Preliminary studies with with chemical sprays (Benomyl and Manganous ethylenebisdithiocarbamate) show promising results.

Phytophthora root rot

Three **Phytophthora** spp., **P. erythroseptica, P. cryptogea** and **P. drechsleri,** have been associated with root-rots of cassava. In all cases, the disease has been found associated with conditions of excess soil moisture, the most severe damage resulting after swollen roots were attacked. The symptoms of the three types of rots are similar; diseased roots are discolored and rapidly disintegrate in the soil. When partially rotted, they exude a foul smelling liquid. The spread of infection throughout the roots results in wilt, some leaf drop and, in severe cases, the plants may die.

A similar disease, found in Colombia, results in more than 80 per cent loss of yield in certain plantations. This disease was found in water-logged soils, frequently alongside drainage ditches or in heavy soils following excessive rainfall.

Causal agent

Phytophthora drechsleri has been found to be the causal agent of this disease in Colombia. This fungus grows well on a wide variety of artificial media at temperatures between 19 and 32°C.

Pathogenicity studies

Storage roots from one-year-old plants were inoculated with a 10 mm mycelial/agar disc. When inoculated in artificial wounds, roots commenced rotting after 72 hours, and medium-sized roots (60 x 250 mm, approx.) were completely destroyed after 12 to 15 days. Before breakdown occurred, the roots turned yellow/brown and exuded a pungent liquid. Successful inoculation of apparently undamaged roots was achieved after incubation in a moist environment. The roots were inoculated by placing agar discs of mycelia on the root surface and covering them with moist sterile soil.

Similar inoculations were also made on damaged and apparently undamaged swollen roots still attached to growing plants in the field. Following inoculation the roots were covered with moist soil. In all cases, the inoculated roots were completely destroyed in 15 days.

Rooted shoot-tip cuttings of three cassava cultivars were inoculated by dipping the washed roots in a sporangial/zoospore suspension. The cuttings were replanted in pots of sterile soil. All cultivars showed symptoms of wilt and leaf drop after five days. Death of these young plants ocurred after 15 to 30 days, depending on the cultivar. This suggests that there may be varietal resistance.

Root-knot nematode

A cassava crop heavily infected with nematodes was found in a garden where vegetables have been cultivated for more than three consecutive years. Although the aerial part of the cassava plants did not show any visible symptoms, the root system of infected plants was poorly developed. Few swollen roots were present. The ones present showed knots or galls on the epidermis of the roots and considerable root proliferation. The many nonswollen roots also showed knots or galls. Most of them were rotting (See lower photo page 89).

By breaking these galls, adult female nematodes were found. They were pear shaped, white and large enough to be seen with the naked eye, presenting characteristic features of the genus **Meloidogyne.** By artificial inoculation with clean eggs and females, symptoms were reproduced in bean and tomato plants, two months after inoculation. Seventy cultivars of cassava are presently being screened for resistance against **Meloidogyne.**

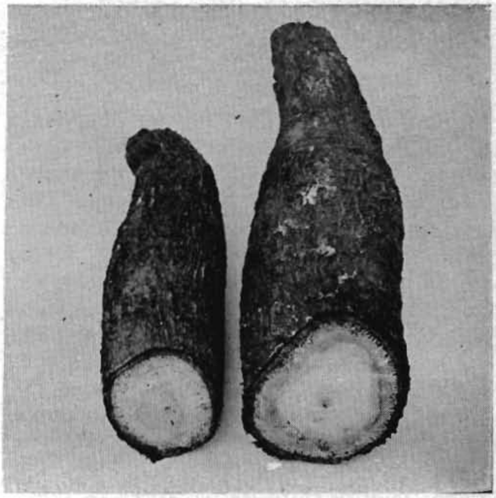
Rosellinia root-rot

This disease was found in the coffee zone of Colombia which has wet soils and is high in organic matter. The disease frequently occurred when cassava was grown following a woody or forest crop. The disease, which is also named "black rot," characteristically shows black discoloration and cankers on below-ground portions of infected plants;

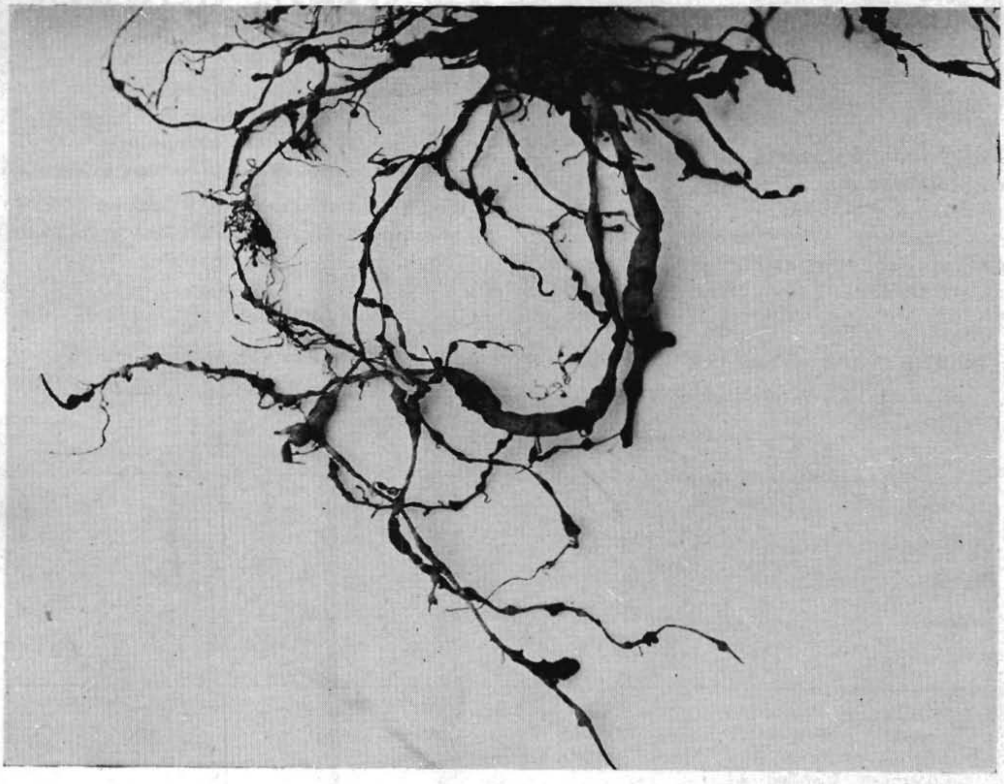
photograph on right column of this page, shows Rosellinia symptoms. Young plants were not found infected by this disease but when older diseased plants were detected, their root system was severely damaged.

Cercospora leaf spots

Research on **Cercospora** disease was particularly concerned with the **C. henningsii,** causal agent of the cassava brown spotting, probably the most important of the cassava leaf diseases. Although the fungus grows well on several artificial media, sporulation is low or nil. However, sporulation of **C. henningssi** was enhanced (2-3 x 10^4 spores/ml) by spreading spore suspensions on sterile susceptible cassava leaves placed on



Rosellinia root-rot in cassava

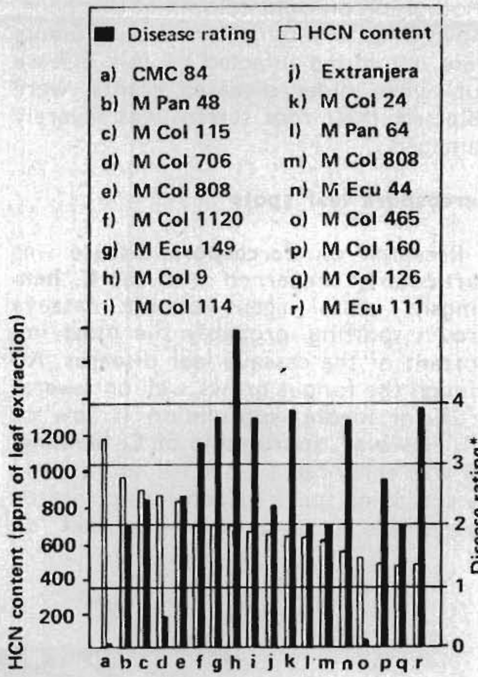


Ten months old cassava roots infected by Meloidogyne **sp., the root-knot nematode**

simple agar in Petri dishes, which were incubated for 10-12 days at 28-30°C before spore counting.

A good infection (more than 10 spots/leaf) has been obtained by spray inoculation. Inoculated plants were kept under mist and symptoms appeared 12-15 days after inoculation. For disease evaluation inoculated cultivars were maintained in a moist chamber for 45 days. Three spray inoculations were performed during this period and the final evaluation was taken 15 days after the last inoculation. Three resistant and six tolerant cultivars were identified among the 40 cultivars tested.

The relationship between HCN content and **C. henningsii** reaction showed that there was no correlation between the resistance or the susceptibility of the cultivars tested and the HCN content (Figure 33). Some of the most susceptible cultivars (M Col 9, M Ecu 111) contained as much HCN as the most resistant (M Col 84, M Col 465 and M Col 706) (Figure 33).



* Disease rating:
1 = less than 2 spots/leaf (resistant);
2 = 2 – 5 spots/leaf (tolerant);
3 = 6 – 10 spots/leaf (susceptible);
4 = more than 10 spots/leaf (very susceptible).

Figure 33. **HCN content and Cercospora** henningsii **reaction of 18 cassava cultivars.**

Fungicide treatments on cassava establishment

Losses above 20 per cent from stem or root rot pathogens during cassava establishment have been recorded in

Table 19. Effect of fungicide treatments on cassava establishment (Experiment No. 1)

Fungicide	Replication						
	1	2	3	4	5	6	$\bar{x}$
Demosan 65*	19**	18	20	20	20	19	19.3
Arazan	19	19	17	18	20	20	18.8
Agallol	18	16	15	16	18	16	16.5
Brassicol 75	13	14	17	18	18	16	16.0
Control	14	12	16	13	16	14	14.1

* Demosan 65 = 1-4-Dichloro-2, 5-dimethoxy benzene;
Arasan = Tetramethyl thiuram disulfide; Agallol = Methoxy ethyl mercury chloride; Brassicol 75 = Pentachloronitrobenzene;
Control = Distilled water

** Number of germinated cutting of 20 per replicate

Table 21. **Effect of fungicide treatments on cassava establishment (Experiment No. 2)**

Fungicide	Replication				
	1	2	3	4	$\bar{x}$
Vitavax-thiram*	20**	17	19	19	18.7
Demosan 65	19	18	17	18	17.5
Tecto 60	13	15	16	12	14.0
Brassicol 75	14	13	12	13	13.0
Arasan	14	12	12	13	12.7
Control	11	12	8	10	12.0

* Vitavax-Thiram = DCMO-Tetramethyl thiuramdisulfide;
Demosan 65 = 1-4-Dichloro-2, 5-dimethoxy benzene;
Tecto 60 = Thiobendazole; Brassicol 75 = PCNB;
Arasan = Tetramethylthiuramdisulfide; control = Distilled water

** Number of germinated cutting of 20 per replicate

Table 22. **Cutting germination (CMC 39) after-water treatment at different temperatures and periods of exposures**

Type of cutting	Temperature (°C)	Percentage of germination after time of exposure (min)						
		10	20	30	40	50	60	CK**
old	65	0*	0	0	0	0	0	100
mature	65	0	0	0	0	0	0	100
green	65	0	0	0	0	0	0	70
old	60	0	0	0	0	0	0	100
mature	60	0	0	0	0	0	0	100
green	60	0	0	0	0	0	0	65
old	58	0	0	0	0	0	0	100
mature	58	0	0	0	0	0	0	100
green	58	0	0	0	0	0	0	70
old	56	10	0	0	0	0	0	100
mature	56	0	0	0	0	0	0	100
green	56	0	0	0	0	0	0	70
old	53	80	80	60	40	20	10	100
mature	53	70	70	60	10	0	0	100
green	53	0	0	0	0	0	0	65
old	50	100	100	100	80	50	50	100
mature	50	100	80	80	60	40	30	100
green	50	20	10	0	0	0	0	60
old	47	100	100	100	100	100	100	100
mature	47	100	100	100	100	100	100	100
green	47	50	50	40	40	30	20	60

* Average of two replications with ten cuttings each

** Control (CK): untreated cuttings

some cassava growing areas of Colombia. In order to minimize such losses, cuttings were treated with different fungicides before planting in an infested soil where establishment losses were higher than 25 per cent in a previous cassava crop. Cuttings were dipped in an aqueous fungicide solution for three minutes before planting. Two months after planting the number of germinated cuttings was recorded.

Demosan 65 and Vitavax-Thiram (1:1 w/w) treatments were highly effective. Although Arasan was highly effective in the first experiment (Table 19) its performance was poorer in the second one (Table 20) which suggests a lack of inoculum concentration during the first experiment. There was no significant difference between Demosan 65 and Arasan treatments, but these two products were significantly superior to the other compounds in experiment one (Table 19).

Experiment two (Table 20) showed that the difference between Demosan 65 and Vitavax-Thiram was not significant but they were significantly better than the other treatments. Among Tecto 60, Brassicol and Arasan there were no significant differences but all were superior to the control.

Effects of physical therapeutic agents on cassava stem cuttings

As commercial cassava is propagated vegetatively, pathogenic causal agents, such as bacteria, viruses, mycoplasma, fungi, nematodes and even insects, may

Table 22. Cutting germination (Llanera) after hot water treatment at different temperatures and periods of exposures

Type of cutting	Temperature (°C)	Percentage of germination after time of exposure (min)						
		10	20	30	40	50	60	CK**
old	65	0*	0	0	0	0	0	90
mature	65	0	0	0	0	0	0	70
green	65	0	0	0	0	0	0	40
old	60	0	0	0	0	0	0	60
mature	60	0	0	0	0	0	0	80
green	60	0	0	0	0	0	0	30
old	58	0	0	0	0	0	0	80
mature	58	0	0	0	0	0	0	80
green	58	0	0	0	0	0	0	35
old	56	0	0	0	0	0	0	80
mature	56	0	0	0	0	0	0	60
green	56	0	0	0	0	0	0	40
old	53	60	40	20	10	0	0	80
mature	53	60	40	20	10	0	0	80
green	53	40	0	0	0	0	0	45
old	50	80	70	40	20	20	10	80
mature	50	90	90	50	50	50	30	75
green	50	30	20	0	0	0	0	45
old	47	80	80	80	80	60	40	75
mature	47	80	80	70	80	50	70	80
green	47	45	50	50	40	30	30	50

* Average of two replications with ten cuttings each

** Control (CK): untreated cultings

Table 23. **Cutting germination CMC 84) after hot water treatment at different temperatures and periods of exposures**

Type of cutting	Temperature (°C)	Percentage of germination after time of exposure (min)						
		10	20	30	40	50	60	CK**
old	53	77*	73	53	50	40	23	100
mature	53	67	60	43	33	33	13	100
old	52	100	97	87	63	50	23	100
mature	52	97	93	83	70	60	37	100
old	51	100	90	83	67	53	40	100
mature	51	97	87	87	67	47	33	100

* = Average of three replications with ten cuttings each

** = Control (CK): untreated cuttings

be disseminated by moving material from one area to another. This investigation evaluated the effects of hot water, microwaves and ultraviolet light (u. v.) on germination of cassava cuttings. Results related to each one of the treatments were:

Hot water treatment

Tables 21, 22, 23 and 24 present results of the hot water treatments. Temperatures above 53°C seriously reduced the germination of the cuttings of all varieties. Hot water treatment at 53°C reduced the germination of Llanera cuttings more than that of CMC-39 cuttings (Tables 21 and 22). It is thought that the best treatment with hot water is 52°C for 30 minutes, since germination is still higher than 80 per cent in both cultivars (CMC-84 and Llanera) (Tables 23 and 24). Treatments at temperatures above 52°C also considerably reduced the size of the shoots of treated cuttings, but three months after treatment the size of these shoots were almost the same as those of the controls.

Microwave treatment

Germination of both Llanera and CMC-39 was seriously reduced by exposure to more than 105 seconds of microwave. Seventy-five to ninety seconds of exposure seem to be the best treatment periods (Table 25).

Table 24. **Cutting germination (Llanera) after hot water treatment at different temperatures and periods of exposures**

Type of cutting	Temperature (°C)	Percentage of germination after time of exposure (min)						
		10	20	30	40	50	60	CK**
old	53	83*	77	70	43	23	10	93
mature	53	60	60	47	27	13	10	80
old	52	90	83	80	73	50	33	97
mature	52	67	83	77	57	47	17	83
old	51	93	87	83	57	40	33	93
mature	51	87	83	77	60	47	20	83

* = Average of three replications with ten cuttings each

** Control (CK): untreated cuttings

Table 25. Cutting germination after microwave exposures for different periods of time

Time of exposure (seconds)	Cultivar Llanera		Cultivar CMC-39	
	Type of cutting and % of germination		Type of cutting and % of germination	
	old	mature	old	mature
0	83*	87	100	100
15	87	83	100	100
30	93	93	100	100
45	83	83	100	100
60	87	87	100	100
75	90	87	100	97
90	70	67	100	93
105	3	0	33	10

* Average of three replications with ten cuttings each

Ultraviolet light treatment

Germination was not affected by u.v. treatments even after six hours exposure. No differences in germination between Llanera and CMC-84 were observed (Table 26).

Sensitivity in vitro **of some cassava pathogens**

CBB's highest sensitivity to hot water was at 54°C/30 minutes. After forty-five seconds exposure to microwaves CBB was disrupted. Ultraviolet light did not

Table 26. Cutting germination after ultraviolet exposure for different periods of time

Time of exposure (hours)	Cultivar Llanera		Cultivar CMC-84	
	Type of cutting and % of germination		Type of cutting and % of germination	
	old	mature	old	mature
0	90*	90	100	100
1	90	100	100	100
2	90	90	100	100
3	100	90	100	100
4	90	80	100	100
5	90	90	100	100
6	90	90	100	100

* Average of two replications with ten cuttings each

Table 27. **Presence of Botryodiplodia sp. in CMC-84 cuttings after treatments with hot water, microwaves and ultraviolet light**

Cutting number	Treatments and exposure periods: Hot-water 52ºC/30 (min)	microwaves (60 seconds)	u.v. (6 hours)
1	+*	—	+
2	—	—	+
3	—	—	+
4	±	—	—
5	—	—	+
6	—	—	+
7	—	—	+
8	—	—	+
9	—	—	+
10	—	—	+
CK**	+	+	+

* + = positive isolation; ± isolation from only one of three samples
— = negative isolation. These results are means of three samples taken of each infected cutting

** Control (CK): untreated cuttings. Isolation from three semples/cutting

induce any inactivatory effect on CBB suspension in sterile distilled water, even after seven hours of treatment.

Botryodiplodia sp. and **Glomerella** sp. were inactivated by 30 seconds of microwave exposure. Seven hours of ultraviolet light did not induce any effect.

Inhibitory or inactivatory effects on the host parasite relationships

In all cases, CBB was isolated from a hot water treated cutting. A bacterial population closely similar to the untreated cutting was found in mature and old stem portions after being treated at 65ºC for 60 minutes. Similarly, 90 and 105 seconds of microwave exposure or 6-7 hours of u. v. exposure did not induce any inactivitory or inhibitory effects on CBB.

In contrast, **Botryodiplodia** sp., **Glomerella** sp. and the causal agent of the superelogation disease were controlled both by 52ºC/30 minutes hot water treatment and 60 seconds of microwave exposure. However, u.v. exposure did not control any of the above pathogens infecting old cassava cuttings. Table 27 shows the inhibitory effects on **Botryodiplodia** sp. by treatment with hot water (52ºC/30 minutes), microwaves (60 seconds) and u.v. (6 hours).

The following are the general conclusions of the aforementioned investigations:

1. Treatments using hot water or microwave can seriously reduce the germination of cassava cuttings. Ultraviolet light for seven hours apparently does not induce any effect on germination.

2. Optimum hot water treatment to cassava cuttings seems to be 52ºC/30 minutes; optimum microwave treatment: 75 to 90 second exposure.

3. CBB, a vascular pathogen, was not controlled by hot water or microwave treatments. Its inactivatory or inhibitory

point, when associated with its host, is higher than the optimum point of sensitivity of cassava cuttings to these treatments. This could be similar for other vascular pathogens of the cassava plant.

4. **Botryodiplodia** sp., **Glomerella** sp. and the causal agent of the superelongation disease, common epidermal or cortical pathogens, were controlled by hot water or microwave treatments. Ultraviolet light exposure did not control these pathogens.

5. As green cuttings were sensitive to hot water and microwave applications, these treatments appear to be unsuitable for these type of cuttings.

Other treatments to control cassava pathogens **in vitro** are at present under study.

ENTOMOLOGY

Cassava is often reported to be a crop that is rather free of insects and disease problems. When the cultivation of cassava becomes more intensive it becomes apparent that a number of organisms have the potential to reduce substantially both the yield and the quality of planting material. There are indications that the cassava plant has been selected over the centuries for resistance to pests; e.g., thrips.

Thrips

The thrips species and spider mites may well be the most important cassava pests (see section on Economics). Thrips live in the growing points of the plant and because of their feeding habits deform expanding leaves.

Light infestations produce yellow dots on the leaves; heavier infestations result in serious leaf deformation, absence of part of the leaf blade tissue and eventually, in death of the growing point. The sidebuds which subsequently develop are also killed and "witches broom" type symptoms appear. The internodes of the stems are shortened and covered

Table 28. **Resistance to thrips of cassava clones related to plant pubescence and cyanide content**

Clone	Damage rating	No hairs/ leaflet underside)	No thrips per terminal bud	Cyanide content of 5th leaf (ppm)
M Colombia 1462	0*	12,996	1.0	647
M Colombia 379	1	11,368	1.7	734
M Colombia 606	0	4,352	0.0	630
M Colombia 562	0	3,876	0.0	630
M Colombia 442	2	3,596	2.7	235
M Colombia 913	3	220	0.0	974
M Colombia 139	3	68	0.0	886
M Colombia 802	2	60	0.7	962
M Colombia 1516	2	20	1.0	962
M Colombia 758	3	4	0.3	609
M Colombia 559	4	0	0.3	1,006
M Colombia 1339	4	0	1.3	840

* Resistance rating: 0 = immunity; 5 = growing point dead; excessive sprouting of side buds

with brown wound tissue. The most important species, **Frankliniella** sp., is yellow colored.

On the expanded leaves, especially of younger plants, **Caliothrips masculinus** can be found while **Corynothrips stenopterus** is found on leaves of older plants. Both these species are black in color.

Chemical control of thrips is effective with Diostop but the use of thrip-resistant varieties is the best approach towards control. Evaluation of the germplasm bank, carried out in two different dry seasons showed that 29 per cent of the clones did not have thrips damage, 31 per cent with slight leaf deformations, and the remainder had considerable leaf deformation presenting witches-broom-like symptoms. The resistance seems to be associated with hairiness of the leaflets when still folded. The hairy varieties have up to 13,000 hairs per leaflet on the underside (Table 28), while the susceptible varieties have none or few hairs. The resistance classification was based on the scale: o = no damages; up to 5 = witches-broom-like symptoms.

Plants grown from sexual seed of the Llanera variety were more susceptible than would be expected from the average germplasm bank susceptibility. In the germplasm bank, 29 per cent of the clones showed no thrips damage, while of 238 Llanera seedlings, only 2.1 per cent showed no damage. After years of cultivation, farmers may have eliminated the majority of thrips-susceptible clones.

Spider mites

Several species of spider mites attack cassava in the dry season, among them **Mononychus tanajoa.** In March, at the end of the dry season, the germplasm bank was evaluated for resistance to mites. Although the infestation was not uniform and some of the apparently resistant lines are certainly escapes, out of 1,300 Colombian collections, no plants were found without mite damage. About one third were classifield as 1 (o = no mite damage and 5 = serious defoliation dieback and sprouting). Only one per cent of the clones were classified as 5. Great differences in mite attack were not only apparent in mite damage but also in numbers of mites per plant. The mites were counted per plant on 100 clones, 3 discs of 1.8 cm diameter of each of 3 leaves from the basal, middie and upper part of the plant. The lowest number of mites was found on M Colombia 813 (9 mites), the highest on M Colombia 25 (1,476 mites) (Table 29). Also, on some clones, mites were mainly located on the basal leaves and on other plants on the top leaves. It is possible that different species are involved.There was no correlation between mite damage rating and number of mites, probably because the first rains occurred when the mite counts were made. The correlation between mite damage and cyanide level of the plants was 0.29 (Signif. P = 0.01). This indicates that plants with higher cyanide levels were more damaged.

Shoot flies

The shoot flies that attack cassava can be divided into two groups. In one group the species attack the growing point causing mortality, followed by germination of one or more sidebuds. Among these species are **Silba pendula** and **Silba** sp. Other species attack below the growing points. Small entrance holes can be found in stems and, on opening these stems, the pith tissue is completely destroyed. A secondary infestation of pathogens cause the stem to turn black or the leaves to drop without any further obvious damage symptoms. This pest is a Tephretidae fly that is similar to a fruit-attacking species, **Anastrepha pickli,** which attacks the cassava fruits.

In an attempt to simulate the damage made by **Silba pendula,** the growing points of two varieties were clipped at 3, 4 and 5 or at 3,4,5,6,7 and 8 months after planting to obtain 0, 50 or 100 per cent levels of damage. The results from

Table 29. **Mite counts and damage scores on clones with a: lowest number of mite; b: highest number; c: mites mainly on basal leaves; d: Mainly on top leaves (March, 1973)**

	Top leaves	Middle leaves	Basal leaves	Damage Score (O-5)*
a: lowest number of mites				
M Colombia 813	0	0	9	3
M Colombia 803	0	3	7	2
b: highest number of mites				
M Colombia 52	111	780	300	2
M Colombia 25	257	709	520	4
c: mites mainly on basal leaves				
M Colombia 34	6	64	103	2
M Colombia 61	58	89	177	3
M Colombia 709	120	268	428	3
d: mainly on top leaves				
M Colombia 39	46	21	7	3
M Colombia 21	143	176	15	2
M Colombia 38	214	65	43	4

* O = no damage; 5 = mortality of growing point and/or sprouting of sidebuds

one variety were eliminated because of soil salinity. The yields under the various treatments of M Mexico 23 tended to increase because of the clipping (Table 30), but were not significant (signif. p = 0.10). At 50 per cent of the terminals cut, the yield increased when cut at the younger growth stages. But a 100 per cent cut gave equal yield to the control. When cut all through the growing cycle, the yields stayed the same. Apparently, during the early growth (up to six months) clipping increases yield. However, later on in the growth stage, the influence of clipping is greater. Plants clipped show a more rapid germination of the sidebuds than when attacked by the shoot fly.

The plants of clones M Colombia 10 and 65, at 4 months of age, due to shoot fly attack, were about 25 cm in height. Current experiments with insecticidal treatments of the cuttings will determine damage in terms of yield reduction and control of the shoot fly.

Fifty-five Colombian clones that were planted on May showed greatest shoot fly attack at 2 months of age. After this,

Table 30. **Root yield (in ton/ha) of M Mexico 23 at 10 months of age, after clipping of growing points at various degrees, to simulate shoot fly damage**

Time of clipping (in months) after planting	Percentage of growing points cut		
	0	50	100
3, 4 and 5	28.5	38.0	32.1
3, 4, 5, 6, 7 and 8	31.3	33.8	33.4

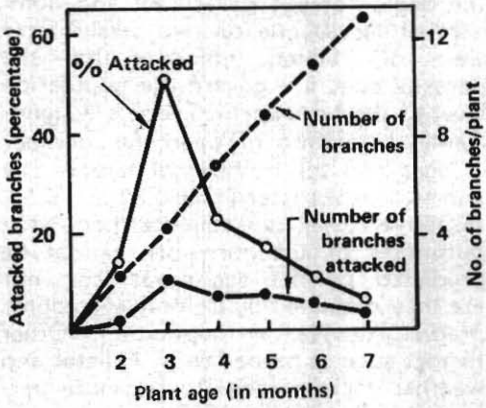


Figure 34. **Relationship between shootfly attack and branching of 90 clones, planted May 1, 1973.**

the number of attacked shoots continued to decrease and because of an increasing branch number, the percentage of attacked branches decreased (Figure 34).

Successive three-monthly plantings of these clones will give information on the most susceptible plant stage, shoot fly population fluctuations and varietal resistance. Of these 55 clones, some appear to have resistance (eg. M Colombia 642, 647, 1142, 1703, M Mexico 5 and 35, and Llanera), while others are susceptible (e.g., M Colombia 10, 65, and 1084, and M Panama 48).

Cassava hornworm

The cassava hornworm, **Erinnys ello,** this year only twice reached a population level that made chemical control appear necessary. The cause of the low population levels is not understood. Reduced chemical applications may have enhanced the egg parasitism by **Trichogramma,** larval predation by **Polistes** sp. and larval parasitism. Weekly counts of the egg and larval population fluctuations (in CIAT and ICA at Palmira), showed

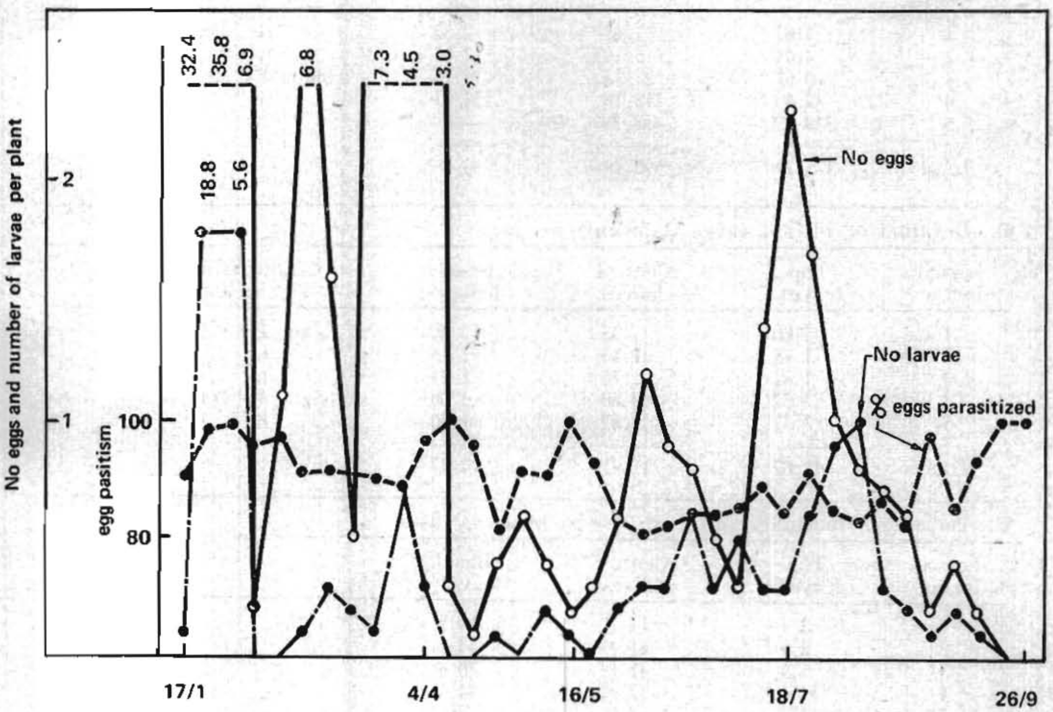


Figure 35. **Relationship between number of eggs, number of larvae per plant and percentage of egg parasitism of the cassava hornworm**

that egg parasitism was never below 53 per cent (Figure 35). The number of eggs per plant varied from 0-36 and the number of larvae from 0-19.

The percentage of egg parasitism was not correlated with the number of eggs (r = 0.23), indicating that the **Trichogramma** has sufficient other hosts to maintain its populations when the hornworm is absent. However, the number of eggs per plant and percentage of eggs parasitized one and two weeks later was correlated significantly, indicating that a relationship does exist in the fluctuation of the two populations. However, the degree of egg parasitism and numbers of larvae one or two weeks later were not related, indicating that the parasite does not govern the population level of the hornworm. There is a significant correlation between the number of eggs and the number of larvae, one and two weeks later (r = 0.82 and 0.58, respetively). In consequence, populaton outbreaks of the hornworn cannot be predicted by the egg parasitism, nor are they regulated by it; only egg counts predict the larval population. Other factors such as predation by **Polistes** and weather factors seem to be more pertinent.

Table 31. **Foliar area consumed per larval instar and duration of the instar of larvae fed on cassava leaves (in laboratory conditions) located at the top, central or basal part of the plant**

A. Foliar area consumed (avg. 30 larvae) in cm^2

Larval instar	Top leaves	Central leaves	Basal leaves	Statistical significance
1	1.63	1.68	2.32	ns
2	4.03	5.10	7.11	ns
3	10.62	27.72	16.16	sign. P< 0.01
4	89.40	118.10	154.43	ns
5	319.79	438.39	——	ns
Total	425.79	590.99	——	

B. Duration of instars (avg. 33 larvae) in days

Larval instar	Top leaves	Central leaves	Basal leaves	Statistical significance
1	2.00	1.33	2.30	sign. P< 0.01
2	1.88	1.86	1.86	ns
3	1.31	1.75	1.91	ns
4	3.52	2.60	3.00	sign. P< 0.01
5	3.31	3.87	1.00	ns
Total	12.02	11.41	10.07	

C. Percentage mortality recorded at end of each instar

Larval instar	Top leaves	Central leaves	Basal leaves
1	2.9	14.7	14.7
2	5.9	41.2	44.1
3	5.9	47.1	70.6
4	11.8	52.9	94.1
5	17.6	55.9	100

Table 32. **Influence of cyanide level on larval and pupal development and larval head capsule width (avg. 25 larvae, reared in the laboratory on leaves of 10-month old plants)**

I. Duration of larval and pupal instars (days) Larval stage	Leaf cyanide content		
	Low	Medium	High
1	2.19 a *	2.92 b	2.52 b
2	2.19 a	2.00 ab	1.87 b
3	2.66 a	1.92 b	2.13 ab
4	2.90 a	4.00 b	3.52 b
5	9.52 a	7.92 b	8.91 b
pupae	14.00 a	13.44 ab	12.91 b
	33.51	32.20	31.82
II. Head capsule width			
1	0.79 a	0.81 b	0.79 ab
2	1.24 ab	1.22 a	1.24 b
3	1.96 a	1.93 a	1.84 b
4	3.04 a	3.00 a	2.86 b
5	4.95 a	4.13 b	4.43 b
III. Pupal weight **			
	2.40 a	3.37 c	2.91 b

* Numbers followed by the same letter in each line are not significantly different

** Field collected pupae weighed 3.61 g which was not statistically different from 3.37

The economic importance of the damage caused by hornworms is being studied. Larval leaf consumption is compared with area of artificial defoliation and subsequent influence on yield.

The hornworm larva when it pupates consumes an average of 425.47 cm^2 of area of cassava leaves of plants, about 10 months old, under laboratory conditions (Table 31). Larvae on lower leaves consume more than those on upper leaves. About 75 per cent of the total area consumed is eaten in the last instar. The larval stage in this trial lasted 12 days. The more basal leaves caused high larval mortality and none of the larvae reared on the basal leaves reached the pupal stage.

Cassava is often reported as a plant relatively resistant to pests because of its cyanide content. To test the influence of cyanide of the leaves on larval development, larvae were reared in the laboratory on mixtures of leaves of plants with high, medium or low content of cyanide. From each class of cyanide content a mixture of four clones was used. When larvae were reared on leaves high in cyanide content, they developed fastest and those on low cyanide slowest (Table 32). Although the pupae weighed most when reared on leaves average in cyanide content, there were no clear indications that high or low cyanide content greatly influenced the larval development.

Resistance to hornworm may be found using oviposition preference. In cage studies the regression for numbers of eggs in free choice tests with leaf width and plant height as variables were:

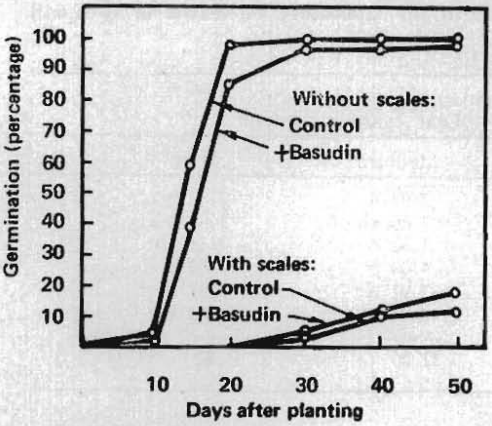


Figure 37. **Influence of scales and insecticidal treatment on germination of cuttings.**

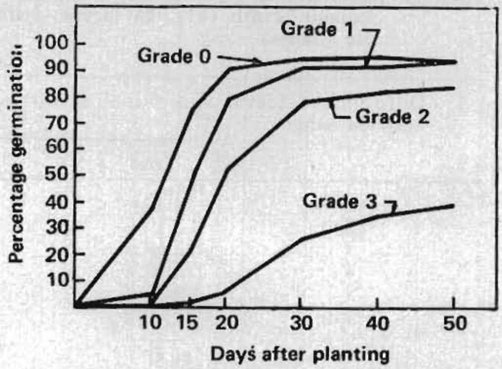


Figure 36. **Germination of cuttings infested to various degrees with scales (grade 0 = no scale, grade 3 = covered with scales)**

No. eggs = -22.59 + 2.84 (cm) x (plant height)
No. eggs = + 18.25 + 0.71 (mm) x (leaf width)

The hornworm in cage studies preferred to oviposit on taller plants, regardless of leaf width. The effect of plant height in oviposition preference studies with plants, differing in cyanide level, has to be taken into account.

Scale insects

Direct damage by the cassava scale **Aonidomytilus albus** (Fam. Diaspididae) has been observed in the form of dieback of branches. This grey-white mussel-shaped scale, about 2-3 mm in length can also greatly reduce germination of stakes (Figure 36). Insecticidal treatment of stakes completely covered with scales did not increase the germination (Figure 37). Apparently, the damage occurred before planting. Only occasionally were scales found on the young shoots germinating from scale infested cuttings. Not only germination is reduced but also initial plant growth is retarded in cuttings infested with scale (Table 33).

Stake dipping in insecticidal and acaricidal solutions should be used in any movement of planting material to prevent introduction of new pests. Some insecticidal treatments delayed germination (parathion) others not (monitor and malathion).

A second species, **Saissetia miranda** (Fam. Coccidae) is frequently found on young branches. However, its nymphs are heavily predated by Coccinellids

Table 33. **Plant height and number of leaves per plant, 40 days after planting cuttings infested to various degrees with the scale A. albus (grade O = no scales; 3 = completely covered)**

Infestation grade	Plant height	No. of leaves per plant
0	33.4 a	32.6 a
1	32.9 a	28.2 ab
2	23.1 b	19.2 b
3	5.5 c	4.8 c

Table 34. **Vatiga manihotae adult and nymphal populations per leaf on different plant parts (average 10 plants and 10 leaves per plant part) May, 1973**

Plant Part	No. of insects per leaf	
	Nymphs	Adults
Top	45.3	60.7
Middle	207.6	40.6
Basal	11.0	8.7

and its adults parasitized. The adult is a shiny black round scale, about 3-4 mm in diameter.

Vatiga manihotae

The lace bug is a potential cassava pest whose damage, expressed in yellowing of leaves and leaf drop, is similar to that of spider mites. The biology of **V. manihotae** was studied. The five nymphal instars are passed in 4.2, 2.2, 2.4, 3.5 and 5.5 days, respectively, with a total of 17.8 days. The egg stage lasted 14.8 days on the average. The adults measure 3.2 mm on the average and they prefer the top leaves (Table 34). Because of slow nymphal development, most of the nymphs are found on the central part of the plant.

Cutworms and Centipedes

In some plantings, the cutworms and centipedes clipped off newly emerged shoots and ate the buds of the cuttings. A bait of 3 liters of honey, 25 kg of corn meal and 1 liter of Dipterex (80%) applied around the cuttings, gives good control for both pests.

WEED CONTROL*

Weed control research continued to evaluate the competitive effects of weeds in cassava and to develop safe herbicide recommendations for chemical weed control.

* Names of substances used as herbicides appear with lower case letters. Names of commercial products appear with initial letters in capitals. **Editor's note.**

Table 35. **Effects of different weed competition periods on cassava fresh root yields and the percentage of yield as compared to cassava kept weed-free with herbicides for CMC-39 and CMC-84, 280 days after planting**

Number of weedings	Frequency of weedings	CMC-39 Fresh wt. (ton/ha)*	CMC-39 % of max. yd**	CMC-84 Fresh wt. ((ton/ha)*	CMC-84 % of max. yd**
4 +***	15,30,60,120, UH****	18.0	86	19.3	96
3 +	30,60,120, UH	16.0	76	15.3	77
2 +	60,120, UH	11.0	52	9.5	42
1 +	120, UH	7.0	33	2.8	14
4	15,30,60,120	19.5	92	14.7	73
3	15,30,60	12.9	61	16.8	84
2	15,30,	13.3	63	11.6	58
1	15	5.8	28	6.0	30
2	30,60	16.3	77	16.9	84
2	15,45	15.4	73	13.2	66
0	Weedy check	1.4	7	1.0	5
0	Chem. weed-free	21.1	100	20.1	100

* LSD (5%) = 2.9 ton/ha for weeding treatments
** Yield expressed as a percentage of the chemically weed-free treatment
*** The "+" indicates additional weedings were performed
**** UH = until harvest

Competition studies

Results of an experiment on the critical period of competition (CIAT's 1972 Annual Report) show that serious losses occur when weeding operations are not performed at the right time (Table 35). Maximum yields were always obtained in plots kept weed free with herbicides, and there was complete crop loss when no weeding was done.

CMC-39 and CMC-84, kept mechanically weed free all season, produced 86 and 96 per cent, respectively, of the yield of chemically weeded cassava

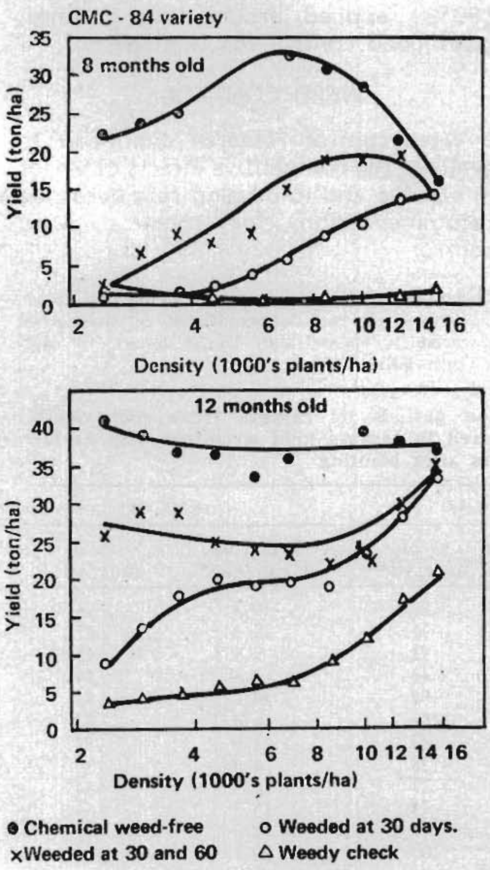


Figure 38. Effect of cassava density and weeding system on fresh root yields 8 and 12 months after planting in CMC – 84 variety

There was a significant yield reduction in the shorter variety (CMC-84) but not in the taller one (CMC-39) resulting from weeds that germinated after 120 days. One weeding was insufficient, but two well-timed weedings gave great yield increases over the controls.

Weed competition during the first 60 days reduced yields by more than 50 per cent. Keeping cassava weed free during the first 60 days gave an average yield of 76 per cent of the maximum. This indicates that the critical period of competition is from planting time to between 60 and 120 days after planting.

The weeding times and frequencies did not affect the root moisture content. The harvest index (ratio of root dry weight to total plant dry weight) was lowest for cassava kept weed free with herbicides for both varieties. Thus, in complete absence of weed competition, there was a tendency toward proportionately more aerial than root production. This would be beneficial in areas where the leaves are consumed or fed, or where planting material is being produced.

Two factors affecting the degree of weed competition in cassava are the crop density and the weed population. It can be assumed that completely weed-free cassava will be able to utilize all the available nutrients, light and water and that under these conditions, lower plant populations may be able to yield as much or more than higher ones. When weeds are present, higher crop populations are expected to be more competitive than lower ones. The interaction of plant spacing and the weed control system is being studied by using the systematic design.

Plant populations range from 2,380 to 15,850 plants/ha and the weed control treatments include one hand weeding at 30 days, two weedings at 30 and 60 days, a chemically weed-free treatment (fluometuron plus alachlor

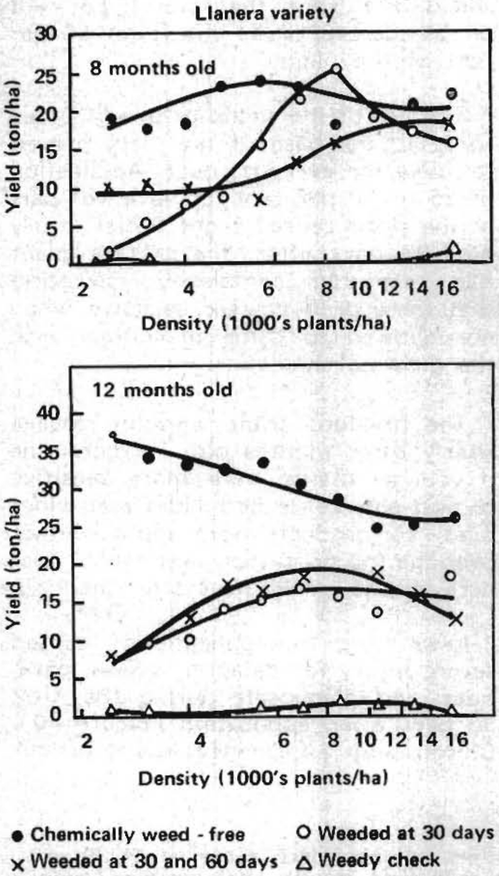


Figure 39. **Effect of cassava density and weeding system on fresh root yields 8 and 12 months after planting Llanera variety.**

pre-emergence and directed post-emergence applications of paraquat, as needed), and a weedy check.

The first trial was harvested 8 and 12 months after planting. Results are presented in Figures 38 and 39 for CMC-84 and Llanera, respectively. Eight months after planting, definite interactions exist in CMC-84. The maximum yield was reached with 6,000 to 8,000 plants/ha and then decreased by 50 per cent at 15,850 plants/ha for the chemically weed-free treatment. In contrast, the yield of CMC-84 weeded at 30 or 30 and 60 days reaches its maximum at the higher densities. Without weed control, eight months after planting yields were nil.

At twelve months after planting, yields increased little in the CMC-84 kept chemically weed-free over that harvested four months earlier. Lower densities tended to give higher yields but the differences are small. Cassava weeded at 30 or 30 and 60 days after planting produced more at higher than at lower populations, twelve months after planting. This means that cassava in the presence of some weeds has a higher optimum density for yield than when grown in weed-free conditions. The cassava in the weedy check plot made a notable recovery at 12 months, especially at high plant populations. Thus, part of the reason that cassava in many parts of the world is harvested 12 or more months after planting may be associated with the early weed competition which delays root production.

Yields of Llanera at eight months (Figure 39) are somewhat variable, but the same general trends are observed. Twelve months after harvest, the maximum yield was produced in the chemically weeded cassava at low plant densities, showing again that in weed-free cassava, lower plant populations yield more than higher ones. Llanera weeded once or twice reached maximum production between 7,000 and 10,000 plants/ha. When no weeding was performed, no cassava was produced at either eight or twelve months after planting. The absence of recovery at twelve months, as was observed for CMC-84, indicates that Llanera is a less competitive variety.

Herbicide studies

Reports about post-emergence herbicide applications in cassava are rare. Nevertheless, there is enough experimental evidence to support that such applications may provide good weed control until the cassava forms a closed canopy. Studies were undertaken to determine which herbicides can be safely applied in post-emergence, which is the best method to apply them and what effect the age of cassava has on its resistance to post-emergence applications.

Results show that diuron was the only completely safe product (Table 36). Despite early visual injury, the fresh weight root yield was not reduced. Herbicidal rates of dalapon, paraquat and MSMA caused severe injury, and the cassava did not recover. Lower rates caused correspondingly less damage and the cassava generally recovered as reflected by the yield data.

The method of application trial was done with a herbicidal rate of the same products mentioned above in Llanera Rojas, 84 days old. Application was done with a standard back-pack sprayer fitted with a flood-jet nozzle and used: 1) with an aluminum shield around the nozzle, 2) as a directed spray toward the base of the plant without the shield, 3) to spray the lower 25 per cent of the cassava, or 4) the lower 50 per cent of the plant.

The use of the shield or directing the spray to the base of the plant proved selective for every product. Application of 25 or 50 per cent to the lower part of the plant caused slight initial injury but, 30 days after, the cassava plant had recovered completely indicating that these products are selective when not allowed to come in contact with the growing shoots.

The previous trials were in cassava nearly three months old. To determine if younger plants were more sensitive to post-emergence herbicides than older ones, six products were applied either over the top or to the lower half of Llanera, 40, 65, or 90 days after planting.

Over the top-applications caused severe injury for dalapon, MSMA, paraquat and glyphosate during the first 60 days after application (Figure 40). Diuron and 2,4,-D were less injurious

Table 36. **Effect of five post-emergence herbicides on the injury rating at 14, 30 and 60 days after application, and fresh yield eight months after planting Llanera Rojas**

Herbicide	Rate of application (kg/ha)	Injury rating* 14	30	60	Yield (ton/ha)
1. Dalapon	2	0	0.6	1.7	10.9
2. Dalapon	4	6.1	7.1	5.7	10.1
3. Dalapon	8	9.1	9.8	10	0.6
4. Glyphosate	.12	0	0	0	10.5
5. Glyphosate	.25	2.0	2.6	2.0	12.0
6. Glyphosate	.50	3.0	6.8	5.2	9.4
7. Paraquat	.12	3.3	3.5	1.8	13.9
8. Paraquat	.25	7.3	7.1	4.0	9.4
9. Paraquat	.50	9.0	9.5	9.0	0.9
10. MSMA	2	1.8	4.1	3.3	11.9
11. MSMA	4	4.0	7.0	7.3	5.7
12. MSMA	8	4.5	8.5	9.3	0
13. Diuron	.5	2.8	2.5	1.0	11.1
14. Diuron	1	4.5	3.1	1.7	13.9
15. Diuron	2	7.0	6.3	2.7	11.4
16. Control	—	0	0	0	12.4

* 0 = no injury; 10 = death of cassava

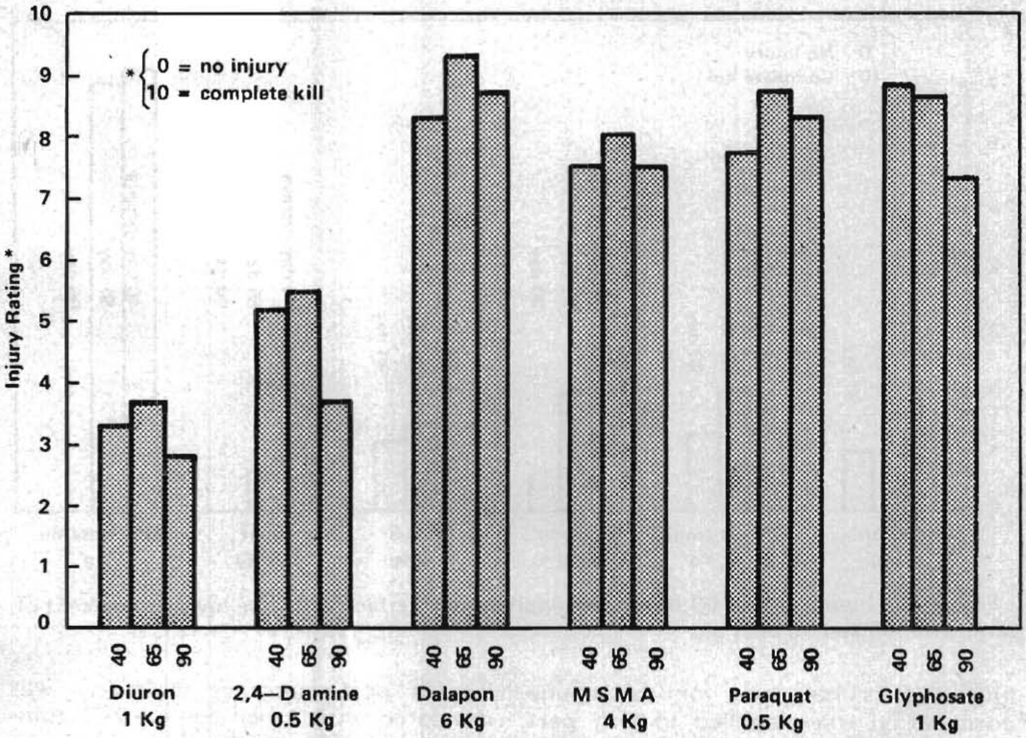


Figure 40. **Injury ratings 60 days after applying six herbicides over the top of 40, 65 and 90 days old cassava plants**

and there was slightly less injury in 90 day old cassava only with 2,4-D, diuron and giyphosate.

However, the fresh root yield at 270 days show that cassava has a tremendous capacity to recover from early injury (Table 37). Yields from the diuron -treated plants were only slightly less than that of non-treated cassava. Dalapon, MSMA, and paraquat were highiy toxic at all three stages of growth when applied over the top. Glyphosate was selective when the cassava was 90 days old and completely non-selective at the earlier stages.

In the more realistic situation, most herbicides were selective when applied only to the lower half of cassava. No interaction between age of the cassava and herbicide was observed for diuron, 2,4-D or MSMA applied to the lower half (Figure 41 and Table 37). Paraquat was toxic at 40 days but not at the later stages of application. Glyphosate was highly toxic at 40 and 65 days; when applied in these stages, the cassava was dwarfed and the development of the growing points severely affected. Nevertheless, when applied 90 days after planting, it was selective.

Paraquat was toxic when applied to the lower half of young cassava but not to more mature plants. As it is a nontransiocated compound, injury was observed only where it hit the plant.

The selectivity of 2,4-D amine when not applied to the growing points is noteworthy as cassava is normally thought to be highly susceptible to the hormonal herbicides. The results show

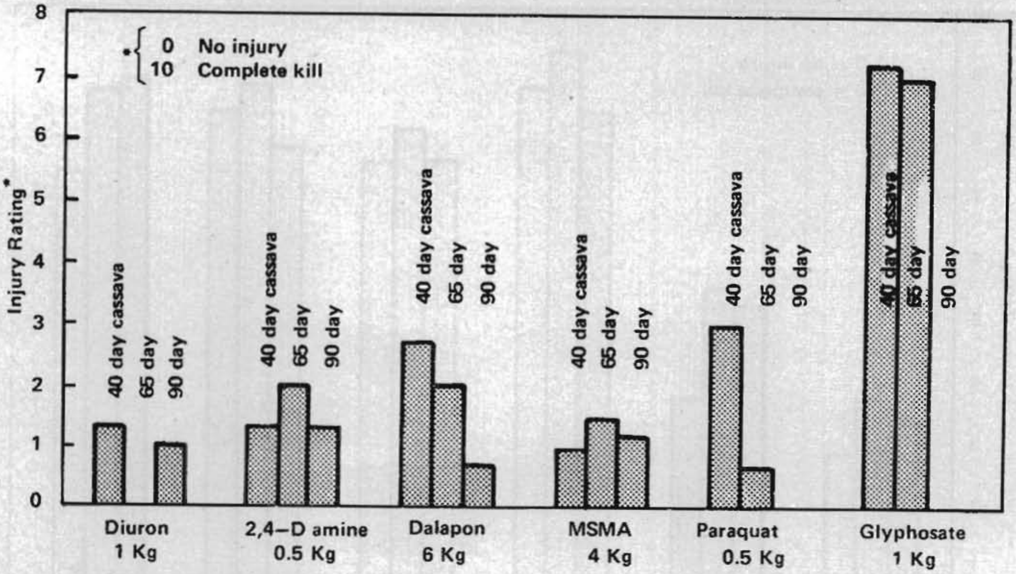


Figure 41. Injury ratings 60 days after applying six herbicides to the lower 50 percent of cassava 40, 65 and 90 days old

that this is not true for the amine formulation when applied to only part of the plant. The over-the-top application caused serious root deformation as well as yield reductions.

Since diuron is only one of many herbicides of the substituted urea family, its post-emergence selectivity was compared with other commercial compounds of this group.

The most selective substituted urea herbicides were fluometuron, norea, DPX-6774 and the most toxic were chlorbromuron, methobromuron, linu-

Table 37. **Fresh root yields at 270 days of Llanera as affected by method of post-emergence application of six herbicides and age of cassava**

Herbicide	Rate of application (kg/ha)	Method of application	Yields (ton/ha) Age at application (days)		
			40	65	90
1. Diuron	1	Total	32.1	28.0	32.2
2. Diuron	1	LH*	39.0	37.9	40.5
3. 2,4-D amine	0.5	Total	20.9	13.6	29.3
4. 2,4-D amine	0.5	LH	34.3	32.3	35.7
5. Dalapon	6	Total	9.7	3.2	3.6
6. Dalapon	6	LH	31.9	52.6	46.5
7. MSMA	4	Total	13.6	12.8	7.6
8. MSMA	4	LH	40.9	33.3	35.6
9. Paraquat	0.5	Total	20.0	7.6	7.8
10. Paraquat	0.5	LH	26.9	33.0	44.9
11. Glyphosate	1.0	Total	1.6	2.3	32.9
12. Glyphosate	1.0	LH	5.7	18.3	42.6
13. Control	—	—	36.9	36.9	36.9

* LH = Lower half of the plant treated

ron and diuron. The controlling factor seems to be the presence or absence of a halogen atom on the phenyl ring. Those ureas which do not have a halogen on the ring are much more selective than those which do.

Llanera Rojas was significantly more susceptible than CMC-84 to all treatments. As the leaf area of Llanera Rojas is less than that of CMC-84, less total product was applied per plant to Llanera Rojas and yet it was the more susceptible. The explanation for this must be in either differential rates of penetration or translocation.

PROCESSING

Fresh root storage*

Studies on the nature and occurrence of the rapid post-harvest deterioration of cassava roots have continued and two phases of deterioration have been recognized.

* Tropical Products Insitute/CIAT joint project.

Primary deterioration

The initial cause of loss of acceptability of harvested roots is internal discoloration. This is first evident as a fine blue-black net of vascular streaks. This streaking increases in intensity and spreads to non vascular tissue where a more diffuse brown discoloration accompanied by dry white lesions occur.

Secondary deterioration

Following discoloration, rotting, fermentation and/or softening of the roots occurs. Softening commences in the central core of the roots and gradually spreads outwards.

Continued studies on the use of surface sterilants have confirmed that these may delay the onset of primary deterioration (Table 38). As a result of this, 50 per cent commercial alcohol dips have been investigated as an aid to the natural drying of cassava chips.

The importance of the role of mechanical damage in the initiation of primary deterioration has been confirmed. Thus,

Table 38. **Effect of calcium hypochlorite and commercial alcohol on the deterioration of cassava root slices**

Treatment*	Deterioration index (%)				
	0	1	2	3	4 (days)
Undipped control	0	100	100	100	100
30 sec. dip in sterile distilled water	0	100	100	100	100
30 sec. dip in 1.0% commercial alcohol	0	100	100	100	100
30 sec. dip in 5.0% commercial alcohol	0	75	100	100	100
30 sec. dip in 10.0% commercial alcohol	0	50	75	100	100
30 sec. dip in 20.0% commercial alcohol	0	25	50	75	100
30 sec. dip in 40.0% commercial alcohol	0	0	12	25	30
30 sec. dip in 60.0% commercial alcohol	0	0	0	0	2
30 sec. dip in 0.1% Ca hypochlorite	0	81	100	100	100
30 sec. dip in 0.5% Ca hypochlorite	0	25	50	75	100
30 sec. dip in 1.0% Ca hypochlorite	0	0	12	50	60
30 sec. dip in 2.0% Ca hypochlorite	0**	0**	0**	0**	12**
30 sec. dip in 3.0% Ca hypochlorite	0**	0**	0**	0**	12**
30 sec. dip in 5.0% Ca hypochlorite	0**	0**	0**	0**	12**

* 4 x 4 slices per treatment
** Slight discoloration because of phytotoxicity

Table 39. **Effect of severity of damage on fresh weight loss and deterioration of cassava roots stored at ambient conditions * in the laboratory**

Time in storage (days)	Fresh weight loss** %		Deterioration index** %	
	Slightly*** damaged	Severely**** damaged	Slightly*** damaged	Severely**** damaged
1	2.9	3.5	2	15
2	7.4	10.1	27	32
4	12.4	15.9	62	65
7	17.9	21.5	57	67
11	22.1	34.2	72	75

* Ambient conditions temperature 20°C ± 4°C
** 3 x 10 roots per sample
*** Roots with no obvious gross physical damage
**** Roots with obvious physical damage

it is recommended that produce intended for storage should be harvested and handled with extreme care (Table 39). It is considered that those varieties with an obvious root stalk may be best suited to storage as the roots can be severed from the plant with a minimum of damage. This character needs to be studied in conjunction with such factors as root shape and distribution which also influence the ease of harvesting and the degree of harvesting damage. The normal commercial practice of packaging, transporting, and marketing roots in large sacks containing between 80 and 100 kilos results in severe damage.

Continued trials in clamp storage and storage in experimental concrete tubes have shown that, as with many other root crops, cassava roots can be cured, during which process, wounds are healed. The exact conditions under which curing occurs have not been determined but high relative humidity and a temperature in the range of 30° to 40°C appear suitable. Once cured, cassava roots can be stored (either in clamps or in the laboratory) for up to two months without primary deterioration occurring.

A preliminary trial on the use of clamp storage in different environmental regions of Colombia has revealed that clamps must be modified to local conditions so as to reduce internal clamp temperature as required. Temperatures in excess of 40°C result in heavy losses (Table 40). Also, during the rainy sea-

Table 40. **Results of clamp storage at different temperatures**

Time in storage (months)	Undeteriorated roots* (Percentage) — Temperature of stored roots	
	30-35°C	40°C and above
1	85-90	5-25
2	70-75	0- 5
3	40-60	0

* Average of five clamps within each temperature range. Each clamp contained 500 roots which weighed approximately 300 kilos

Table 41. Comparison of shelf life of fresh uncured roots (A) with that of roots that had been cured and stored in a clamp for eight weeks (B)

Laboratory storage (Weeks)	Deterioration Index* (Percentage)	
	A	B
1	45	10
2	80	7
3	100	20

* 3 x 10 roots per sample

son,clamps need protection to prevent water penetration. Once the roots become wet, they rot rapidly. In all cases, losses that occur during clamp storage are the result of secondary deterioration.

Undeteriorated roots, even after three months of clamp storage, pass local freshness tests such as nature and firmness of the skin, flesh moisture, and latex exudation. However, following clamp storage, certain quality changes in the roots have been observed. Stored, uncooked roots taste considerably sweeter than freshly harvested roots of the same variety. This sweetening is less noticeable in cooked samples and only with a few individuals has there been a marginal loss of acceptability. In a few samples, a slightly longer cooking period was required to soften the stored roots than was required for freshly harvested roots. Roots which had softened internally during prolonged storage frequently regained an acceptable texture and edible quality during cooking.

It has also been observed that after successful curing the shelf life of the roots subsequent to removal from storage was considerably longer than that of freshly harvested roots kept under the same conditions (Table 41). This raises the possibility that under some circumstances it may be advantageous to remove roots from clamps after two weeks, when curing is complete, and store them in a simple building in boxes rather than leave them for longer periods in the clamps.

Cassava drying*

Cassava particles of various geometrical forms were dried under different measured ambient conditions and their rate of drying was determined. A complex simulation model was designed and with this model 98 per cent of the variation in drying rates was accounted for by the set of constants for the drying system being used, variations in relative humidity, variations in wind speed, and variations in temperature. Figure 42 shows the close correlation between actual and simulated moisture contents.

The model simulations have been used to describe the improvements that may be made in present drying methods by changing particle form and size and drying systems under different conditions. The use of average ambient conditions of the effective drying hours of a day can be used to predict average drying rates with accuracy.

Because cassava particles are white and have high reflectivity, they do not absorb incoming solar radiation efficiently. The root-drying rate is, therefore, almost completely independent of the direct effects of solar radiation.

Cassava chips dry quickly when there is a rapid movement of warm dry air through the mass of chips. The energy required for evaporation is supplied by the available energy of the air. Therefore,

* This work forms part of a doctoral dissertation presented by Gonzalo Roa at Michigan State University.

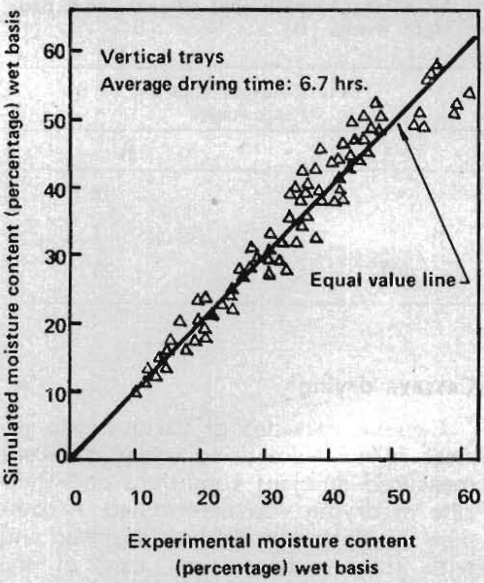


Figure 42. **Comparison of experimental and simulated moisture content values at the end of a drying day**

efforts to improve cassava drying systems, where air of ambient relative humidity and temperature is used, should concentrate on increasing air movement through the mass of chips.

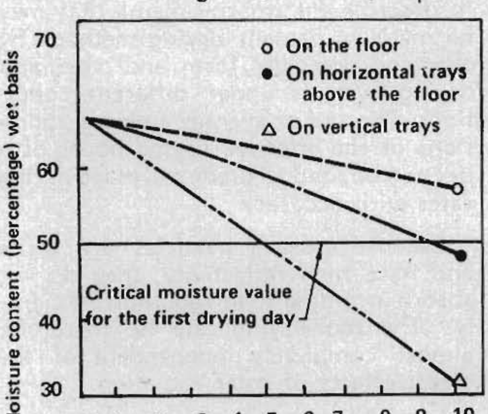


Figure 43. **Drying curves as a function of different drying systems using bars 0.9 x 0.9 x 5.0 cm. (simulated)**

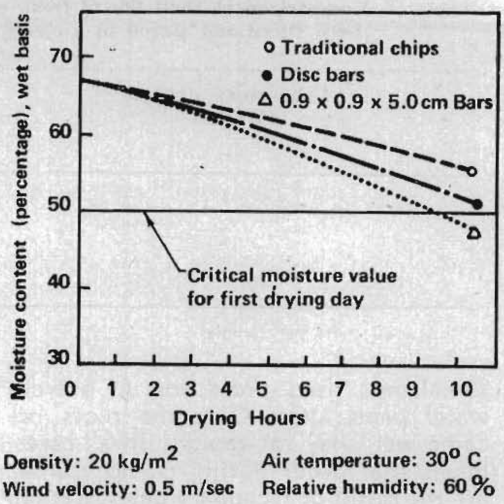


Figure 44. **Drying curves of different types of particles using horizontal trays at 30 cm above the floor (simulated).**

In most of the commonly used drying systems, cassava roots are placed directly on a concrete pad. The wind speed at or near the ground surface is low, and air movement through the cassava would be expected to be low. Cassava particles in trays raised 30 cm above the ground level dried much more rapidly than those on the ground because of increased air movement (Figure 43). Placing the cassava chips in vertical trays which "catch" more of the wind increased drying rate still further.

To take advantage of such air movement, the chips being dried need to permit air passage. Rectangular bars of cassava have better aerodynamical properties than conventional sliced chips. A comparison of their drying rates using simulation shows that they are superior if the bar's section is less than 1.2 x 1.2 cm (Figure 44) and particularly, at high densities of particles-per-unit area. Using a simple disc chipper that produced irregular rectangular bars (disc bars), drying rate was better than with the conventional chips.

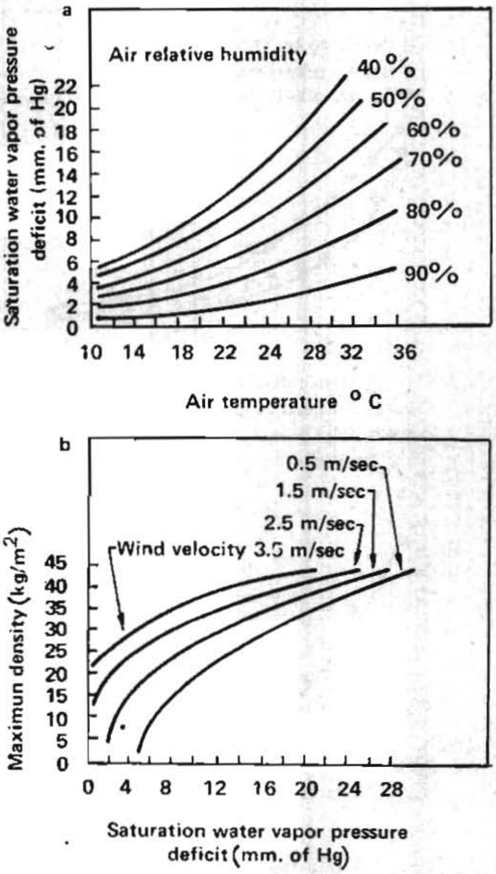


Figure 45. **Maximum density permissible under different weather conditions for use with vertical drier using disc bars. Time: 11 hrs**

The most rapid simple drying system so far obtained has a chip form with small section and high porosity (e.g., 0.8 x 0.8 x 1.0 to 5.0 cm bars) placed in vertical trays. The rate of drying with this system is more than double that of the conventional system.

Cassava must lose at least 50 per cent of its initial water content in the first day so as not spoil. The maximum permissible density which will allow cassava to reach 50 per cent moisture content, wet basis, in the first day, can be calculated for different drying conditions if the average temperature, humidity, and wind speed for the effective drying hours of a day are known. The water vapor pressure deficit is obtained from Figure 45-a and hence, the layer density from Figure 45-b. These graphs are applicable only to the vertical drier using disc bars; further curves can be constructed for any system of drying. Using layer densities calculated with these curves, chips would take about three days to reach a moisture content close to the equilibrium moisture value fixed by weather conditions (Figure 46).

To store cassava without deterioration, it must be dried to 14 per cent moisture content, wet basis. Using air at ambient temperature and moisture conditions, cassava can only be dried to its equilibrium moisture content. When relative humidity does not go below about 75 per cent it is necessary to use supplemental heat to dry cassava to a safe storage level.

Cassava is normally grown for periods of 10 to 24 months; hence, harvesting on the exact date planned is not vital. Thus, cassava can be harvested in the dry season, or when conditions are suitable for drying.

The construction of vertical trays to hold cassava would be costly and they would be difficult to fill. The use of horizontal trays, or inclined wire mesh trays, appears to be quite feasible and should give much more rapid drying than present methods.

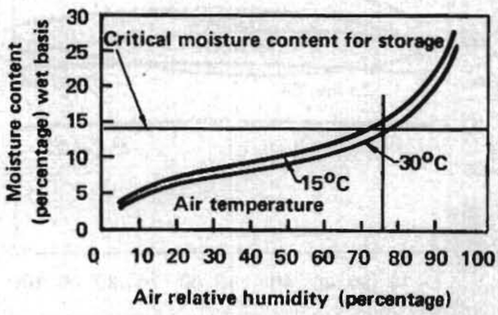


Figure 46. **Equilibrium moisture content curves of cassava.**

The construction of a cheap chipper that produces chips of the required geometrics needs to be further studied. There is little doubt that more rapid drying can be achieved by using a square rectangular bar of about 0.8 x 0.8 x (0.8 to 5) cm.

BIOMETRICS

More effective experimental designs and analysis techniques are being developed to make efficient use of the relatively scarce planting material and land because, cassava being a large plant, requires relatively large experimental plots.

Another related issue has been the concern for statistical precision in the research efforts. Cassava has exhibited large inter plant variability and this characteristic has been taken to imply the need for large experimental plots. These large plots, in turn, tend to reduce the number of replications. As the vegetative cycle for cassava is long, there is high risk that costly long-term experiments may to be non conclusive.

A variety trial experiment arranged in a randomized complete block design, with four replication in plots of 10 x 7.8 m at a population density of 17 x 10³ plants per hectare, was harvested and data collected on each individual plant. The varieties included were Llanera, Extranjera, M Colombia 65, M Panama 64, CMC-84, M Colombia 22, M Colombia 645, Llanera Rojas, M Colombia 463.

For each variety, random samples of (5, 10, 15, ..., 100) were taken to simulate plots of the respective sizes. The coefficient of variation was computed for each of these simulated plot sizes. With these data, a quadratic function was fitted expressing yield as a function of plot size. Figure 47 presents the composite of these curves. There is no

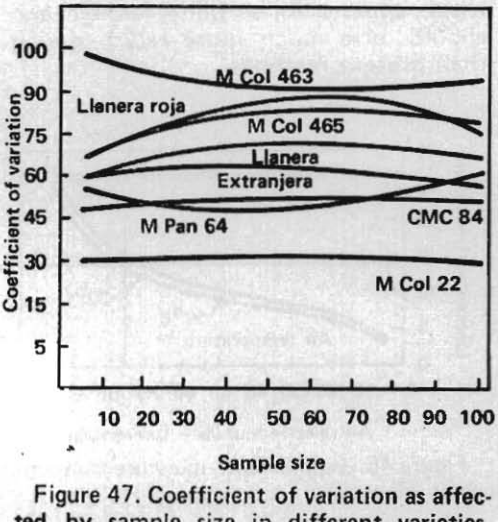


Figure 47. Coefficient of variation as affected by sample size in different varieties.

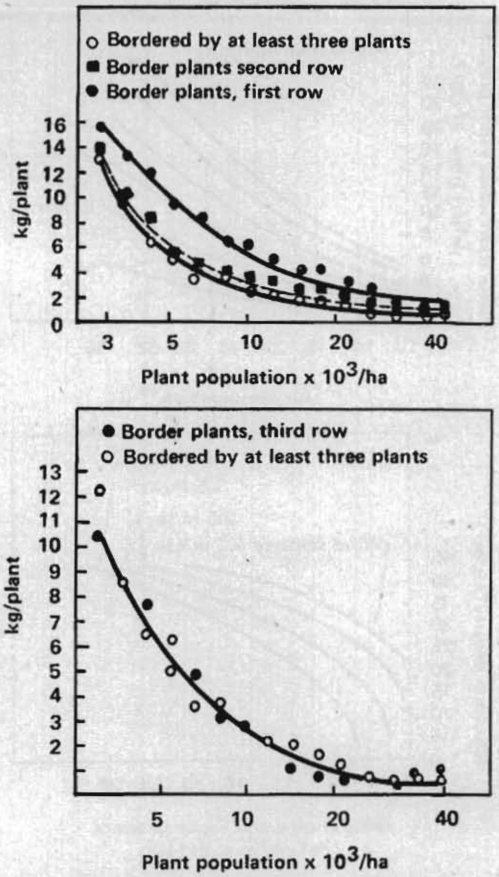


Figure 48. Relative yield of border plants of Llanera at different plant populations.

appreciable decline in the coefficient of variation as a function of plot size. This suggests that more effective designs would require a large number of small plots. Using the same data, mean square errors were computed for randomized complete block designs, using plot sizes of (5, 10, 15, ..., 35). While these results are inconclusive (for some varieties, mean square error decreases as a function of plot size and for others it increases), there appears to be an inflection point located somewhere between 20 and 25 plants per plot for most of the varieties tested. This suggests that a preliminary recommendation would be to use square plots of 25 plants each.

This practice was tested by calculating the required number of replicates to detect a five ton per hectare difference in production, given the mean square error calculated for the square plots of 25 plants. The results indicate that at least five replications would be required to detect differences of five tons per hectare. The preliminary recommendation is, therefore, that cassava field experiments using randomized complete blocks consist of at least six replicates of 25 experimental plants laid out in square plots.

The plot size referred to is the area to be harvested. In Figure 48 it can be seen that the harvested area should be surrounded by at least two border rows on all sides, so that real yield values are approached.

ECONOMICS

Estimated labor use in cassava production

Data on labor use was collected from 300 producers in 19 Departments of Colombia. Obtaining reliable information on production costs and input use was emphasized. Only the major findings, with respect to labor use, are reported here.

About 30 per cent of the sample farms used machinery to prepare land. No other activities were mechanized. Considering the impact of mechanized land preparation on labor use and cost of production, the sample farms were divided into two groups according to whether land preparation was mechanized or not.

Table 42 shows the estimated labor use by production activity. Total annual

Table 42. **Estimated labor use in the production of cassava in Colombia by activity**

Activity	Mechanical land preparation		Manual land preparation	
	Man-days per ha/yr	%	Man-days per ha/yr	%
Land preparation	—	—	25.0	22.6
Planting	9.1	10.4	10.8	9.8
Replanting	0.3	0.3	0.6	0.6
Weeding	46.8	53.4	43.2	39.0
Application of fertilizers	0.5	0.6	0.3	0.3
Application of insecticides	0.3	0.3	0.7	0.6
Harvesting and packing	30.7	35.0	30.0	27.1
Total	87.7	100.0	110.6	100.0

Table 43. **Labor use per hectare and per ton of cassava produced in Colombia, Brazil and Jamaica**

Countries and areas	Man-days per ha/yr	Yield (ton/ha)	Man-days per ton
Colombia*			
Mechanized land preparation	87.7	12.6	7.0
Manual land preparation	110.6	11.5	9.6
Colombia**			
Coffee zones	105.0	—	—
Northeast Brazil***			
Alagoas	96.0	10.7	9.0
Maranhao	69.0	10.0	6.9
Sergipe	165.4	13.9	11.9
Average	110.0	11.5	9.6
Jamaica****			
Mandeville	191.5	15.9	12.0
Santa Cruz	186.0	6.3	29.5

* Data estimated in this study

** Source: Fondo de Desarrollo y Diversificaciones de Zonas Cafeteras. **Cultivos y Empresas de Sustitución para Zonas Cafeteras Marginales.** 1968, p. 35

*** Source: **Feasibility of Manioc Production in Northeast Brazil.** University of Georgia, 1971, p. 45

**** Source: Rankine, Lloyd B. and Marlene Hee Young. **A Preliminary View of Cassava Production in Jamaica.** Occasional Series No. 6. Department of Agricultural Economics, University of West Indies, Trinidad, December, 1971

labor use per hectare was estimated at 87.7 man-days under mechanized land preparation and 110.6 man-days where the land was prepared manually. Weeding was the major labor-using activity. Manual land preparation and harvesting were other important labor activities.

To assess the general applicability of the results reported in Table 42, comparisons are made with results from similar studies in other regions. Total labor use per hectare in cassava production in the coffe zones of Colombia was estimated to be similar to that estimated for producers preparing land manually (Table 43).

Estimates from Northeast Brazil show a considerable variation among regions. However, the average labor requirements are similar to those estimated for Colombia. Labor requirements in the production of cassava in Jamaica were estimated to be considerably larger than those estimated for Colombia and Brazil.

The labor needed to produce a ton of cassava was estimated to be 7 man-days if machines were used for land preparation and 9.6 man-days if the land was prepared manually. Labor needs per ton of cassava produced appear to be similar for Colombia and Northeast Brazil, while they are somewhat larger for Jamaica (Table 43).

Table 44. **Preliminary data on cassava disease frequency (First visit: farms were included)**

Disease	Per cent of farms affected
Cercospora henningsii	40.0
Cercospora caribae	37.5
Cercospora sp.	21.7
Phyllosticta sp.	14.2
Erysiphe sp.	8.3
Superelongation	5.8
CBB	4.2
Others	3.3
No diseases were recorded	29.2

Description of the cassava production process in Colombia

The overall objective of this project is to make information available to support decision making on the allocation of resources in research, extension, production and public policy with respect to cassava. The more specific objectives are: a) to describe the technological characteristics of the production process including an estimation of the quantity and quality of the production factors used and their cost; b) to describe the varieties presently grown; c) to describe the biological factors limiting yields such as plant diseases, insect damage, etc.; d) to estimate total and net returns to the producers; and e) to develop and test a methodological framework aimed at studying the factors lim-

Table 45. **Preliminary data on insect damage in cassava (First visit: 120 farms were included**

Insect	Per cent of farms affected
Scirtotrips manihote	79.2
Hiperdiplosia brassiliensis	49.2
Bemisia sp.	40.8
Atta sp.	26.7
Silba pendula	26.7
Empoasca sp.	21.7
Anastrepha sp.	16.7
Erinnys ello	14.2
Diabrotica sp.	7.5
Aleurothrixus sp.	5.8
Others	5.8
No insect damage recorded	5.0

iting cassava yield in other regions and how these factors may be changed.

The study is based on the collection of primary data from personal visits to approximately 300 cassava producers located in five regions of Colombia. Each farm is being visited three times during the growing season by a team of previously trained agronomists and economists. The data will be obtained partly from field observations and sample gathering and partly from interviews with the producers.

At year's end, data from the first visits to 120 cassava producers were being analyzed. Tables 44 and 45 show preliminary results with respect to disease and insect frequency. These preliminary results refer to cassava crops less than four months old, hence disease and insect frequencies during the complete growing cycle may differ considerably from the preliminary data presented here. For example, CBB does not usually present itself severely in the first months after planting. Attempts are presently being made to estimate the impact of the various disease and insect attacks on yields in order to provide information on expected relative pay offs from disease and insect resistant cassava varieties.

Swine

production systems

Approximately 85 per cent of the swine are grown as a secondary or back yard enterprise on small or subsistence farms. Although there are more than 100 million head of pigs in Latin America, the yield of pork from these animals is only 10 to 15 per cent of that produced from efficient, commercial swine farms. Swine diseases are responsible for significant economic losses, but the greatest initial impact on the quantity of pork produced will be realized through improved feeding, nutrition and management.

NUTRITION

Although progress to evaluate tropical feedstuffs and to develop nutritionally sound life-cycle feeding systems for swine based on these feeds has been made, the high cost of many of these feed ingredients and government control of livestock prices have limited profit margins.

As 80 to 90 per cent of the total cost of producing pork in Latin America is associated with feed cost, emphasis has continued on the utilization of available feedstuffs which are diverse and of greatly varied quality. Available feedstuffs are first evaluated nutritionally and if satisfactory, incorporated into an overall feeding system.

Cassava

As the cassava root is an abundant source of energy in the lowland tropics, evaluations have continued in order to develop feeding systems that make maximum use of this feedstuff.

Experiments have determined the effect of hydrocyanic acid (HCN) content, feeding method and physical form of cassava on the performance and health of growing and finishing pigs. Two varieties, Llanera and CMC-84, were used. Llanera contains a low level of HCN (less than 50 mg/kg) and CMC-84 a medium level of HCN (between 150 to 250 mg/kg).

When fed free-choice along with a protein supplement, daily consumption of fresh sweet cassava was 3.00 kg as compared to only 986 g when bitter cassava (CMC-84) was fed (Table 1). Pigs consuming sweet cassava (Llanera) also consumed an average of 814 g of protein supplement. As the consumption of bitter cassava was low, these pigs compensated by consuming more (1,212 g) of protein supplement. Low consumption of bitter cassava and the over consumption of protein supplement resulted in a diet excessive in protein (Figure 1) and also that was not economical.

Mixing of the protein supplement with the bitter cassava to prevent overconsumption of protein did not increase cassava consumption or pig performance. In fact, because of the reduction of protein supplement consumption from 1,212 to 223 g, the pigs lost approximately 79 g of body weight per day. When this system was used with sweet cassava, neither daily feed consumption nor pig performance was improved over that obtained when both cassava and protein supplement were fed free-choice.

Cassava meal was also prepared from these two varieties and fed in bal-

Table 1. **Comparison of consumption and performance of finishing pigs fed either sweet or bitter fresh cassava**

Parameters	Experimental diets			
	Sweet cassava + Prot. sup. *Ad. lib.*	Sweet cassava + Prot. sup. Cont.	Bitter cassava + Prot. sup. *Ad. lib.*	Bitter cassava + Prot. sup. Cont.
Avg. daily gain, kg	.661	.770	.557	–.079
Daily cons. cassava, kg	2.990	3.402	.986	.929
Daily cons. prot. sup., kg	.814	.816	1.212	.223
Total feed cons., kg*	1.977	2.007	1.595	.584
Protein, %	14.1	13.3	23.5	13.3
Feed/gain	2.99	2.61	2.86	Neg.

* Expressed to contain 10 per cent moisture

anced diets to growing swine. Figure 2 demonstrates the average daily consumption of feed by pigs fed diets based on either sweet or bitter cassava meal. Pigs fed bitter cassava meal consumed less feed during the first week, and this reduced consumption to a lesser degree continued throughout the four-week trial. The lower level of consumption of this diet resulted in a reduction in average daily gain from 618 g for sweet cassava to only 558 g per day for those pigs fed bitter cassava (Table 2).

This reduction in gain and feed consumption was accompanied by an improvement in efficiency of feed conversion. This suggests that the bitter cassava meal reduces the palatability of the diet. But once it is consumed, it has little if any detrimental effect on metabolic processes except those related to detoxification of residual HCN or HCN produced from beta-glucosides present in the cassava meal.

Another study measured the effect of the method of drying bitter cassava on rat performance and plasma and urinary thiocyanate levels. Fresh bitter cassava (CMC-84) was ground and dried either in the sun or in a forced-air oven at 60 and 86°C. This dried material was reground and included in equal quantities as the major energy source (80%) in diets for growing rats. Rat performance was excellent when any one of the three drying methods was employed. Although growth rate, feed consumption, feed efficiency and protein efficiency ratio (PER) were similar for all three treatment groups receiving cassava meal, the rats fed the meal dried in a forced-air oven at 60°C tended to perform better.

Other groups of rats maintained in metabolism cages and fed equal quantities of the same diets demonstrated that plasma level of thiocyanate is associated with dietary level of cyanide. This metabolism study also provided substantial evidence to indicate that the beta-glucosides (linamarin and lotaustralin), even after the beta-glucosidases have been destroyed by heating to 86°C, are metabolized in the body and when present also increase thiocyanate production and excretion. When bitter cassava is dried at a temperature (60°C) below that required to destroy the beta-glucosidases (72°C), there is a greater production and excretion of the cyanide detoxification product, thiocyanate.

A series of experiments evaluated chemically and biologically the nitrogen fraction of the cassava root and studied other factors affecting nitrogen utilization.

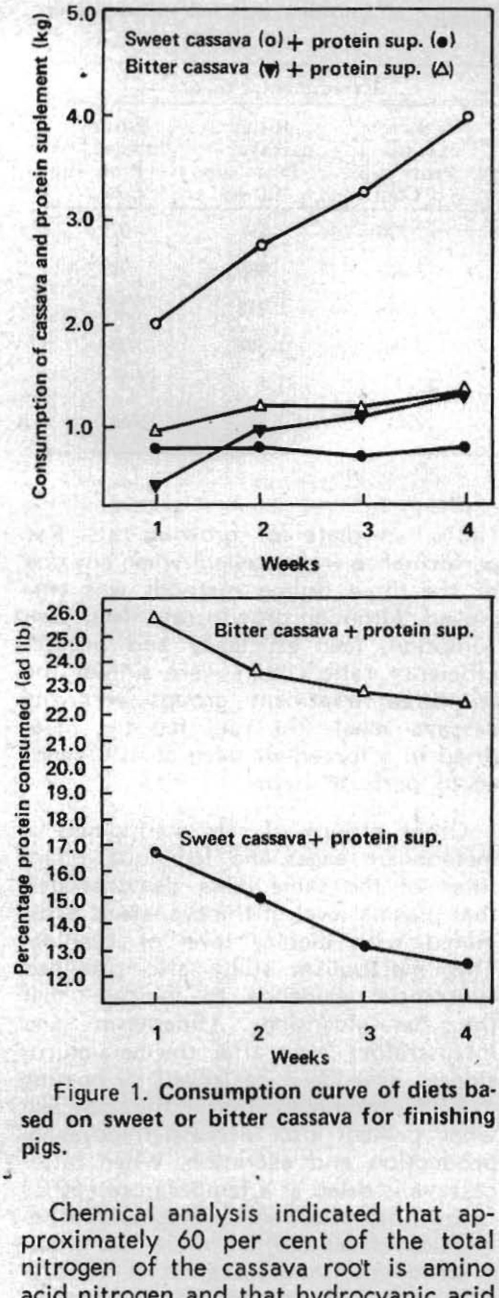


Figure 1. **Consumption curve of diets based on sweet or bitter cassava for finishing pigs.**

Chemical analysis indicated that approximately 60 per cent of the total nitrogen of the cassava root is amino acid nitrogen and that hydrocyanic acid and nitrates-nitrites make up less than one per cent of the nitrogen fraction (Figure 3).

Subsequent studies estimated the value of cassava protein for rat growth

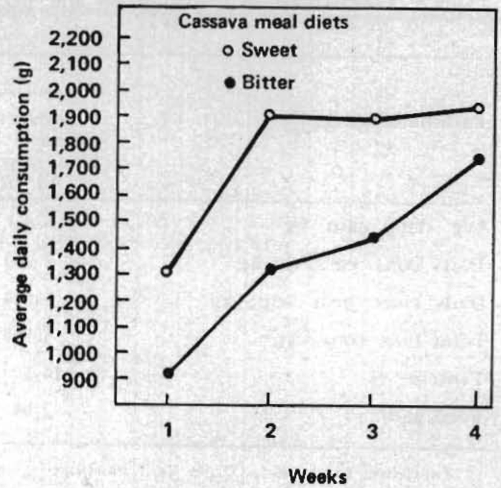


Figure 2. **Consumption curve of diets based on sweet or bitter cassava meal for growing pigs**

and measured the effect of supplemental methionine on improving the value of cassava protein. The biological data demonstrated that the nitrogen fraction of the cassava root is approximately 50 per cent utilizable by the growing rat and that methionine supplementation to cassava meal-based diets significantly improved rat performance.

Although differences in tolerance to dietary cyanide were observed among rats, it was demonstrated that 3,200 ppm or higher levels of cyanide added to the diets as potassium cyanide was

Table 2. **Effect of sweet and bitter cassava meal as the major carbohydrate in diets for growing swine**

	Cassava meal	
Parameters	Sweet	Bitter *
Initial weight, kg	39.8	39.3
Final weight, kg	57.1	54.9
Avg. daily gain, kg	.618	.558
Avg. daily feed, kg	1.767	1.354
Feed/gain	2.86	2.43

* Estimated to contain 150 to 200 mg HCN per kg of fresh cassava

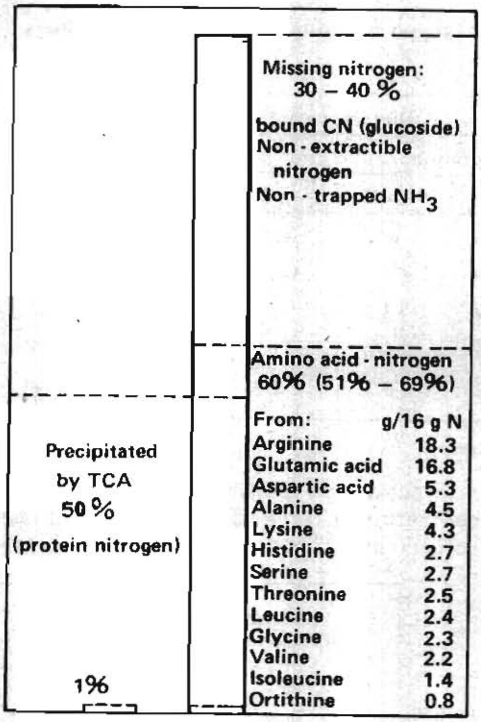


Figure 3. Nitrogen fraction of cassava roots of the variety Llanera with 0.4% total nitrogen (air dry basis).

lethal for growing rats and that cyanide levels of 2,400 ppm or lower, although sublethal, reduced rat performance (Table 3). Each increase in level of dietary cyanide resulted in a corresponding linear increase in urinary thiocyanate excretion, but the same correlation was not observed in plasma thiocyanate.

Two additional growth and metabolism trials with rats studied the effect of supplemental methionine on the protein quality of the diet based on cassava meal and on the detoxification of dietary cyanide. The experimental data obtained (Table 4) demonstrated that each increase in dietary cyanide from 0 to 2,400 ppm depressed growth and increased the amount of feed required per gram of gain and that dietary cyanide, from either cassava meal or cyanide added to the basal diet, induced high levels of urinary thiocyanate excretion; however, as shown before, plasma thiocyanate concentration did not follow the same pattern. Supplemental methionine improved rat performance at all levels of added cyanide and when fed increased the urinary excretion of thiocyanate.

Thiocyanate, the main detoxification agent of cyanide or hydrocyanic acid, has been suggested as the antithyroid agent that causes goiter in areas of high

Table 3. Effect of cyanide on mortality and performance of rats

Level of added cyanide (as KCN), ppm.	Number of rats		Total wt. gain, g	Feed consumed g	Urinary* thiocyanate excretion mg/8 days	Plasma** thiocyanate concentration mg/100 ml
	Initial	Final				
0	5	5	27.9	127.2	0.33	1.49
480	5	5	24.4	109.5	3.07	2.37
960	5	4	18.5	92.3	5.88	3.18
1600	5	4	14.6	87.6	8.65	2.33
2400	5	5	11.5	84.4	6.98	2.59
3200	5	2	2.6	72.9	11.81	2.77
4800	4	1	4.1	81.6	14.23*	—
8000	4	1	–9.1	61.5	18.47*	—

* Mean of two rats per treatment unless otherwise indicated
** One rat per treatment

Table 4. **Interaction of methionine and cyanide supplementation to cassava meal diets in rats**

Parameter	Dietary variables					
	0.2% Methionine			0% Methionine		
CN^- ppm*	0	1200	2400	0	1200	2400
Total weight gain, g	111.7	103.3	76.1	91.5	73.4	56.0
Food consumed, g	362.8	360.9	276.5	348.7	285.5	236.1
Feed conversion	3.3	3.4	3.7	3.8	3.9	4.2
Total urine CNS^-, mg*	68.1	87.5	116.0	43.7	62.3	63.5
Plasma CNS^- mg/100 ml	2.05	3.24	2.72	2.34	2.45	2.81

* CN^- represents cyanide and CNS^- represents thiocyanate

cassava consumption. The effect of supplemental methionine and iodine on sweet and bitter cassava meal-based diets and the nutritional implications that high levels of dietary glucoside may have in the absence of dietary methionine or iodine were studied in rats and pigs. Growth curves of rats fed sweet cassava in the presence and absence of methionine and iodine were similar (Figure 4). Supplemental methionine to either bitter or sweet cassava improved gains in the presence or absence of supplemental iodine. Iodine had no effect during the 56-day study even when bitter cassava was fed. Urinary thiocyanate excretion of rats fed bitter cassava meal-based diets was approximately five times greater than that of rats fed sweet cassava meal-based diets.

In pigs, low palatability of the diets based on bitter cassava meal resulted in low daily feed consumption and in body weight losses in all treatments. The presence of high levels of cyanogenic glucosides and their conversion through detoxification to thiocyanate as measured by the high plasma and urinary levels of thiocyanate was also confirmed. Supplemental methionine significantly improved both feed consumption and body weight gains in the presence or absence of iodine. The results with pigs suggest a methionine-iodine interaction on plasma thiocyanate concentration (Table 5); however, these results are contrary to the results ob-

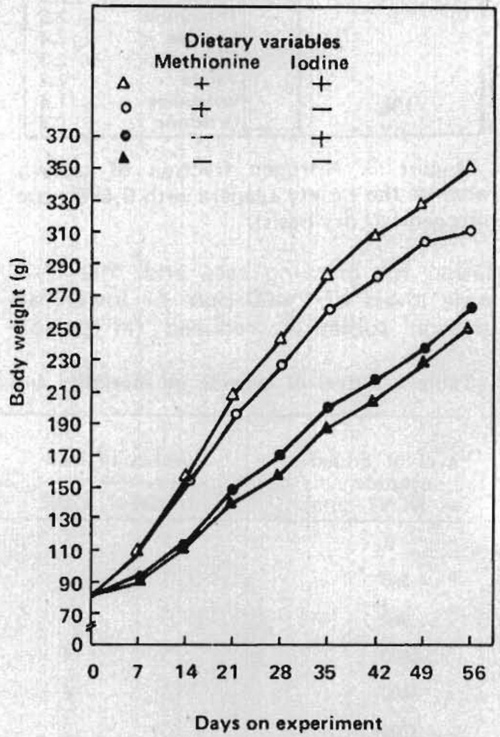


Figure 4. **The effect of supplemental methionine and iodine to sweet cassava (Llanera) meal-casein based diets on body growth in rats.**

Table 5. **Effect of supplemental methionine and iodine to bitter cassava (CMC.84) meal-soybean meal based diet on the parameters studied in growing pigs** [a,b]

Parameter	Met % [c] / Iodine [d]	Dietary variables 0.2 +	0.2 —	0 +	0 —
Total weight gain, kg		8.92	11.18	6.25	5.88
Total feed consumed, kg		16.16	19.49	11.90	12.41
Urinary thiocyanate excretion (mg/kg feed consumed)		66.58	70.63	36.85	51.4
Plasma thiocyanate concentration (mg/100 ml plasma)		3.43	4.53	7.37	4.93
Hemoglobin, g/100 ml blood		9.1	10.1	8.7	8.9

a. Each value represents the mean of three pigs per treatment, during a 28-day experimental period
b. Pigs fed bitter cassava (CMC-84) meal-soybean based diets + 20% sucrose and 20% water added at feeding time
c. DL-methionine
d. Addition of iodized salt (+) or sodium chloride (—) to the mineral premix

tained with rats and must be confirmed.

Yams

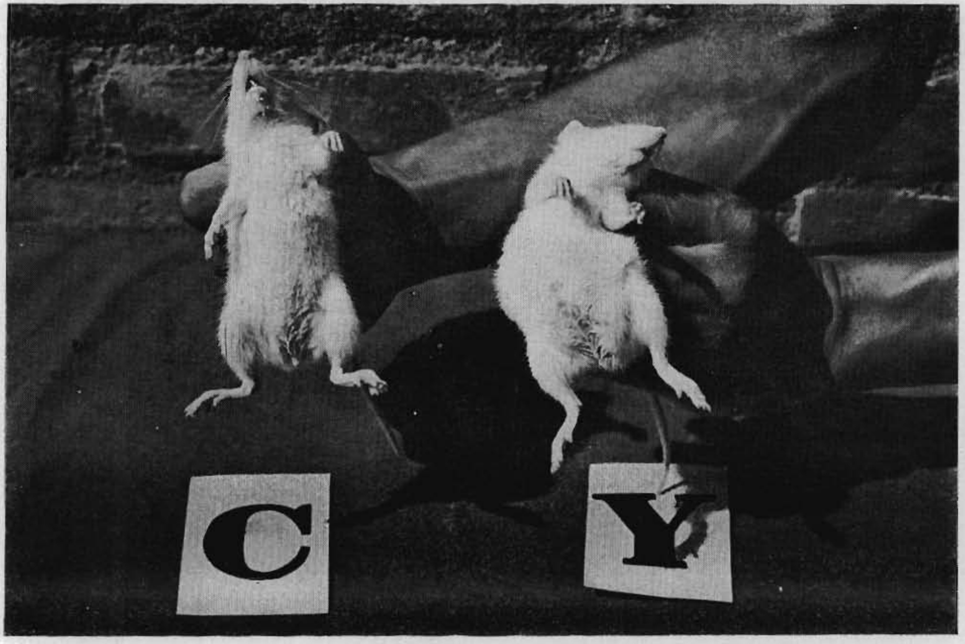
Yams (**Dioscorea** sp.) are a basic food for many millions of people in the tropics. As yams are available in some areas for livestock feed, studies are evaluating yams as both a carbohydrate and protein source.

One test studied the effect of drying and processing methods on the nutritional value of two varieties (Criollo and Espino) of **D. alata** on the performance of growing rats. Results (Table 6) demonstrate that some factor in crude yams reduces the utilization. In general, rats fed crude yams consumed more feed than when cooked yams were fed, but this increased consumption

Table 6. **Nutritive value of yams (Dioscorea sp.) for growing rats** [1]

Parameter	Var. Criollo Raw sun dried	Var. Criollo Raw oven dried	Var. Criollo Cooked oven dried	Var. Espino Raw sun dried	Var. Espino Raw oven dried	Var. Espino Cooked oven dried
Total feed consumed, g	365.76	374.98	240.46	253.30	338.22	252.80
Total gain, g	46.14	61.26a [2]	49.62ab	39.02b	40.84b	60.78a
Feed conversion	8.22d	6.15bc	4.92ab	6.96cd	8.60d	4.18a
PER	1.28	1.63	2.05	1.48	1.20	2.40
Gastrointestinal distension [3]	+	++	—	+	++	—

1. Five rats per treatment; 21 days experimental period
2. Values with different superscripts are statistically different at 0.05 level of probability
3. (++): severe distension; (+) distension to a lesser degree; (—): normal



Abdominal distension caused by feeding high levels of yam meal (Y) as comparated to rat fed normal corn (C) diet

supported slower gains and less efficient utilization of feed and protein.

Consumption of crude yams also resulted in gastrointestinal distension. Rats fed crude yams developed a large abdomen as contrasted to the normal body structure of the rats fed diets based on normal corn (Upper photograph). The distension was an engorgement of the entire gastrointestinal tract with undigested feed. This phenomenon was not observed in rats fed cooked yams. Cooked Espino yams supported satisfactory performance; performance of rats fed cooked Criollo yams was less favorable.

A second study compared the protein value of two varieties (15088 and 15209) from Puerto Rico. The variety 15088, with 7.81 per cent crude protein, was fed as the only source of energy and protein and in diets supplemented with soybean meal at levels to provide 10.0 and 13.0 per cent protein diets. These treatments were compared to diets based on common corn and soybean meal and containing the same levels of crude protein. All control diets contained the same balance of amino acids with the protein level varied by dilution with cassava starch.

At all levels of protein, the yam meal / soybean meal combination supported growth equal or superior to that of rats fed the corn-soybean meal control (Table 7). However, efficiency of utilization of both feed and protein was superior for the control diets. This reduced efficiency was the result of a significantly greater feed intake by rats fed the diets containing yam meal. Severe abdominal distension occurred in all rats fed diets containing crude yam meal.

A third trial measured the effect of cooking on diet digestibility and compared performance and diet digestibility of rats fed either **D. alata** or **D. esculenta.** The starch particles of the latter species are much smaller than those of **D. alata.**

Table 7. **Nutritive value of two yam (Dioscorea alata) varieties (15088 and 15209) in diets for growing rats** [1]

Diet	Feed consumed/ animal, g	Total gain, g	Feed conversion	PER	Gastro-intestinal distension [2]
Raw yam with peel, Var. 15088, 7.2% prot.	395.20a [3]	38.40	10.39a	1.36	++
Common corn + soybean meal, 7.2% prot.	208.39bc	31.14d	6.99bc	2.08	—
Raw yam with peel, Var. 15088 + soybean meal, 10.0% prot.	438.52a	69.15b	6.40cd	1.58	++
Common corn + soybean meal, 10.0% prot.	181.04c	34.00d	5.42d	1.87	—
Raw yam with peel, Var. 15088 + soybean meal, 13.0% prot.	421.05a	76.02ab	5.59d	1.43	++
Common corn + soybean meal, 13.0% prot.	254.77b	83.24a	3.08e	2.52	—
Raw yam with peel Var. 15209 + soybean meal, 10.0% prot.	409.95a	52.49c	7.87b	1.30	++
Cooked yam without peel Var. 15209 + soybean meal, 10.0% prot.	196.29c	28.82d	6.83bc	1.46	—

1. Six rats per treatment; 21 days experimental period. Yam from Puerto Rico
2. (++): severe distension; (—): normal
3. Values in same column with different superscripts are statistically different at 0.05 level of probability.

The results in Table 8 demonstrate that cooking reduces the effect of the factor present in raw yams and improves the digestibility of the yam by approximately 10 per cent, irrespective of the size of the starch molecule present in the yam. **D. esculenta** which has smaller starch molecules was approximately 10 per cent more digestible than the **D. alata**. Cooking also eliminated the distension observed when raw yams were fed.

Maize

Studies continued to evaluate the nutritive quality of vitreous endosperm (VE-21) maize and to compare it to that of the soft opaque-2 (H-208) maize. Additional experiment with rats

Table 8. Nutritive value and dry-matter digestibility of two yam species for growing rats [1]

Parameter	Control	*Dioscorea alata*		*Dioscorea esculenta*	
		Raw	Cooked	Raw	Cooked
Total feed consumed, g	276.52	272.70	234.36	163.56	257.40
Total gain, g	66.56	39.44	39.84	6.06	49.64
Feed conversion	4.17	6.95	5.94	36.01	5.21
PER	2.36	1.42	1.68	0.38	1.92
Gastrointestinal distension [2]	—	+	—	++*	—
D.M. digestibility, %	—	70.6	79.9	77.8	88.7

1 Five rats per treatment; 21 days experimental period
2. (++): severe distension; (+): distension to a lesser degree; (—) normal
(*) Severe diarrhea

Table 9. **Performance of rats fed diets based on whole kernels or endosperms of opaque-2 (H-208) or vitreous opaque-2 (VE-21) maizes** *

Diets	Total body gain, g	Feed/gain ratio	PER
Whole kernels			
Opaque-2 (H-208)	94.6	4.38	2.67
Vitreous opaque (VE-21)	64.3	5.21	2.25
Endosperms			
Opaque-2 (H-208)	39.5	7.86	1.78
Vitreous opaque (VE-21)	25.9	10.39	1.40

* Each value is the mean of eight rats, obtained during a 28-day experimental period. Overall average initial body weight: 48.3 g

confirmed previous results (CIAT Annual Report, 1972), indicating that vitreous whole kernels as well as their separated endosperms are nutritionally inferior to opaque-2 kernels and endosperms, respectively (Table 9). However, studies with growing pigs showed that vitreous kernels were only slightly inferior to opaque-2 kernels, supporting a 10 per cent less body gain but with similar feed conversion than the opaque-2 group during a 63-day experimental period (Table 10). Vitreous kernels are significantly superior to common maize both for growing rats and pigs.

A comparison of opaque-2 and vitreous kernels in combination with soybean meal to provide approximately 12 per cent crude protein-diets showed that there is practically no difference in the nutritive quality of the two maizes under these conditions (Table 11).

Chemical analyses of the endosperms suggest that lysine may be the most limiting amino acid responsible for the slightly lower nutritive value of vitreous endosperm maize as compared to the opaque-2 (H-208) maize (Table 12). Preliminary observations in rats sup-

Table 10. **Comparative nutritive value of Colombian common, opaque-2 (H-208) and vitreous opaque (VE-21) maizes in the growing pigs** [a]

	Control		9.6% Crude Protein		
Parameter	16% CP	9.6% CP	Common maize	Opaque-2	Vitreous opaque
Number of pigs/group	7[b]	7[b]	7[b]	8	8
Total body wt. gain, kg	39.0[c]	32.4[d]	10.5[f]	30.3[e]	27.3[e]
Feed efficiency	2.67[c]	3.55[d]	5.81[e]	3.52[d]	3.51[d]

a. Experimental period: 63 days. Overall initial average body weight: 18.7 ± 0.4 kg

b. One animal from each group was eliminated during the first week of the experimental period due to feet and leg problems not related to treatment

c, d, e, f. Means with the same superscript are not significantly different ($P<0.05$)

Table 11. **Performance of growing pigs fed Colombian opaque-2 (H-208) and vitreous opaque-2 maizes, at two protein levels** [a]

Parameter	Experimental diets: 9.6% Crude prot. Opaque-2	9.6% Crude prot. Vitreous opaque	12% Crude prot. Opaque-2 + SBM [b]	12% Crude prot. Vitreous opaque + SBM
Number pigs/group	6	5	6	6
Avg. initial body wt., kg	19.6	19.7	19.5	19.8
Avg. final body wt., kg	37.0	35.5	43.6	45.0
Avg. daily gain, kg	0.435	0.395	0.603	0.630
Feed/gain	3.54	3.98	2.69	2.81

a. Experimental period: 40 days
b. SBM: soybean meal

port this suggestion. Despite these nutritive differences, the propagation of the vitreous endosperm variety (VE-21) seems to be promising to improve human and swine nutrition in tropical areas, as it will reduce the supplemental protein requirements, and it will be less susceptible to weevil damage than the opaque-2 maize.

Cowpeas

The cowpea (**Vigna sinensis**) is adapted and produces well in the lowland tropics. It is eaten by humans and to a lesser extent the damaged and broken peas are fed to swine. Studies of processing methods for destroying the antidigestive factors it contains and its value as a supplemental source for a variety of food products are of prime importance.

Previous studies have shown that boiling the cowpeas for 15 minutes destroys the antidigestive factors. Results from germination have varied. A recent study clearly indicates that neither soaking in water, soaking in a 0.9 per cent NaCl solution or autoclaving improved the quality over that of the raw cowpeas. The study clearly confirmed that boiling is still the preferred method of processing.

Although cooked cowpeas alone are an adequate source of protein, of greater importance is their combining ability with other feeds in the diet. A series of studies measured the ability of

Table 12. **Lysine and tryptophan contents of endosperms of Colombian common, opaque-2 (H-208) and vitreous opaque (VE-21) maizes**

Maize	Protein %	% Tryptophan in [a] sample	% Tryptophan in [a] protein	% Lysine in [a] sample	% Lysine in [a] protein
Endosperm					
Common	9.69	0.06	0.63	0.21	2.17
Opaque-2	7.75	0.10	1.29	0.34	4.39
Vitreous opaque	8.19	0.09	1.04	0.30	3.67

a. Expresed as percentage of sample or protein

Table 13. **Nutritive evaluation of cooked cowpeas (Vigna sinensis) in sweet and bitter cassava meal-based diets in rats** [a]

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Casein + Cassava starch	98.3	3.71	2.68
Sweet cassava meal [b]			
+ Cowpea	35.1	7.17	1.41
+ Cowpea + 0.2% Met	79.6	4.28	2.27
Bitter cassava meal [b]			
+ Cowpea	46.7	6.31	1.60
+ Cowpea + 0.2% Met	101.7	3.91	2.54

a. Twenty-eight day feeding trial; eight rats per group; overall average initial body weight: 47.8 g
b. Sweet and bitter cassava meals were prepared from varieties Llanera (CMC 9) and CMC 84, respectively

the amino acids in cowpeas to complement those present in other foods.

A diet based on either sweet or bitter cassava and cowpeas does not effectively promote growth, efficiency of feed or protein utilization. The data further show that rat performance is more than doubled when 0.2 per cent methionine is added to the diets based on cassava and cowpeas (Table 13). Methionine is the first limiting amino acid in the protein of both cassava and cowpeas.

The data found in Table 14 complement earlier studies to measure the nutritional adequacy of maize-cowpea diets and demonstrate that the amino acids of cowpea complement the amino acids of opaque-2 maize differently than they do those of common maize.

A diet based on common maize and cooked cowpeas supported a level of

Table 14. **Nutritive evaluation of cooked cowpeas (Vigna sinensis) in common and opaque-2 maize-based diets in rats** [a]

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Casein + cassava starch	93.5	3.76	2.75
Common maize (CM) + soybean meal	74.5	4.45	2.26
Common maize (CM) + cowpea	75.2	4.23	2.37
CM + cowpea + 0.1% Tryptophan (Trp)	64.1	4.47	2.25
CM + cowpea + 0.2% Methionine (Met)	71.6	4.04	2.48
CM + cowpea + 0.1% Trp + 0.2% Met	78.0	3.96	2.53
Opaque-2 (0-2) + cowpea	88.5	3.79	2.65
0-2 + cowpea + 0.1% Trp	88.0	3.84	2.63
0-2 + cowpea + 0.2% Met	97.3	3.47	2.89
0-2 + cowpea + 0.1% Trp + 0.2% Met	95.6	3.88	2.62

a. Twenty-eight day feeding trial; six rats per group; overall average initial body weight: 36.9 g Isoproteic diets to contrain 10% crude protein

Table 15. **Effect of methionine supplementation to cowpeas (Vigna sinensis) and rice or sorghum based diets for growing rats**

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Rice	76.73[bc1]	4.88[b]	2.07[b]
Rice + cowpea	117.19[a]	3.55[b]	2.35[a]
Rice + cowpea + 0.2% Met	123.89[a]	3.99[b]	2.40[a]
Sorghum	9.96[d]	26.63[a]	0.40[e]
Sorghum + cowpea	66.84[c]	5.76[b]	1.46[d]
Sorghum + cowpea + 0.2% Met	81.64[b]	5.15[b]	1.63[c]

1. Values in same column with different superscripts are statistically different at 0.05 level of probability.

performance of growing rats equal to that obtained with common maize and soybean meal. Neither supplemental tryptophan or methionine or a combination of these two amino acids improved growth, but tended to improve efficiency of feed and protein utilization. These data indicate that some other amino acid or amino acids, probably lysine, is more limiting than tryptophan and methionine in this diet.

The combination of cowpeas and opaque-2 maize is more adequate nutritionally than cowpeas and common maize. Results demonstrate that methionine is the first limiting amino acid in this diet and that supplemental tryptophan has no effect. The cowpea opaque-2 maize diet supplemented with 0.2 per cent methionine supported performance equal to that produced by the diet containing milk protein (casein). As opaque-2 maize contains a level of lysine much higher than that of common maize, these results support the suggestion that lysine is the first limiting amino acid in the common maize-cowpea diet.

The combining ability of cowpeas with rice and sorghum and the effect of supplemental methionine is shown in Table 15. As would be expected when sorghum is fed as the only source of protein to growing rats, performance is poor. The addition of cowpeas to produce a 12 per cent diet stimulated a more than sixfold improvement. Supplemental methionine also significantly improved this diet; however, complementary studies (Table 16) indicate that neither tryptophan nor methio-

Table 16. **Effect of methionine and tryptophan supplementation to cowpeas (Vigna sinensis) and sorghum-based diets for growing rats**

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Sorghum + cowpea	85.37	4.54	1.85
Sorghum + cowpea + Trp	81.25	4.74	1.76
Sorghum + cowpea + Met	87.64	4.72	1.77
Sorghum + cowpea + Met + Trp	84.98	4.58	1.83

nine alone or in combination improved rat performance when a diet based on sorghum and cowpeas was fed.

Cowpeas combine well with rice which alone has a value equal to a combination of sorghum and cowpeas. Adding cowpeas to the basal rice diet improved performance by more than 50 per cent. Supplemented methionine had no beneficial effect.

This series of studies clearly indicates the need to identify high yielding cowpea varieties that contain higher levels of methionine and, to a lesser degree, higher levels of lysine.

Beans

The cereal grains, commonly used as the principal ingredient in swine and human diets, support only limited growth because of their low level of protein and poor balance of amino acids. Small amounts of legume protein added to cereal grains improve the amount of utilizable protein in the diet.

Black beans (**Phaseolus vulgaris** L.) are produced in many regions of Latin America and are a major ingredient in human diets. Small quantities of these beans, broken during harvest or with weevil damage, are available on small farms to feed swine. The nutritional value of cooked beans is low when they serve as the only source of protein. The same is true for sorghum grain. The combination of these two feed sources improved performance four-to eight fold (Table 17). But this combination supports rat growth at a level equal to only 40 per cent of that produced by combination of sorghum and soybean meal. The addition of methionine improved growth over the unsupplemented diet by approximately 50 per cent. Added tryptophan produced no improvement even in the presence of methionine. Combinations of methionine and tryptophan with either threonine, isoleucine or lysine did not further improve rat performance; the addition of all five amino acids significantly improved the performance of rats fed the sorghum-bean diet (Table 18).

Cottonseed

Unprocessed seeds are available in some areas where processing plants have not been constructed. These seeds are sometimes wasted for lack of means to convert them into useful feedstuffs. Such has been the case with cottonseed. Methods of on-the-farm processing adequate to convert cottonseed into a useful protein supplement were studied.

Table 17. **Effect of tryptophan and methionine supplementation to black beans** (Phaseolus vulgaris L.) **and sorghum-based diets for growing rats** [a]

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Black beans	5.2	19.33[b]	0.47[b]
Black beans + sorghum	47.9	6.44	1.34
+ 0.05% Tryptophan (Trp)	51.9	6.12	1.38
+ 0.2% Methionine (Met)	75.5	4.83	1.73
+ Trp, Met	71.5	5.06	1.66
Soybean meal + sorghum	126.4	3.67	2.28

a. Experimental period: 28 days. Each value represents the mean of six rats per group, unless otherwise indicated. Diets were calculated isoproteic to contain 12% crude protein

b. Average value of only four rats that gained weight during the experimental period

Table 18. **Effect of amino acid supplementation to sorghum and black beans (Phaseolus vulgaris L.) based diets for growing rats** [a]

Dietary variables	Average gain, g	Feed/ gain	Protein efficiency ratio
Sorghum (8.6% CP)	13.1	16.42	0.52
+ Black beans + 0.05% Trp + 0.2 Met (12.0% CP)	53.4	5.76	1.47
+ 0.10% Threonine (Thr)	58.7	5.43	1.56
+ 0.10% Isoleucine (Ile)	50.1	5.82	1.51
+ 0.30% Lysine (Lys)	47.2	6.23	1.35
+ Thr, Ile, Lys	83.9	3.88	2.16
Sorghum + Soybean meal (12.0% CP)	95.6	3.92	2.14

a. Each value represents the mean of six rats per group. Experimental period: 28 days.

Pigs fed diets in which cottonseed replaced one-third, two-thirds, or all of the protein supplied by soybean meal gained poorly; and mortality was a problem at the higher levels of cottonseed (Table 19). The results occurred with the presence of 300, 600 and 900 ppm, respectively, of added ferrous sulfate which has been shown to complex gossypol, a toxin in cottonseed and to render it inactive for pigs.

Two additional experiments using rats determined the value of calcium hydroxide and ferrous sulfate mixed dry and in solution with the unextracted cottonseed meats in reducing gossypol toxicity. When calcium hydroxide was mixed dry with the cottonseed meats, the rats lost weight and mortality rate was high. Performance was greatly improved when either calcium hydroxide or ferrous sulfate was added to the cot-

Table 19. **Effect of substituting unextracted (full fat) cottonseed for soybean meal in diets for growing pigs** [a]

	Treatments			
	Control	Cottonseed as a % of the SBM		
Parameter	corn-soy	33	66	100
	Kilograms			
Starting weight	18.3	18.5	18.4	18.4
Final weight	32.3	26.9	22.8	18.2
Average daily gain	0.714	0.344	0.117	—0.043
Average daily feed	2.21	1.09	0.63	0.43
Feed/gain	3.09	3.17	5.36	negative
No. deaths	0	0	2	4

a. Sixteen pigs started per treatment (eight pens of two pigs each) four pens received cottonseed raw and four pens received cottonseed that was cooked for 24 hours (8 hrs at 60°C and 16 hrs at 80°C). There was no significant difference between the raw and cooked C.S. treatments so the data were combined as presented tonseed meats in water solution. There was no apparent benefit in performance of the rats as a result of adding calcium hydroxide in combination with ferrous sulfate. Rats fed diets containing cottonseed meats treated with ferrous sulfate solution (800 ppm of air dry diet) gained faster and required less feed per unit of gain than those fed cottonseed meats treated with a calcium hydroxide solution.

Other studies showed that rats fed a corn-based diet supplemented with dehulled cottonseed kernels which had been boiled in ferrous sulfate solution for 30 minutes gained as rapidly and required no more feed per unit of gain than those fed a corn-soybean meal diet. Boiling cottonseed kernels in the absence of ferrous sulfate greatly improved its nutritive value. But boiling for one hour did not improve the cottonseed as much as mixing it with a ferrous sulfate solution (17°C) followed by oven drying at 70°C.

In an additional experiment, sun drying of either cottonseed meats or whole cottonseed (pretreated in a ferrous sulfate solution) was equal to oven drying in promoting rat growth. Similar results (Table 20) were obtained when these principles were applied to cottonseed meats used in pig diets; pigs fed diets containing cottonseed treated with a ferrous sulfate solution followed by either sun or oven drying performed as well as those fed the corn-soybean meal control diet.

Forage legumes

Forage legumes are being evaluated as a possible source of supplemental protein for swine. Initially, **Desmodium** and **Stylosanthes** in monogastric diets are being studied.

Two trials with rats have measured the value of **Desmodium** as a replacement for soybean protein and as a supplement to opaque-2 maize. Each increase in level of dried **Desmodium** meal up to 30 per cent protein substitution resulted in a linear depression in rat gain; increasing the substitution to 45 and 60 per cent did not have any addi-

Table 20. **Full fat cottonseed meats as a protein and energy source for growing finishing swine** [a,b,c]

Parameter	Treatments			
		Cottonseed meats [b]		
	Control	$+H_2O$	$+ FeSO_4$ Solution	
	Corn SMB	Oven dried 70°C	Oven dried 70°C	Sun dried
	(kg)			
Avg starting weight	23.4	22.4	23.7	23.6
Avg daily gain	0.683	0.547	0.699	0.661
Avg daily feed	1.96	1.64	2.01	2.00
Feed/gain	2.86	2.99	2.88	3.02
Avg final weight	71.3	60.8	72.6	69.9

a. Four pigs individually fed per treatment, ten-week trial

b. All diets were self-free choice in meal form

c. The cottonseed meats contained 32 per cent protein, 34 per cent fat and 94.3 per cent dry matter

Table 21. **Evaluation of tropical legume forages as protein sources for animal nutrition. Effect of substitution of soybean meal protein by Desmodium protein in growing rats** [a,b]

Dietary variables		Average gain,g	Feed/ gain	Protein efficiency ratio	% dry-matter digestibility [c]
% Protein combination					
Soybean meal	*Desmodium* meal				
100	0	117.6	3.37	2.00	90.9
85	15	102.8	3.55	1.90	83.0
70	30	93.4	3.83	1.75	76.7
55	45	94.0	3.93	1.70	71.7
40	60	93.9	4.15	1.62	66.6

a. Diets were calculated to be isoproteic to contain 15% crude protein; soybean and **Desmodium** meal contained 50 and 17.75% crude protein, respectively

b. Experimental period: 28 days. Each value represents the mean of nine rats per group, except for dry-matter digestibility

c. Values for dry-matter digestibility are means of three rats per group

tional detrimental effect on gain (Table 21). Feed/gain, protein efficiency ratio and dry matter digestibility were all linearly depressed as the level of **Desmodium** increased in the diets. This suggests that at the first three increments of **Desmodium** (0, 15 and 30 per cent substitution), the linear depression in performance results from a depression in protein quality, and at the higher levels the digestible energy was the most critical factor.

This concept is confirmed by the data from the second study which measured the effect of adding increasing levels of **Desmodium** to a basal opaque-2 maize diet and comparing the results to similar diets where soybean was used to supply the same level of additional protein as **Desmodium** (Table 22). The first two increments in level of **Desmodium** to the opaque-2 maize diet improved rat gain and feed efficiency; however, the highest incre-

Table 22. **Evaluation of tropical legume forages as protein sources for animal nutrition. Comparison of the protein quality of soybean and** Desmodium **meals in opaque-2 maize based diets for growing rats** [a]

Dietary variables	Dietary protein %	Average gain, g	Feed/ gain	Protein efficiency ratio
Opaque-2 basal diet	9.20	67.2	4.88	2.23
0-2 + *Desmodium* meal	10.75	79.8	4.54	2.05
0-2 + *Desmodium* meal	12.30	78.2	4.84	1.69
0-2 + *Desmodium* meal	13.85	66.9	5.54	1.32
0-2 + Soybean meal	10.75	101.6	3.67	2.54
0-2 + Soybean meal	12.30	117.6	3.29	2.47
0-2 + Soybean meal	13.85	124.8	3.26	2.22

a. Each value represents the mean of six rats per group. Experimental period: 28 days ment in **Desmodium** level depressed both growth rate and efficiency of feed conversion as well as the protein efficiency ratio. This effect at the high level of substitution is considered to be an effect of reduced digestible energy intake, resulting from the low digestibility of the **Desmodium.** Soybean meal was superior to the **Desmodium** at all levels of supplementation.

Studies tested the value of fresh-cut **Stylosanthes guyanensis** as a supplement to growing pig diets based on either opaque-2 maize and this maize supplemented with soybean meal to provide a 13 per cent protein diet (Table 23). Pigs fed **Stylosanthes** consumed less concentrate than pigs fed only the concentrate. Growing pigs will consume approximately 600 g of fresh-cut **Stylosanthes** per day. **Stylosanthes** did not improve either growth or feed efficiency when used to supplement opaque-2 maize diets; in fact, it produced a slight but non-significant depression in gain and feed conversion efficiency. **Stylosanthes** did not improve pig performance when the 13 per cent diet was fed.

SMALL AND/OR SUBSISTENCE FARMS

Eighty to 85 per cent of all swine produced in tropical Latin America and, in general, in other developing countries of Asia are grown on small farms. Many, if not most, are family subsistence farms. The total production of pork from this, the major portion of the swine population, is low, representing less than 10-15 per cent of that produced from efficient swine operations.

The swine program is now engaged in a small farm project in one community (Cacaotal) on the North Coast of Colombia to gain knowledge of existing production systems and levels of production and to develop, through research and practice, systems that will improve swine production and increase family farm income.

Table 23. **Utilization of fresh** Stylosanthes guyanensis **as protein supplement of opaque-2 and of opaque-2 plus soybean meal based diets for growing pigs** [a]

Parameter	Treatments			
	Op-2	Op-2 + Soybean	Op-2 + *Stylosanthes*	Op-2 + Soybean + *Stylosanthes*
Protein content basal diets, %	9.75	13.05	9.75	13.05
Days on experiment	64	52	66	51
Avg initial wt, kg	20.17	20.30	20.25	20.46
Avg final wt, kg	50.04	49.54	50.09	49.92
Total gain wt, kg	29.87	29.24	29.84	29.46
Avg daily gain, kg	.467	.566	.454	.579
Avg daily feed consumption				
Concentrate, kg	1.66	1.62	1.50	1.56
Forage (dry matter), kg	—	—	.144	.148
Crude prot. forage, kg	—	—	.027	.028
Feed conversion concentrate	3.52	2.86	3.30	2.68
Feed conversion concentrate and stylo	—	—	3.62	2.95

a. Each value represents the mean of six pigs per group

Initial data clearly demonstrate that the existing systems of swine production in the community contribute little to total available meat supplies or to increased farm income.

Pigs are traditionally grown under a completely extensive system. They are allowed to roam freely in the fields and around the village. The sows, predominately of a native breed, "Zungo Pelado," are bred by any boar that happens to be present at the time of estrus.

Given this initial germplasm, system of management and nutritional regimen, the sows which weigh an average of 67 kg at parturition produce an average of 8 pigs per litter that weigh 0.88 kg at birth. Of those born, only 2 to 6 live to be weaned at an average body weight of only 4.9 kg. Each sow loses approximately 17 to 20 kg of body weight during the lactation period. After weaning, the pigs do not reach 20 kg body weight until 6 to 8 months of age and are normally marketed at 50 to 70 kg at 16-18 months of age.

Studies carried out on farms using traditional systems of management and feeding show that these pigs gain only 3.9 kg in an 8-week period and require 9.4 kg of common corn to produce a kilogram of gain. At present prices (corn $3.20/kg* and pigs at $14/kg), the farmer feeds $30.08 of corn to produce $14 of marketable pig if death losses do not occur. Drugs and labor cost are not included.

Under traditional systems of management, at least five to eight different species of internal parasites are commonly encountered. These reduce both animal health and vigor. Brucellosis was also shown to be endemic, but available data suggested that it was not responsible for significant reproductive losses.

Primary among the reasons for the continued existence of swine on these subsistence farms is the fact that the pigs are traditional farm animals and serve as a ready source of cash to meet family emergencies. It is a readily acceptable source of collateral for agricultural loans, and in many cases the pig functions as a marketing tool for farm products that cannot be sold because of quality, distance to market or market value. The latter factor increases in importance in light of preliminary data from Cacaotal which indicate that 20 to 30 per cent of the corn is not marketable because of field and weevil damage, 20 to 30 per cent of the cassava roots are too small to be marketed for human consumption, and 25 per cent of grain legumes produced under the new program are cracked or damaged during harvest and manual thrashing.

Efficiency of crop production is not much better than that described for swine. Three crops: common corn, cassava and yams, are traditionally grown in association on the same land. The corn is planted first and serves as a support for the development of the yam vine which is planted about one month later. Cassava is seeded in any area between these plants not covered by foliage. Yields per hectare-year are extremely low. The food and income from one to four hectares per family (seeded under this system) supports the family of 7 to 16 people during the year.

The approach to improved swine production and increased farm income for the overall benefit and well-being of the human population on these small farms has been multidisciplinary. Not only has it included studies, research and demonstrations to increase pork production from the existing swine population, but has also included work focused on both increasing crop yields and nutritional quality through improved cultural practices and the introduction of improved varieties and species.

The initial goal of the project was to increase the efficiency of swine pro-

* All prices given in Col. pesos

duction in the village. Progress has been made towards this goal. Through on-the-farm demonstrations and complementary studies at the ICA Turipaná Station, it has been demonstrated that a program of sound management, disease and parasite control, simple but adequate housing and proper nutrition will significantly improve the efficiency of production. Under small farm conditions and utilizing locally available native pigs, the application of available technology adapted to local conditions has increased birth weights from 0.88 kg to 1.2 kg,increased weaning weights from 4.9 to 9.7 kg, has increased growth rate from 70 g of gain per day to 465 g and feed efficiency from 9.41 kg of feed per kilogram of gain ot only 3.85 kg.

Longer term tests have shown that under station conditions, the native pig, "Zungo Pelado", will gain an average of 542 g per day on 3.85 kg of feed and obtain a market weight of 100 kg in 7 months.

Housing, management and parasite control were quickly adopted by the swine producers of the village. Because of a lack of understanding of nutritional principles, limited capital and commercial unavailability of the protein-vitamin-mineral supplement, adoption of the improved feeding systems has been much slower. Initial attempts were made to make this supplement available through national organizations and institutions. In the early stages of development, these attempts were not possible; therefore, supplements prepared by CIAT were made available to the farmers. Recently, through the collaboration of the swine program of ICA, the supplement has been made available through CECORA, a division of INCORA, the land reform organization of the national Government. At the present time, farmers can purchase the feed in bag lots to supplement their locally available energy sources.

It was decided that the development of swine production in the village and the nutritional status of the human population would be significantly improved if a larger portion of a balanced diet could be produced on the farm. Opaque-2 maize was introduced but was not widely accepted because of its soft endosperm. More recently, a vitreous endosperm high-lysine (opaque) maize variety has been introduced into the village in collaboration with the CIAT Maize Program. Yields of this new variety are promising, and since it is an open-pollinated variety, it is expected to be widely accepted.

As both the swine and human populations were receiving little dietary protein, and grain legumes were not included in the traditional cropping system, with the collaboration of the Crop Production Specialist Training Program, 42 varieties and species were seeded in the village to test the growth and yield potential of each and to demonstrate cultural practices. Only the cowpeas, pigeon peas and the mungo bean produced seed, with the cowpea production the most promising. From this early start, in two seasons the area seeded to cowpeas increased from zero to approximately 15 hectares. This area is significant as approximately 100 to 120 hectares represents the entire crop area for the village.

Swine Health

The great majority of swine disease information was obtained from the collaborating pig farms in the Cauca Valley. These were increased from 16 to 20 representing an approximate total of 14,500 swine.

The specific diseases or conditions diagnosed or seen on the collaborative group of 20 farms were arranged in the order of numbers of farms affected (Table 24).

By invitation of ICA, diagnoses of hepatosis dietetica and balantidiasis

Table 24. Farm incidence of diseases observed on 20 collaborating farms

Disease			No. of farms affected
Piglet diarrhea			14
Abortions	Brucella	7	
	Leptospira	1	
	Undiagnosed	4	12
Abscesses			9
Arthritis			8
Piglet pneumonia			7
Foot and Mouth			6
Mastitis			5
Otitis			3
Non specific dermatitis			3
Transmissible gastro-enteritis			3
Skin necrosis			2
Helminthiasis			2
Metritis			1
Exudative epidermitis			1
Heat stress			1

were made on farms without including yields of the other 20 farms.

In September a change of emphasis was made in the Cauca program. Instead of routine and frequent visits to farms to determine the spectrum of diseases present, less frequent visits were made and specific problems on specific farms were selected for examination in depth. The first project was to examine the economic impact of foot-and-mouth disease on two swine herds. This also provided the first meeting point between the economics and animal health groups within CIAT. The second project involved balantidiasis as a cause of piglet diarrhea. Future projects are anticipated to focus further on piglet diarrhea and the causes of abortion.

Foot-and-Mouth disease

The owners of commercial piggeries in the Cauca Valley fear foot-and-mouth disease more than any other. Not only is the syndrome normally far more severe than in cattle but also there is no effective vaccine for use in this species.

The first herd was infected with virus type A 27 (typed by the ICA Foot-and-Mouth reference laboratory) and started with a total of 1,093 animals. Deaths from all causes in 4 months from the start of the outbreak numbered 307, and 105 fetuses were aborted. From the previous history of the farm, expected mortality from all causes would have been approximately 0.3 per cent for the same period and confined to sucklings. At no time had any vaccination program been carried out.

The second herd was infected with virus type 0 and started with a total of 561 animals. Deaths from all causes in 2 months from the start of the outbreak numbered 13, and 37 fetuses were aborted. Similarly to the first herd, the previous history of the farm indicated an expected mortality of 0.2 per cent in the same period of time. This herd had been vaccinated three times at one month intervals, the third vaccination being carried out after the first clinical cases had been seen. The vaccine incorporated both O and A strains.

Transmissible Gastro-Enteritis (TGE)

This important swine disease was not known to exist in Colombia before an outbreak occurred in the Cauca Valley involving collaborating herds in January, 1973. A report was received of an epidemic of diarrhea on one farm, closely followed by reports of a similar condition on two others.

By the fifth day after the initial report the situation had become acute, and extra resources were allocated to seek a diagnosis. On the following day a diagnosis of TGE was made based on symptomology, epidemiology and histopathology. At this time a strong relationship appeared to exist between the outbreak and an importation of pigs received by air at the Cali airport. The Director of Veterinary Sciences of ICA was informed immediately by telephone and he alerted the persons responsible within the ICA organization. CIAT facilities were put at the disposal of the national authority. By agreement, material was sent to the Laboratorio de Investigaciones Médicas Veterinarias (ICA) in Bogotá and to USDA Exotic Diseases Laboratory at Plum Island. The diagnosis was confirmed by virus isolation in Bogotá and serologically by Plum Island.

Subsequent investigations by ICA were assisted by pre-and post-episode serum samples from the CIAT Serum Bank. Clear confirmation was obtained that the disease had been introduced by the imported animals. Although the impact of the disease on affected farms was devastating, the majority of weaner and suckling pigs being lost, no evidence existed by the end of the year that any spread to other localities had occurred.

Leptospirosis

Leptospirosis is potentially an important cause of abortion in pigs. The condition was diagnosed on one collaborating farm following a wave of abortions. **Leptospira pomona, pomona** serogroup was isolated from two aborted fetuses. The Pan American Zoonosis Center confirmed the identity of one culture and found strong positive reactions to the **pomona** subgroup in all eight sera samples submitted. Weak positive reactions to the **icterohemorrhagiae** serotype were found in three.

Brucellosis

Brucellosis has been a cause of abortion of some collaborating farms and **Brucella suis** has been isolated from aborted fetuses on three occasions. An offer was made to institute a control program with the elimination of reactors to serological tests. Three farms already have instituted control programs based on the elimination of reactors. To the end of the year 2,375 serum samples were tested and positive titres found in 420 (17.68%).

Abscesses and Arthritis

Cutaneous abscesses are commonly seen in swine herds in the Cauca Valley. Most often they appear associated with arthritis on the same farms.

In one imported herd abscesses were not only rampantly found cutaneously but also in deep-seated situations. Six valuable breeding animals were slaughtered **in extremis.** Autopsy revealed deep-seated abscesses associated in three with the spinal cord. Concurrent abortions and still births may also have been related to the syndrome.

Investigation in the same herd showed that **Staphylococcus aureus, Streptococcus equisimilis** and **Streptococcus pyogenes** (Group A and E) could commonly be isolated from the abscesses, but the same organisms could also be isolated from the nostrils and genital tracts of apparently healthy gilts. This appeared to indicate a carrier state. A bacterin was prepared using isolations from clinical cases and ten adult pregnant animals were inoculated. The effectiveness of the bacterin is being evaluated. In addition, sensitivity tests to antibiotics were carried out and the most effective one was chosen for use.

Hog cholera

No hog cholera has been seen on any collaborating farm during the period of observation. All practiced vaccination. However, 21 pigs out of 87 died on a pig farm in the Cauca Valley which was not one of those normally collaborating with CIAT. Of those that died, 16 were four months old and five were adults. Necropsies were carried out by an ICA veterinarian who submitted specimens to CIAT for histological examination. Deep-seated ulcers involving mucosa and submucosa were found in the large intestines. The changes in the blood vessels below the ulcerated regions were characteristic of those described for hog cholera.

Skin necrosis (Pityriasis rosea)

This condition was closely followed in one herd, but a similar if not identical condition has been reported in several swine herds in the Cauca Valley.

Only weanling pigs of approximately three months of age were affected (33/59). Lesions were characterized by erythematous papules occurring anywhere on the body surface and which by the second or third day had depressed necrotic scaly centers. Some of the lesions coalesced forming well-developed nodules. No other symptoms were noted. No bacteria were isolated from skin biopsies and histology showed a skin reaction similar to that described for **Pityriasis rosea** in man and swine. The condition lasted seven to eight days after corticosteroid treatment and all pigs were clean by the third week.

Heat stress

Dramatic cases have been seen in imported pigs with unpigmented skin which have been handled or moved in hot weather. This represents an important hazard in the introduction of exotic animals.

Exudative epidermitis (Greasy pig disease)

This acute generalized dermatitis of young pigs was seen in imported animals in the Cauca Valley. Death appears to result from loss of skin function. Three animals died suddenly in two litters and several other piglets appeared clinically sick. Biopsy samples have been stored for further studies on the etiology of the condition. A similar condition was also seen in "zungo" pigs at Cacaotal where the pustular form appeared to predominate over the scaly form. No deaths were reported. As far as can be traced, these are the first reports from Colombia.

Hepatosis dietetica

An outbreak was seen in a swine herd in the Cauca Valley. Massive liver, heart and skeletal muscle necrosis is said to be associated with deficiency of selenium, sulphur containing amino acids and vitamin E. The diet was adjusted and the problem ceased. This is the first written report of the condition in Colombia.

Balantidiasis

With the invitation of ICA a visit was made to a farm not normally in the collaborating group where there was an outbreak of profuse diarrhea and dehydration. Twenty-seven pigs were affected ranging in age from three to four months. Four animals died and seven more were killed or sold by the owner of the farm. Histological examination showed that the disease was caused by the normally nonpathogenic **Balantidium coli.** A study is being made of the epidemiology and pathogenesis of the condition.

Other conditions diagnosed include: a) Coliform enteritis in baby pigs (Cauca Valley); b) Atrophic rhinitis (Cacaotal); c) Atresia ani in a Yorkshire baby pig (Cauca Valley); d) Periportal liver cirrhosis probably due to **Ascaris** migration (Carimagua); and e) Acute conjunctivitis caused by a **Streptococcus** Group A (Cacaotal).

Economics

Farm management analysis was applied to examine the relative profitability of alternative feed supplies, which were thought to be in abundant supply, under the prevailing conditions of commercial producers in the Cauca Valley (Colombia). Special attention was given to cassava, as a potential substitute for maize, at the growing and fattening stages.

Based on experimental data obtained from ICA (Palmira), it was concluded that fresh cassava could substitute for maize only if the unit price of the former is equivalent to one half or **less** of the unit price of maize. Compared to maize, dry cassava should be preferred, as long as its unit price is equal to or below the unit price of maize. Present price ratios (cassava/maize) in Colombia favor the use of cassava instead of maize.

Using a linear programming (LP) approach, least-cost diets were estimated for swine from 5 to 100 kilograms of liveweight and also for the lactation and breeding periods.

Results suggest that costs of production could be lowered by more intensive use of the by-products from local industries. Specifically, this is the case with rice meal, cottonseed meal, sesame meal, sugar, etc. Also, minor reductions in the price of cassava (1-5%) make it profitable to introduce dry cassava into the diet.

With the LP model already in operation now at CIAT, it is possible to collaborate with national research centers and other public agencies in Latin America in the analysis of the effects of price variations and of alternative feed sources on the composition and cost of rations for swine.

As an illustration, see Table 25. The composition of the least-cost diets for swine presented here are based on the requirements and on the nutritional content of products currently available in the Cauca Valley, using relative prices prevailing during the second half of 1973. The average cost of these diets is approximately 10 per cent below the cost of rations of equivalent nutritional value offered today in the Cauca Valley. The composition of the least-cost rations proved to be sensitive to relative price variations.

Training

Three production-research interns and one research scholar completed training in 1973. All four of these young scientists have returned to their respective institutions. One intern from Bolivia and one research scholar from Costa Rica, who has now received the master's degree from the University of Florida, have returned to their parent institutions as professors of swine production and as directors of new swine programs which they are now developing in collaboration with CIAT and with special project funds provided by IDRC. One Colombian intern has returned to the Instituto Politécnico in Medellín to continue as professor of swine production in that institution. The third production-research intern has been named as leader of the ICA swine program at the Turipaná station in Montería.

Five production-research interns from Perú, Bolivia and Ecuador were selected to receive training at CIAT. They began their training during the year. Four are working in swine production and one is being trained in animal pathology with emphasis on swine diseases.

One research scholar from INIAP, Ecuador, began studies for a master's degree at the ICA Graduate School. A research fellow from Germany and with support from his Government began work at CIAT to collect data for a doctoral thesis. His thesis will evaluate the native breed, "Zungo Pelado," and compare the production and physiological parameters of this breed with that of one of the improved breeds.

Table 25. **Composition of least-cost rations for swine (in percentages)** *

Liveweight (kilos)	Swine Category							
	Baby pigs		Growing		Finishing	Gestation	Boar	Lactat.
Feeds	5—10	10—20	20—35	35—60	60—100	100—160	110—180	140—200
	%	%	%	%	%	%	%	%
Maize, yellow								
Maize, opaque	2.2							
Sorghum								
Rice								
Maize bran								
Rice bran and polishings	23.1	28.7	29.0	29.2		17.0	17.0	7.2
Wheat flour								
Cassava, fresh								
Cassava, dry								
Banana, fresh								
Banana, dry								
Yam, fresh								
Yam. dry								
Sugar *	42.7	46.0	35.3	35.3	49.2	42.6	42.6	47.0
Molasses			14.4	19.1	25.8	19.0	19.0	19.0
Soybean meal								
Cottonseed meal	4.8	4.8	9.5	5.4	13.6	9.3	9.3	14.3
Sesame meal	12.9							
Meat meal	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Blood meal	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Bone meal			0.9			0.9	0.9	2.3
Oyster shell								
Fish meal	4.2							
Dicalcium phosphate		0.7	0.1	0.3	1.1	0.6	0.6	
Calcium carbonate		0.9	0.4	0.5	0.5	0.3	0.3	
Salt	0.2	0.2	0.5	0.5		0.5	0.5	0.5
Lysine								
Methionine			0.1					
Methionine + Cystine								
Vitamin premix	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Average cost (pesos ($) per kilo)	3.89	3.40	2.94	2.8	2.7	2.8	2.8	2.8

* For commercial producers in the Cauca Valley (Colombia), under price rations prevailing during July-December, 1973

CIAT is providing partial support for a research scholar in swine nutrition now studying at the University of Guelph, Ontario, Canada. This scholar who has an assistantship at Guelph will return to CIAT to conduct research for his master's thesis.

A total of 20 hours of lectures were given to the trainees in the Livestock Production course. In addition several papers were prepared for the course which included all phases of swine production.

Outreach

The network of institutions collaborating with the swine program was increased in 1973 by the initiation of collaborative programs in Bolivia and Costa Rica. These programs, which will receive support from special project funds, are being developed at the Universidad de Bolivia and the Universidad de Costa Rica and will be under the direction of scientists previously trained at CIAT.

The new program of the Universidad de Bolivia "Gabriel René Moreno" in Santa Cruz, Bolivia, is being developed on 15 ha at the new university station located 19 km from Santa Cruz. The new swine center will provide facilities for a 40-50 sow herd and will be used for teaching university students, for demonstrating established production techniques and for seeking solutions to problems that limit local swine production.

The collaborative program in Costa Rica will be developed with special project funds at a new Universidad de Costa Rica Regional Center being developed near the town of Turrialba and adjacent to the IICA Station. All animal production students at the Universidad de Costa Rica will receive one year training at this new center. The center will also be used for research and demonstration and as a training center for extending production information to the small farmers and swine producers of the region.

Other collaborative programs were continued in other areas of Latin America. Initial contacts were also made for developing collaboration in Perú and Guatemala.

Food legumes

production systems

Food legumes and dry beans, specifically, are an important component of the human diet in Latin America and throughout the tropics. These protein sources are particularly important in the diets of middle and low income groups where animal protein may be limited or not available. The crop is grown by subsistence farmers through much of the highlands and medium elevations in the zone and for many provides the principal source of quality protein for direct consumption on the farm.

The Bean Production Systems Program, initiated as an integrated team effort in 1973, expanded its orientation and scope of activities. The main objective is to increase the productivity, production and consumption of beans in Latin America, to improve the diets of low income people, and to enhance the welfare of subsistence farmers. Commercial beans are emphasized as well as associated cropping systems used by the small farmer, where there will be an expected application of most results to commercial-sized operations as well.

A series of specific objectives guides the research:

1. To improve the yield potential of existing germplasm through collection, evaluation, recombination and testing of promising germplasm, particularly in the lowland tropics.
2. To increase the range of adaptation of new varieties to variations in soil type, moisture, temperature and photoperiod.
3. To increase yield potential through development of genetic resistance to pathogens and insects with the integration of this genetic material into a total control package.
4. To study production systems under different levels of technology and demonstrate those which can effectively increase economic yields of existing and improved varieties of field beans.
5. To identify, then to reduce or eliminate, the limiting physical and socio-economic factors which influence the production, marketing, and consumption of beans.
6. To support national programs and other institutions concerned with bean research, development and promotion, through training and team organization and orientation.
7. To promote exchange of germplasm and ideas through annual meetings of researchers, special topic workshops, uniform regional trials, newsletters, and visits to programs in the region.
8. To improve the protein quality and nutritional value of beans for their use in direct human consumption.

The program is divided into seven working groups: agronomy, breeding, economics, entomology, microbiology, pathology and physiology.

PLANT IMPROVEMENT

Major emphasis has been to bring together existing collections of **Phaseolus vulgaris** and to evaluate this material under different environmental conditions. The total number of bean accessions now existing in the germplasm bank at CIAT is 9,413. Terminology is being standardized and a computer format and program prepared which will allow publishing the first data summary in 1974.

Data from the initial field observations will be used to choose groups of parents to start the breeding and development of genetic populations. In the process of population improvement, outstanding biotypes will be identified and included as sources of disease resistance, insect resistance, photosynthetic efficiency, **Rhizobium** interactions and efficiency, as well as other specific factors.

Germplasm evaluation

Four environments were chosen for initial germplasm evaluation: Palmira, Turipaná and La Selva (Colombia), and Boliche (Ecuador).

Locations

Palmira, Colombia (CIAT Research Station)

Latitude, 03°32′ north; altitude, 1,000 m; annual mean temperature, 23.9°C; total annual rainfall, 1,000 mm; annual mean relative humidity, 71%; annual mean sunshine, 49%.

A total of 6,290 accessions of **P. vulgaris** were studied on the CIAT farm, including 808 new accessions. Climatic conditions in Palmira favor rapid progress as three plantings can be made each year. Planting dates in March and July use natural rainfall, while the November planting is irrigated.

More than 20 morphological characteristics of the plant and other field observations were recorded. On the basis of such yield components as pods per plant, seeds per pod and seed size, a total of 238 selections were made for "yield potential"; 220 were individual plant selections and 18 were mass selections. Two of these individual selections are shown in the photos on page 148.

Turipaná, Montería, Colombia (ICA Research Station)

Latitude, 08°87′ north; altitude, 13 m; annual mean temperature, 28°C; total annual rainfall, 1,200 mm; annual mean relative humidity, 80%.

In this location, 1,390 bean collections were studied under rainfall conditions; this number included the selections previously made in Turipaná and Palmira.

The Turipaná station environment is the one used at present to study the effect of high temperatures on fruiting. There were 56 selections made for yield potential, 44 individual and 12 mass selections. The 56 selections were blooming and fruiting within a 42-day period where the average of maximum temperatures was 34°C; the rainfall during the complete growing period was 516 mm. These selections will be studied in other areas to identify heat-tolerant lines of beans.

La Selva-Rionegro, Colombia (ICA Research Station)

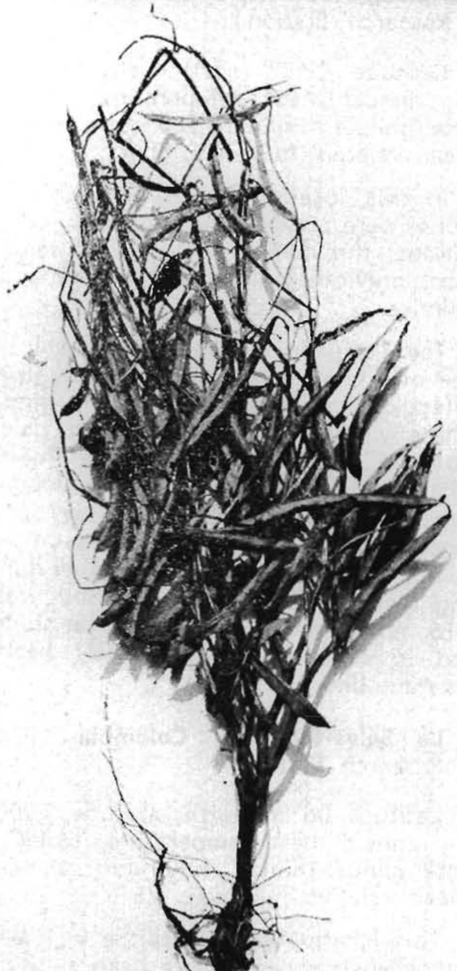
Latitude, 06°20′ north; altitude, 2,200 m; annual mean temperature, 16.1°C; total annual rainfall, 1,400 mm; annual mean relative humidity, 75%.

This location represents the high altitude environment where bean cultivation is almost always associated with maize. Studies included 200 collections of climbing beans.

Boliche, Guayaquil, Ecuador (INIAP Research Station)

Latitude, 02°20′ south; altitude, 17 m; annual mean temperature, 25.4°C; total annual rainfall, 690 mm; annual mean relative humidity, 84%; annual mean sunshine, 30%.

A distinctive characteristic of this environment is the reduced solar radiation through the year. A total of 990 bean collections, including selections from Palmira and Turipaná, were stud-



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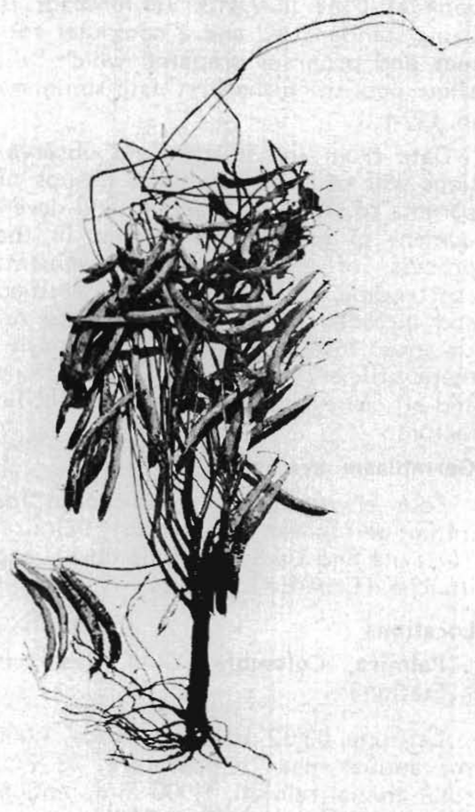

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Two individual plant selections with specific morphological characterictics.

ied in Boliche and ten characteristics recorded. A total of 58 selections were made for yield potential, including 37 individual selections and the rest mass selections. Seven mass selections of climbing beans with grain characteristics of local acceptance (light red, white and light brown) were included in a preliminary yield trial along with two native varieties of the Boliche region.

Principal observations

Genetic variability

The evaluation of bean collections conducted to date has shown the existence of high genetic variability in **Phaseolus vulgaris,** not only with respect to yield potential, but also in such factors as days to blooming, days to maturity, growing habit, size of the plant, branching, stem thickness, height to the first node, root system and grain characteristics.

Environmental effects

Adaptation. The most noteworthy environmental effects came from 200 collections in La Selva. The material showed a general non-adaptation at this high altitude location, probably because the entries originally came from lowland areas.

Growing habit. This character is influenced significantly by the environment. The commercial variety ICA-Huasano had a semi-indeterminate short guide growing habit in Palmira, while at Turipaná it appeared to be completely indeterminate. A similar situation occurred with the variety Jamapa from Guatemala, an indeterminate non-climbing bean in Palmira, but an indeterminate climbing bean in Turipaná.

Leaf area. The conditions of Boliche in Ecuador most favored leaf area development. Plants with large leaves were observed in the majority of the 990 bean collections tested. Also apparent was an exaggerated elongation of internodes, a result presumably of increased activity of growth auxins under the low solar radiation at this site.

Expression of yield potential. Considering the individual selections for

Table 1. **Mean values for yield components and production of individual selections for yield potential in beans of five growing habits in two locations, Palmira and Turipaná, 1973**

Growing habits	No. of selections	No. of pods	No. of fruiting racemes	Weight/ of dry grain (g)	Days to harvest
Palmira					
Determinate (I A)	(33)	32.0	24.6	45.3	87.2
Semi-indeterminate short guide (I B)	(29)	36.3	22.3	40.6	85.1
Semi-indeterminate medium guide (II C)	(8)	38.1	24.6	45.4	86.3
Indeterminate non-climbing (III E)	(19)	51.0	32.9	57.4	90.5
Indeterminate climbing (IV F)	(3)	83.3	49.3	92.4	97.0
Turipaná					
Determinate (I A)	(2)	38.5	23.0	34.3	79.0
Semi-indeterminate short guide (I B)	—	—	—	—	—
Semi-indeterminate medium guide (II C)	(4)	55.0	21.5	51.4	84.2
Indeterminate non-climbing (III E)	(10)	78.1	49.0	73.0	90.0
Indeterminate climbing (IV F)	(34)	98.1	52.7	98.6	88.9

yield potential that were made in Palmira and Turipaná, the relationship of yield factors and five plant growing habits is shown in Table 1. Biotypes with indeterminate growing habit appear to have higher yield potential than those with either semi-indeterminate or determinate growing habits. The highest potential is evident in the biotypes with a climbing habit planted with maize (growing habit IV F).

When the yield factors under rainfall conditions are compared between these two locations, it is apparent that the average values were higher in Turipaná than in Palmira, except in the case of growing habit I A. Turipaná has, in general, less favorable growing conditions for common beans than the Palmira location. The higher values may be because of the different distances between planting beds (0.90 m in Palmira, 1.50 m in Turipaná) with less competition for light and nutrients at Turipaná. The higher temperature in the coastal station may have been the stimulus for increased growth and production. In Turipaná, beans with growing habits I A and I B which have less vegetative growth were severely affected by the web blight disease **Thanathephorus cucumeris,** reducing the number of selections of this type to a minimum.

Formation of genetic populations in beans

After evaluating and selecting best genotypes with wide adaptation, the program will start the formation of the first genetic populations by means of a multiple crossing method (See photo page 151). The genotypes to integrate into each compound variety must have similar growing habits and plant sizes. As much variability as possible in grain color and other characters of the seed will be maintained, since there is an extensive range of preferences in Latin America (See photo on page 152).

Other breeding projects

Germplasm bank

The common bean germplasm bank at CIAT includes 9,413 accessions. The systematization of morphologic characteristics of each accession tested from the germplasm bank is being developed in collaboration with the Instituto Colombiano Agropecuario (ICA). The objective is to establish an operational system in the computer that will allow handiing a large number of different bean characteristics at one time.

Natural crossing in common beans

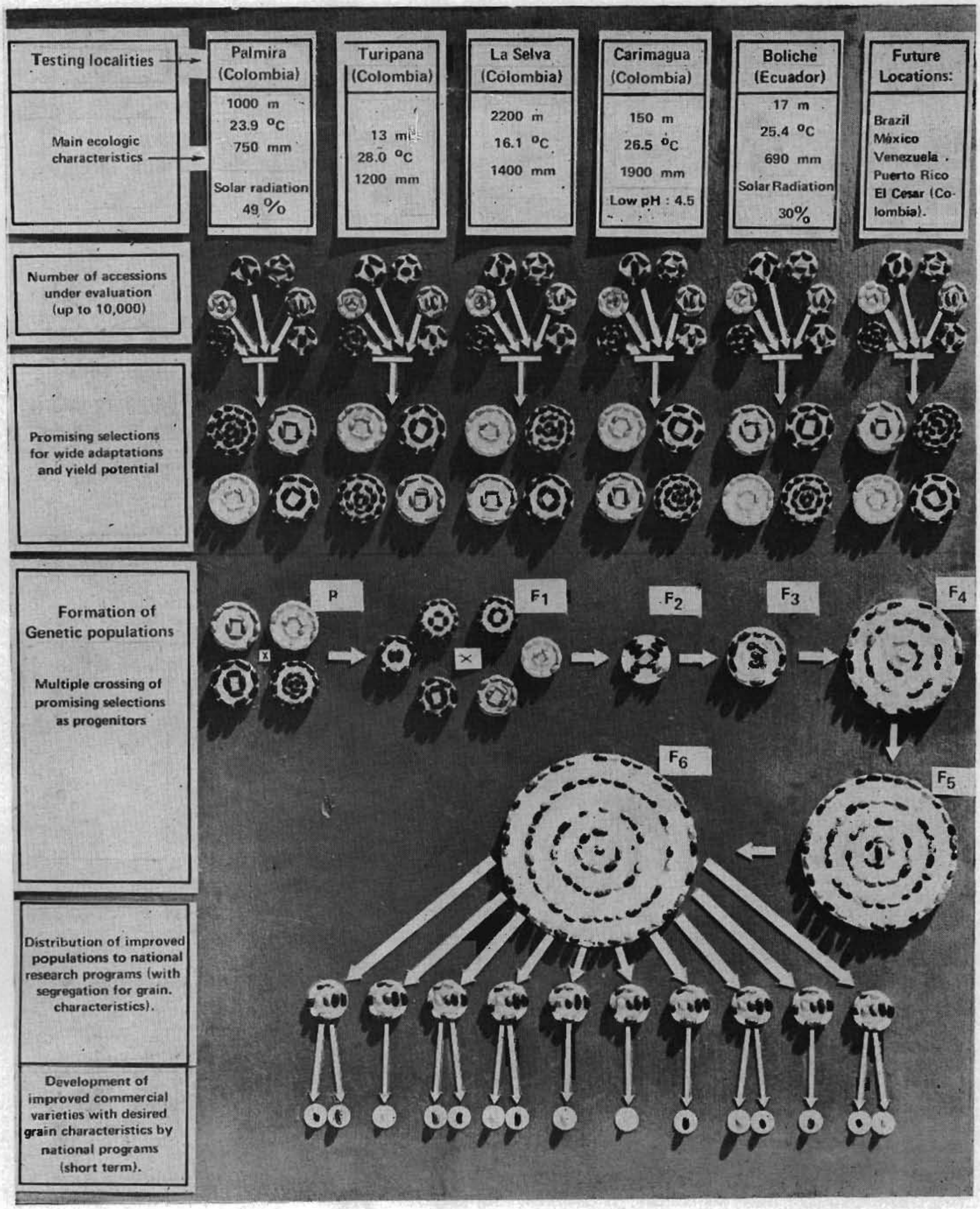
To determine the percentage of natural cross pollination in Palmira, two groups of contrasting varieties were used which varied in a seedling characteristic "hypocotyi color." Varieties were planted at three row distances. The F_1 plants will be analyzed in the next growing cycle.

Protein quality of common beans

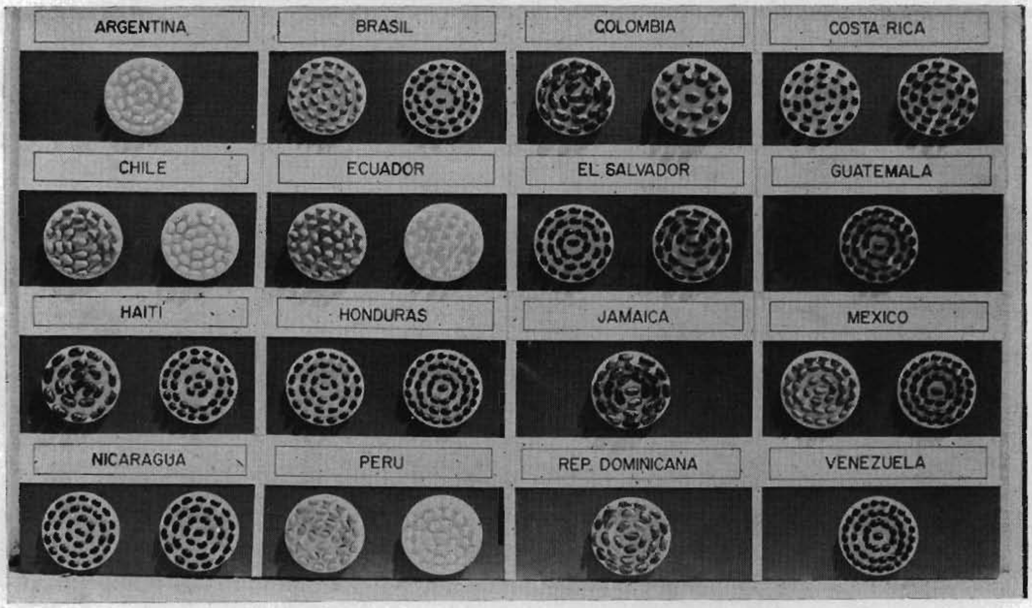
The inheritance of total crude protein and methionine by analyzing hybrid generations of four common bean selections is being studied as part of a thesis research project. The laboratory analyses have been completed for one of the original crosses where the progenitors have 28.9 per cent and 20.9 per cent total protein, and 0.656 g and 0.945 g methionine per 100 grams of protein. The first estimate of protein heritability is high in the F_2 generation of a breeding program. Further regression studies for protein and methionine will be done by testing the F_3 and F_4 progenies. The research will also explore the biological value of the protein.

Studies of drought tolerance

Through the screening of the bean germplasm in several locations, 457 collections have been identified which have root systems with a tap root tendency. This material will be studied more in detail to evaluate morphologic efficiency and possible genetic or physiologic components for drouth tolerance.



Breeding method for the formation of genetic populations of beans, *Phaseolus vulgaris*



Consumer preferences for common beans, Phaseolus vulgaris, **in Latin American countries**

Tap rooted plants will also be used in nodulation and nitrogen fixation studies (see page 178, Food Legumes section in this report).

AGRONOMY

The CIAT team is interested in determining for existing varieties the maximum potential, and also the economically optimum yields, which are possible through proper spacing, fertility and pest control. This will help to guide physiology and breeding work to overcome the existing yield plateau. Optimum combinations of populations of maize and beans, and eventually other crops as well, must be determined to be able to increase production with these systems.

The problems of acidity and infertility encountered in soils of the Colombian Llanos, coupled with the long-term agricultural potential of the zone, justify initial studies of agronomic practices for a maximum bean productivity for those soils. While cowpeas and peanuts seem particularly adapted to the zone, trials have shown that black-seeded bean lines will also grow and produce well in the region.

Principal research locations

Five ecological zones with distinct soil and climatic conditions were selected during the first year as principal research locations. Characteristics of the locations are described in Table 2.

Production of beans in monoculture

Studies of NPK and minor elements

Two experiments at CIAT evaluated effects of NPK and microelements on the production of two commercial bean varieties, a red bean (Calima) and a black bean ICA-Tui. Increases obtained with applications of nitrogen and phosphorus were not significant. Of the microelements studied, B deficiency seems the major factor limiting production.

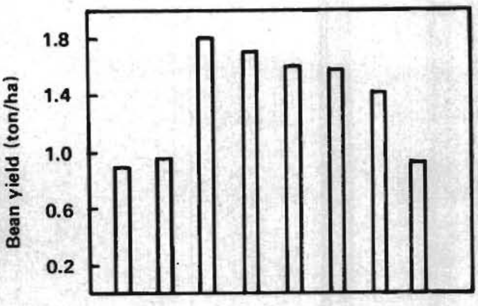
Table 2. Characteristics of sites where CIAT has cooperative bean agronomy experiments

	Climate			Soil	characteristics *		
Location	Altitude	Temp. (Mean (°C)	Precip. Annual) (mm)	pH	O.M.	P	Bean production
Colombia							
Palmira	1000	24	1000	7-8	M	H	Important
Popayán	1600	20	1600	5-5.5	H	L	Some importance
Rionegro	2200	16	1400	5-5.5	H	L	Very important
Carimagua	150	27	1900	4-5.5	M	L	Future potential
Ecuador							
Boliche	17	25	690	6-6.5	M	M	Potentially important

* H = High M = Medium L = Low

Figure 1 shows the contrast between some fertilizer treatments, and indicates the significance of boron deficiency.

With this problem identified, research concentrated on boron fertilization. Experiments were carried out with B levels, sources, times of application, method of application, foliar fertilization, interaction with minor elements, and sensitivity of some varieties to the deficiency. Also, the critical level of this element in the bean plant was determined by relating B levels in the leaves with productivity.



kg/ha								
N	—	40	40	40	—	40	40	40
P_2O_5	—	50	50	50	—	50	50	50
K_2	—	20	20	20	—	20	20	20
Zn	—	—	5	10	5	—	5	5
B	—	—	1	2	1	1	1	—
Fe	—	—	1	1	1	1	—	1
Mn	—	—	6	6	6	6	6	6

Figure 1. **Effect of some fertilization treatments on the production of Calima beans**

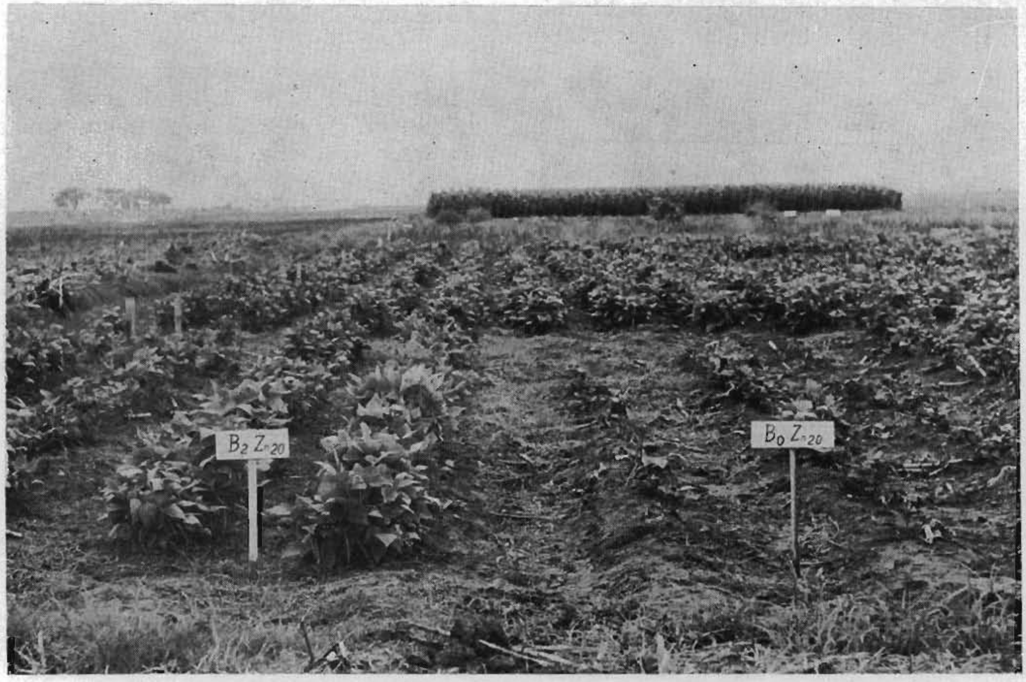
Responses to boron application were dramatic (see photos on page 154). In some plots not fertilized with boron there was a total crop failure.

Boron deficiency at CIAT also affects maize, sorghum and soybeans. In an experiment carried out in one of the B deficient plots in CIAT with the maize hybrid ICA H-208, boron applications of 2 kg/ha produced increases of 1,300 kg/ha of maize as compared to the control. The residual effect of the treatments of this experiment was measured with the bean variety ICA-Gualí. Figure 2 shows the results obtained; part of the B applied to maize remained in the ground and was used by the bean crop. The critical level of B in the bean leaves (Calima variety) can be estimated from Figure 3. Boron contents of less than 20 ppm in the leaves indicate an acute deficiency of the element, while B contents above 45 ppm indicate normal growth and yields.

Most of the experiments related to the boron deficiency problem are still to be harvested, but the following preliminary recommendations can be made for soils similar to those of the CIAT farm:

Boron level: 1 kg/ha
Application time: at time of planting.

Boron deficiency is one of the limiting factors in bean production in some experimental plots, at CIAT's farm



Boron application in bean fields must be made at time of seeding or shortly thereafter

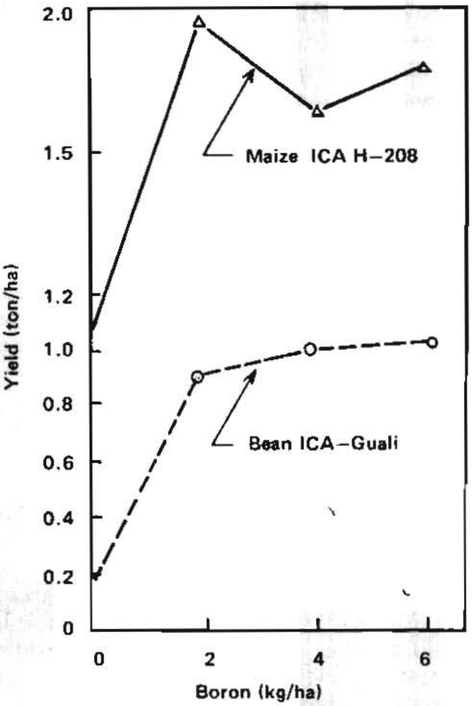


Figure 2. **The effect of application of boron on the yield of ICA H–208 maize and its residual effect on the yield of bean variety ICA–Guali**

Application method: banded a few cm to the side and below the seed. The approximate cost of 1 kg/ha is

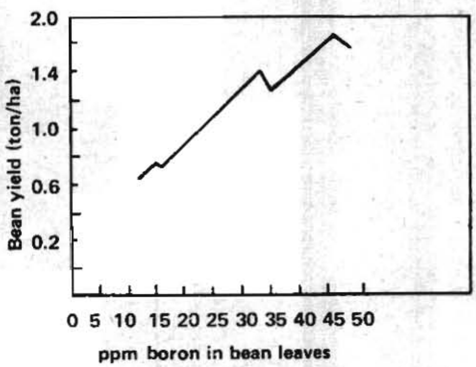


Figure 3. **Relation between the boron content in bean leaves and the production of Calima beans**

$120 (Colombian pesos) or $5 (US dollars).

No significant responses were observed for applications of other minor elements.

Mung beans (**Phaseolus mungo**), cowpea (**Vigna sesquipedalis**) and pigeon pea (**Cajanus cajas**) were more tolerant to boron deficiency than 16 varieties of common beans (**Phaseolus vulgaris**) and 5 varieties of soybean (**Soya max**). Mung bean seems to be resistant to boron deficiency.

Studies of plant density

The interaction of plant density and fertilizers on bean production was examined in two experiments. The different plant populations were obtained by changing the number of rows per ridge and the distance between plants within the row, while maintaining the distance between ridges constant at 90 cm.

Figure 4 shows that production increased when the number of rows per ridge was increased to three and the plant distance decreased to 5 cm. Considering the cost of seed, the most

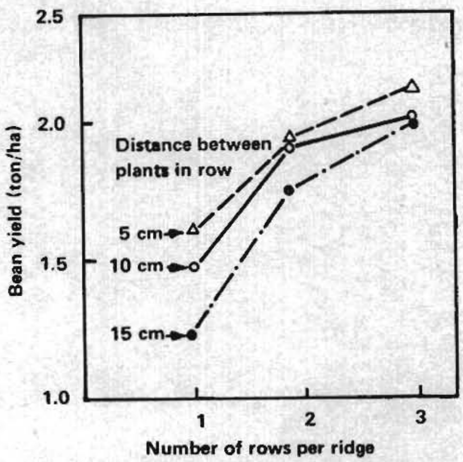


Figure 4. **Effect of number of rows per ridge and the distance between plants in the row on the production of Guali beans.**

economical plant density would be two rows per ridge and 10 cm between plants.

In another experiment without ridges, there were no significant differences in yield among row spacings of 60-60-60 cm (166,000 plants/ha), row spacings of 30-45-30 (266,000 plants/ha) and 15-45-15 (332,000 plants/ha) in the varieties ICA-Tui, ICA-Gualí, and Calima.

Studies on the effect of water management on production

In many important bean growing areas in Latin America, a lack of water is often limiting the production. Under these conditions, water may be utilized more efficiently, through practices that reduce evaporation and store or keep water in the soil. In this way, an additional short cycle crop like beans may be feasible at the end of the rainy season.

In cooperation with INIAP, an experiment at Boliche, Ecuador, studied the effect of ground cover on the rate of water evaporation and bean yield. Ground cover included maize residues, rice straw, castor bean leaves, sesame crop residues and plantain leaves. Preliminary observations indicate that:

1) the use of ground cover decreases weed competition; and 2) the most promising materials for ground cover are maize stubble, rice straw and plantain leaves.

Production of beans in intercropping systems

There is a great lack of knowledge about the traditional farming practice of intercropping used by low resource farmers in the bean production areas of Latin America. The agronomists initiated studies to answer the most elementary questions related to these traditional systems.

If two crops can be grown in the same field normally used for one crop, there is a substantial saving of space, time and inputs

Free spaces between rows of a crop —maize in this case— may be used by another crop such as beans

Mechanical seeding of maize amidst beans planted in double rows

Alternative methods to intercrop maize and beans

This experiment was planted in Boliche, Palmira, Popayán and Rionegro. The objective of the experiment was to grow two crops in the same space that would normally be occupied by one crop (photo on page 156). Upper photo on page 157 shows a trial in which four rows of beans were planted in the free space between the corn rows. Light competition appeared to be the main limiting factor.

The application of these principles of intercropping can be available to large and small farmers. One of the difficulties caused by these systems, mechanized seeding, does not seem important. Lower photo on page 157 shows mechanized seeding of maize amidst beans planted in double rows. Beans are harvested manually.

Maize and beans competition studies

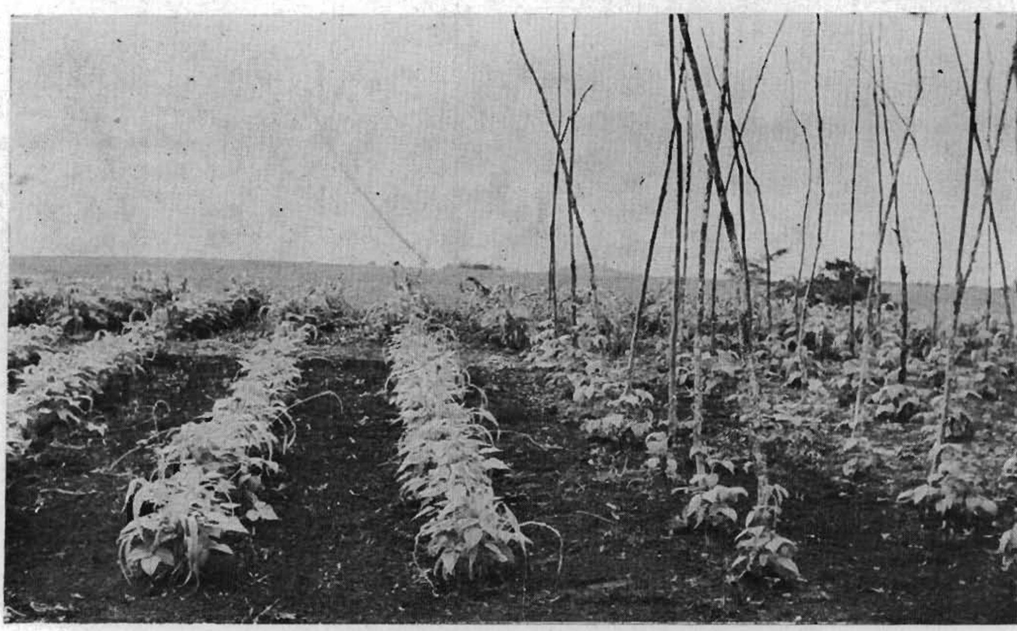
In the system of intercropping, maize and beans compete for light, water, and nutrients, but they also complement each other, as physical support. Photograph on this page shows a maize/bean intercropping system in Popayán using a regional climbing bean variety, compared to beans planted in monoculture using stake supports. Photo on page 159 shows an experiment of different planting dates of corn relative to those of beans.

Population studies for the mixed system, maize and beans

Several experiments are evaluating the effects of plant density and fertilization on intercropped maize and beans in Popayán and Rionegro, using the local climbing bean varieties Cargamanto and Sangretoro.

Weed control studies for multiple cropping

An experiment at CIAT tested the effectiveness of several herbicide treatments in intercropped maize and beans. The crops were planted simultaneously and the herbicides were applied before



Competition of a mixed maize-bean crop

Crop competition in intercropping systems depend on the planting date of one crop in relation to the other

emergence. The most outstanding treatments in the study were the mixture of Linuron and Alaclor or Alaclor and Linuron by themselves when applied at high rates.

Tolerance to soil acidity

A collection of 50 varieties of black beans, 2 soybeans (**Glycine max**) and 20 cowpeas (**Vigna sesquipedalis**) were screened for tolerance to soil acidity on an oxisol at Carimagua. The collection was seeded at four lime levels of 0, 0.5, 2 and 6 ton/ha. Without lime the soil has a pH of about 4.3 and 3.0 me/100 g of exchangeable Al, while the high lime application of 6 ton/ha increased the pH to about 5.4 and decreased the exchangeable Al content to about 0.4 me/100 g (see page 211 Rice section in this report). Figure 5 shows the average response of the species to lime applications. It is clear that all species responded to liming, but the black beans and soybeans responded up to 6 ton/ha, while the cowpeas responded significantly only to the first increment of 0.5 ton/ha. Because of the high level of production and the general tolerance to acid soil, the cowpeas show the most potential for these very acid, infertile soils.

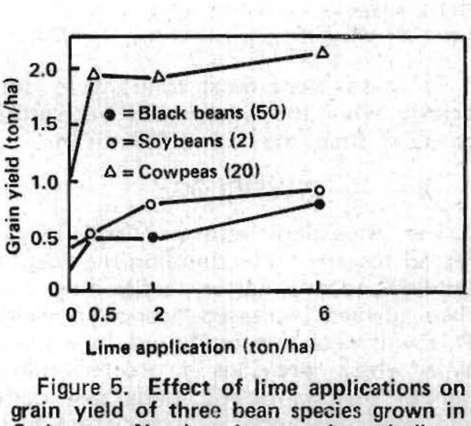


Figure 5. **Effect of lime applications on grain yield of three bean species grown in Carimagua. Numbers in parentheses indicate number of collections tested**

To determine the effect of liming on the nutritive value of these species, samples of the grain of 6 black beans, 2 soybeans and 4 cowpeas, harvested at each lime level, were analyzed for N, P, K, Ca, Mg, Zn and Cu. Liming had only a clearly positive effect on the Ca-content of the grain, hardly any effect on the N, Mg and Cu contents, a slightly negative effect on the P and K contents, and a strongly negative effect on the Zn content. The latter may be of great significance considering the apparent importance of Zn in the metabolism of vitamin A. It is clear that soybeans are not only much higher in protein, but also significantly higher in all minerals analyzed, in comparison with black beans and cowpeas. The black beans had a slightly higher mineral content (except Zn) than the cowpeas.

Another collection of 100 non-black beans, 125 black beans and 45 cowpeas were screened at Carimagua at 0.5 and 2 ton/ha lime levels. The same collection was seeded with maize as support for the climbing varieties.

The following average yields were obtained for the three types of beans and peas:

	Grain yield (g/6 meter row)	
	0.5 ton/ha lime	2 ton/ha lime
Non-black beans (100)	26.5	46.8
Black beans (125)	65.0	115.6
Cowpeas (45)	384.8	539.0

Cowpeas were most tolerant to soil acidity, while the black beans were more tolerant than the non-black beans.

PHYSIOLOGY

The physiology effort is initially directed toward understanding the plant's growth and dry matter partitioning, and then toward increased economic yield. This will probably be found in a plant type which provides a greater number of fruiting nodes, pods per node and seeds per pod in a variety which can stand up under this load. A cooperative effort organized with Cornell, Michigan State, and Hokkaido universities will lead to research in crop physiology to establish plant type guidelines for the breeder.

In evaluations of the germplasm collections at CIAT, special emphasis is placed on yield potential and the morphologic characteristics which appear to contribute to beans in monoculture, as well as in association with maize. The apparent adaptive superiority in the tropics of black-seeded beans over other types is a characteristic which will give a better yield potential to other acceptable types. Adaptation of beans to zones which differ in photoperiod and ambient temperature is being studied in the field in the tropics.

Other activities are complementary to the primary effort on determining an optimum plant type and selecting for that potential. One growth analysis trial and another on interplant competition were carried out during 1973. Growth and yields of **P. vulgaris** varieties were reduced by common bean mosoic virus, and the trials must be repeated using clean seed and protective insecticides and fungicides.

Simplified Growth Analysis over Locations

A series of trials which include a simplified description of final dry matter distribution in beans is being organized with national programs in the region and will be initiated in 1974.

In practice, these analyses include a limited number of additional measurements in the normal yield trials conducted by all improvement programs. In principle, it is an attempt to define with greater precision the contribution of plant type to eventual economic yield. The main advantage of simplified growth analysis is that it measures the two component physiological processes that are all inclusive and closest to final yield expression. These two processes are net accumulation of photosynthate, and the partitioning of this photosynthate between the economically important seed and other plant organs. These processes are measured using the total plant dry weight accumulated in each plot of the yield trial, and from the harvest index or the per cent of total plant dry weight that is economic yield, of seed.

In addition to the total plant dry weight collected in all trials with cooperators, some locations with an interested physiologist, breeder or agronomist will collect additional data: pods per hectare, seeds per pod, average weight per seed, percentage of light interception during flowering, dates and duration of flowering, weather data, and black and white photos of each genotype tested. This series of trials will soon provide guidelines to regional physiology efforts which are associated with breeding programs focused on searching out ideal plant types and selection for these types.

Photoperiod Insensitivity

The first testing for photoperiod sensitivity in beans included 14 varieties of **Phaseolus vulgaris,** and the soybean variety ICA-Mandarín as a sensitive check. The same field installation described in the chapter on maize research (page 197) was used, with beans planted in rows perpendicular to the line of 300 W incandescent bulbs used as light source. The criterion for insensitivity was uniform flowering and fruiting along the length of the row from light source out to 30 m. Two varieties, ICA-Bunsi and 73 Vul 6 (from the CIAT germplasm bank), were insensitive in this cycle.

In addition to this comparison of the extremes in the row, weekly data were taken at 5 m intervals along the row on plant height, number of leaves, flowers and pods, length of first internodes and number of branches. The increased intensity of light used to extend the day, i.e., observations near the light source, showed the following effects in beans:

1. Increased branching and excessive stem moisture which made plants brittle and easily broken.
2. Reduced leaf abscission when pods were completely dry in some varieties.
3. Increased leaf size and total leaf area.
4. Change in growth habit in some varieties from bush type to semi-climbing.
5. Flowering delayed or inhibited altogether, with a critical intensity for this reaction at about 15-20 m from the lights.
6. Increased number of empty pods per plant.

Trials with Cowpeas

In collaboration with the CIAT swine program, 15 varieties of cowpeas from ICA were tested for yield and nutritional value. Six of these produced more than 2 ton/ha in a replicated trial, while two produced 7 ton/ha. Nutritional test results are reported in the section on swine.

The exceptionally high yield levels of these two top varieties were obtained in four consecutive harvests, over a total period of 110 days.

PHYTOPATHOLOGY

Among the many diseases which affect beans in the tropics, the most serious in reducing crop production were designated by pathologists who attended the workshop in March as common bacterial blight (**Xanthomonas phaseoli**), rust (**Uromyces phaseoli** var. **typica**) web blight (**Thanatephorus cucumeris**), anthracnose (**Colletotrichum lindemuthianum**), the complex of root rots (**Pythium** sp., **Sclerotium** sp., **Sclerotinia** sp., **Fusarium** spp., and **Rhizoctonia** sp.), common mosaic virus, and golden mosaic complex whose causal agents is unknown and is transmitted by the whitefly **Bemisia tabaci.**

Research was initiated on estimating crop losses, principal epiphytotic factors, search for resistant varieties, chemical control, and in some cases etiologic studies. As more than 50 per cent of these limiting diseases are transmitted through the seed, an extensive program was launched to clean pathogens from all seed in the collections of the germplasm bank, as well as the principal local commercial varieties in Latin America. A quarantine program for **Phaseolus** sp. and other legumes was continued in collaboration with ICA.

Bacterial Diseases

The bacterial species **Xanthomonas phaseoli** and **Xanthomonas phaseoli** var. **fuscans** have been isolated from various sites in Colombia, Perú, Guatemala, Brazil, El Salvador and Costa Rica. The principal activity includes screening lines and varieties from Michigan State University and CIAT for resistance to this pathogen. The screening revealed 5 tolerant and 46 moderately tolerant varieties among the 283 tested. Most tolerant were GN 1 Sel. 27, Jules, Tara, S-562P, and 605-3. Climatic conditions were adverse for good disease development in the field, although two artificial inoculations were made at 35 and 45 days after planting.

In the same manner, a number of lines were tested in the second season. These included 209 lines from M.S.U., and 61 individual selections and 77 lines from the breeding program at CIAT. Conditions for disease development were favorable, and the most tolerant varieties were 1024-3, 916-1, 918-2, and 451-1.

Fungus Diseases

Rust

The fungus causing this disease consists of many physiologic races, and a search for vertical or specific resistance is not the best solution. For this reason, the program seeks partial, or horizontal resistance by testing a large number of resistant lines and varieties in several locations in Latin America. Under test in Colombia are 22 collections from Puerto Rico, 93 from Central America and 60 promising collections from CIAT. The most resistant are Puerto Rico 5, 17 and 18, and CIAT 73V-3214, 3229, 3231, 3243, 3249, 3268, 3275, 3285, 3287 and 3683, to races present in the fields in CIAT.

Root Rots

There are various fungi (**Pythium** sp., **Rhizoctonia** sp., **Fusarium** spp.) which attack small bean plants from the moment of emergence, and sometimes even before they break the soil surface. Another fungus present in the soil **Sclerotium rolfsii** attacks beans in the early stages of development. At CIAT, a special lot was designated for testing for resistance to this complex of organisms. The soil is of heavy texture, with poor drainage, where beans are planted continuously and inoculum of various organisms grown on sterilized wheat is applied. In the first test, materials included PI 109859, PI 165435, and PI 226895 registered as resistant to **Rhizoctonia solani**; PI 203958 and R-275 with resistance to **Fusarium solani** v. **phaseoli**, and the Colombian varieties ICA-Guali, ICA-Tui, ICA-Huasano and ICA-Duva. The collection PI 165435 showed good resistance to the root rot complex, while the commercial varieties were highly susceptible.

Anthracnose

This disease is not of much importance in the lowland tropics, although it limits production in crops grown over 1,500 meters elevation. Preliminary studies with bean crops in several locations in Colombia indicate that there are races different from those previously reported and even more virulent.

Virus Diseases

The program is working with common mosaic virus, and with the golden mosaic complex, classified as a viral disease, but whose causal agent is still unknown.

Bean common mosaic virus

All commercially-cultivated varieties in Latin America and the Caribbean are susceptible to this virus, whose major importance is because of ease in seed transmission and efficient dissemination in the field by several aphid species.

Seed transmission

Plants which were apparently sick and others which were apparently healthy were selected in semi-commercial crops of ICA-Gualí. Of 1,000 seed tested from each lot, the apparently healthy plants showed 6% virus transmission, while the sick plants showed 51% virus. In addition, it was determined that removal of the seed coat increased the percentage by 8 to 10%.

Seed treatment with micro-waves

A test was carried out to inactivate the virus by treatment with heat from micro-waves generated in a small oven during times of 0, 15, 30, 60, 120, and 240 seconds. Percentage of seed germination was drastically reduced, while the virus was not inactivated, except in the most drastic treatments of micro-waves.

Losses from common bean mosaic virus

Experimental plots severely infested with virus were compared to nearby plots apparently free of virus in the bean variety ICA-Gualí. Results indicate a yield reduction of 25 per cent. A trial is undeway which will assess the importance of age of the bean plant **vs.** time of infection, to determine when the most critical time is for attacks by the virus.

Strain determination

Using the differential strains suggested by Zaumeyer, it has been determined that tropical strains of virus are more virulent than those from temperate zones. These include isolates from Perú, Colombia, Costa Rica, Venezuela and Guatemala.

Identification of common bean mosaic virus

The electron microscope has allowed identification of the virus from infected plant tissue **in situ,** without the danger or necessity of transporting live plant material. This technique has led to CBMV identification in material "fixed" in Brazil, Colombia, Guatemala and Perú. The virus is identified by spiral inclusions in the cells, as shown in photo on page 164.

Resistance to common bean mosaic virus

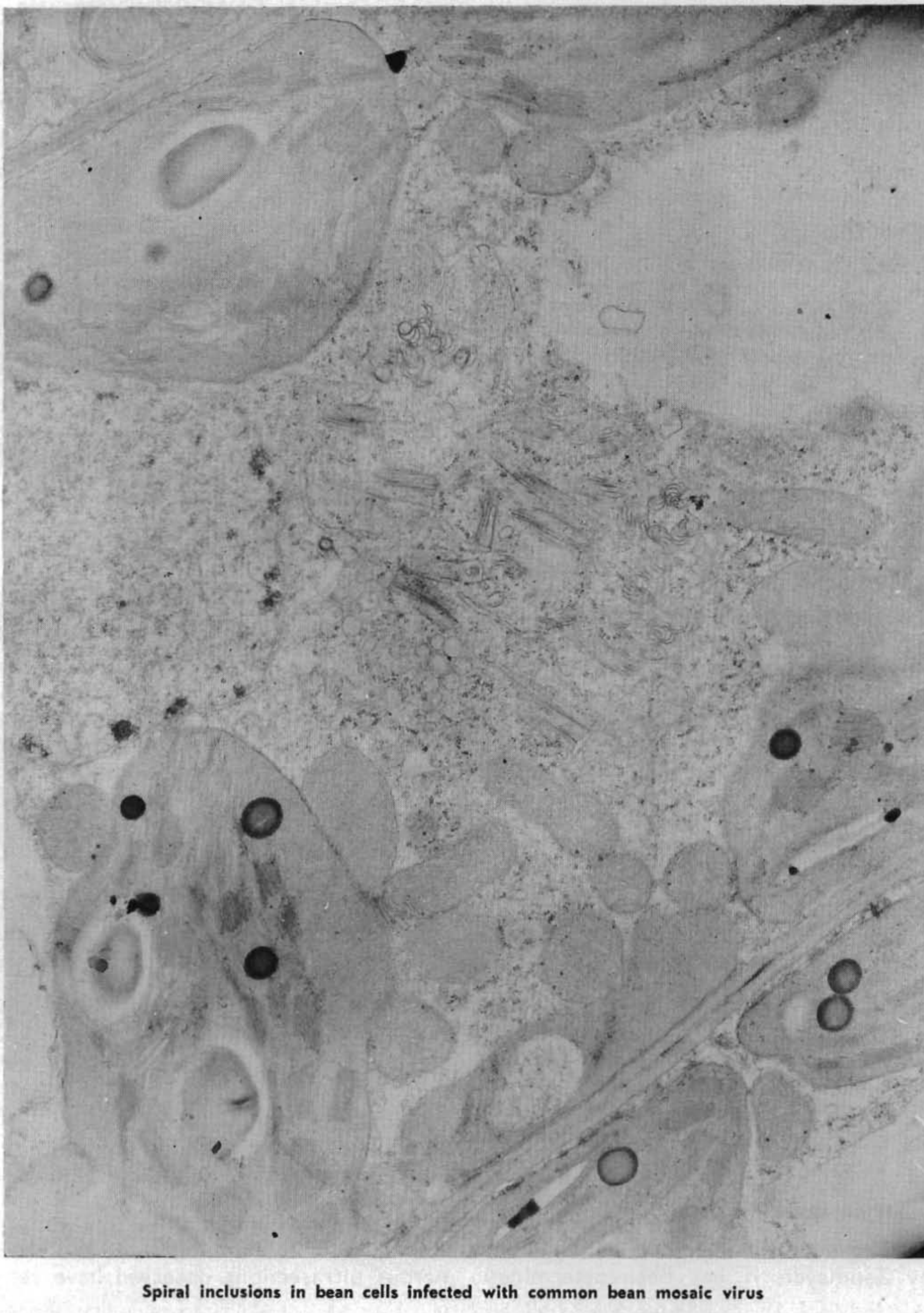
Varieties from the germplasm bank were tested against several isolated strains of the CBM virus to search for sources of resistance. Initial tests indicate good resistance in the varieties Michelite, Sanilac, and Topcross.

Golden mosaic

This complex of diseases transmitted by the white fly **Bemisia tabaci** is one of the principal factors limiting tropical bean production in El Salvador, Guatemala, Jamaica and Brazil. The pathogen complex may be a composite of several strains of one organism, or may be several different pathogens from the same group. To date there has been no possitive identification nor classification of the causal agent of any of the diseases transmitted by white fly in beans or any other crop.

Electron microscope studies

In collaboration with the Agronomic Institute of Campinas and the University of Brasilia in Brazil, and Hokkaido University in Japan, a study was initiated on golden mosaic in beans and other host species. To date, none of the numerous ultrasections observed have re-



Spiral inclusions in bean cells infected with common bean mosaic virus

vealed particles similar to virus, nor any inclusions typical of mycoplasma or ricketsia. These observations do not entirely rule out a virus as the possible causal agent, but they do suggest prudence in classifying this disease as one of viral origin.

Resistance to golden mosaic

This disease has as principal host plants beans (**Phaseolus vulgaris**) and **Calopogonium** sp. The University of Costa Rica has tested more than 4,000 varieties, CENTA in El Salvador 800 varieties, and ICTA in Guatemala (with CIAT collaboration) 1,236 varieties, and there has been no acceptable resistance found. Few varieties even show tolerance to the disease. Although the white fly vector causes no significant direct damage to the plant, even at high insect populations, it is an efficient vector for transmitting the disease.

Mottled mosaic

This disease occurs in beans in countries with an abundance of alternate host species such as **Sida, Rhincosia, Euphorbia** and **Malva.** Importance varies with the location, and resistant varieties have been found. The disease is especially important in soybeans. Attempts to transmit this disease mechanically using a phosphate buffer 0.01M and pH 7 or DIECA have been unsuccessful.

Swelling mosaic

A disease with symptoms similar to 2,4-D damage on the leaves has been observed in El Salvador. The isolate is easily transmitted mechanically and will be identified and characterized in the near future in collaboration with CENTA and the University of El Salvador.

Rugose mosaic

The virus which causes rugose mosaic in beans is transmitted by three **species of Diabrotica.** Studies in the University of Costa Rica have provided identification and characterization of the virus. In cooperation with this group and with the Agronomic Institute of Campinas it has been possible to identify the virus **in situ** with the electron microscope, which will facilitate its identification in other countries. This virus forms crystals in the cell, as shown in photo on page 166.

Abnormal leaf formation

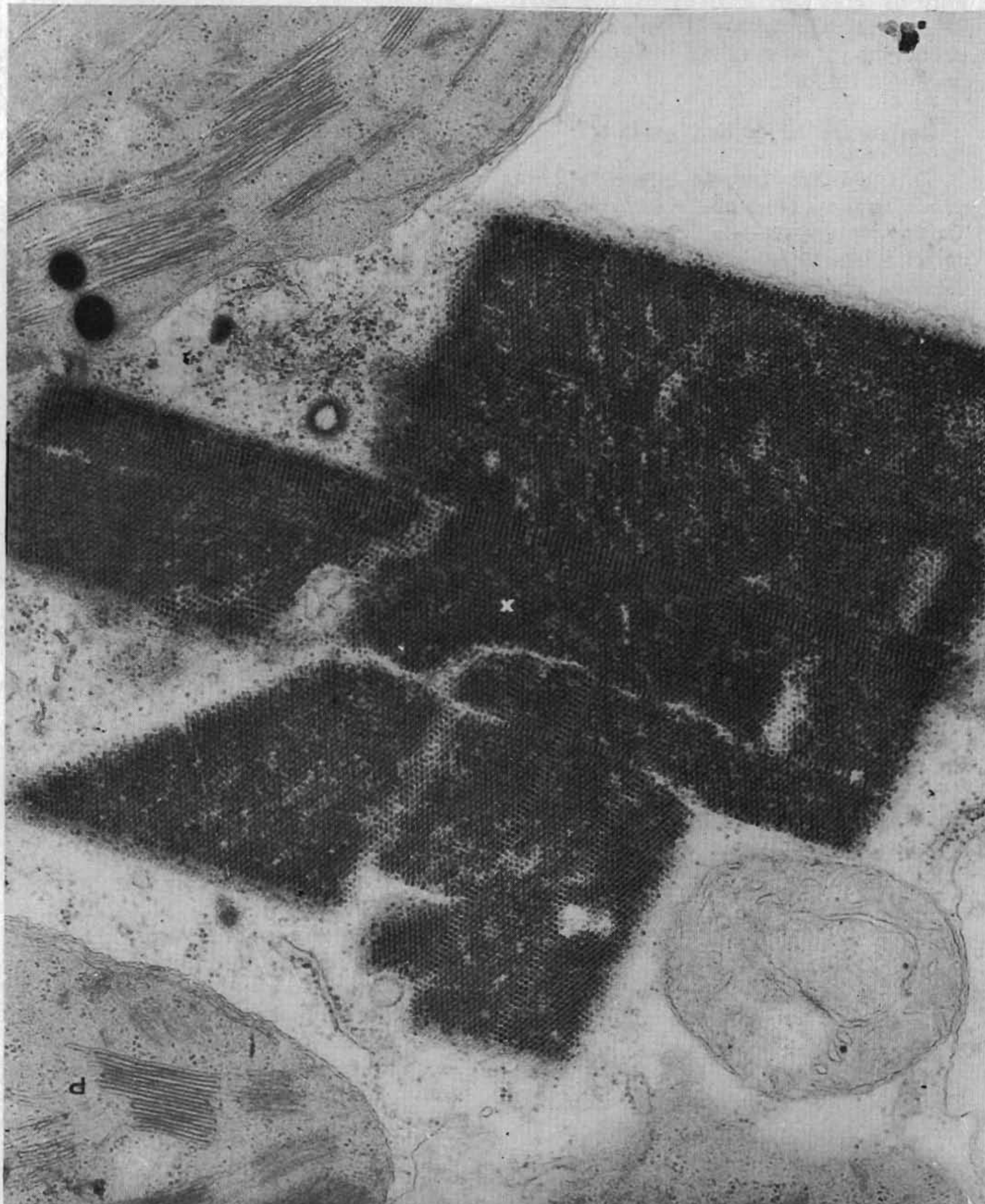
An unusual and abnormal leaf condition which is similar to symptoms caused by virus or herbicides has been observed occasionally at CIAT and at ICA-Palmira. After many observations, it has been concluded that this damage is due to a microscopic white spider mite which is now being identified.

Diseases Caused by Nematodes

In collaboration with ICA, plots have been infested with **Meloidogyne incognita** var. **acrita,** the causal agent of root knot condition. As soon as the population increases in these plots to a satisfactory level, material from the germplasm bank will be tested for resistance to the nematode.

Production of Seed Free from Pathogens

Fifty per cent of the important diseases of beans are transmitted by the seed, among these common mosaic, anthracnosis, angular leaf spot, web blight, bacterial blights, etc. Local commercial varieties in Latin America, as well as the majority of the collections in the germplasm bank are infected with one or more of these organisms. This severely limits physiologic or agronomic studies, seed exchange, and international nurseries. In addition seedborne disease is a critical limiting factor for yield experiments on the farm, as this is a primary source of inoculum. Seed cleaning under carefully controlled conditions of present commercial varieties and collections from the germplasm bank is a priority project.



Cellular inclusions of crystals caused by the Rugose Mosaic virus

Seed cleaning

This project began as soon as greenhouse facilities were available. To date, 120 selections from the CIAT breeding program and 43 varieties and collections from Perú, Colombia, Guatemala and the U.S. have been cleaned. These varieties include those with current commercial importance and those which have genes for resistance to one or more pathogens.

Increase of clean seed

Of these 163 varieties, 46 have been increased at CIAT. Every effort has been made to eliminate any doubtful plants, and to control or eliminate any possible contamination with frequent applications of insecticides, fungicides and bactericides. This foundation seed will be turned over to the countries of origin to initiate serious and productive national programs of seed certification.

Ideal zones for production of clean seed

Zones have been sought and explored where conditions are ideal for seed production. With a 35 to 40 per cent relative humidity and only 230 mm of rainfall, the Idaho area (USA) is exceptional and has been dedicated almost exclusively to production of certified seed. In Latin America it will not be possible to locate zones with exactly these characteristics, but there are regions which combine much better conditions than are currently used for seed production. For example, major progress could be made in producing clean seed if the seed production areas were far from commercial production areas, instead of side by side.

Of the many sites visited, several have been selected for trials.

Colombia, a zone north of Valledupar in the Department of Cesar where relative humidity is 60-70% and rainfall 40 mm (in collaboration with ICA).

Perú, a zone in the Department of ICA, near Pisco, with a relative humidity of 80-90% and absolutely **no rainfall** (in collaboration with the Experiment Station in La Molina).

Guatemala, the valley of San Jerónimo in the State of Baja Verapaz, with a relative humidity of 70-80% and about 500 mm rainfall (in collaboration with ICTA). The national research organization has purchased an experiment station precisely for this purpose.

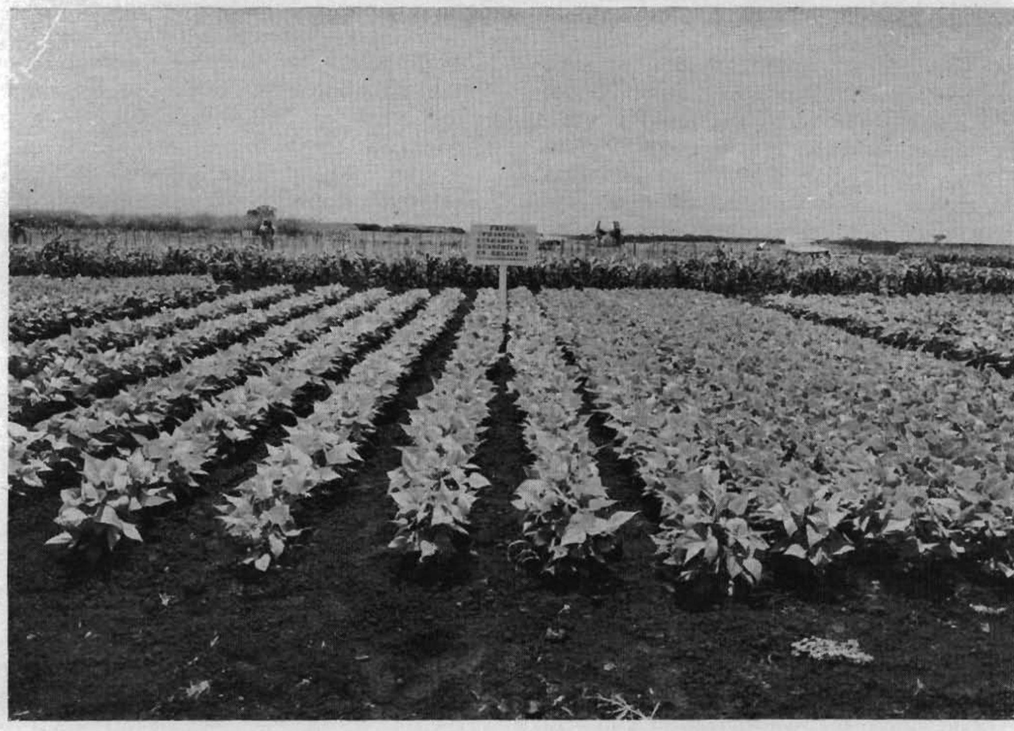
Brazil, the valley of San Francisco where relative humidity is 60-70% and rainfall 400 mm (in collaboration with the Agronomic Institute of Campinas or the University of Brasilia).

Epiphytotic Studies

Yields as related to plant density and disease incidence

One of the practices which could substantially increase yields is an increase in plant density, a change in cultural practices which creates microclimatic conditions in the tropics which favor development of some diseases: rust, bacterial blight, web blight, etc. Trials were planted using the "parallel row" design of Bleasdale, in which distances between rows varied from 18 to 95 cm and distances between plants from 4 to 20 cm. This corresponds to plant populations from 60,000 to 1,500,000 per hectare (see photo on page 168).

Varieties ICA-Gualí, ICA-Tui, ICA-Duva and Jamapa were planted in one plot protected by fungicides and one with no protection. There was not a high incidence of diseases. During the evaluation at harvest, an equal number of plants were harvested per row. The response of each variety to population density was different. In spite of the low level of infection of rust and bacterial blight, there were consistently higher yields in the protected plots, especially



Parallel row design for bean populations from 60.000 to 1.500.000 vs. disease incidence

at high densities in those varieties most sensitive to diseases, ICA-Gualí and ICA-Duva (red-seed types). Black seeded varieties (ICA-Tui and Jamapa) were more resistant, yet still showed an increased yield in protected plots.

Artificial defoliation to estimate disease losses

Per cent defoliation vs. time of defoliation

Artificial leaf removal with scissors reduced leaf area by 10, 20, 40, 60 and 80 per cent of the total by clipping each leaf, and these treatments were compared to an absolute check. Leaf cuts in several directions were applied at 15, 30, 45 and 60 days from emergence, corresponding to the following growth stages in Palmira: three first trifoliate leaves, initiation of flowering, pod filling, and initiation of physiological maturity. The variety ICA-Gualí was chosen because of its determinate growth habit and large leaves which facilitated defoliation treatments. In Table 3, it is apparent that the critical stages are initiation of flowering and the pod-filling period, where yield reductions of 29.4 and 39.5 per cent, respectively, were observed with 80 per cent defoliation. When treated at 15 days of age, the plant recovered notably, and losses were reduced to 15.7 per cent. At 60 days, treatment had essentially no effect.

Artificial defoliation at two levels

Some foliar diseases are found primarily in the lower part of the plant where higher humidity favors the pathogen. Partial defoliation was effected leaf by leaf with removal of 30 and 60 per

Table 3. **Bean yields (kg/ha) of ICA-Gualí in response to partial defoliation at different plant ages, CIAT 1973A**

Plant age	Per cent defoliation	Yield kg/ha	Yield reduction per cent
15 days	10	1790	5.9
	20	1583	16.8
	40	1652	13.2
	60	1561	17.9
	80	1605	15.7
	Check	1902	
30 days	10	1728	14.4
	20	1735	14.1
	40	1666	17.3
	60	1623	19.6
	80	1424	29.4
	Check	2018	
45 days	10	1822	4.4
	20	1786	6.3
	40	1478	22.5
	60	1463	23.3
	80	1152	39.5
	Check	1905	
60 days	10	1830	10.8
	20	2076	+ 1.2
	40	1942	5.3
	60	1579	13.0
	80	2050	0.1
	Check	2051	

cent of the foliage either high or low. These treatments were applied to the variety ICA-Gualí at 20, 40, and 60 days from emergence.

Striking effects of removing the upper leaf area, and no effect with lower leaves, are shown in Table 4. At 20 days, a defoliation of 60 per cent caused a 22.8 per cent yield reduction, while the same treatment at 40 days reduced yields by 29.4 per cent. Partial defoliation at 60 days caused no loss in yield.

Evaluation of Fungicides

To maintain current information on the efficiency of new protective and systemic chemical products, a small trial with fungicides and bactericides was planted to test control of rust and common bacterial blight. First results were not satisfactory because of low infection and variability among the four replications, indicating a need for precise experimental designs in this type of experiment.

Table 4. **Seed yield (kg/ha) and yield reduction in ICA-Gualí resulting from partial defoliation at three plant ages, CIAT 1973A**

Plant age	Defoliation level	Defoliation per cent	Yield (kg/ha)	Reduction per cent
20 days	Upper part	30	1608	7.2
		60	1337	22.8
		Check	1732	
	Lower part	30	1521	1.9
		60	1496	3.6
		Check	1551	
40 days	Upper part	30	1206	22.9
		60	1101	29.4
		Check	1564	
	Lower part	30	1664	1.0
		60	1645	2.1
		Check	1680	
60 days	Upper part	30	1677	+ 0.8
		60	1685	+ 1.3
		Check	1664	
	Lower part	30	1431	4.8
		60	1395	7.2
		Check	1503	

Disease evaluation in Germplasm Bank plantings

Palmira (CIAT)

An evaluation was made in 3,792 collections of beans for resistance to common bacterial blight and to powdery mildew. There were 58 collections resistant to **Xanthomonas** (blight) and 156 resistant to **Erysiphe** (mildew).

La Selva - Rionegro (ICA)

In 200 collections, the only serious epiphytotic was **Alternaria** sp., to which 11 varieties showed resistance.

Turipaná - Montería (ICA)

An epiphytotic condition of web blight **(Thanatephorus cucumeris)** occurred in the 1,427 collections, and 20 were resistant to the disease. This station is ideal for disease screening of materials under tropical hot, humid conditions.

Las Monjas - Guatemala (ICTA)

In the past season there was a tremendous epiphytotic of golden mosaic. No collection from CIAT, Puerto Rico, Guatemala, or PCCMCA (uniform nursery) showed resistance. Of these 1,500 collections, there were 50 with some tolerance, and the best varieties were Turrialba 1 and Porrillo 70.

ENTOMOLOGY

Of the 208 insect species reported to attack beans in Latin America, only a few are commercially important. In probable order, these are **Empoasca kraemeri,** spidermites, Chrysomelids (**Diabrotica** sp., **Ceratoma** sp., etc.), leafeating caterpillars (**Estigmene acrea, Hedylepta indicata, Trichoplusia ni,** etc.), cutworms (mainly **Spodoptera frugiperda, Feltia** sp.) and the tingid **Gargaphia sanchezi.** The white fly as vector of virus diseases and the bean pod weevil **Apion godmani** are of great local importance, eg. in Central America. Aphids and **Diabrotica** also transmit important virus diseases.

Empoasca kraemeri

To determine the most important bean pests and how their populations fluctuated, beans were planted every 15 days and sampled for insect pests every 10 days through one year. Diacol Calima and ICA-Tui were planted on alternate dates, together with 13 other commercial varieties. Four pubescent cultivars were included.

By far the most important pest on the CIAT farm appeared to be **Empoasca kraemeri.** Damage appeared as yellowing and curling of the leaf margins, stunted growth, early dessication and in extreme cases no yield. The commercial varieties Calima and Gualí (red beans) appeared to be susceptible and ICA-Tui and Jamapa (black beans) tolerant to leafhopper attack. The population development on Calima and Tui is given in Figure 6. The population is highest on Calima, 30 to 40 days after planting, but then decreases from damage to plant tissues. On the tolerant variety ICA-Tui, maximum population level is reached 50-60 days after planting, and is twice as high as the maximum reached on Calima. On young plants, the population of leafhoppers is higher on Calima. Although Calima is preferred, the susceptibility of the variety makes this a less desirable host in later stages of development.

The population of leafhoppers on 40-day-old plants of ICA-Tui and Calima varied similarly with a higher incidence from the beginning of May until the last half of July, which is the end of the wet season (Figure 7).

The yield of beans varied greatly with planting date. Without insecticidal protection maximum yields were obtained from plantings between February 11 and May 11. Therefore, farmers have only one month to plant the beans in

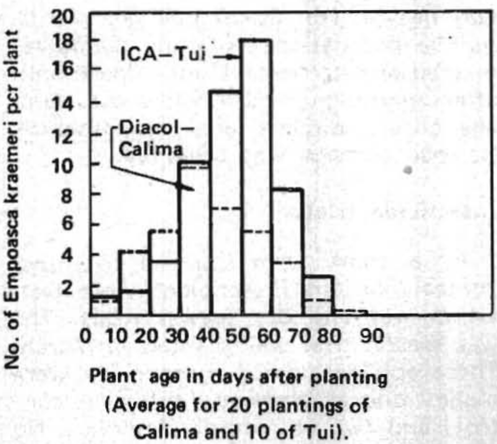


Figure 6. **Population levels of** Empoasca kraemeri **on bean varieties ICA-Tui and Calima**

the first half of the year and still achieve maximum yields. ICA-Tui, tolerant to **Empoasca**, outyielded Calima, especially at the optimum planting time. Under insecticidal protection, Calima outyielded ICA-Tui in a trial planted in April. Apparently the resistance of ICA-Tui is sufficiently strong for the wet season under a low **Empoasca** population, but is not sufficient for protection during the dry season. High **Empoasca** populations go together with low bean yields and with the dry season (Figure 7). The economic importance of **Empoasca** and the relation between insect population and yield is clear.

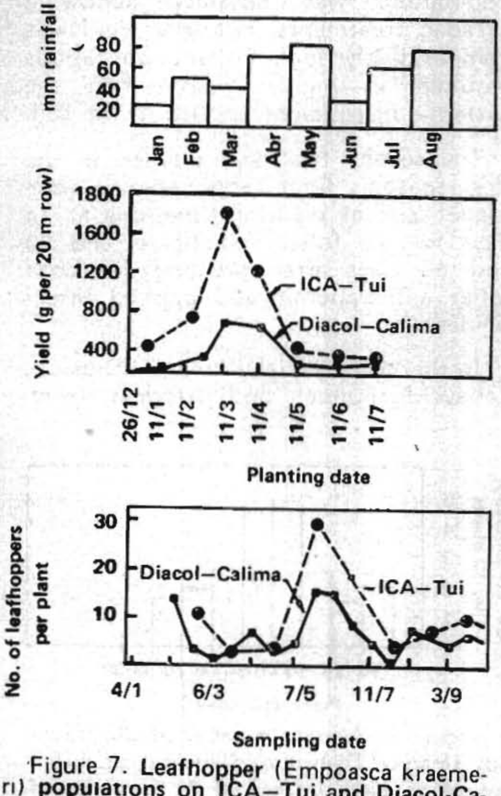


Figure 7. **Leafhopper** (Empoasca kraemeri) **populations on ICA–Tui and Diacol-Calima varieties.**

Maximum yield was obtained from March 13 planting when the **Empoasca** population during the early growth stages of the beans was low. In the May 11 planting the leafhopper population was high in this period and yields were low. The early growing stage appears to be the most crucial time to protect against **Empoasca** (Figure 8).

The type of resistance of ICA-Tui is being investigated. Besides the higher population levels tolerated by ICA-Tui, there may also be a non-preference for oviposition, as shown in nymphal counts on Tui and Calima (Table 5).

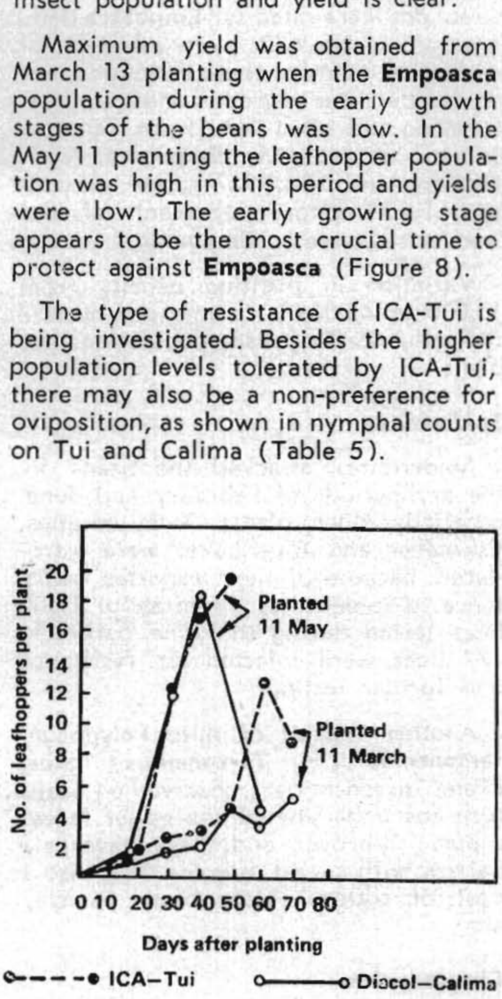


Figure 8. **Leafhopper population buildup on resistant (ICA–Tui) and susceptible (Calima) bean varieties at different planting dates.**

Table 5. **Number of nymphs per 10 leaves of varieties Tui and Calima, planted October 1973**

	Plant age (days)			
Varieties	17	27	37	46
Calima	0.6	1.6	7.4	21.8
Tui	0	0.4	5.0	11.0

In a search for higher levels of resistance than found in ICA-Tui, 1,638 selections were rated for **Empoasca** damage, of which 472 were selected for replanting. Many of these selections may be escapes. The varieties Jamapa, ICA-Huasano and 12e I-947 (from Venezuela) are resistant to **Empoasca,** with Huasano and 12e I-947 more resistant than Tui. The four pubescent varieties were susceptible to **Empoasca.**

Variation in planting density from 16,000 to 4,000,000 plants per hectare did influence **Empoasca** populations per plant.

Spidermites

Spidermites attacked the beans in the dry periods of February and June, especially older plants. Two varieties, Eskaseher and Blue Lake, were introduced because of their reported resistance to spidermites. From about 1,500 lines tested during the June outbreak, 177 lines were selected for resistance and further testing.

Another species of mite **Polyphagotarsonemus (= Tarsonemus) latus,** (Fam. Tarsonemidae) observed on beans turn the underside of the upper leaves a purplish-brown, and these leaves are narrow with curled margins. It is also a pest of cotton, castor bean, papaya, etc.

Chrysomelids

The **Chrysomelid** population, mainly **Diabrotica balteata** and **Ceratoma** sp., fluctuated over the year without distinct population peaks. The population was heaviest on 30-50 day old plants. As the population on young plants remained about constant until one month after planting (Figure 9), most damage occurs directly after germination. No pod damage was observed.

Insecticide trials

As a short term solution to insect control, various insecticides were tested in wet and dry season trials. The wet season trial was planted in March. Three applications of insecticides were made: one at planting (cutworm control) and two at monthly intervals. No cutworm damage was observed, and **Empoasca** was the most important insect pest. Highest yields were obtained following treatments with Diostop, Lebaycid and Methilparathion. However, the leafhopper populations were not the lowest for these treatments. The lowest population was obtained following furadan treatments, but seed yield was comparatively low. Foliar applications resulted in higher yields than the systemic insecticides applied in the soil.

The second trial was planted in the dry season. Four applications were made: one at planting time, one at 14 days for the foliar insecticide, and 30 and 60 days after planting for both foliar and systemic soil applied insecticides.

In this second trial, Tamaron, Diostop, Lebaycid, Fundal and Azodrin treat-

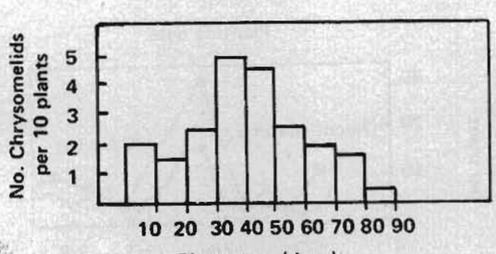


Figure 9. **Average number of Chrysomelids (mainly** Diabrotica balteata**) at different plant ages; average of 21 plantings of variety Calima**

ments gave the highest bean yields. There was a negative correlation between bean yield and **Empoasca** populations, except for the product Fundal. Systemic insecticides applied in the soil gave lower bean yields than those foliar applied. Applications of Tamaron and Azodrin retarded the harvest date by about two weeks. Future trials will emphasize times and rates of application of Diostop, Lebaycid, Bidrin and Sevin, all of which are less toxic foliar insecticides than Tamaron and Azodrin. Also the systemic soil applied insecticides will be further evaluated.

Forms of Furadan applications

Systemic soil applied insecticides are considered a relatively safe form of insect control. As bean yields after soil applied insecticides were below those of foliar applied insecticides, studies were carried out to improve the efficiency of Furadan, an insecticide commercially available. Applications of 30 kg/ha at planting and 30 days thereafter were made by broadcasting and incorporation of the insecticide in the soil, or by applying a band along the plants, then covered by soil. Band applications resulted in increased yields, but results were not significantly different because of plot variability and salinity.

Furadan coated seed is the easiest form of chemical insect control. Seed of Calima was coated with Furadan wettable powder (75%) at 800 g a.i./ha. A control and a treatment of 30 kg per ha (3%) applied in the soil at planting time were included. Seed coating with Furadan resulted in poor germination. Cutworm control by this systemic soil insecticide appeared ineffective. Because of low germination no yield data were taken.

Furadan, a carbamate insecticide, decomposes more rapidly in alkaline soils than in acid soils, therefore more frequent applications are needed under high pH conditions. To increase the effect of Furadan, triple super-phosphate was applied at 15 kg P_2O_5 per ha. Furadan was applied as band application or coated on the bean seed. The phosphate did not increase bean yields, either with or without Furadan nor did it increase the effectivity of the insecticide. Furadan applied as a seed coating resulted in the highest yield per plant. This was also because of reduced competition, a result of the low germination. The yields per hectare were extremely low because of soil conditions. The experiment is continuing with sulfur applications, which in pot experiments substantially reduced the soil pH.

Varietal resistance and Chemical control

Resistance to **Empoasca kraemeri** in ICA-Tui is not high enough to eliminate the use of insecticides in the dry season. With two applications of 25 kg Furadan 3 per cent per hectare (at planting time and 30 days later) the following yields were obtained with Tui, Jamapa and Calima.

	Yield (gr per 10 m row under treatment)	
Variety	Control	Two applications of Furadan
Tui	715	1549
Jamapa	307	956
Calima	72	819

With two applications of Furadan, Calima yielded as much as Tui without insecticide protection. However, the yield of Tui was almost doubled under this protection. The **Empoasca** population (Figure 10), both for Tui and Calima, were higher under Furadan protection than under the control, because of increased plant vigor. The population on Tui without insecticidal protection was about double that on Calima with treatment.

In view of Tui's higher **Empoasca** resistance it was thought that the

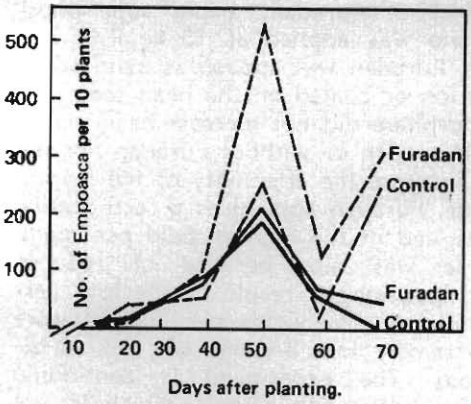


Figure 10. Empoasca **populations (per 10 plants) in two bean varieties**

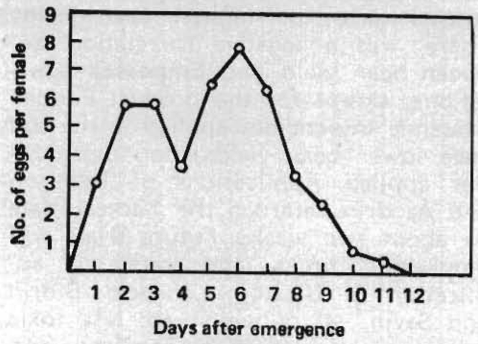


Figure 11. **Oviposition curve of** Zabrotes subfasciatus.

frequency of Furadan application (3% granular, 25 kg/ha) could be lower on Tui than on Calima. Therefore, Furadan was applied at planting and repeated at 20 or 40 day intervals on Tui and Calima. Although the **Empoasca** population was related to the frequency of insecticide applications, the yields were not. Plants produced so much foliage that lodging impared accurate interpretation, especially for Tui. Also applications every 40 days in the rainy season apparently were sufficient for Calima.

Stored Bean Insects

The most important pest of stored beans is **Zabrotes subfasciatus.** Adults lay eggs on the seeds and cover these with a protective cover. Eggs are laid rapidly after emergence up till nine days, with an average of about 46/female (Figure 11).

Control is sought by screening for resistance, chemical and non-chemical methods. To develop a screening method for resistance, five females and five males were placed on 25 or 50 seeds of Tui and Calima in five replications. However, equal numbers of eggs and adults emerged, indicating that five males and five females per 25 seeds per replicate were sufficient, although the percentage of eggs that develoced into adults was only 29 per cent (Table 6).

Of 46 varieties tested the number of eggs per replicate varied from 63.6 to 251.2, with a mean of 143.0, in Calima (125.4 eggs) and Tui (149.8 eggs). There was a significant negative correlation (r = -0.62) between numbers

Table 6. **Number of eggs and subsequent adults on 25 or 50 seeds of Tui or Calima, infested with five female and five male** Zabrotes subfasciatus **(avg. of five replications)**

Variety	Per rep.	Avg. No. eggs per repl. and per fem.	Avg. No. emerged adult per replication	% of eggs resulting in adults
Calima	25	42.6	12.4	29.1
	50	38.9	11.2	28.8
Tui	25	36.5	10.6	29.0
	50	46.2	14.4	29.3

Table 7. **Strain effectiveness trials in Phaseolus vulgaris, 1972-1973**

	Dry weight/ plant	Nodule weight/ plant
	(g)	(mg)
Best 10 strains	1.76	127.9
Worst 10 strains	0.91	88.9

of eggs and percentage of eggs which resulted in adult emergence.

Small samples of beans can be preserved by storage at below 0°C temperatures. Seed of Calima stored at -15°C for 0, 1, 3 and 10 days germinated at 87, 96, 89 and 99 per cent, respectively. The influence of the seed storage conditions (temp. about 5°C) is currently being tested on adults, eggs, larvae and pupae of **Zabrotes.** The adult longevity is increased by a few days' storage at 5°C, but with 15 days' storage mortality is equal compared with days in the coldroom. **Zabrotes subfasciatus** is also used as a bioassay for detecting insecticidal residues in beans.

MICROBIOLOGY

Nodulation and nitrogen fixation by legumes is dependent on either natural or introduced inoculum and the nitrogen status of the soil. Initial work at CIAT has concentrated on collection and evaluation of a range of **Rhizobium**

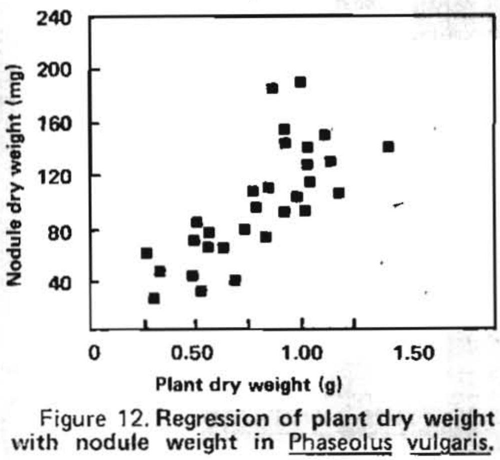


Figure 12. **Regression of plant dry weight with nodule weight in Phaseolus vulgaris.**

strains across varieties of beans, for potential use as inoculants. Soil, climatic and other factors which affect nodulation in beans have been evaluated, as well as nodule pattern in different types of root systems in **P. vulgaris.**

Strain Isolation and Testing

Initial testing of 110 rhizobial isolates from **P. vulgaris** was completed in 1973. Leonard jars containing perlite were used with the variety ICA-Tui as host plant. Strain differences in plant and nodule dry weight are shown in Table 7. As expected, there was a strong positive correlation between nodule dry weight and plant dry weight (Figure 12). Twenty-five of the more effective strains were retested using, additional varieties, including Gualí, Cargamanto and Duva. Further differences in strain effectiveness were noted (Table 8), as well as marked strain by variety interactions (Table 9). Strain specificity will have to be considered in future varietal selections. To date, 10 strains have been selected as efficient with a range of cultivars, and are being tested under field conditions in Popayán and Medellín.

Thirty-one rhizobial strains from **Glycine max** have also been screened for symbiotic effectiveness, and strain by variety interactions are evident (Table 10).

Factors affecting Nodulation of Phaseolus vulgaris

Soil acidity

Many tropical soils contain virtually no rhizobia able to nodulate **Phaseolus vulgaris,** and thus plants depend on inoculation for nodule formation. In acid soils, such as those of the Eastern Llanos, inoculated rhizobia die rapidly as shown in Figure 13. To minimize this effect, peat-inoculant cultures and lime-pelleted seeds must be used. The methods proven for plants such as clover

Table 8. **Difference in plant dry weight (grams) as a result of inoculation with assorted Rhizobium strains in Phaseolus vulgaris var. Gualí**

139	=	2.29
145	=	2.19
148	=	2.06
134	=	1.97
95	=	1.96
114	=	1.96
129	=	1.95
113	=	1.91
122	=	1.90
143	=	1.88
125	=	1.88
252	=	1.83
257	=	1.83
251	=	1.78
123	=	1.78
350	=	1.73
161	=	1.69
147	=	1.64
160	=	1.59
255	=	1.54
115	=	1.51
119	=	1.35
T	=	1.38

Treatments joined by the same bar are not significantly different at the .01% level

Table 9. **Response of two varieties of P. vulgaris to inoculation**

(Ranking based on dry weight data)

Strain	Var. Gualí	Var. Cargamanto
139	1	12
145	2	5
148	3	6
134	4	9
95	5	7
114	6	4
129	7	10
113	8	8
122	9	11
143	10	3
160	11	2
255	12	1

and lucerne (Beef Program), have also been satisfactory for bean nodulation. There is increasing evidence, however, of varietal and strain tolerance to these acid conditions. An example is shown in Figure 14. Because of the obvious importance of these differences, this aspect of the program will be strengthened further in 1974.

Temperature

Studies in temperature-controlled growth beds during 1973 have shown an optimum temperature for nodulation in most varieties between 28 and

Table 10. **Influence of soybean variety and Rhizobium strain on dry matter production (grams/plant) in soybean ***

Variety	No inoculant	Strain 1	3	4	51	90	Variety Sub-totals
Mandarin	11.9	19.93	17.72	20.32	15.31	16.11	101.29
Pelikan	11.7	18.03	21.3	18.69	12.99	22.06	104.78
Americana	16.89	18.80	18.96	20.26	14.31	20.68	109.90
Lili	9.04	16.49	18.97	25.81	27.02	15.70	113.03
Strain sub-totals	49.53	73.25	76.96	85.08	69.63	74.55	

* Average of 20 plants

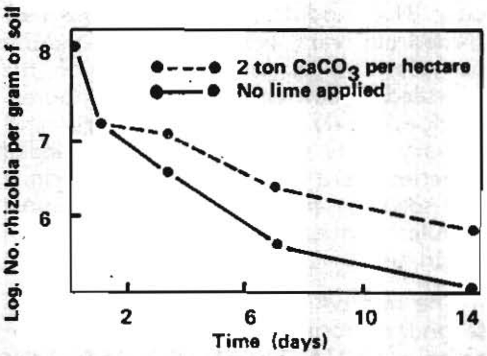


Figure 13. **Influence of soil condition on survival of R. phaseoli strain 57 in Carimagua soil.**

32°C. Because soil temperatures in the Cauca Valley commonly exceed this level, a preliminary experiment evaluated whether increasing inoculation levels might be of value. The results demonstrate a need for high quality inoculants and/or increased inoculation level. The ability of the strain CIAT 57 to form fewer but larger nodules (Annual Report, 1972) was again evident here.

Fungicide and Insecticide influence

There is considerable evidence to suggest that most soil applied insecticides, herbicides and fungicides do not inhibit nodulation in **Phaseolus vulgaris.** However, there are two areas where pesticide application harms nodulation.

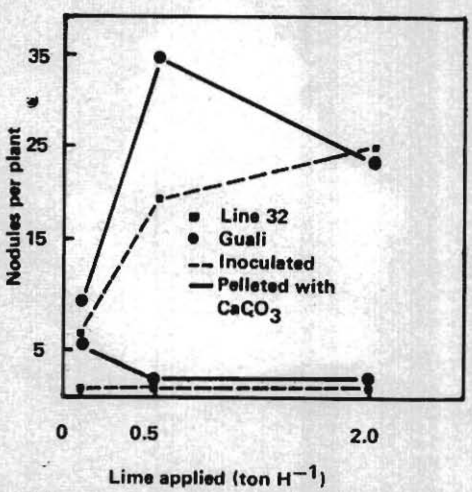


Figure 14. **Influence of lime amendment, variety and inoculation on nodule number per plant in Carimagua soil.**

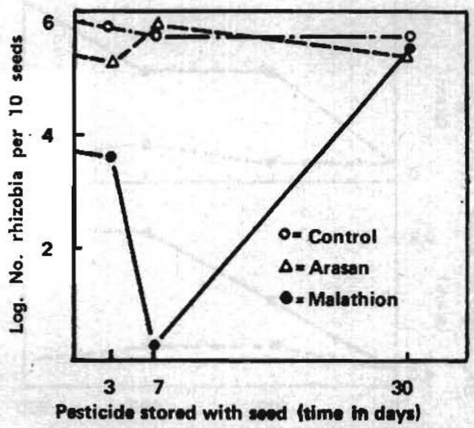


Figure 15. **Survival of** R. phaseoli **CIAT 57 when applied to seeds stored various periods in contact with pesticides;** Rhizobium **counts made 3 hours after inoculation of treated seed**

1. Much of the bean and soybean seed sown in Colombia is pretreated with insecticide and fungicide before planting. Malathion and Arasan are the most common pesticides used in this process, and each can limit the survival of inoculated root-nodule bacteria, as shown in Figure 15.

2. Systemic insecticides or fungicides, for example Furadan could accumulate in plant tissues to the point where nodule development was inhibited. This aspect is being investigated in collaboration with the entomologist, preliminary results indicating no depressive effect on nodulation.

Nutrition Studies with Phaseolus vulgaris

Field nodulation studies begun at Popayán in 1973 were plagued with nutritional problems afecting both plant growth and nitrogen fixation. Foliat

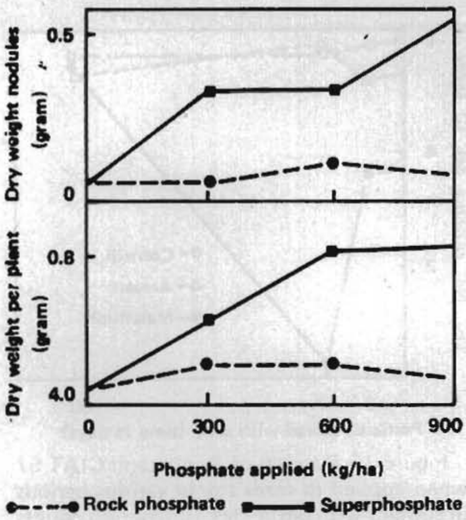


Figure 16. **Influence of form and level of phosphate on bean development in Popayán soils**

analysis of plants receiving almost two tons of rock phosphate per hectare showed only 0.18 per cent P.

Unfertilized plants were also limited in zinc, copper, boron and magnesium. To resolve these problems in soils high in organic matter, studies have begun on the effect of source, quantity and placement of phosphorus and copper on growth, nodulation and nitrogen fixation in beans. Figure 16 shows plant growth and nodule development with superphosphate and rock phosphate applications. The need for available forms of phosphate is evident, further emphasizing the need for studies with endomycorrhizal fungus as suggested on page 18 (Beef section).

Studies on the characteristics of nodulation in *Phaseolus vulgaris*

Studies were continued in 1973 on the differences in nodulation among ***P. vulgaris*** cultivars (see Annual Report, 1972). Most evident is the difference in nodule number per plant. Where the black-seeded varieties (Tui, Line 32 and Huasanó) tested averaged only 31.8 nodules per plant, the red-seeded cultivars averaged 69.7 nodules per plant. Also while nodules of the red-seeded cultivars were distributed predominantly on the secondary and tertiary roots those of the black-seeded varieties were more of tap root origin. Red-seeded cultivars produced most nodule tissue/plant, independent of strain used.

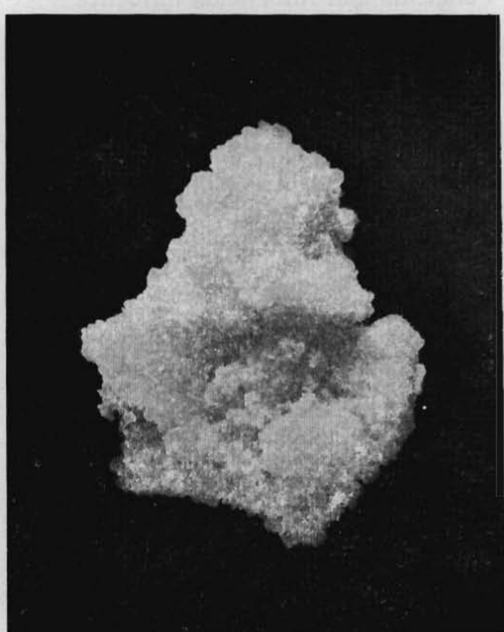
The relative efficiency of tap root **vs.** secondary root nodules will be investigated in 1974, but it is already clear that nodule architecture will need to be considered in the bean breeding program.

Tissue Culture of Phaseolus vulgaris

Callus cultures have been developed of a range of bean cultivars and will be available for virus and physiological studies (see photo on this page).

ECONOMICS

The year was dedicated to collection and summary of existing data on bean



Callus culture of *Phaseolus vulgaris* **cultivar**

production, productivity, foreign trade, and consumption in the tropics by region, country, and continent, to gain perspective on the current situation in beans and establish a statistical base.

The role of the economics group within the program has been defined, and interaction with other groups in the program has been initiated. An economic model has been outlined for

Table 11. **Principal countries producing dry beans in Latin America; annual production in tons during five periods**

Country	1951-54	1955-58	1959-62	1963-66	1967-70
Guatemala					
Tons	25,333	25,250	31,250	41,000	65,500
%	1.23	1.08	1.14	1.18	1.62
Honduras					
Tons	18,250	26,000	34,750	48,000	55,000
%	0.88	1.12	1.27	1.38	1.36
Nicaragua					
Tons	31,000	26,500	32,250	34,750	42,500
%	1.50	1.14	1.19	1.00	1.05
México					
Tons	307,000	400,250	576,000	857,250	1,059,750
%	15.00	17.26	21.17	24.79	26.25
Brazil					
Tons	1,388,500	1,500,250	1,663,250	2,082,750	2,406,250
%	67.45	64.69	61.15	60.23	59.61
Colombia					
Tons	51,750	62,750	46,750	40,250	45,000
%	2.51	2.70	1.71	1.16	1.11
Perú					
Tons	22,750	25,000	39,750	51,000	66,750
%	1.10	1.07	1.46	1.47	1.65
Sub-total					
Tons	1,844,583	2,066,000	2,424,000	3,155,000	3,740,750
%	89.67	89.06	89.09	91.21	92.65
Other countries					
Tons	213,917	252,916	295,667	302,500	295,750
%	10.33	10.94	10.91	8.79	7.35
Total					
Tons	2,058,500	2,318,916	2,719,667	3,457,500	4,036,500
%	100.00	100.00	100.00	100.00	100.00

Source: Derived from FAO Year Book

the Colombian bean sector that will predict the effect of changes (eg. agricultural technology) on: (1) demand for labor and other inputs, (2) producer incomes, (3) producer and consumer nutrition, and (4) distribution of benefits from new technology. This model is expected to identify the limiting factors in this sector, and draw attention to those variables for which additional information is required.

Collection of Basic Data

A literature review is under way which will identify and assemble all relevant references on economic studies on beans in Latin America. Basic statistics such as annual production, area sown, yields, consumption and prices are being tabulated for each country. As an example, Table 11 shows the production in the principal bean-producing countries in Latin America from 1951 to 1970. Seven countries produce 90 per cent of all the beans in Latin America; and Brazil and Mexico alone produce more than 80 per cent of the total. All countries except Colombia increased bean production during this time, some up to a threefold increase.

Bean yields per hectare

One of the causes of relatively slow increases in production is yield per hectare. Table 12 lists average yields from 1951 to 1970 in principal producing countries, and illustrates little increase in yields over about 500 kg/ha in most of the major producing countries. Since Brazil and Mexico are the main producers, any increase in their productivity results in a considerable total increase.

Bean prices in Latin America

The market in beans is dynamic, and the current price at any moment is influenced by a great diversity of variables which affect both consumers and producers. In 1969, prices to the producer varied from US$ 120/ton in Brazil to US$ 341/ton in Colombia, with an average price of US$ 133 for South America. This price in Colombia was extremely high, relative to other countries. Within Colombia, wholesaler prices in 1972 varied from (Col. Pesos) $ 9.62/lb for Guarzo, to (Col. Pesos) $ 16.01/lb for Sangretoro, a preferred variety.

Imports and exports in Latin America

A potentially important influence on economic aspects, is the international market. Data are being compiled for the past 15 years on annual imports into and exports from each country, to establish which countries have an important segment of the bean sector involved in foreign trade.

Table 12. **Bean yields (kg/ha) in principal producing countries in Latin America**

Country	1951-54	1955-58	1959-62	1963-66	1967-70
Guatemala	747	660	597	620	625
Honduras	390	430	440	512	457
Nicaragua	800 (?)	540	590	722	705
México	300	327	400	422	535
Brazil	520	682	665	655	645
Colombia	547	492	505	555	560
Perú	915	875	972	920	1,020

Source: Derived from FAO Year Book

Costs of production in several countries

Principally due to ecological factors, infrastructure, level of technology and availability of inputs, there is a variation among countries in use of inputs and total production costs. In one case, the Cauca Valley of Colombia (1972) reported yields of 1900 kg/ha with a production cost of US$ 0.11 per kilo and 50 days hand labor (mechanized culture). In comparison, the dry Pacific coast of Costa Rica (1972) produced 500 kg/ha at a cost of US$ 0.21 and 25 days hand labor (also mechanized). These data are important in determining which levels of technology are most economical and which regions are most favorable for bean production. Other indicators which are being summarized include:

1. **Physical factors** - production/day of labor, production/unit land area, production/unit capital invested.

2. **Economic factors** - gross and net income, cost/benefit relations, productivity of capital, productivity and profit/unit labor.

Bean consumption

A complete report is being prepared on the importance of beans in world nutrition, with emphasis in Latin America and in pre-school children. Results from this study indicate a great disparity between prices of protein from dry beans (US$ 0.67/kg) and beef (US$ 19.14/kg) in South America. The difference is greater in some countries, as in Brazil for beans (US$ 0.60/kg) **vs.** beef (US$ 26.04/kg). Differences in protein quality (amino acid distribution) between these sources reduce the price differential, but there is a potential for partial substitution if consumer preferences can be modified.

The percentage of total protein consumption which comes from beans varies among countries in Latin America, from a high in Brazil of 23 per cent to a low in Perú of 5 per cent and in Colombia of 2 per cent. There is an unequal distribution of food within countries and specifically within families in the protein consumed by adults versus children, and also among regions and among families. The income elasticity of demand for beans in Brazil is zero, while in Colombia the coefficient is a positive 0.55; with price as a constant, an increase in income will not result in increased consumption in Brazil, while the same change in income in Colombia will increase consumption slightly. When bean consumption in Colombia was compared among families at different income levels, there was a non-significant increase from 27 to 36 grams/day in the range of the groups studied. In the same study in Cali, however, an increase in availability and reduction in price did increase bean consumption in lower income groups.

Model of Bean Production, Marketing and Consumption

The central focus of the economics group is to develop a realistic model which describes the bean sector of Latin American countries. The objective is to estimate the impact of a technological change on producer and consumer income, producer and consumer nutrition, and the use of labor in farms producing beans. For example, there is currently no adequate response to such a question as, "If bean yields are increased by 50 per cent, will this improve the income and nutrition of farm families?". The principal focus which the program is seeking is whether a given change in technology will directly benefit the producer, especially the subsistence farmer, and improve consumers' diets. In Figure 17, a preliminary scheme is presented which relates the key variables of interest. It is necessary to consider the farm an integral and real unit, and also consider the effects on this unit of any technological change.

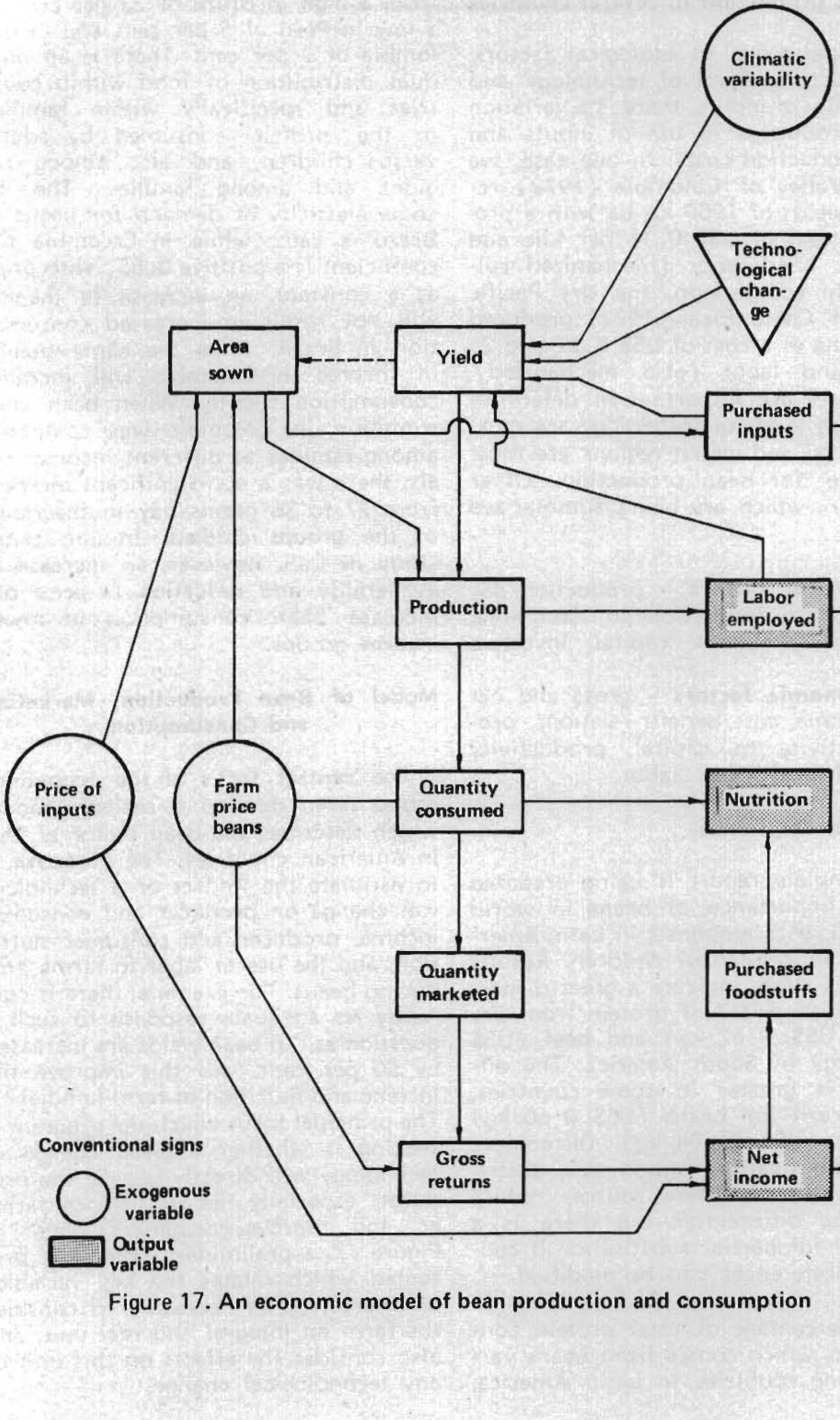


Figure 17. An economic model of bean production and consumption

Table 13. **Example of the effects of technological change on nutrition, income and employment at the family level, monoculture beans**

	Present technology (T_1)	New technology (T_2)	Change (T_2-T_1)
Yield (kg/ha)	580	900	320
Nutrition:			
Protein (gms/day/person)	47.62	63.63	13.01
Calories (cal/day/person)	2054	2244	190
Family income (Colombian pesos/year)	9,975	36,829	26,854
Employment (man days/year)	390	546	156

To indicate the potential results of this type of model, some calculations were made, based on the following principal assumptions:

1. The farm is the experimental unit.
2. Price levels are constant for inputs and outputs.
3. The cropping system is monoculture beans.
4. The only change introduced is a higher yielding bean variety.

The hypothetical results from the model are given in Table 13, which shows the implications of the change in yields. The increased yield of 320 kg/ha, would require a 40 per cent increase in labor, but would produce a 34 per cent increase in protein available per capita, a 9 per cent increase in calories, and a 269 per cent increase in family income.

Elasticity of Supply of Beans and Other Traditional Crops

Crops included in this study are beans, maize, sugar cane, barley, potato, banana, wheat, cassava, coffee and cotton. These crops were selected due to their competition for resources such as labor, land, capital, etc. with the bean crop. The objective is to determine the effects of changes in prices of these competitive crops on supply of beans. The study is necessary in order to understand the impact of technological change on nutrition, income, and employment at the farm level. It is essential to predict variations in production level of all crops on the prices which the farmer will receive. This study will reveal how the change in supply of the several crops will modify prices of beans. Variations in prices and yields have also been included to reflect risks facing the farmer. Data have been collected for Colombia, and are currently being processed.

TRAINING

The emphasis on training in the bean program is reflected in the number of trainees considered in 1973. Four research interns from Ecuador, Guatemala and USA, and one research fellow from England received training in bean breeding. Three research interns worked in weed control, with part of the time dedicated to training in beans. Additional trainees included one from Ecuador in plant pathology, one from Guatemala in soil microbiology, and one from Colombia in agricultural economics. A research fellow from Justus Liebig University in Germany initiated training and research in field beans as part of his Ph.D. thesis requirement. The trainees in the Crop and Seed Production Specialists Courses also received training in bean production.

INTERNATIONAL ACTIVITIES

The real results and benefits of CIAT's research and development are expressed through advances made by national research teams and their contributions to farmers in their respective countries. Thus, the international focus of the program and importance of the collaboration with other agencies is evident. The following specific activities are designed to give maximum contact of the CIAT program with others in Latin America, and these provide the basis for our potential effectiveness and impact.

1. **Program organization and evaluation** have been requested by several national programs, and this is a high priority among the other activities. This is particularly important when a new program is being organized and priorities established.

2. **Training** is central to international collaboration, and considerable time and energy is dedicated to the young scientists who spend from three months to one year in the CIAT program. These researchers are the future of their respective national programs, and a close working relationship with them will strengthen CIAT's capability to efficiently exchange germplasm and ideas, and to conduct cooperative projects. During the first year of activities, 10 young scientists have been trained in Bean Production Systems. At least 15 trainees are expected in 1974.

3. **Annual workshops** for field research people have been proven valuable as an activity which promotes both individual and group interaction.

4. **Special topic workshops** planned for the next three years will emphasize the importance of an integrated team approach to research, as well as specific topics of importance.

5. **The publication of an informal newsletter** with details on available publications, meetings, personnel currently working in national programs, and research abstracts is an effective way to maintain communication among researchers between the annual workshops.

6. The **germplasm bank** in CIAT will be catalogued, and an up-to-date description of seed availability and agronomic data provided each year. Within about one year, a catalog of improved selections and advanced generations of crosses will supplement the one on original collections. Seed of either bean collections or improved lines will be available to national universities, and other interested groups.

7. **An abstracting service** in both English and Spanish will be provided to bean research workers and libraries in the zone. This will supplement the bibliographical service already available from Turrialba.

8. **International travel** of the CIAT core team, organized into working groups in early 1973, has included the major bean programs in Latin America and the Caribbean zone, and established working collaboration with many of them. These initial contacts included 74 visits to some 15 countries, and some projections on collaborative work in 10 additional countries.

Maize production systems

The Maize Program cooperates with national research programs in the Andean zone (Venezuela, Colombia, Ecuador, Perú and Bolivia) to resolve the most serious factors continuing to limit yields. These factors include excessive height, low plant populations in the field, losses to prevalent insect pests (especially **Spodoptera frugiperda** and **Diatraea saccharalis**), specific soil and management problems, narrow adaptation of commercial hybrids, and non-availability of improved seed and other inputs in much of the zone.

The development of realistic production "packages" or systems for the small farmer is particularly crucial for improved nutrition of his family. Maize is only one component of a farming system which usually includes field beans and other crops in mixture. This implies a complexity of questions to answer before defining the eventual farming system or systems for a zone, including appropriate crop mixtures, dates of planting, fertilization and weed control practices, as well as the complex dietary mix when these crops are harvested and consumed on the farm.

The Maize Program is one link in an international network of national, regional and international centers under the general coordination of CIMMYT (International Center for Maize and Wheat Improvement) in Mexico. As the Andean zone representative in this network, CIAT works with national agencies to test new introductions from CIMMYT, and organizes regional activities such as annual meetings, special topic workshops, uniform trials, publication of a newsletter, and distribution of new germplasm through progeny selections.

AGRONOMY

Research in agronomy emphasized cultural practices, solutions to specific soils problems, and international trials of germplasm. This work was concentrated on the CIAT Palmira farm, although several trials planted in mixtures with beans were located in other stations. These are described under the Bean Production Systems section of the report.

International trials

During the year 1973, nine trials were harvested in the first season (1972B) and four in the second season (1973A). Results are summarized in Table 1, where the average yield for the trials is presented along with the yield of the best entry. These trials included CIMMYT international uniform tests (IMAN, IOMT), CIMMYT progeny trials (CPBB, CFSB), PCCMCA trials from Central America (BA, ME, OP), and the CIAT regional uniform trials (ENZAS and ENZAT).

The lowest yields in these trials were observed in the opaque-2 tests (IOMT and PCCMCA-OP), and in one trial more adapted to highland regions (ENZAS), but grown in CIAT to test range of adaptation in these varieties. Most promising yields were found in trials of present commercial maize hybrids and the experimental materials from PCCMCA

Table 1. **Results of international trials planted at CIAT, 1972B and 1973A**

Trial	Name	Number varieties	Number reps	Avg. yield (kg/ha)	Best entry	Yield (kg/ha)	Source of best entry
CIAT 1972B							
72B-86	IMAN (CIMMYT)	50	2	1,428	Pioneer X-324	5,168	Pioneer (Jamaica)
72B-87	BA (PCCMCA)	31	4	3,292	Pioneer X-304A	4,612	Pioneer (Jamaica)
72B-88	ME (PCCMCA)	30	4	3,918	DeKalb Exp-4	6,223	DeKalb
72B-89	ENZAT (CIAT)	37	4	2,870	HFM-7	5,250	Venezuela
72B-90	ENZAS (CIAT)	15	4	1,359	ICA H-207	4,779	Colombia
72B-93	IOMT (CIMMYT)	30	3	2,563	ICA H-207	4,706	Colombia
72B-99	OP (PCCMCA)	10	4	2,831	CIMMYT O_2 Comp	3,529	CIMMYT (Mexico)
72B-113	CPBB (CIMMYT)	49	4	3,564	Eto P.B. x Tux.P.B.	5,472	CIMMYT (Mexico)
72B-114	CFSB (CIMMYT)	60	4	2,207	C.Carib. x Eto Bl.	3,028	CIMMYT (Mexico)
CIAT 1973A							
73A-34	IOMT (CIMMYT)	30	4	287	ICA H-255	1,555	Colombia
73A-35	OP (PCCMCA)	10	4	1,136	ICA H-255	2,445	Colombia
73A-36	ME (PCCMCA)	30	4	3,254	DeKalb Exp. 4	5,556	DeKalb
73A-37	CPBB	49	4	2,650	Tuxp. Comp. x Eto	4,278	CIMMYT (Mexico)

Field at CIAT in which the world composite lines from the variable source populations from CIMMYT are being planted

and CIMMYT. In several trials, an introduced hybrid or selection produced more than locally developed double cross checks, indicating a potential for further advances in the Cauca Valley environment. Those specific materials which perform well in the Andean zone will be studied in detail, and the lines for open pedigree hybrids obtained for recombination in the elite populations under development in CIAT for use in the zone.

Soil fertility - microelements

Soil fertility and grain quality

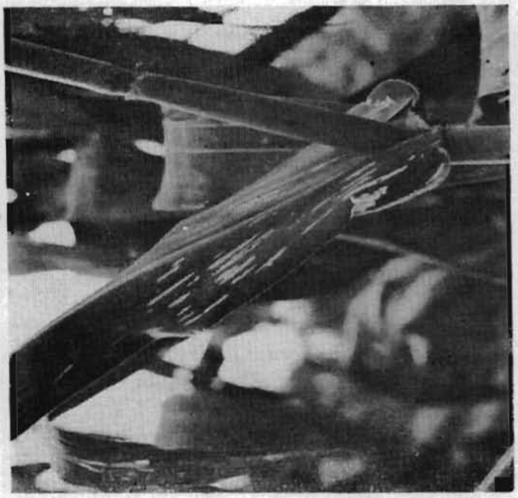
A trial was planted in late 1972 to evaluate the effects of zinc and boron with NPK in an apparently deficient soil on the CIAT farm. The opaque-2 double cross hybrid H-208 was planted on raised beds and thinned to 36,000 plants/ha. There were no significant differences in this trial among the treatments in grain yield, nor in levels of major elements in the grain. The indicators of protein quality, N and tryptophane, also showed no differences.

In the second season of a long-term study of the effects of gypsum on maize and other row crops, an evaluation was made of Ca content in the grain. In treatments from 0 to 40 tons of gypsum per hectare, there were no differences in content of Ca in the grain. The highest absolute value was found in the untreated check, with .0097 per cent Ca. In another trial, grain samples from unfertilized plots were compared to samples from plots treated with N, P_2O_5, K_2O, Zn, B and Fe. Although N content was slightly higher in the fertilized plots, there was no significant difference in grain content of N, P, K, Mg, Zn, or tryptophane. These results suggest that there is little or no effect of fertilizer treatments on grain quality in maize grown on the soils in CIAT.

Plants in the right plot were fertilized with NPK and 5 tons of gypsum showing a marked advantage over the plants in the left plot which received only gypsum

Maize response to boron and zinc

To evaluate further the effects of microelements on maize yield, a factorial design with four levels of B (0, 2, 4 and 6 kg/ha) and three levels of Zn (0, 10, and 20 kg/ha) were used with the opaque-2 hybrid ICA H-208. The optimum levels of application appear to be 10 kg Zn/ha and 2 kg B/ha. There is no large benefit in applying both elements in higher doses. The residual effects of these soil treatments were tested with the bean variety ICA-Gualí, and the results are included in the Bean Program section of this report.



Boron deficiency appears on maize leaves as longitudinal white stripes near the base

Plants from an additional greenhouse trial with six levels of B (0, 1, 2, 3, 5, 10 kg/ha) and four maize genotypes (H-207, H-208, H-255, and Tuxpeño) were analyzed for foliar content of B. This level varied in a straight line relationship from about 5 ppm with no B applied, to 45-55 ppm with 10 kg/ha of B. Deficiency symptoms disappeared with applications of 3 kg B/ha, and a slight toxicity was indicated by a burning on the margins of the leaves at 10 kg/ha. Deficiency symptoms appeared when the maize reached 30 cm of height, with Tuxpeño the most sensitive and H-255 the least sensitive among the four strains tested.

Barren or unfilled ears result from maize planted on boron deficient soils

Agronomic practices

Planting systems

A comparison among three planting systems —single beds, double beds, and flat planting without beds —showed a definite advantage for the systems with prepared rows and raised ridges. Yields in single beds (4,174 kg/ha) and double-row beds (4,093) kg/ha) were significantly higher than the flat planting (2,696 kg/ha). Ease of uniform irrigation during dry periods and rapid surface drainage after excessive rains are probably the major advantages of this bedding practice.

Residue management

A minimum tillage scheme in CIAT compares the effects of four residue management treatments in maize over several seasons to test the long-term impact on yields and soil characteristics. The treatments include: 1) burning residue, 2) cutting stalks in place, 3) bending two rows of stalks and combining these into one windrow between the two rows (leaving alternate middles open), and 4) complete removal of the stover. Yield results from the two seasons harvested to date are shown in Table 2. There was no signif-

Table 2. **Yields in residue management and minimum tillage trial in maize**

	Yield (kg/ha)		
Treatment	1973A	1973B	Average
Burning residue	4,018	4,275	4.146
Cutting in place	3,917	4.336	4,126
Combining two rows	3,710	4,352	4,031
Complete removal	4,025	4,071	4,048
Average yield	3,918	4,258	4,088

icant difference among the four treatments in either season, and thus the simplest or cheapest treatment would be the most indicated for a cropping system. This field, now in its fourth continuous crop of maize after a single land preparation two years ago, demonstrates a tremendous potential for continuos cropping and minimum tillage in the Cauca Valley. The savings in time (2-3 weeks) and preparation costs (about 25 per cent of total production cost) make this alternative a valuable possibility for either the commercial or small-scale farmer.

Minimum tillage

A comparison of traditional land preparation with systems which minimize land tillage prior to planting has shown no conclusive differences between treatments in the first seasons of the test. Treatments include: 1) traditional tillage - one disking, one plowing, one disking, bed formation and planting, 2) one disking followed by bed forming, 3) ridging or bed forming only, and 4) direct planting on beds from previous season. Yields in the trial averaged just over 3 ton/ha, with no differences among the four tillage treatments.

Yield trials are planted by hand with jab planters, a tool which some commercial farmers now use for late replanting in skips in the field

Selecting superior materials at harvest

PLANT IMPROVEMENT

The breeding program has continued to concentrate on three principal objectives: reducing plant height, widening the zone of adaptation of source populations for producing commercial maize varieties or hybrids, and improving protein quality.

In cooperative trials with ICA-Colombia in two locations (La Selva and Turipaná) and INIAP-Ecuador in two locations (Boliche and Pichilingue), maize selections have been tested over the past two years and put together into composite populations. These basic populations and progeny have had a limited distribution among national and commercial breeding programs in the zone. Improvement of protein quality has concentrated on hard endosperm selections, through selection and increase of a CIMMYT population and development of brachytic materials to combine the short plant characteristic with opaque-2 quality and an aceptable endosperm type.

Reduced plant height and wider adaptation

Excessive plant height in tropical maize hybrids and varieties make these materials extremely susceptible to lodging, especially in areas with high rainfall and strong winds. These tall types also store a disproportionate fraction of their total dry matter production in vegetative organs such as leaves and stalk, further reducing grain yield potential. Additional advantages of shorter plant types include the potential for higher plant populations and increased fertilizer use, without the complication of greater stimulation of vegetative growth.

Wider adaptation of commercial hybrids or varieties is critical in a region where large and climatically uniform maize zones are scarce, and there are many microclimates typical of inter-Andean valleys and coastal plains which vary in temperature, soil type, solar energy, and moisture available for the crop. The complexities of producing quality seed preclude the development of a specific hybrid or synthetic for each climatic niche, and essentially dictate that commercial materials must be adapted to as wide a zone as possible. The critical needs of the small farmer in terms of improved germplasm with increased yield potential (and improved protein quality) will probably never be met with specific hybrids which are narrowly adapted to the fertile commercially farmed valleys.

The breeding system used to reduce plant height and increase range of adaptation, described in detail in CIAT 1972 Annual Report, consists of generation of full-sib progeny in the Palmira location followed by testing in several additional locations. Final progeny selections for the next cycle are based on results from several locations, not on the Palmira data alone. Basic germplasm for the program was obtained from CIMMYT in Mexico, with some

Severe lodging in Andean Zone maize is due to excessive plant height and stalk borer damage

Sacks that contain selected ears from short maize types. This material will be evaluated for ear rot resistance and the composite sample planted in a future cycle of recombination and further selection

Table 3. **Progeny trials for wide adaptation in four location, 1972A, showing trial average yield ($\overline{X}$) and best progeny yield (MP) in tons/ha**

		Boliche		Turipaná		Palmira		La Selva	
Trial	Material *	$\overline{X}$	MP	$\overline{X}$	MP	X	MP	X	MP
E-72-21	br_2 Bl	3.4	4.3	2.8	6.8	5.6	9.0	2.0	4.8
E-72-22	br_2 Bl	3.2	4.8	3.4	5.6	6.1	8.6	2.9	6.4
E-72-23	br_2 Bl	2.6	4.2	4.2	5.6	5.7	8.6	1.4	4.6
E-72-24	br_2 Bl	3.3	4.9	3.8	5.8	5.6	9.9	3.0	5.5
E-72-25	br_2 Bl	2.6	4.7	2.9	5.8	6.0	8.9	1.4	4.7
E-72-26	br_2 Am	3.4	6.0	3.1	5.2	5.5	9.9	2.0	4.5
E-72-27	PB Bl	3.9	5.1	3.8	6.2	5.7	8.6	1.5	4.6
E-72-28	PB Bl	3.3	5.2	4.1	6.5	5.6	8.1	3.4	8.2

*br_2 refers to brachytic-2 populations, Bl to "Blanco" or white maize, Am to "Amarillo" or yellow maize, and PB to "Planta Baja" or short plant

additional materials incorporated from the Andean zone, Central America, and Asia.

Principal locations for these tests include:

Palmira, CIAT (Valle, Colombia): 1000 m elevation, 24°C Annual temperature
Turipaná, ICA (Montería, Colombia): 40 m elevation, 28°C Annual temperature
La Selva, ICA (Rionegro, Colombia): 2100 m elevation, 18°C Annual temperature
Boliche, INIAP (Guayaquil, Ecuador): 20 m elevation, 27°C Annual temperature
Pichilingue, INIAP (Quevedo, Ecuador): 30 m elevation, 27°C Annual temperature

In 1972A, yield data were obtained from Boliche, Turipaná, Palmira and La Selva, and the trial summaries appear in Table 3. Best yields were obtained in Palmira, where cultural conditions and supplemental irrigation were closer to optimum, in addition to the favorable temperature regime. Yields in the two coastal stations were lower, and the highland station had the lowest average yields because of the tropical source of most materials. Some progeny excelled in each trial in each location, indicating a genetic yield potential for this range of climates within the source material.

Based on yield, resistance to lodging, absence of ear rot and relative resistance to **Diatraea** sp., crosses were selected which had two favorable parent progeny, and these planted in CIAT in 1972B. The average yields and best progeny in the trials are summarized in Table 4. Crosses between the best

Table 4. **Brachytic and short plant yields (tons/ha) in CIAT, 1972B**

		Grain yield (tons/ha)	
Material	No. of trials	Range in trial means	Best progeny
Brachytic (white)	13	4.1 — 5.3	8.5
Brachytic (yellow)	9	4.9 — 5.4	9.3
Short plant (white)	9	2.7 — 4.7	7.9
Short plant (yellow)	2	5.3 — 5.6	8.1

among the progeny tested were selected for wide testing, and trials were planted in 1973 in Palmira (CIAT), Turipaná (ICA), and Pichilingue (INIAP). Yields of the progeny were slightly lower than in the previous cycle, probably because of less favorable growing conditions.

During the past year, seed of progeny were sent on request to several national programs and commercial companies. Composites of open-pollinated ears from highest yielding progeny rows have been formed, mixed, and used in semicommercial plantings on the CIAT farm. Yields similar to commercial double cross hybrids have been observed, with an advantage for harvesting the brachytic population due to less lodging. The principal limitations in these populations are susceptibility to **Spodoptera** sp. and lack of prolificacy; both characteristics are included as selection criteria in the current cycles.

Protein quality improvement

Selection for enhanced quality through use of the opaque-2 gene has concentrated on hard endosperm types for direct human consumption. Basic breeding material came from selections within the commercial opaque-2 hybrids, ICA H-208 (yellow) and ICA H-255 (white). After selection of lines for two cycles, with concurrent tryptophane analyses in each cycle, the most promising materials were intercrossed and the full-sib progeny were increased in 1973B. This population will be mixed in 1974A for increase and distribution as a source material to programs in the zone. A broader based population will result from the current cycle of increase and selection in crosses of the above opaque-2 maize with an introduction from CIMMYT, the flint endosperm opaque variety (Ver. 181 x Ant. Gpo. 2) x Ven. 1. This population will also be increased in 1974 for testing and distribution.

A conversion of the most promising brachytic progeny to a high quality protein type was initiated in 1972B, by crossing these with the (Ver. 181 x Ant. Gpo. 2) x Ven. 1 opaque-2 variety. Two self– and sib- pollination cycles have given double mutant selections with both the opaque-2 quality in a flint endosperm and the plant type advantage of the brachytic. Recombination of the best selections in 1974A will provide another useful source population for the zone.

The CIMMYT yellow hard endosperm variety mentioned above was selected during three cycles for shorter plant height, prolificacy, and resistance to local disease and insect problems. This variety has been distributed to programs in the zone, and has been tested most extensively in Colombia. Yields from one of these trials in a farmer's field are shown in Table 5. The two versions of this variety, one an intermediate endosperm type and the other a hard selection, produced more than the opaque-2 soft endosperm hybrids, but less than the normal double cross hybrids tested. One disadvantage of this new variety is an excessive plant height and susceptibility to lodging.

A thesis project in collaboration with Purdue University is exploring the possibility of new quality mutants in four Colombian races, the world composite, and six commercial varieties. Modifier genes for endosperm type are being sought from eight races: Amagaceño, Comun, Clavo, Chococeño, Pira, Pira Naranja, Pollo, and Puya. The bulk of field crossing is done at CIAT, while analyses of samples and genetic determinations are carried out at Purdue. The cooperative work on protein quality with both CIMMYT and Purdue keeps the CIAT research team up to date on latest advances in this area.

Screening on acid soils

A screening program has been carried out in the eastern plains of Colom-

Table 5. **Yield of commercial hybrids and experimental opaque-2 variety with hard endosperm, two nitrogen treatments, Tuluá, 1973**

Genotype	Description	Yield (kg/ha)	
		100 kg. N	200 kg. N
H-302	Yellow double cross (normal)	4,857	5,852
A-Doble-6	Yellow double cross (normal)	7,575	6,571
H-253	White double cross (normal)	7,000	6,428
H-208	Yellow double cross (opaque)	5.285	2,938
H-255	White double cross (opaque)	5,071	3,928
VE-21 int	CIMMYT variety (opaque intermed)	4,857	5,000
VE-21 hard	CIMMYT variety (opaque hard)	5,571	4,642

bia. The acid soils in this zone represent hundreds of thousands of hectares in Brazil and Venezuela, as well as those in Colombia. Initial screening of maize with four lime treatment levels (0, 0.5, 2 and 6 ton/ha) showed little or no production at the lowest level, and near-normal growth at the highest. These extremes were eliminated in succeeding tests, with the 0.5 ton/ha level used to indicate tolerance to low lime and phosphorus and high aluminum levels, and the 2 ton/ha level to show genetic potential at about the highest economically feasible treatment for this zone.

The step-wise selection procedure is based on open-pollination, partial selection pressure on the male pollinators, and a minimum input of professional time because of the distance of the Carimagua experiment station. Two hundred lines, varieties, hybrids, or single ear selections are planted each season under the two lime levels in the introduction phase, with no replication (Phase I). These include new introductions from outside and progeny from the CIAT or other breeding programs, or single ears selected from the previous cycle in Carimagua. Fifty of the best among these introductions are planted in the following season in four-row plots, two replications, at the 2 ton/ha lime level (Phase II). From this replicated yield trial, the five best entries are selected for semi-commercial testing (1/10 ha) on the station at 2 ton/ha lime level (Phase III). The best white and best yellow variety from this semi-commercial test are distributed in the zone as experimental materials for on-farm testing of yield potential under real ranch conditions (Phase IV).

Selection criteria in each phase include vigor and plant growth potential on these soils, resistance to cutworm (**Spodoptera** sp.) and stalk borer (**Diatraea** spp.), resistance to foliar and ear diseases, and final yield.

These four selection steps are carried out concurrently in each season, two cycles per year, with germplasm moving through the four steps as quickly as possible. During the second season of 1973, for example, the varieties selected from Phase I to plant in Phase II ranged in yield from 3.3 to 6.0 ton/ha, based on the single row plots (2.8 m^2). The best yellow and white varieties selected in Phase II for planting in Phase III produced about 3.7 tons/ha (plot size 28 m^2). The best yellow variety in Phase III during the second semester produced 3.2 tons/ha, in a semi-commercial field of 500 m^2.

PHYSIOLOGY

Two of the factors which most severely limit adaptation of specific maize genotypes are photoperiod and temperature. When broader adaptation is achieved in maize, or mechanisms are available to select for insensitivity, it will be possible to exchange and intercross germplasm over a much wider range of latitudes and altitudes. Tropical maize improvement programs can thus take advantage of highly selected and productive combinations from the temperate zone, while programs in the higher latitudes can have available the variability present in tropical collections.

In collaboration with ICA, two trials were planted in 1973 to confirm previous information collected in Colombia on photoperiod and temperature sensitivity in maize (see CIAT Annual Reports, 1971 and 1972).

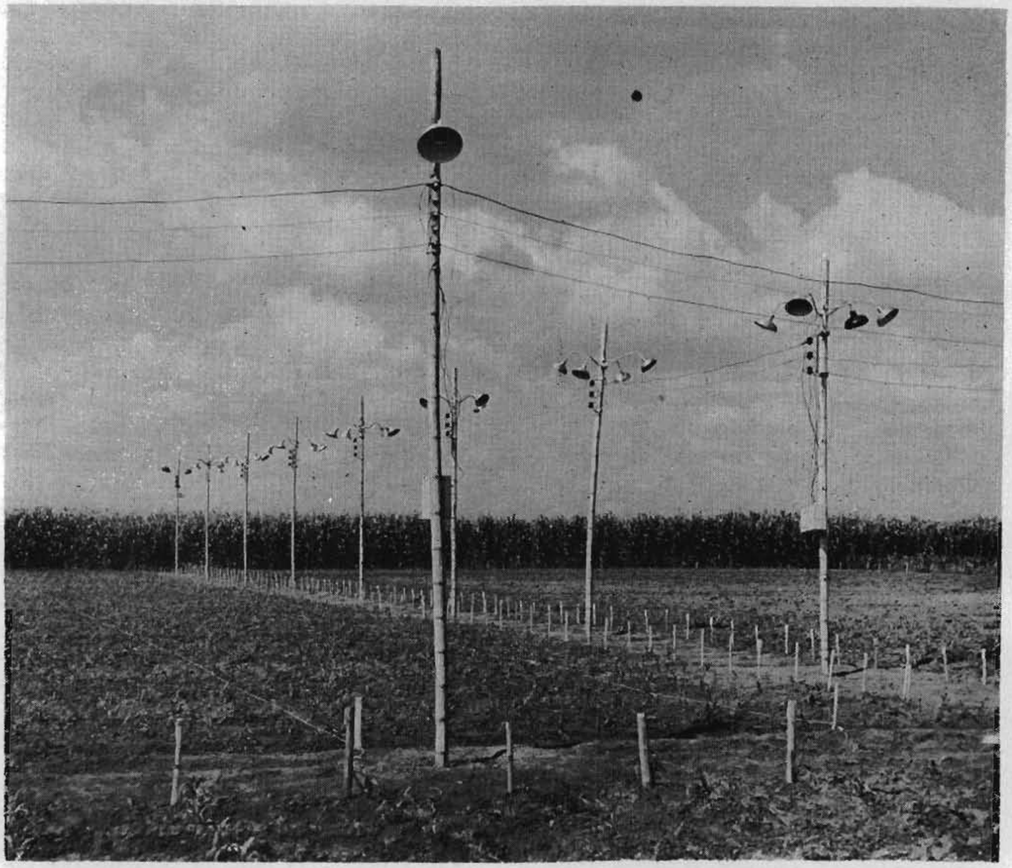
Using the growth stages published by Bonnett and Leng, and interpreted and utilized in CIAT photoperiod research since its inception, the two trials were observed through their growth cycle. Table 6 presents data on growth stage of five genotypes on two specific dates, 36 and 56 days after crop germination. On both dates, there is a significant difference between the growth stages at 2 m and 15 m from the light source. This confirms the previous observations of a critical intensity for the major photoperiodic response, with a light intensity threshold of 4 to 5 foot candles. There is an additional threshold reaction between 15 m and 30 m, the less pronounced but consistent delay in differentiation and flowering which occurs in most tropical genotypes at intermediate intensities between 1 to 2 foot candles and 4 to 5 foot candles.

In comparing the two locations, there was generally more rapid development, and flowering occurred earlier, in the lowland Turipaná station. The 4°C temperature difference caused earlier differentiation, as shown by data at 2 m and 36 days between the two locations, and on earlier flowering as shown by 30 m data at 56 days, in Turipaná. However, the absolute sensitivity in terms of growth stage between the distances, 2 m **vs** 15 m, and 15 m

Table 6. **Growth stage (1 to 20T) and sensitivity of five maize genotypes at different distances from light source, Turipaná (T) and Palmira (P)**

	36 days						56 days						
	2 m		15 m		30 m		2 m		15 m		30 m		
Genotype	T	P	T	P	T	P	T	P	T	P	T	P	Sensitivity
H-154	4	2	9	6	10	10	11	9	20T	15	F	18	Sensitive
H-207	5	3	9	10	11	10	10	12	20T	17	F	18	Sensitive
Eto Blanco	5	2	8	3	11	7	11	8	19	13	F	17	Sensitive
Minita CVSME	6	4	10	10	11	11	12	9	20T	17	F	18	Sensitive
Zap. Chico	13	13	17	13	20	17	F	F	F	F	F	F	Insensitive

1 – 20: Growth Stages (Bonnett and Leng, Francis **et al**)
20T: Tassel Visible
F: Flowering or past flowering



Artificial lights are used in two research locations in Colombia to extend natural daylength for photoperiod studies.

vs 30 m, was practically identical in the two locations in spite of the temperature differences.

The effects of photoperiod and temperature on leaf number and plant height in two locations indicate no difference in growth rate among the three distances from the light source (light intensities used to extend the day), and this confirms previous observations that there is no effect of photoperiod on growth rate, whether measured by leaf number or by plant height.

The period from flowering to physiological maturity in maize is the most important in terms of photosynthate production for direct translocation to the developing ear. The lengthening of this period has been suggested as a means of increasing yield potential. The effects of photoperiod on the total growth cycle in two locations are shown in Table 7. There is a definite delay in differentiation, flowering, and maturity under long days in each location in three sensitive varieties exposed to light. No significant difference was observed in the one insensitive variety tested, Zapalote Chico from Mexico. Although the differences between long and short days were most apparent in the growth phase leading to differentiation in Turipana, there was a definite delay in both flowering and physiological maturity due to the long days. This is in direct contrast to reports which attribute all

Table 7. **Days from germination to differentiation, to flowering, and to physiological maturity under long days (17 hours) and normal days (12 5 hours) in two locations, 1973B**

Genotype	Long days A	Long days B	Long days C	Long days D	Short days A	Short days B	Short days C	Short days D	Difference A	Difference B	Difference C	Difference D
Turipaná (40 meters elevation, 28°C mean annual temperature)												
ICA H-207	34	39	60	133	20	35	48	103	14	4	12	30
ICA H-302	41	39	54	134	25	34	48	107	16	5	6	27
Eto Amarillo	32	42	55	129	22	38	47	107	10	4	8	22
Zap. Chico	18	30	43	91	17	24	42	83	1	6	1	8
Palmira (1000 m. elevation, 24°C mean annual temperature)												
ICA H–207	38	46	52	136	26	34	48	108	12	12	4	28
ICA H–302	38	46	54	138	29	35	42	106	9	11	12	32
Eto Amarillo	39	51	48	138	30	40	37	107	9	11	11	31
Zap. Chico	19	36	38	93	18	30	37	85	1	6	1	8

A: Germination to differentiation
B: Differentiation to flowering
C: Flowering to physiological maturity
D: Germination to physiological maturity

effects of delayed maturity under long days to the delay in growing point differentiation. As this data contradicts previous information, it should be confirmed in another cycle.

ENTOMOLOGY

Insect damage, particulary that caused by **Spodoptera frugiperda** and **Diatraea** spp., severely limits maize production in the Andean zone. The emphasis in entomology on control of these two serious pests has concentrated in four areas:

1. Varietal Resistance: screening of germplasm for resistance to **Spodoptera** sp. and **Diatraea** spp.

2. Chemical Control: direct control of **Spodoptera** sp. and residual effect on **Diatraea** spp. has centered on testing granular insecticides which are applied to the whorl, and which have a minimum effect on beneficial predators.

3 Microbiological Control: trials with **Bacillus thuringiensis** to control **Spodoptera** sp., and the nematode **Neoplectana carpocapsae** to control both **Spodoptera** sp. and **Diatraea** spp.

4. Biological Control: liberation of parasites for large area control of **Diatraea** spp.

Varietal resistance

One approach to reduce insect attack and minimize crop loss is the development and use of varieties with as high as possible a degree of resistance. A group of 400 progeny of full-sib white brachytics and 132 half-sib families of brachytics were evaluated in the breeding nursery during selection and generation of the next cycle of progeny. Of these, 34 progeny were selected which had relative resistance, and five additional materials from the Antigua group were added. Classification in the field was based on percentage of plants with **Spodoptera** sp. larvae present.

Of the 39 genotypes, 16 were discarded, and in the selected entries two to four plants with least apparent damage were selected per row to effect sib pollination. The most resistant materials among the Antigua Gpo. 2 x República Dominicana and brachytic progenies showed 11-15 per cent affected plants, while the most susceptible had 32 per cent damage. Selection of progeny in the breeding program at harvest time always includes a rapid visual evaluation of damage by stalk borer (**Diatraea** spp.), when stalks are cut longitudinally to assess their resistance.

Chemical and microbiological control

The attack and damage by whorl worm (**Spodoptera frugiperda**) is most severe during the first 30 days of the vegetative cycle. This is the most critical period for control. A number of the products tested also had a residual effect in controlling **Diatraea** spp. Results from three trials presented in Table 8 show the highest yield with each of three maize genotypes to result from treatment with Furadan (R) 3 per cent. There is no correlation of yield data with control of **Spodoptera** sp. by granular products, since the treatments with best whorl worm control were not necessarily highest yielding. Table 8 also shows the importance of residual effects of the products applied on incidence of **Diatraea** spp., and there was a direct association of higher yield with lower observed damage from stalk borer. These studies were conducted as part of a thesis program of two students from the National University, Agronomy Faculty in Palmira.

Another serious problem in the complex of soil insects on the CIAT farm is a small centipede which destroys the

Table 8. **Chemical and microbiological control of** Spodoptera **sp. and residual effect on** Diatraea **spp. in three maize genotypes**

Genotype	Product	Dose [1]	*Spodoptera* control (%)	Damage to *Diatraea* (%)	Yield (kg/ha)
ICA H-253	Furadan (LTR) 3%	750	71	45	4,233
	Cytrolane 2%	500	99	49	4,013
	Hoe-2960 2%	400	99	61	3,789
	Cebiran 3%	600	94	60	3,671
	B. thuringiensis	7,500[2]	28	65	2,846
	Check	—	—	69	2,667
ICA H-207	Furadan (R) 3%	750	65	23	5,700
	Cytrolane 2%	500	97	45	5,300
	Thiodan 3%	750	93	40	5,300
	Cebiran 3%	600	91	59	5,200
	Dipterex 3%	600	89	57	4,900
	Nematodo	200-300[3]	16	56	4,800
	Cutvel 2.5	500	91	70	4,600
	Dipel 3.2%	16,000[2]	50	51	4,500
	Check	—	—	61	4,400
Brachytic Comp.	Furadan (R) 3%	750	56	30	4,300
	Thiodan 3%	750	48	33	4,200
	Cytrolane 2%	500	97	48	4,100
	Cebiran 3%	600	63	51	3,900
	Dipterex 3%	600	71	49	3,800
	Dipel 3.2%	16,000[2]	34	50	3,800
	Nematodo	200-300[3]	15	58	3,300
	Cutvel 2.5	500	62	73	2,800
	Check	—	—	55	3,400

1 Dose in grams active ingredient per hectare
2 **Bacillus thuringiensis**: number indicates international units of potency per mg
3 **Neoaplectana carpocapsae**: number of nematodes per plant

embryo, especially with minimum tillage practices. To control this problem and other soil larvae, a trial was planted with seed protected by Furadan 75 per cent with a surfactant Triton AE. Seed is soaked in the solution of insecticide and sticker. Plots with the highest plant population were those treated with 500 grams active ingredient.

A trial in both field and laboratory examined the potentials of **Spodoptera** sp. control by the nematode **Neoaplectana carpocapsae.** In the laboratory test, the nematode showed greatest effectiveness at 48 and 72 hours after treatment with the highest dosage (4,000 nematodes per larva). Under field conditions, there was a marked reduction in **Spodoptera frugiperda** populations with an application of 4,000 nematodes per plant, especially when there was high relative humidity. Applications were made with a back-pack sprayer at a pressure of 60 psi, directed into the whorl. In Table 9, the population of **Spodoptera** sp. larvae are shown for treatment at three different plant ages. The differences between the chemical treatment (check) and the best nematode treatment (highest concentration) were not significant, but the control by nematodes was apparent when compared to the absolute check (untreated). There were no significant differences among treatments at 30 days.

Biological control

Approximately 10,000 flies of the species **Paratherisia claripalpis** were liberated during the first six months this year, increasing parasitism in the field from 3 per cent to 7 per cent. In addition, a parasite of **Paratherisia** sp. was found in the field, and identified by Dr. B.D. Burks (USA) as **Signophora dipterophaga** Girault.

AGRICULTURAL ECONOMICS

The work related to the economics of maize during 1973 was limited to an analysis of data collected from a number of small farms. The purpose of the study was expressed in CIAT 1972 Annual Report. Table 10 reports a few selected data on sample characteristics and input use. The analysis is not yet completed.

As shown in Table 10, yields were found to be low, about 700 kg/ha on the average. The use of purchased inputs was likewise found to be low. Improved seed was used on only 4.3 per cent of the farms. Although 39 per cent of the farms used fertilizers for the

Table 9. **Population of** Spodoptera frugiperda **following treatment with three nematode** (Neoplectana carpocapsae) **concentrations, at three plant ages**

Treatment	Plant age at time of treatment					
	8 days		15 days		30 days	
(Nematodes/plant)	Initial [1]	Final [2]	Initial [1]	Final [2]	Initial [1]	Final [2]
4.000	10.3	4.3	16.0	7.2	22.0	15.0
2.000	9.6	5.0	16.0	8.0	22.3	16.3
1.000	9.6	7.3	15.3	10.3	23.0	21.0
Absolute Check	10.0	9.3	15.6	14.3	23.6	24.3
Chemical Check [3]	10.3	4.0	14.3	4.6	23.3	6.3

1 Larva population counts 24 hours **before** treatment
2 Larva population counts 96 hours **after** treatment
3 Dipterex 80, 1.5 kg/ha commercial product

Table 10. Sample characteristics and input use by altitude and cropping system: preliminary data from 372 farms

Altitude (km)	0 - 1.0		1.1 - 2.5		2.6 - 3.0		Total
Cropping system [1]	A	B	A	B	A	B	
Number of farms interviewed	74	48	96	47	31	76	372
Average size of farms (ha)	5.0	3.3	3.1	9.2	13.9	1.6	4.8
Average size of maize acreage (ha)	1.1	0.8	0.8	0.7	1.0	0.4	0.8
Average yields (kg/ha)	823	594	726	515	480	776	709
Input use (% of farmers)							
Improved seed	8.1	2.1	6.2	4.2	0.0	1.3	4.3
Fertilizers for maize	9.4	27.1	34.4	57.4	51.6	64.5	39.0
Fertilizers for other crops	12.2	31.2	10.4	6.4	0.0	3.9	10.8
Insecticides for maize	25.7	66.7	9.4	17.0	29.0	5.1	35.8
Insecticides for other crops	2.7	8.3	6.3	8.5	0.0	0.0	4.3
Herbicides	0.0	2.1	0.0	0.0	0.0	1.3	0.6
Tech. Assistance	4.0	6.2	2.1	6.4	3.2	2.6	3.8
Irrigation	13.5	0.0	1.0	2.1	0.0	n.a.	n.a.
Credit	1.3	31.2	2.1	0.0	3.2	2.6	5.6
Mech. land preparation	18.9	58.3	10.4	2.1	25.8	35.5	23.7

1 A Refers to monocropping
B Refers to intercropping
n.a. not available

maize crop, the quantities used were small. Technical assistance and credit had reached only a few of the sample farmers. The data are presently being analyzed to estimate the reasons for the low input use.

Helminthosporium was the disease most frequently found on the farms visited, followed by **Phyllacora** and rust. The insect most often reported was **Spodoptera,** followed by **Diatraea.** Attempts are presently being made to estimate the yield depressing effect of the diseases and insects reported in order to help establish research priorities related to disease and insect resistant varieties in maize.

TRAINING

A total of eight trainees received instruction and carried on field and laboratory experiments in the maize program during 1973. Six Colombian agronomists finished training in production and research, and three continue as members of the maize team, presently in charge of physiology, agronomy and outreach-nutrition. Two aditional specialists from Ecuador and Nepal were trained in protein quality work, inciuding both field and laboratory procedures, and selecting the new hard endosperm types which are important for lowland zones.

The Crop and Seed Production Specialist Training Courses provided training in maize to 26 trainees with an equivalent of 2.0 man-years. The maize team presented various topics in the two courses.

Several students from the Faculty of Agronomy in Palmira worked in the program during vacation to gain practical experience in maize production and research. Two final year agronomy students completed a thesis project in maize entomology, and one is now working as a research assistant.

Early in 1973, an unique training course was sponsored by CIAT and INIAP in Ecuador, where eight recent agronomy graduates were given a complete season of practical experience and specific information on maize production. This experience prepared the agronomists for practical extension work in an expanded maize production scheme for the zone. Two members of CIAT's junior staff in the Maize and Crop Production Training Program were commissioned in residence at Pichilingue for periods of two and a half months each. They shared responsibility for day-to-day planning and supervision of the practical work on the experiment station as well as in trials planted with farmers in the immediate Pichilingue-Quevedo area. Five other members of the CIAT staff also participated with conference-discussion sections on specific topics. INIAP research scientists and crop specialists also carried much of the responsibility for instruction.

This course proved to be an excellent opportunity to demonstrate CIAT's in-the-field approaches to training. These approaches are now being adopted by INIAP's own training program in Ecuador, and will be used by CIAT to organize similar courses in other countries by invitation.

INTERNATIONAL ACTIVITIES

All activities of the Maize Program are directed toward the Andean zone, and are focused on the same problems which are of general concern to the several national programs in the region. CIAT priorities are based on the problems which limit production in the zone, and the program is designed to collaborate with national programs to resolve these problems. Specific activities which have been carried out in the past year include:

Selection, generation and testing of germplasm

Progeny of short-plant and brachytic maize from CIMMYT, as well as an opaque-2 quality hard endosperm yellow variety, have been selected in Palmira, increased, and sent to national programs and commercial companies. Several new germplasm sources will be available as populations or varieties in the next year.

Uniform regional trials

The first cycle of regional trials of commercial hybrids and varieties from the Andean zone, for the tropics (ENZAT) and for the sierra (ENZAS), has been planted in 1972 and 1973. Some results have arrived in CIAT, and the entire series of trials will be analyzed as soon as the results are complete.

Annual meeting in Cochabamba

The annual meeting of maize research workers was held in Cochabamba, Bolivia, in March. Some 30 specialists from 10 countries attended the working sessions, and most significant were the cooperative work plans of three committees: plant improvement, plant protection, and agronomy/soils/physiology. The next meeting is scheduled for Maracay, Venezuela, in August, 1974.

Special topic workshop in plant protection

A workshop in plant protection and integration of research teams was held in CIAT in February, with about 15 professionals in entomology, pathology, and breeding. Laboratory and field practice stressed the importance of a team working together to select maize and solve production problems. CIMMYT specialists in plant protection assisted in the organization and implementation of the workshop.

Training

Six Colombian agronomists, and two professionals from Ecuador and Nepal, were trained in production and special research areas during 1973. In addition, a special course already described was carried out for extension agronomists in Pichilingue, Ecuador.

Newsletter

The regional newsletter "El Maicero" was published and distributed throughout Latin America four times in the year, with research results from CIAT, news and reports from national programs, announcements of meetings and publications, and a list of names and addresses of maize researchers in the region.

International travel

Visits to countries in the zone have given CIAT personnel the opportunity to learn from the experiences of national programs in the zone, and to share this knowledge where needed for program planning and setting priorities.

Rice production systems

The rice program directs ist activities toward increasing farm yields of lowland rice in the American tropics. Research results obtained, combined with contributions from the International Rice Research Institute (IRRI), have been accepted readily by national programs. Strong national efforts in farm demonstration and seed distribution of new varieties have stimulated a dramatic adoption of the new technology in several countries.

Large percentages of the rice areas of Mexico, Cuba, Costa Rica and other Central American countries, Colombia, Venezuela, Ecuador and Peru are planted with CICA 4, IR22, IR8 and selections from materials provided by CIAT and IRRI. Yield increases in the areas of adoption are excellent. In Colombia the new technoiogy has resulted in a yield advance from 3.0 to about 5.2 tons/ha over the entire irrigated area since 1966.

The blast disease, as expected, is beginning to depress farm yields of the new varieties in Colombia and elsewhere. This problem will increase with continued plantings, emphasizing the urgent need for blast resistance in the new varieties.

AGRONOMY

Efforts and resources of the agronomists concentrated on multiplication of seed of promising genetic lines.

Seed multiplication

Six promising lines were grown in areas ranging in size from 0.4 to 1.8 hectares to evaluate yield and milling quality under simulated commercial conditions. These increased basic seed stocks are used to supply national seed multiplication programs.

Three lines were rejected because of susceptibility to **Pyricularia oryzae** and undesirable plant characteristics, while three were harvested and processed for distribution of pure seed.

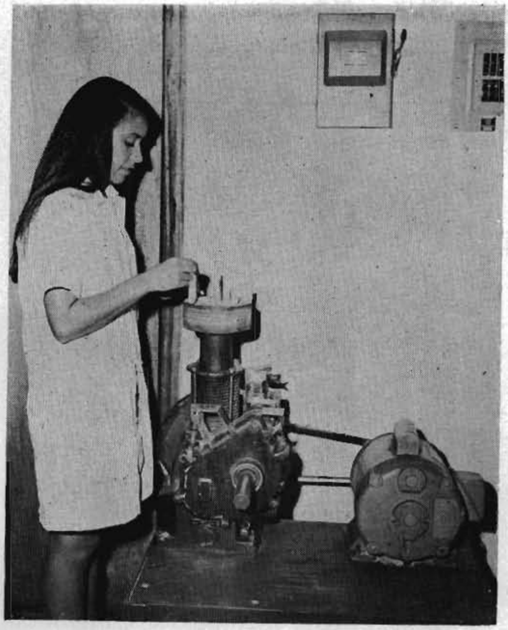
The selection P723-6-3-1, resistant to blast, showed extraordinary milling quality and grain appearance in a commercial test of two tons. Its field yield was acceptable. P738-137-4-1 has excellent yielding ability and a milling quality and grain appearance superior to CICA 4. The third line, IR5-164-2-2, has good field resistance to blast but suffers from "white belly."

One ton of each of these first two lines was given to ICA for the production of foundation seed and 100 kilos of P723-6-3-1 went to Guayana, where blast severely attacks local varieties. Smaller quantities of pure seed were shipped to Brazil, Honduras, Guatemala, Costa Rica and Panama.

Nitrogen sources on upland rice

This experiment was planted at the ICA Turipaná Research Center in an area severely infested with nutsedge (**Cyperus rotundus**). CICA 4 was treated at 15 days after planting with a mixture of nine liters/ha of Stam F-34 and one liter/ha of 2,4,5-T to control the nutsedge.

There was a good response to nitrogen, and yields were increased from 1,723



A test tube mill developed for analysis of cooking and milling quality of single plant selections

kg/ha in the check plot to an average of 3,104 kg/ha and 3,803 kg/ha, respectively, for 50 and 100 kg nitrogen applications. The common urea and sulfate of ammonia were equal or superior to the sulfur-coated urea formulations. Phosphorus gave no additional increase in yield.

Upland rice variety test

This experiment, planted at Turipaná, had to be treated with the mixture of Stam F-34 and 2,4,5-T to control nutsedge. The varieties used and the results obtained are shown in Table 1.

Although yields were reduced by the delayed harvest and late season weed growth in three lines, all of the lines, with one exception, produced from 50 to 100 per cent higher yields than the traditional tall varieties.

Iron deficiency on alkaline soils

Soils on the CIAT farm are alkaline, the pH varying from 7.5 to more than

A promising blast resistant line of rice in a seed multiplication field

Table 1. **Yields of varieties and lines under upland conditions**

Variety or pedigree No.	Average yield
Traditional varieties	
	kg/ha
Bluebonnet 50	1,759
Miramono	1,660
New dwarf varieties	
CICA 4	3,453
IR5-64-2-2	2,925
IR930-2 x IR822-432	1,490*
IR930-53 x IR579-160	2,662*
IR930-2 x IR662-1-108-5	2,479*
IR442-2-58-1-1-2	2,936

* Yields were affected by over-ripe harvesting and late season weed growth

8.0. With conventional methods of land preparation and seeding, iron deficiency symptoms are common and at times so severe that the plants die within a few weeks after emergence.

Different sources and methods of applying iron as a means of correcting this condition were composed.

Iron deficiency symptoms appeared a few days after emergence. No treatment produced normal vigorous seedlings although treatments of five tons of sulphur and 200 kg/ha of ferrous sulfate were slightly better than other treatments.

In the foliar application plots, ferrous sulfate at 3 per cent concentration and rayplex were slightly better than other treatments. Treatments had to be repeated at weekly intervals, and even with these, normal plants were not produced.

Flooding of the soil for a three-week period before planting appears to be a better way to correct iron deficiency. With this practice, no iron deficiency symptoms were noted in areas in which rice plants had died from an earlier planting in which the soil was prepared in the conventional manner.

Red rice and varietal mixtures

Rice fields planted for years with seed containing mixtures of other varieties and red rice do not produce satisfactory yields or rice with good cooking and milling quality. Recommended fertilization and weed control practices do not reduce the mixtures or improve the quality. Conventional methods of cultivation to kill germinating plants are costly and may require several years to eliminate the seed from the fields.

The effect of flooding and a combination of flooding with cultural practices on red rice control were studied in a greenhouse pot experiment. Red rice was seeded at a rate of 600 kg/ha and mixed in the soil to a 15 cm depth. Results are shown in Figure 1.

Results indicate that flooding for a three-to-four week period efficiently reduces the red rice seed in the soil. As some seeds germinate under water, it will not completely eliminate the problem unless deep flooding is used. Some of the seed germinated under water from a five cm depth. Seeds that did not emerge through the water during the two-to-three week flooded period rotted.

BREEDING

Crosses

A total of 102 new crosses was made in 1973. Thirty-five of these involved

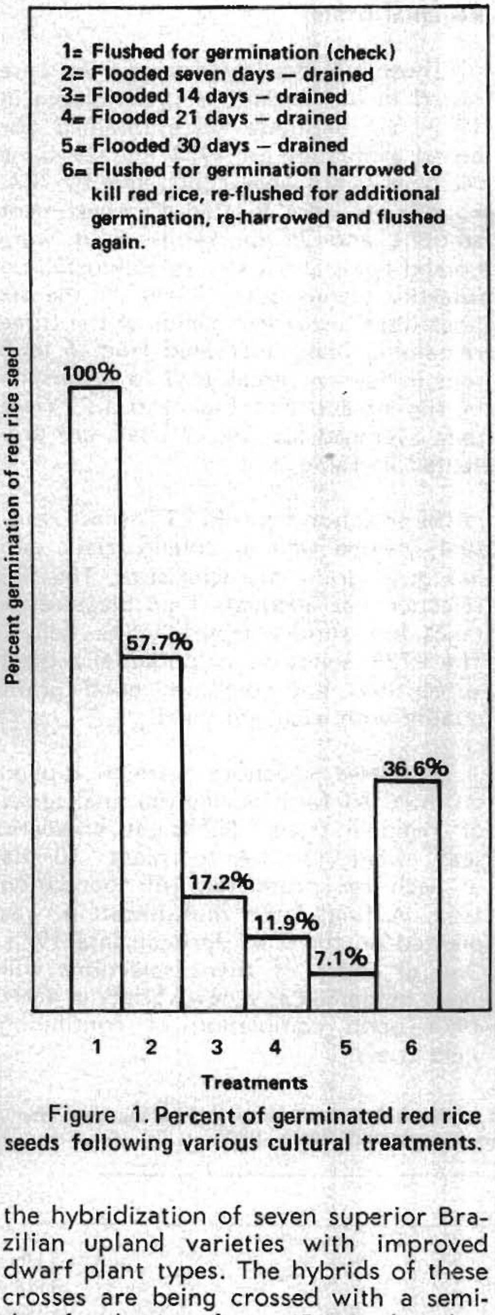


Figure 1. Percent of germinated red rice seeds following various cultural treatments.

the hybridization of seven superior Brazilian upland varieties with improved dwarf plant types. The hybrids of these crosses are being crossed with a semi-dwarf selection from IR442 that has some drought tolerance. The seed from several hundred short-statured F_1 segregates of the new three-way crosses will be sent to the Instituto Agronomico in Campinas, Brazil for F_2 evaluation.

The remainder of the new crosses were single, three-way and multiple crosses for blast resistance using Monolaya and dwarfed selections of Tetep and Colombia 1 as donors. Large numbers of F_1 seeds were produced for each three-way and multiple cross. The resistant F_1 segregates were identified and retained for continuing crosses or for field evaluation of the F_2. The crossing program has progressed to the point where all F_2 material carrying resistance is dwarf in stature, eliminating the need to remove the undesirable tall F_2 segregates in the field.

F_2 nurseries

More than 1,460 large F_2 families and populations carrying blast resistance were planted. A new procedure was adopted to facilitate identification of resistant F_2 segregates in the field where the blast disease does not occur. F_2 seed is sown in blast disease nurseries exposed to massive natural infection. Susceptible families are discarded in the seedling stage. Segregating families are evaluated plant by plant, discarding susceptible plants. The resistant plants from segregating and resistant families are transplanted in the field assuring that all field material carries resistance The F_2 families are also rated for **Sogatodes** resistance, cooking quality, and milled grain appearance to guide field selection.

F_{3-6} nurseries

About 12,000 pedigree rows were directly seeded in the field in five staggered plantings from February to September. Most of these involve crosses planned for the transfer of blast resistance to satisfactory plant and grain types. Blast reaction, cooking quality, endosperm appearance, and **Sogatodes** resistance are evaluated in all generations.

None of the many crosses made in past years with Colombia 1 as the source of stable blast resistance has been outstanding because of apparent unfavorable linkage of resistance with unsatisfactory plant and grain types. One cross, P881 = IR22 x (IR930 x Colombia 1) gave a few promising F_5 selections that performed well in preliminary yield trials. Seventy-five panicles of each of five resistant P881 selections were transplanted into large plots to purify and multiply seed for wider evaluation.

Relatively small three-way cross populations combining resistance to the "hoja blanca" virus from ICA 10 with improved plant type are in the F_3. Although the new varieties grown commercially are genetically susceptible to hoja blanca, they remain unaffected by the virus because of their excellent resistance to the insect vector, **Sogatodes oryzicola.** As it is not known if the insect resistance will continue indefinitely to protect varieties against the virus, the program seeks to transfer both resistances into common dwarf backgrounds.

Yield trials

A small number of blast susceptible new selections were yield-tested during the year. Several of these have excellent yield and grain types and are earlier maturing than CICA 4 indicating improved low temperature tolerance. The better ones were sent to Argentina and southern Brazil to evaluate performance in temperate climates.

Regional trials

Fifteen advanced promising lines were tested in four locations in Colombia in 1972. Six of these were retained for broad evaluation in 1973 and 29 large regional trials were conducted by ICA. Four trials were located on experiment stations and 25 on farms. Four were upland trials and six were conducted on infertile Llanos soils. Three of the six lines were discarded. Yields of the three remaining lines fluctuated from 6 to 8 tons in favored areas to 2 to 4 tons/ha in the upland and Llanos trials. Yield data averaged for the 29 trials are presented in Table 2.

The selection from P723 is blast resistant, yielded well in upland trials, and has good grain characteristics. The IR5 selection has adequate field blast resistance but suffers from "white belly." The P738 selection is potentially blast susceptible but combines good grain quality with excellent yield.

The three selections were multiplied on the CIAT farm during the final series of regional trials. Sufficient breeders' seed went to ICA to plant 10 ha of each for production of foundation seed. A final large multiplication was planted on the CIAT farm in late 1973. One or more of these selections will likely be named as a new variety in early 1974 upon completion of continuing yield trials.

Table 2. **Average yield in ton/ha at 14 per cent grain moisture of three promising new rice selections and four check varieties in 29 regional trials, 1973**

Cross or variety	Pedigree	Yield
IR930-2xIR822-432	P723-6-3-1	5,116
IR930-53xIR579-160	P738-137-4-1	5,918
Peta x Tangkai Rotan	IR5-64-2-2	5,188
CICA 4		5,515
IR8		5,074
IR22		4,640
Bluebonnet 50		3,570

Main emphasis was placed on upland rice production, with a limited amount of work continuing on flooded rice.

Upland rice

The extreme soil acidity of the high savanna soils, such as in the Llanos Orientales, is one of the major factors limiting upland rice production. The problem can be solved either through liming the soil to increase the pH, or through varietal resistance.

Liming

A liming experiment in pots showed that 6 ton/ha of $CaCO_3$ + $MgCO_3$ (Ca/Mg = 10) raised the pH to 5.4 and nearly eliminated all exchangeable aluminum (Figure 2). Using basic slag (60% $CaCO_3$ equivalent) as a lime source, the pH increased and the Al-level decreased more than with comparable levels of lime. Calcium chloride, a neutral Ca source, had no effect on pH but slightly decreased the Al-level. The latter source decreased yields while the $CaCO_3$ and basic slag increased yields significantly, except at 1 ton/ha.

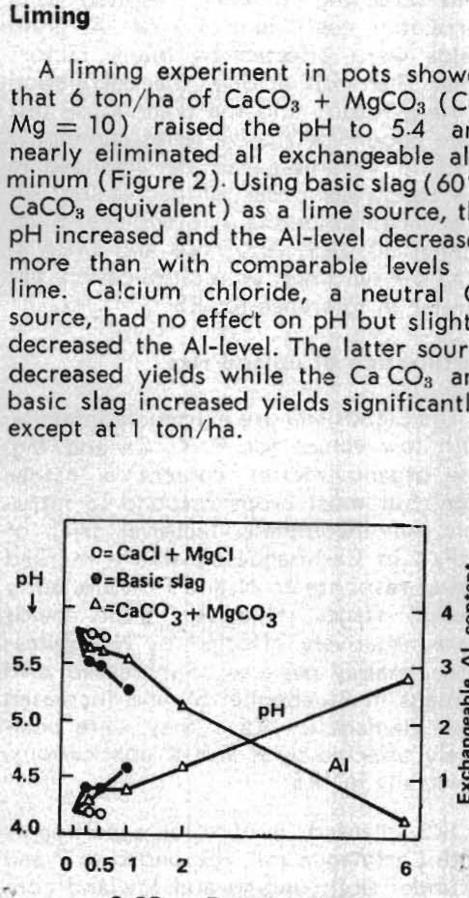


Figure 2. **The effect of applications of three Ca and Mg sources on the pH and exchangeable Al-content of Carimagua soil, used in a pot experiment**

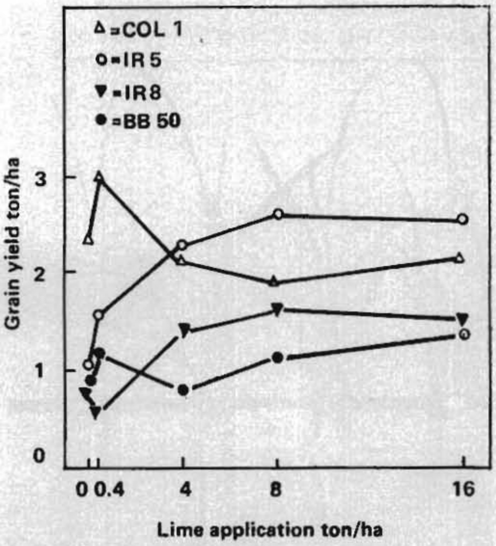
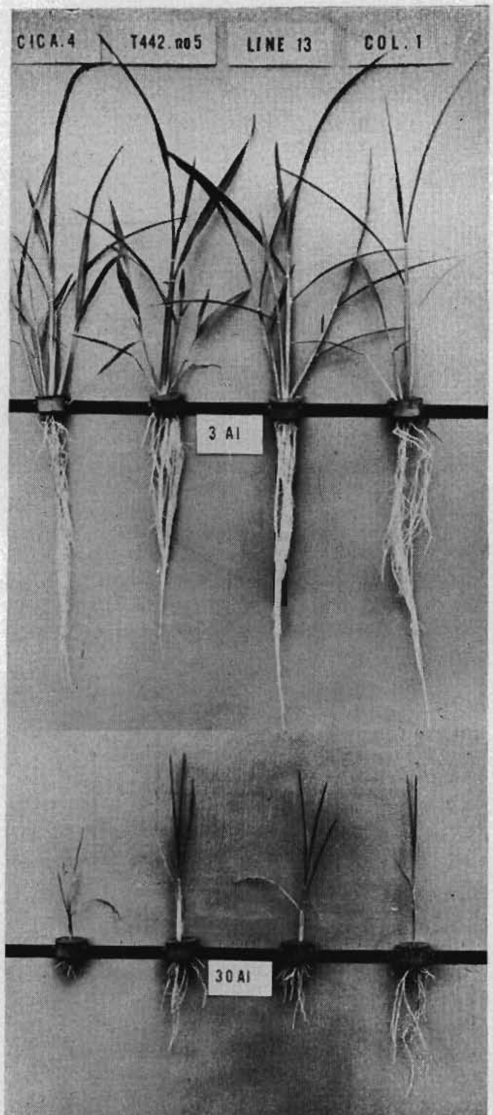


Figure 3. **The effect of lime applications on the grain yields of four rice varieties grown under upland conditions in Carimagua**

Two dwarf varieties, IR5 and IR8, responded to 8 ton/ha of lime (Figure 3) in the lime x P experiment in Carimagua. The tall varieties, Colombia 1 and Bluebonnet 50 (BB 50) showed a marked response to the first increment of 0.4 ton/ha lime, but no positive response to higher lime applications. The negative response to lime of these varieties was mainly because of lodging and bird damage. Although there was a marked visual response to P applications in the early stages of growth, there was no positive response with respect to grain yield, apparently because of increased neck blast in IR8 and IR5 and more lodging and bird damage in Colombia 1 and BB 50 at the higher P levels.

Varietal resistance to soil acidity

Rice varieties differ markedly in tolerance to acid soil factors. To identify aluminum tolerant varieties, nearly 1,000 lines from IRRI and CIAT were screened at Carimagua at lime levels of 0.5 and 6 ton/ha, while nearly 400 of the varieties also were screened at 0



The ratio of root length at 30 ppm aluminum level over that at 3 ppm aluminum in solution (referred as relative root length or RRL), is used as an indication of a variety's tolerance to high levels of aluminum in the soil

and 2 ton/ha. At about six weeks of age, they were evaluated for resistance to soil acidity and blast. One replication was harvested at maturity.

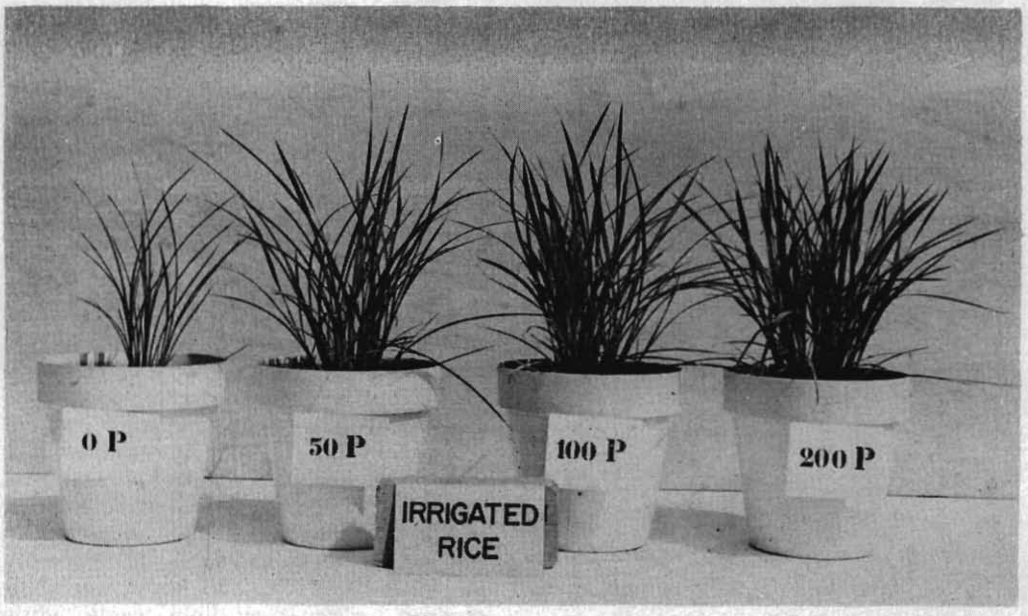
As field screenings consume time, and final results are affected by soil variations and differential resistance to blast and bird damage, a rapid greenhouse screening test for Al-tolerance was developed. Rice seedlings are grown in nutrient solutions at two Al-levels of 3 and 30 ppm. At three weeks of age, root lengths are measured, and the ratio of root length at 30 ppm Al over that at 3 ppm Al is used to indicate Al-tolerance. This ratio is called relative root length (RRL). A correlation analysis of RRL values of 240 varieties with their respective grain yields, obtained in a field screening in 1972, resulted in a correlation coefficient of 0.64. As grain yields were affected by many factors other than soil acidity, the correlation of field results and the greenhouse test seem good. The rice varieties commonly used in Colombia can be arranged in the following order of decreasing Al-tolerance: Colombia 1, Monolaya, Bluebonnet 50, IR5, IR22, IR8 and CICA 4. CIAT's new lines in multiplication are similar in tolerance to IR8.

Fertilization of upland rice

The Llanos soil are extremely infertile, with low values for P, K, Ca and Mg. The organic matter content is rather high, but most crops respond to nitrogen. An incomplete factorial trial of NxPxK in Carimagua showed a marked visual response to N and P in the early growth stages. However, grain yields were negatively affected by N applications, mainly because of increased bird damage in Bluebonnet 50 and increased blast damage in IR5; they were positively affected by P and K applications, especially in IR5.

IR5, planted in two pot experiments with Carimagua soil, responded to P and K under both upland and lowland conditions in the absence of blast and birds (Figures 4 and 5). Under flooded conditions, it responded to 400 kg P_2O_5 and 600 kg K_2O/ha, while under upland conditions there was a significant posi-

Comparison of plants of same variety of rice grown in two water cultures, one with 3 ppm aluminum level (left) and other with 30 ppm aluminum level (right). Note depressed growth at higher aluminum concentration



Response of variety IR5 to four levels of phosphorus applications in Carimagua soil under flooded conditions. Numbers indicate application levels expressed as P_2O_5 kg/ha

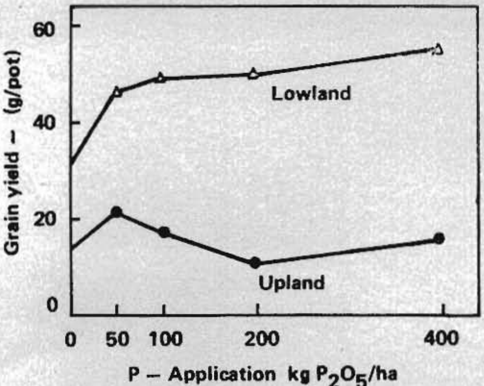


Figure 4. **The effect of P-applications on grain yield of IR5, grown under upland and lowland conditions in a pot experiment with Carimagua soil**

tive response only to 50 kg P_2O_5 and 100 kg K_2O/ha. Yields for upland rice were generally low.

Colombia 1 responded positively to P at 100 kg P_2O_5/ha in a field experiment comparing six sources of P at levels of 25, 50, 100 and 200 kg P_2O_5. BB 50 did not show a significant response. There was no significant difference in yield of Colombia 1 among applications of triple superphosphate (TSP), basic slag, and rock phosphates from north Florida and Huila, Colombia.

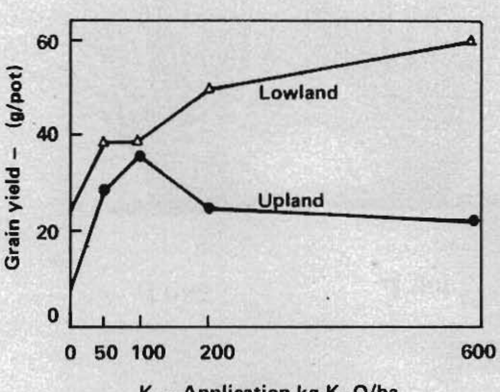


Figure 5. **The effect of K-applications on grain yield of IR5, grown under upland and lowland conditions in a pot experiment with Carimagua soil**

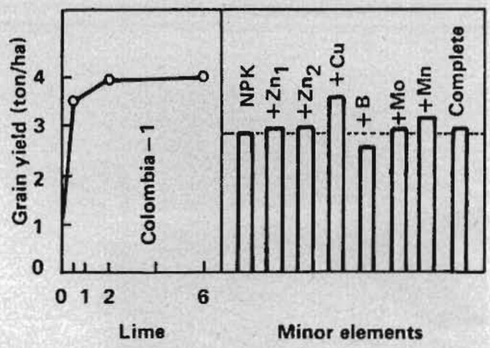


Figure 6. **The effect of lime and minor elements on the grain yield of Colombia 1, grown under upland conditions in Carimagua (lime response averaged over all minor element treatments; minor element response averaged over all lime treatments)**

A similar experiment conducted in pots compared six sources of P at the level of 200 kg P_2O_5/ha and with 0 or 2 ton lime/ha and resulted in marked responses to all P sources. There were no significant yield differences between lime levels. The rather soluble rock phosphate from North Carolina gave the highest yields, followed by basic slag, TSP, and rock phosphates from central Florida, Huila, and Boyacá.

Experimental results to date indicate that there is no significant difference in agronomic effectiveness between TSP and basic slag, while Huila rock phosphate is only slightly less effective for upland rice under these acid soil conditions.

A field experiment at Carimagua studied the interaction of lime and micronutrients. Figure 6 shows the response of Colombia 1 to liming, indicating a marked responce to 0.5 ton lime, a small additional yield increase with 2 ton lime, and no additional response to 6 ton/ha. Of the minor elements, the application of copper resulted in the largest yield increases, followed by Mn (Figure 6). The Cu applications increased yields at all lime levels, while Mn applications increased yields at all but the 6-ton lime level.

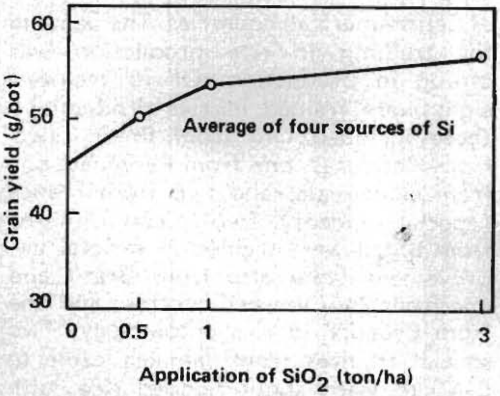


Figure 7. **The effect of SiO_2 applications on the grain yield of IR8 grown under lowland conditions in a pot experiment with Carimagua soil (average of four sources of Si)**

Contrary to expectation, Mo decreased yields with O lime, but gave increased yields at the higher lime levels. The application of all minor elements combined decreased yields at 0 lime, but resulted in successive yield increases over the check with each increment of lime added. This indicates that minor element applications become more important as lime levels are increased.

Lowland rice

As silicon levels in rice plants grown in the Llanos were found to be quite low, a pot experiment studied Si fertilization in flooded rice, using IR8 as a test. Four silicon sources — TVA slag, Colombian slag, rice hulls and burned rice hulls — were applied at three levels of SiO_2. Figure 7 shows the average response. Yields increased significantly up to 3 ton SiO_2/ha. There was no significant difference in grain yield among Colombian slag (33% SiO_2), rice hulls (18% SiO_2), and burned rice hulls (41% SiO_2) while TVA slag (42% SiO_2) was slightly inferior.

Upland and lowland rice

Many parts of the Llanos, especially north of the Meta River, are dry during the dry season, but flood during the wet season. A pot experiment with soil from such an area indicated the soil's great potential for flooded rice because of the low level of Fe. Because of natural flooding, there is no need for irrigation equipment, diking and puddling. The lack of water control may result in excessively deep flooding, and there is a need to time land preparation, weed control, and fertilization rather precisely at the onset of the rainy season before the soil gets too wet to support machinery.

The effect of water depth on five varieties, seeded at three dates, was studied at Carimagua in one such naturally flooded area. Varieties were grown in long plots of 3 m x 400 m, along a gentle slope of about 0.5 per cent. During the dry season the whole field was dry, while in the wet season the lowest 140 m were under water, with a water depth of about 70 cm at the lowest point. At the highest point the water table was at 2.8 m during the dry season and at 1.3 m during the wet season.

The first seeding was made shortly after the onset of the rains on April 25; the second seeding at the time the lowest part inundated on June 4, and the third seeding at the time the maximum water level had been reached on July 19. The five varieties, T-442-2-58 (floating rice), CICA 4, IR5, Monolaya, and Bluebonnet 50, were seeded in long parallel strips down the slope so that each variety was subjected to the same water regime, which changed continuously with time and with location on the slope. At harvest, samples of 5 m^2 blocks were taken at 20 m intervals along the slope.

Yields decreased as seeding was delayed, even under purely upland conditions. The effect was most pronounced, however, in areas that became deep flooded before seeding or when the rice was still young. Under these conditions, even the floating rice barely survived in the deep-flooded areas. IR5 behaved much as a floating rice, increasing in height with increasing water depths to 120 cm under deep-flooded conditions. Although the floating rice was severely affected by blast, it produced the highest over all yields, followed by Bluebonnet 50, Monolaya, IR5 and CICA 4. Under deep water conditions, IR5 did as well as Bluebonnet 50; the floating rice was superior to both.

Under flooded conditions, the optimum water depth was between 20 and 50 cm, while under upland conditions maximum yields were obtained with a water table at about 1 m below the surface. The low yields at the upper end of the slope probably result from increased soil acidity under more aerobic conditions.

Results confirm that the naturally flooded soils and their surrounding areas have a great potential for rainfed rice as long as the water level does not rise above 50 cm, the land is prepared during the dry season, the rice is seeded at the onset of the rainy season, and varieties are used that are either tall or have floating rice characteristics.

TRAINING

The rice program gives particular attention to providing for the needs of trained personnel in the rice programs of Latin American countries. The demand for training in rice production was strong in production. Of 15 trainees, eight were trained in rice production; these included two from Brazil, two from Honduras, one from Paraguay, one from Guatemala, and two from France (special trainees). Two research interns from Brazil were trained in varietal improvement; one also from Brazil and one from Perú in weed control; and one from Ecuador in rice entomology. Two special trainees from Jamaica came to CIAT to learn about flooded rice cultivation techniques. The 15 professionals trained represented an equivalent 4.2 man-years. In addition, the crops and seeds courses provided for 4.7 man-years of training in rice for 26 trainees.

Training consisted in assisting in the research work programs of the CIAT senior staff members or conducting research proyects under their supervision. They made trips to other rice growing areas to see and to learn to identify problems. They also participated in technical conferences conducted by the national rice program of Colombia. Upon termination they were furnished copies of rice production training materials, reference books and color slides illustrating the principal rice problems which occur in their home countries.

SMALL FARMS SYSTEMS PROGRAM

Activities

Program activities centered on sharpening the focus and developing a specific outline of activities for 1974. During the latter half of 1973, the program was staffed by a systems engineer and an economist, both serving on a half-time basis.

Several visits were made to the Llanos and North Coast areas of Colombia for discussions with farmers. In addition, the program has maintained a continuous interest in the rural development projects being conducted by ICA in Colombia, and visits were made to several project areas. In February a basic document entitled The Agricultural Systems Program: A Course of Action was produced, and formed the basis for internal review of the program together with review by selected international agencies.

The program has maintained close inter-institutional ties throughout the year. This has been reflected in a visit to the International Institute for Tropical Agriculture in Nigeria, where one member of the team had the opportunity to learn of the work being undertaken in their farming systems program. That program appears to be centered on the development of a specific technology to improve a prevalent farming system in that area. It should perphaps be emphasized that their approach differs from that being adopted in CIAT, where concern is more with the overall problem of understanding a variety of farming systems with a view to achieving modifications in them.

In addition, the program was represented at the annual conference of the Latin American Association for Rural Development (ALADER) in México. In conjunction with this visit, the program was invited to send a participant observer to the review sessions on Plan Puebla.

In October, a four day planning session was held with approximately 40 participants from CIAT's staff, Universidad del Valle, ICA, and international agencies and foundations. While a diversity of views were expressed, the underlying concern of all participants was with the establishment of a team within CIAT to focus on the understanding of existing farming systems in order that the impact of new technology on farm family welfare be understood. The real incomes and nutritional levels of the people dependent on farming in tropical Latin America must be the ultimate goal of production programs within CIAT.

The overall product of the activities during 1973 was the preparation of a program document, to define the philosophy, approach and near term activities of the program. The highlights of this document are presented below.

BACKGROUND AND PHILOSOPHY

The fundamental characteristic of Latin American agriculture at this moment is the simultaneous existence of a small, highly commercialized farming sector on one hand, and a numerically large sector of small family farm units which operate at a near subsistence level on the other.

The commercialized farming sector is typically located in the more favorable ecological regions, and is principally oriented toward the production of export crops (e.g., coffee, cotton, sugar, bananas) and/or to high value crops (including large commercial extensions of feed grains and rice). These relatively large, capital intensive holdings have had access to new agricultural methods, technical assistance, credit, agro-chemicals, markets and transportation.

The situation has come about as a result of public policies; partly because of their export orientation (together with greater political influence) large commercial farming enterprises have benefited from favorable governmental policies with respect to research, extension, and product and input prices. These policies were motivated by the need for expanded food production and export earnings, both of which were to be generated by concentration on the commercial farm sector.

There exist a large number of small farms whose productivity has changed little, if at all. That the levels of income, nutrition, health, housing and schooling lag far behind the commercial farm sector and much of the urban population has been amply documented. This sector is principally (although not exclusively) concentrated in the less favorable ecological areas, with limited access to transportation, storage, input supplies and credit.

The small farmer has had few if any profitable opportunities. He responds to the set of rewards and penalties he perceives. He has evolved farming systems that are often near optimal for the economic, political and ecological environment in which he operates, given the alternatives he can perceive. This essential rationality of the small farmer implies that successful agricultural development requires new production alternatives that are adapted to his environment, that increase his income, that recognize this risky nature of his decision problems, and that fall within the availability of input supplies and stable markets.

National goals of expanded food production and employment opportunities are not incompatible with efforts to promote growth among small farmers. In fact, small farms are an important source of food production in many countries. In Guatemala, which is exemplary of many countries, 84 per cent of the farmers own farms of less than seven ha that occupy 17 per cent of the land in use, yet produce close to 60 per cent of the basic grains.

In the light of the above considerations it has been proposed that CIAT's Agricultural Systems Program should be called the **Small Farm Systems Program.**

Already in CIAT, there is a strong integrated commodity focus, in which integrated teams work together for achieving goals related to Commodity Production Systems. The evolution of the Small Farm Systems Program is a natural consequence of the need to again integrate the efforts of the individual Commodity Production Systems Programs in the context of the whole farm unit.

The Small Farm Systems Program is a basic research activity of CIAT which is charged with understanding the great diversity of agriculture in tropical Latin America. Because CIAT is concerned with the improvement of agriculture and rural life, the **Small Farm Systems Program is concerned with family farms as integrated systems.** Because of the diversity and complexity of small scale farming in Latin America, it is possible for the commodity focus to isolate the researcher from the small farmer. The program is concerned with small scale farming in all its complexity and is focused on the farm family. Its primary goal **is to develop a process for the identification and analysis of existing farm systems so as to facilitate the utilization of agricultural technology in the development of rural areas.**

An essential element of the systems approach is the recognition that a family farm system is really a system within a larger agricultural sector. The focal system is one in which the farm family and others living on the farm assemble individual enterprises into a production, consumption, and a marketing system, in which biological and physical factors interact with social, political and economic systems. The explicit recognition of the importance of these interactions is a key part of the methodological approach towards the development of a process for identification, analysis and facilitation of technological change of small farms.

An intrinsic feature of the systems approach is that it requires that the farmer's objectives be made explicit. For the farm family these objetives probably include income, nutrition, cash flow, security, health, and education. There is no clear nor explicit understanding of these objectives as yet. In addition, public-policy goals are frequently not made explicit. Much research effort can be misdirected unless there is a clear specification of the problem so that **objectives** are not confused with the **activities** that can be undertaken to achieve those objectives.

A scheme for the development of this process is as follows:

1. Analysis of family farm systems

In this phase, a number of prototypical systems in tropical Latin America will be studied by the Small Farm Systems Program. These systems will be described in relation to how the farm family transforms its resources of time, land, energy, species, information, etc., into crops and real income.

2. Synthesis of prototypical farming systems

The insights derived from the analysis phase will be tested both on a component basis and a systems basis. These insights will be useful in creating physical and analytical models of prototypical farming systems and their components to predict the impact of new technology.

3. Design of improved agricultural systems technology

The analysis and synthesis phases should produce the requisite information to specify the technology which is feasible for introduction into small farms in order to better achieve farm family and national food production goals. The knowledge gained in the earlier phases would permit the biological scientists on the team to select and specify the cultural practices, the species mixes, the levels of inputs, etc. to be tested for potential introduction to the family farm.

4. Validation of the process

The process will be validated by demostrating that: a) farm families in selected areas of study achieve their objectives through the use of the tecnology selected by the process, and b) national agencies adopt the process as a tool to help them achieve their goals.

5. Implementation

Implementation of the process is the role of the national agencies. CIAT will collaborate with them in the development of new technology, and in training for the application of the entire process.

6. Evaluation

CIAT will develop methodology for evaluating the impact of new technology and will also serve as a focus for the documentation and analysis of the experiences of the various countries in the application of the process.

The process will provide guidelines for identifying limiting factors and selecting research alternatives. It will provide a framework for assessing the probable adoption of research results and the impact of food availability and incomes as a result of that adoption. It will suggest alternative ways of achieving explicitly stated objectives.

In the execution of these phases the program will provide analytical support and information to its two principal clients and collaborators: CIAT commodity teams and national agricultural development agencies. When the process is developed it will be useful as a planning and evaluation tool for these clients and for international agricultural development agencies. The ultimate clients are, of course, farm families and the consumers of Latin America that benefit from the implementation of the process by national agencies.

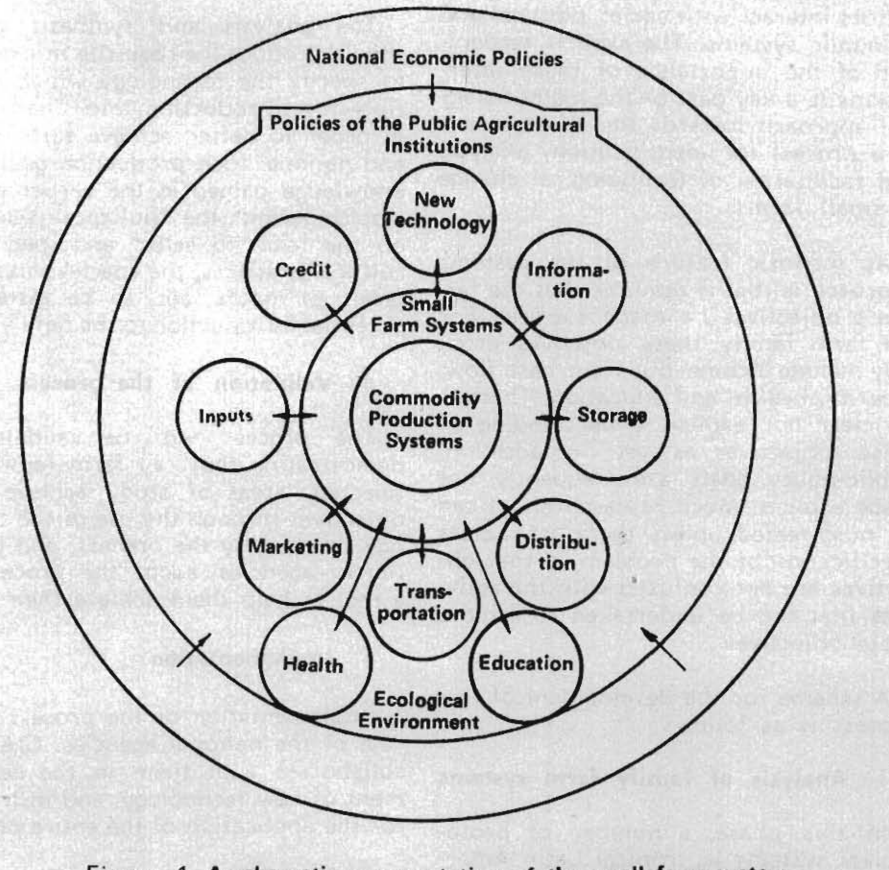


Figure 1. **A schematic representation of the small farm system**

BIOMETRICS

The Biometrics Unit was organized in July 1973. During its first months of operation it has concentrated its functions in providing in-service training to the units data processing staff. Under this mode of operations it has provided consultation and analysis services to the commodity production systems programs, data processing services for the administration and begun a collaborative program with the Information Systems Division of the Instituto Colombiano Agropecuario.

Bean Production Systems Program

The principal collaborative activity of the Biometrics Unit with the Bean Program is the continuing effort to create an information system for CIAT's **Phaseolus vulgaris** germplasm collection. This effort, which is in its early stages and is being viewed as a basis for collaboration with the various national and regional grain legume programs, will focus on producing a computer-based information system for use by the various collaborating programs. The need for such a system arises from the fact that these germplasm collections are large and that there is much ongoing research throughout Latin America where the same materials are being used. The specific objectives of the system are: 1) to provide for the timely retrieval of the existing information on the characteristics of the collected material; 2) to record the results of trial with a standardized nomenclature and observation criteria; 3) to select material satisfying multiple criteria (e.g., yield, plant type, grain color, root type, etc.) simultaneously; and 4) to provide the basis for the taxonomic classification of the materials.

The Unit has also collaborated in the training of the program's staff on experimental design and analysis methods and in providing consultation on research designs for the breeding, pathology, and physiology efforts.

Beef Production Systems Program

Biometrics personnel have visited the Carimagua research station with a view towards establishing a basis for support to the **Herd Systems Project.** A data processing system is being designed for this study which will generate large volumes of data over the course of the next few years. Data analysis services have been provided to the animal health, nutrition and husbandry components of this research project. Preparations are being made to establish the special computer programs required to analyze this large integrated set of data.

The economics component of the beef program has been supported through the preparation of small computer programs to test certain hypotheses on technical coefficients and cattle populations in the Colombian Llanos.

The Unit has begun methodological research to adapt a certain class of research designs and analyses for experiments for the pastures and forages component of the beef program. This type of experiment is characterized by cost and management constraints, severe biological constraints on the structure of treatments for the multifactorial experiment and the desirability of estimating functional relationships for use in economic analyses. The class of designs to be adapted are response surface designs based on incomplete factorial experiments. The designs currently in the literature (and which have been tried on CIAT) have proven to be inadequate. Working with the program staff it is expected that satisfactory designs will be developed.

Cassava Production Systems Program

The Cassava Production Systems Program has been the principal client and collaborator for the Biometrics Unit. Included in these efforts have been the work to optimize the use of experimental resources, work to obtain more efficient research designs and field plot techniques and the work on the design and analysis of a longitudinal survey to achieve an "Agro-economic description of the Cassava Production Processes in Colombia." Preliminary results from these efforts are presented in the Cassava Program's section of this report.

Biometrics also provided research design consultations and data analysis services to the various components of the Cassava Program.

Maize Production Systems Program

Consultation and analyses were provided in testing the effectiveness and reliability of a scheme for the simple and rapid evaluation of protein quality in maize grains.

Station Operations

The Unit provided consultation and engineering computations in adjusting multivariable nonlinear functions for an empirical study of tractor tire designs for operations in mud.

Swine Production Systems Program

The Unit provided data analyses support to the program's experimental work and computer support for the optimization of least costs balanced rations for swine using linear programing methods.

Capital Budget Analysis

At the request of the Director General, the Unit collaborated with the administration and the comptroller's office in establishing a computer-based accounting system for the capital expenditures related to the construction and equipping of CIAT's facilities.

Training

Training has been the principal function of the Biometrics Unit. Since personnel trained in statistics and computing are scarce in Colombia (as elsewhere in the Latin American tropics), the unit has provided in-service training to its staff. The Unit has also provided over 60 hours of formal lecture time to: a) the center's associated and assistant economists on the design and execution of sample surveys; b) the associated and assistant personnel of the commodity programs in the design and analysis of experiments; c) the crop and seed production specialists training programs on the design and analysis of experiments; and d) to the livestock production specialists training program on methods for making decisions from research results.

Collaboration with the Instituto Colombiano Agropecuario: Information Systems Division

The collaboration with the Systems Division of the Institute is a principal foundation for CIAT's biometrics and data analysis services. The Institute has provided CIAT with the consultation services of its staff, and CIAT has also provided consultation and data processing services to the Institute particularly with regard to the analysis of base line data for the Institute's rural development projects.

The collaborative efforts are based on sharing of scarce resources such as professional personnel, computer programs, systems for data analysis and computer time. A highlight of these efforts was the establishment of the University of North Carolina "Statistical Analysis System" at the computer centers of the National Administrative Department for Statistics (DANE) and of the Universidad Nacional de Colombia. This system has already been used to perform many of the analyses reported herein.

It is expected that the collaboration will continue to generate resources which should help both institutions obtain more timely and complete results from their research and operations.

Organization and Functions of the Biometrics Unit

The Unit is organized as a central service unit responsible for providing consultation and data analysis services to all of CIAT's research and training activities. These services are provided out of the Unit's own budgeted funds at no cost to the research or training programs. In the development of the Unit, it is expected that capability will be developed or improved in the following areas:

a) Design and analysis of sample surveys,

b) Experimental designs and analyses,

c) Epidemiology (animal and crop diseases),

d) Production functions and response surface designs,

e) Mathematical modeling,

f) Information system,

g) Multivariate analyses,

h) Training in all of the above.

While the biometrics personnel attempt to provide these services on whatever basis any CIAT scientist or trainee should request them, the services are more effective when the biometrics staff participates with the scientists in all phases of planning the research. These include but are not limited to:

a) The specification of the scientific questions to be answered in the context of the overall objectives of the proposed research,

b) Specification of the domain of impact or desired generalizability of the research,

c) Experimental or survey design and field methods,

d) Data collection and recording methods,

e) Data analysis plan,

f) Interpretation of results.

The scientists and trainees who invite the participation of the biometrics staff in all of these phases of their research receive priority service from the units.

The Unit is equipped with a Monroe 1860 "desk top" computer for statistics computations required by most crop experiments. Large experiments, animal experiments, economic analyses, surveys and the like require the use of large scale computers; through the ICA collaborative arrangement the Unit utilizes either an IBM 370 Model 145 or an IBM 360 Model 44 computer in Bogotá.

WEED CONTROL

In cooperation with the Crop Production Specialist Training Program, the use of postemergence herbicides in dry beans and the preemergence use of trifluralin plus atrazine in sorghum were investigated.

A postemergence application of bentazon (1 kg/ha in the 5 to 6-leaf stage) increased the yield of dry beans 52 per cent (903 kg/ha) above that of the control plot. A preemergence treatment with linuron plus fluorodifen (0.5 + 2 kg/ha) produced the highest yield (967 kg/ha) and 2,4-DB was extremely toxic at 0.75 kg/ha in both the 2 to 3 and 5 to 6-leaf stage. Bentazon controlled only broadleaf weeds and may become the first highly selective postemergence herbicide for beans available to farmers.

The most widely used preemergence herbicide in corn and sorghum is atrazine, and its repeated application may result in residue accumulations to toxic levels for rotation crops such as soybeans, rice and dry beans. One solution is to use lower atrazine rates in combination with less residual compounds. A persistent grass weed, **Rottboellia exaltata,** is resistant to atrazine and susceptible to trifluralin, a product which is not selective to corn or sorghum when soil incorporated as recommended. The use of trifluralin and atrazine in a preemergence mixture was studied to determine its selectivity and effectivity in sorghum.

Field trials have shown the combination to be completely selective with 0.8 + 0.72 kg/ha atrazine and trifluralin, respectively, giving good weed control. Screenhouse trials have shown that rainfall immediately after planting up to 25 mm is selective in medium to heavy textured soils. However, in light textured soils, sorghum was injured when 25 mm of rain fell soon after application. **Rottboellia** was controlled by preemergence trifluralin application in screenhouse conditions.

Rainfall soon after the application of postemergence herbicides often reduces their effectiveness. The effect of time after applying glyphosate when rain fell and its ability to control weeds was studied. **Paspalum fasciculatum** (bullgrass) was used as the test plant. After spraying 1 or 2 kg/ha glyphosate, 25 mm of simulated rain fell immediately or 0.5, 1, 2, 4, and 8 hours later. The rate of glyphosate penetration appears to be related to its concentration, i.e., at higher rates there is more rapid penetration. Thus, if rainfall appears certain and glyphosate must be applied, the rate should be increased.

In another experiment, the residual life of atrazine, an excellent herbicide widely used in corn and sorghum, is being monitored. After two consecutive applications, 0.45 ppm atrazine were detected in the 0 to 7.5 cm soil zone. This was sufficient to injure oats seriously. No residues were found below

7.5 cm. When atrazine was applied in combination with alachlor at the rate of 1 kg/ha for two seasons, 0.2 ppm had accumulated. This caused slight injury to the oats. Thus, the use of atrazine in combination with other herbicides greatly reduces the carryover of residues.

In many postemergence herbicide applications, a small amount of a surfactant to increase penetration and activity by altering the physical characteristics of the spray solution is recommended. However, little is known about how environmental conditions affect their behavior. Also there are many products commercially available but no comparative information exists to indicate which one is the best under varying tropical conditions. Thus, as a masters' thesis, a Colombian student investigated the influence of temperature and humidity on the effectiveness of different surfactants in controlled environment chambers. Environments of high temperature-high humidity, high temperature-low humidity and low temperature-low humidity were selected because they exist in the Andean zone of South America.

In general, the action of the five surfactants decreased in the following order: high temperature - high humidity, high temperature - low humidity, low temperature - high humidity. There are marked differences for each surfactant between the three environments.

Th surfactants in themselves were somewhat phytotoxic in concentrations of 0.5 and 1.0 per cent (v/v basis). The rate of 0.5 per cent was equally as effective as higher concentrations in all environments and, therefore, the use of higher rates is not justified.

AGRICULTURAL ENGINEERING and STATION OPERATION PROGRAMS

This report summarizes the major objectives and achievements of the Agricultural Engineering, Experiment Station Development, and Station Operations Programs for the period September 1968 to December 1973.

Experimental field layout, Development and Operations

Aerial photographs and plans based on aerial photographs were made in 1968 (Figure 1). Bench marks were established on a 300 by 300 meter grid and plane table mapping gave topography accurate to 25 cm contour intervals. These plans served as a basis to lay out the roads, drains and locate wells and irrigation systems.

Experimental field layout and development as of September 1973 is shown in Figure 2. Accomplishments to date include the following: 520 hectares cleared of scattered trees and brush; 36 hectares cultivated without being leveled; 264 hectares leveled for irrigation and leached of excess salts, 34 hectares developed and fenced for grazing trials; 100 hectares in commercial pastures; 36 hectares in buildings and grounds around the buildings; 4.5 hectares of Tifgreen lawn and shrubs established; 50 hectares in roads, drains, fences, canals and field boundaries; 35 kilometers all weather gravel roads constructed. 43 kilometers of drains excavated; 35.5 kilometers of fence erected; 22.5 kilometers of earthlined irrigation canals made; 6 kilometers of irrigation canals lined with concrete; 36,000 cubic meters of reservoirs constructed to retain reserve irrigation water; 2,000 concrete pipes installed for roads, crossing drains and canals; and 25,000 plants of "Fique" **Furcraea cabuya** planted along drains, fences, and railroads to aid in weed control and to serve as barriers.

Organizational and staffing accomplishments have included a tractor pool, a unit work contract system and labor pool, and selection, training and supervision of personnel to manage and operate the station. As of the end of 1973, the entire operation was managed and staffed by Colombians.

During 1973 a total of 400 hectares of land was prepared, planted, irrigated and harvested by the various research programs. Extra land and equipment time was used by Station Operations to develop the station, control weeds, obtain experience and cost data on commercial production and to earn income.

During 1972 and 1973, the field operations produced 470 tons of rice on approximately 80 hectares. This project leveled the fields for irrigation, leached out excess salt, provided training for rice and crop production trainees, and gave experience and data necessary to develop a method of **Continuous Rice**

Aerial photographs of CIAT's headquarters near Palmira, Departamento del Valle, Colombia.
Above: **August, 1968.** Below: **September, 1973**

Production complete with necessary modified equipment. This method has been described in a how-to-do-it bulletin to be published in 1974.

During 1972 and 1973, assistance was given upon request to INIAP in Ecuador in the development and operations activities on the Boliche, Portoviejo, and Pichilingue Experiment Stations. The directors of these stations have visited CIAT's center and also ICA's Turipaná station. The development of the road, drain, and irrigation systems of Boliche; the drainage and irrigation pump; and the flood protection levees have been the topics of major interest.

A concentrated effort was made in 1973 to assist in the development and operations of the ICA-Turipaná Research Center. Tractors and equipment have been purchased for the ICA-CIAT program. Two former CIAT agricultural engineering trainees are working on the station. The continuous rice production system has been already implemented and 67 hectares of land leveled, irrigated and planted.

A proposal for the development of the entire 1,400 hectares of the station has been made by the ICA Regional Director and supported by the ICA Director General. Loans from the Caja Agraria have been used for station development. The harvest from rice fields was sold and used to repay part of the loan.

Physical plant layout, Development and Operations

In late 1968 and 1969 the basic decisions were made on the physical plant. An architectural firm, consulting engineers, and contractors, were selected and made responsible directly to the Director General for the major buildings and their interior services. The agricultural engineer and physical plant superintendent took over the responsibility for services not directly contracted or those in which CIAT was best equipped to carry out.

Air drying of cassava in vertical wire mesh trays

Major accomplishments directly contributing to the development and operation of CIAT included the following: Establishing of maintenance shops, modifying old farm buildings to serve as offices and laboratories, development and operation of a motor pool with more than 100 vehicles, supervising the drilling of five major and ten small wells, supervising erection of 2,000 KVA high tension electric mains, paving of main entrance and service areas, installation of lighting system on grounds, design and construction of three large cold storage rooms, erection of four grain storage bins, installation and operation of a rice mill, construction and operation of a sewage treatment plant, and modification and repair of new construction after completion of the general contract.

Related activities included installation of the telephone and radio systems, organization and supervision of security and janitorial services, construction of prototype equipment for research projects, and repair and modification of research equipment and installations.

Training Program

A training program has been carried out according to the needs of CIAT. A major effort has been to select and train personnel vital to CIAT's development and operations. These are listed as employees and not trainees but the training effort was still necessary for CIAT's operations.

There is a shortage of persons qualified in experiment station development and operations. The work covers a broad range of activities. No short formal training is available to develop qualified personnel even though there is a real need. CIAT has attempted to fill this need in several ways.

At the initiation of CIAT's program in 1969, one agronomist was trained as an intern by working on all station development activities for more than one year. He was later joined by a second agronomist and both were supported by CIAT to complete master's degrees in agricultural engineering, with their research and thesis work on projects related to drainage and machinery. Since completing their degrees in 1973, they have been employed in the development and operations of the ICA-Turipaná Station, in 1973.

Six recently graduated agricultural engineers received intern training for six months in 1971. One was employed by ICA in experiment station operations and one was employed by INCORA to work in an irrigation and drainage project. Two were employed by universities and one by a technical school.

During 1973 short periods of observation were provided to three directors of the INIAP Experiment Stations in Ecuador. They are now searching for young Ecuadorian graduates to employ and to send for training so that they will have trained assistants.

Agricultural engineering students of the Universidad del Valle and the Facultad de Agronomía de la Universidad Nacional have been employed as temporary workers while on vacation. They are first assigned to work as irrigation laborers, tractor driver assistants, mechanic helpers, topography crew members, etc. They keep a record and make a report on their work which is accepted as part of their degree training and serves as an experience reference.

TRAINING and COMMUNICATION

Completion and dedication of the new physical facilities provided opportunity for closer integration of the behavioral science-oriented approaches to training and communication with the multidisciplinary agricultural and development programs of the organization.

Although trainees had been housed in the new training quarters from September 1, the conference housing facilities were used for the first time during Dedication Week; and the new simultaneous interpretation and other conference equipment had first use on Dedication Day.

The Information Services staff not only planned and produced a number of publications appropriate to the events, but worked closely with the two major local newspapers, each of which published special sections on CIAT for circulation on Dedication Day. The occasion was marked also by extensive television, film and radio coverage, with the United States Information Agency producing a film of the event for circulation and use on television around the world.

Growth in the commodity programs was reflected in increases in the number of trainees enrolled during the year, 159, and active planning for a series of international seminars and symposia early in 1974.

Funds for the core and special activities in training and communication came from the W.K. Kellogg Foundation, this being supplemented by additional funds from the core program plus support from the Interamerican Development Bank for the production specialist training programs and the regional seminar on beans. To an increasing extent, national agencies provided direct support for a number of trainees, the most notable being the Government of Ecuador's complete funding of a special training program on seed production and certification.

Of particular significance was the opportunity to expand the research and evaluation activities to include a comprehensive study of the CIAT training program with particular emphasis on the training of postgraduate interns. Results of the study, being made available in early 1974, will provide useful guidelines for improving the entire training process from selection to utilization.

CIAT accepted the first of what may become a series of undergraduate fourth year Dutch students in rural sociology who will do their field work in rural areas in cooperation with CIAT. This arrangement with Wageningen University is similar to that which has existed for the past three years in which students in animal science come to CIAT for 6 to 9 months.

Also encouraging has been the growth in interest among doctoral candidates and their degree-granting institutions for the candidates to spend from one to two years at CIAT, engaged in their thesis research.

TRAINING IN ANIMAL SCIENCE

Specific training activities in beef and swine are reported in their respective sections (see pages 55 and 142, respectively).

TRAINING IN PLANT SCIENCES

Commodity programs in the plant sciences continued to move toward their established objectives in training and research. Numbers of trainees from countries outside Colombia increased substantially in pace with the international contacts established by the senior staff. Seventy per cent of the research interns and production specialists came from other countries.

Two additional training assistants received short-term appointments to the training staff: Mr. Néstor Tafur, agronomist, as a field instructor for the Crop Production Specialist Training Program (CPSTP) at Turipaná; and Mr. Guillermo Vallejo, seed specialist, as field instructor for the seeds course (SPCSTC) at CIAT.

Specific training activities related to the commodities are described in the respective commodity sections. In summary, the number of man-years of training provided in each of the commodities during the year were: Cassava 9.3, Rice 8.9, Field Beans 8.0 and Maize 4.7

Early in 1973, CIAT assisted INIAP, in Ecuador, to organize and conduct a five-month course in corn production for eight agronomists, with the base of operations in Pichilingue, but using farms in the surrounding area.

Crop production specialist training programs

In previous years this program concentrated its efforts on the organization and conducting of a 12-month course (CPSTP) on production of crops, primarily beans, soybeans, rice, corn, sorghum and cassava. Two such courses had been completed and a third one was started on March 1, 1973. This year, in addition, a new kind of production training was initiated on September 1, in the form of a Seed Production and Certification Training Course (SPCSTC), limited primarily to the same crops as covered in the CPSTP.

Crop production specialist training course (CPSTC)

The process of interviewing and admitting candidates initiated in the previous year was completed in January, 1973 with the admission of 20 participants from five countries: Colombia (3), Dominican Republic (8), Ecuador (7), El Salvador (1), and Mexico (1).

Recruiting action concentrated on two countries, the Dominican Republic and Ecuador, where there was evidence of genuine interest to adopt the CPSTP model for future in-country programs to muitiply this effort.

The CPSTP seeks and tests innovations and methodology of training through an approach that emphasizes the acquisition of up-to-date knowledge and skills with emphasis on learning by doing. It uses a combination of field activities in the real life of agricultural commercial production and classroom conference-discussion sessions led by specialists in various commodities and disciplinary fields. Presently, emphasis is being placed on the application of technology, economics and communication to small-and medium-scale farm situations.

An initial 6-month phase of instructional field and classroom experiences on the CIAT farm, under fairly controllable management conditions, preceded a second 6-month phase in which the trainee acquired further knowledge and expertise right on farmers' fields of small- and medium-sized operations on the North Coast of Colombia.

The distribution of time during the first six months was 60 per cent to field operations and 40 per cent to conference-discussion sessions on subject matter of crop technology, field experimentation, agricultural economics-farm management and communication. Fifty-eight specialists from CIAT, ICA and other institutions provided 346 hours of instructional inputs in these conference-discussions. The 20 participants were divided into five groups, and each group was assigned a 10-hectare "small farm" within the CIAT grounds. Each group operated its farm with production of fields of beans, rice, corn, sorghum and soybeans. Separate fields were assigned for cassava and vegetables.

The economic aspects of crop management were stressed together with the utilization of technology throughout the production cycle of the crops and a cost/benefit analysis was made at the end to set the stage for critically evaluating the crop management decision-making process, in the production system of the small farms.

Toward the end of this first 6-month phase, the group carried out a communication exercise in a rural development project in the Cauca Valley and later visited a second similar project in the Río Negro area of Antioquia.

A major change in the course this year constituted the transfer, in September, of its second 6-month phase to the area near Montería, on the North Coast of Colombia. The Turipaná research center of ICA serves as a residence and operational headquarters. The emphasis on field activities was increased to 72 per cent of the time. Friday and Saturday mornings were devoted to conference-discussion and planning sessions on the field problems encountered in technical, socio-economic and cultural issues.

Moreover, the most important aspect of this second phase is that training takes place right in the farmer's real-life ecologic, socio-economic and cultural environment that constitutes the "agricultural production systems." Each trainee chooses from 5 up to 20 farmers on individual or cooperative farms to work with and to learn from the farmers' experiences.

Although this course deals mostly with production technology through a communication approach, the pragmatic aspects of scientific experimentation constitute an important part of the activities. Trainees conducted replicated experiments on their assigned CIAT plots of land and later on the farmers' fields on the North Coast with the objective of being trained in "validation of technology" to insure that the technology offered for adoption can increase productivity for the farmer.

Seed production and certification training course (SPCSTC)

In response to a request from INIAP, Ecuador, this 6-month instructional experiment was started in September, 1973. Six trainees participated, all from Ecuador. The same training approaches, as in the CPSTP, were used with heavy emphasis on providing opportunities for the acquisition of new knowledge and skills in some 9 hectares of seed production plots, entirely managed by the trainees under supervision of the instructors, as well as on commercial seed farms in the Cauca Valley.

The cooperation of the Seed Certification Program of the Colombian Agricultural Institute (ICA) was obtained for substantial instructional inputs. In addition, four important private firms producing, processing and distributing seed in the area gave assistance and allowed for periods of practice on their fields and plants. Twenty-eight specialists in various disciplines participated in lecture-discussion sessions (occupying one-fourth of the course time) and field exercises.

COMMUNICATION RESEARCH AND TRAINING

The activities of this social sciences unit were dedicated to training, evaluation research and consultation. Courses for production specialists organized by CIAT and the corn production course organized by INIAP in Pichilingue, Ecuador, were supported. Training programs and seminars were evaluated. Research was continued on the process of adoption and diffusion of new rice and corn varieties. Personnel participated in the consultation on the strategies for change in the small farm areas in connection with the Asociación Latinoamericana de Desarrollo Rural.

Training

With the purpose of giving an integrated approach to the teaching of social sciences in the postgraduate courses for production specialists, part of the time of a research associate and of a research assistant was dedicated to reviewing the methodology and programming of the courses and to the production of teaching materials on the decision-making process, the concepts of information, communication, sociology, economics and administration. This effort provides trainees with a frame of reference on the role of technology in agricultural development.

The understanding of the agricultural realities also involves an understanding of rural population. For this reason, a substantial part of the social sciences support was carried out during the months in which the trainees worked directly with farmers.

The preparation of the trainees for direct work with the farmers of the North Coast of Colombia was complemented with exercises carried out in the Proyecto de Desarrollo Rural del Norte del Cauca and in the Proyecto de Desarrollo Rural del Oriente Antioqueño. The trainees exchanged information and experiences with the three groups that integrate these projects: the farmers, the technicians and the representatives of the institutions involved in agricultural development.

In 1973, the crop production specialists had 120 class sessions in social sciences. The trainees received written material on about 80 subjects.

Evaluation

The Unit evaluates seminars and training at CIAT. As far as the seminars are concerned, the activities to measure achievement have been directed at the degree of communication and cooperation existing among the participants in those events. The Unit tried to 1) concentrate the attention of the participants on the objectives; 2) to learn opinions about the restrictive factors, priorities, problems and solutions related to the main subjects of the seminar in question; 3) to identify specific ways of inter-institutional and international cooperation through which the efforts in agricultural and livestock development can be coordinated and supported; and 4) to determine the failure and the success in the organization of seminars and courses in order to improve future events.

Research on Training

CIAT monitors and studies the progress of its various training programs in several ways. Most are casual and fairly limited in scope. In 1973 a larger study of training was undertaken at CIAT's invitation by a person funded by the Foreign Area Fellowship Program.

The study concentrated on three main populations: trainees at or near the end of their period of study at CIAT, those who had been back in their home countries for a year or more and thus with a view tempered by experience, and the senior staff who had directly supervised the majority of the trainees. Both the production specialist groups and the research/production interns were considered. Major focus was given to the research/production interns in the overall study as they are the largest group and represent the widest variety of training experiences.

All trainees falling within these definitions were taken as the study population and data was obtained on 74 per cent. In addition to findings on questions on specific items, indices of utilization and satisfaction and a combination of the two, were constructed from a series of questions. Some of the major findings include the following:

Recruitment. The major problem identified in recruitment was the lack of and vagueness of pre-interview information for potential candidates and institutions.

Selection. There was a notable shift in the importance of the sending institutions in selecting more recent trainees (those just departing) and those selected earlier (the former trainees). Whereas 27 per cent of the former interns thought their institutions had had a primary role in their selection, this rose to 43 per cent among the departing interns. Similarly, 24 per cent of the early trainees thought that their institutions had no involvement in the process but this dropped to less than 2 per cent among those departing.

Training. The participants in CIAT's training program indicated they would prefer more orientation on their arrival at CIAT, especially to the programs and objectives of the institution as a whole and to its personnel and physical plant. Many would like to see more direct involvement with the smaller farmers, more study of their methodologies and possible improvements at that level, and greater opportunity for trainee participation in such work. The use of some junior staff in training roles seems to have been beneficial for both the trainees and the staff members and well received by the trainees.

The trainees were generally satisfied with the length and level of training. They most commonly indicated the lack of a specific training plan as the greatest obstacle to getting the most out of it, followed by lack of adequate personal relationship with the supervisor.

Practical experience was by far the dominant choice among all trainees as the most valuable aspect of the training period. A year in the field seems to generate an increasing appreciation of the practical experience at CIAT as the most valuable part of the training period; i.e., while only 24 per cent of the departing trainees cited this as most valuable (still the biggest single category); 38 per cent of those in the field for a year or more put it at this level. The rating for experience in research dropped from 14 to 6 per cent (which may suggest that many trained in research are now in extension, production or administrative roles).

Post-CIAT activities. The types of institutions in which former trainees are now occupied include: Government agricultural institutions, 67 per cent; agro-business, 11 per cent; bank or credit institutions, 6 per cent; and university or college, 17 per cent.

At least one fifth of the trainees indicated their positions are highly responsible and involve the supervision of many people. About half list research as one of their primary activities followed by administration, extension and training.

The trainees gave a high evaluation of the opportunity while at CIAT to meet other workers in the region. Ninety-three per cent indicate they have since had some contact with such new acquaintances and 74 per cent of these were to some extent professional in nature.

Utilization. In estimating the degree to which they believe they are applying their training in their work, 59 per cent indicated extensively, 27 per cent said moderately, 10 per cent thought little was applicable and 4 per cent none. Those giving little or none included some dissatisfied with the training and others in activities where their training is superfluous.

Ninety-two per cent felt they had multiplied the effect of their training to a moderate or large extent.

CONFERENCES AND SYMPOSIA

Conferences and Symposia became actively involved in the preparations for Dedication Day Activities centered around making ready the new facilities, consisting of six conference rooms with capacities ranging from 20 to 150 participants, an amphitheatre with fixed seating for 192 for special lectures and exhibits, and large registration, administrative, exhibit and coffee-break areas.

By the time of inauguration, the new facilities were almost completely furnished and equipped with a six-channel simultaneous interpretation system, a recording studio and audio-visual equipment.

Before these installations were operational, however, a large international seminar was carried out at the Inter-Continental Hotel. On February 26 through March 1, participants met for a seminar on "The Potentials for Field Beans and Other Food Legumes in Latin America and the Caribbean."

From an administrative point of view, this seminar was probably the most successful of some 10 international events held to date. It was rounded off by an efficient evaluation of objectives and accomplishments, a professional editing and publishing of proceedings, and a summing up of conclusions and recommendations which was followed up by a post-seminar meeting of a special committee to identify the course of action.

October 12 also marked an important turning point for Conferences and Symposia. The new facilities that were dedicated on that day immediately set a new perspective on the program's activities. It was then in the position to broaden its national and international scope to the extent that it could make them available for international seminars and symposia. More important, it opened the field for CIAT's program leaders to plan ahead for future opportunities to bring together scientists, policy makers, administrators and other people who are active in their respective commodities, for the active interaction, exchange of experiences and diffusion of decisions, that make up such an important part of CIAT's mission.

In early December a national Seminar on Food and Nutrition, sponsored by UNICEF, was held at CIAT with more than 150 participants.

The large interest shown in the conference facilities, both within and outside CIAT, has led to the establishment of a policy by which they will be assigned, firstly, to the supporting of CIAT's programs and objetives and, secondly, to use by organizations with similar aims; namely the agricultural, social and economic development of countries.

INFORMATION SERVICES

Information Services activities increased in 1973 as a result of the expansion of CIAT's research and training programs. This unit also served the expanded activities in conferences and symposia and other operational units of CIAT.

The established publication series are: technical bulletins, information bulletins, reference bulletins, the seminar series, the newsletter "Noti-CIAT" and the annual report. Most of these series appear in Spanish and English. A weekly internal information media, "Citas del CIAT", has circulated among CIAT's employees for more than two years.

The preparation of charts, graphs and other visual aid materials increased notably in 1973. The production of printed material also showed a marked increase in the year, both of internal documents and of CIAT's series of publications.

The Photography Unit processed nearly 800 orders; some of these individual orders represented the production of 50 or more slides or enlargements. A classified negative and photo contact collection has been started. Also, a classified collection of color slides is being made.

All Information Services personnel were deeply involved in CIAT's inauguration activities. There was an extraordinary demand for editorial, artistic and printed work in preparation for the inauguration. In connection with this event, several press releases were prepared and distributed and, on Inauguration Day there was adequate handling of local press, radio and television representatives.

Information Services cooperated with two Colombian television networks in the production of two documentary films, one about CIAT itself and the other about all CIAT-ICA research programs. The latter film will be finished early in 1974.

Table 1. **CIAT Trainees appointed and/or completed training. January 1, 1973 to December 31, 1973**

By Category of Training, Country, and Field

Name	*Country*	*Program/Subject*	*Months Training Completed in 1973*	*Status as December 1973 (C = Completed)*
Postgraduate Interns				
Arias, Diego	Colombia	Cassava/Ag. Economics	1½	C
Argel, Pedro José	Colombia	Beef/Past. & Forages	2	C
Armijos, Fernando	Ecuador	Beans/Plant Pathology	7	C
Aguilera, Rolando	Guatemala	—Soils Microbiology	6	C
Betancourt, Luz Helena	Colombia	Maize	2	C
Badía, Armando	Honduras	Rice	5	C
Buestán, Héctor	Ecuador	—/Beans	5	C
Castro, Edgar	Colombia	Maize	2	C
Calderón, Humberto	Colombia	Cassava	2	C
Cavallo, Renato	Italy	—/Soils Microbiology	2	C
Cañola, Gonzalo	Colombia	Maize/Production Systems	6½	C
Daccarett, Isa Víctor	Honduras	—/Beans	5	C
Escobar, María Delia	Colombia	Beef/Past. & Forages	4	C
Florez, Zacarías	Bolivia	Swine	4½	C
Fuentes, Margarita	Mexico	—/Soils Microbiology	5	C
Guerrero, Marco Fidel	Colombia	Swine	5	C
Herrera, Carlos A.	Colombia	Cassava/Plant Pathology	1	C
Hurtado, Joaquín	Colombia	—/Weed Control	2½	C
Lovato, Luis Alberto	Brazil	—/Weed Control	2½	C
Leiva, Oscar René	Guatemala	—/Beans	2	C
Mejía, Luis Omar	Colombia	Swine	1	C
Miranda, Beatriz	Brazil	Rice	3	C
Mayeregger, José	Paraguay	Rice	2	C
Moreno, Juan Francisco	Ecuador	Maize	5	C
Molina, Hugo	Colombia	Cassava/Ag. Economics	9	C
Ortega, José César	Honduras	Rice	5	C
Oliveros, Beatriz	Colombia	Cassava/Plant Pathology	8	C
Posada, Luis Fernando	Colombia	Maize	2	C
Pérez, Jorge	Mexico	Beef/Past. & Forages	5	C

Name	Country	Program/Subject	Months Training Completed in 1973	Status as December 1973 (C = Completed)
Postgraduate Interns				
Rosas, Juan Carlos	Perú	Cassava/Production Systems	12	C
Scherer, Clovis	Brazil	Rice	2½	C
Sandoval, Antonio J.	Colombia	Maize/Production Systems	4½	C
Veloz, Alfredo E.	Ecuador	—/Weed Control	1	C
Vera, Vinicio	Ecuador	—/Entomology	3	C
Vidarte, José Ignacio	Colombia	—/Social Sciences	10	C
Varón, Uldarico	Colombia	Cassava/Ag. Economics	10½	C
Zuluaga, Guillermo	Colombia	Maize/Production Systems	6½	C
Alburez, Carlos	Guatemala	Rice	3	—
Castedo, Antonio	Bolivia	Swine/Production Systems	3	—
Camacho, Carlos Alberto	Perú	Swine/Production Systems	3	—
Dos Santos, Daniel C.	Brazil	Rice	4	—
De León, Rony	Guatemala	Swine	3	—
Escobar, Rodrigo	Colombia	Cassava/Ag. Economics	1	—
Gutiérrez, Uriel	Colombia	Beans/Ag. Economics	6	—
Gianella, Héctor	Bolivia	Beef/Animal Pathology	3	—
Kueneman, Eric	USA	Beans	6	—
Moscoso, Patricio	Ecuador	Swine	3	—
Mesía, Rubén	Perú	—/Weed Control	3	—
Oliva, Francisco	Ecuador	Swine	9	—
Otero, Carlos Eduardo	Colombia	—/Station Operations	6	—
Quintero, Bolívar	Ecuador	Beef/Past. & Forages	6	—
Teixeira, Geraldo	Brazil	Rice	2½	—
Zambrano, Oswaldo	Ecuador	—/Soils Microbiology	5	—
Research Scholars				
Agudelo, Fernando	Colombia	—/Entomology	12	C
Calderón, Fernando	Costa Rica	—Swine	5½	C
Lasso, Héctor	Colombia	—/Ag. Engineering	3	C
Urrea, Augusto	Colombia	—/Ag. Engineering	3½	C
Alvarez, Camilo	Colombia	—/Ag. Economics	12	—
Castaño, Jairo	Colombia	Rice/Plant Pathology	4	—
Celleri, Walter	Ecuador	Swine/Nutrition	3	—
García, Adriano	Colombia	—/Ag. Economics	7	—
Guzmán, Víctor Hugo	Colombia	Beef/Animal Pathology	12	—
Lucena, Juan Manuel	Perú	—Weed Control	12	—
Rivas, Libardo	Colombia	—/Ag. Economics	12	—

Name	Country	Program/Subject	Months Training Completed in 1973	Status as December 1973 (C = Completed)
Research Scholars				
Rueda, Camilo	Colombia	Beef/Animal Health	3	—
Santos, Jorge	Colombia	Swine/Nutrition	2	—
Villegas, Gustavo	Colombia	—/Horticulture	12	—
Zuluaga, Hernando	Colombia	—/Ag. Economics	12	—
Research Fellows				
Ferguson, John	Australia	Beef/Past. & Forages	8	C
Roa, Gonzalo	Colombia	—/Ag. Engineering	7	C
Fitzsimons, John	United Kingdom	—/Communication	12	C
Danso, Seth	Ghana	—/Soils Microbiology	5	—
Gabela, Francisco	Ecuador	—/Weed Control	10	—
Ikotun, Babatunde	Nigeria	Cassava/Bacteriosis	7	—
Kelly, James	United Kingdom	Beans	10	—
Kleeman, Gunter	Germany	Swine	1½	—
Leihner, Dietrich	Germany	Rice/Physiology	12	—
Schultze-Kraft, Rainer	Germany	Beef/Past. & Forages	3	—
Stolberg, Alexander	Germany	Beans/Production Systems	½	—
Wholey, Douglas	United Kingdom	Cassava	12	—
Production Specialists				
Alvarez, José A.	Dominican Rep.	LPSTP*	4½	C
Campos, José Yezid	Colombia	LPSTP	4½	C
Camacho, Antonio José	Colombia	LPSTP	4½	C
Cuéllar, Adalberto	Bolivia	LPSTP	3	C
Echeverry, Huberman	Colombia	LPSTP	4½	C
Gil, Juan	Dominican Rep.	LPSTP	4½	C
Guzmán, Silvio	Colombia	LPSTP	1	C
Morel, Juan Andrés	Paraguay	LPSTP	4½	C
Narváez, Ramón	Honduras	LPSTP	4½	C
Olvera, Eduardo	Mexico	LPSTP	4½	C
Páez, Pedro Alirio	Colombia	LPSTP	4½	C
Parra, Alberto	Colombia	LPSTP	4½	C
Ronquillo, Severo	Ecuador	LPSTP	4½	C
Rodríguez, Antonio	Paraguay	LPSTP	4½	C
Sierra, Reyes Manuel	Colombia	LPSTP	4½	C
Santillán, Raúl	Ecuador	LPSTP	7½	C
Villarreal, Ricardo	Mexico	LPSTP	4½	C

* Livestock Production Specialist Training Program

Name	Country	Program/Subject	Completed in 1973 Months Training	December 1973 Status as (C = Completed)
Production Specialists				
Acebedo, Fernando	Colombia	LPSTP	3	—
Alva, Alejandro	Perú	LPSTP	3	—
Arias, Ramón	Dominican Rep.	LPSTP	3	—
Bogado, Benigno Andrés	Paraguay	LPSTP	3	—
Bardales, Enrique	Perú	LPSTP	3	—
Berganza, Maximiliano	Salvador	LPSTP	3	—
Carrión, Freddy	Ecuador	LPSTP	3	—
Cortez, Miguel	Bolivia	LPSTP	3	—
Montán, Tirso	Dominican Rep.	LPSTP	3	—
Ravelo, Guillermo	Dominican Rep.	LPSTP	3	—
Riveros, Antonio	Paraguay	LPSTP	3	—
Salazar, Jairo	Colombia	LPSTP	9	C
Velasco, Francisco	Bolivia	LPSTP	3	—
Villegas, Carlos	Colombia	LPSTP	3	—
Villalba, Juan Francisco	Paraguay	LPSTP	3	—
Florencio, Carlos D.	Dominican Rep.	CPSTP*	5	C
Guzmán, Juan Antonio	Dominican Rep.	CPSTP	5	C
López, Elías	Mexico	CPSTP	5	C
Rodríguez, Nelson	Dominican Rep.	CPSTP	5	C
Alvarado, Aquiles	Ecuador	CPSTP	8	—
Carcelén, Raúl	Ecuador	CPSTP	8	—
Bello, Carlos Nelson	Dominican Rep.	CPSTP	9	—
Castro, Luis Jorge	Colombia	CPSTP	9	—
Cea, Jaime	El Salvador	CPSTP	9	—
Camilo, Antonio	Dominican Rep.	CPSTP	9	—
Díaz, Rafael	Dominican Rep.	CPSTP	9	—
De León, Rodolfo	Dominican Rep.	CPSTP	9	—
Herrera, Fernando	Colombia	CPSTP	9	—
Jiménez, Ramón Antonio	Dominican Rep.	CPSTP	9	—
Livingston, Jorge	Ecuador	CPSTP	9	—
Pérez, Germán	Colombia	CPSTP	9	—
Ruiz, Arturo	Ecuador	CPSTP	9	—
Venegas, Fausto	Ecuador	CPSTP	8	—
Valverde, Félix	Ecuador	CPSTP	9	—
Veintemilla, Manuel	Ecuador	CPSTP	9	—

* Crop Production Specialist Training Program

Name	Country	Program/Subject	Months Training Completed in 1973	Status as December 1973 (C = Completed)
Alvarado, Juan Roberto	Ecuador	Seed Production	3	—
Balarezo, Sergio	Ecuador	Seed Production	3	—
Medrano, Néstor	Ecuador	Seed Production	3	—
Puga, Wilson	Ecuador	Seed Production	3	—
Quimi, Freddy	Ecuador	Seed Production	3	—
Sarmiento, Walter Iván	Ecuador	Seed Production	3	—
Special Trainees				
Amador, Ignacio	Colombia	Beef/Production	3	C
Bermúdez, Facundo	Ecuador	—Station Operations	2	C
Carvallo, Gustavo	Venezuela	—/Weed Control	½	C
Camacho, Daniel	Colombia	—/Electronics	2	C
Faber, Luitzen	Netherlands	Beef/Past. & Forages	7	C
Francillon, Philippe	France	Rice	1½	C
Gore, Tom	USA	Beef/Animal Health	2	C
Henández, Philippe	France	Beef/Production Systems	1	C
Jansen, Hendrik Jan	Netherlands	Beef/Past. & Forages	½	C
Lazier, John Robert	Canada	Beef/Past. & Forages	½	C
Matamoros, Jorge Eduardo	Ecuador	—/Station Operations	½	C
Olson, Timothy	USA	Beef/Animal Breeding	3	C
Pochard, Francois	France	Rice	1½	C
Rizo, Nora	Colombia	—/Library Science	3½	C
Shakya, Purna	Nepal	Maize	2½	C
Tascón, Angela	Colombia	—/Electronic Microscopy	5	C
Valverde, Francisco	Ecuador	—/Station Operations	½	C
Coppes, Adolph	Netherlands	Ag. Production Systems	3	—
Martínez, Jaime	Colombia	—/Ag. Economics	12	C
Morris, Roberto C.	USA	—/Social Science	12	C
Roeleveld, Alexander	Netherlands	Beef/Past. & Forages	5	—

Table 2. **CIAT Trainees appointed and/or completed training.**
January 1, 1973 to December 31, 1973

By Field of Specialization and Category of Training

	In-Service	*Production Specialist*	*Research Fellow*	*Research Scholar*	*Special*	*Total*
Cassava/Ag. Economics	4					4
Rice	8				2	10
Maize/Production Systems	3					3
Beans/Plant Pathology	4		2		4	10
Beef/Past. & Forages	1					1
Soils Microbiology	4		1			5
Beans	4		2			6
Swine	8		1	1		10
Cassava/Plant Pathology	2					2
Weed Control	4		1	1	1	7
Cassava/Production Systems	1					1
Entomology	1			1		2
Social Science	1				1	2
Beef/Animal Pathology	1			1		2
Station Operations	1				3	4
Livestock Production		32				32
Crop Production		20				20
Seed Production		6				6
Ag. Engineering			1	2		3
Communication			1			1
Cassava/Bacteriosis			1			1
Rice/Physiology			1			1
Cassava	1		1			2
Maize	4				1	5
Beans/Ag. Economics	1					1
Ag. Economics				4	1	5
Rice/Plant Pathology				1		1
Swine/Nutrition				2		2
Beef/Animal Health				1	i	2
Horticulture				1		1
Beef/Production					2	2
Electronics Maintenance					1	1
Beef/Animal Breeding					1	1
Electronic Microscopy					1	1
Library Science					1	1
Ag. Production Systems					1	1
TOTALS	53	58	12	15	21	159

Table 3. **Trainees processed by CIAT classified by field of specialization.**
January 1, 1973 to December 31, 1973

Trainee Category	*Field of Specialization*						*Total*
	Animal Sciences	*Plant Sciences*	*Agricultural Economics*	*Agricultural Engineering*	*Communication Social Science*	*Other Fields*	
In-Service	13	33	5	1	1		53
Production Specialists	32	26					58
Research Fellows	3	7		1	1		12
Research Scholars	5	4	4	2			15
Special	8	5	1	3	1	3	21
	61	75	10	7	3	3	159

Table 4. **Trainees processed by CIAT classified by country of origin**
January 1, 1973 to December 31, 1973

Country	*Training Category*					*Total*
	In-Service	*Production Specialist*	*Research Fellow*	*Research Scholar*	*Special*	
Colombia	21	13	1	12	5	52
Ecuador	9	16	1	1	3	30
Guatemala	4	—	—	—	—	4
Honduras	3	1	—	—	—	4
Italy	1	—	—	—	—	1
Bolivia	3	3	—	—	—	6
Mexico	2	3	—	—	—	5
Brazil	5	—	—	—	—	5
Paraguay	1	5	—	—	—	6
Perú	3	2	—	1	—	6
USA	1	—	—	—	3	4
Costa Rica	—	—	—	1	—	1
Australia	—	—	1	—	—	1
United Kingdom	—	—	3	—	—	3
Ghana	—	—	1	—	—	1
Nigeria	—	—	1	—	—	1
Germany	—	—	4	—	—	4
Dominican Republic	—	13	—	—	—	13
Salvador	—	2	—	—	—	2
Venezuela	—	—	—	—	1	1
Netherlands	—	—	—	—	4	4
France	—	—	—	—	3	3
Canada	—	—	—	—	1	1
Nepal	—	—	—	—	1	1
TOTAL	53	58	12	15	21	159

Table 5. Trainees in training during 1973, completed training in 1973, and continuing in 1974

Classification	*Completed in 1973*	*Continuing in 1974*	*Total*
In-Service Interns	37	16	53
Production Specialists	22	36	58
Research Scholars	4	11	15
Research Fellows	3	9	12
Special	19	2	21
TOTAL	85	74	159

LIBRARY and DOCUMENTATION SERVICES

In its three years of operation, the CIAT Library has accumulated an approximate total of 23,000 volumes. The journal collection at present stands at 1,100 titles received regularly. All these publications follow the areas of CIAT's specific interests.

The CIAT Library performs the regular functions of a specialized library but, in addition, it operates a Documentation Center initially specializing on cassava but gradually covering other fields. It also provides a current awareness service of journal tables of contents.

Documentation Center

For a traditional library, the "unit of information" is usually the book and thus the identification and descriptive cataloguing are restricted to the book title, author, and a general subject matter classification. A Documentation Center, on the other hand, goes into analyzing the content of publications with the purpose of producing a surrogate of the document (usually, some form of an abstract) together with an appropriate mechanism for retrieving information at a more specific level of description. This is usually accomplished through the use of key-words or descriptors. At CIAT, a Cassava Information Center is operated along these lines. Of the estimated 4,000 documents existing in the world on this crop, approximately 3,500 have been identified and purchased by CIAT and over 3,000 are already at the Library. The Center produces abstract cards on these documents and an interior-punched card system is used for retrieval. At present, approximately 1,500 cassava documents have been fully processed. Abstract cards are periodically distributed to about 100 cassava scientists in the world who then can purchase xerocopies of the original documents at cost. Retrospective searches are also provided on request. This service is partly financed under a special project arrangement with the International Development Research Center, IDRC, of Canada, limited to cassava. Through special agreements with some CIAT scientists, however, this service is being expanded to other areas, such as Animal Health and the Bean Program. The expertise of scientists themselves, therefore, is utilized by the CIAT Library for keywording documents and some additional clerical help to support other routine activities involved is also given by individual CIAT programs. A paper describing this service more thoroughly was presented by the Director of the Library at the Third International Symposium on Tropical Root Crops which took place in Ibadan, Nigeria, on December 2-9, 1973. In this paper an announcement was made of the possibility of subscribing to this service at a nominal annual cost.

Content pages

Frequently, scientists allocate only a minor portion of their time to library consultation. From the behavioral standpoint this is not surprising since the so called "information explosion" makes literature searching a tedious and frustrating experience for a scientist. Information specialists, therefore, should take charge of this task and release the scientist's time by filling in the bulk of his information needs.

On the basis of personal selection of those journals a scientist would regularly review, the CIAT Library and Documentation Services provide copies of journal contents tables so articles can be selected from them individually. Scientists mark on these copies those articles they would like to read and xerocopies are forwarded by the Library to them on a monthly basis. Therefore, this service builds a collection of reprints in each scientist's office which can be used regularly by him, his staff, and students.

During 1973, approximately 150 scientists from CIAT, the ICA Experiment Center at Palmira, and the ICA Veterinary Science Laboratories in Bogotá and Turipaná (LIMV and LIVET) received this service regularly. As a result, these scientists purchased over 5,000 articles during 1973 for a total of 52,973 pages of technical literature. The Library, on the other hand, distributed 19,172 copies of contents pages, thus giving a total of 72,145 pages xerocopied in 1973 within this service.

As a byproduct of this service bibliographies of those articles selected by a CIAT commodity team are published monthly for wider distribution in the world. These commodity bibliographies are called the **CIAT Library Letter** and, at present, four are being published: Beans, Beef, Swine, and Maize.

Further developments in documentation

Although the CIAT Library and Documentation Services have had initially as their primary goal that of serving CIAT scientists and students, the internationalization of these activities has followed almost as a necessary consequence. The volume of information produced in the world at present is such that it would be practically impossible for any information center alone to provide a totally comprehensive coverage. Consequently, there is a tendency to have informal networks among information centers on the basis of reciprocal interchange of information and services.

Recently, however, there have been several attempts to formalize these so called "invisible colleges" so as to avoid duplication of efforts and expand the coverage of literature to those areas presently being neglected precisely because of lack of a formal organization of networks. One such attempt is the AGRIS project, sponsored by FAO, in which CIAT participates as a Level 2 center.

AGRIS is organized into a central coordinating body located in Rome and two inter-connected networks of Level 1 and Level 2 centers. Level 1 centers attempt to collect and broadly classify all the literature produced in the world in agriculture, in order to make it available to Level 2 centers which will do the in-depth analysis by specialty and adopt a system of retrieval compatible to all other centers. Therefore, Level 1 centers are organized on a geographical basis, while Level 2 centers are chosen in terms of their capacity to analyze the literature by discipline or commodity.

In addition to participating in this type of international projects, documentation activities at CIAT are growing through **special projects.** A proposal has been presented to the Ford Foundation for the establishment at CIAT of an Agricultural Economics and Rural Development Information Center (CEDEAL) similar to the Cassava Information Center described above. Pending approval of this proposal, CEDEAL will start its operation early in 1974.

Publications

In addition to the **CIAT Library Letter** described above, the following series are being issued:

The CIAT Library Serials Catalogue. An annual publication describing the contents of CIAT's journal collection. This publication is the basis for the Contents Pages Service and for any copying service that the Library may offer.

The Bibliographic Series. A comence and awareness tool for scientists as well as a valuable selection criterion for other specialized libraries especially in Latin America.

The New Acquisitions List. A referprehensive Cassava Bibliography containing all cassava abstracts in the Cassava Information Center will be published in 1974 within this series.

FINANCE

Price Waterhouse & Co.

APARTADO AEREO 180 · CALI, COLOMBIA

April 1, 1974

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, 1973 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 and comparison of approved budget and actual expenditures for the year ended December 31, 1973, which are presented as supplementary information, and, in our opinion, these schedules present fairly the information shown therein.

We stated in our opinions on the financial statements for the years ended December 31, 1970 and 1971 that total Core program expenditures were understated by US$88,275 and overstated by US$155,783 in 1970 and 1971 respectively.

Price Waterhouse & Co.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

BALANCE SHEET

(Expressed in thousands of U.S. dollars - Note 2)

	December 31			
	1973	1972	1971	1970
ASSETS (NOTE 3)				
CURRENT ASSETS:				
Cash	139	272	450	959
Accounts receivable:				
Donors (Note 4)	497	499	471	446
Employees	69	73	29	16
Others	174	287	334	86
	740	859	834	548
Inventories (Note 1)	100	54	7	
Prepaid expenses	120	17		
Total current assets	1,099	1,202	1,291	1,507
FIXED ASSETS (Note 1):				
Revolving fund balances (Note 5)	42	64	51	44
Operating equipment	335	313	295	224
Research equipment	332	329	255	171
Vehicles	305	314	257	249
Furnishings and office equipment	378	369	236	145
Buildings	3,950	2,359	1,276	474
Micellaneous	135	116	68	45
In transit	883			
Total fixed assets	6,360	3,864	2,438	1,352
Total assets	7,459	5,066	3,729	2,859
LIABILITIES AND FUND BALANCES				
CURRENT LIABILITIES:				
Bank overdraft	137	7		
Accounts payable	351	181	423	74
Payable to donors	25	25	25	25
Others	127	100		
Total current liabilities	640	313	448	99
GRANTS RECEIVED IN ADVANCE	117			
FUND BALANCES:				
Invested in fixed assets	6,360	3,864	2,438	1,352
Unexpended funds (deficit):				
Core —				
Unrestricted	(37)	(12)	77	(69)
Working fund grant	100			
Capital grants	175	891	703	1,477
Special projects —				
Donors	144	35	63	
Other	(40)	(25)		
	342	889	843	1,408
Total fund balances	6,702	4,753	3,281	2,760
Total liabilities and fund balances	7,459	5,066	3,729	2,859

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			
	1973	1972	1971	1970
Revenue:				
Core:				
Operating grants —				
Unrestricted	2,672	2,286	2,144	924
Restricted	790	433	352	165
Working fund grant	100			
Capital grants	1,779	1,614	312	942
Total Core	5,341	4,333	2,808	2,031
Special projects	404	98	191	145
Earned income	168	98	8	34
Total revenue	5,913	4,529	3,007	2,210
Expenditures:				
Core programs:				
Direct research —				
Beef	661	417		
Swine	202	177		
Cassava	330	309		
Beans	262	114	(1)	(1)
Rice	135	240		
Maize	121	150		
Small farm systems	36	110		
	1,747	1,517	1,338	754
Training and communication	518	371	300	143
Total direct research	2,265	1,888	1,638	897
Support operations:				
Library, documentation and information services	139	77	88	62
Other services	521	347	117	
General administration	340	314	230	238
Total support operations	1,000	738	435	300
General operating costs	365	265	285	237
Total core programs	3,630	2,891	2,358	1,434
Special projects	305	166	128	145
Purchases of fixed assets	2,493	1,426	1,086	709
Returned to donors				106
Total expenditures	6,431	4,483	3,572	2,394
Excess of revenue over expenditures:				
Unrestricted funds		(89)	146	(417)
Working fund grant	100			
Capital grants	(717)	188	(774)	233
Special projects	99	(53)	63	
	(518)	46	(565)	(184)
Unexpended funds at beginning of year	889	843	1,408	1,592
Grants receivable for prior years written off	(29)			
Unexpended funds at end of year (see balance sheet)	342	889	843	1,408

(1) Comparative figures for 1971 and 1970 are not available.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
NOTES TO FINANCIAL STATEMENTS
DECEMBER 31, 1973

NOTE 1:

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

Inventories —

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

Depreciation —

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

NOTE 2:

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

	P/$1	
Peso balances included in current assets and current liabilities	24.79	Approximate year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	23.63	Average monthly rate of exchange applicable to sales of dollars

NOTE 3:

CIAT operates under an agreement signed with the Colombian Government, the most important stipulations of which are as follows:

1. The agreement is for ten years from October 1967 but may be extended if so desired by the parties thereto.
2. CIAT is of a permanent nature and termination of the agreement would not imply cessation of CIAT's existence.
3. If CIAT ceases to exist, all of its assets will be transferred to a Colombian educational or other institution considered appropriate by the parties to the agreement.
4. CIAT is exempt from all taxes.
5. CIAT is permitted to import, free of customs duties and other taxes, all the equipment and material required for its programs.
6. The government provides land for CIAT's purposes under a rental contract for ten years, at a nominal rent. This contract may be extended by mutual agreement.

NOTE 4:

Accounts receivable from donors as at December 31, 1973 comprised the following:

		$000
Agency for International Development - Balance of 1973 grant which was received in 1974		226
The Rockefeller Foundation:		
Allocations for purchases and expenses		121
Other		26
		147
Interamerican Development Bank - balance of 1973 scholarship expenses		79
Others		45
		497

NOTE 5:

The account denominated revolving fund in used to record CIAT's livestock operations. The movement on the fund for the year ended December 31, 1973 was as follows:

	$000
Inventory of livestock - December 31, 1972	64
Purchases during the year	37
Sales during the year	59
Inventory of livestock - December 31, 1973	42

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
ANALYSIS OF GRANTS AND RELATED EXPENDITURES FOR THE YEAR ENDED DECEMBER 31, 1973

(Expressed in thousands of U.S. dollars)

	Grants	Expenditures					% of support and general operating to direct	Unexpended balance
		Direct research	Support operations	General operating	Fixed assets	Total		
Unrestricted Core (1)	2,840	1,772	782	286		2,840	60	
Restricted Core:								
Canadian International Development Agency	500	312	138	50		500	60	
The W.K. Kellogg Foundation, Battle Creek	290	181	80	29		290	60	
Total restricted Core	790	493	218	79		790	60	
Working fund grant (Core):								
International Development Association, Washington, D.C.	100							100
Capital grants:								
The Rockefeller Foundation, New York	1,779				2,496	2,496		(717)
Special projects:								
Interamerican Development Bank, Washington, D.C.	161	147				147		14
The Rockefeller Foundation, New York	84	50				50		34
The W.K. Kellogg Foundation, Battle Creek	77	25				25		52
International Development Research Centre, Ottawa	30	38				38		(8)
Others	52	45				45		7
Total special projects	404	305				305		99
Total grants and expenditures	5,913	2,570	1,000	365	2,496	6,431		(518)

(1) Includes earned income of $ 168,000

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

SUPPLEMENTARY INFORMATION

EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1973

(Expressed in thousands of U. S. dollars)

Sources of earned income:	
Interest on deposits	59
Sale of farm produce	106
Use of CIAT facilities	3
Applied to core programs	168

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1973
(Expressed in thousands of U.S. dollars)

	Core unrestricted		Core restricted		Special projects		Capital	
	Approved budget	Actual	Approved budget	Actual	Approved budget	Actual	Approved budget	Actual
Programs								
Research:								
Beef	633	661						
Swine	3	22	180	180				
Cassava	6	10	320	320	40	32		
Beans	268	262						
Rice	140	135						
Maize	121	121						
Small farm systems	72	36						
Training and communication	305	228	290	290	355	223		
Support operations	807	1,000						
General operating costs	322	365						
Other					78	50		
Total	2,677	2,840	790	790	473	305		
Capital								
Fixed assets							2,394	2,496
Total							2,394	2,496
Analyses of variances								
Budget surpluses:								
Unexpended balance						99		
Grants not received						69		
Total						168		
Deficits:								
Covered by —								
Additional grants		65						
Increased earned income		98						
Unexpended balances at beginning of year								102
Total		163						102