Annual report
1976

Centro Internacional de Agricultura Tropical, CIAT

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

Contents

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* As of December 31, 1976

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(as of 31 December, 1976)

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***Eduardo Alvarez-Luna**, PhD, Associate Director General, International Cooperation
Kenneth O. Rachie, PhD, Associate Director General, Research

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Bean Production Systems Program

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Peter H. Graham, PhD, Microbiologist

Senior staff
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Charles A. Francis, PhD, Agronomist
Guillermo Galvez, PhD, Plant Pathologist
***Guillermo Hernández-Bravo**, PhD, Plant Breeder
****Reinhardt Howeler**, PhD, Soil Scientist
Douglas Laing, PhD, Physiologist
John Sanders, PhD, Agricultural Economist
Aart van Schoonhoven, PhD, Entomologist
Steven Temple, PhD, Plant Breeder
Oswaldo Voysest, PhD, Agronomist

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****John Halliday**, PhD, Soil Microbiology

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* Left during 1976

* Left during 1976
** Assigned to more than one program.

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Richard Swindell, PhD, Breeding
Kazuhiro Yoshii, PhD, Plant Pathology

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***Lawrence Hammond**, MS
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***César Paniagua**, MS
David Webster, MS

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Ricardo Campos, Ing. Agr.
Mauricio Castaño, Ing. Agr.
***José J. Galindo**, Ing. Agr.
James García, Ing. Agr.
Luis A. Gómez, Ing. Agr.
***Carlos González**, Ing. Agr.
***Carlos Gutiérrez**, Ing. Agr.
Pablo Guzmán, Ing. Agr.
***Roberto Hernández**, Ing. Agr.
Nora Ruiz de Londoño, Ing. Agr.
Nelson Martínez, Ing. Agr.
Carlos J. Medina, Ing. Agr.
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Juan C. Rosas, Ing. Agr.
Hember Rubiano, Ing. Agr.
Fernando Takegami, Ing. Agr.
Rafael Valderrama, Ing. Agr.
Guillermo Valencia, Ing. Agr.
Silvio Zuluaga, Ing. Agr.

Cassava Production Systems Program

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J. Carlos Lozano, PhD, Plant Pathologist
Julio César Toro, PhD, Agronomist

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Abelardo Castro, PhD,
Cultural Practices Agronomy

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Rupert Best, PhD, Cassava Drying

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Jairo Castaño, MS

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Gustavo Jaramillo, Ing. Agr.
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Uldarico Varón, Ing. Agr.
Ana Cecilia Velasco

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(until 30 April 1976)
Pedro Sánchez, PhD, Soil Scientist
(from 29 Dec. 1976)

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Donald Corrier, PhD, DVM, Animal
Pathologist (Texas A&M Univ. Project)
John E. Ferguson, PhD, Seed Production
Specialist
Bela Grof, PhD, Agrostologist

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* Left during 1976
** Assigned to more than one program.

* Left during 1976

****C. Patrick Moore**, PhD, Animal Scientist
Gustavo Morales, PhD, DVM, Animal Pathologist
Gustavo Nores, PhD, Agricultural Economist
Osvaldo Paladines, PhD, Animal Scientist (on sabbatical leave)
Rainer Shultze-Kraft, PhD, Forage Exploration Specialist
James M. Spain, PhD, Soil Scientist (Acting program leader, 1 May - 28 Dec. 1976)
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Radmilo Todorovic, PhD, DVM, Hemoparasitologist (Leader, Texas A&M Univ. Project)
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Eric Wells, PhD, Epidemiologist

Postdoctoral fellow

****John Halliday**, PhD, Soil Microbiology

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Specialist

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Mauricio Salazar, MS
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Luis Enrique Beltrán, DVM

CIMMYT-CIAT
Regional Andean Maize Unit

Coordinator
Gonzalo Granados, PhD, Entomologist

Research assistant
Edgar Castro, Ing. Agr.

Rice Improvement Program

Leader
Loyd Johnson, MS, PE, Agricultural Engineer

Senior staff

***Robert L. Cheaney**, MS, Agronomist
Manuel Rosero, PhD, Agronomist
***Grant M. Scobie**, PhD, Agricultural Economist
Hector Weeraratne, PhD, Breeder

Research associates

Rodrigo López, Ing. Agr.

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* Left during 1976

**Assigned to more than one program

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Alicia Pineda
Raúl Valderrutén, MS
Gustavo Villegas, MS

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Training and Conferences

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****C. Patrick Moore**, PhD, Coordinator,
Beef Production Training

Training

Training associates
Fernando Bernal, MS, (Station Operations Unit)
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Carlos Lascano, MS, (Beef Program)
Marceliano López, MS
Eugenio Tascón, Ing. Agr.
Gustavo Villegas, MS, (Rice Program)

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Luis Fernando Ceballos, Ing. Agr.
Silvio Guzmán, DVM
Reyes Sierra, DVM

Administrative assistant
Carlos Suárez, BS

Conferences

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Stellia de Salcedo, Licenciatura en traducción,
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Amparo de Madrigal

Public Information Office

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Assistants
Marvin Andrade
Catherine J. Crane, BA
***Juliana Garcés**, Lisence es Lettres

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* Left during 1976

** Assigned to more than one program

* Left during 1976

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Postdoctoral fellow
Gastón A. Mendoza, PhD, (Acting head)

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Jorge A. Porras, BS
Maria Cristina de Quiñónez, MS

Research assistants
Patricia Juri de García, BS
Gerardo I. Hurtado, Ing. Agr.
***Yamel López**, Ing. Agr.

Special Studies Unit

Coordinator
***Jerry Doll**, PhD, Weed Control Specialist

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Petrus Spijkers, MS, Associate Expert FAO

Research assistants
***Pedro Argel**, Ing. Agr.
Cilia Leonor Fuentes, Ing. Agr.
Guillermo Giraldo, Ing Agr.
***Wilson Piedrahita**, Ing. Agr.
Manuel Restrepo
Marcelino Torres
Manuel Lorenzo Villegas, BS

Experiment Station Operations

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Alfonso Díaz-Durán, MS, PE, Experimental Farm Superintendent

Research assistants
Ramiro Narváez, Ing. Agr.
Bernardo Salazar, Ing. Agr.

Laboratory Services

Assistants
Charles McBrown, BS
***Daniel Camacho**, BS

International Programs

Guatemala (Rockefeller Foundation) Instituto de Ciencias y Tecnologia Agrícola (ICTA)

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

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* Left during 1976

* Left during 1976

Foreword

The objectives of CIAT are:

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

Dramatic increases in food production in the American tropics are essential in the face of rapidly rising populations and increasing consumer demands. However, the statement of our objectives indicates that welfare issues as well as production goals are included in the total concerns of CIAT. For this reason, the results of a one-year economics study on the effect of new rice production technology in Colombia, which was completed in 1976, were particularly gratifying.

This study found the gross value of additional production attributed to the high-yielding varieties in Colombia for 1974 alone to be US$ 149 million. An analysis of the distribution of these benefits indicated that, because rice prices were much lower than they would have been in the absence of the high-yielding varieties, Colombia's consumers were the chief beneficiaries of this increase. Rice prices fell due to the increase in production, both in real terms and even more so in relative terms. Consequently, both absolutely and relatively, the greatest net benefits went to consumers with the lowest incomes. That portion of Colombian households which receive only 14 percent of the national income captured 62 percent of the net benefits from the development and introduction of high-yielding varieties. These results encourage us to think that the results reported in this document for our various commodity programs can have a major beneficial effect in improving nutrition and purchasing power of many people.

Program Features

The results achieved in 1976 are described in detail for each program in this report and the highlights summarized at the beginning of each program section. Rather than repeat these here, some of the key features which are common to all or several programs will be described.

Maximum use of natural resources

During 1976, the CIAT Beef Program began to implement a decision by the CIAT Board of Trustees to more sharply focus the efforts of this program, to concentrate on the development of new technology for the increase of beef production on the under-utilized resource of the acid, highly infertile soils which cover vast land areas in tropical Latin America. Accelerated efforts to develop improved pastures for these conditions in order to solve the main constraint, i.e. poor animal nutrition, in this ecosystem are expected to greatly improve the productivity and insure ecologically sound development of this important natural resource. Similarly, efforts to collect, evaluate, and conserve the important genetic resources of *Phaseolus* beans, tropical forages, and cassava were expanded in 1976.

Minimum input philosophy

It is generally recognized that in order to make maximum use of land and human resourcss, increased production levels are urgently needed which will require some use of purchased inputs such as fertilizers and pesticides. CIAT's programs are operating under a philosophy which aims to develop technology to increase productivity with a minimum use of such inputs whenever feasible. This is in recognition of the following factors: (1) the limited resources which small farmers have for the purchase of such inputs; (2) the fact that some of these materials represent scarce, non-renewable resources; and, (3) the environmental implications of excessive use of some of these products. Consequently, all CIAT programs attempt to solve insect and disease problems to the largest extent possible by using genetic resistance; where this is absent or of limited value, cultural practices or natural control factors are employed to minimize the need for pesticides. Similarly, our various programs actively seek genotypes which are less demanding of certain nutritional elements in short supply, such as phosphorus, and are adapted to adverse soil conditions. It is encouraging to note the advances which have been made in all these areas, as reported by the respective programs for 1976.

Outreach expansion

The year 1976 saw a rapid expansion of collaborative networks of testing with local agencies to move the CIAT technology to various areas of the tropical Americas and other parts of the world. In 1976, the Bean Program forwarded 57 international yield and adaptation nurseries to 16 countries in Latin America, and distributed a total of 76 nurseries to 25 countries throughout the world. Similarly, cassava seeds were sent to cooperators in 28 countries, and vegetative planting materials to eight cooperators in eight countries. Uniform cassava yield trials, which had previously been conducted in various ecological zones within Colombia, were established in Ecuador, Guyana and Mexico in 1976.

In the Beef Program sufficient progress was made in producing seed of improved forages to make large quantities of some varieties available for large-scale collaborative testing for the first time. For example, in 1976, 700 kilograms of seed of *Stylosanthes guyanensis* (CIAT 136), a promising line, were sent to cooperators who established collaborative forage trials in 11 countries.

Also, in collaboration with IRRI, a conference was held for leading rice workers throughout Latin America to greatly expand the activity of the International Rice Testing Program in the Western Hemisphere.

The Swine Program held a six-month Swine Training Course for 20 participants from 10 countries, thereby greatly expanding the network of collaborators in the transfer of swine production technology previously developed at CIAT.

Inter-country collaboration within the Andean Zone on maize improvement was greatly expanded by the implementation of the CIMMYT/CIAT maize cooperation project and extensive travel and workshops by the personnel assigned to CIAT for this purpose.

Integration of training and research

This year marked a turning point for training and conferences, in which the programs, organization, strategy and actions were adjusted in the direction of decentralizing training activities and putting them more in the realm of each of CIAT's commodity programs. This culminated a growing trend away from regarding training and conferences as a separate program in recognition that training is an intrinsic part of each commodity, and that it exists for total support of both the development and transfer of the new production technology.

International Cooperation

Directors of agricultural research from 22 countries were invited to participate in the 1976 annual Presentation Days which was followed by a round table discussion to determine how CIAT can best serve the needs of local institutions. This was a further step in the warm and productive relationships which CIAT has with these institutions. It was both heartening and sobering to observe the great degree of expectancy which exists for the fruits of this collaboration.

CIAT also continued to work with national programs in helping develop in-country training activities. It was a privilege for CIAT to participate, through one of its training associates, in the exciting training program of ICTA in Guatemala, where new agricultural research workers learned to implement the philosophy of on-the-farm testing in a course which was conducted largely on farmers' fields.

Through special IDRC funding CIAT developed its first regional commodity outreach service by stationing a cassava specialist for Southeast Asian collaboration with SEARCA in the Philippines.

Staff Changes

The year 1976 saw an unusual turnover of senior staff. The Center particularly felt the loss of two of its most senior pioneers. Dr. Eduardo Alvarez-Luna, who had been with the Center from its inception, serving first as Director of Plant Sciences, and later as

Associate Director General for International Cooperation, returned to his native Mexico to serve in a high position with the government of that country. Fortunately, by the end of the year another highly qualified and distinguished international agricultural scientist, Dr. Alexander Grobman of Peru, was named to fill this important post. He is expected to join CIAT in the first days of 1977. Dr. Ned Raun, who had also served CIAT since its founding and prior to that, the Rockefeller Foundation in Colombia, resigned as Director of the Beef Program to enter a high level position in USAID/Washington. By the end of the year, a highly qualified replacement, Dr. Pedro Sánchez, joined CIAT to fill this important vacancy. Other staff changes were as follows:

Departures

Per Andersen	February 22, 1976
Neil MacLellan	May 16, 1976
Alberto Valdés	May 3, 1976
Grant Scobie	July 21, 1976
Robert Cheaney	August 13, 1976
Guillermo Hernández-Bravo	September 22, 1976
Jerry Doll	November 30, 1976
Eugenio Martínez (ICTA)	December 31, 1976

Arrivals

Oswaldo Voysest	January 5, 1976
Fritz Kramer	April 18, 1976
Manuel Rosero	June 1, 1976
Gustavo Nores	September 4, 1976
Hector Weeraratne	October 6, 1976
Rainer Shultze-Kraft	November 7, 1976
John Sanders	November 27, 1976
Robert A. Luse	December 21, 1976

New appointments (appointed in 1976 for arrival in early 1977)

James Barnett
Abelardo Castro-Merino
Howard Schwartz
Ingo Kleinheisterkamp
Dietrich Leihner

John L. Nickel
Director General

Climatological data for three CIAT research sites

CIAT scientists conduct primary research at several locations within and outside of Colombia. Summary data on temperature, rainfall and edaphological conditions at most of these stations are listed in the individual reports of the Beef, Bean, Cassava and Maize Programs reprinted from this comprehensive Annual Report.

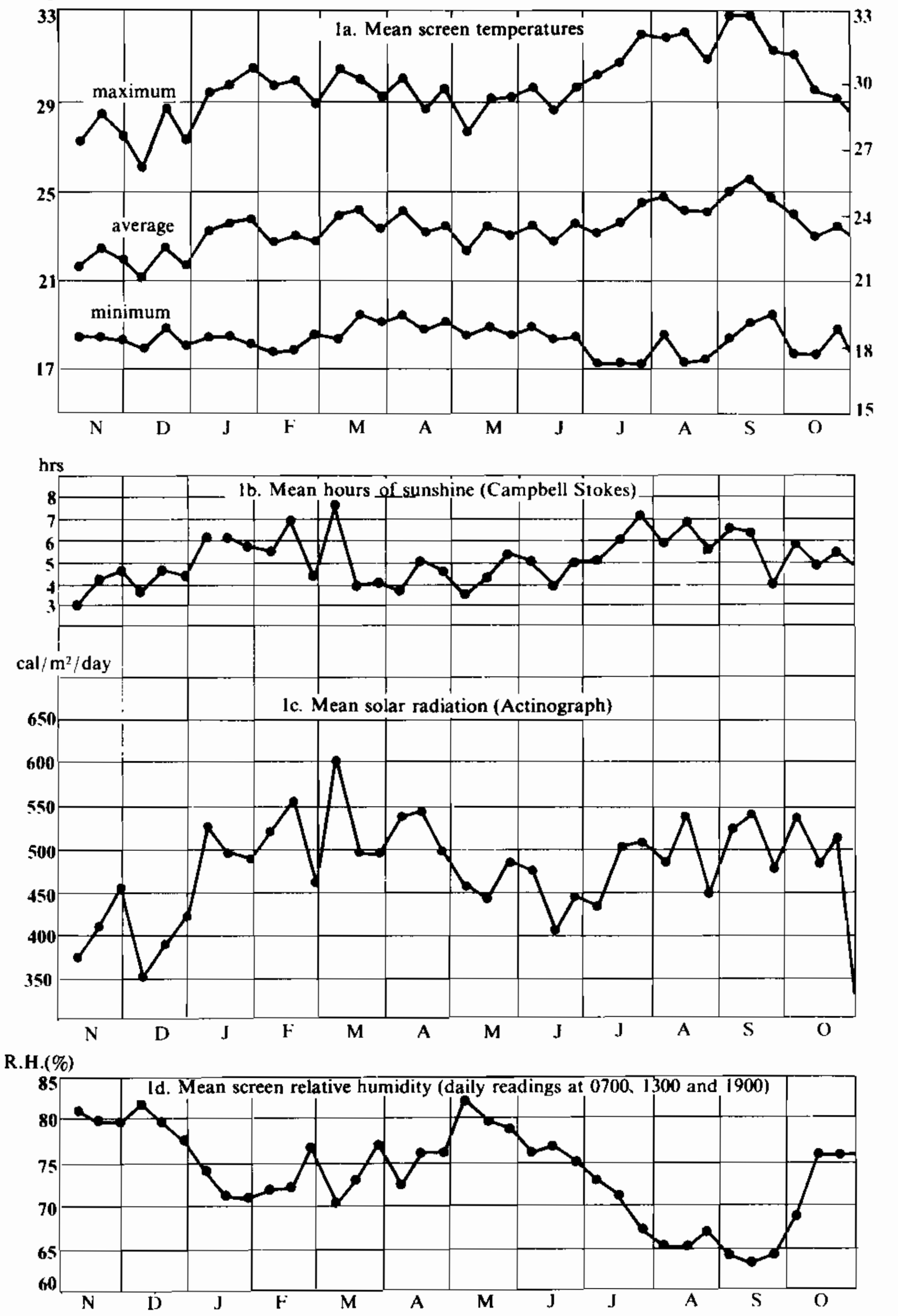
In this section rainfall and temperature data for the period covered by this report (November 1975-October 1976) and longer-term averages are given for three locations — CIAT's headquarters near Palmira; the Popayán research station of the Secretaría de Agricultura of Cauca; and the Carimagua research station of the Instituto Colombiano Agropecuario (ICA). Data are from adjacent (Popayán and CIAT) or nearby (Carimagua) weather measuring stations. Detailed data for other climatological factors are given for the Palmira site where much of CIAT's basic screening and early crop development work is conducted.

Palmira

Meteorological data for the ICA weather station approximately three kilometers east of the CIAT farm are presented in Figure 1 and Table 1. Data in the figure are plotted for either 10- or 20-day periods for the research year while data in the table represent monthly and long-term averages.

Temperature conditions were close to the long-term mean throughout the year except for the maximum temperatures during August and September 1976. The 10-day mean maximum (Figure 1a) rose to almost 33°C during this period, about 3°C above the August and September mean maximum values of 30.1° and 30.2°C, respectively. The high temperatures were associated with an unusually dry period from June to September when a total of only 25.9 millimeters was received compared to the long-term average of almost 200 millimeters.

Figure 1. (See description on next page.)



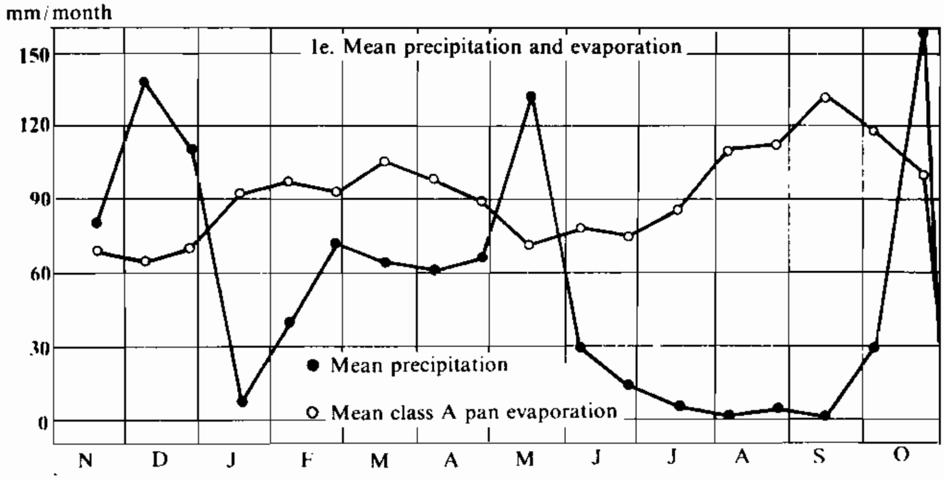


Figure 1. **Ten-day (1a, b, c, and d) and 20-days (1e) means of several climatological factors for CIAT, Palmira (meteorological station at ICA research station, Palmira, Departamento del Valle: Lat. 3°31'N, Long. 76°19'W; altitude 1,001 meters) for November 1975-October 1976 and longer terms.**

The failure of the rain in September meant that the normal second semester wet season was only one month long, in October. Relative humidity was low during the extended dry season reaching mean daily values of 64 percent in mid-September. Radiation showed the usual variability. Since radiation data has been

Table 1. **Monthly meteorological data for CIAT (station at ICA Palmira, Departamento del Valle, Lat. 3°31'N; Long. 76°18'W, altitude 1,001 meters), for October 1975-October 1976 and long-term mean data.**

	Mean[1] temperature (°C)		Monthly rainfall (mm/month)		Mean solar[2] radiation (cal/cm²/day)	
Month	1975-76	1930-74	1975-76	1930-74	1975-76	1972-74
October	23.4	23.6	244.1	146.6	480	452
November	23.1	23.5	130.7	105.7	416	417
December	22.8	23.1	190.4	76.3	392	426
January	24.0	24.1	40.9	40.9	480	448
February	24.5	24.3	77.2	69.4	517	504
March	24.3	24.3	125.6	87.2	524	475
April	23.6	24.0	96.4	141.7	525	461
May	24.0	23.7	133.0	124.4	490	435
June	23.6	23.7	15.1	70.8	432	405
July	24.1	24.0	6.1	27.2	483	451
August	24.6	23.9	3.5	36.6	486	424
September	24.6	24.0	1.2	62.3	519	452
October	23.7	23.6	229.6	146.6	504	456

[1] Maximum plus minimum divided by two

[2] Actinograph (Belfort Science Associates)

collected for only five years, long-term means are unavailable. The hours of bright sunshine were high throughout the extended dry season although this was not reflected in exceptionally high solar radiation values. Although cloud cover was very much reduced, the sky was never completely clear due to smoke, dust and other interference. More irrigation than usual was necessary during the second semester due to exceptionally high evaporation and very low rainfall.

Popayán

Field research near Popayán done by CIAT (mainly by the Bean Program) is at the research farm of the Secretaría de Agricultura of Cauca. The meterological station is one kilometer away and is maintained by the National Coffee Growers' Federation.

Conditions at Popayán during the second semester reflect the dry conditions which prevailed over most of Colombia during the second half of 1976 (Table 2). Rainfall in June, July and August was considerably below normal. Mean monthly temperatures did not deviate very much from normal. The mean long-term annual temperature of 17.5°C reflects the difference of 850 meters altitude between CIAT and the Popayán location. No explanation can be given at this time for the larger temperature range shown in the long-term mean data compared for that observed in 1975-76.

Carimagua

The meterological data for the Carimagua location of CIAT research in the Colombian Llanos is reported in Table 3. Rainfall in 1975-76 showed the usual

Table 2. **Meteorological data for Popayán (station Jose Maria Obando, National Coffee Growers' Federation, Departamento of Cauca; Lat. 2°27'N; Long. 76°34'W, altitude 1,850 meters) for October 1975-October 1976 and long-term mean data.**

	Temperature (°C)						Rainfall (mm/month)	
	Maximum		Minimum		Mean[1]			
Month	1975-76	1951-70	1975-76	1951-70	1975-76	1951-70	1975-76	1951-70
October	-	27.7	-	10.7	-	17.5	174.9	275.9
November	-	26.4	-	11.1	-	16.9	294.3	310.3
December	-	26.5	-	10.8	-	17.3	425.0	272.4
January	22.9	26.9	12.3	10.5	17.3	17.4	104.4	156.6
February	22.3	27.4	12.5	11.0	16.9	17.6	199.3	154.0
March	23.3	27.5	13.6	11.1	17.6	17.6	365.6	163.2
April	23.3	27.6	13.2	11.4	17.6	17.5	152.5	183.2
May	23.6	27.5	13.7	11.5	17.9	17.6	95.9	141.6
June	24.1	27.4	13.1	10.4	17.9	17.4	50.5	96.5
July	25.7	28.8	13.0	10.6	18.8	17.6	1.1	40.5
August	26.4	28.7	13.0	10.3	19.2	18.0	12.4	34.9
September	26.5	29.0	13.6	10.3	19.4	18.0	141.1	93.4
October	-	27.7	-	10.7	-	17.3	350.6	275.9

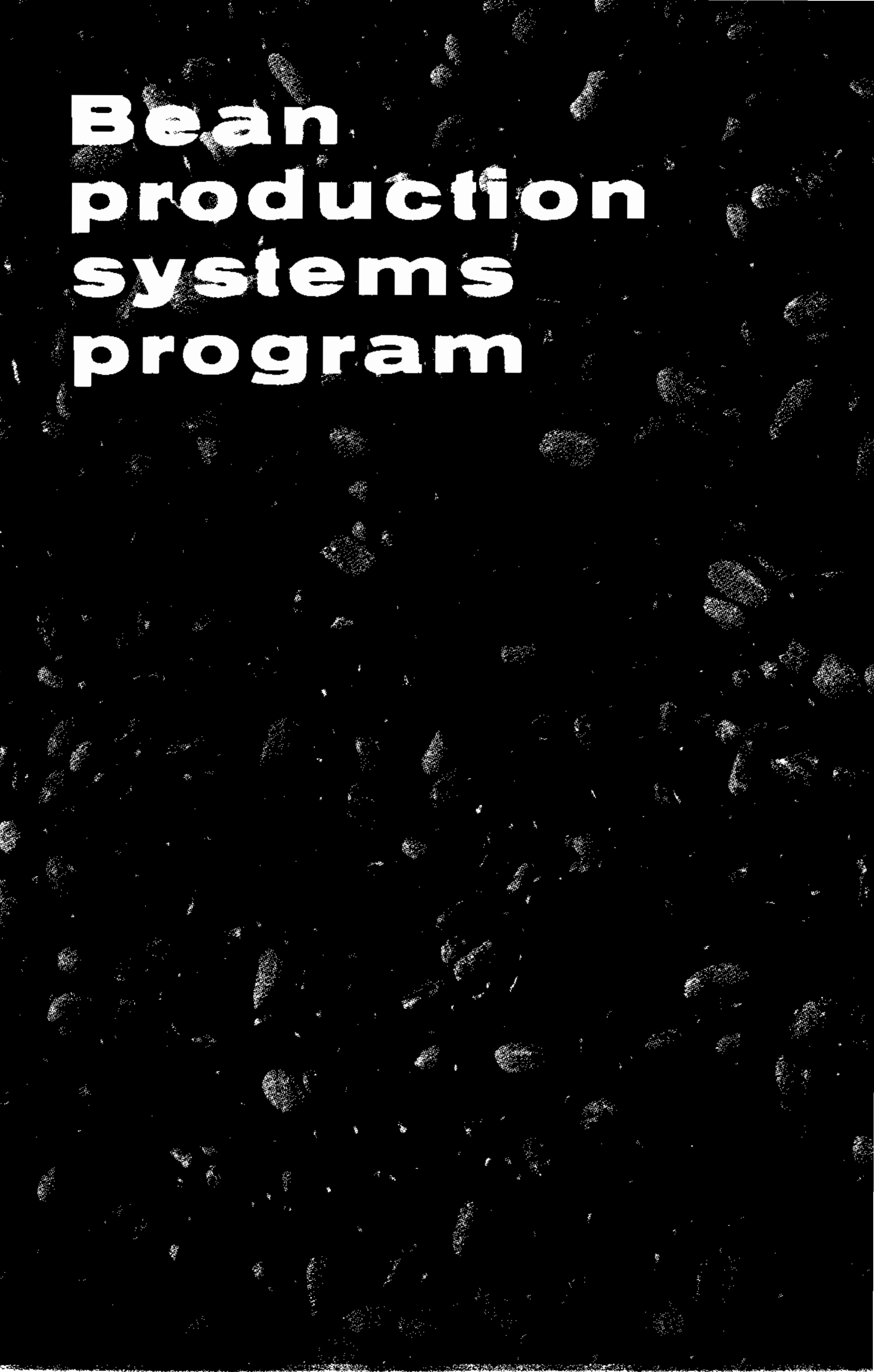
[1] Average of four measurements during each daily period.

Table 3. **Meteorological data for Carimagua area (observed at the station Las Gaviotas, Centro de Desarrollo Integrado, Comisaria de Vichada; Lat. 4°30'N, Long. 70°40'W (approx.), altitude 150 meters) for October 1975-October 1976 and the long-term mean values.**

	Temperature (°C)						Rainfall (mm/month)	
	Maximum		Minimum		Mean			
Month	1975-76	1968-71	1975-76	1968-71	1975-76	1968-71	1975-76	1968-71
October	30.4	32.4	22.0	21.0	26.2	26.7	210.6	305.1
November	30.3	32.3	22.2	21.7	26.3	27.0	136.5	112.6
December	30.1	32.2	21.8	21.7	26.0	26.9	158.7	122.1
January	30.8	32.4	21.3	21.5	26.1	26.9	0.0	36.8
February	32.5	33.4	21.7	21.5	27.1	27.4	30.3	55.7
March	31.9	33.2	22.9	22.4	27.4	27.3	66.8	157.3
April	30.8	32.5	22.5	22.6	26.7	27.5	293.1	188.6
May	29.3	30.6	22.4	22.2	25.8	26.4	240.1	348.0
June	28.2	30.1	22.0	20.4	25.1	25.2	453.9	421.8
July	27.8	29.6	21.3	20.5	24.6	25.0	425.0	278.6
August	29.9	30.5	21.7	20.3	25.8	25.4	197.0	339.4
September	30.5	31.4	22.2	20.8	26.4	26.1	317.0	162.8
October	31.6	32.4	23.6	21.0	27.6	26.7	139.6	305.1

seasonal variation although January, February and March were below normal (compared to five years of data). Temperatures were close to the long-term mean values throughout the year.

Bean production systems program



Bean production systems program

HIGHLIGHTS IN 1976

National bean programs in Latin America vary. While some are limited to a few scientists undertaking activities which must span several disciplines, others have multidisciplinary research teams with numerous highly qualified scientists.The CIAT bean program, which was asked by the Technical Advisory Committee of the Consultative Group for International Agricultural Research to establish a collaborative bean research network in Latin America, must, therefore, be attentive to markedly different needs. While the program's chief product is germplasm, this may be supplied to national programs as a promising source of disease or insect resistance; as hybrid material with nationally-important varieties already crossed to the resistance source; as late generation "elite" materials previously screened at CIAT; or as formed varieties from CIAT or other national programs. Even so-called "technology packages" will differ according to the needs and capabilities of each country and its predominant agricultural forms.

The major highlights of the program's work in 1976 illustrate the breadth of activities and their integration with the needs of national bean programs.

In 1976, and after consultation with national programs on methodology, CIAT established the first International Bean Yield and Adaptation Nursery (IBYAN). To date 128 requests for the trial have been received. These derive from 20 countries in the Americas as well as from England, India, Israel, Japan, Kenya, Malawi, Portugal, Tanzania and Thailand. Seventy-six trials have already been shipped. While most plantings were scheduled for the second semester of 1976, results have already been received from 12 trials.

The second International Bean Rust Nursery (IBRN) is being tested in 14 locations in 1976. Results from the first IBRN showed three accessions resistant to rust attack at all six testing locations. Two of these accessions, P699 and P717, are being used as rust resistance sources by the breeding program.

This year CIAT was named as the world center for *Phaseolus* germplasm resources. The first meeting of the *Phaseolus* Germplasm Advisory Committee, in September, reviewed and approved program plans for the storage, identification, characterization and data retrieval associated with germplasm activities. A detailed catalogue of more than 700 promising cultivars has been published.

Rates of nitrogen fixation as high as 40 kg/ha/growing season were obtained. High fixation was most common in climbing cultivars and was strongly correlated with high soluble carbohydrate levels in the plant.

Evaluation of cultural practices and cultivars for associated cropping of maize and beans continued with the maximum bean yield of 2,070 kg/ha achieved in association with a yield of 4.93 tons of maize.

One hundred seventy-eight cultivars were used in bean hybridizations during 1976 with approximately 3,000 different parental combinations effected. Detailed plans were developed to sequentially evaluate these hybrids for disease resistance and yield, and to pass promising material as rapidly as possible to interested national programs.

In 1976 the program received 38 trainees including four postdoctoral scientists. Continued contact with former trainees has permitted a wide range of screening activities for diseases, insects and stress conditions not found at CIAT. These include resistance studies on *Apion, Epinotia,* golden mosaic virus and on drought tolerance screening.

GERMPLASM

In 1976 CIAT accepted primary responsibility under the International Board for Plant Genetic Resources (IBPGR) for the maintenance and characterization of *Phaseolus* germplasm.

Germplasm Evaluation

Of the 12,000 seed samples already received at CIAT, some 7,000 have been multiplied and characterized morphologically. Another 3,000 accessions are currently being multiplied to provide 10,000 evaluated materials by the end of 1976. These accessions include a number of active or obsolete land cultivars of *Phaseolus vulgaris,* improved commercial varieties, wild and indigenous types, and natural and artificial crosses of *P. vulgaris* by *coccineus, P. acutifolius, P. lunatus,* and wild species such as *P. ritensis, P. dumosus, P. polystachus,* and *P. adenanthus.*

Some 2,200 new accessions were received in 1976, including 1,200 samples from the Norvell explorations of Mexico and Guatemala and interesting new materials from Germany, Holland and France. After meeting at CIAT in September to review the current status of *Phaseolus* spp. germplasm, the *Phaseolus* Germplasm Advisory Committee (PGAC) recommended additional collecting in Africa and Central America during 1977. Additional information will also be sought from major existing collections not already included in the CIAT bank.

Field evaluation and characterization of accessions for 52 plant morphological features continued in 1976. The PGAC has identified 20 of these as essential descriptors for *Phaseolus* collections. Results from an evaluation of 781 materials identified by CIAT scientists as "promising" were published in the form of a descriptive listing (Fig. 1)[1]. A second listing with information for 2,400 additional accessions will be prepared in 1977.

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[1] Many of these promising accessions are referred to in this report. A list on page A-80, further identifies these accessions (referred to as P000) by their varietal name or other title, the CIAT germplasm bank number (as G 00000) and the source country (but not necessarily its origin) for the accession. Germplasm bank accessions mentioned in this report are listed following the promising accessions.

Figure 1. **A catalogue characterizing 780 promising accessions of *Phaseolus vulgaris* was completed and published in 1976.**

Germplasm Storage

CIAT bean germplasm is currently maintained in cold rooms without humidity control, necessitating frequent germination tests and seed regeneration at four-year intervals. In 1976 plans were completed for a new germplasm facility to become available early in 1977. The structure will accomodate up to 60,000 accessions at +15°C conditions, and an equal number, in small quantities, at -15°C. All seed will be packaged under low humidity, ensuring viability for 6-10 years in the +15°C section and for up to 100 years in the -15°C section.

Seed Shipments

More than 3,000 seed samples were shipped in 1976. Table 1 shows the distribution of those materials by major region.

Table 1. **Distribution of seed samples in 1976 from the CIAT *Phaseolus* Germplasm Bank.**

Region	Samples sent
South America	923
Africa	869
Central America, Caribbean	714
Europe	343
North America	100
Australia	454
Total	3,403

PATHOLOGY

Common Bacterial Blight

Pathogenic variation

CIAT screening for bacterial blight from 1972 through 1975A used the Colombian isolate C6, originally obtained in 1969 by Schuster and Coyne from *Phaseolus vulgaris* var. Diacol Calima.

Additional studies were undertaken in 1976 to obtain new isolates and compare them with the C6 isolate. Isolations of the blight pathogen *Xanthomonas phaseoli* were made from blight-infected leaves and seed obtained in Colombia. Isolates were identified by colony morphology and pathogenicity tests, then compared in pathogenicity with isolates C6 and C7, the latter also isolated by Schuster and Coyne from Colombian seed material. Isolate 611 from the Cauca Valley of Colombia was most virulent, causing complete wilting of a susceptible host two weeks after inoculation (Fig. 2). In contrast, isolate C6 was only weakly virulent, causing flagging of the primary leaves. Isolate C7 was not pathogenic by this test, suggesting that the bacteria may decline in pathogenicity after repeated subculturing. Studies are in progress to determine how best to use such differential pathogenicity in screening for bacterial blight tolerance under controlled conditions.

Field screening

Field experiments were conducted at CIAT in 1975 and 1976 and also in 1976 at Nataima, a site in the Tolima region of Colombia where temperature and moisture conditions are excellent for blight development. These tests compared disease reactions of 4,000 accessions from CIAT's germplasm bank. Materials from the University of Nebraska (U.S.A), Michigan State University (U.S.A.) and Puerto Rico were included, as were two lines of *P. acutifolius*, as tolerant checks.

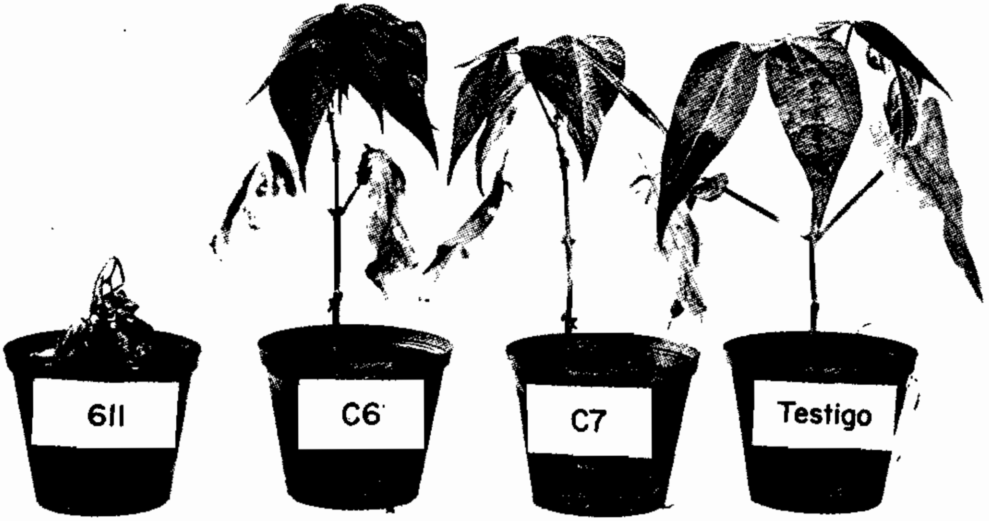


Figure 2. **Pathogenic variation among Colombian isolates of *Xanthomonas phaseoli* on *Phaseolus vulgaris*. Seedlings of the cultivar Manitou, a light red kidney bean, were inoculated in the cotyledonary node at the crook-neck stage with isolates 611, C6, C7 and a water control (check). The picture was taken two weeks after inoculation.**

Entries were evaluated first at CIAT in an unreplicated planting. Tolerant materials were reevaluated in replicated tests at CIAT and Nataima. The plot design for disease screening at CIAT (Fig. 3) was similar to methods previously described (CIAT Annual Report, 1974), while at Nataima rows were spaced 60 centimeters apart without ridges. Infected seed of the susceptible cultivar Porrillo Sintético was planted as borders 2-3 weeks before the general planting date.

Plants at CIAT were directly inoculated five weeks after planting using *X. phaseoli* isolate 611 as a suspension containing 5 x 10^7 cells/ml. Inoculum was applied at sunset as a spray at about 100 psi to produce leaf water-soaking (Fig. 4), and bean rows were furrow irrigated the day before and the day after inoculation to create a favorable microclimate for disease development. Plants were then sprayed with water and irrigated each week thereafter to enhance spreading of artificial as well as natural infections. At CIAT, reactions were recorded three weeks after inoculation using a 1-5 scale for foliar and a 1-3 scale for pod reactions.

At Nataima, severe infection occurred naturally and no inoculation was needed. Disease reaction was recorded 7-8 weeks after planting.

Two lines of *P. acutifolius* (P597 and Tepary 10) had the highest tolerance, showing no symptoms on either foliage or

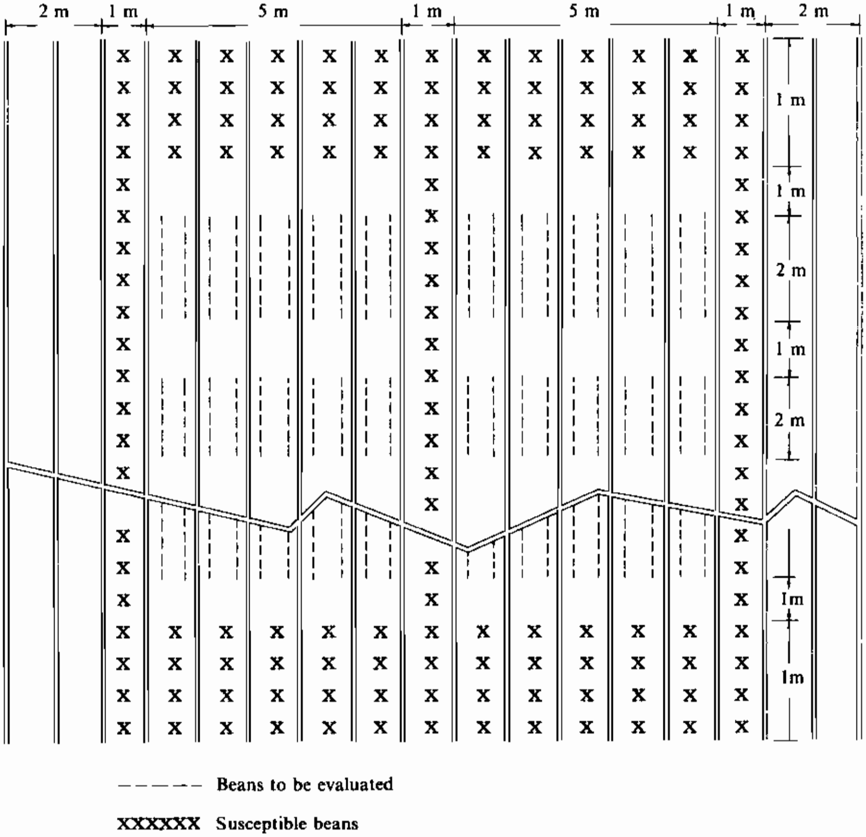


Figure 3. Planting pattern for evaluating bean tolerance to common blight, at CIAT.

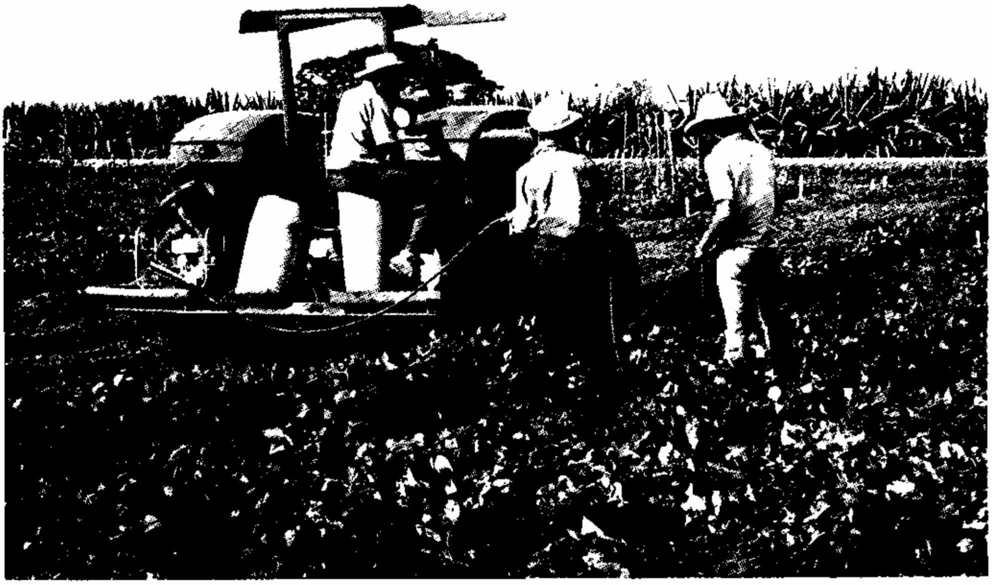


Figure 4. **Bean plants are inoculated with the bacterial suspension in the field at CIAT using a pressure sprayer.**

pods (Table 2). No *P. vulgaris* entries were free of leaf symptoms. Two *P. vulgaris* lines (P662 and P261) were tolerant in foliar reaction, but the latter showed pod susceptibility. P464 and P252, tolerant in 1975, were susceptible in subsequent tests. PI 169 727, P684, PI 197 687, Guali and P694, reported in other studies to be tolerant to U.S. isolates of *X. phaseoli,* were susceptible in these tests. Tolerant commercial U.S. cultivars P698, P567 and G.N. Valley were susceptible as they neared maturity.

Fungal Diseases

Rust (*Uromyces phaseoli*)

In 1976, 1,700 collections from the germplasm bank were evaluated for rust resistance at CIAT and Popayán; 189 were resistant at both locations. These collections will be further tested and incorporated into future International Bean Rust Nurseries (IBRN) for testing against races of the fungus not present in Colombia.

Twenty-six IBRN sets, each containing 123 cultivars, reported as resistant to different races of the pathogen, or of promise in donor countries, were sent to 14 cooperators during the year. Results from 12 of 14 sets sent in 1975, and four of the 26 sent in 1976 have been received. These were analyzed by computer using a resistance index generated from pustule size (1-5) and percentage of infection intensity, from observations at 30 and 45 days after planting (Fig. 5). Summarized results have been distributed to IBRN collaborators and other interested scientists.

The accessions P693, P699 and P717 were consistently resistant to rust in two years of IBRN testing. P699 and P717 have

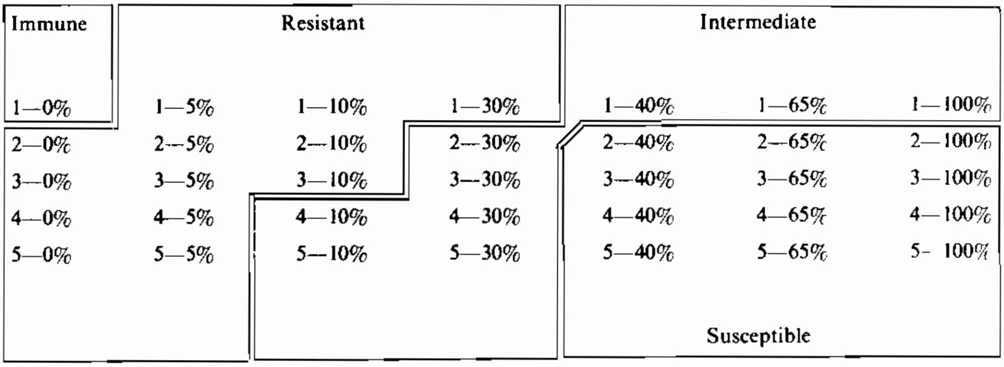
Table 2. **Reaction of pods and foliage of several field-grown bean cultivars and lines to Colombian isolates of *Xanthomonas phaseoli*.**

Accession no. or other identification	Foliage reaction [1]			Pod reaction [2]		
	CIAT		Nataima	CIAT		Nataima
	1975B	1976A	1976A	1975B	1976A	1976A
Phaseolus acutifolius						
P597	1	1	1	1	1	1
Tepary Nebr. Acc. 10	3	1	1	—[3]	1	1
Phaseolus vulgaris						
P662	2	2	2	2	1	1
P261	2	2	2	3	3	3
P464	2	2	3	2	1	1
P252	2	3	3	2	3	2
P.I. 169 727	—	4	—	—	3	—
P.I. 197 687	—	3	—	—	1	—
ICA-Guali	3	4	3	3	3	2
G.N. Valley	—	3	3	—	1	2
P684	3	3	3	2	1	1
P698	3	3	3	3	1	2
P498	3	3	3	2	1	1
P567	3	3	4	2	1	2
P694	3	3	3	2	2	2
P092	3	3	3	3	2	3
P760	—	4	4	—	2	2
P566	3	4	4	2	2	2

[1] Foliage reactions: 1 *Highly tolerant* — no visible symptoms; 2 *Tolerant* — slight, small lesions on 1-5% of leaves; 3 *Moderately susceptible* — moderate lesions of various sizes, some leaves chlorotic; 4 *susceptible* – severe with many large lesions on most leaves, pronounced chlorosis and necrosis; and 5 *Highly susceptible* — very severe , plants chlorotic and largely defoliated.

[2] Pod reactions: 1 *Tolerant* — no lesions; 2 *Intermediate* – a few small lesions; and, 3 *Susceptible* — numerous large lesions.

[3] Blanks mean not tested at this site or season.



1—0%	1—5%	1—10%	1—30%	1—40%	1—65%	1—100%
2—0%	2—5%	2—10%	2—30%	2—40%	2—65%	2—100%
3—0%	3—5%	3—10%	3—30%	3—40%	3—65%	3—100%
4—0%	4—5%	4—10%	4—30%	4—40%	4—65%	4—100%
5—0%	5—5%	5—10%	5—30%	5—40%	5—65%	5- 100%

Figure 5. **Resistance index used to evaluate the International Bean Rust Nursery (IBRN). The number is a rating of the pustule size on a scale of 1-5 with the infection intensity given as a percentage.**

been widely used in CIAT crossing programs for rust resistance.

Anthracnose *(Colletotrichum lindemuthianum)*

Screening for resistance. A total of 524 promising accessions were screened for anthracnose in Popayán (1,600 m) and Bogotá (2,600 m). More than 100 were resistant at both sites and additional accessions were resistant in one location and susceptible in the other. The β race of *Colletotrichum lindemuthianum* was present in Popayán. Accessions P685, Widusa, P302, P347, P432, and P540 have been consistently resistant in two years of testing. P685, P782, Cordonco and Vernandon are being used as resistance sources in the breeding program.

Powdery mildew *(Erysiphe polygoni)*

Screening for resistance. An epiphytotic of powdery mildew *(Erysiphe polygoni)* occurred in the anthracnose nursery in both Bogotá and Popayán. Accession P278 was observed to be highly resistant.

Web blight *(Thanatephorus cucumeris)*

Screening for resistance. Environmental conditions during 1976 were not favorable for the development of *Thanatephorus cucumeris.* Nevertheless, from 3,505 collections planted at Turipaná, only 310 were rated tolerant. These collections will be further tested under more controlled conditions. The most tolerant materials were P017, P358, P401, and P716. They have also been tolerant in previous screenings.

Root rots

Endemic infestation of *Rhizoctonia solani* permitted evaluation of 524 promising materials under natural conditions in Popayán. The most outstanding collections for resistance were P235, P334, P352, P502, P503, P646, and P693.

Viral Diseases

Common bean mosaic virus

Seed contamination. The study of recontamination of seed under field conditions resembling those of small farmers (1975 Annual Report) was continued. When seed free of internally seed-borne pathogens (clean seed) was increased far from commercial beans, harvested seed remained virus-free. Plots close to contaminated fields, planted with clean seed developed 15 and 12 percent infections for the susceptible varieties ICA-Gualí and ICA-Duva, respectively, and 6 and 5 percent infections for the tolerant varieties ICA-Tuí and P459, respectively. No control of the vectors was programmed.

In the case of tolerant varieties such as ICA-Tuí, the symptoms are not clearly expressed and this may lead to a constant use of infected seed. Nevertheless, clean-seed plots of ICA-Tuí yielded much more than plots planted with infected seed (2,720 kg/ha vs. 1,691 kg/ha).

Screening for resistance. CBMV consists of more than seven strain classes. Several are present in tropical zones and also perhaps, new ones as yet unidentified. Using a mild strain isolated at CIAT from the Calima cultivar, 151 promising accessions were evaluated in the greenhouse. Eighty-eight were resistant, and 63 were susceptible. Neither necrosis nor black-root symptoms were observed in accessions known to have the hypersensitive gene in this test.

Among 436 climbing accessions evaluated in the field, 345 were susceptible. The others either showed mild symptoms or were disease-free. These will be reevaluated under controlled conditions. From 3,610 entries from the germplasm bank, 2,955 were susceptible in the field.

F_1 seed of 76 single crosses (families), that included three sources for the dominant source of tolerance to CBMV were tested in the screenhouse by mechanical inoculation; 72 were tolerant and four susceptible.

Bean golden mosaic virus

Screening for resistance. A total of 2,150 entries were evaluated under natural conditions in Guatemala, El Salvador and Brazil with no accession being resistant to the virus. With this evaluation 5,850 accessions have now been tested, but few materials tolerant to BGMV have been identified

International Bean Golden Mosaic Virus Nursery. An International BGMV Nursery consisting of 80 collections was established. Sets were sent to Guatemala, El Salvador, Brazil and Tanzania for evaluation. The results indicated that some promising materials (including P466, P709, P757, P488, P566, Puebla 441, Venezuela 68, PI 313 878, and PI 313 882) were tolerant to the virus present in both Central America and Brazil.

The 1977 IBGMVN will contain 190 collections and will be planted in more sites in the Americas and Africa.

BGMV antiserum. The purification of the BGMV (1975 Annual Report) made possible preparation of a specific antiserum. Antiserum tests have established that the disease present in Guatemala, El Salvador, Colombia and Puerto Rico is caused by the same virus. These serological tests will be further expanded to several Latin American, Caribbean and African countries to better identify a "yellow mosaic" reported in all these countries (Fig. 6).

Seed Pathology

Production of pathogen-free seed

Cleaning seed of seed-borne pathogens continued as a priority project. In the screenhouse, 442 collections were cleaned. Promising materials, as well as entries from the Netherlands, Belgium, New Zealand, Perú, Honduras, Haití, and the international nursery sets were included. A total of 875 materials were increased in field plantings.

Large-scale production of clean seed for experimental and national program purposes was done by the bean agronomy group. Three tons of seed of 20 varieties

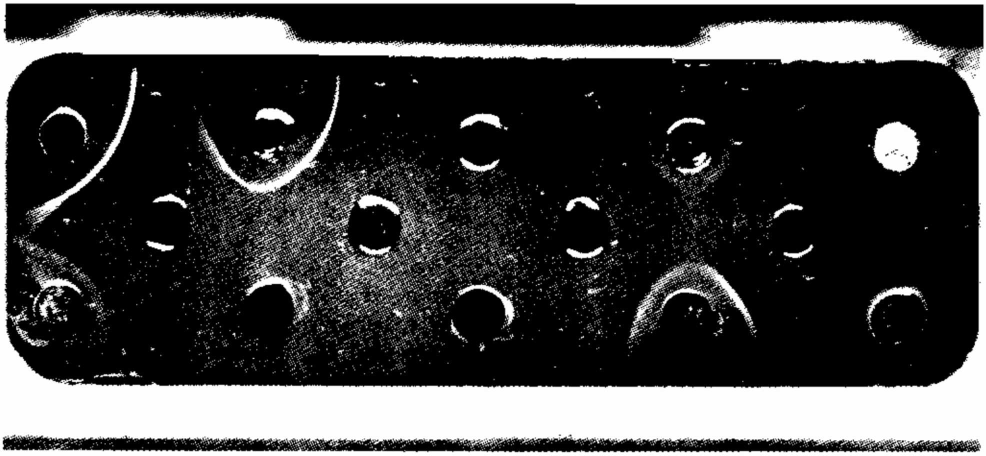


Figure 6. Serological tests help in identifying virus diseases in Latin America. Reactions of bean rugose mosaic, swelling mosaic and golden mosaic to their homologous antisera are shown.

was produced at Loboguerrero, a relatively dry site outside the bean producing area of the Cauca Valley where CIAT is located.

Production of anthracnose-free seeds using fungicides

Seeds of the susceptible variety Nima were planted at Popayán where anthracnose is severe and endemic. Applications of benomyl (a systemic fungicide) and captafol (a protectant fungicide), were made singly or in combination beginning 30 days after planting. Due to disease severity, treatments were made five times, at nine-day intervals.

Plants sprayed with benomyl at 1 kg/ha remained free of anthracnose, and at .5 kg/ha good control was attained. Poor disease control was attained on plants sprayed with benomyl at .25 kg/ha plus captafol at 1.5 kg/ha. Captafol at 3 kg/ha did not control the disease because of heavy rains. All nonsprayed (control) plants were killed by anthracnose within 50 days after planting. No significant yield differences were measured between plants sprayed with benomyl at .5 and 1 kg/ha. Plants in both treatments yielded significantly higher than plants sprayed with benomyl (.25 kg/ha) plus captafol or captafol alone, though benomyl- plus captafol-sprayed plants yielded significantly higher than plants sprayed with captafol alone. Bioassays for internally seed-borne fungi showed seed from plants sprayed repeatedly with benomyl at 1 kg/ha to be free of *C. lindemuthianum*. All plants sprayed with benomyl produced seed with significantly less total internally seed-borne fungi as *C. lindemuthianum* and *Fusarium* spp. than plants sprayed with captafol alone.

Under normal environmental conditions four applications of benomyl are needed to control anthracnose. The price of the bean seed in Colombia makes the use of this systemic fungicide economically feasible, even when five applications are necessary to ensure the production of good quality seed.

Effect of late harvest and of foliar applications of systemic fungicides on seed quality

To evaluate the effect of late harvest on seed quality, seeds of the variety Tuí were harvested at maturity or harvesting was delayed up to a maximum of four weeks. Fungicides were applied at maturity or post-maturity in some cases. Results are in Table 3.

With seed harvest at plant maturity, all treatments including the control had good seed quality, having a percentage germination *in vitro* and field emergence of at least 85 percent. As harvest was delayed, germination and emergence percentages decreased while seed infection increased, in treated and nontreated groups alike.

Fungi of 13 genera were recovered from seed in this study. The majority of seed infection in the control treatment was due to *Fusarium* spp. while most infections in both treatments which included benomyl were caused by *Alternaria* spp.

The results indicate that time of harvest appears to be extremely important in producing high quality seed. Delaying harvest can result in reduced germination in vitro and field emergence, as well as increased seed infection by fungi. Increases in the percentage of seeds infected by fungi appears to be accompanied by decreases in seed germination. Moreover, delayed harvest can result in physical damage to seeds, due to alternating wet and dry field conditions.

Effect of pod contact with soil on fungal infection of seeds

As revealed in the bean economic survey discussed in the 1975 Annual Report, many Colombian farmers save seed from a

Table 3. **Percentage germination *in vitro*, field emergence, internally seed-borne fungi and 1.000-seed weights of seeds from *Phaseolus vulgaris* cv. Tui plants not treated or treated with two systemic fungicides and harvested at maturity or at weekly intervals thereafter.**

		Mean %[1]			
Treatment	Time of harvest	Germination	Emergence at 15 days	Seed with fungi	1,000-seed wt (g)
benomyl	Maturity	95	87	4	201
	1 week after	92	84	15	205
	2 weeks after	92	87	26	201
	3 weeks after	93	82	38	205
	4 weeks after	76	71	96	206
oxycarboxin	Maturity	98	86	4	194
	1	97	86	13	207
	2	91	84	26	204
	3	82	82	56	198
	4	75	67	99	197
benomyl + oxycarboxin	Maturity	94	85	5	201
	1	95	84	17	208
	2	92	86	27	203
	3	86	84	54	203
	4	74	72	98	205
Nontreated	Maturity	87	86	13	152
	1	79	75	48	149
	2	63	69	86	147
	3	64	67	100	150
	4	60	61	100	154
	L.S.D. at .05	3.71	3.43	8.87	13.86
	L.S.D. at .01	4.94	4.57	11.82	15.15

[1] Three replications of 100 seeds each for each treatment and harvest date.

crop for later plantings. While they select from seeds available for those with reasonable grain features, they do not select the seed they harvest. Since pod contact with soil both decreases seed germination and promotes internal seed-borne fungi, studies were done to evaluate selective seed harvest as a means of improving crop stands on small farms. Results of the experiment are in Table 4.

While many seeds from pods in contact with soil were discolored, wrinkled or lesioned, most appeared physiologically normal. All seeds from pods not in contact with soil appeared normal. Similarly, while the percentage recovery of internally-borne fungi varied with cultivar, the levels were always greater in seed from pods in contact with soil. *Phomopsis* spp. and *Macrophomina phaseolina* were never

Table 4. **Percentage germination, seed with internally seed-borne fungi, viability, and field emergence of seeds from pods of five *Phaseolus vulgaris* cultivars in contact or not in contact with soil in the field at CIAT.**

Treatment [1]		Cultivar				
		Calima	Gualí	Huasanó	Porrillo Sintético	Tuí
Germination						
Soil contact		57	46	50	47	59
No contact		100	92	95	97	99
	L.S.D. at .05	17.9	9.3	16.9	10.5	11.6
	L.S.D. at .01	41.2	2.4	38.6	24.2	26.9
Seed with fungi						
Soil contact		64	90	88	92	78
No contact		3	30	26	19	14
	L.S.D. at .05	22.2	21.1	13.6	6.1	6.9
	L.S.D. at .01	34.0	44.4	31.3	13.9	15.9
Seed viability						
Soil contact		75	68	65	65	78
No contact		95	91	91	100	95
Field emergence						
Soil contact		63	47	58	51	69
No contact		92	86	84	83	95
Soil contact, treated with thiram		82	75	69	68	85
No contact, treated with thiram		95	90	86	86	94
	L.S.D. at .05	18.7	13.4	13.0	12.4	14.8
	L.S.D. at .01	28.9	20.7	19.7	19.0	22.3

[1] Three replications of 100 seeds each, except for viability test which was 100 seeds. Viability measured by the tetrazolium test. Thiram treatment was 2 g/1,000 g of seed.

recovered from pods not in contact with soil while *Rhizoctonia solani* was not recovered from seeds of Calima, Huasano or Porrillo Sintético pods not in contact with soil. The mean percentage germination *in vitro* and viability (by the tetrazolium test) of seeds from pods not in contact with soil was over 90 percent and significantly higher than for seeds from pods in contact with the soil. Similarly emergence was greater for seeds from pods not contacting soil.

The following fungal species were recovered from surface-sterilized seeds out of pods touching the soil: *Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp., *Fusarium* spp., *Isariopsis griseola, M. phaseolina, Monilia* spp., *Nigrospora* spp., *Penicillium* spp., *Pestalotia* spp., *Phoma* spp., *Phomopsis* spp., *Rhizopus* spp. and *R. solani*. *Fusarium* spp., *R. solani, M. phaseolina, Phomopsis* spp. and *Alternaria* spp. were most commonly encountered.

"Problem X"

A disease of unknown cause, reported in the Cauca Valley of Colombia as early as 1953, has become significant at CIAT in the last two years.

The symptoms are most striking in the varieties P011 and P459 (Fig. 7). Symptoms appear in the first trifoliate, becoming systemic and more severe in the new leaves. Vein clearing is observed on the leaves which become malformed resembling damage by hormonal herbicides. Witches' brooms form and the vegetative period is extended. Pods hardly ever form. When a few seeds are produced, they are deformed and wrinkled, although some plants subsequently undergo a secondary flowering and produce apparently normal seed. The disease is soil-borne, and the symptoms might be due to soil conditions, physiological disorders or genetic abnormalities, pathological conditions or a combination of these. The spreading of the problem in the field is not, however, typical of a pathogenic, soil-borne disease, as whole blocks of plants show symptoms almost overnight.

Figure 7. **Plants of *Phaseolus vulgaris* accession P459 affected by Problem X.**

Because this condition interferes with experiments and limits evaluation of breeding materials through changes induced in growth habit or yields, considerable attention has been paid to it in 1976.

Soil-transmission. When seeds of the varieties P011, P459, P566 and P634 were planted in the greenhouse in soil from infested areas, Problem X symptoms were reproduced. Symptoms were not observed when seeds were sown in soil sterilized with methyl bromide, nor in soil from a commercial nursery. Accessions P011 and P459 were more affected than P566 and P634 (68, 90, 47 and 11 percent, respectively) and P634 and P635 did not show any symptoms in some experiments.

Soil mixtures and filtrates. When infected soil was mixed 1:1 with disinfected soil, susceptible varieties did not develop symptoms. Likewise, disease symptoms were not observed when disinfected soil was irrigated with filtrates from infected soil.

When plants, grown either in disinfected soil or in Petri dishes on filter paper, were irrigated during two days with root soakings, no symptoms of the disease were reproduced.

Mechanical inoculation. Using common mechanical transmission methods for viral diseases, attempts were made to transfer the possible causal agent from diseased to healthy plants. Extracts were obtained in different buffers (phosphate, citrate, borate, EDTA, tris) with different molarities and pH's, and with reducing and chelating agents added to stabilize the possible causal agent. Over 1,000 bean seedlings of susceptible varieties have been inoculated without any success.

Grafting. Healthy P459 plants have been grafted onto diseased P459 plants, and vice versa. No symptoms were subsequently observed in healthy plants in which grafting was successful.

Seed transmission. Over 5,000 seeds from plants showing Problem X symptoms have been grown out in sterilized soil from infected fields to determine seed transmission. No plant showed symptoms during 45 days of observation. Differences in the severity of the symptoms of P459 were observed according to the origin of the seed when plants were grown in infected soil. This may suggest that the cause is associated with some factor involved with the seed coat.

The treatment of seed with fungicides or silver chloride or sodium hypochlorite did not improve control of the disease. While methyl bromide fumigation reduced the incidence of the disease in the field SMDC or PCNB had no effect.

Nematode extraction. Infected soil was submitted to nematode extraction by screening, centrifugation on sugar, and soil suspensions on distilled water. The population of nematodes was almost nil.

Electron microscopy. Preliminary observations of fixed tissue, and of partially clean extracts have not revealed any suspicious virus- or mycoplasma-like bodies.

Host-range. Soybeans (vars. Amsoy and Pelican), lima beans, cowpea, pumpkin, squash, cucumber, tomato, lettuce, broad beans, tobacco, *P. lathyroides, Rhinchosia minima, Gomphrena globosa, Datura stramonium, Nictiana glutinosa, Chenopidium album, Chenopodium quinoa,* and *P. vulgaris* were planted in infected soil. Only *P. vulgaris* showed symptoms of the disease as follows: P011 (92%), P459 (95%), P566 (90%), P714 (80%), P634 (0%), and P635 (0%). A variety of winged bean *(Psophocarpus tetragonolobus)* planted in an infected field also suffered severely from the condition.

The same hosts (at least 30 plants/host) were inoculated mechanically with extracts from diseased plants. None showed any sort of symptoms resembling those produced by Problem X.

Soil nutritional evaluations. Because of the alkaline soil conditions on the CIAT farm, a number of field and glasshouse studies have been undertaken to determine whether Problem X might result from a soil nutritional imbalance. Microelements such as zinc, iron, manganese or boron, applied either to the soil or foliarly and singly or in combination, have not decreased the severity of the condition in infected plots. Sulfur (2 t/ha) and bagasse (2 t/ha) incorporated into soil have both reduced the severity of the condition but have not eliminated it. Several explanations could be advanced for such results.

Since the cause of the problem remains to be identified, pathological and agronomic studies will continue in 1977. Experiments to evaluate the control of the problem by better rotational systems are also being planned.

ENTOMOLOGY

Emphasis in 1976 was again on screening germplasm and segregating populations for resistance to *Empoasca kraemeri,* the leafhopper. Cooperative screening of germplasm for resistance to insects of major importance in other countries but not present at Colombian testing sites was also intensified. Studies on using insecticidal sprays more efficiently by proper timing or to reduce pest levels by cultural methods were continued.

Empoasca kraemeri

Resistance studies

Initial screening of the germplasm bank for resistance to *E. kraemeri* revealed only moderate tolerance levels to this important insect. Seventy-six promising cultivars will be retested to determine levels and types of resistance present. Some lines were tolerant though carrying high nymphal populations. In others tolerance was associated with low nymphal counts (Table 5). Levels of tolerance were recovered in first screenings of segregating populations involving resistant parents.

As no oustanding resistance was found within *P. vulgaris,* resistance was sought in species such as *P. coccineus* or related wild types which hybridize with this species. Among 54 accessions tested, two *P. coccineus* accessions (G 04834 and G 04835) showed good resistance levels (Table 6). Ancestral types and interspecific *P. coccineus* x *P. vulgaris* hybrids tested were all susceptible. This experiment again showed that there was no relationship between damage grade and nymphal count. The susceptible variety Diacol Calima was so heavily damaged by leafhoppers that it supported only low levels of nymphs while adults moved to Tuí variety, which was damaged less and therefore provided better oviposition sites.

Table 5. ***Phaseolus vulgaris* accessions showing high tolerance to *Empoasca kraemeri* attack at two levels of nymphal populations.**

	Avg. damage score (0-5)		Nymphs/ leaf[1]	
Accession	1975	1976	1975	1976
High nymphal populations				
P466	1.8	1.6	12.1	16.6
G 04165	1.3	1.3	10.0	13.9
G 02704	2.4	2.0	7.7	13.2
Low nymphal populations				
P414	2.3	2.6	3.7	6.9
G 05086	2.4	1.8	4.4	7.8
P 325	2.3	1.5	5.1	8.0

[1] Average of three counts of 20 leaves each.

Table 6. **Resistance to *Empoasca kraemeri* in two *Phaseolus coccineus* accessions compared with susceptible and resistant *Phaseolus vulgaris* varieties.**

Species and identification	Nymphs/ leaf [1]	Avg. damage score (0-5) [1]
Phaseolus coccineus		
G 04834	1.5	1.2
G 04835	1.5	1.6
Phaseolus vulgaris		
Diacol-Calima (susceptible)	3.2	5.0
ICA-Tuí (resistant)	8.7	2.0

Four observations of 20 leaves/plant.

Since most resistance sources located thus far show only field tolerance, it is difficult to distinguish tolerance levels among accessions or between plants in segregating populations involving resistant parents. A study is in progress using 10 varieties, planted in dry and wet seasons and under four insect control regimes to identify optimum screening conditions and to select those plant parameters most likely to reflect differences in tolerance levels. Yield data for the two seasons are in Table 7. In each treatment and variety several characteristics, including leaf number and size, petiole length, plant height and flowering dates, are measured and correlated with treatment effects. An analysis of data from wet season plantings showed adult and nymphal populations, plant height and weight and leaf area, correlated with increased yield due to pesticide protection. The dry season data are being analyzed.

Table 7. **Average yields of 10 *Phaseolus vulgaris* varieties with differing levels of resistance to *Empoasca kraemeri* in wet and dry seasons and under four levels of insect control.**

	Yield (kg/ha)	
Insect control level	Wet season	Dry season
Control throughout season	2,500 a	1,911 a
Control before flowering	2,355 a	1,524 b
Control after flowering	2,399 a	1,571 b
No control	2,138 b	1,007 c

[1] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D. method.

Cultural control

In previous experiments beans grown with maize were less infested with *E. kraemeri* than beans grown alone. To study this effect further, beans (var. Diacol Calima) were grown untreated, under shading (50% light interception), and with a mulch of rice straw. Shading was chosen to simulate the microclimatic effect of maize on bean insect populations. In early stages of plant growth, shading, and more so mulching, greatly reduced leafhopper infestations. Later, the mulched plots were so much less damaged that the leafhoppers migrated to them causing highest infestations on these plots late in the growing season (Fig. 8). Despite this, yields in the mulched plots were twice those of non-treated plots.

Maximum reduction of leafhopper populations on beans planted with maize occurred when the maize was planted 20-30 days before the beans (Table 8). Similarly, maximum suppression of *Spodoptera frugiperda* on maize-bean associations occurs when beans are planted up to 20 days before maize.

Beans in pots placed in weedy plots remained less damaged by insects than beans potted in clean fields. To test this effect further, beans were planted in the wet season with varying percentages of weed soil cover. As shown in Table 9, the increasing weed cover reduced leafhopper populations significantly, while yields remained equal. It is probable that in terms of yield the reduced leafhopper population was counterbalanced by increased weed competition. The reduction of leafhopper populations in weedy habitats was not due to increased activity of *Empoasca* predators and parasites, as *Anagrus* parasitism and populations of Nabidae, Reduviidae and Dolichopodidae were equal in all treatments.

Chemical control

To better rationalize the use of insecticides in controlling *Empoasca*, studies were done in which the susceptible variety Calima was treated with the systemic insecticide monocrotophos when leafhopper populations reached varying levels per leaf. Non-treated plots and plots with complete insect control were included. In two experiments linear regressions of yields on leafhopper nymphal population were obtained, with each additional nymph reducing yield about 6.4 percent (Fig. 9). A later study yielded a regression best fit by a quadratic curve, indicating that the first nymphs permitted per leaf before chemical control was made, reduced yields more than did additional nymphs (Fig. 10). This is unfavorable for integrated control methods where one tries to permit the highest possible population without reducing yields. In the latter trial, when 3-7 nymphs were allowed per leaf, the yield was again reduced 6 percent per additional nymph permitted per leaf. In yet another study, plants of the variety Diacol Calima were chemically protected in the dry season with low dosages of monocrotophos. In this study, where the leafhopper attack began relatively late in the bean growing cycle, it appeared that chemical control was not needed until 44 days after planting (Fig. 11). Furthermore, plots receiving

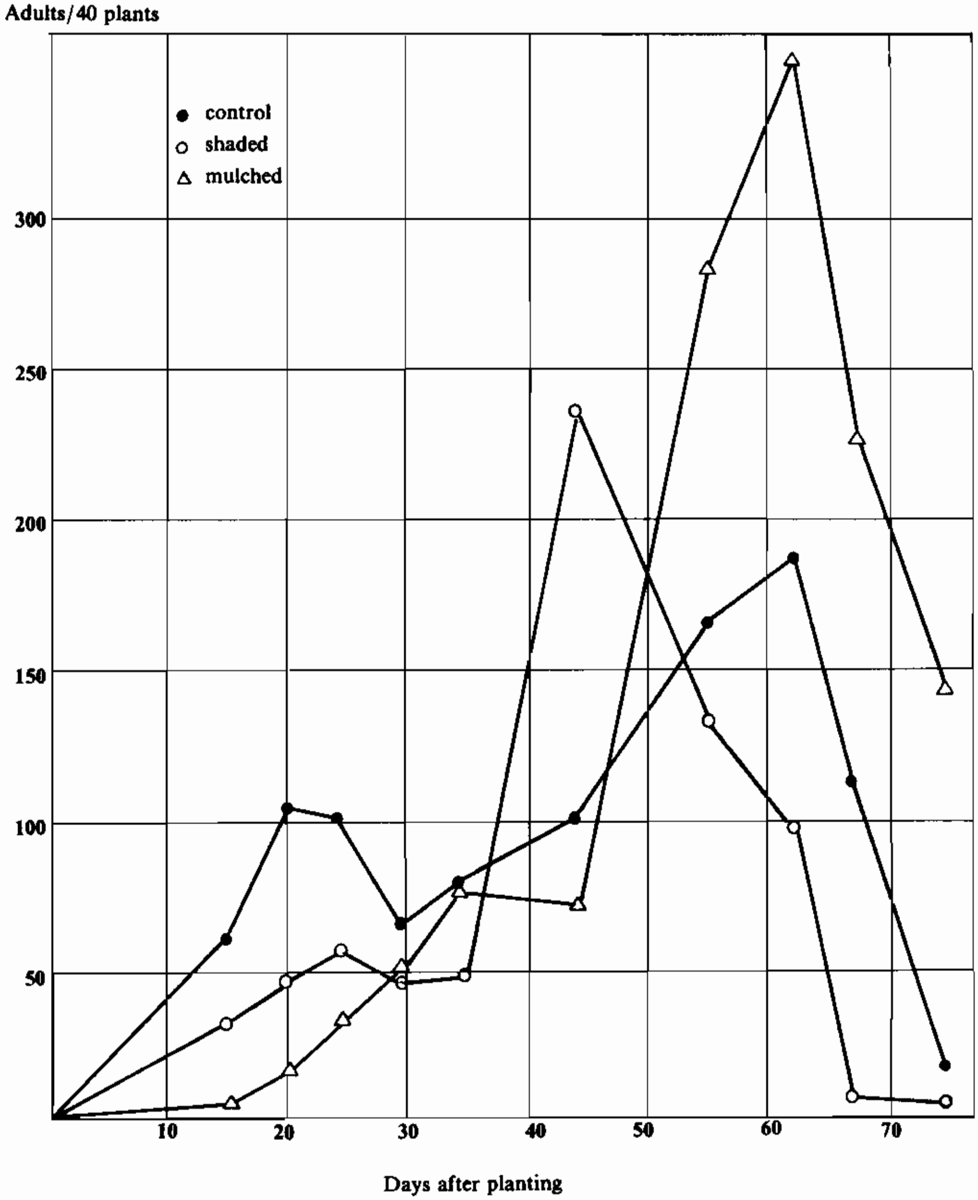


Figure 8. *Empoasca kraemeri* **adults on control, shaded and mulched beans. (Avg. of 3 replications each date.)**

only two applications of insecticide yielded the same as those receiving five applications. A curious note was the high incidence of attack by *Heliothis* sp. in the chemically-protected plots (41% incidence) compared to an average of 19 percent in non-treated plots.

Systemic, soil-applied insecticides have strong ecological advantages and can

Table 8. *Empoasca kraemeri* **adults on** *Phaseolus vulgaris* **associated with maize and planted at different times in relation to the maize.**

No. of days maize was planted before beans	Adults/80 bean plants[1]
30	25.7 a [2]
20	72.3 b
10	138.2 bc
0	133.1 bc
-10	152.9 c
-20	149.5 bc

[1] Average of three replications on each of five sampling dates.

[2] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D. method.

provide long-lasting protection, as seen in Figure 12 for carbofuran. Higher nymphal populations developed on carbofuran-protected plots after the residual effect of the pesticide had worn off.

Polyphagotarsonemus latus (Banks)

Resistance screening

Screening continued for resistance to the *P. latus* mite, with about 2,000 accessions being tested. Differences in resistance were observed, but infestations were not high enough to draw proper conclusions. The mite was effectively controlled chemically with a wettable sulfur powder formulation.

Table 9. *Empoasca kraemeri* **adults and nymphs on** *Phaseolus vulgaris* **and yields under five densities of weeds.**

% Soil cover with weeds	Adults/ 80 plants [1]	Nymphs/ 15 leaves [1]	Bean yield (t/ha) [1]
0	52.8 a[2]	22.4 a	1.70
25	37.7 b	13.8 b	1.78
50	29.7 c	10.5 b	1.75
75	28.4 c	11.8 b	1.79
100	30.1 c	6.7 c	1.85

[1] Average of three replications on each of six sampling dates.

[2] Means within columns and followed by the same letter are not significantly different at .05 by the L.S.D. method.

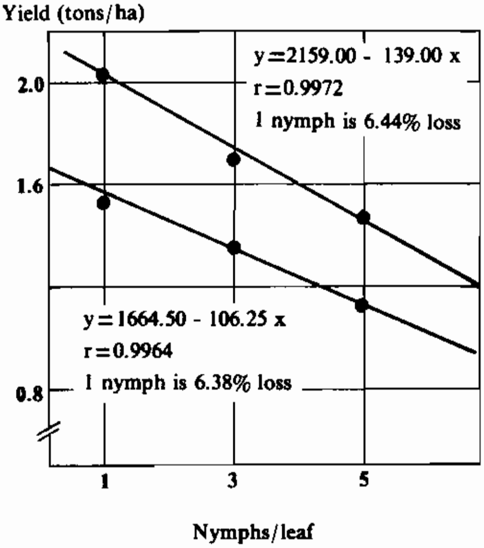


Figure 9. **Dry bean yields at increasing** *Empoasca kraemeri* populations in 2 experiments. Fields were sprayed when populations were 1, 3 or 5 nymphs/leaf. (Avg. of 4 replications each treatment.)

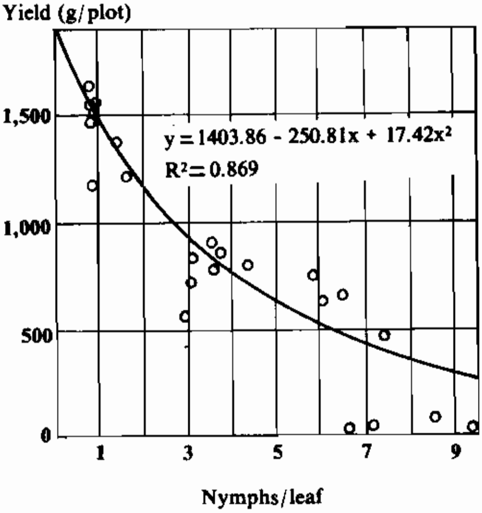


Figure 10. **Dry bean yields at increasing populations of** *Empoasca kraemeri*. **Fields were sprayed when populations were 1, 3, 5, 7 or 9 nymphs/leaf.**

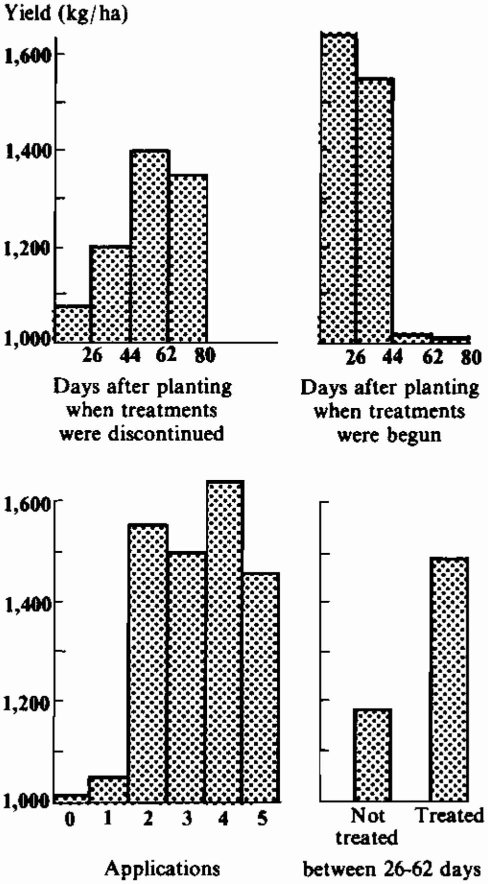


Figure 11. **Yields of Diacol Calima beans under different treatments for insect control with monocrotophos.**

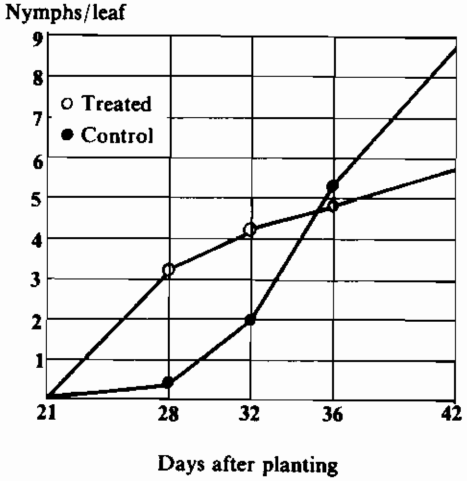


Figure 12. **Residual effect of carbofuran (0.9 kg/ha a.i., granular soil-applied) on *Empoasca kraemeri*. (Variety Diacol Calima, 30 leaves/sample).**

Zabrotes subfasciatus

Among 781 promising accessions currently selected, 112 have shown initial resistance to *Z. subfasciatus*. These materials were selected because, when infested with adult *Zabrotes* at the rate of five pairs/50 seeds, few eggs were laid, few adults emerged or their emergence was retarded. Several seed samples were contaminated with pesticides and are being retested. Some materials, which appeared resistant in the first test were susceptible during successive testing with newly harvested seed. Apparently resistant materials have to be retested for three generations prior to being classed as resistant.

Nonchemical control of *Z. subfasciatus* was further studied. Harvest plant debris provided only a low degree of control in stored beans to this bruchid attack (Table 10). It appears that the control is mechanical as beans in the bottom part of the jars are best protected.

Vegetable oils were tested for their action against *Z. subfasciatus*, a custom

Table 10. **Percentage seed damaged by *Zabrotes subfasciatus* when various percentages of harvest debris were added to stored seed.**[1]

	% debris		
Section of jar	0	10	20
Top	100.0	99.0	99.3
Middle	99.8	97.2	95.7
Bottom	99.6	76.3	61.8

[1] Diacol Calima variety with ten pairs of adults per 100 g seed in six replications for 90 days.

Table 11. **Effects of vegetable oils mixed with stored *Phaseolus vulgaris* on emergence of *Zabrotes subfasciatus* adults.**[1]

	Emerged adults	
Treatment	1 ml oil/kg	5 ml oil/kg
Coconut oil	13.8	0.2
Soybean oil	28.0	2.4
Oil palm oil	4.2	0.0
Cottonseed oil	5.2	0.0
Control	264.8	

[1] Diacol Calima variety with seven pairs of adults on 100 g of seeds.

for pulses in India and tested with cowpeas at International Institute for Tropical Agriculture (IITA), and appeared to be effective (Table 11). The oils were applied on the seeds and mixed in a tumbler. In time, oils were increasingly absorbed into the seed, leaving the physical appearance of the bean unaffected.

Chemical control of *Z. subfasciatus* is readily obtained with a variety of products, of which the pyrethrins and pyrethroids may be among the safest. Some of these compounds gave long residual control, when tested under laboratory conditions in continued darkness (Table 12). The products on bases of marc (ground flower) adherred less to the seed, but made them more acceptable in appearance after treatment as compared with products on talc bases.

Table 12. **Effects of pyrethrins and pyrethroids on *Zabrotes subfaciatus* adults in stored *Phaseolus vulgaris*.**[1]

			% Adult mortality 2 days after reinfestation at			
Treatment	Dosage (ppm)	Adhesion to seed (%)	0	120	360	Emerged adults/rep.
			days after treatment			
pyrethrins +	1.5	77.3	100.0	93.4	80.9	0.4
piperonyl butoxide	2.5	57.0	100.0	90.7	83.1	0.0
(on marc base)	4.0	32.5	100.0	97.5	91.6	0.1
pyrethrins +	1.5	100.0	100.0	99.4	91.6	2.8
piperonyl butoxide	2.5	100.0	100.0	100.0	96.9	0.0
(on talc base)	4.0	100.0	100.0	100.0	99.1	0.4
bioresmethrine +	1.5	57.0	100.0	74.4	54.7	29.1
pyrethrins	2.5	43.0	100.0	80.3	48.1	31.4
(on bean residues)	4.0	31.5	100.0	82.5	61.6	8.0
bioresmethrine +	1.5	100.0	100.0	65.9	46.3	36.5
pyrethrins	2.5	100.0	100.0	98.8	75.6	3.1
(on talc base)	4.0	100.0	100.0	100.0	91.9	0.5
Control			0	1.1	0	398.2

[1] Average of eight replications; Diacol Calima variety with 100 g seed/rep, and infested with 20 pairs of adults at beginning.

Economic Importance of Stored Grain Insect

In a survey with the bean economics group, the relative importance of stored grain insects was studied on the farm and in 30 warehouses in bean producing areas of Colombia. Average losses were estimated at 7.4 percent (Table 13). Losses are probably low because of the short storage period for beans (an average of eight and 44 days on farms and in stores, respectively).

Table 13. **Losses from Bruchid attack in 30 bean warehouses in Colombia.**

Percentage of stores with infested beans	20.0
Percentage of bags infested	2.3
Percentage of bags refused due to Bruchids	5.1
Estimated loss from Bruchids 2.3% + 5.1% = 7.4%	

MICROBIOLOGY

Nitrogen Fixation

Studies in 1976 employed acetylene reduction techniques for weekly or biweekly testing of nitrogen fixation in *P. vulgaris*. First, an understanding of parameters of fixation in a number of phenologically distinct bean cultivars was sought, then, explanations of observed differences were developed. Breeding for improved nitrogen fixation in beans was initiated as was a reevaluation of a number of inoculant strains.

Parameters of nitrogen (C_2H_4) fixation in beans

During the year nitrogen fixation rates (measured by ethylene produced from the reduction of acetylene) up to 38μ mol/plant/hr were obtained in replicated conditions at Popayán. Fixation rates commonly surpassed the highest levels achieved in 1975. Specific nodule activities ranged from 130-250μmol C_2H_4/g nodule dry wt/hr with maximum nodule mass more than 600 mg dry wt/plant. As Table 14 shows, these figures are amongst the highest reported so far for grain legumes. Varietal differences in fixation over the growing season were very marked (Fig. 13). Based on the data in this figure the cultivar P590 achieved fixation levels equivalent to a nitrogen gain of 41 kg/ha/growing season. The average for 14 cultivars studied was over 20 kg N/ha/growing season. Figure 14 shows early nodulation in one of the promising

Table 14. **Parameters of nitrogen fixation in some grain legumes (data from various sources).**

Species	Nodule dry weight (mg/plant)	Specific nodule activity (μ mol/g nod wt/h)	Acetylene reduction (μ mol/plant/h)	Nitrogen fixed (kg/ha/yr)
Phaseolus vulgaris (P590)	167-300	228	20-30	82
P. vulgaris, 20 cultivars	259-665	124-270	18.5-38.8	50-60
Glycine max	133	35-176	4-29	57-94
Arachis hypogea	80	135	27	35
Vigna unguiculata	210-413	80-288	42	95
Pisum sativum	2-150	60-228	4-16	25

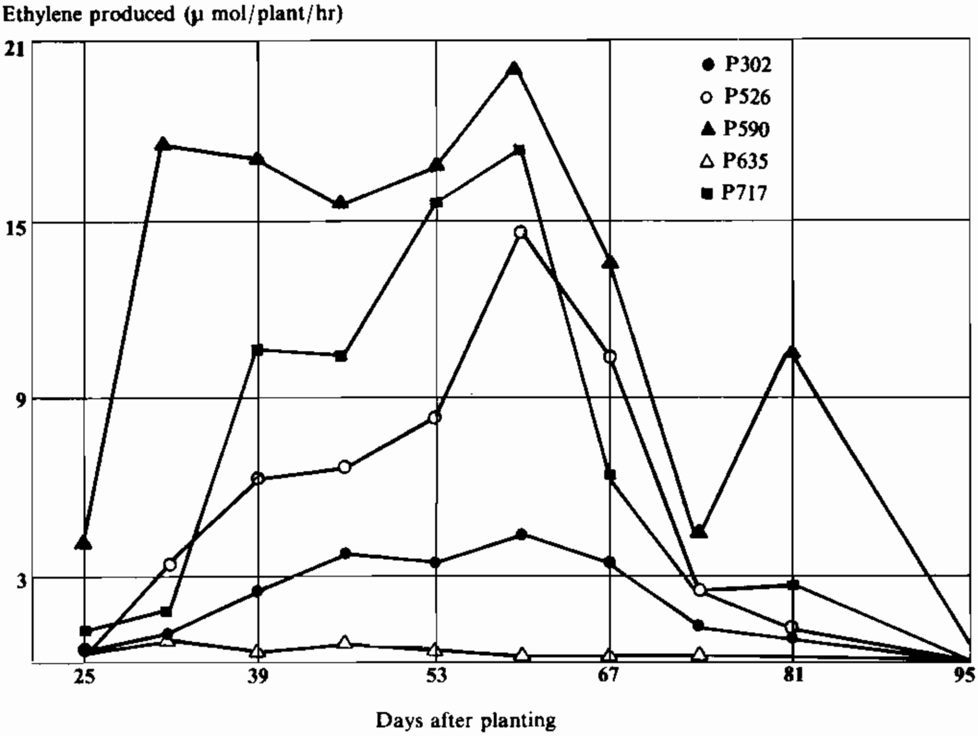


Figure 13. **Acetylene reduction profiles for 5 accessions of *Phaseolus vulgaris* at Popayán, 1976A.**

Figure 14. Nodule distribution and lateral root development in *Phaseolus vulgaris* 18 days after planting.

cultivars with nodules mainly found on secondary roots.

In a second study in which 10 cultivars from each group were compared, bush beans proved weaker in fixation than the more primitive climbing cultivars (Fig. 15). Cultivar P590 again proved outstanding in nitrogen fixation in this study. In contrast, a soybean cultivar (Pelikan) included as a control proved disappointing.

Figure 16 shows that bush cultivars assimilated more soil nitrogen in the prefixation period than did climbers. Breeders. have tended to select for yield in this plant type using N-fertilized conditions, perhaps inadvertently also selecting for plants with early rooting vigor. In such plant types, nodules would face strong competition for energy and could

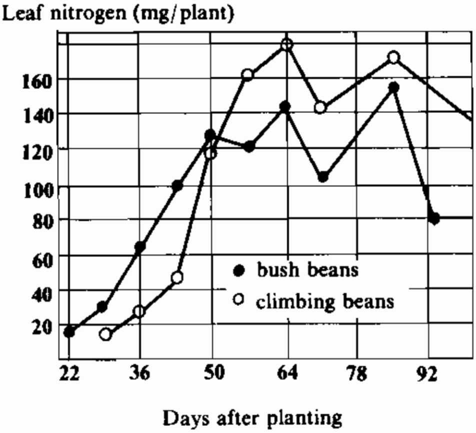


Figure 16. Nitrogen content of leaves of bush and climbing cultivars of *Phaseolus vulgaris* at different stages in the growing season. Each point averages results for 10 cultivars in 4 replications.

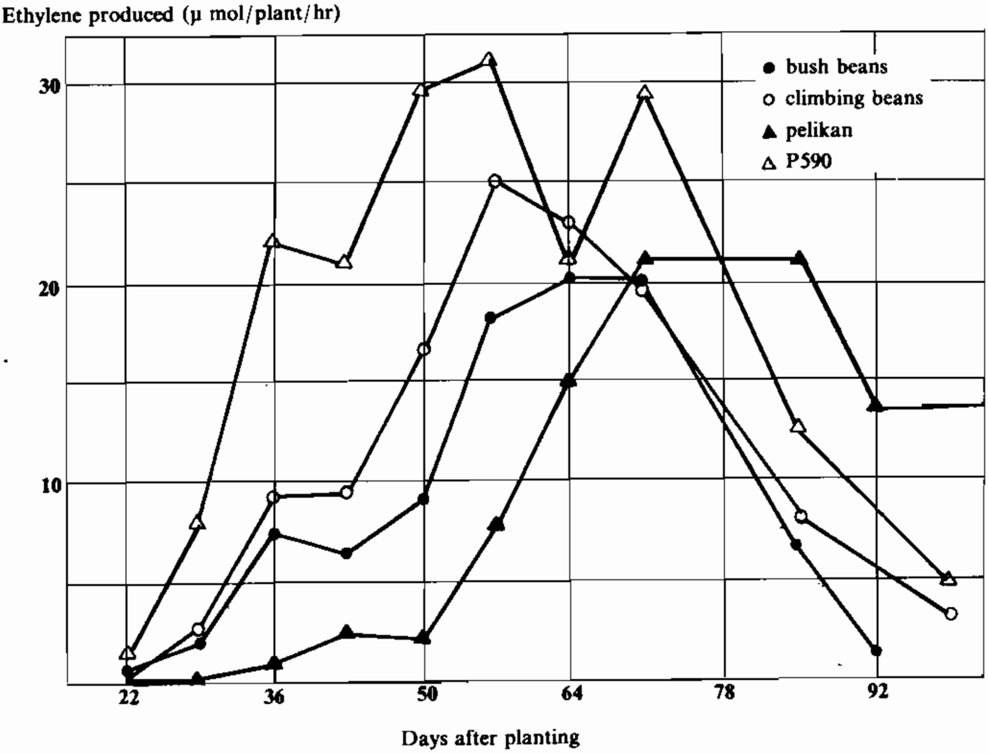


Figure 15. Acetylene reduction profiles for bush and climbing cultivars of *Phaseolus vulgaris*. Each point averages results for 10 cultivars. Accession P590 and the soybean variety Pelican were checks.

even be repressed by rapid nitrogen uptake. The effect is being further investigated.

As is evident in Figures 13 and 15, the fixation period for most bean cultivars was short. At 18-20ºC few cultivars initiated fixation prior to 28 days after planting, and in most, activity began to decline at about 10 weeks. This period compares unfavorably with the 90-105 day fixation period reported for soybean and *Vicia.*

Carbohydrate supply and nitrogen fixation

Following up work begun last year (CIAT Annual Report, 1975) a number of experiments were undertaken to measure carbohydrate form and availability in different cultivars and to relate this information to nitrogen fixation.

In one experiment, 14 cultivars inoculated with the CIAT *Rhizobium* strain 57 were sampled at 39 (initiation of active fixation) and 61 (beginning of decline of fixation rates) days after planting. All plant parts were sampled and analyzed for ethanol soluble and insoluble carbohydrate. The acetylene reduction data of Figure 13 formed part of this study.

Again marked varietal differences were found. Tables 15 and 16 compare carbohydrate patterns in the cultivars P590 and P635, the former being highly active in fixation, the latter inactive despite copious nodulation (Fig. 13). P590 not only has a higher percentage soluble carbohydrate in

Table 15. Distribution of carbohydrate[1] in two accessions of *Phaseolus vulgaris* at two plant development stages.

	Total carbohydrate (mg/plant)			
	39 days after planting		61 days after planting	
Plant part	P590	P635	P590	P635
Nodules	35.35	10.94	100.62	0.92
Roots	55.29	90.84	175.39	247.04
Stem				
nodes 1 + 2	124.58	395.13	110.07	678.68
nodes 3 + 4	118.68	118.67	414.51	71.97
nodes 5 + 6	52.23	—	111.06	174.23
nodes 7 + 8	—	—	157.44	—
8	—	—	70.40	—
Leaf				
nodes 1 + 2	270.02	336.44	191.50	88.03
node 3 + 4	114.48	171.38	404.65	60.29
nodes 5 + 6	66.40	—	146.60	99.06
nodes 7 + 8	—	—	227.43	—
8	—	—	51.50	—
Pods	—	—	—	132.76
Total	837.03	1,123.40	2,121.17	1,552.98

[1] Both ethanol soluble and insoluble carbohydrate.

Table 16. **Ethanol soluble and insoluble carbohydrates in selected varieties or accessions of *Phaseolus vulgaris* at two plant development stages.**

				% of total carbohydrate			
		Avg. 14 varieties		P590		P635	
Plant part	Carbohydrate source	39 days after planting	61 days	39 days after planting	61 days	39 days after planting	61 days
Nodules	Soluble	0.68	0.34	1.34	1.84	0.61	0.02
	Insoluble	1.40	0.69	2.87	2.81	0.29	0.04
	Total	2.08	1.03	4.21	4.65	0.90	0.06
Root	Soluble	3.82	2.95	4.02	3.71	5.08	4.09
	Insoluble	2.46	5.40	2.58	4.41	3.00	11.82
	Total	6.28	8.35	6.60	8.12	8.08	15.91
Stem	Soluble	10.92	16.52	15.90	28.46	15.76	5.29
	Insoluble	17.66	25.22	19.39	11.49	29.98	54.26
	Total	28.58	41.74	35.29	39.95	45.74	59.55
Leaves	Soluble	20.36	21.62	29.30	31.53	15.43	4.33
	Insoluble	43.33	25.98	24.56	15.75	29.78	11.60
	Total	63.69	47.60	53.86	47.28	45.21	15.93
Pods	Soluble	-	0.90	-	-	-	5.17
	Insoluble	-	0.78	-	-	-	3.38
	Total	0	1.68	0	0	0	8.55
Total	Soluble	35.25	42.33	50.59	65.56	36.50	18.90
	Insoluble	64.78	58.07	49.41	34.44	63.50	81.10

all organs but partitions more of its total carbohydrate to the nodule.

Starch accumulation in the stem of determinant (bush-type) cultivars of *P. vulgaris* (as is P635) was reported last year (CIAT Annual Report, 1975) and is currently being investigated for its influence on flower and pod abortion and on yield (see p. A-56). In this study, the best five cultivars in nitrogen fixation tended to maintain more carbohydrate in a soluble form (Fig. 17) and had lower starch accumulation in the stem.

A strong correlation existed between carbohydrate supply and nitrogen fixation. Figure 18 relates total soluble carbohydrate in the nodule to levels of acetylene reduction, with the suggestion— not previously reported— that the nodular system can be oversupplied with energy and not fully utilize it. Figure 19 shows starch accumulation in stem cells and in uninvaded cells of the nodule complex. Invaded cells showed little starch.

A comparative study of seasonal and diurnal changes in nitrogen fixation by a

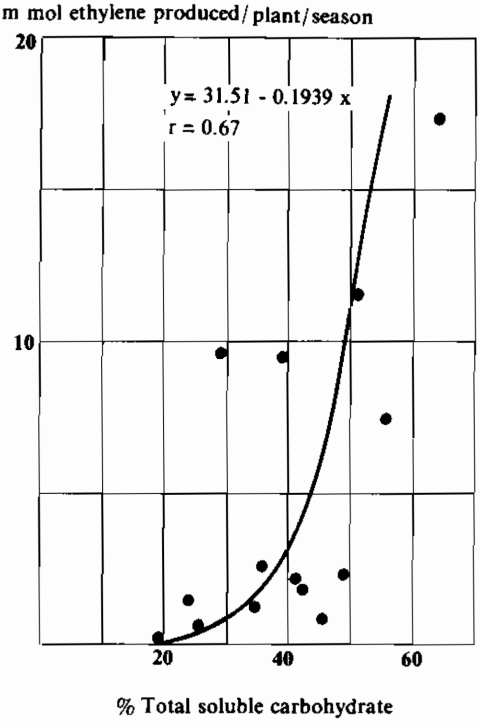


Figure 17. **Relationship between seasonal levels of nitrogen fixation and percentage nonstructural carbohydrate maintained in soluble form.**

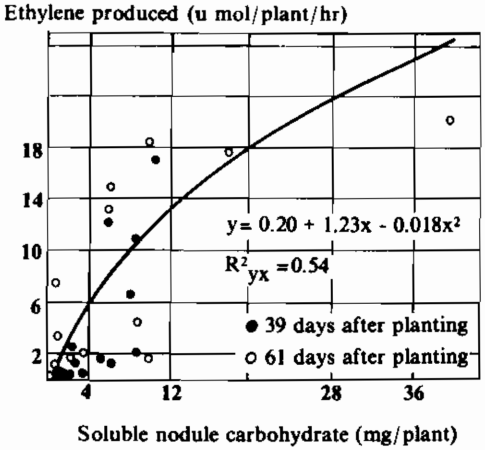


Figure 18. **Relation between soluble nodule carbohydrate and acetylene reduction levels in 14 cultivars of *Phaseolus vulgaris*.**

representative bush (P302) and climbing (P590) cultivar reconfirmed the importance of the form and location of compartmented carbohydrate. The bush cultivar, while poorer in nitrogen fixation and with considerable stem starch, still accumulated starch in its nodules at a time when energy requirement for nitrogen

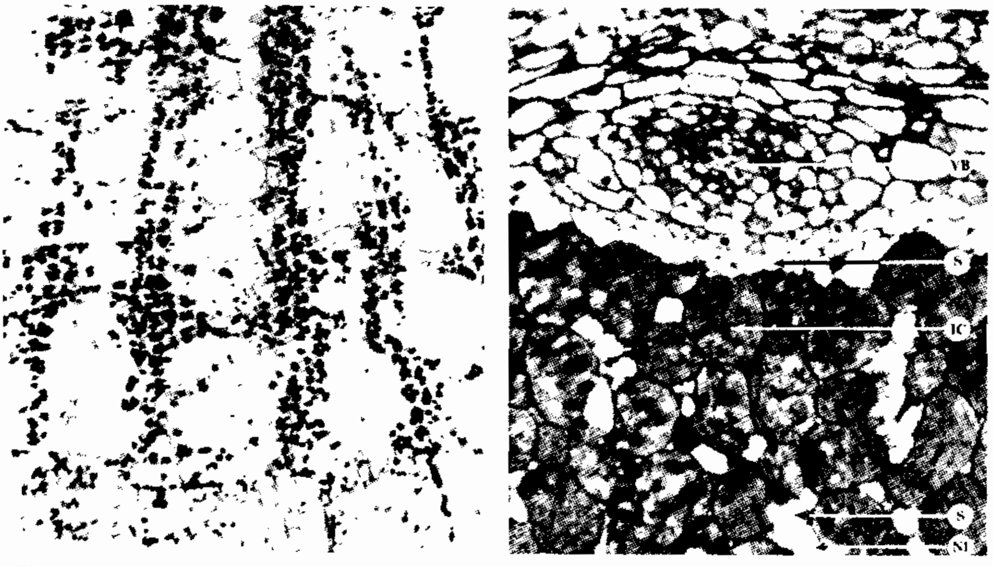


Figure 19. **(Left) Stem section of *Phaseolus vulgaris* cv. 72V 26689 showing starch accumulation in 60-day-old plants. (Right) Nodule section of same plants showing vascular bundle (VB), starch granules (S) in noninfected (NI) cells and cells infected with *Rhizobium* (IC). (Photos R. Martinez)**

fixation would have been greatest (Fig. 20). Specific acetylene reducing activities in nodules of each cultivar were similar in mid-vegetative growth and declined only slightly at night (Fig. 21). The soluble carbohydrate pools of the leaves became depleted in the late afternoon (Fig. 22a) and continued carbohydrate support to sinks was maintained by release of leaf starch at night (Fig. 22b). The bush cultivar released 33 percent of its leaf starch but it appears that the roots benefited more from the translocated carbohydrate than nodules since the former were able to accumulate starch (Fig. 22c) whereas the latter consumed some of their storage reserves (Fig. 22d). The climber released much more (75%) of its leaf starch (Fig. 22b) and the nodules were able to acquire sufficient of the translocates not only to maintain nitrogenase activity but also to synthesize starch (Fig. 22d).

In 1975, in the laboratory, correlation was shown between maximum nodule dry weight achieved and days taken to flowering. This study was continued in 1976 in the field. Fourteen cultivars were used of which eight flowered in 63 and six in 43 days. Leaf, stem and root development for each group is shown in Figure 23 with cultivars used as replicates, The earlier increase in leaf and stem weight/plant of the more precocious cultivars is apparent, as is the rapid decline in leaf weight in this group after flowering. Plants flowering in 63 days showed a longer period of leaf weight increase with limited decline in leaf weight by the time the experiment was terminated. Despite this, seasonal curves for nodule dry weight development and nitrogen fixation were remarkably similar (Fig. 24) with significant differences only at the last sampling date. This experiment is being repeated to determine the effect of shorter leaf life on nitrogen fixation.

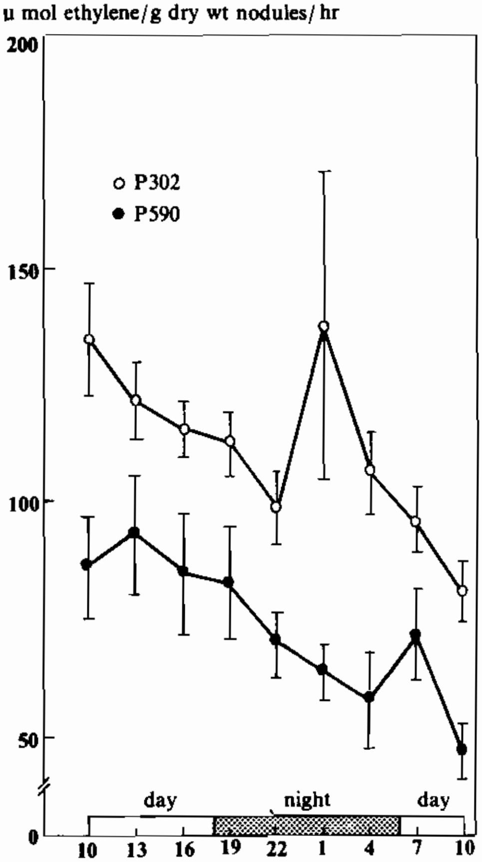


Figure 21. Specific nodule acetylene reducing activity in two *Phaseolus vulgaris* accessions over a 24-hour period.

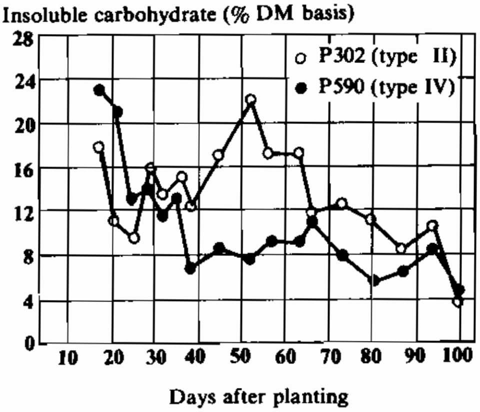


Figure 20. **Seasonal variation in nodule starch concentration in two *Phaseolus vulgaris* accessions.**

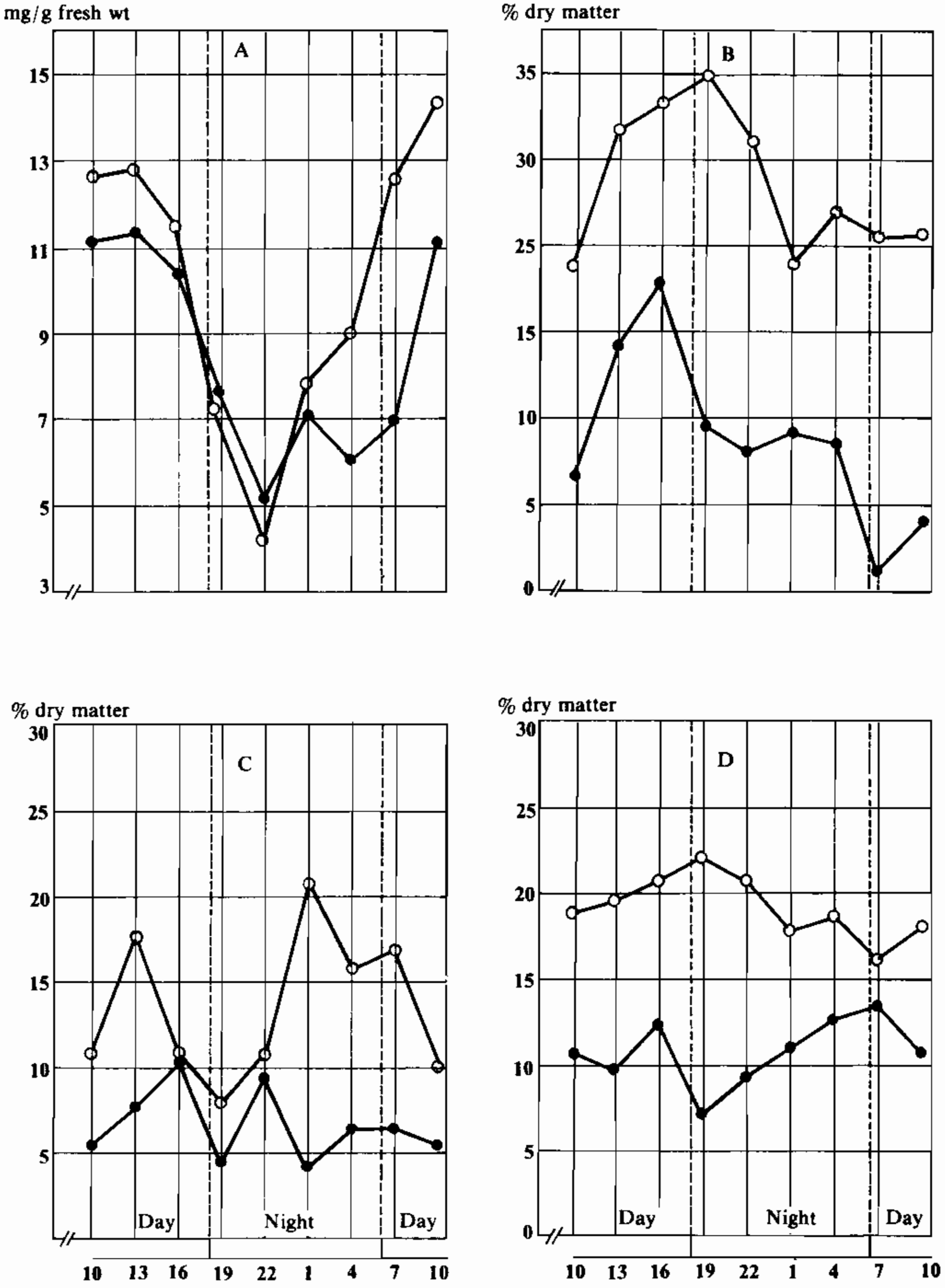


Figure 22. **Diurnal changes in soluble carbohydrate concentrations in leaves (A) and insoluble carbohydrate concentrations in leaves (B), roots (C) and nodules (D), in two** ***Phaseolus vulgaris*** **accessions. (○ P302, and ● P590).**

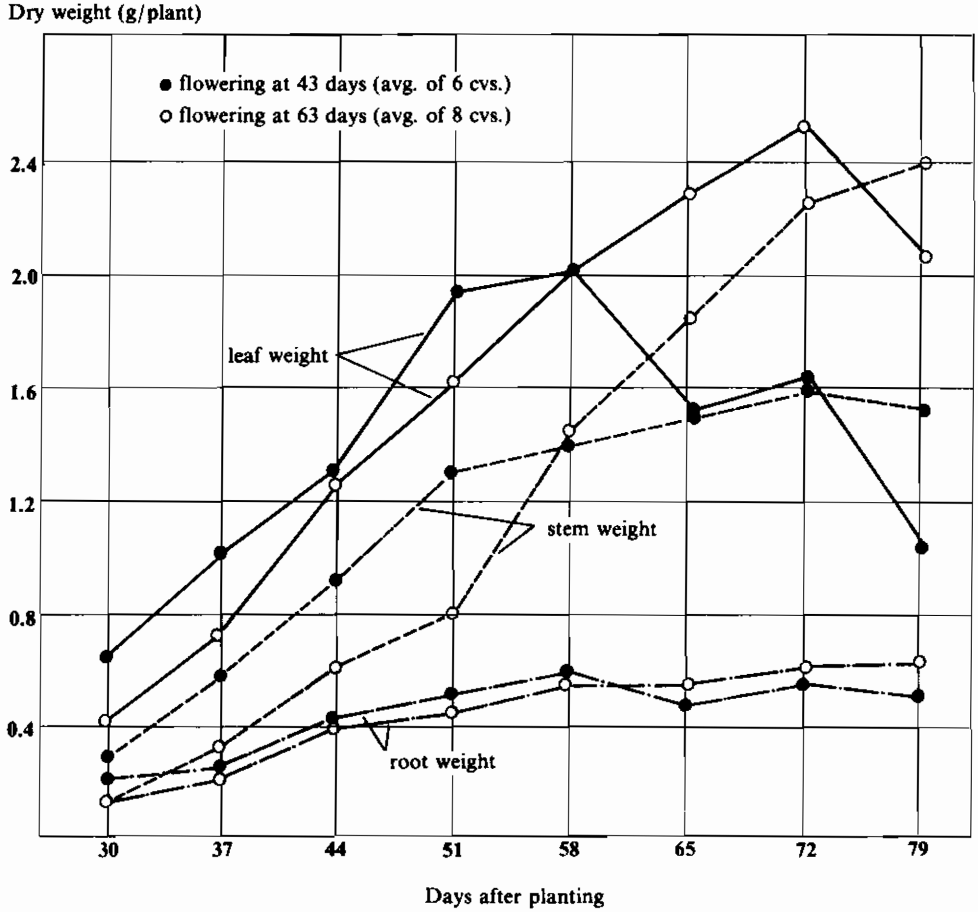


Figure 23. **Changes in leaf, stem and root dry weight for *Phaseolus vulgaris* cultivars flowering at two periods.**

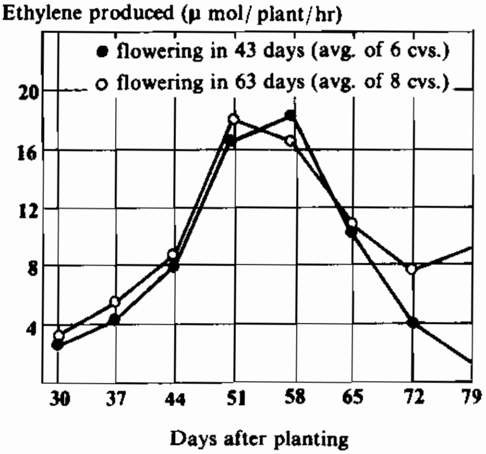


Figure 24. **Seasonal profiles in nitrogen fixation for *Phaseolus vulgaris* cultivars flowering at two periods.**

Nitrogen fixation in maize-bean associations

Because beans are grown with maize in many areas, and could have to compete for light, experiments were begun to determine nitrogen fixation levels under monocrop and associated cropping conditions. The cultivar P590 was grown on trellises (200,000 plants/ha) or in association with the maize hybrid H 207 (40,000 maize and 200,000 bean plants/ha). Although the maize was planted one month before the beans, it failed to compete with the bean or to provide adequate support for bean development. It is of interest, however, that in the early period of development nitrogen fixation levels in the associated cropping were greater than in the monocrop (Fig. 25). This can probably be attributed to improved soil aeration or temperature control; additional experiments in 1977 will further evaluate this finding. Later in the plant cycle the beans on trellises fixed more nitrogen than did the plants grown with maize. This undoubtedly reflected the poor canopy presentation of associated beans in the absence of satisfactory support. At no stage was nitrogen fixation detected in any of the maize plants sampled.

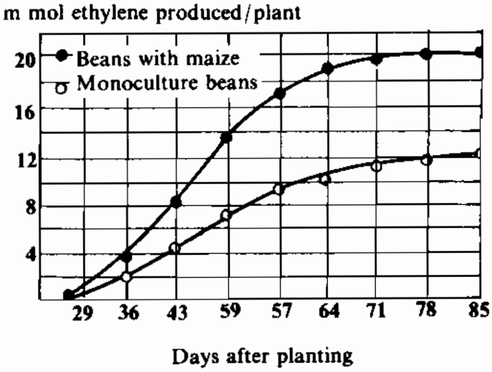


Figure 25. **Effect of cropping system on the total nitrogen (C_2H_4) fixed by the cultivar P590. Correction has been made for diurnal variation in fixation.**

Strain testing of *Rhizobium phaseoli*

Sixty-one strains of *Rhizobium phaseoli* were tested in the field for inoculation response in the cultivars Porrillo Sintetico and 72 vul 20972. Response to inoculation was striking, with uninoculated plants showing clear symptoms of nitrogen deficiency. With Porrillo Sintetico only seven strains produced nodule dry weight and acetylene reduction responses similar to, or better than, the CIAT strain 57 commonly used in field experiments (Table 17). Only three strains (CIAT 75, 135 and

Table 17. **Response of *Phaseolus vulgaris* var. Porrillo Sintetico to inoculation with different *Rhizobium* strains.**[1]

Treatment	Nodule dry wt (mg) 45 days after planting	Nodule dry wt (mg) 60 days after planting	Nitrogen fixation at 60 days (µ mol ethylene/plant/hr)	Plant dry wt at 60 days (g/10 plants)
Not inoculated, no added nitrogen	209.5	66.2	0.98	35.34
Not inoculated, with added nitrogen	100.3	137.2	0.16	53.41
Inoculated:				
Strain 57	996.0	1,083.0	15.09	62.23
Strain 147	503.2	1,770.0	47.62	72.68
Strain 686	1,369.1	1,335.0	39.53	66.96
Strain 404	1,107.9	738.5	26.40	70.98
Strain 73	- [2]	2,034.5	21.90	69.91
Strain 160	1,115.4	888.7	37.79	81.51
Strain 78	1,022.2	1,233.8	26.74	78.00
Strain 255	1,455.9	1,800.0	39.48	68.60

[1] Un replicated 10-plant sample for each strain; control: repeated every 10 strains

[2] Sample destroyed accidently.

255) equaled CIAT 57 when 72 vul 20972 was used as host. These strains will be compared again in future experiments.

Hybridization for improved nitrogen fixation

In collaboration with breeders in the program a number of crosses have been made to study the inheritance of nitrogen fixation in beans. These crosses stressed P590 as a parent combining both high fixation capacity and high levels of soluble carbohydrate, and used P635, P589 and P569 as cultivars weak in nitrogen fixation and/or soluble carbohydrate levels. P302 was also crossed with P590. F_2 seed will be grown at Popayán in the next season. Techniques for evaluating fixation in hybrids are being developed.

Inoculant supply

As in previous years the soil microbiology group continued to supply inoculants to requestors in Latin American countries.

AGRONOMY

Varietal Testing

Experiments to identify high-yielding materials among both bush and climbing cultivars of *P. vulgaris* intensified in 1976.

Bush cultivars

During the year, 146 new bush cultivars were evaluated in four Preliminary Yield Trials at CIAT (methodologies of different trials are described in CIAT's 1975 Annual Report).

Seed yields in the first trial ranged from 1,233 to 2,996 kg/ha and for the second trial from 1,010 to 3,659 kg/ha. Thirty black varieties equalled or exceeded the yield of the black check varieties, but in the non-black seeded group only 14 of the cultivars tested performed as well as the standard varieties included.

Promising varieties selected from Preliminary Yield Trials of the previous season were entered in Uniform Yield Trials, with seven such trials conducted as of September 1976. In the first group of trials, at two locations in Colombia and one in Ecuador, materials of all colors were included. Results of the 15 best entries are presented in Table 18; eight of the best nine materials were black-seeded. The exception, P758, a brown-seeded, type III plant, outyielded all cultivars in the CIAT trial. Because of this marked difference, cultivars were separated according to color in the two subsequent trials with each group tested at CIAT and Popayán. Results of these four trials are shown in Tables 19 and 20.

Climbing cultivars

Because studies were initiated later and required considerable seed multiplication, yield trials with climbing beans are not as advanced as with bush beans. More than 1,500 collections of type IV and tall type III beans have been screened for yield under trellis (monoculture) conditions, and 700 of these are currently being evaluated in association with maize. Several type IV promising cultivars have been planted in replicated yield trials both monocropped and associated with maize. Yields of five of these are shown in Table 21 and a typical cultivar, in Figure 26.

Uniform Yield Trials with climbing beans are planted in five locations in Colombia and Ecuador, and compare 20 high-yielding cultivars associated with maize. In these trials, and as a result of findings by the microbiology group, *Rhizobium* inoculation is being used. Bush bean trials depend to the moment on fertilizer nitrogen.

Table 18. **Highest yielding bean cultivars and check varieties in Uniform Yield Trials in Colombia (CIAT and Dagua) and Ecuador (Boliche).**

			Yield (kg/ha)			
Identification	Seed color	Growth habit	CIAT	Dagua	Boliche	Mean
Test materials						
P302	Black	II	2,009	2,618	3,396	2,674
P737	Black	II	2,011	2,585	3,145	2,580
P712	Black	II	1,895	3,060	-	2,477
P758	Brown	III	2,144	2,313	2,841	2,433
P675	Black	II	1,461	2,628	3,187	2,425
P459	Black	II	2,008	2,496	2,725	2,410
P560	Black	I	1,513	2,718	2,936	2,395
P511	Black	II	1,671	2,405	3,037	2,371
P512	Black	III	1,847	2,606	2,488	2,314
P692	Red Mottled	I	1,926	2,378	2,076	2,127
P566	Black	II	1,640	2,329	2,406	2,125
P498	Black	III	2,061	1,835	2,470	2,122
P637	Red Mottled	I	1,530	2,634	2,183	2,116
P757	Black	II	1,687	1,789	2,694	2,057
P756	White	I	1,793	1,487	2,610	2,030
Check materials						
Procaraota	Black	II	1,652	2,594	-	-
P458	Black	II	1,688	2,452	-	-
P635	Red Mottled	I	1,128	2,232	-	-
P402	Beige	I	-	-	3,108	-
Amarillo	Yellow	III	-	-	1,444	-
Blanco	White	II	-	-	1,067	-
Trial means and ranges						
Yield mean (kg/ha)			1,614	2,222	2,380	
Lowest yield (kg/ha)			772	1,487	556	
Highest yield (kg/ha)			2,144	3,060	3,396	
L.S.D. at .05			396	371	609	
C.V. (%)			15.3	10.4	16.0	

International Bean Yield and Adaptation Nurseries (IBYAN)

Proposed methodologies for a series of international yield and adaptation nurseries were presented in the 1975 Annual Report. Objectives are to evaluate the yield and adaptation of cultivars over a wide range of experimental conditions and to allow national programs to compare a

Table 19. **Yield of non-black bean varieties of the Uniform Yield Trial at two locations in Colombia.**

			Yield (kg/ha)		
Identification	Seed color	Growth habit	Popayan	CIAT	Mean
Test materials					
G01212	Red	III	2,641	2,106	2,374
P524	Beige	II	2,540	2,185	2,362
P17	Brown	II	2,572	1,949	2,260
G01540	Yellow	I	2,050	2,396	2,223
G01224	Brown	II	2,329	2,106	2,218
P381	White	I	2,189	2,206	2,198
G01213	Grey	III	2,186	2,107	2,146
Lamanier	Purple	II	2,070	2,198	2,134
Linea 20667	Beige	I	2,426	1,832	2,129
G00805	Red	III	2,082	1,681	1,882
Pintado	Beige	II	1,585	2,059	1,822
Linea 00738	Purple	I	1,382	1,796	1,589
Mean			2,171	2,052	
Check materials					
P756	White	II	2,792	1,944	2,368
P459	Black	II	2,700	1,774	2,237
P692	Red	I	1,998	1,661	1,830
P392	White	I	1,383	1,414	1,398
Mean			2,218	1,711	
L.S.D. at .05			532	422	
C.V. (%)			17.3	15.6	

range of promising materials. This testing was activated in 1976 with strong support. Through late 1976, 128 requests for the first IBYAN have been received, covering 90 sites in 35 countries. As shown in Table 22, seed has already been dispatched to 76 collaborators, with the remainder to be shipped shortly. Figure 27 shows an IBYAN set being prepared for shipment. Plans are being developed for a limited climbing bean yield and adaptation nursery in 1977.

Bean-Maize Associations

Plant densities

Under monocrop conditions at CIAT, optimum planting density for highest production in climbing beans is 120,000 plants/ha and for maize, 80,000 plants/ha. In association with maize at a constant density of 40,000 plants/ha, optimum bean density remains about 120,000 plants/ha (Fig. 28). The apparent lack of interaction

Table 20. **Yield of black bean varieties of the Uniform Yield Trial at two locations in Colombia.**

Identification	Growth habit	Yield (kg/ha)		
		CIAT	Popayan	Mean
Test materials				
P209	II	2,930	3,174	3,052
P668	II	2,822	2,788	2,805
P700	II	2,741	2,840	2.790
P481	II	2,538	3,009	2,774
P579	II	2,838	2,653	2,746
P437	II	2,602	2,814	2,708
P509	II	2,763	2,544	2,654
P225	II	2,475	2,708	2,642
P9	II	2,588	2,687	2,638
P443	II	2,667	2,587	2,627
P667	II	2,548	2,694	2,621
P226	II	2,454	2,772	2,613
P14	II	2,448	2,658	2,553
P527	III	2,689	2,161	2,515
P199	II	2,320	2,675	2,498
P322	III	2,292	2,690	2,491
P320	II	2,259	2,715	2,487
P337	II	2,141	2,713	2,427
P349	II	2,479	2,224	2,352
P491	III	2,413	2,159	2,286
P422	II	2,169	1,577	1,873
Mean		2,523	2,612	
Check material				
P459C	II	2,693	2,831	2,762
P459B	II	2,826	2,671	2,748
P675	II	2,804	2,396	2,600
P566	II	2,318	2,252	2,285
Mean		2,660	2,538	
L.S.D. at .05		277	382	
C.V. (%)		9.6	10.6	

Table 21. **Yields of five promising accessions of climbing beans in replicated trials in CIAT.**

Accession	Color	Country of origin	No. of trials	Yield (kg/ha) Monocrop Min.	Monocrop Max.	Associated Min.	Associated Max
P589	Cream	Colombia	6	2.0	4.3	.6	2.1
P526	Black	Venezuela	5	1.4	4.3	.4	1.7
P525	Black	Venezuela	5	1.4	2.3	.5	1.5
P259	Brown	Chile	14	1.5	3.6	.2	1.5
P006	Black	Guatemala	4	1.8	2.7	.3	1.7

of bean density by planting system simplifies both experimental procedures and eventual recommendations to national programs.

Figure 26. **A promising type IV bean grown in association with maize can yield over 2 t/ha without seriously reducing maize yields.**

Table 22. **Countries collaborating in the first International Bean Yield and Adaptation Nursery (IBYAN).**

	Requests	Dispatched through October 1976
Latin America and the Caribbean		
Belize	2	1
Bolivia	3	1
Brazil	21	9
Colombia	8	7
Costa Rica	1	1
Chile	4	4
Ecuador	10	4
El Salvador	6	5
Guadalupe	2	-
Guatemala	4	3
Haiti	5	-
Honduras	4	3
México	4	4
Nicaragua	3	3
Panamá	1	1
Perú	5	5
Dominican Republic	4	4
Surinam	1	-
Trinidad	1	-
Venezuela	4	2
	93	57

Cont.

Table 22.Continuation.

	Requests	Dispatched Through October 1976
North America and Europe		
Canada	1	1
Portugal	1	-
United Kingdom	2	2
United States	2	2
	6	5
Africa - Asia Oceanía		
Afghanistan	1	-
Iran	1	-
Israel	1	1
Japan	2	2
Kenya	5	5[1]
New Caledonia	1	-
Malawi	3	-
Pakistan	1	-
Philippines	3	1
Tanzania	5	4
Thailand	6	-
	20	14
Total	128	76

[1] Due to quarantine restrictions, seed samples were sent to be increased locally.

Bean and maize yields

Reduction in bean yields due to association with maize depends on relative planting date, maize and bean density, plant type and location. At CIAT near optimum production of both maize and beans is obtained by simultaneous plantings, though yields of bush types are increased somewhat when they are planted one week before the maize (Fig. 29). Over a large number of trials, bean yields in association with maize were reduced about 30 percent in types II and III (non-climbing), and about 50 percent in type IV (climbing) beans. In current trials lower maize densities are being tested to develop response surface comparisons of various maize/bean density combinations. The optimum system for greatest economic return depends also on relative prices of maize and beans. The maize:bean price ratio varies in Latin America from 1:2 up to 1:6 in some countries for special colors and seed sizes of beans. Many factors appear to contribute to the well-being of the maize and bean system when the two species are intercropped, and to compensate for light and nutrient competition. Differences in attack by major insect pests and improved nitrogen fixation by the bean component are discussed in previous

Figure 27. **Each shipment of seed for an International Bean Yield and Adaptation Nursery is accompanied by a workbook detailing essential and suggested measurements to be taken and the methodologies to be used. Workbook data can pass directly to biometric analysis.**

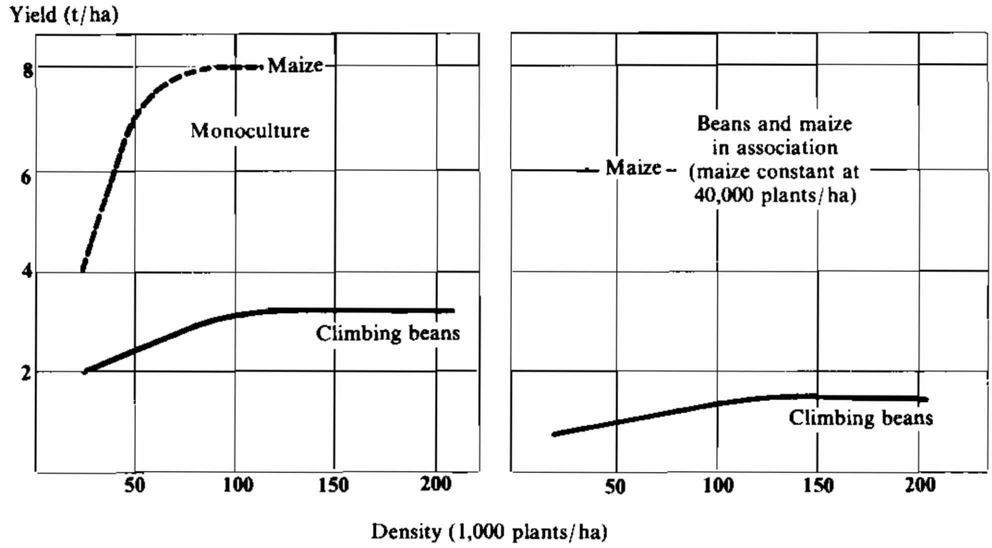


Figure 28. **Yields of maize and beans in monoculture and in association as a function of planting density.**

sections. Table 23 shows the reduced lodging in maize grown associated with beans.

Trials in CIAT with both bush bean/maize associations and climbing bean/maize associations show that when fertility and moisture are not limiting, maize yields are not reduced due to the association. In paired comparisons of plots with densities from 30,000 up to 90,000 plants/ha of maize, this relation was maintained. There also were no differences in maize plant height, harvest index, biological yield, prolificacy, length and diameter of ear and cob, row number, and moisture content of grain and stover in the two systems.

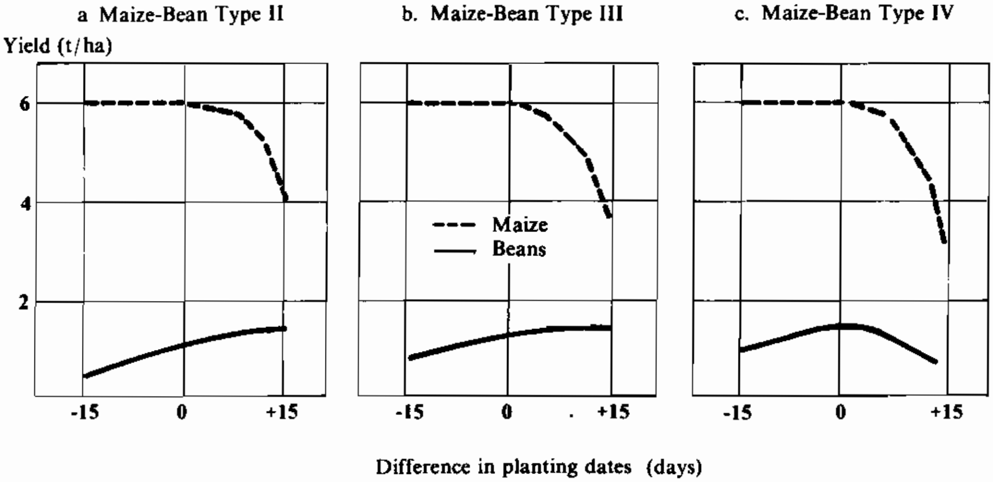


Figure 29. **Effects of relative planting dates of maize and beans on yields of each species in association.**

Table 23. **Percentage maize lodging in six trials in monoculture and in association with bush and climbing beans at CIAT.**

Maize hybrid	Bean cultivar	Root lodging		Stalk lodging		Total lodging	
		mono	assoc.	mono	assoc	mono	assoc
H-210	P259 (climbing)	1.6[1]	.3	9.6	3.8	11.2	4.2
H-207	Pijao (bush)	29.4	9.6	6.4	5.2	35.8	14.8
H-207	P259 (climbing)	53.2	17.0	6.2	6.5	59.4	23.5
H-207	Jamapa (bush)	64.3	14.0	1.0	3.3	65.3	17.3
H-207	P259 (climbing)	46.5	2.2	15.8	3.0	62.3	5.2
H-207	Pijao (bush)	14.0	26.0	9.0	0	23.0	26.0
Average lodging in 13 trials						33.8	16.1

[1] Underscored data in adjacent columns are not significantly different at .05 by the L.S.D. method.

Planting systems for associated cropping

Manipulating the spatial arrangement of two species in association to achieve the best possible light environment for each space should result in higher total system yields. Growing maize in paired rows did not affect bush bean yields compared to uniformly spaced rows (Fig. 30). In association with climbers grown in paired rows, maize yields were decreased relative to those achieved with normally-spaced rows. In this trial, maximum bean yields of 2.07 t/ha were obtained with a 4.93 t/ha maize yield. Monocrop bean yields of 4.3 t/ha were produced with P589, a cream-colored, late-flowering cultivar.

Genotype x system interaction

It is crucial to the breeding program to determine whether the best bean varieties selected under monoculture conditions are also the best when associated with maize. Preliminary results on this system x genotype interaction suggest that there is a strong correspondence between results from the two systems, both in rank order and yields. In nine varieties of bush beans, the correlation between ranks in the two systems was highly significant (r = 0.93**), as was the correlation for yields (r = 0.91**). In nine varieties of climbing beans, results were similar — ranks (r = 0.88**) and yields (r = 0.90**). When 15 varieties of maize were tested in three systems (monoculture, and associated with bush beans or climbing beans), results were less consistent. Correlations between pairs of systems for yield and rank order, respectively, were the following: monoculture vs. association with bush beans (r = 0.23, r = 0.45), monoculture vs. association with climbing beans (r = 0.46, r = 0.56*), association with bush vs. association with climbing beans (r = 0.66**, r = 0.72**). These data will be confirmed in other locations and seasons but suggest that selection and testing of bean varieties, as well as progeny evaluation, may be carried out in the most convenient or lowest cost system available.

Technology Packages

To determine the relative importance of certain agronomic practices, the possible components of a "technological package" for beans, experiments were planted in CIAT, Popayán and Montería. In each trial the complete package was compared

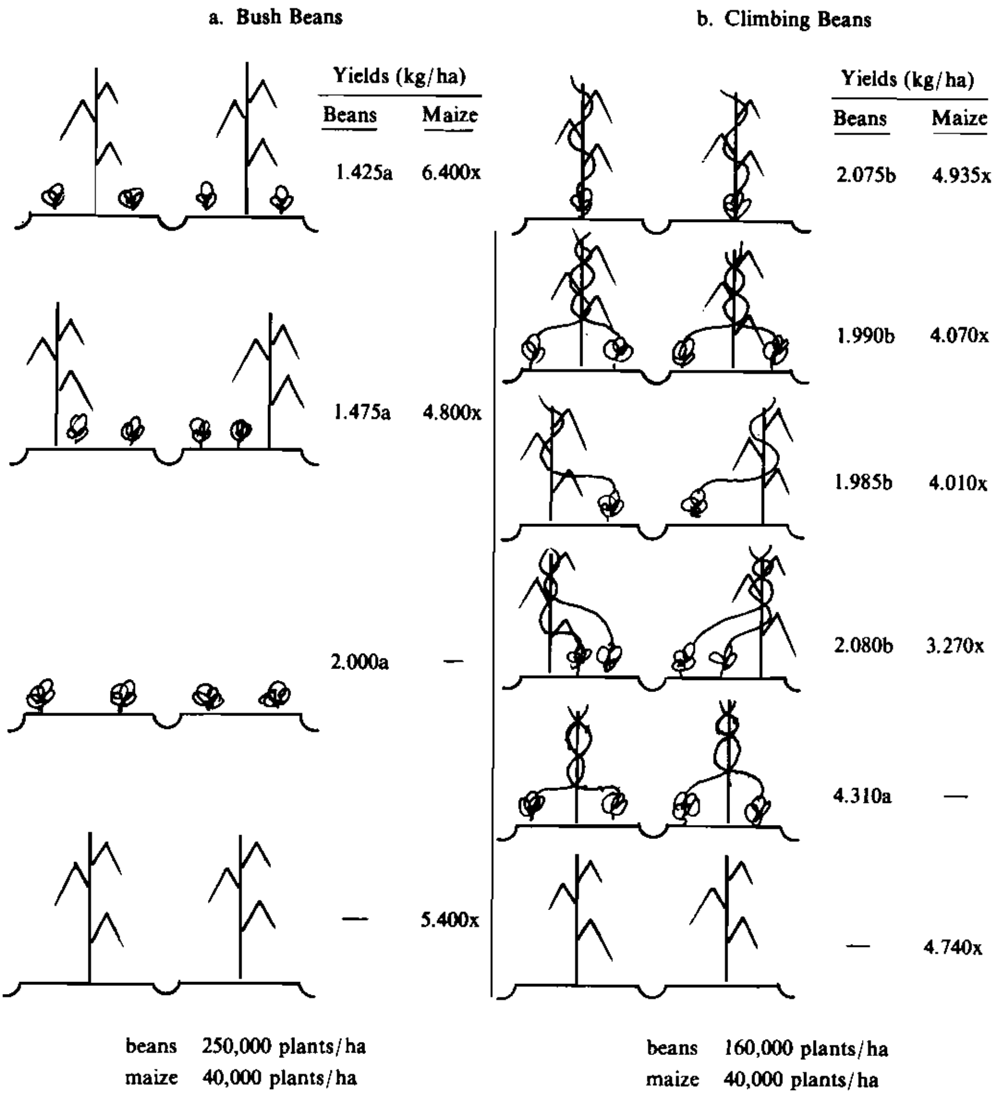


Figure 30. Comparisons of several bush bean/maize (a) and climbing bean/maize systems (b).

with various treatments in which, in turn, each component was left out; an absolute check without any cultural practices was included.

Figure 31 shows the effect of using seed free of internally-borne pathogens (clean), the use of beds, disease, insect and weed control, irrigation, liming and fertilization on bean yields. In each trial cleaned seed of a different black-seeded variety was used, except for the "minus clean seed" treatment in which no special precautions were taken to ensure seed of highest quality. Yields in Montería were extremely low because of unfavorable climatic conditions and an infestation of nutsedge, which was not controlled by the herbicides used.

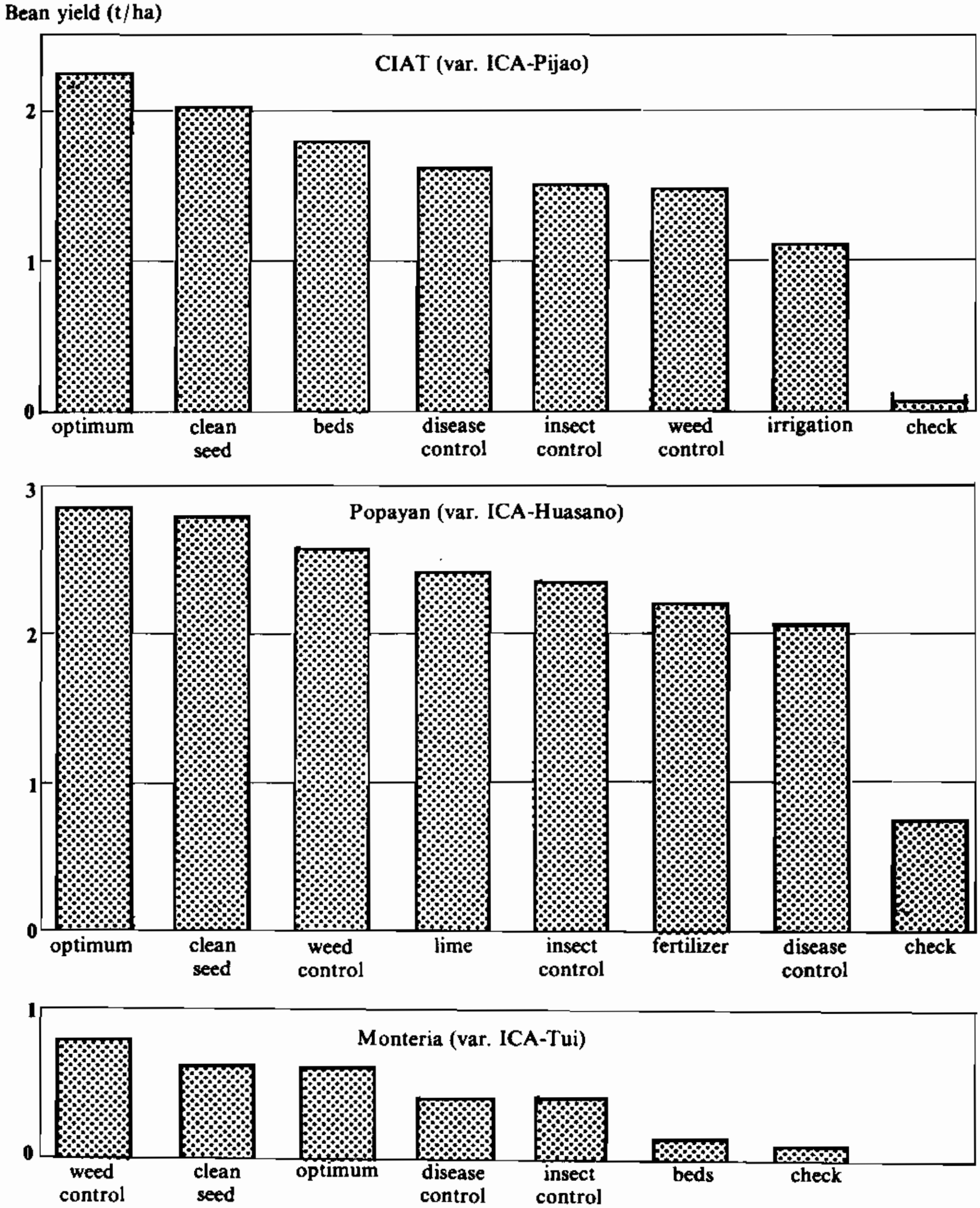


Figure 31. The effect of agronomic practices on the yield of three black bean varieties grown in CIAT, Popayán and Montería.

In all, the use of seed free from internal pathogens had the least effect on yield. This is contrary to other reports in which large yield increases were obtained with the use of "cleaned" as compared to "farmers" seed (see also p. A-7). In the present trials however, the seed used was of relatively good quality, with little more disease incidence than had the cleaned seed.

In CIAT, the lack of irrigation during the dry period between flowering and maturity affected yield most profoundly, with the lack of disease, insect and weed control reducing yields 27, 34 and 34 percent, respectively. The absolute check gave zero yield clearly demonstrating the need for proper cultural practices in bean cultivation.

In Popayán, the factors most influencing yields were disease control, fertilization and insect control, in the absence of which yields were reduced by 30, 28 and 19 percent, respectively. Residual fertilizers from the previous semester masked to some degree the effect of P-fertilization; virgin soil without P-fertilization normally yields only 20-30 percent of fertilized plots (see following section).

In addition to experiment station trials, several experiments were planted on small farms in collaboration with the Colombian Coffee Growers Federation in the Restrepo region (1,500 meters elevation, 1,300 millimeters rainfall). This thesis project focused on the introduction of new technology to farmers with limited resources. Results from the first season (Table 24) indicate a potential for high yields among small farmers using improved technology and plant materials. In bush varieties tested in four locations, yields of Calima variety currently used by farmers was significantly lower than yields of introduced varieties under both systems of production and both levels of technology. Four varieties in monoculture and one black-seeded variety in association with maize gave bean yields over 2 t/ha using improved technology (increased density, granular insecticide at planting and a low level of chemical fertilizer).

Table 24. **On-farm yields (kg/ha) of bush and climbing beans at Restrepo, Colombia, with two systems and two levels of technology.**

		Monoculture System		Associated with Maize		
Bean identification	Color	T (farmer technol.)	T (impr. technol.)	T (farmer technol.)	T (impr. technol.)	Overall mean
Bush Beans (mean of two trials)						
P459	Black	1,807a[1]	2,291abc	707abc	2,073a	1,720a
P302	Black	1,589a	2,439a	750ab	1,663bc	1,610ab
ICA Tui	Black	1,711a	2,331ab	652abc	1,664bc	1,590ab
P524	Cream	1,698a	2,032 bcd	836a	1,476bcd	1,511 bc
P756	White	1,165bc	1,744 d	432 c	1,470bcd	1,203 d
P643	White	1,475ab	1,953 d	605abc	1,590bc	1,406 c
ICA Linea 17	Red	979cd	1,291 e	528 bc	1,200 d	1,000 e
P758	Brown	1,674 a	1,964 cd	582abc	1,798ab	1,505 bc
Calima	Red	780 d	1,086 e	452 c	576 c	724 f
Mean		1,431	1,903	616	1,501	1,363
C.V. (%)		20.7	14.3	36.9	17.5	-

Cont.

Table 24. Continuation.

		Monoculture System		Associated with Maize		
Bean identification	Color	T (farmer technol.)	T (impr. technol.)	T (farmer technol.)	T. (impr. technol.)	Overall mean
Climbing Beans						
P525	Black	1,176a	1,570a	624a	1,048a	1,105a
P259	Brown	678bcd	1,431a	351b	672ab	783bc
P364	White	1,021bcd	1,324ab	369b	832a	887 b
P449	Brown	455cd	917bc	263b	800a	609c
P589	Cream	858abc	1,243ab	424ab	673ab	800bc
Radical	Red	389d	682c	304b	227b	401d
Mean		763	1,195	389	709	764
C.V. (%)		28.9	21.8	35.9	46.6	

[1] Values not followed by the same letter are significantly different at the .05 level of significance by the L.S.D. method.

Introducing improved technology increased bush bean yields by 33 percent in monoculture and by 144 percent in association with maize. Climbing bean yields from two marginal locations showed the same tendencies, with a maximum yield of 1,570 kg/ha for cultivar P525 in monoculture in one trial. These results indicate that varieties and technology can be adapted to farm conditions, and give the small farmer significant production increases.

Time of seeding

The time of seeding trial in Popayán (1975 Annual Report) was repeated this year. Figure 32 shows the influence of seeding date on yield with and without insect and disease control. Because of the extended cropping sequence, disease and insect damages were more severe than in the previous year and yields were zero during eight months of the year. Without proper control even under protected conditions yields decreased from 2.7 t/ha in the June seeding to 61 kg/ha in the October seeding because of excessive rainfall during October and November.

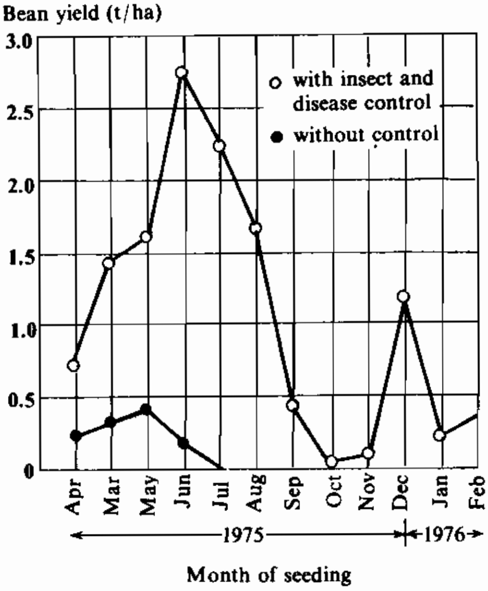


Figure 32. Effect of month of seeding in Popayan on the yield of Guali beans grown with and without control of insects and diseases.

SOIL FERTILITY

Tolerance to Low Phosphorus

A total of 176 promising bean accessions were screened in Popayán for tolerance to low levels of soil phosphorus. Beans were seeded in single rows in plots having phosphorus treatments of 0 and 300 kg P_2O_5/ha, applied as triple superphosphate (TSP) in bands. Figure 33 shows that plant growth without applied phosphorus was extremely poor compared with luxurious growth at the high phosphorus level. Maximum bean yield obtained without phosphorus was 0.97 t/ha while at the high phosphorus level, maximum yield was 3.96 t/ha. With no phosphorus added the most tolerant variety yielded 44 percent of that produced with high phosphorus, while on the average, percentages were as follows for the various bean colors: white, cream, yellow beans (16%); brown and gray beans (19%); red, pink, purple beans (20%); and, black beans (21%).

Further studies are in progress to confirm these differences using intermediate levels of phosphorus. Given the low availability of phosphate fertilizer in many countries and the limited credit available to many farmers, the results could be of major significance.

Levels and Sources of Phosphorus

This research was done in cooperation with the International Fertilizer Development Center (IFDC). Figure 34 shows the response of beans to various levels and sources of applied phosphorus in Popayán (see also CIAT Annual Report, 1975). A positive response to application rates as high as 400 kg P_2O_5/ha was obtained. Though TSP produced the best response, relatively soluble rock phosphates from Gafsa (Morocco), North Carolina (U.S.A.), Sechura (Perú), and Huila (Colombia) also gave good responses. Yields with more insoluble rock phosphates from Tennessee and Central

Figure 33. **Screening of bean varieties for tolerance to low levels of phosphorus. Each row is one variety with beans in foreground grown without phosphorus while the same varieties in the background have received 300 kg P_2O_5/ha.**

Florida (U.S.A.) were lower but still significantly better than the control. The agronomic effectiveness of the sources followed closely their solubility in *N* ammonium citrate (Fig. 34), a commonly used measure of "available" phosphate. A critical phosphorus content in the leaves at flower initiation was determined to be 0.35-0.4 percent.

Lime x Phosphorus Interactions

Manganese toxicity symptoms have been observed in Popayán experiments in beans where previous heavy fertilization had produced a decrease in soil pH. Liming such soils is the most effective way to eliminate manganese toxicity but at the same time, can reduce the effectiveness of rock phosphates. The interaction of lime and phosphorus was studied using three levels (0, 200 and 400 kg P_2O_5/ha) and three phosphorus sources (TSP and Gafsa and Huila rock phosphates) at four levels of lime (0, .5, 2 and 6 t/ha).

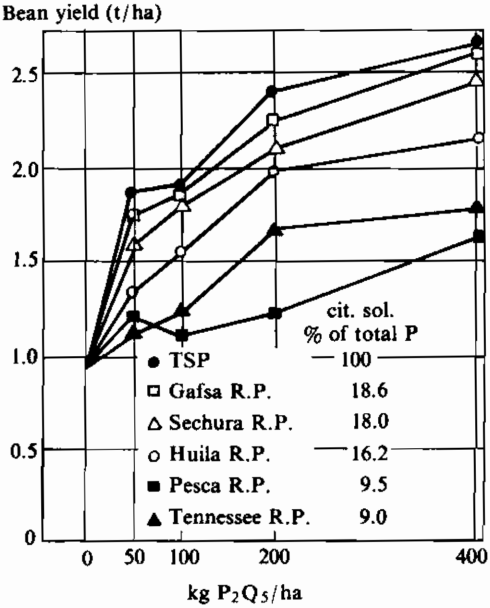


Figure 34. **Response of beans to various levels of phosphorus applied as triple superphosphate (TSP) and various rock phosphates (R.P.) in Popayán.**

Figure 35 shows the effect of phosphorus levels and liming on yield. Although the Gafsa rock was slightly better than TSP at 0 lime and slightly poorer at the high lime level, there were no significant differences among the phosphorus sources. At low liming rates response to phosphorus was significant, but at the high lime levels, there was no phosphorus response (some residual phosphorus remained from a previous crop). Above 0.5 t/ha of lime applied, beans responded mainly to the application of lime. The negative response to the lowest lime application was unexpected considering that lime consistently increased pH, decreased exchangeable aluminum (Fig. 36a) and slightly decreased manganese. However, both the exchangeable calcium in the soil and the calcium content of the leaves was lower at 0.5 ton lime than at 0 lime, while the phosphorus content (Bray I) of the soil reached a minimum at the 2 t/ha lime level, both for the residual phosphorus as well as the recently applied phosphorus treatments (Fig. 36b). Thus, liming was beneficial by increasing pH and calcium and decreasing toxicity of aluminum and manganese but at low levels was detrimen-

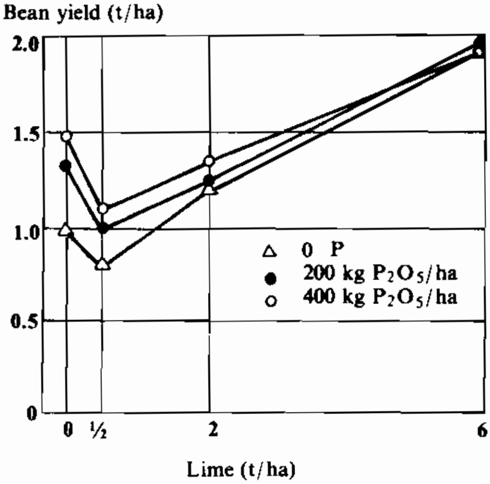


Figure 35. **The effect of the application of lime and phosphorus on bean yields in Popayan. Curves are the average of three phosphorus sources.**

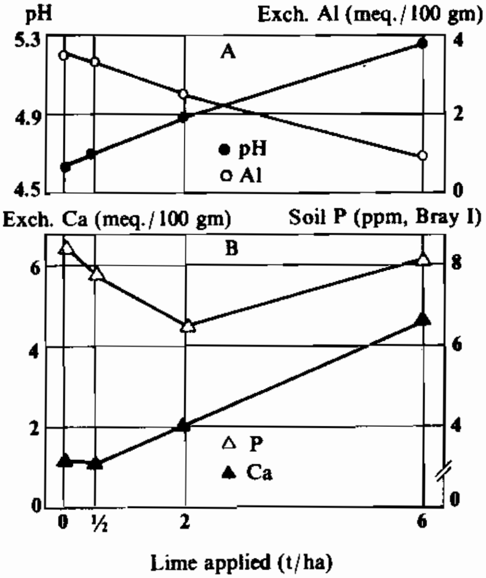


Figure 36. **The effect of lime applications on soil pH, exchangeable Al, exchangeable Ca and available P in Popayan. Curves are the average of three levels and three sources of P.**

tal because of decreased phosphorus availability as well as reduced phosphorus and calcium dissolution from the rock sources. Yields were best correlated with exchangeable calcium and aluminum in the soil, and were highest with more than 4.5 meq calcium and less than 1.5 meq aluminum/100 g soil. The critical calcium content of leaves was 1.44 percent.

Foliar Application of Phosphorus

In soils like those of Popayán with a very high phosphorus-fixing capacity, foliar applications of phosphorus could supply small quantities to the plant without fixation by the soil. However, foliar application must be combined with soil phosphorus application to ensure foliar development sufficient to spray and the right combination of soil and foliar applied phosphorus is difficult to determine.

Figure 37 shows the result of the foliar application of various phosphorus sources compared to the check and to soil applied phosphorus. All plots received 150 kg P_2O_5/ha as incorporated basic slag, resulting in a relatively high yield for the check. The best foliar treatment was that of three applications of 2.4 percent $NH_4H_2PO_4$ which increased yields 225 kg/ha while applying only 6 kg phosphorus/ha. Part of the beneficial

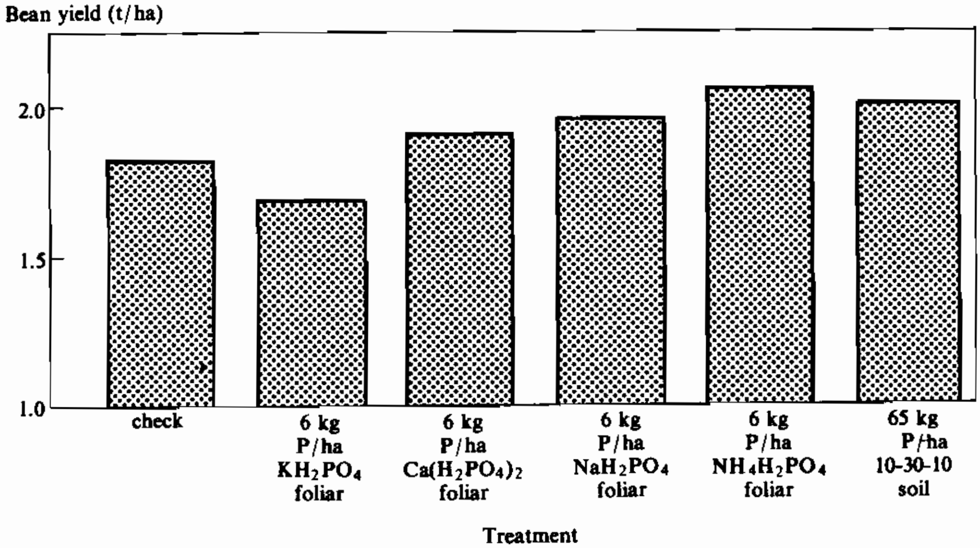


Figure 37. **Effects of soil and foliar applications of various phosphorus sources on bean yields.**

effect may be due to the nitrogen in the source. Other sources were not very effective, because of the high basal soil application. Studies using potassium polyphosphate and urea in foliar dressings are continuing.

PHYSIOLOGY

Physiological studies on yield limiting factors and adaptation characteristics continued during 1976, under irrigated, fertilized and protected conditions at CIAT.

Growth and Development

Bean growth and development studies concentrated on the cultivar P566, a material representative of several type II varieties showing high yield and relatively wide adaptation (see p. A-33). The results of two semesters (1975A and 1975B) of growth analysis with P566 are compared in Figures 38 and 39 and in Table 25. Leaf area development, node structure and pod number are very similar for the two semesters although total yields differed 19 percent. Climatic data for the two semesters were very similar with respect to temperature and solar radiation. The main

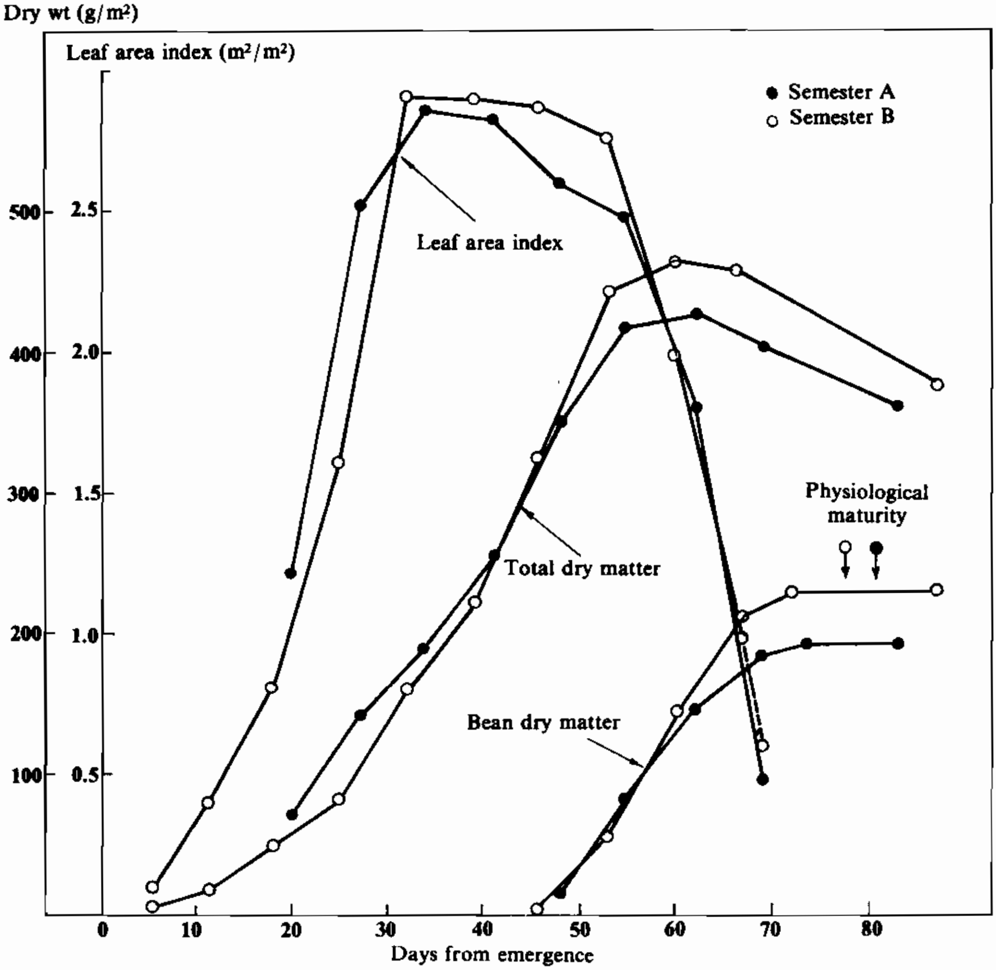


Figure 38. Key parameters for accession P566 in growth analysis experiments.

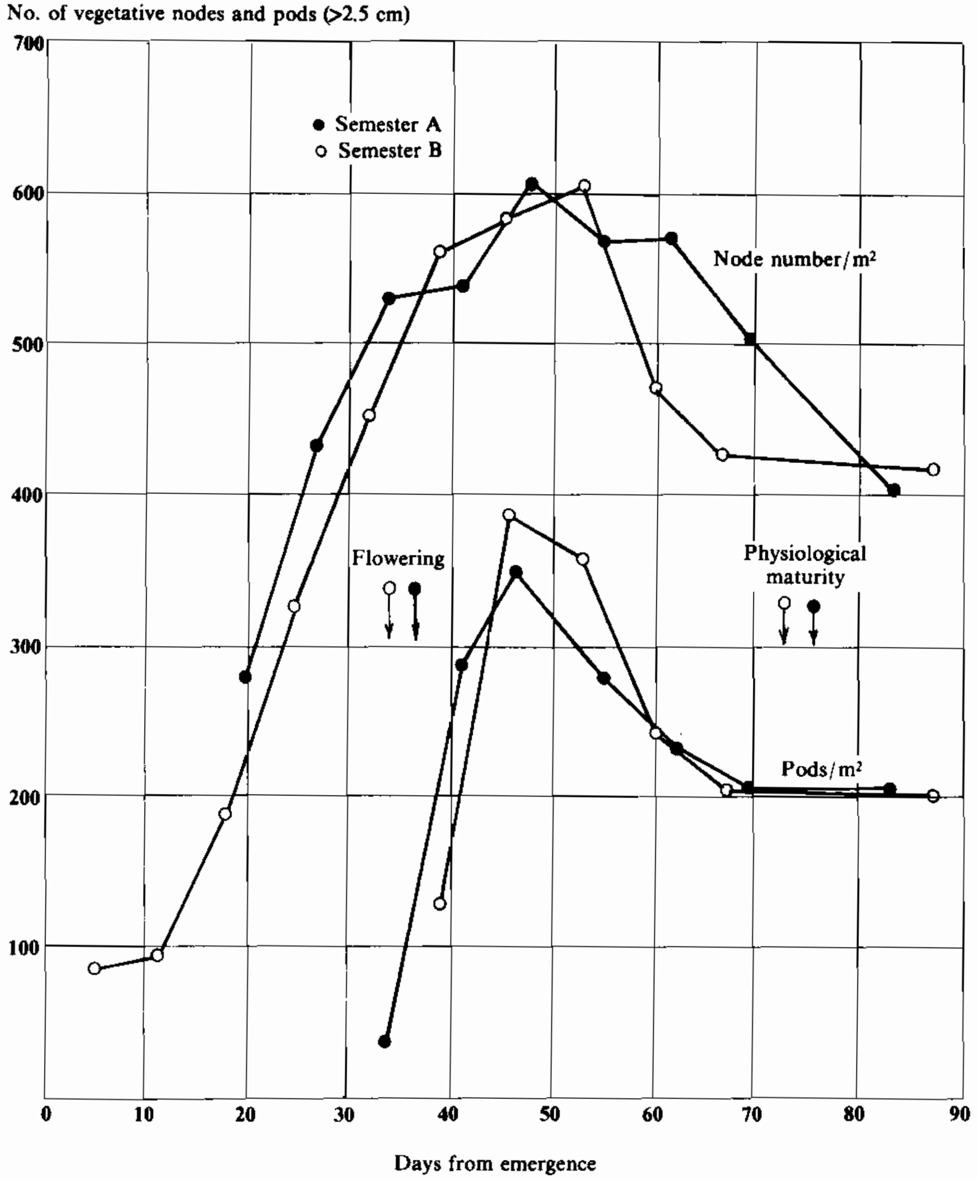


Figure 39. **Key parameters for accession P566 in growth analysis experiments.**

yield component associated with this yield difference was the number of mature beans per pod. The crop in the first semester lodged more extensively resulting in poor canopy structure after flowering and, possibly, lowering the efficiency of the available leaf area. The higher proportion of yield borne on the branches in semester A also suggests that lodging may have stimulated greater pod set on branches.

The vertical distribution of yield components for semester B is shown in Figure 40. Yield variation is strongly associated

Table 25. **Yield and associated final harvest parameters for accession P566 in growth analysis experiments in two semesters at CIAT**

Parameter	Semester A	Semester B	(A/B x 100) %
Yield (t/ha, 14% moisture)	2.28	2.71	(119)
Yield (g/m², dry wt)	195.85	232.89	(119)
Bean size (mg/bean)	191	191	(100)
Harvest index (%)	0.57	0.62	(109)
Total dry matter (g/m²)[1]	342.6	376.7	(110)
Stem weight (g/m²)	81.70	82.20	(101)
Pod wall weight (g/m²)	65.08	61.50	(94)
Node number/m²	410.9	421.7	(103)
Raceme number/m²	111.8	118.3	(106)
Pod number/m²	210.4	205.5	(98)
Stem height (cm)	71.86	87.18	(121)
Root weight (g/m²)	17.95	16.66	(93)
Bean number/pod	4.87	5.93	(122)
Bean yield/pod (g)	0.93	1.13	(122)
Yield on branches (%)	22.6	12.0	

[1] Above ground dry matter at maturity not including petioles and leaves.

with pod set at each node and with the number of mature seeds per pod; both parameters peaked at node 7. Mean bean size did not vary greatly among those nodes contributing most to yield.

Close observations of flower and pod development in P566 showed effects similar to those reported previously (1975 Annual Report). Figure 41 shows pod set data by node position on the main stem and by position within each raceme. The within-raceme positions are numbered consecutively from position 1 nearest to the main stem. Usually two flowers are borne simultaneously at each position on either side of the raceme. The critical features of this data are: (a) the high proportion of flowers at position 1 which set mature pods, and, (b) that nodes flowering earlier in the sequence usually bear mature pods. Flowers opening later on the same raceme (in positions 2 and 3) usually abscise. At all nodes the day of flower opening for position 1 is usually three to four days earlier than position 2. The pod set ratio for position 1 on the respective racemes decreased from 100 percent at node 5 to 0 at node 14. The presence of earlier fertilized pods on the raceme appears to strongly influence the abscission of later formed flowers.

The yield profile in Figure 40 directly reflects this pod set pattern. Node 7, with the earliest flowers and high pod set, has the highest yield per node. The importance of time of flowering is further demonstrated in Figure 42 where the flower production/m²/day and the number of mature pods which were produced from those flowers are plotted. Almost all pods were produced from flowers opening in the first 10 days of the 20-day total flowering period. The peak of pod production occurred 3-4 days after the commencement of flowering. As was observed in 1975, pod set on branches in this variety is low. Flowering normally occurs later on the branches and they

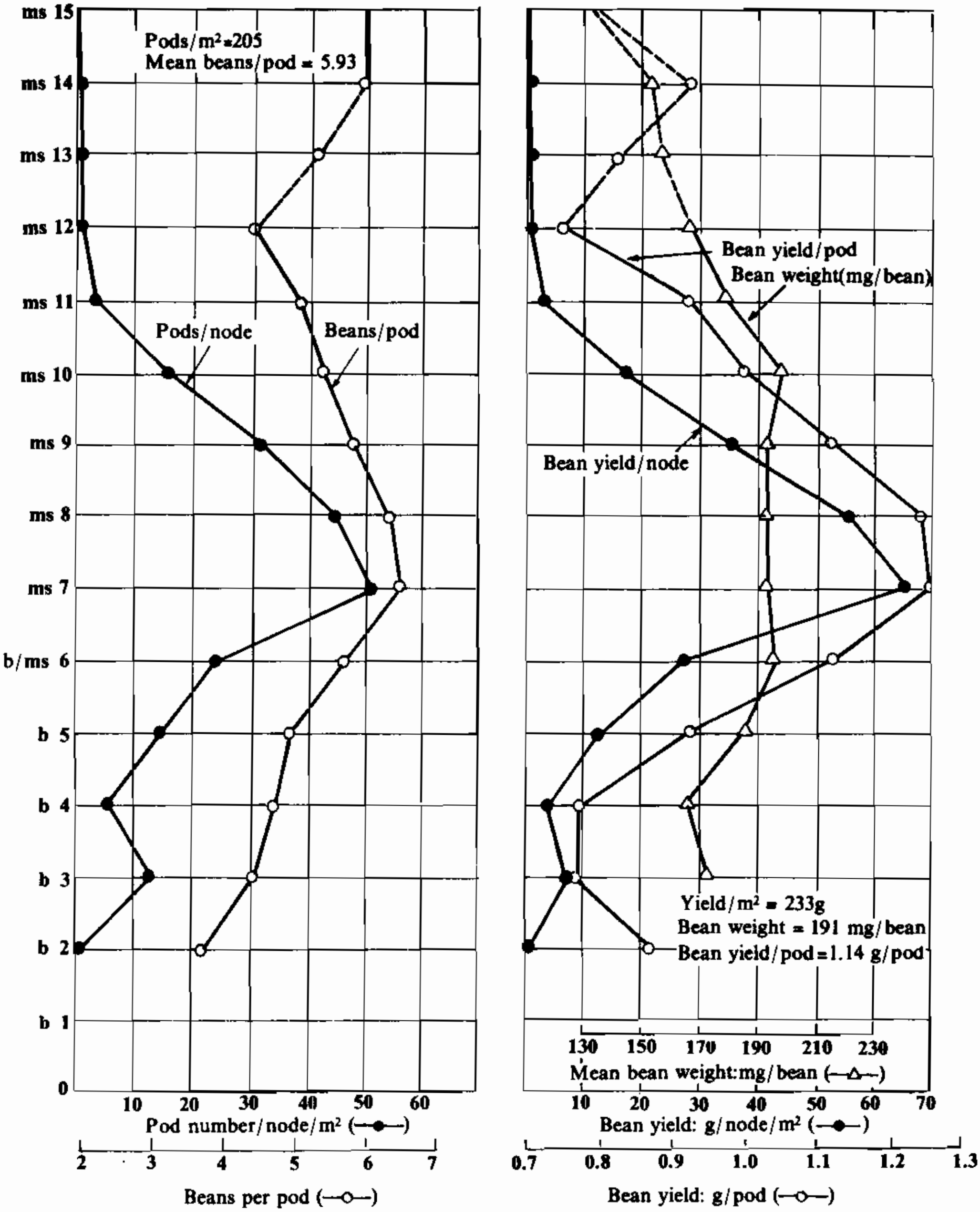


Figure 40. Distribution of yield components by leaf node position in the accession P566.

probably suffer greater competitive stress due to self-shading at the lower node positions and at the plant densities utilized in these experiments (30 established plants/m²).

Maximum leaf area in P566 usually occurs at about 12-15 days after flowering. Figure 43 shows the leaf area profiles at flowering and 15 days after flowering (maximum LAI). Green leaf area lost from

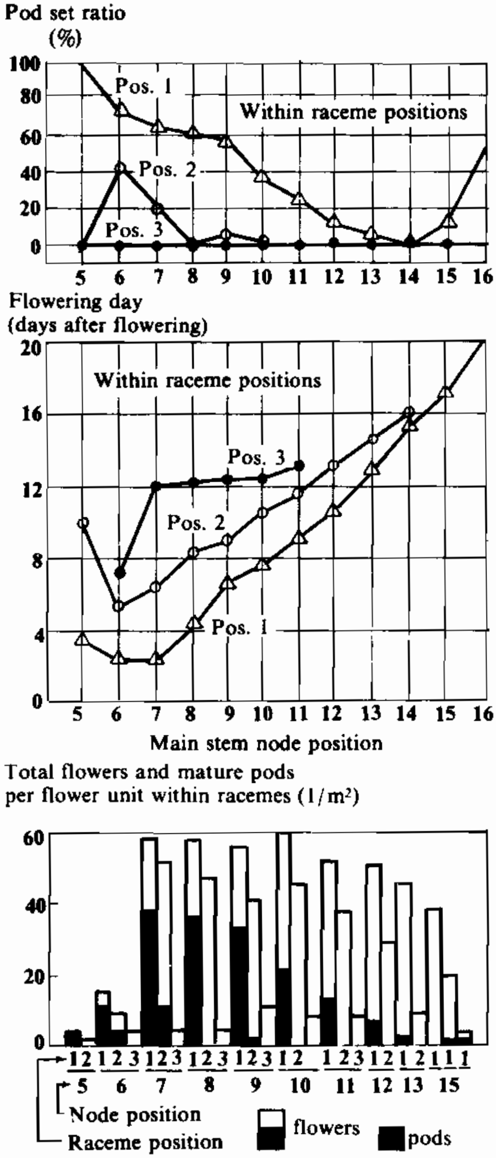


Figure 41. **Relationship between flower unit within each raceme at each node position and flowering day of each flower unit and the pod set ratio for each flower unit on the racemes on the mainstem for Porrillo Sintético. Data of branches excluded due to high variability. Data obtained from eight plants observed daily; adjusted for the final plant density**

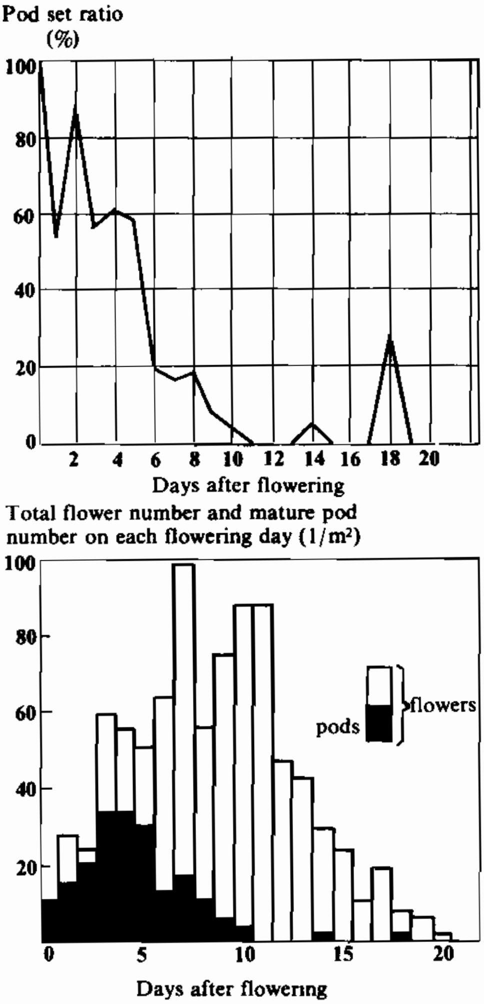


Figure 42. **Relationship between flowering day and pod set ratio (the ratio of mature pod number to total flower number blooming on each day of the flowering period) and the actual number of flowers bloomed and pods produced per flowering day for Porrillo Sintetico. Data are the mean of eight plants observed daily and corrected for the actual plant stand at harvest.**

the base of the canopy (nodes 3-7) is more than compensated for by new leaf area produced at nodes 8-15. Since the pod set on the upper nodes is very low, it is reasonable to assume that this new and active leaf area is contributing photosynthate during bean filling to the lower nodes where the majority of yield is borne. This loss of leaf area on the lower nodes has considerable relevance to post-

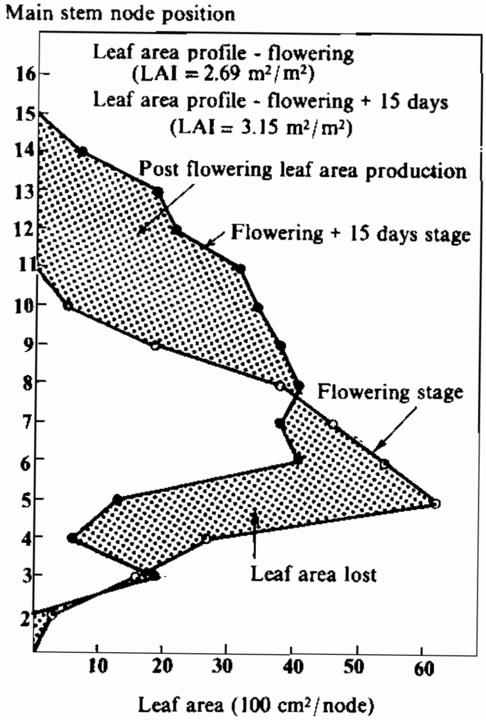


Figure 43. **Leaf area profiles per main stem node position, including branches subtended at each node, for two growth stages in accession P566**

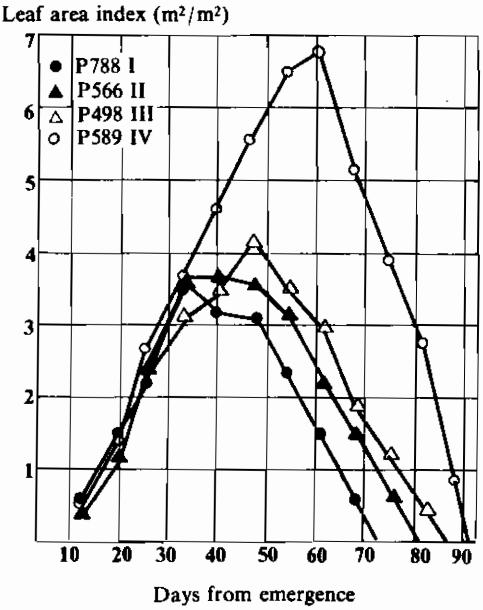


Figure 44. **Leaf area index for four contrasting varieties in growth analysis experiment.**

flowering decreases in nitrogen fixation (see page A-30).

Table 26. **Comparison of attributes among four varieties of *Phaseolus vulgaris* used in growth analysis studies at CIAT.**

Accession Growth habit	P788 I	P566 II	P498 III	P589 IV
Bean yield (g/m^2 14%)[1]	2.85	2.65	3.05	4.54
Bean yield (g/m^2 dry wt)[2]	262	282	296	393
Pods/m^2	311	255	294	315
Beans/pod	2.65	2.97	4.07	6.22
Bean weight (mg/bean)	317	186	247	200
Percent yield on branches (%)	76	16	80	5
Days to flowering[3]	31	39	40	47
Days to physiological maturity[3]	77	82	90	96
Bean yield per day (g/day)[4]	3.70	3.23	3.39	4.73
Total dry matter (g/m^2)[5]	454	494	475	583
Harvest index (%)	57.8	57.5	62.5	67.4
Percentage abscission (pods 3cm)[6]	65	52	59	55
Percentage abscission (pods 3cm)[6]	10	17	17	18
Percentage abscission total [6]	75	69	76	73

[1] Yield from 10m^2 yield sample area

[2] Yield of subsample (1 m^2) used for yield profile in Figure 10

[3] Days from seeding

[4] Seeding to physiological maturity

[5] Minus leaves and petioles at maturity

[6] Percentage of total flowers bloomed/m^2.

A growth analysis of four accessions (P788, P566, P498 and P589) with contrasting growth habits (types I-IV) was carried out.

The climbing bean (P589) under supported monoculture conditions developed a maximum LAI (Fig. 44) of 6.8 at about 60 days while the three non-climbers attained maximum LAI's of 3.5-4.0. Types I and II differed mainly in time at which leaf area decline commenced while P498 (type III) showed a later and slightly higher peak with a similar rate of decline. Table 26 summarizes other key characteristics. The yield differences between the bush bean varieties (types I-III) were associated with maturity (bean yield/day values similar). The determinate variety P788 used in these trials showed excellent yield potential as across a wide range of varieties and environments, type II varieties normally outyield the more determinate types. The higher yield level of the climbing variety (P589) is also shown in Tables 21 and 22. The overall pod abscission pattern of the four varieties is quite similar with a slight tendency for the type I variety to abscise more small pods (flowers opened up to a pod size < 3 cm). No conclusions can be drawn at this stage with respect to the existence of major genetic differences in pod abscission rates.

The pattern of flower and pod formation during flowering is illustrated in Figure 45. The other varieties show trends similar to those discussed earlier for P566, especially with respect to the importance of the earlier formed flowers. The type III variety had the longest flowering period (28 days) and the determinate type I, the shortest period (13 days). P788 (I) and P566 (II) differed in pattern of flower set during the first five days of flowering with pod abscission during this period being much more severe in the tupe I plant. Cyclic flower production is also apparent, particularly in the indeterminate varieties.

Yield profiles for the four growth habits are presented in Figure 46 with the yield per node strongly correlated with pod number per node and mature beans per pod. Differences in branching pattern

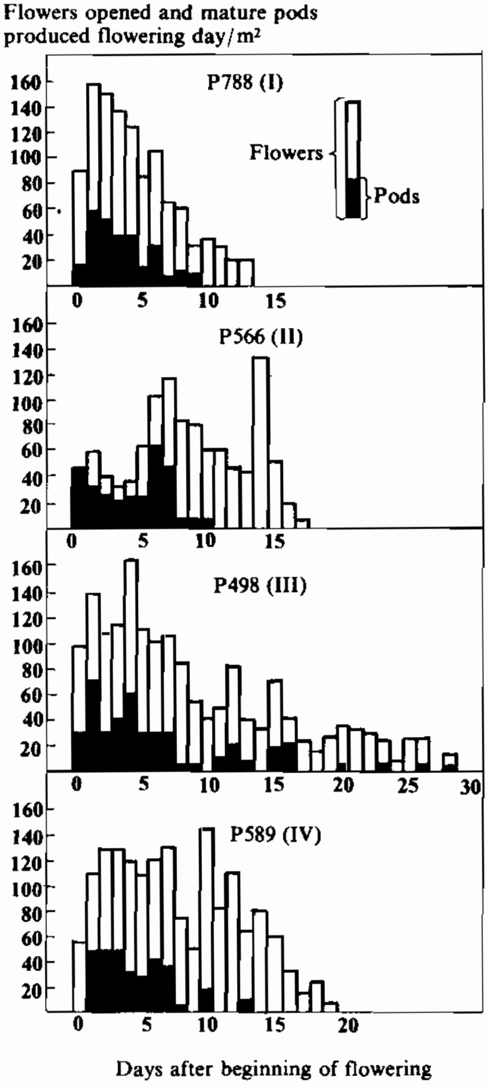


Figure 45. Flower and pod production/m² with respect to days from flowering commencement in four varieties in growth analysis experiment.

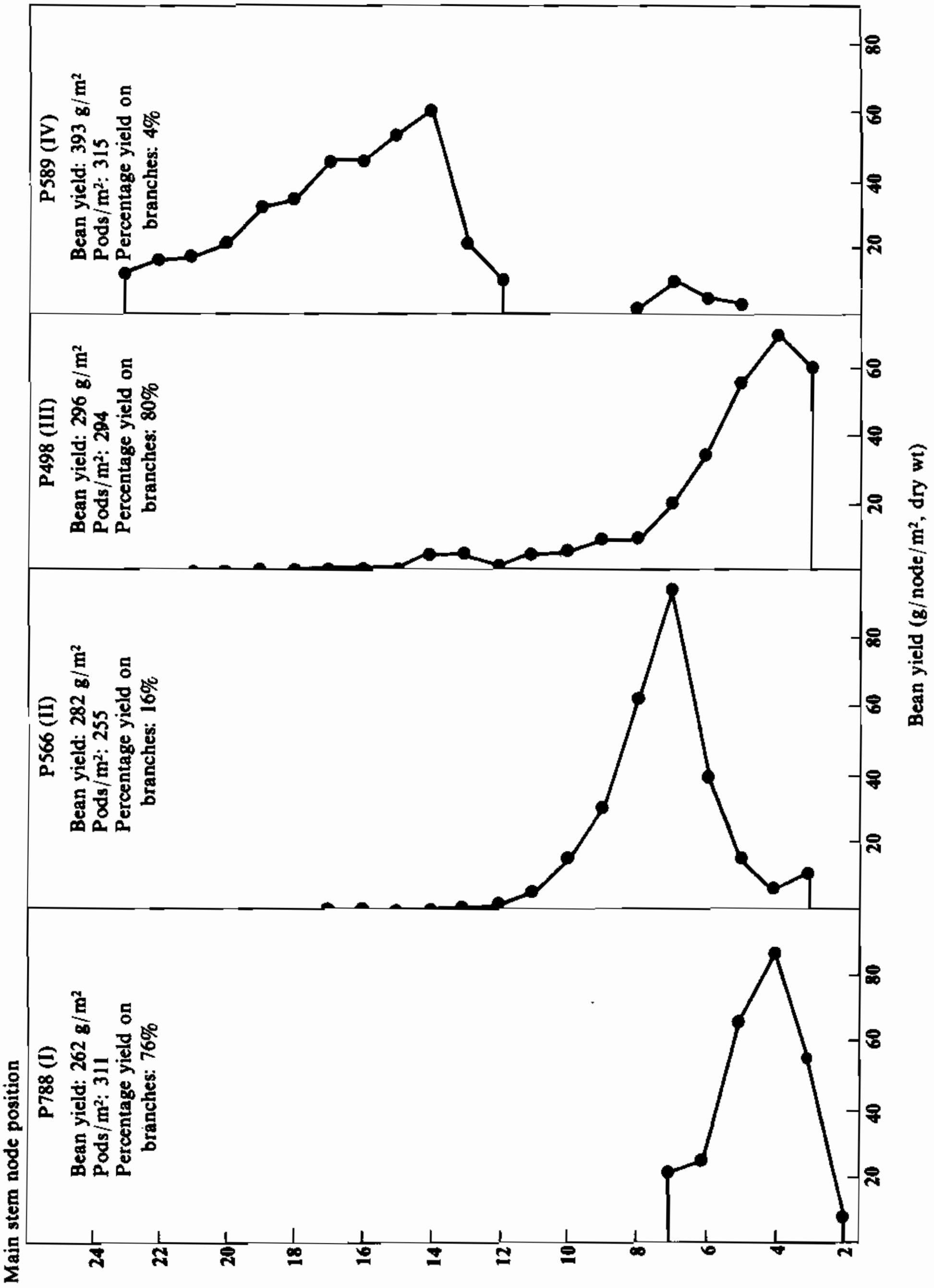


Figure 46. Yield profiles by node position (including branches) for four varieties of beans in growth analysis experiments.

between varieties are reflected in the yield profiles. Thus P498, a heavily branched, prostrate variety with good yield potential has a heavy yield concentration on lower nodes (3-7) where branches comprise 100 percent of the yield, while the relative lack of branches in P566 results in a yield peak at a higher node level. The low proportion of yield on branches in P589 is rather typical of the strong climbers at high density. While variation within growth habits exists for the proportion of yield borne on branches, the varieties used here appear typical of the majority of germplasm lines within each habit.

Contrasting growth habits differed in the proportion of nonreproductive dry matter production after flowering (Fig. 47). The determinate P788 produced 50

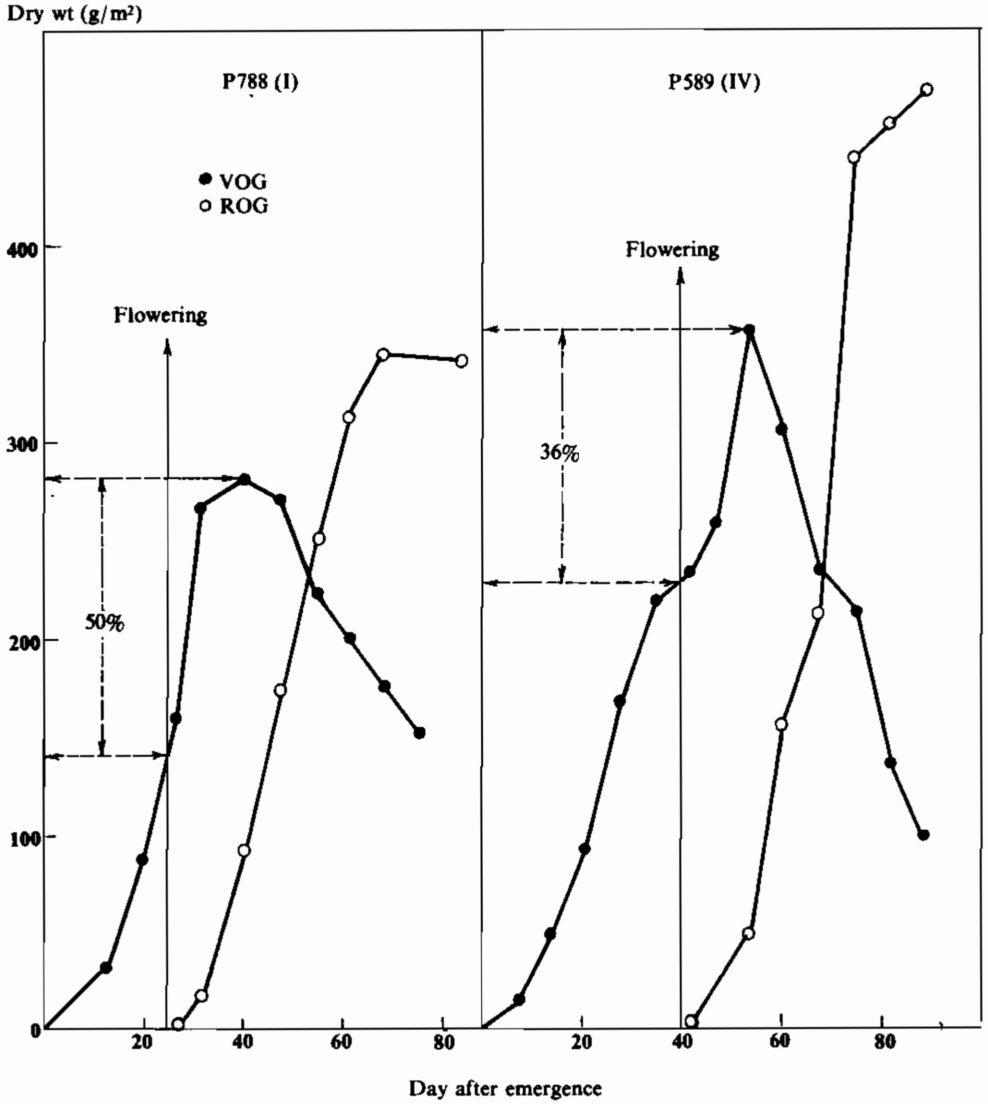


Figure 47 **Vegetative (VOG) and reproductive organ growth (ROG) in two contrasting varieties in growth analysis experiments.**

percent of the maximum dry weight of its vegetative organs after flowering whereas P589 (IV) produced only 36 percent. Post-flowering growth of branches in the determinate variety compensates for the increased dry matter production in main stem structures in the indeterminate variety.

Carbohydrate (sugars and starch) determinations were carried out on the main stem and branches. Results in 1975 suggested large differences in stem storage between varieties. Data for the 1976 experiment for three varieties is presented in Figure 48 for grams of stem carbohydrate/m². Maximum storage (about 10-12 days after flowering) occurs just prior to the commencement of rapid bean filling and subsequent pod filling reduces storage levels considerably in all varieties. The actual quantities transferred from the stem are relatively small in relation to final bean yield, i.e. from 2-5 percent. The relationship between the stored photosynthate and pod abscission has not yet been studied intensively. However, the varieties in this study with very similar levels of flower abscission (Table 26) had quite different levels of stem storage in the period immediately after flowering. The results for P589 (IV) very sharply contrast to results for Trujillo 3 (IV) (CIAT Annual Report, 1975).

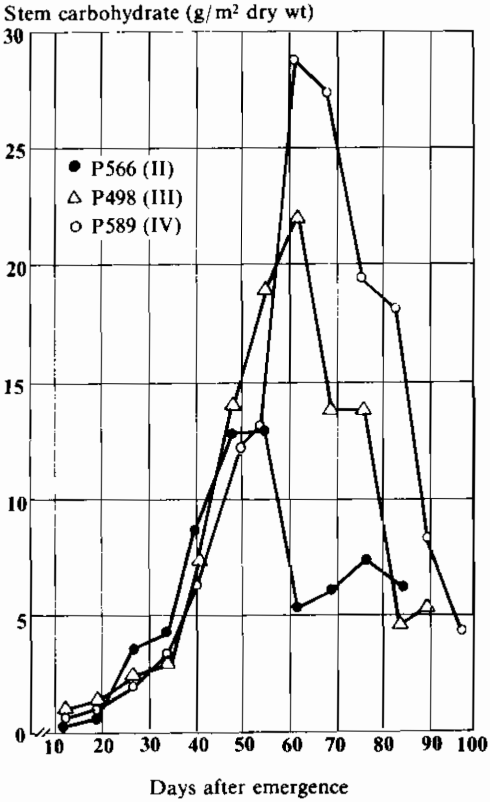


Figure 48. **Total stem carbohydrate (sugar and starch) for three varieties of beans, in growth analysis experiments.**

Crop Manipulation

A series of experiments was carried out with P566 and other selected varieties to study the influence of alterations in crop structure and/or environmental conditions on yield potential.

Extension of crop cycle using photoperiod response

The photoperiod sensitive P566 (grade 2 on a 1-5 scale of increasing sensitivity) was grown in a 16 h 30 min photoperiod as described in 1973. Growth analysis and final yields were measured on a series of plots at various distances from the light source. By using a slightly higher intensity light (lamps at 2.5 m height), preflowering was extended 15 days. The yield response comparing control plots 19-20 m from light (effective daylength ≃ 12 h 20 min) with "treated" plots 1-2 m from the lights was from 2.77 t/ha to 4.12 t/ha. The data in Table 29 compares key parameters measured at four distances from the light source. The majority of the yield increase occurred on branches, with increased branching at nodes 7-14 in the upper part of the canopy where light conditions and leaf efficiency are better than at lower levels. An increase in pod number/m², partly influenced by reduced pod abscission and partly through an increase in total flowers bloomed/m², was the only yield

Table 27. Crop parameters for accession P566 measured at varying distances from a linear light source with a photoperiod of 16h 30 min.

Parameter	Distance from light source (m)			
	1-2	7-8	13-14	19-20
Bean yield (g/m^2) (14%)[1]	412	347	298	277
Pods/m^2 (2)	314	255	214	208
Beans/pod	5.73	5.78	5.65	5.49
Bean weight, mg/bean	197	201	210	207
Nodes on mainstem/m^2 (3)	520	460	407	370
Nodes on branches/m^2 (3)	268	272	147	179
Total dry matter (g/m^2) [4]	778	646	614	532
Harvest index (%) [5]	49	50	51	54
Maximum leaf area (m^2/m^2)	3.96	3.76	3.01	2.66
Days to flowering [6]	51	43	36	36
Days to physiological matur. [6]	95	84	71	69
Bean yield/day, (g/day) [7]	4.04	3.81	3.82	3.64
Percent yield on branches (%)	82	39	18	14
Percent total abscission [8]	59	-	-	68

[1] Mean of four replications, plot area 8 m^2/replication

[2] All yield components derived from 1m subsample area

[3] Nodes counted at maturity

[4] Minus leaves and petioles at maturity, 1m^2 subsample

[5] Determined on 1 m^2 subsample

[6] Days from seeding

[7] Seeding to physiological maturity

[8] Percent of total flowers bloomed on eight plants per treatment

component changing significantly with treatment. The harvest index was lower near the lights suggesting excessive vegetative growth over the longer growth period available. The light treatment did not significantly alter crop growth rate, the differences in dry matter accumulation being due solely to the increased period of growth. While bean yield/day, increased slightly, most of the 49 percent yield increase was associated with increased length of growing season. LAI (Fig. 49) was ≃ 1.3 units higher near the lights compared to the control plots with a similar rate of decline of LAI after the maximum in all treatments.

The results of this experiment, as in 1975, demonstrate one direction for yield improvement, namely, an extension of the preflowering period, allowing greater node development and hence increased sink potential while at the same time increasing leaf area index (source) in order that the crop has sufficient capacity to fill the increased sink available. Though there was no lodging in this experiment, improved lodging resistance could be necessary to maintain post-flowering canopy integrity, given the increased vegetative development.

The results of a shading experiment with P566 are presented in Figure 50. The shade treatment (66% interception) was applied in each of nine growth stages of one week commencing 20 days before flowering. Significant yield reductions occurred during the first four weeks after flowering. In the first two weeks after flowering (periods 4 and 5) pod number was most reduced, in the third week (period 6) bean number per pod was reduced while in the fourth week (period 7) individual bean

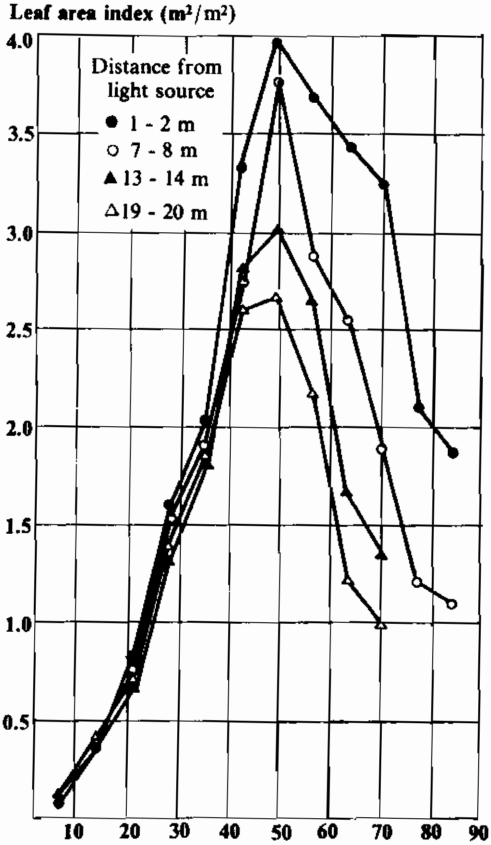


Figure 49. **Leaf area index for accession P566 at four distances from the lights in photoperiod extension of growth cycle experiments.**

weight was most affected by shading. Sequential determination of the yield components is clearly demonstrated in this experiment. Reduced photosynthate supply, particularly during the immediate post-flowering period, increased flower and small pod abscission.

In another experiment (Fig. 51) with a range of varieties and with two-week shading intervals the maximum yield reduction occurred at different growth stages according to variety. P459 and P302 showed the largest reduction at 14-28 days after flowering while the other varieties showed the largest reduction 0-14 days from flowering. In all cases however, the yield component most associated with reduced yield was pod number/m² (Fig. 52). Difference in source-sink balance between the varieties at different growth stages probably account for these differences. The variety P302 has been recommended to the Cassava Program as a variety showing less yield reduction due to shading for use in associated cassava-bean experiments.

Carbon Dioxide Fertilization

Carbon dioxide fertilization (CO_2 concentration 1,200 ppm) was used as an experimental tool to evaluate effects of increased photosynthate supply on yield, particularly on pod set. Transparent open-topped chambers, 1 m² in area, were placed in a crop of P566 at four growth stages of 10 days each. Results are summarized in Table 28. CO_2 significantly increased yield through higher pod set when applied from -2 to +8 days from flowering. The immediate post-flowering period is critical with respect to pod production from flowers which bloom in this period. The results suggest that increased photosynthate supply applied over a short period can increase pod set. The importance of total photosynthate supply during the pod set period is clearly demonstrated.

Canopy Support and Artificial Lodging

Three treatments involving degrees of canopy support in P566 were applied to evaluate the importance of canopy structure on yield. Control plots (S_1) were compared with two horizontal wire supports, 30 and 60 centimeters high on either side of the row (S_2) and a 2-meter trellis with a vertical array of strings (S_3). Lodging occurred at flowering in S_1 and to some extent in S_2. The variety showed a natural tendency to climb on the strings in S_3 reaching a final canopy height of 140 centimeters compared to a maximum prelodging height of 65 centimeters and 75 centimeters in S_1 and S_2, respectively (Fig.

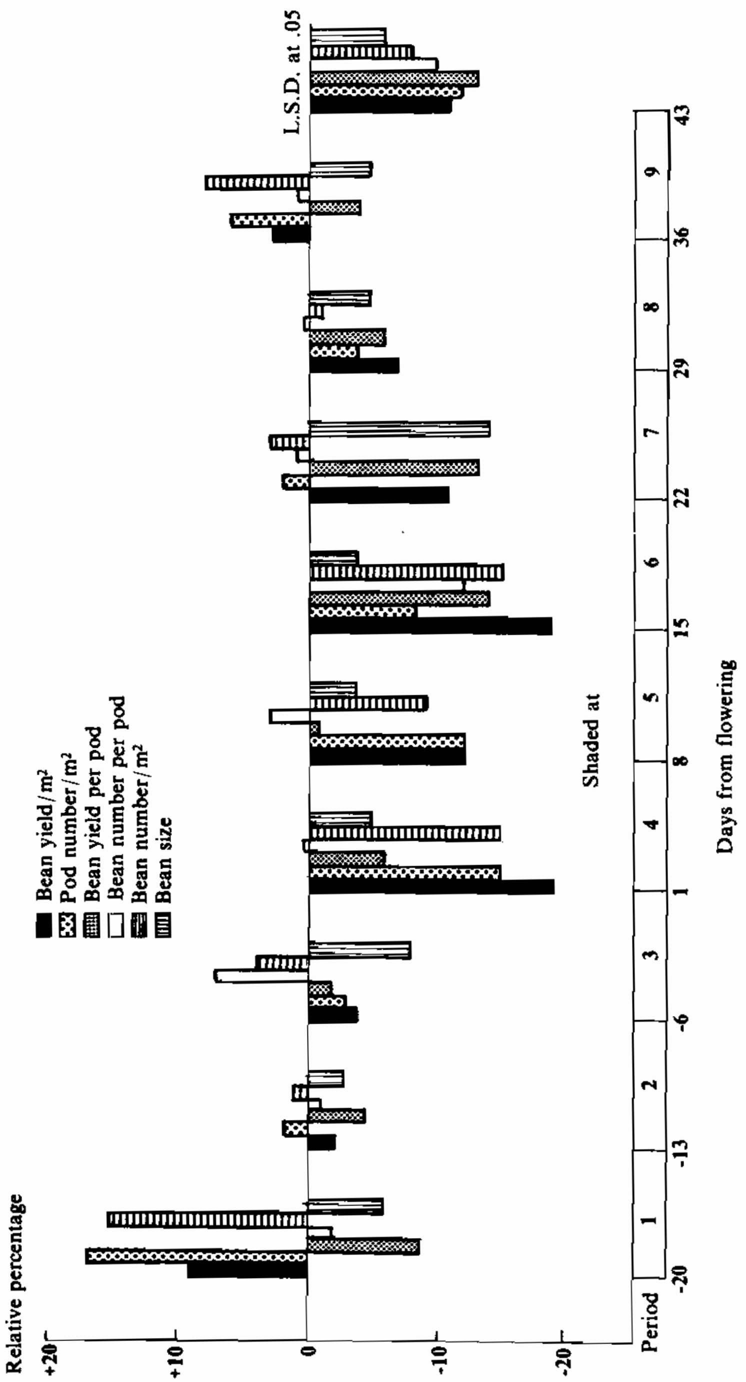


Figure 50. Effect of shading at different growth stages on bean yield and yield components for P566. Data are expressed as relative values (control plot: 100%)

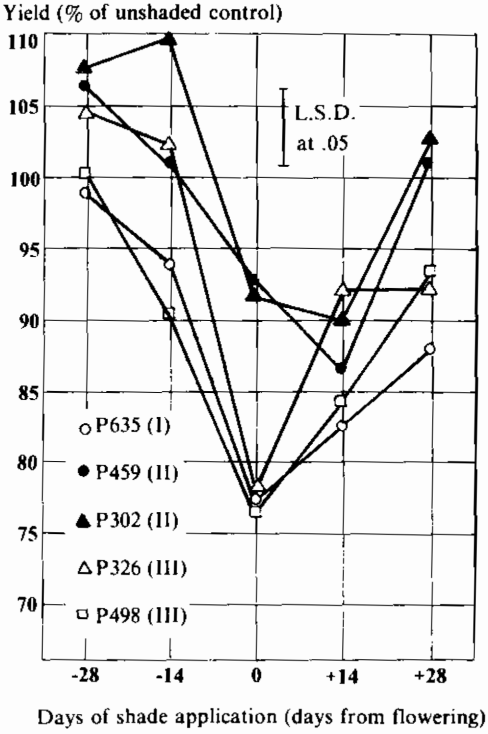


Figure 51. **Effect of shading at five growth stages on five varieties of beans.**

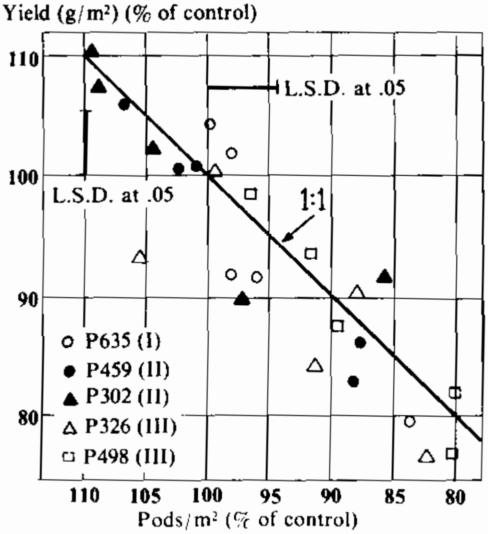


Figure 52. **Relative reduction in yield and pods/m² for five bean varieties. Results are expressed as a percentage of unshaded control plots in each variety.**

53). S_3 had a longer leaf area duration particularly on the upper nodes of the main stem although maximum LAI values were similar. Increased node production 20-40 days after flowering and increased pod set on these upper nodes in S_3 over the other treatments was also observed. The yield increase from 2.77 t/ha to 3.55 t/ha (28%) from S_1 to S_3 was mainly associated with increased pod set on the upper nodes of the main stem. S_3 reached physiological maturity 13 days after S_1 due to later flowering and pod set on the new nodes formed late in the growth cycle.

Determinations of total carbohydrate content in the main stem (Fig. 54) at various stages shows a higher level of stem storage in S_3 and a slower rate of decline

Table 28.**Response[1] to carbon dioxide fertilization at four growth stages in accession P566.**

Growth[3] stage	Yield (g/m²)		Pod number/m²	
	Control	CO_2	Control	CO_2
-2 - +8	330	363(110)[2]	267	297(111)[2]
+8 - +18	297	310(104)[4]	268	282 (105)
+18 - +28	272	286 (105)	253	264 (104)
+28 - +38	288	298 (103)	265	271 (102)
L.S.D. at .05	31.4		23.3	

[1] Mean of five chambers in control and CO_2 treatments at each stage.

[2] CO_2 as % of control treatment

[3] Days from flowering

[4] Mean of three replications only

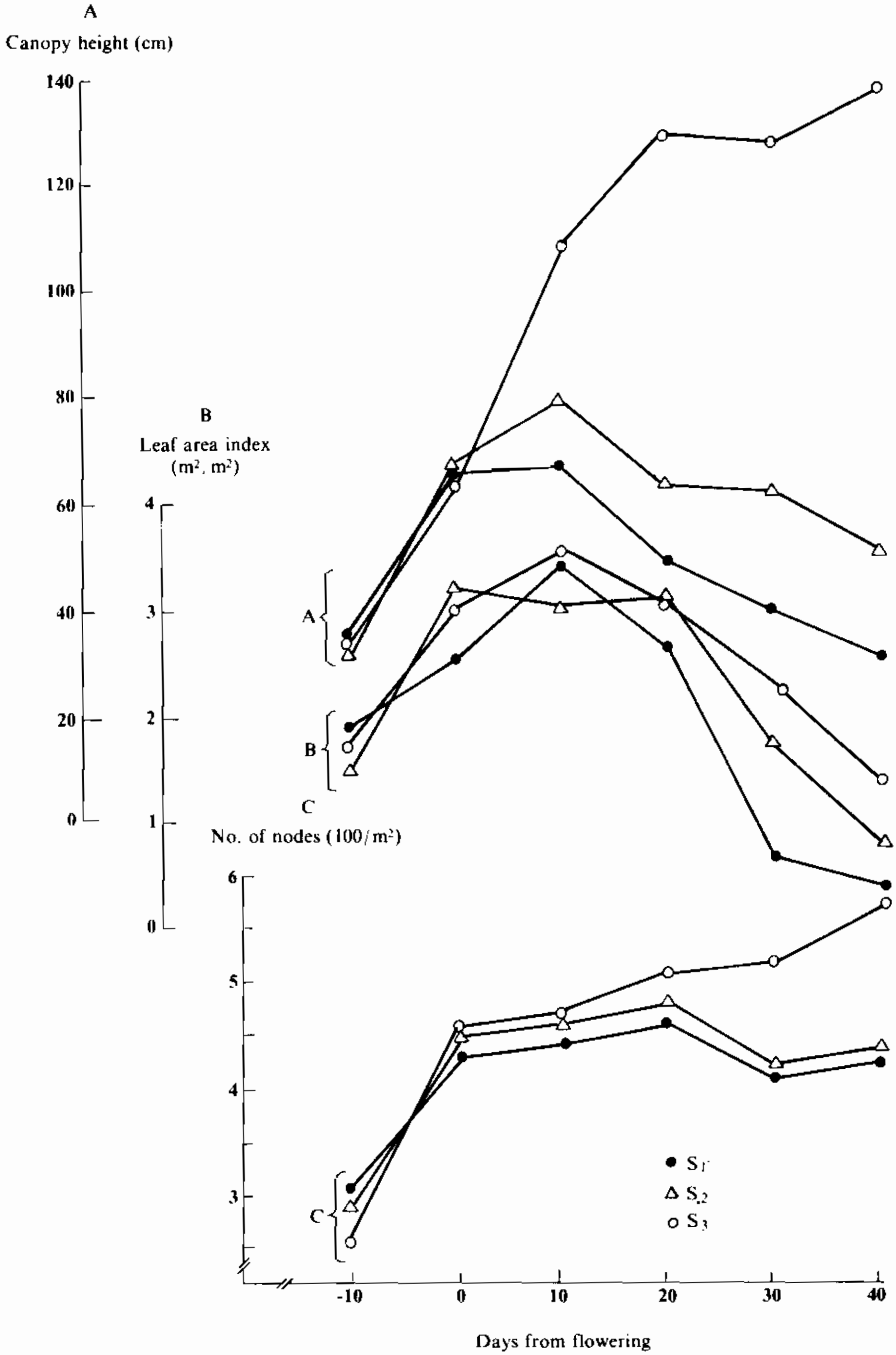


Figure 53. **Canopy height, leaf area index and total node number of three support systems (S_1, S_2, S_3) at different growth stages in P566.**

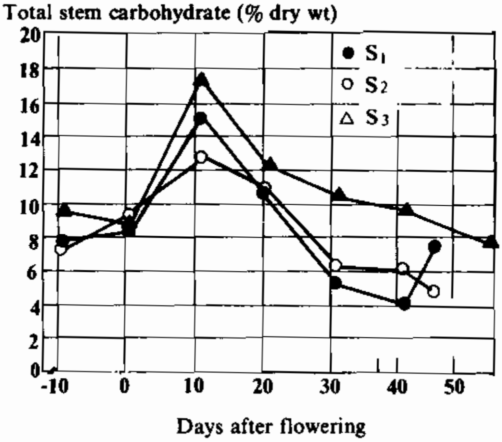


Figure 54. **Total carbohydrate (sugar and starch) content in stems of three support systems (S_1, S_2 and S_3) at different growth stages in P566.**

after the maximum (10 days after flowering). This evidence of excess photosynthate availability in the supported system during a period when increased pod set occurred may suggest that excess photosynthate was available above the requirements for pod set and pod filling.

Artificial lodging (Fig. 55) at seven growth stages (at one-week intervals) was applied to P566 by rolling the plots with a bamboo pole. Prior to the rolling treatment all artificially lodged plots were supported using system 2 described in the previous support experiment. Maximum yield reduction, compared to the fully supported control, occurred during the immediate post-flowering period with yield reduction associated both with decreased pod set and decreased bean number/pod. The results of various shading and lodging experiments at different growth stages show a striking similarity suggesting that lodging disturbs canopy light conditions and reduces photosynthate supply during the pod set and filling stage. Reasons for the yield differences in Table 25 are now more clearly identified and related to the effects of reduced photosynthate supply on the number of mature beans/pod.

Leaf and Raceme Removal

Leaf and pod removal treatments were applied to P566 to evaluate the stages at which yield components are formed at a specific node position (node 9). The source-sink balance was manipulated by (a) removing two of the three trifoliate leaflets on nodes 7-11 (reduced source to node 9), or, (b) removing adjacent racemes at nodes 7, 8, 10 and 11 (increased source for node 9). Both treatments were applied at five growth stages in seven-day intervals, commencing at flowering of the 9th node, to randomly selected plants in a normal crop stand. The results in Figure 56 show the relative value of the yield and components of yield at node 9. A large increase in yield at 0 and 7 days from flowering was directly associated with increased pod set when the competition from adjacent racemes were removed. On the other hand, two-thirds leaf removal from all adjacent nodes had a small depressing effect upon yield. Leaf removal at 14 days after flowering also had the additional effect of reducing beans per pod. Effects on bean size were non-significant in all treatments.

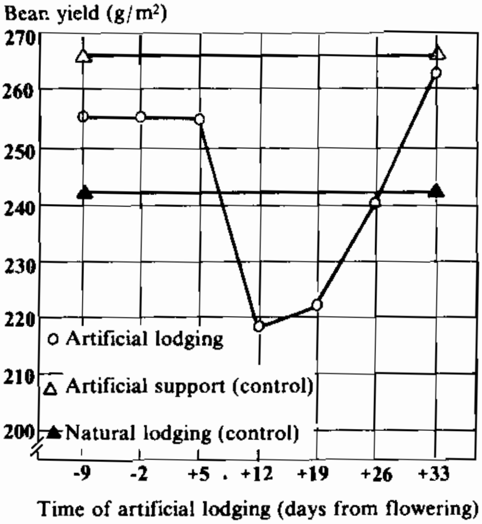


Figure 55. **Effect of time of artificial lodging on yield of P566 in relation to natural lodging and artificially supported plots**

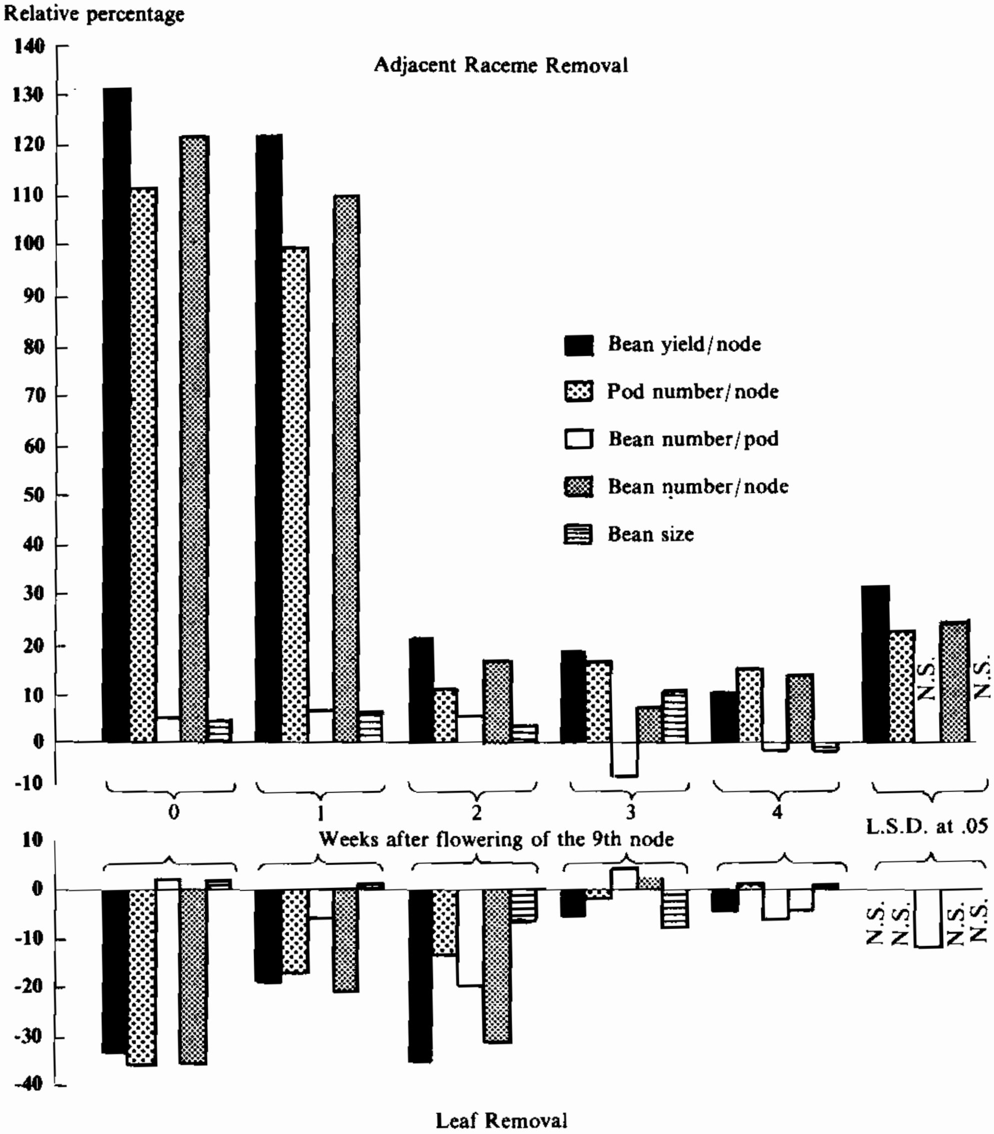


Figure 56. **Effect of adjacent raceme removal (at nodes 7,8,10 and 11) and two-thirds leaflet removal (at node 7,8,9,10 and 11) at different growth stages of the 9th node on bean yield and yield components of the 9th node of P566. (Data expressed as relative percentage (control plants: 100%).**

The increased pod set at node 9 was due to increased flower set at position 2 on the raceme whereas reduced pod set was due to increased abscission at position 1. The results suggest that pod set is controlled strongly by photosynthate supply. The smaller effects of leaf removal are possibly due in part to the mobility of photosynthate within the plant from leaf area above node 11.

In the same P566 crop leaf removal treatments were applied to three strata: lower (nodes 3-6), middle (nodes 7-10), and upper (nodes 11-14). All leaves were removed (branches included) on the flowering day of the central node in each strata so that source reduction would occur at the same physiological stage. Four days separated this date from the lower to the upper strata. Mean yield results on a whole plant basis for each treatment are presented in Figure 57. Though all leaves of the middle stratum were removed at flowering, the relative importance of the middle stratum was maintained, the earlier pods set at these nodes continuing to act as strong sinks which attracted photosynthate from the upper and lower strata. There appears to be no real independence of each source-sink nodal unit. Photosynthate is highly mobile in the plant, moving during pod growth to the earliest fertilized pods in a highly polarized manner. C^{14} studies will be necessary to confirm these observations. The importance of endogenous hormone production by the young growing pods and seeds in controlling the direction of photosynthate movement is also an important consideration.

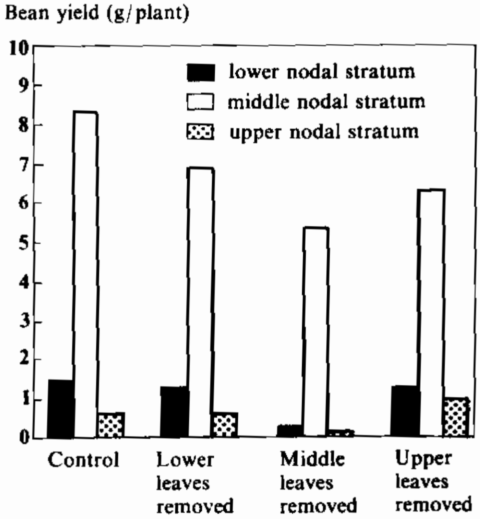


Figure 57. **Effect of leaf removal from lower, middle and upper nodal strata on bean yields of each nodal stratum for P566.**

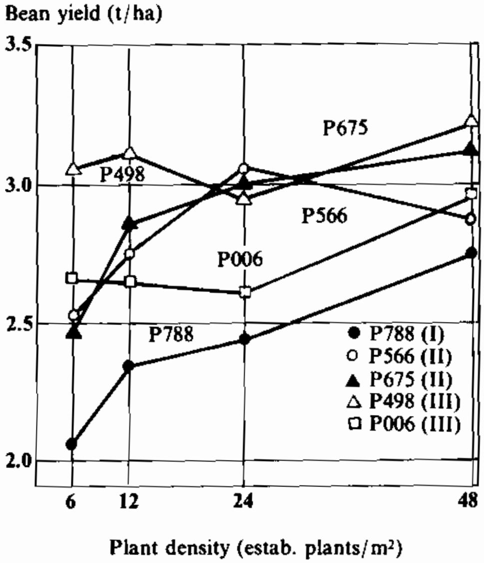


Figure 58. **Yield response to plant density in five varieties of beans from growth habits I-III.**

Response to Plant Density

The yield results of a plant density x variety experiment are shown in Figure 58. The varieties were selected as representative of the three nonclimbing growth habits (I-III). In two previous experiments with P498 (III) almost no response to density was observed. These results are confirmed in the present experiment where a yield of more than 3 t/ha was obtained at a plant density of 6 plants/m² (60,000 plants/ha). The type II varieties showed density response up to 24 plants/m² but P566 showed a negative response at 48 plants/m². The determinate variety P788 showed a strong response at all densities. This latter result is not typical of density response data from previous experiments. The variety P006, also type III, showed no density response over the range of normal plant densities in the field. These results bear on discussions of plant ideotypes for breeding selections (see page A-67).

Adaptation

Components of adaptation in dry beans

are under study at CIAT and elsewhere and include photoperiod sensitivity, drought resistance (La Molina, Peru), resistance to excess water, and stability of growth habit (Cornell University, U.S.A.).

Photoperiod Screening

A further screening of promising lines was conducted in 1975B. Included in this second group were a number of type IV promising lines. The complete results for all material screened to date are presented in Table 29 by growth habit and in Table 30 by days to flowering. The definition of the photoperiod response classifications is given at the top of each table. Of the 278 individual genotypes screened, 40 percent are photoperiod insensitive at CIAT field temperatures (mean 23.8°C). The existence of photoperiod insensitive climbing beans (IV) is an important finding though there appears to be a higher proportion of type II varieties in the insensitive group (4 days delay) than type IV. Further evaluations will be necessary in type IV to confirm these preliminary observations. The search for late (days from planting to flowering) photoperiod insensitive lines continues. Many of the photoperiod insensitive lines shown in Table 30 as being late (>44 days to flowering in 12h 20min days) have not proved stable in this character in different sowings at CIAT.

Growth Habit Stability

Research in progress at Cornell University, in collaboration with CIAT, has shown that the phytochrome reaction directly controls the degree of climbing exhibited by bush bean varieties considered to be unstable in growth habit (CIAT Annual Report, 1974). The provision of a red light break of 15 min was sufficient to induce climbing in some varieties. Indeterminate genotypes showing stable growth habit did not tend to

Table 29.Summary of results for all materials screened in 1975 by photoperiodic response classification and growth habit[1]

Growth habit	Photoperiod response (days of flowering delay)[2]					
	(<4)	(4-10)	(11-20)	(21-30)	(>30)	Total
I	17 (40.5%)	4 (9.5%)	13 (31.0%)	6 (14.3%)	2 (4.8%)	42 100
II	65 (51.2%)	18 (14.2%)	34 (26.8%)	7 (5.5%)	3 (2.4%)	127 100
III	23 (37.1%)	12 (19.4%)	13 (21.0%)	11 (17.7%)	3 (4.8%)	62 100
IV	5 (10.6%)	5 (10.6%)	15 (31.9%)	12 (25.5%)	10 (21.3%)	47 100
Total	110 (39.6%)	39 (14.0%)	75 (17.0%)	36 (13.0%)	18 (6.5%)	278 100%

[1] Data in table gives number of genotypes in each group.

[2] Days of flowering delay in 18h days compared to natural daylength of 12h 20m, CIAT 3ºN

Table 30. Summary of results for all materials screened in 1975 by photoperiod response classification and number of days to flowering in 12h 20 min natural daylength.[1]

Days to flowering	Photoperiod response: days of flowering delay[2]					
	(<4)	(4-10)	(11-20)	(21-30)	(>30)	Total
25-29	-	-	1 (50.0%)	1 (50.0%)	-	2 (100%)
30-34	14 (73.7%)	1 (5.2%)	3 (15.8%)	1 (5.2%)	-	19 (100%)
35-39	43 (47.8%)	10 (11.1%)	26 (28.9%)	8 (8.9%)	3 (3.3%)	90 (100%)
40-44	44 (43.1%)	11 (10.8%)	29 (28.4%)	12 (11.8%)	6 (5.9%)	102 (100%)
45-49	7 (19.4%)	8 (22.2%)	12 (33.3%)	6 (16.7%)	3 (8.3%)	36 (100%)
50-54	3 (18.8%)	3 (18.8%)	4 (25.0%)	4 (25.0%)	2 (12.5%)	16 (100%)
55-59	2 (25.0%)	2 (25.0%)	1 (12.5%)	1 (12.5%)	2 (25.0%)	8 (100%)
60-64	-	1 (25.0%)	1 (25.0%)	1 (25.0%)	1 (25.0%)	4 (100%)
65-69	-	-	-	-	1 (100%)	1 (100%)
Total	113	36	77	34	18	278
%	41.7%	13.0%	27.7%	12.2%	6.5%	100

[1] Data in body of table gives number of genotypes in each group.

[2] Days of flowering delay in 18h days compared to natural daylength of ± 12h 20 min, CIAT 3°N

climb with this treatment. The response was reversible with a further period of infrared light. Preparations are under way to evaluate this method as a screening technique for growth habit stability under field conditions at CIAT.

Breeding Implications

Bean production in Latin America occurs under a wide range of climatic conditions, cropping systems and with variable levels of technological inputs.

Such differences must be recognized and plant types suggested which are appropriate to the major growing areas.

Following the experiments described in previous sections, four ideotypes have been defined and suggested to the breeding program as goals for growth habit, plant architecture and maturity selection. A summary of major features in each ideotype follows.

Ideotype A

Ideotype for short growing seasons. A type I variety with maturity of $\simeq$75 days is suggested. The plant would require high seedling vigor and production of 8-10 nodes on an erect main stem before flowering. Branching should be minimal. Plant densities close to 250,000 plants/ha would be required since the low density compensation characteristics of type I genotypes appears poor. The ideotype could be expected to yield no more than 2.5 t/ha under reasonable conditions given the maturity limitations.

Ideotype B

Ideotype for high-yielding commercial conditions. This ideotype is suggested for higher levels of technology where environmental conditions (particularly length of growing season) are good and where plant densities can be maintained close to 250,000 plants/ha. Under such conditions, a late flowering (50 days or more) type II plant allowing high levels of node production prior to flowering, erect main stem and branches and with lodging resistance, seems to offer the best alternative, particularly where monoculture by mechanized means is practiced. P566 has many characteristics that could form a genetic base for the Ideotype B. Research on this variety has identified important yield limiting factors which must be manipulated genetically if higher potential is to be obtained.

Ideotype C

Ideotype for variable growing conditions and/or low technology. This ideotype is needed for variable rainfall conditions both with respect to length of growing season and to rainfall variability within season and/or for conditions of highly variable and often low plant density. Capacity to compensate for low and irregular plant distribution would be necessary, particularly for small farmer production conditions. P498 (Fig. 58) could form the genetic base for a type III ideotype with strong branching characteristics, relatively prostrate growth habit, a long flowering period, and with reasonable water stress resistance to flower abscission. The need for genotypes with different maturity classifications is probably greater in this ideotype than in the other three. The ideotype would need to have stable yield under difficult growing conditions but to respond when growing conditions are favorable. The ability to maintain the pod load out of contact with the soil surface would be an advantage.

Ideotype D

Ideotype for planting in association with maize. Climbing bean research suggests that strong climbing types with a capacity to yield well in association with maize are available. Research on yield limitations in climbing beans in association have commenced with a view to drawing up an ideal plant type in this category.

In all ideotypes it is envisaged that the genotypes would have wide adaptation features such as photoperiod insensitivity, temperature insensitivity (particularly with respect to flowering behavior), water stress resistance, excess soil water resistance and stable growth habit. Research is continuing on these adaptation features. Early results suggest that sources of variation exist for all of these latter characters within the germplasm collection at CIAT. Many of these requirements for adaptation can be evaluated through the international testing of potential parents in the IBYAN and other programs.

BREEDING

Bean breeding focuses information from all program disciplines toward the production of genetic variability, seeking to recombine qualities such as resistance to important diseases and insects with high yield and desirable seed characteristics. It also pursues an orderly management of hybrid progenies which extracts all useful genetic variability from hybridizations.

The Bean Program's short-term breeding emphasis is on greater yield stability in the four major plant groups shown in Table 31. As indicated in this table, and in the agronomy section (page A-33), many black-seeded lines currently yield 2.5-3t/ha under protected conditions. While stabilization of such yields by incorporating disease and insect resistance factors is a reasonable, albeit ambitious goal, raising the yield potential by 0.5 t/ha in the same period would demand greater effort with much lower return. By contrast, the difference between existing and forseeable yields for the non-black beans appears greater, justifying simultaneous improvement for both increased yield and stability. The program expects to obtain red-seeded beans equal in yield to their black counterparts. Climbing bean yields of 2 t/ha in association with maize (see page A-38) are very promising, but given the low input levels of the small farm (where such associations predominate) will be unstable without genetic resistance to insects and diseases. Breeding in the short term for yield stability will benefit the small farmer by increasing yield, the commercial grower by reducing costs.

Table 31 also shows the disease and insect problems to which the breeding program has given major emphasis. Although the major factor determining these priorities was the importance of each problem to Latin American bean production, the availability of suitable resistance (donor) sources, the existence and importance of races/strains, and the ease or difficulty of screening large numbers of progenies with reasonable experimental precision, had also to be considered.

Table 31. **Key characters for the short-term imporvement of four important plant groups of *Phaseolus vulgaris*.**

	Yield (t/ha)		
Bean group	Present	Sought	Key character under improvement
Black Bush	2.5-3.0	3.0 (stable)	CBMV, Rust, *Empoasca*, Variable maturity, Anthracnose.
Colored Bush	1.5-2.3	3.0 (stable)	CBMV, Rust, *Empoasca*, Indeterminate/Variable maturity, Anthracnose.
Climbing (different colors)	2.0 [1]	2.5 (stable)	CBMV, Anthracnose, Rust, Photoperiod insensitivity
Commercial varieties	variable	3.0 (stable)	Specific factors requested by national programs

Associated with 40,000 plants/ha maize yielding 4+ t/ha.

In the intermediate and long term we expect to raise the physiological yield potential of the species significantly, developing cultivars which are more efficient in their architecture, use of the available growing season, and carbohydrate and nitrogen metabolism. A clearer picture of the physiological requirements for higher yields in the different areas and production systems of Latin America is emerging (see page A-67) and already permits increased breeding for yield potential.

Bean Hybridization Program

Both the number of new parents and of new crosses increased substantially in 1976 (Table 32); so too did the emphasis given parents and crosses holding the promise of segregants with desirable genes for multiple factors. To support the priorities shown in Table 31, extra weight has been given recently to common mosaic, rust, anthracnose, and *Empoasca* resistance in crosses and their progenies. Although extensive crossing has not yet been initiated with climbing beans (group 3, Table 31) many of the major gene resistance sources (i.e. P699 and P717 for rust), are of growth habit IV and segregate recoverable climbing types in filial generations.

Table 33. **Range and mean for yield of donors with major gene or field resistance to key production-limiting factors, used at CIAT during 1974-76**[1]

	Number of donors		Yield potential (t/ha)	
Year	Total	With yield data	Range	Avg.
1974	7	7	1.9-3.3	2.5
1975	29	13	1.2-3.3	2.5
1976	58	27	1.9-3.3	2.7

Donors with resistance to CBMV, rust, anthracnose, or *Empoasca*

Continued screening of germplasm collections by pathology has produced resistance sources higher yielding than many of the poorly-adapted sources initially used in crosses (Table 33). Similarly, our confidence in yield sources has increased through continued testing of promising lines and cultivars by the different disciplines, particularly agronomy. The best yielding and most stable representatives of each major color group are well-known, and receive high priority in terms of crossing frequency. Non-black parents combining yield potential with more than one resistance factor are scarce; a high priority has been placed

Table 32. **Cumulative number of parents and hybrid progenies with single and multiple resistance factors during 1974-76.**[1]

	Common mosaic	Rust	Anthracnose	*Empoasca*	Two factors	Four factors	Total
Parents							
1974	5	2	1	5	5	-	10
1975	16	15	11	31	16	-	100
1976	28	20	22	47	24	-	178
Progenies							
1974	16	8	2	16	-	0	20
1975	433	279	165	461	-	21	835
1976	1,501	1,273	786	1,841	-	192	3,482

[1] Cumulative for both parents and progenies (number of parents and progenies used during 1976 include those from 1974 and 1975).

upon recovering such materials from progenies.

Given the large crossing capability of the program, many crosses have been made for national programs. These normally seek to incorporate specific resistances into important commercial varieties. Where practicable these are screened at CIAT under inoculated conditions in the F_2, then delivered directly to the national program for further selection.

Progeny Testing and Selection

Studies conducted by trainees in the breeding program have shown that early generation selection of single plants for yield was not effective. Yields of F_2 single plant selections of five single crosses were not significantly different from those of the best parent and the unselected bulk (Table 34). Results from other studies showed no advantage for double crosses over single crosses.

Given this difficulty, a plan for progressive mass selection has been developed in which early generation screening focuses on the more highly heritable major gene disease resistances (CBMV and rust). Yield, *Empoasca* tolerance and anthracnose resistance are evaluated in later generations where larger quantities of seed and more homozygous families are available (Fig. 59). Improved screening procedures for the latter characters are being developed, and will be applied both to progeny testing and to recurrent selection for higher levels of resistance.

Since it is essential to maintain genetic variability for yield, plant architecture and seed color into advanced generations, the initial stages of progressive mass selection demand a massive effort in terms of seed handling, inoculations, and land. Therefore in November 1976, more than 100,000 F_2 plants were hand-inoculated with CBMV (Fig. 60). The need for such large nurseries should decline rapidly as broad-based progenies homozygous for at least two key resistances are identified. Despite this, the presence of modifier genes in some host cultivars and genetic variability (strains/races) of the pathogen will necessitate reevaluation of some progeny groups and the international testing of some F_4/F_5 families. This is neither surprising nor an inconvenience, as local preferences for seed color and grain type demand evaluation and selection at the national level.

Difficulty has also been experienced in selecting promising plant architectural types from among segregating F_2 pop-

Table 34. Yield (kg/ha) of families from F_2 single plant selections, compared to the best parent and the unselected bulk, of five single crosses.[1]

		F_2 selection			
Cross	Best parent	No.	Avg. yield	Bulk	Analysis of variance
2 P006 x P459	2,300	3	2,353	2,327	NS
9 P459 x P568	2,233	7	2,287	2,300	NS
11 P008 x P459	2,233	3	2,087	2,367	NS
16 P004 x P459	2,233	6	2,120	2,540	NS
17 P004 x P566	2,820	3	2,393	1,967	

Average of three replications; L.S.D. at .05 – 593 kg; C.V. = 19.6.

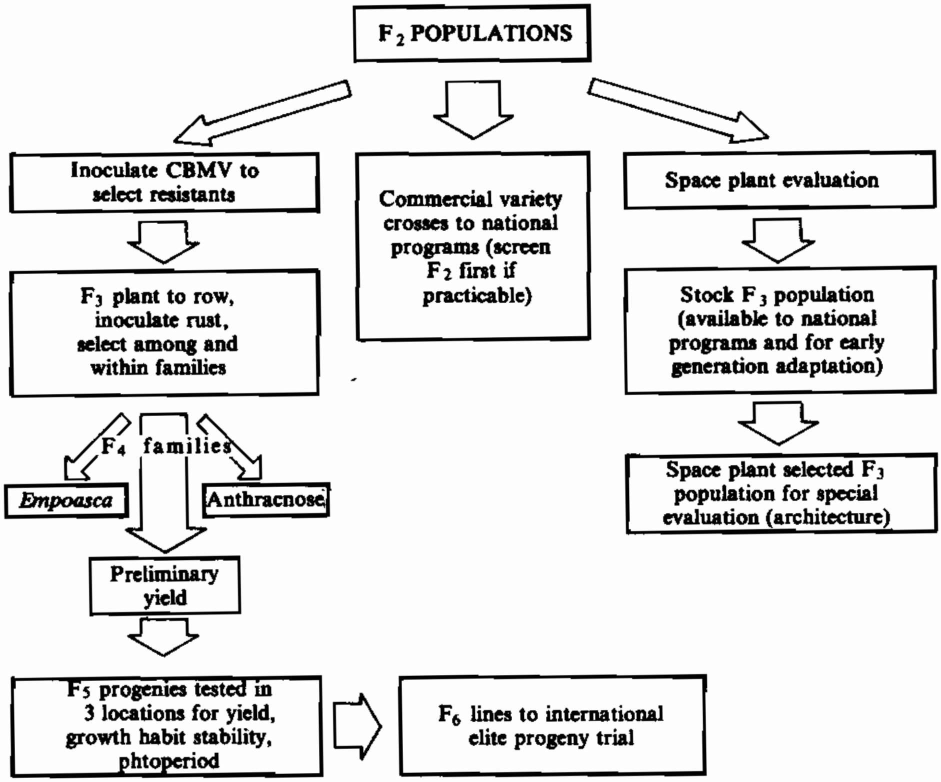


Figure 59. Progressive mass selection scheme used by CIAT bean breeding program.

ulations. As stated earlier, many F_2 populations derive from crosses featuring type IV parents. Screening such segregating populations at normal crop densities results in the elimination of the less competitive genotypes which in several other small grains have ultimately proved to be those materials most responsive to high densities and intensive management. Studies on the differential effects of intergenotypic competition in relation to progeny screening are under way, and aim to develop a planting and genetic management scheme minimizing phenotypic competitiveness (habit-architecture) x environment (spacing) effects on the selection of high yielding genotypes.

Until such results are available, F_2 populations are being space planted for simultaneous evaluation by breeder, physiologist, and pathologist (as in Fig. 60). The unidentified bean disturbance (Problem X) observed in the Cauca Valley and under study by pathology and agronomy (see page A-14) has made selection for plant architecture and yield components extremely difficult, primarily because of the varietally specific nature of expressed symptoms.

Bean Information System

Considerable attention was given in 1976 to developing an integrated information system which not only defines the origins of the many crosses being undertaken and the desirable factors to be selected in each hybrid population, but also maintains results from the progeny

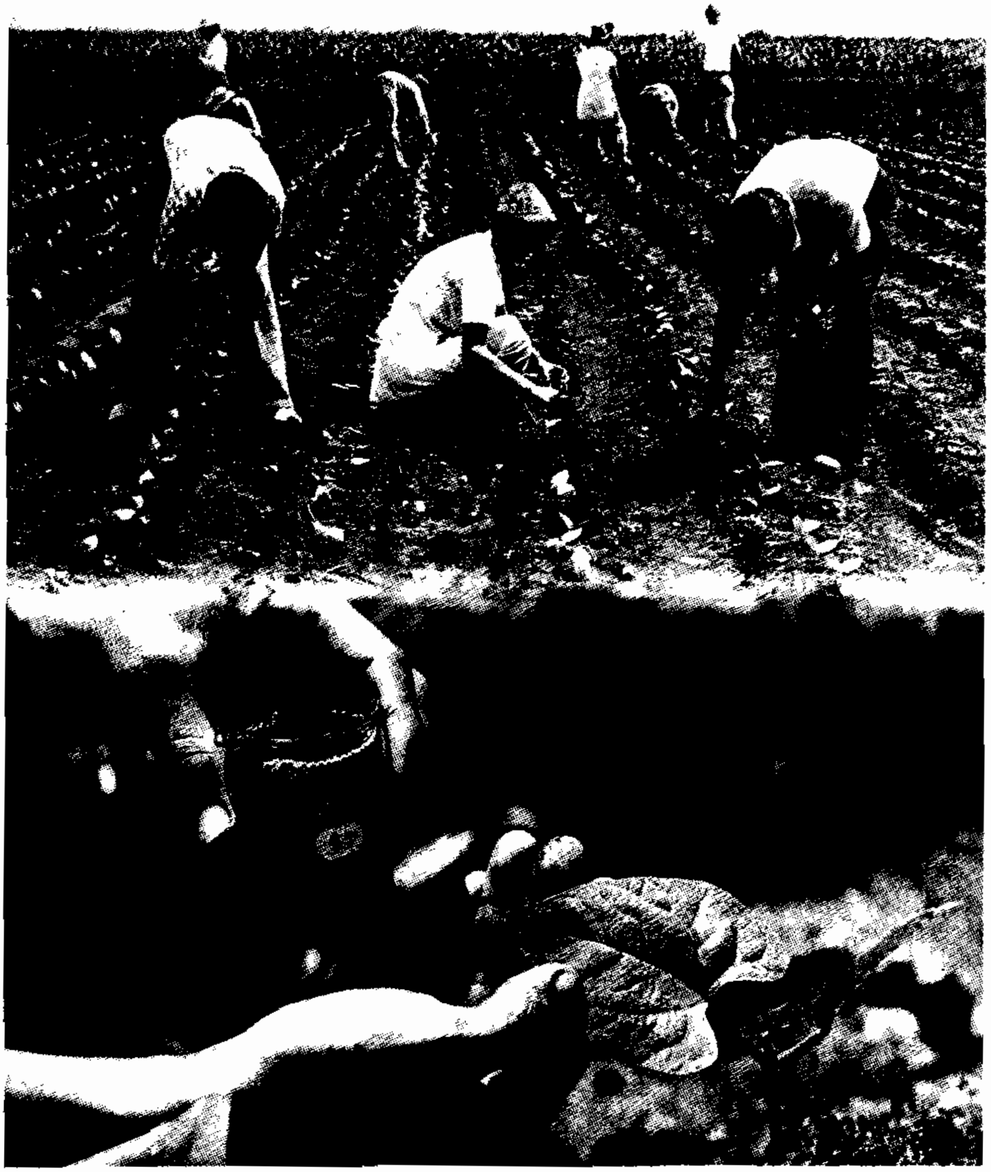


Figure 60. Screening for resistance to bean common mosaic virus (BCMV) is the first stage in the mass selection procedure to maintain wide genetic variability in materials uniformly resistant to major pests and diseases. The photos show aspects of field inoculation of F_2 plants with suspensions of BCMV.

testing in a computerized and continuously updated form. This system helps the disciplines in their progeny screening programs, permits the breeder to better plan his crosses, and ensures that maximum advantage is taken of genetic variability in the segregating progenies.

Management of progenies is further facilitated by the use of information cards, which serve as a working field book. These may be photocopied as needed, and physically accompany all seed distributed.

Multi-location Progeny Testing

Several factors demand that, seed supply permitting, progenies be moved rapidly into a system of multi-location testing. These factors include: (a) The importance of seed size and color to national program interests, (b) the atypical behavior of several BCMV resistance sources when tested at Palmira, (c) the existence of major race differences for diseases such as rust in the different areas of Latin America, (d) different needs in maturity time, (e) the need to obtain an active interest and participation from national programs, and (f) the absence of certain important disease and insect pests in Colombia.

By mid-1977, the bean breeding program will generate 2,000 F_4/F_5 families per semester. Plans are under way for two systems of multi-location testing.

(a) A multi-location progeny trial at three locations within or near Colombia, controlled by the program for the purpose of screening large numbers of progenies.

(b) Elite international nurseries, to be distributed according to national program preferences, and coordinated by the bean agronomy group.

This multi-location testing will become increasingly important in 1977 when the breeding program initiates crossing among progenies homogeneously resistant to several key diseases.

ECONOMICS

The principal objective of the bean economics group has been to identify the most important constraints to increasing production and productivity of beans, one approach being the identification of factors influencing bean yields at the farm level. To accomplish this and to better understand bean production systems, intensive field interviews were done in four regions of Colombia in 1974 and 1975. Table 35 summarizes the location of these sites and the number of observations in each. In the 1975 CIAT Annual Report various results were presented on disease and insect incidence, input use and factors affecting bean productivity in the Valle region. This report will focus on the regions of Huila and Nariño.

First, it is useful to review the characteristics of production in the four regions (Table 36). Valle is characterized by large farms with high levels of purchased inputs, producing small black beans primarily for export, and utilizing monocropping. The other three regions are characterized by smaller farms, using fewer purchased inputs, producing large red beans in combination with other crops and having only slightly lower yields in bean equivalent terms[1]. One bean system in Antioquia gave substantially higher bean equivalent yields; however, the entire crop cycle was 14 months compared with only

Table 35. **Number of farms interviewed in four Colombian regions for bean economics survey, 1974/75.**

Region	No.
Valle	31
Huila	105
Nariño	19
Antioquia	22
Total	177

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[1] Bean equivalents convert the other commodities into beans by multiplying these yields by the relative prices. See footnote 3 in Table 36.

Table 36. **Characteristics of bean producers in four regions of Colombia.**

Mean farm characteristics	Regions			
	Valle	Huila	Nariño	Antioquia
Total area[1] (ha)	91.7	29.5	9.2	4.4
Crop area (ha)	40.5	6.8	3.1	1.7
Bean area (ha)	22.6	4.1	1.8	1.5
Systems of bean production[2]	monocrop	30% monocrop (principally level areas) 70% beans/maize (principally sloping land)	beans/maize	54% beans/maize beans/maize/potatoes 46% beans/maize/arracacha others
Type of bean	black-bush	red-bush	red-bush	red-climbing
Yields for monocropped beans (kg/ha)	906	805	—	
Yields of bean equivalent (kg/ha)[3]	[4]	834	732	723[5] 2,754[6]

[1] This is the total area available to the farmer.

[2] With more than one system of beans, percentages refer to the number of farmers in each category.

[3] Bean equivalents are calculated by utilizing prices of other commodities relative to beans as follows: Yield (beans) + Price (maize) Yield (maize) = Yield (bean equiv.)

[4] The bean crop in the Valle region can be grown in 3.5 months and followed by another crop

[5] Refers to the first intercropping combination of beans/maize.

[6] Refers to the second intercropping combinations of beans/maize/potatoes, beans/maize/arracacha and others.

four months in the Valle. The input use in Antioquia was also very high.

Yields varied substantially among farms in each zone. In Table 37, the average yields of a small sample of five farms from each end of the yield distribution are shown. In all four regions small groups of farmers were already obtaining higher yields than the subjective expected yields[1] from a low-cost technology package for monoculture beans. In several cases, yields higher than were estimated as being possible from a high-cost technology package were obtained by this group of farmers. One policy implication is that an improved understanding of how some farmers obtain higher yields and why other farmers do not, could help orient strategies in the bean program.

Yields are expected to be a function of inputs utilized, cultural practices, native soil fertility, climate, insect, and disease attack. The following regression explained almost two-thirds of the variation in bean yields among farms in the Huila and Nariño regions (Table 38).

It was assumed that the above sample in the regression is representative of the Huila and Nariño area. Using an estimated beans/maize crop area of 23,000 hectares some estimates of total effects from the various factors influencing yields were made for the two regions (Table 39).

The most important factor determining bean yields is the type of cropping system. With increased maize crop density bean yields are reduced. Considering the dis-

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[1] These subjective potential yield estimates with two types of technologies were obtained from estimates by Bean Program scientists and included a 30 percent discount between experiment station and farm yields. For more details see footnotes 4 and 5 in Table 37.

Table 37. **Best and worst yields from the survey sample in four regions of Colombia and potential monoculture yields with low- and high-cost technologies.**

	region			
	Valle	Huila	Nariño	Antioquia
Best yields	1,773	1,563	1,193	3,379
Difference between best farmer and average farmer yields (%)	96%	87%[2]	63%	23%[3]
Worst yields[1]	245	239	368	184
Expected farm level yields of improved bean varieties with improved cultural practices, monoculture[4]	1,500	1,000	1,000	1,000
Expected farm level yields of improved varieties, improved cultural practices and high input use, monoculture[5]	2,200	1,600	1,600	1,600

[1] Averages for the five best and worse yields were calculated for each region. These are yields for monoculture in the Valle and for multiple-cropping in the other regions. There were no extreme values.

[2] Compared with bean equivalent yields.

[3] Compared with mean yields for the more profitable crop combinations of beans/maize/potatoes, beans/maize/arracacha and others.

[4] These were subjective estimates of mean yields for improved varieties with recommended plant density, time of planting, and the use of clean seed. A 30 percent discount from expected experiment station yields was utilized to adjust for differences in soil quality and management ability.

[5] Besides new varieties and improved cultural practices, high input use implies high levels of fertilization and other agricultural chemicals. However, irrigation was not included.

tribution of returns, multiple cropping results in lower profits and lower risks so that farmers able to take higher risks gradually shift into monoculture bean production, higher input use, and longer storage periods to avoid the seasonal price collapse[1]. Besides risk reduction multiple cropping may reduce leaching and erosion especially on sloping soils and enable increased nitrogen fixation (see page A-31). For the second most important factor, topography, there is little that the farmer can do other than farm elsewhere so this variable has little policy importance.

Thrips and *Empoasca* can be controlled by spraying systemic insecticides after the pests are identified in the field. Work is also in progress in CIAT on genetic resistance to *Empoasca* (see pages A-15 and A-68). The four diseases excluding mildew led to a combined total production loss of 2,199 tons in the two regions or an average yield reduction of 168 kg/ha. Can these four diseases be controlled with clean, treated seed? This would be a low cost, low risk technology, which would increase average yields by almost 28 percent if the disease did not appear in the field after being removed from the seeds. The yield increment is small: however, average yields are also low and the distribution of clean, improved seed would involve only a small expenditure by the farmer.

Increased aggregate yields in a country can be obtained (a) by helping the rest of the farmers move toward best farmer yields, (b) by introducing adapted varieties of higher yield potential than those currently used by the best farmers, or, (c) a combination of these two strategies. Given

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[1] Camilo Alvarez P., "Análisis Económico Comparativo de dos Sistemas de Producción de Fríjol: Zona Sur del Huila - Colombia". M.S. Thesis, Universidad Católica, Santiago, Chile, 1976. In the sample year multiple cropping produced slightly higher profits; however, considering the entire distribution of returns for the two systems of production, monoculture bean production gave higher returns at higher risk levels. See p.147.

Table 38. Regression results from the analysis of bean yields for the states of Huila and Nariño, Colombia.

Factor	Regression coefficient	Unit	Average value of variable	level of confidence
Maize plant population	- 11.3	1,000/ha	17.9	0.99
Topography of lot	82.5	Dummy[2]	0.62	0.94
Thrips	- 1.9	% of lot	25	0.98
Empoasca	- 0.1	1,000/ha	383	0.99
Potassium content of soil	92.3	Dummy [2]	0.28	0.96
Fallow prior to bean crop	- 63.7	Dummy [2]	0.39	0.90
Virus	-104.6	Dummy [2]	0.76	0.99
Anthracnose	- 4.8	% of pods	4.7	0.98
Mildew	- 6.4	% of foliar area	3.4	0.99
Stem rot	- 8.7	% of lot	2.3	0.99
Angular leaf spot	- 45.9	% of foliar area	0.43	0.99
Rainfall conditions	58.1	Dummy [2]	0.32	0.84
Organic matter content in soil	63.2	Dummy [2]	0.27	0.83
Bean plant population	3.1	1,000/ha	-	0.83
(Bean plant population)^2	- 0.008	(1,000/ha)^2	-	0.74
Variable costs [1]	0.067	Col. pesos/ha	1,900	0.99
Phosphorus content of the soil	0.013	ppm	53	0.05

$R^2 = 0.64$

Y = 599 kg/ha of beans

No. of observations = 88

[1] This only includes the costs of bean production and serves as a proxy for all inputs. Family labor was priced at the going wage rate.

[2] Definitions of dummy variables were the following:

- *Topography of the lot* - 0 sloping; 1 level
- *potassium content of the soil* - 0 deficient; 1 adequate
- *Fallow prior to bean crop* - 0 in crops the previous year; 1 fallow the previous year
- *virus* - 0 no disease; 1 existence of the disease
- *rainfall conditions* - 0 considered excessive or deficient by the farmer; 1 considered adequate
- *organic material content* - 0 deficient; 1 adequate

Note that only the sign of the previous cropping pattern was a surprise. It was expected that the soil would be more fertile if it was not in crops the previous year. Our interpretation is that poor soil preparation after a fallow period resulted in lower yields.

the importance of risk from disease, insects, and price fluctuations, lower cost methods to reduce the risk of stochastic factors such as diseases and insects may have a larger impact on aggregate yields over time than high-cost methods to maximize physiological yield potential.

Results from the Huila-Nariño surveys suggest the potential strategy of breeding bean varieties for resistance or tolerance to a series of diseases, insects, and non-irrigated conditions, so that a low cost, current input package can be developed, which a risk avoiding, small farmer would adopt. Wth this strategy the public sector (i.e. CIAT and the national governments) makes investments instead of the farmer being obligated to spray and fertilize at high levels and thus be exposed to more risk and the necessity for credit to finance large cash expenditures on inputs.

Table 39. **Estimated bean production losses by factor in bean/maize cropping systems in the regions of Huila and Nariño, Colombia, 1975.**

Factor	Est. loss in totally affected lot		Est. avg. yield and total production losses		
	kg/ha	%[1]	kg/ha	%[1]	Total production loss (t)[2]
Presence of maize	202	25.2	202	25.2	4.650
Sloping topography	83	12.1	51	7.9	1.176
Thrips	187	23.8	47	7.2	1.078
Empoasca	n.a.	n.a.	46	7.1	1.054
Virus	539[3]	90.0[3]	105	17.4	761
Low potassium of soil	92	13.3	25	4.1	584
Fallow prior to bean crop	64	9.6	25	4.0	572
Anthracnose	484	44.7	23	3.6	521
Mildew	total	100.0	22	3.5	500
Stem rot	total	100.0	20	3.2	463
Angular leaf spot	total	100.0	20	3.2	454
Poor rainfall	58	8.2	18	3.0	421
Low organic matter in soil	63	9.5	17	2.7	387
Non-optimum bean plant population	14	2.3	14	2.3	327

[1] Percentage was based upon the estimated loss due to the particular factor divided by the average yield.

[2] Estimated total production loss is on the basis of a total area of 23,000 hectares with beans/maize intercropping in the two regions.

[3] It was not possible with the regression to estimate the losses of totally affected lots. This estimate of 90 percent was based upon experimental data of artificially innoculating the varieties in the same week as the virus was observed. See p.C-42 of CIAT 1975 Annual Report.

COLLABORATIVE ACTIVITIES

The Bean Program assumed responsibility from the Consultative Group for International Agricultural Research (CGIAR) to develop and coordinate a Latin American network of bean research workers in 1975. Program scientists felt that each national bean program presented a unique situation to be approached differently according to degree of development, local needs and priorities, and interest in collaborating with CIAT. It was, therefore, agreed to divide the task of maintaining contact with national programs, with each scientist accepting responsibility for collaboration with up to three specified countries (Fig. 61).

To promote better understanding of CIAT activities by scientists in national programs, bean program staff visited their assigned countries and invited research leaders and senior scientists from the national programs to CIAT. Training and documentation services, already major program activities, were increased in 1976. Thirty-eight graduate scientists undertook discipline-oriented training with the program (see the report of the Training and Conferences Program) while documentation cards were forwarded by CIAT's Documentation Center to 417 scientists in 43 countries. To date more than 1,500 articles on beans have been identified and processed.

More concretely, CIAT was able to

Figure 61. Latin American country responsibilities for CIAT bean team members, 1976

increase direct germplasm and technical assistance to those programs expressing interest. Details of the first International Bean Yield and Adaptation Nursery (IBYAN) have already been presented (see page p.A-33) Other activities including the second Rust Resistance Nursery (p.A-7) are shown in Figure 62. These included:

(a) Screening of 3,000 germplasm accessions for tolerance to golden mosaic virus at sites in Guatemala, El Salvador and Brazil. BGMV is of limited occurrence in Colombia, but is a major disease in much of Central America and Brazil.

(b) Nineteen accessions reported in the literature as being resistant to the bean pod weevil, *Apion godmani*, were reevaluated in Nicaragua, El Salvador and Honduras. The resistance of Negro 151 and Puebla 152 was confirmed and a crossing program has been initiated to incorporate the resistance into commercial varieties from Central America . A total of 180 cultivars were screened for *Epinotia aporema* resistance in Peru, the

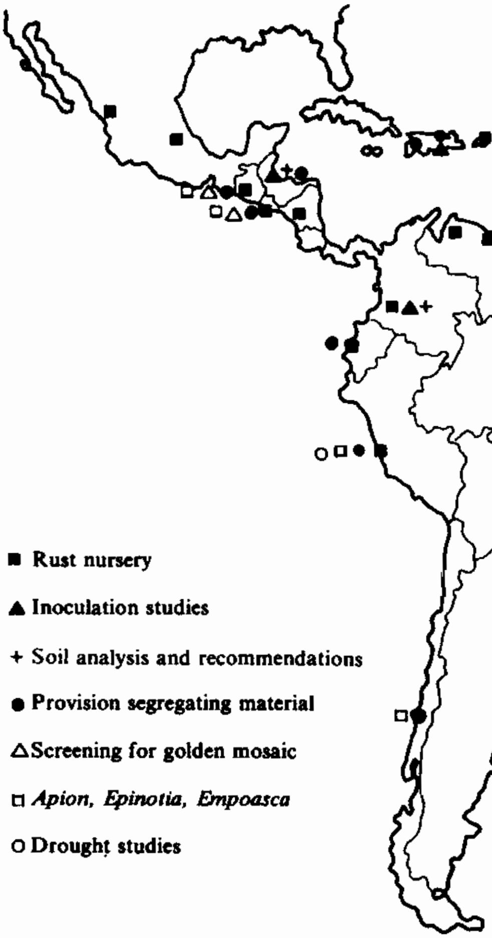


Figure 62. Locations and types of collaborative activities undertaken by the CIAT Bean Program in 1976.

accession G 04421 proving resistant both to *Epinotia* and to *Empoasca* sp.

(c) The program organized soil analysis and fertilizer recommendations for the El Paraiso region of Honduras. As all soils proved deficient in nitrogen, cooperative inoculation and fertilization experiments have been prepared for seven sites in the region. Similar experiments are under way in the Dominican Republic, Venezuela and Colombia.

(d) Given the experience, time and facilities involved in crossing for specific features of yield or disease resistance, the Bean Program has been particularly responsive to the breeding needs of national programs.

More than 20 of the 155 parents included in the crossing program have been included at the request of national programs, and segregating materials have already been forwarded to numerouscountries.In addition, CIAT has served as an off-season location for the multiplication of early generation material from Chile, Guatemala, and Honduras.

(e) Drought tolerance studies continued in Peru and in collaboration with Cornell University (U.S.A.).

APPENDIX

Cross-reference of CIAT promising accessions mentioned in this report and their Germplasm Bank register numbers, identification and source of the accession.

CIAT Promising No.	CIAT Germplasm Bank Register No.	Identification	Seed Source
P004	02115	PI 310 878	United States
P006	02005	PI 310 739	United States
P008	02056	PI 310 814	United States
P009	02959	Pecho Amarillo	Guyana
P011	03729	Argentina 2	Venezuela
P014	02146	PI 310 909	United States
P017	03719	Mexico 12-1	Venezuela
P039	00093	PI 150 948 Canario	United States
P074	00184	PI 166 066 Shimi	United States
P092	00310	PI 169 855	United States
P199	01220	PI 196 927 Criollo	United States
P209	01259	PI 201 333	United States
P225	04433	PI 207 130 Panameno	United States
P226	01308	PI 207 198 CCGB 44	United States
P235	01362	PI 209 488	United States
P252	01070	PI 281 980	United States
P259	01093	PI 282 063	United States
P261	01101	PI 282 086 Rocha	United States
P278	01679	PI 306 149 Caraota	United States
P302	01820	PI 309 804	United States
P320	01967	PI 310 686	United States
P322	01995	PI 310 724	United States
P325	01999	PI 310 732	United States
P326	02006	PI 310 740	United States
P334	02034	PI 310 784	United States
P337	02045	PI 310 797	United States
P347	02164	PI 311 780	United States
P349	02281	PI 311 930	United States
P352	02326	PI 311 991	United States
P358	02382	PI 312 064	United States
P364	02540	PI 313 653	United States
P381	02935	PI 343 734	United States
P392	04498	Sanilac	United States
P393	03736	I 1012 Alabama 1	Venezuela
P401	03065	Blanco 137	Guyana

Continuation.

CIAT Promising No.	CIAT Germplasm Bank Register No.	Identification	Seed Source
P402	03807	Brasil 2 Bico de Ouro	Venezuela
P417	03696	Colección 12D I-964	Venezuela
P420	03607	CCGB44 I-462 CRI2	Venezuela
P432	03153	Fríjol de Parra 350	Guyana
P437	03128	Negro 321	Guyana
P443	03223	Negro Cahabon 453	Guyana
P449	03451	Guanajuato 116	Mexico
P458	04454	ICA TUI	Colombia
P459	03645	Jamapa I-810	Venezuela
P464	04354	Mexico 114	Mexico
P466	03852	Miranda 5	Venezuela
P481	04206	N 257 Sal Rico de M Gera	Costa Rica
P527	03874	Trujillo 7	Venezuela
P540	03784	Venezuela 29 I-1071	Venezuela
P559	03733	50600 I-1009	Venezuela
P560	03834	51051 I-1138	Venezuela
P566	04495	Porrillo Sintetico	Honduras
P567	05478	Tara	United States
P568	05479	PR S 70 15 RST B K	Costa Rica
P569	05481	Cacahuate 72	Mexico
P579	02703	PI 313 868	United States
P588	04455	ICA Huasano	Colombia
P589	02525	PI 313 624	United States
P590	05702	Cargamanto	Colombia
P591	00197	PI 167 201 Aysekadin	United States
P597	01222	PI 196 932 P Acutifolius	United States
P598	01239	PI 199 041 I Iangaza	United States
P634	05683	ICA Duva	Colombia
P635	04452	ICA Guali	Colombia
P637	04523	Linea 17	Colombia
P643	04459	NEP 2	Costa Rica
P646	00881	PI 203 958 N 203	United States
P662	02472	PI 313 343	United States
P667	04191	Coleccion 166 N	Costa Rica
P668	04190	Coleccion 168 N	Costa Rica
P675	04525	Linea 32 ICA Pijao	Colombia
P684	01320	PI 207 262	United States
P685	05694	Cornell 49 242	United States
P692	04494	Diacol Calima	Colombia
P693	05653	Ecuador 299	El Salvador
P694	05477	Great Northern #1 SEL 27	United States
P698	05476	Jules	United States
P699	05652	Mexico 309	El Salvador
P700	05706	Jalpatagua 72	Guyana

Continuation.

CIAT Promising No.	CIAT Germplasm Bank Register No.	Identification	Seed Source
P704	04795	Porrillo 1	El Salvador
P709	04485	Turrialba 1	Guyana
P712	04792	51052	Nicaragua
P714	04505	Top Crop	United States
P716	03738	BaurreD Paulinat	Venezuela
P717	05711	Comp Chimaltenango 2	Guatemala
P737	04456	Jamapa	Costa Rica
P756	04445	Ex Rico 23	Colombia
P757	04461	Porrillo 1	Costa Rica
P758	04446	Puebla 152	Mexico
P760	06334	Vidresco	Holland
P770	02689	PI 313 853	United States

List of CIAT Germplasm Bank reference numbers listed in this report, their identification and the seed source.

CIAT Germplasm Bank Register No.	Identification	Seed source
G00805	PI 197 034	United States
G01212	PI 196 299	United States
G01213	PI 196 462	United States
G01224	PI 196 936	United States
G01540	PI 284 703	United States
G02704	PI 313 869	United States
G04165	Preto 2449 (N-487)	Costa Rica
G04834	Puebla 56-C (Negro)	Mexico
G04835	Puebla 56-C (Blanco)	Mexico
G04835	Puebla 56-C (Blanco)	Mexico
G05086	1886-48 (Brazil 555)	Brazil

PUBLICATIONS

ANDERSEN, P. P., LONDOÑO N. de and M. INFANTE. A suggested procedure for estimating yield and production losses in crops. **PANS 22,** 359-365. 1976.

ELLIS, M. A., GALVEZ, G. E., and SINCLAIR, J. B. Control of dry bean seed infection with *Collectotrichum lindemuthianum.* **Amer. Phytopath. Soc. Fungicide Nematicide Tests 32. 1976.**

GALVEZ, G. E., and CASTAÑO M. Purification of the whitefly-transmitted Bean Golden Mosaic Virus. **Turrialba 26,** 205-207. 1976.

GRAHAM, P. H. Identification and classification of root nodule bacteria **In** "Symbiotic nitrogen fixation in plants." P. S. Nutman Ed.,Cambridge University Press 99-112. 1976.

GRAHAM, P. H. Recent developments in the bean improvement program at CIAT. **BIC Annual Report 19,** 39-41. 1976.

GRAHAM, P. H. and HALLIDAY, J. Inoculation and nitrogen fixation in the genus *Phaseolus.* **In** "Exploiting the Legume- *Rhizobium* Symbiosis in tropical agriculture " J. M. Vincent Ed., University of Hawaii, Maui, 1976.

HERNANDEZ-BRAVO G., and GALVEZ, G. E. Inheritance of disease resistance of dry beans, *Phaseolus vulgaris* in the tropics. I. Rust, Common Bean Mosaic Virus and Bacterial Blight. **BIC Annual Report 19,** 47-48. 1976.

WILDE, G. and SCHOONHOVEN, A. V. Mechanisms of resistance to *Empoasca kraemeri* in *Phaseolus vulgaris.* **Environ. Entom.** 5: 151-5. 1976.

WILDE, G., SCHOONHOVEN, A. v., and GOMEZ-LAVERDE, L. The biology of *Empoasca kraemeri* on *Phaseolus vulgaris.* **Ann. Entom. Soc. Amerc.** 69: 442-4. 1976.

Cassava production systems program

HIGHLIGHTS IN 1976

The development of many aspects of cassava production technology has now reached the stage when it can be used by farmers with only minor changes to adapt it to regional conditions. Although major emphasis is placed on development of new technology more emphasis than before has been placed in training and cooperative projects with agencies from other countries.

The ideal plant phenotype for cassava production appears to be similar for different temperature zones, however, when average temperature is below about 22°C special genotypes are needed.

The spider mites that attack cassava can cause severe yield reductions in areas with long dry seasons. Low to intermediate levels of resistance, depending on the mite species, have been found. Efficient biological control methods for the hornworm are being tested on farmers fields and this system seems to be highly effective.

The "Frog Skin" disease of cassava was shown to reduce yields considerably, however, it can easily be controlled by selection of healthy planting material. Superelongation disease causes extreme yield losses when attacks occur early in the growth cycle. However, planting material can be disinfected by stake fungicide treatments, delaying the onset of the attack. This treatment coupled with tolerant varieties should greatly reduce yield losses.

In order to combine high yielding ability with desirable characters such as disease and pest resistance, ease of harvest, high starch content and long post-harvest shelf life, tens of thousands of hybrids have been made and evaluated. The variety M Col 1684 has exceptional stability with high yields of over 50 t/ha in CIAT, 44 t/ha in Caribia and 36 t/ha in Carimagua. These zones have pH's ranging from 4.5-7.8, mean temperatures from 24-28°C and vary from extremely low fertility to very fertile. It is therefore feasible to obtain broadly adapted high-yielding types.

The yield of over 36 t/ha with low levels of fertilizer input in Carimagua confirms cassava's ability to grow on poor acid soils which are generally underutilized. Good yields (more than 20 t/ha) were obtained on these soils with moderate levels of fertilizer input in several trials.

In other areas selected lines have consistently outyielded local lines by 75 percent with extremely low input levels. The local lines yielded 16 t/ha—about double the national average—due to improved selection of planting material and good cultural practices, suggesting that average yields can be increased to this level by optimizing plant population and level of inputs such as weed control.

The agro-economic study shows that cassava is frequently produced in associated cropping systems which can reduce average yields by about 30 percent. The basic response of cassava in competition with beans is being studied to design more efficient associations.

The development of new production technologies makes it essential that post-harvest handling for the increased production also be improved. Natural drying methods are being developed which appear to improve efficiency over traditional methods by using a modified Malaysian chipper followed by drying on inclined trays.

The movement of new technology to other countries is based on cooperation with national agencies through (1) training, (2) technical advice, (3) germplasm exchange and (4) conferences. The cassava Program was active in each aspect during the year.

A short intensive cassava production course was held at CIAT for 32 agronomists from nine Latin American countries. More than 60 percent of the course was devoted to practical aspects of production including on-site evaluations of production methods used by farmers in different zones of Colombia.

Furthermore, long-term training in research is given to students from Latin America, Africa and Asia. Groups are invited from each country and trained so that they can return to form an effective research team. Eight Mexicans and three Thais are now forming multidisciplinary research teams in their respective countries. Similar training plans are in progress with Brazil and Malaya. Seven of eight professionals at the recently formed Cassava Center in Brazil have received some training at CIAT.

Both the Mexican and Brazilian cassava research and development programs requested technical advice on research and production strategies and CIAT staff has responded to these requests. Similarly, the Indian and Malaysian programs are in close contact with CIAT and their program directors visited CIAT for short periods in 1976.

Most national programs have not been in progress long enough to develop their own genetically superior material and breeding programs. As a result CIAT sent seeds and planting material to 28 countries this year. Regional trials using CIAT and local varieties are being established in Guyana, Mexico, Brazil, Venezuela and Ecuador. The only trial already harvested showed a CIAT line to be the highest yielder of both fresh roots and starch.

Germplasm movement details and the methodology of the international yield trials were determined in a special workshop held in 1975. Cassava researchers from all over the world had the chance to meet and discuss common problems at IV Symposium of the International Tropical Root and Tuber Crops Society held at CIAT in August 1976.

PHYSIOLOGY

Introduction

The factors controlling leaf area development and maintenance so as to define and ideal plant type as well as the existence of an optimum leaf area index (LAI) of about 3 were presented in CIAT's 1975 Annual Report. This year these results have been confirmed and used to construct a plant ideotype. In addition, relations between source and sink have been further studied.

In previous years results have been presented mainly for CIAT conditions; this year responses of different clones have been observed under different temperature regimes to better understand the mechanism of temperature adaptation. The effects of different photoperiods have also been investigated. Work has also been initiated on varietal differences in photosynthetic rate to see if new yield levels can eventually be reached.

Since the understanding of the crop in monoculture is well-developed, emphasis is now being placed on designing efficient mixed cropping systems, which comprise a major part of the world's cassava production.

Leaf Area Development

In 1975 it was shown that in three varieties leaf size reached a maximum about four months after planting and then declined. This was confirmed for ten varieties all of which showed the same trend, irrespective of branching habit. It was also suggested last year that leaf formation rate per apex showed little genetic variability. However, this year one variety, M Col 1120, showed a consistently greater leaf formation rate than nine other varieties. Leaf formation patterns of four of these varieties are shown in Figure 1.

Leaf life was also measured on ten varieties and large varietal differences were observed; leaf lives of three are shown in Figure 2. It is interesting to note that these varietal characteristics were maintained throughout a prolonged dry spell and that maximum leaf life recorded was 18 weeks in M Col 72. The longest and shortest leaf lives were in M Col 72 and M Col 1120, respectively; neither variety produces branches suggesting that leaf life is independent of branching habit.

Leaf life is a varietal characteristic; the differences being maintained even under

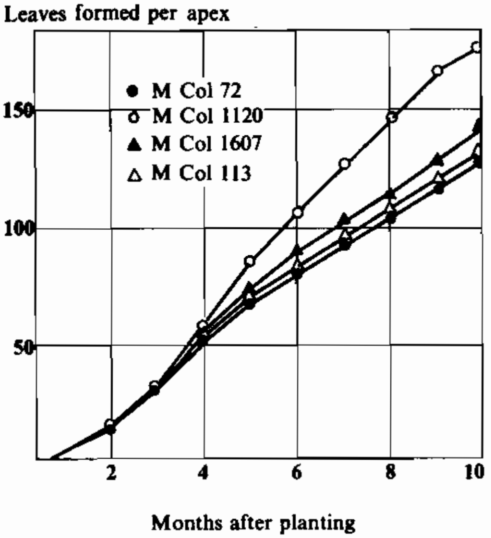


Figure 1. **Leaf formation per apex of four cassava varieties.**

dry conditions. Leaf formation rate per apex shows little genetic variability but one variety with a substantially higher rate than that previously found was identified. Rate of leaf formation declines as plants grow older in all varieties.

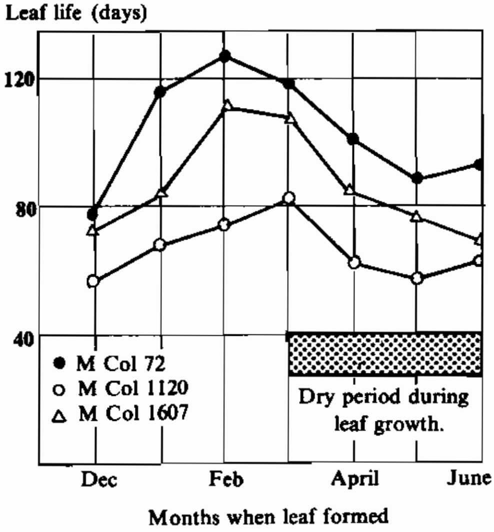


Figure 2. **Leaf life of three selected cassava varieties.**

Relation between LAI and Yield

LAI of M Col 113 increased rapidly after planting reaching a value of more than 5 after six months, after which it declined until the final harvest at 15 months. In CMC 84 and M Mex 11, LAI reached a maximum after four months of 4 and 2.9 repectively, and then declined (Fig. 3). M Col 113 reached its maximum rate of root bulking (7.6 g dry matter/m²/day) during the period of 9-12 months when its leaf area index showed little change and was equal to about 3 (Figs. 3 and 4). During this same period both CMC 84 and M Mex 11 were increasing their leaf area index and although total dry matter weight increased (Fig. 5) root weight showed a very small increase. This trend is particularly noticeable in M Mex 11 where total dry weight increased by 515 g/m² while root weight only increased by 125 g/m², but LAI increased from 0.9 to 2.7. When a high LAI is maintained, as in M Col 113, from 4-9 months root weight increase is small as all available carbohydrate is directed to formation of leaf and stem. Also, when LAI increases rapidly as in M Mex 11 from 9-12 months, there is little root weight increase. These data demonstrate the balance between root production and stem production.

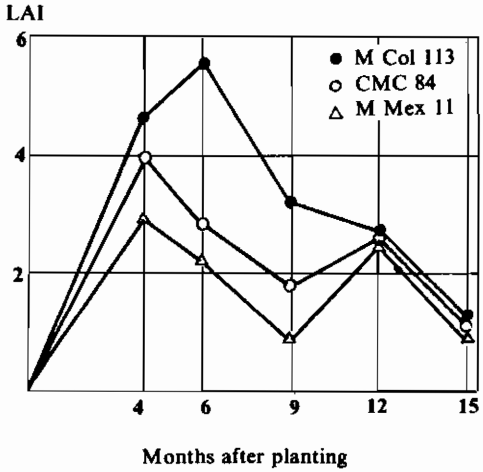


Figure 3. **Development of LAI of three cassava varieties.**

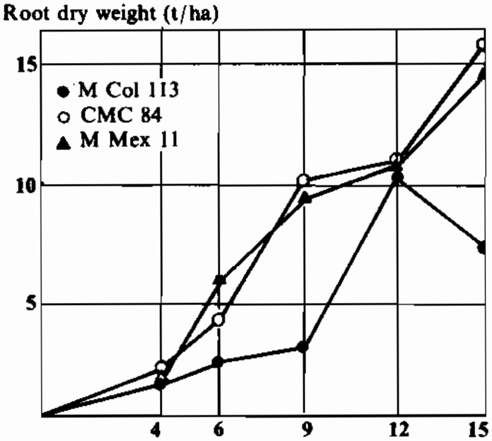


Figure 4. **Changes in dry root yield of three cassava varieties.**

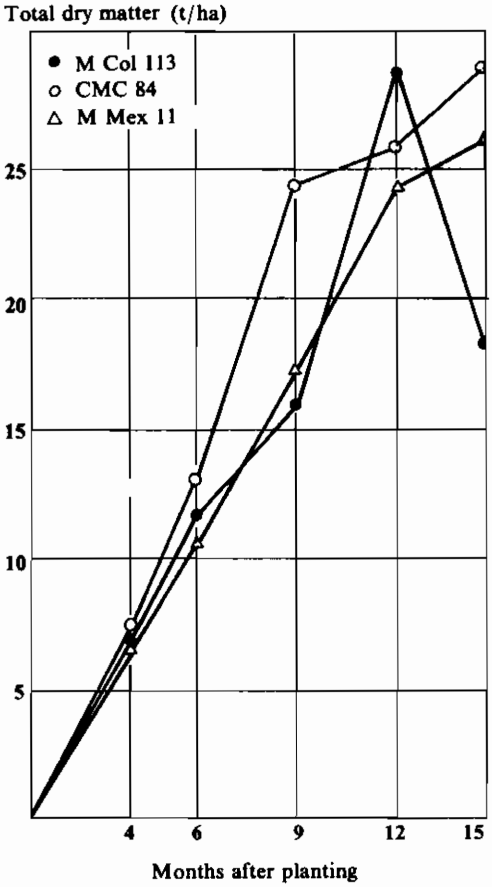


Figure 5. **Changes in total harvestable dry matter of three cassava varieties.**

In results in 1975, the optimum LAI for root growth of M Col 113 was determined as 3-3.5. Data collected this year using three varieties show the same tendency for an optimum LAI of about 3 during the period 4-9 months after planting (Fig. 6). The data for 9-15 months showed the same trend with rather large experimental error due to the unexplained decrease in root weight on M Col 113 from 12-15 months. This confirms that the optimum LAI for cassava is about 3 and that when this is maintained yields will be maximized. When LAI is increasing rapidly, root growth is reduced even though LAI may be optimal.

M Col 113 tends to have excessive LAI during much of its growth cycle leaving little carbohydrate available for the roots, and reducing leaf life by shading. When plants were five months old branch apices were cut so as to reduce the leaf production. The treatments were such that total number of active apices were reduced by 0, 25, 50 and 75 percent. This treatment significantly increased yield from 33 t/ha 10 months after planting to 41 t/ha when active apex number was reduced by 75 percent.

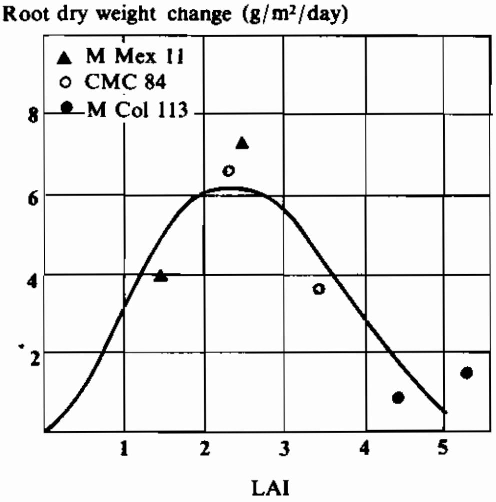


Figure 6. **Changes in root dry weight as related to mean LAI 4-6 and 6-9 months after planting.**

The final LAI was not reduced by this treatment as leaf life was increased. Total dry matter production was not significantly reduced by the treatments but harvest index was markedly increased to give the higher yield (Table 1). Hence control of branching habit appears to be a useful means of controlling LAI,and by breeding for the ideal branching pattern yields can be increased.

Temperature Effects on Cassava Growth

Four varieties of low, medium, high and very high vigor (M Col 22, M Col 113, M Mex 59 and Popayan, respectively) were planted in three sites; one a short distance from CIAT (called Km 27), CIAT and Caribia with mean temperatures of 20°, 24°, and 28°C, respectively. All plots received 300 kg/ha NPK so as to give a high fertility level in all sites. Phoma leaf spot is normally a problem in cooler areas and fungicidal applications were used in Km 27 to control this disease.

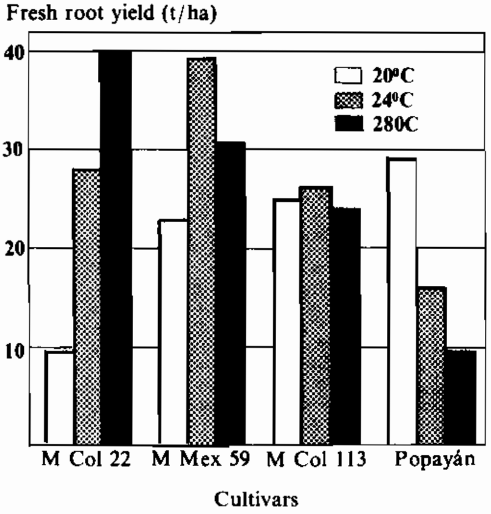


Figure 7. **Yield of four cassava cultivars 12 months after planting at three sites having different mean temperatures.**

At Caribia, a high temperature evironment, M Col 22, gave the highest yield followed by M Mex 59 and M Col 113 with Popayan yielding by far the lowest (Fig. 7). However, at Km 27, a low temperature environment, Popayan gave the highest yield and M Col 22, the lowest. The results at CIAT fell somewhere between the two extreme locations but showed more similarity to Caribia than to Km 27. The data indicate that a clear interaction exists between genotype and temperature.

At 20°C plants grew less rapidly than at higher temperatures; the rate of leaf appearance per apex increased as temperature increased (Fig. 8). The actual rate of leaf appearance showed little varietal variation at 28° and 24°C but quite large differences occurred at 20°C.

Leaf size tended to increase to a maximum and then decline for all varieties at all sites tested. Little difference was observed between 24° and 28°C but at 20°C

Table 1. **Effects of reducing apex numbers on growth of M Col 113 cassava.**

Apex number reduction (%)	Fresh root yield (t/ha)	Dry root yield (t/ha)	Dry stem weight (t/ha)	Harvest index (%)	Final LAI
0	33.6	11.3	12.5	44	4.86
25	38.5	13.3	12.7	47	4.44
50	39.7	13.6	12.0	49	4.28
75	40.3	14.0	11.8	49	4.92
Significant differences	**	**	N.S.	**	N.S

** Means a significant difference at the .01 significance level.

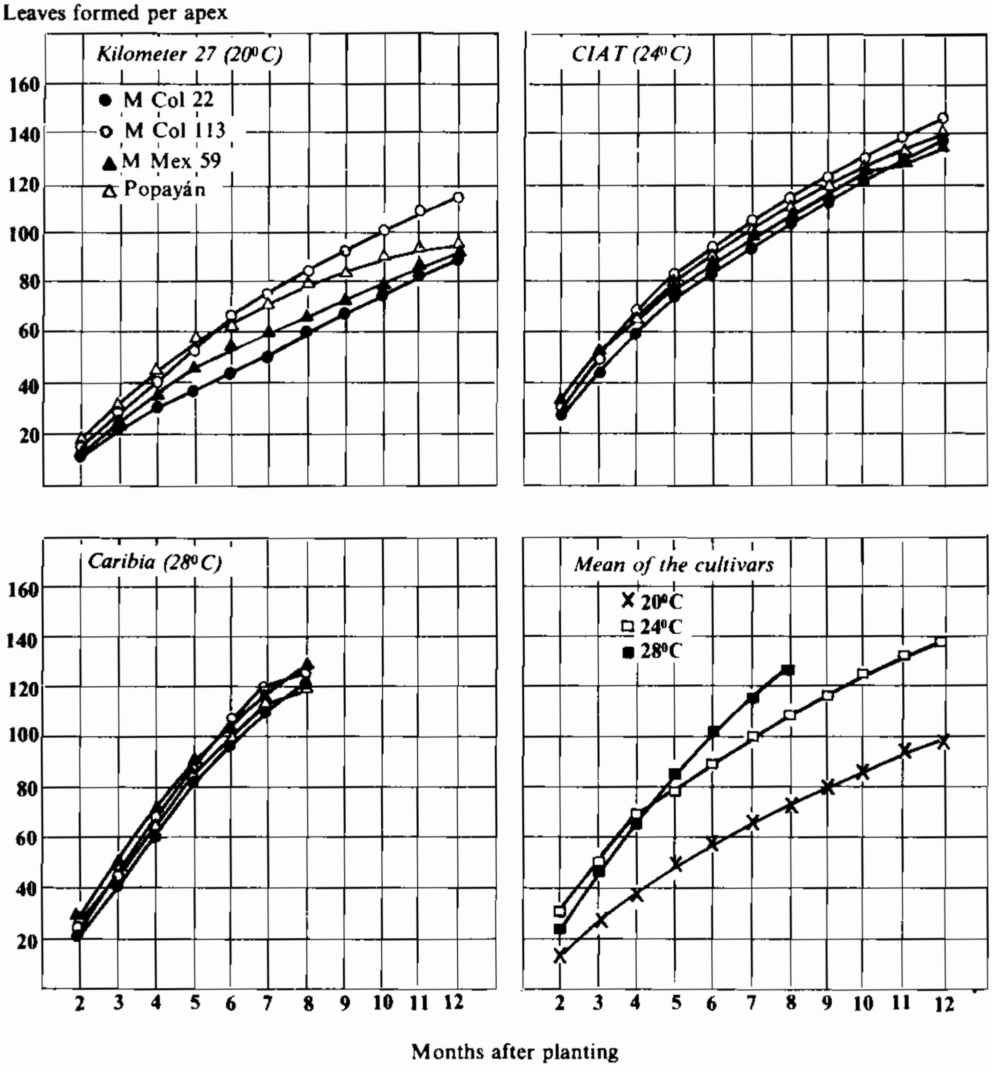


Figure 8. **Total leaves produced per apex by four cassava varieties at three temperature zones.**

maximum leaf size was reached later and was smaller (Fig. 9).

Although leaf size and leaf formation rate were smaller at lower temperatures, leaf life was markedly increased in all varieties (Fig. 10). At 20°C leaf lives of up to 200 days were recorded whereas at 24°C and 28°C maxima of 115 and 90 days respectively were observed.

The number of functional branches per plant did not show a consistent trend with temperature. M Col 22 and M Col 113 produced the same number of branches at 28° and 24°C and fewer at 20°C whereas Popayan and M Mex 59 peaked at 24°C, suggesting that maximum branch production occurs at about 24°C (Fig. 11).

In summary, leaf formation rate per apex and maximum leaf size increase as temperature increases while at lower temperatures maximum leaf size is reached

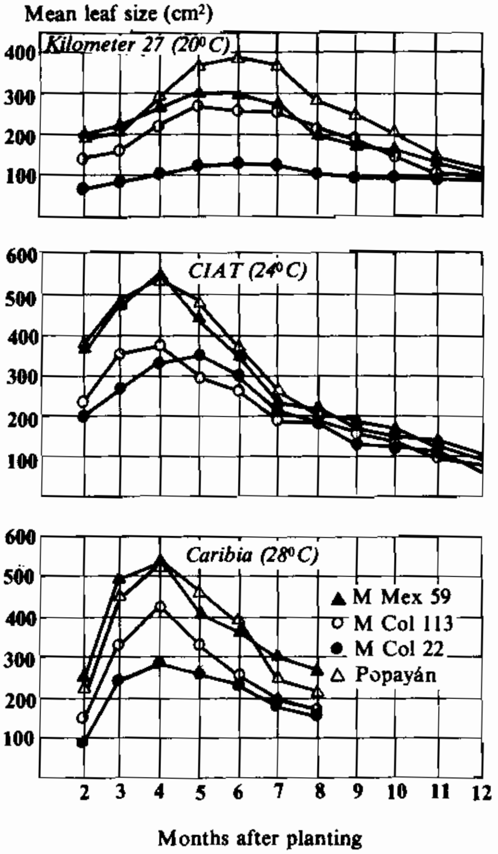


Figure 9. **Leaf size of four cassava varieties at different times after planting in three different temperature zones.**

later with leaf life increasing as temperature decreases and most branching occurring at about 24°C. The combined effect of these factors on LAI is shown in (Fig. 12). As temperature increases LAI increases, except in the case of M Mex 59 where less branching and short leaf life at higher temperatures reduced LAI.

Analyzing the LAI at the most crucial period of yield formation (8-12 months), M Col 22 had an LAI nearest to the previously determined optimum LAI of 3 at Caribia, while all the others had LAI's far exceeding 3 (Fig. 12). At Km 27, Popayan maintained an LAI of nearly 3 during the 8-12 month period while the others failed to reach the LAI of 3. The

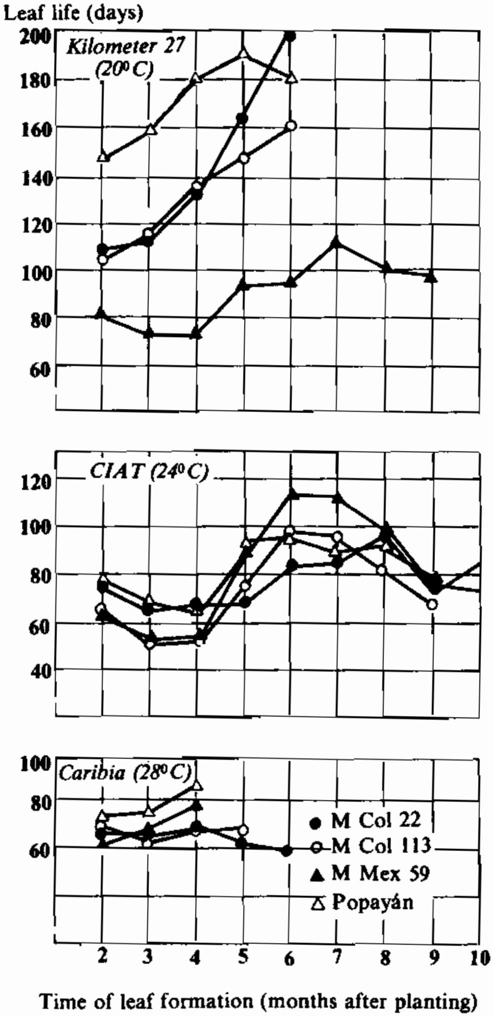


Figure 10. **Leaf life of four varieties as a function of time after planting in three different temperature zones.**

relation between root growth rate and mean LAI (Fig. 13) suggests that the optimum LAI of 3-3.5 is valid over a wide range of temperatures and that the varietal interaction with different temperatures is demonstrated primarily through effects on leaf area formation under different temperatures.

Source-Sink Relations

Previous results on the effects of the root sink capacity on both yield and total dry

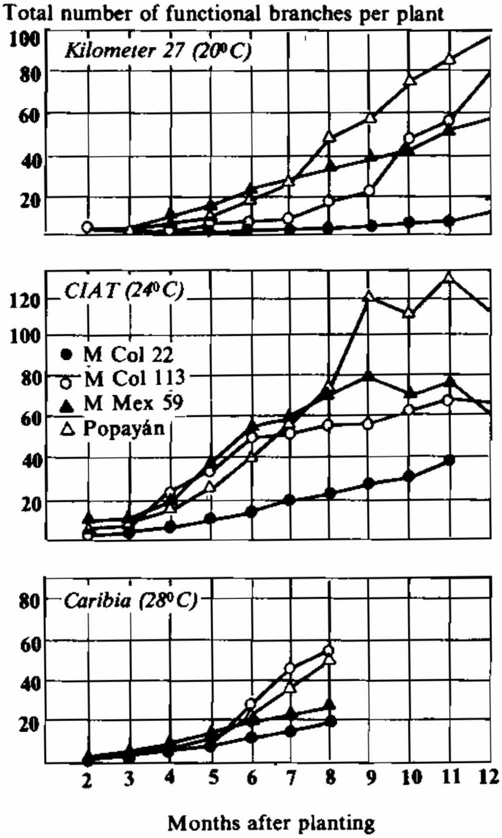


Figure 11. **Total number of functional branches per plant of four cassava varieties at three different temperature zones.**

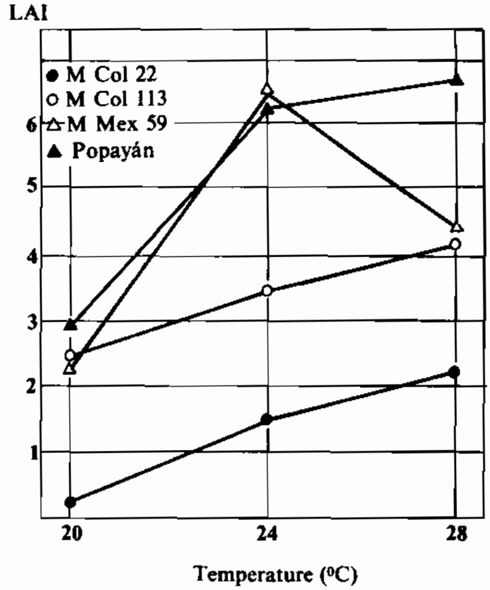


Figure 12. **LAI of four cassava varieties eight months after planting at different temperatures.**

matter production were somewhat equivocal (CIAT Annual Report, 1974). This year two varieties, M Col 22 and CMC 84, were girdled at five months after planting and harvested three and a half months later. No variety by treatment interactions were observed and data are presented as the mean for the two varieties. Root weight showed no significant increase in the treated plants, as would be expected, but increased in the controls (Table 2). LAI and area per leaf were not affected by the girdling treatment. Stem weight was, however, markedly affected by the treatment increasing from 0.4 kg/plant in the controls to 0.7 kg/plant in the treated plants (Table 2). The total dry weight of the plants was not affected suggesting that reducing the root sink does not affect the efficiency of the source nor its size. Elimination of the root sink does, however, cause more carbohydrate to be stored in the stem.

M Col 22 was grown in the field and three months after planting six roots per plant were cut. Harvests were taken at 3, 6, and 12 months after planting. The total

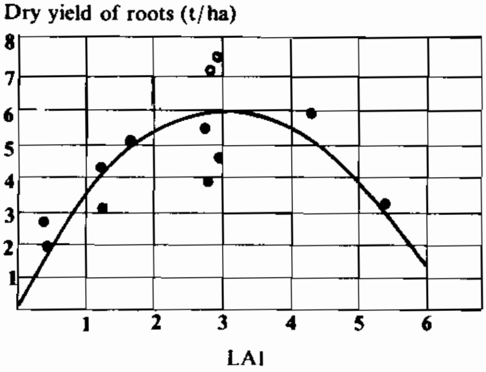


Figure 13. **Changes in root growth rate as related to mean LAI in cassava varieties grown at different sites.**

Table 2. **Effects of girdling at the base of the stem on growth of cassava (mean of two varieties).**

	Root yield increase (g dry matter/m²)	Stem weight increase (g dry matter/m²)	Total dry weight increase excluding leaves (g dry matter/m²)
Control	456	162	618
Treated	60	580	640

number of thick roots per plant was reduced from 12.5 to 9.1 (mean of the last two harvests). However, dry root yield, total dry weight, stem dry weight, and leaf area index were not significantly affected by the treatment at any of the harvests (Fig. 14).

These data suggest that root sink limitations do not alter source size or efficiency and that when root number is reduced to nine roots per plant their capacity to expand is greater than the carbohydrates available but when the root sink is isolated from the source the stem accepts the extra carbohydrate.

A Cassava Ideotype

This and last year's data suggest that the ideal cassava plant for maximum yield would rapidly reach LAI of about 3 and then maintain that level. A computer model was developed to define how this could best be achieved under CIAT conditions. Equations were used to described the relationship of crop growth rate to LAI, the relative leaf size compared to the maximum leaf size over time, rate of leaf formation per apex over time, the reduction of leaf life by shading, and the dry leaf weight per unit area. The same equations were used in all cases as these factors seem to be the same for all varieties with the possible exception of leaf formation rate per apex (Fig. 1). First, branching habit was studied using leaf life (10 weeks), weight per node (1 g), and maximum leaf size (300 or 500 cm²) at plant populations of 10,000 and 20,000 plants/ha.

The highest simulated yields were obtained with branching at 30 weeks at 20,000 plants/ha with a maximum leaf size of 500 cm². When this plant type is compared with other types it becomes obvious that branching time is extremely important (Fig. 15) since early branching types yield very poorly. Increasing leaf life above 15 weeks and reducing node weight from 1 to 0.5 grams give a small yield increase (Fig. 15) and may be difficult for the breeder to accomplish in practice as maximum leaf lives of 20 weeks (140 days) are rarely found in the field but 15 weeks (105 days) are not uncommon. Similarly, a mean node weight of 0.5 grams is generally associated with small leaves and may be difficult to achieve. There is also little advantage in leaves greater than 500 cm² maximum leaf size (Fig. 15).

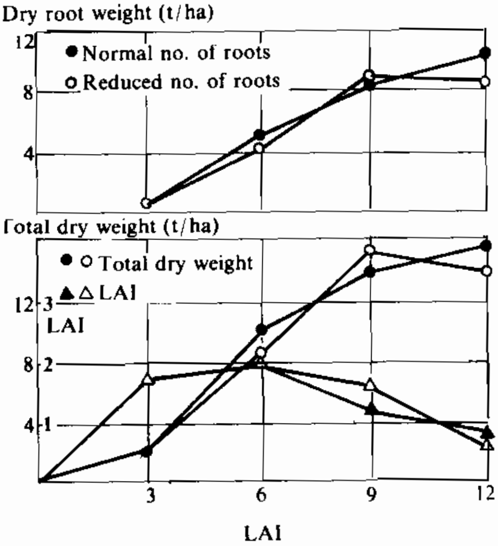


Figure 14. **Change in root yield, LAI and total dry matter of M Col 22 with normal and reduced numbers of thickened roots.**

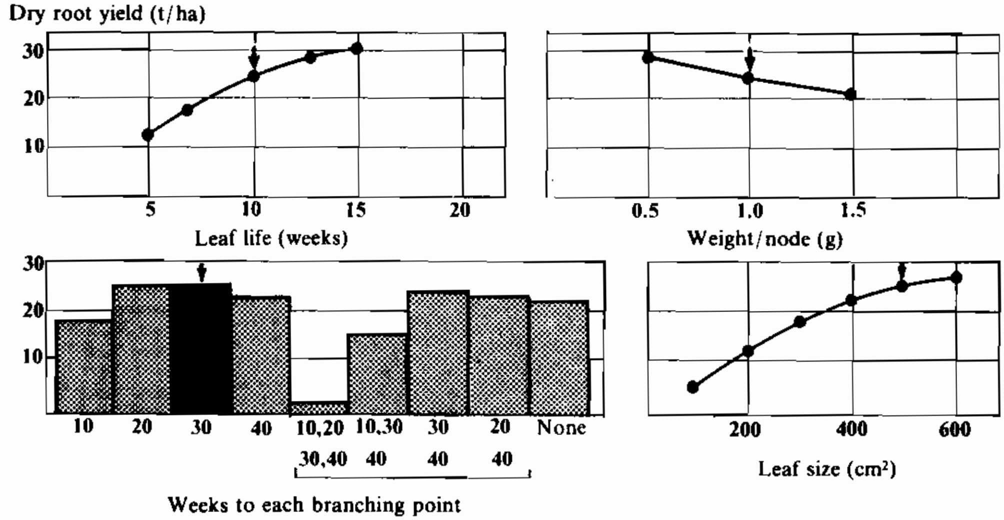


Figure 15. **Simulated effects on yield of varying one character in a cassava plant with the following standards: branching at 30 weeks, leaf life of 10 weeks, population of 2 plants/m², maximum leaf size of 500 cm², and node weight of 1.0 gram. Arrows indicate standard type.**

These simulated data suggest that high yields can be obtained by searching for types that branch about six months after planting, have large leaves and a long leaf life.

Photoperiod Effects

Two varieties, M Col 22 and Llanera, were planted in rows leading away from incandescent lights in the field. The lights were used to increase day length to 18 hours during the period from planting to three months, 3-6 months and 6-9 months after planting. No effect on yield per plant was noted when long days were given to plants older than three months. However, long days for the first three months after planting reduced yield in Llanera but had no effect on M Col 22 (Fig. 16), suggesting that long days during the early growth period may reduce yield and that varieties vary in their sensitivity to photoperiod.

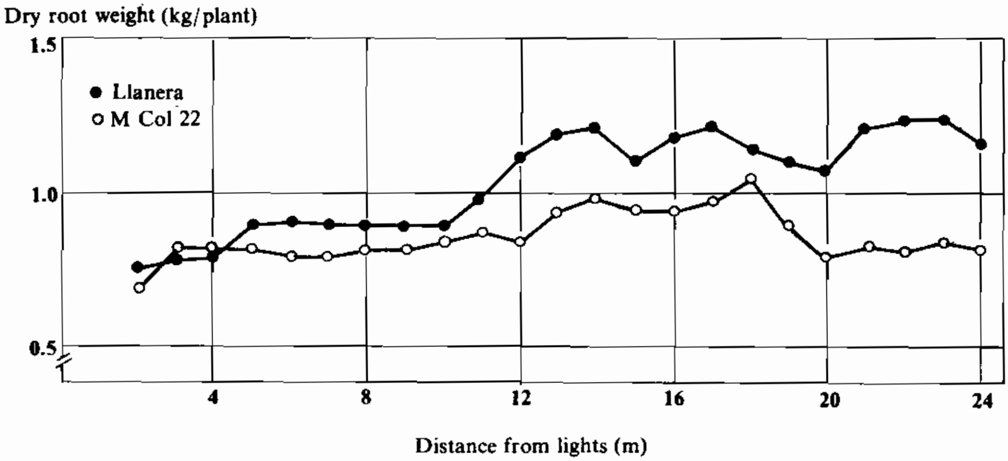


Figure 16. **Effect of 18-hour days during the first three months after planting on the yields of two cassava varieties.**

Photosynthetic Studies

In the section on source-sink relations it has been suggested that in certain cases sink does not limit yield or total growth of the plant. Furthermore, increasing source capacity by increasing its size is counterproductive as extra production of an increased source is more than offset above LAI of 3 by the carbohydrates required for producing and maintaining it. Hence, the only means of increasing source capacity appears to be by increasing efficiency of the individual leaves.

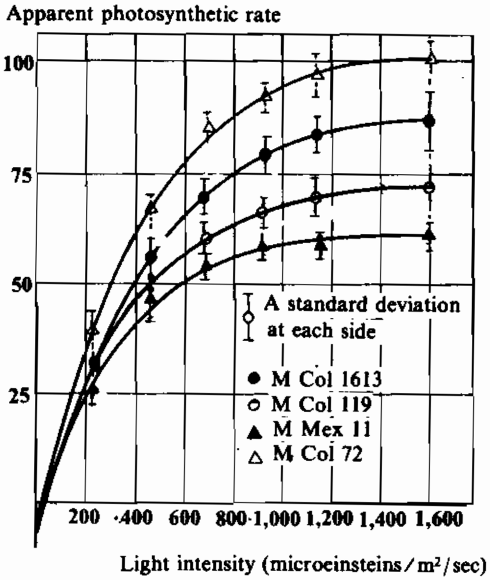


Figure 17. Photosynthetic rates of four different cassava clones.

The photosynthetic rates of different clones were compared, using the first fully expanded leaf, to see if varietal differences occur. Cultivar M Col 72 had the highest photosynthetic rate at all light intensities, being 63 percent greater than M Mex 11 at 1,600 microeinsteins/m²/sec and 57 percent greater at 700 microeinsteins/m²/sec (Fig. 17). Relative values are shown as calibration problems occurred. However, rates of over 40 mg $CO_2/dm^2/hr$ have recently been obtained with M Col 72 using air of about 350 ppm. These differences are large and suggest that there may be possibilities of breeding for increased photosynthetic efficiency.

ENTOMOLOGY

Introduction

The main objective of the cassava entomology program is to develop effective methods of controlling cassava pests below economic injury levels. Special emphasis is given to non-pesticide control methods. However, until these methods are effectively developed, insecticides may be needed to control severe outbreaks of some of the more serious pests such as mites, the cassava hornworm of the cassava fruit fly.

Yield losses were determined for mites and shoot flies and the biology of *Tetranychus urticae* and *Mononychellus tanajoa* was also studied. An extensive program to identify resistance to these mite species was continued throughout the year. Resistance studies were also conducted for whiteflies. The use of insect diseases as control methods was studied for the cassava hornworm and whitegrubs. A biological control program for the cassava hornworm was evaluated on several farms and insecticide control studies were carried out for mites and fruit flies.

Mites

Crop losses

Several species of mites have been reported as attacking cassava throughout many of the cassava growing regions of the world. Recent reports from Africa and

Venezuela indicate that the green mite *(M. tanajoa)* causes crop losses ranging from 30-40 percent. It has long been considered that mites may cause serious crop losses in cassava but until recently there was only minimal experimental data to support this claim.

Four species of mites, *M. tanajoa, M. mcgregori, T. urticae* and *Oligonychus peruvianus,* from Colombia were described in the CIAT Annual Report of 1975. The high mite populations coincide with prolonged dry periods in cassava growing regions. (Dry seasons in many areas of Colombia range from 2-3 months; this normally does not allow mite populations to build up and remain at high enough levels to cause serious crop losses.) To determine the yield loss potential due to mites, cassava plants were artificially infested with *T. urticae* from a screenhouse colony at the onset of the short dry season at CIAT. A natural infestation of *Mononychellus* spp. and *O. peruvianus* occurred in the experimental plots. However, artificial mite infestation allowed for more rapid buildup of mite populations.

Yield losses due to mite attack ranged from 20-53 percent depending upon the age of the plants when the attack occurred, and the duration of the attack (Table 3).

The biology of *T. urticae* and *M. tanajoa* were studied under controlled conditions in an environmental growth chamber (Tables 4 and 5). The female *T. urticae* mite passes from egg to adult in approximately nine days and the female *M. tanajoa,* in eight days. The males complete this phase in slightly less time. Oviposition by *T. urticae* begins during the second day as an adult and each female is capable of ovipositing an average of 40 eggs. Of this total, nearly 29 eggs, or 72 percent of the total during the 20-day adult life, are deposited during the seven-day period between the third and ninth day of oviposition (Fig. 18). Egg viability and the sex ratio were also studied for *M. tanajoa* under growth chamber conditions. Sex ratio studies with 1,186 adults resulted in 62 percent females and 38 percent males. Egg viability for 289 eggs was 92 percent. This data, and the fact that these mites are parthenogenetic, indicates that buildup of mite populations may be very rapid during favorable environmental conditions.

Two predators of mites were identified during the past year. The predatory mite *Typhlodramales peregrinus* Muma (Phytoseiidae) and Coleoptera, *Stethorus* sp. (Coccinellidae) were collected at CIAT.

Resistance studies

Screening of cassava varieties for resistance to *Tetranychus* and *Mononychellus* mites continued under controlled conditions in the screenhouse and greenhouse (CIAT Annual Report, 1975). A major objective of this initial phase of screening is to select about 10-15

Table 3. **Effects of mites *(Mononychellus* spp., *Oligonychus peruvianus* and *Tetranychus urticae)* on cassava yields (var. M Col 22) with artifical infestations of *T. urticae* and biweekly applications of monocrotophos for mite control in treated plots.**

Planting number	No. of artificial infestations	Age of plant when infested (mo.)	Duration of infestation (mo.)	Mites per leaf		Production (t/ha)		% yield loss
				treated	untreated	treated	untreated	
I	1	6	3	110	425	21.8	17.3	21
II	2	4 and 10	4	77	349	16.4	12.3	25
III	2	2 and 8	6	60	263	27.9	13.1	53

Table 4. **Life cycle of *Tetranychus urticae* on excised cassava (var. M Col 420) leaves under growth chamber conditions.**[1]

Developmental stage	No. observed	Range in days	$\overline{X}$ (days)
Female [2]			
Egg	44	3.0- 4.0	3.09
Larvae	27	2.0- 5.0	2.85
Protonymph	23	1.0- 2.0	1.65
Deutonymph	22	1.0- 3.0	2.04
Egg to adult	22	7.0-11.0	9.27
Longevity of adult	20	8.0-22.0	15.05
Egg to death of adult	20	17.0-32.0	24.35
Male			
Egg	6	3.0- 4.0	3.18
Larvae	6	2.0- 4.0	2.66
Protonymph	6	1.0- 2.0	1.33
Deutonymph	6	1.0- 3.0	1.66
Egg to adult	6	7.0-10.0	8.83

[1] Temperature: 28°C day (12h); 25°C night (12h); R.H. 60-70%

[2] Average number of eggs oviposited per female = 40.0

Table 5. **Life cycle of *Monychellus tanajoa* on excised cassava (var. M Col 17) leaves under growth chamber conditions.**[1]

Developmental stage	No. observed	Range in days	$\overline{X}$ (days)
Female[2]			
Egg	35	4.0-5.0	4.14
Larvae[3]	35	1.0- 2.0	1.22
Protonymph	35	1.0- 2.0	1.17
Deutonymph	35	1.0- 2.0	1.60
Egg to Adult	35	7.0-10.0	8.14
Male[2]			
Egg	21	3.0-5.0	4.19
Larvae[3]	21	1.0-2.0	1.14
Protonymph	21	1.0	1.0
Deutonymph	21	1.0-2.0	1.33
Egg to Adult	21	6.0-9.0	7.66

[1] Temperature: 30°C day (12h); 27°C night (12h); R.H. 60-70%.

[2] Sex ratio - female (62%), male (38%).

[3] Percentage egg viability: 92%.

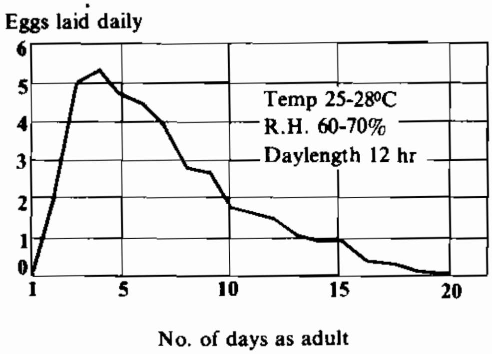


Figure 18. **Daily oviposition by 20 female *Tetranychus urticae* mites on excised cassava leaves (var. M Col 420) in growth chambers.**

percent of the germplasm for further testing. Of 1,973 varieties screened for resistance to the *Tetranychus* mite only low levels of resistance have been found (Table 6). This was expected since this mite is a very general feeder with over 400 host plants. Although most varieties are classed as susceptible, 270 were selected as showing some low levels of resistance. One hundred and eighteen of these were re-evaluated and 12 varieties were selected as promising for resistance to *T. urticae*. These include M Col 310, 288, 289, 230, 395, 282, 256, 560, 371, 674, 624 and CMC 39.

Among 1,349 cassava varieties evaluated for resistance to *M. tanajoa*, there are some showing moderate or intermediate resistance but none with high resistance or immunity has been selected. Forty varieties have been selected for intermediate resistance and 210 have been selected for future testing.

Based on a 0-5 resistance rating scale only 0.4 percent of the varieties evaluated for *T. urticae* received a rating of 3.5 or less. Of the 1,349 varieties evaluated for *M. tanajoa* resistance, 14 percent received a rating of 3.5 or less. In addition, 86.7 percent of the varieties tested received an evaluation of 5.0 for *T. urticae* while only 7.7 percent received a similar rating for *M. tanajoa*. This indicates that there is more

Table 6. **Evaluation of cassava germplasm for resistance[1] to *Tetranychus utricae* and *Mononychellus tanajoa*.**

Mite	No. of varieties evaluated	Varieties in each resistance class			Varieties selected as promising
		(No.)		(%)	
Tetranychus urticae	1,973[2]	5.0	1,711	86.72	270
		4.5	214	10.85	
		4.0	40	2.03	
		3.5	7	0.35	
		3.0	1	0.05	
Mononychellus tanajoa	1,349[3]	5.0	104	7.71	210
		4.5	501	37.14	
		4.0	555	41.14	
		3.5	149	11.05	
		3.0	36	2.67	
		2.5	4	0.30	

[1] Resistance scale: 0-1, resistant; 2-3, intermediate resistance; 4-5, susceptible.

[2] Artificially infested in screenhouse.

[3] Artificially infested in greenhouse.

resistance to *M. tanajoa* than to *T. urticae* in the cassava germplasm bank and that there is little cross resistance between the two species.

In addition to these studies at CIAT, 101 varieties of cassava were randomly selected for mite resistance in the field at Maracay, Venezuela (Fig. 19). High mite populations occurred when the plants reached about six months of age and continued for about five months. Although both *Mononychellus* mite species were present on the plants, *M. tanajoa* was predominant. Many varieties were completely defoliated and terminal and lateral buds were killed. However, several varieties did show intermediate levels of resistance.

Insecticide control

Six acaricides were studied under screenhouse and field conditions for controlling *Tetranychus* mites. Young cassava plants were treated in the screenhouse with six acaricides at four dosis (normal 0,5N, 2N and 4N) in order to measure mite mortality and the effect of the acaricides on plant growth. Several acaricides were toxic to plant growth even at the normal or recommended commercial dosis (Table 7). Monocrotophos and chlordimeform were least toxic at the normal dosage and monocrotophos caused only slight toxicity even at 4N dosis. Both acaricides were also effective in causing mite mortality; effects of the monocrotophos treatments are shown in Figure 20.

These same six acaricides were tested in the field for their effectiveness in mite control. The mite species present were *T. urticae, Mononychellus* spp. and *O. peruvianus*. Monocrotophos, chlordimeform and RH218 effectively con-

Figure 19. ***Mononychellus*** **mite damage in a field at the Centro Nacional de Investigaciones Agropecuarias (CENIAP) at Maracay, Venezuela. Observing the damaged plants are (on the left) Dr. Carlos Arias, of CENIAP, and Dr. Ernesto Doreste S., of the Faculty of Agronomy, Central University of Venezuela.**

Table 7. **Toxicity effects of several acaricides on cassava (var. Llanera) under screenhouse conditions for control of *Tetranychus urticae*.**

	Average grade[1] of toxicity for each application dosis			
Acaricide	.5 x N[2]	N	2 x N	4 x N
chlordimeform	0.1	0.5	1.3	2.3
dicofol	1.3	1.6	2.1	2.4
monocrotophos	0.0	0.1	0.5	0.8
binapacryl	2.5	3.0	3.0	3.0
RH - 218	0.8	1.5	2.4	2.8
Atellic	0.0	1.1	1.3	2.1

[1] Toxicity grades: 0 = No leaf damage; 1 = Upper leaves with light localized damage and lower leaves undamaged; 2 = Upper leaves heavily damaged and lower leaves with some damage; 3 = Plant totally damaged, causing death of leaves and/or plant.

[2] N = Normal or recommended commercial dosis.

trolled mites up to eight days after application (Table 8). In a second trial at ICA, Palmira six acaricides were evaluated for control of natural mite populations of *M. mcgregori*. Again, monocrotophos, chlordimeform and RH218 were the most effective acaricides tested. Monocrotophos still gave good control 24 days after treatment. However, since mite populations were not high applications did not significantly increase yield.

Cassava Hornworm

Observations of heavy hornworm *(Erinnyis ello)* outbreaks with populations reaching 90 larvae per plant on cassava farms this past year indicate that high hornworm populations will consume not only 100 percent of the foliage but larvae

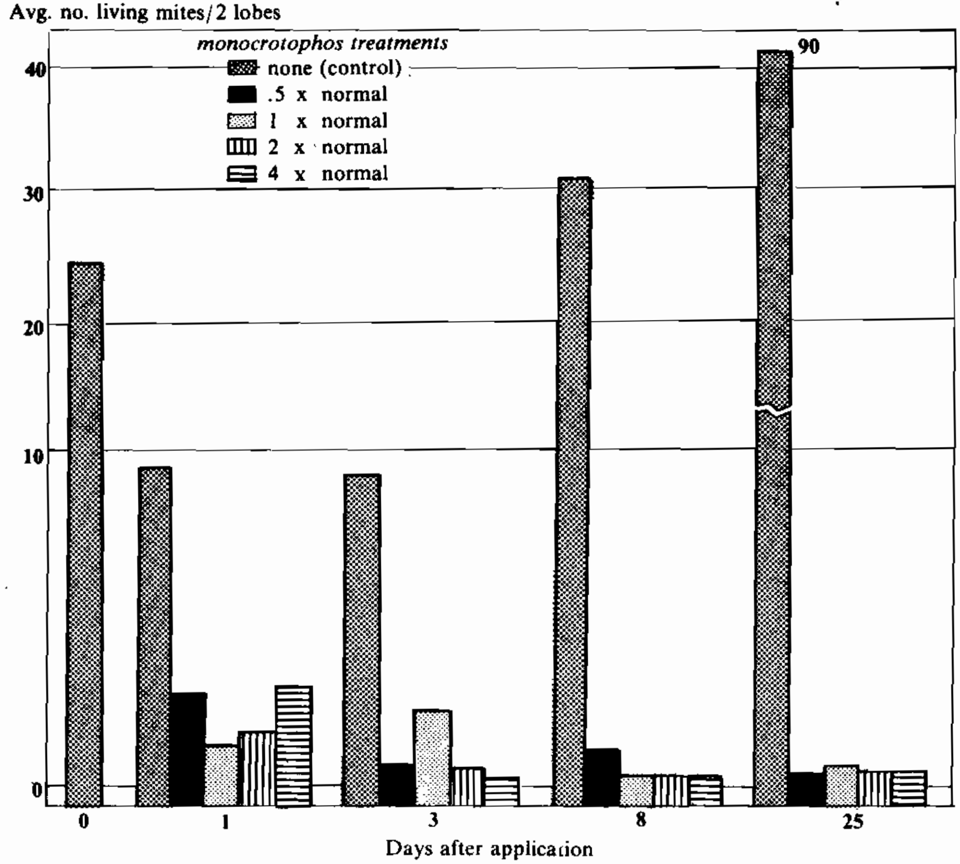


Figure 20. **Average population of *Tetranychus urticae* on cassava after four levels of treatment with monocrotophos, with observations at four periods after treatment.**

Table 8. **Effects of the application of several acaricides on mortality of mites (*T. urticae*, *Mononychellus* spp. and *O. peruvianus*) at one, three and eight days after application (var. M Col. 22).**

		Mites per leaf and % mortality at days:						
		0	1		3		8	
Acaricides	Dosis	Mites (control)	Mites	% Mortality[1]	Mites	% Mortality	Mites	% Mortality
chlordimeform	800 cc/ha	780	346	53	207	72	156	79
dicofol	1000 cc/ha	648	354	43	279	55	306	50
monocrotophos	1000 cc/ha	430	336	18	152	63	106	74
binapacryl	250 cc/ha	369	420	0	124	65	453	0
RH 218	250 cc/ha	593	207	63	87	85	210	63
Actellic	250 cc/ha	448	384	9	144	66	225	47
Control		517	487	0	481	0	453	0

[1] % mortality calculated by Henderson and Tildon method.

will also feed on tender parts of the stem often consuming the upper 20 to 30 centimeters of stem tissue. In addition, larvae will proceed to feed on and completely consume lateral buds. Hornworm larvae and heavily damaged cassava field are shown in Figure 21.

Since the adult hornworm moth is capable of lengthy flight, large populations of adults may migrate into an area and oviposit numerous eggs upsetting the equilibrium existing between biological control agents and the hornworm populations of that area causing a heavy outbreak and severe plant damage. Control methods are being studied which would not destroy the biological control agents and could effectively suppress heavy hornworm outbreaks.

High *Trichogramma* egg parasitism of the cassava hornworm and larval predation by the paper wasp *Polistes erytrocephalus* (as described in the 1974 CIAT Annual Report) naturally occur in

Figure 21. **Larvae of the cassava hornworm (*Erinnyis ello*) and a field of cassava totally defoliated by the hornworm.**

many cassava fields. In order to determine the effectiveness of this biological control system, *P. erytrocephalus* were released on cassava farms and biweekly evaluations are being made of hornworm oviposition, egg parasitism, larval populations and wasp populations.

Bacillus thuringiensis, a commercially available bacterial disease of many Lepidopterous larvae, was studied for cassava hornworm control. In a cassava field with heavy hornworm attack, 50-plant plots were sprayed with a suspension of *B. thuringiensis* and the larval population was measured before application and three days after application. Results showed that the larval population was reduced by 68 percent (Table 9), *B. thuringiensis* being most effective against the first three larval instars and least effective against the fourth and fifth instars.

One half of a five-hectare field was sprayed with *B. thuringiensis* and 50 plants were randomly sampled before application and at three and six days after application. The larval population in the treated field was reduced from more than six larvae per plant to one, while in the untreated field the larval population increased to more than 13 larvae per plant (Table 10).

Table 9. **Number of cassava hornworm (*Erinnyis ellos*) larvae before and three days after application of *Bacillus thuringiensis* on two-month cassava plants (var. Chiroza gallinaza).**

	No. larvae per instar[1]	
Developmental stage	Before application	3 days after aplication
I Instar	1,520	114
II Instar	4,449	982
III Instar	3,375	1,207
IV Instar	1,192	850
V Instar	320	298
Total	10,856	3,451

[1] Eight plots of 50 plants with center 15 plants of each plot sampled (total of 120 plants sampled).

Trichogramma egg parasites were released into treated and untreated fields prior to *B. thuringiensis* application and egg parasitism was recorded at seven and 10 days after release to determine the effect of the application on parasitism. Egg parasitism remained equally high in the treated and untreated fields (Table 11)

Table 10. **Effects of an application of *Bacillus thuringiensis* on a population of cassava hornworm (*Erinnyis ello*) after three and six days.**

	Days after application	No. of larvae[1] Instar I	II	III	IV	V	Total larvae	Larvae/ plant
With *B. thuringiensis*	0	159	97	56	—	—	312	6.24
	3	84	80	39	1	—	204	4.08
	6	7	19	21	3	4	54	1.08
Without *B. thuringiensis*	0	311	160	63	—	—	534	10.68
	3	141	287	100	1	0	529	10.58
	6	127	254	227	51	20	679	13.58

[1] Based on a 50 plant random sample.

Table 11. **Percentage of cassava hornworm (*Erinnyis ello*) eggs parasitized by *Trichogramma* sp[1] seven and ten days after application of (*Bacillus thuringiensis*).**

Treatment	% Parasitism[2] at 0 days after application	7	10
With *B. thuringiensis*	76	98	100
Without *B. thuringiensis*	76	93	97

[1] Approximately 98,000 *Trichogramma* adults released in each treatment plot of 2.5 hectares.

[2] Samples of 100 eggs.

indicating that application of *B. thuringiensis* will not adversely affect *Trichogramma* sp. egg parasitism.

A common complaint of many cassava farmers is that *B. thuringiensis* does not rapidly kill hornworms and that they continue to consume foliage for several days after its application. Therefore, a laboratory study was designed to measure the foliage consumed after leaves had been sprayed with *B thuringiensis*. Larvae were also allowed to feed on untreated leaves to compare leaf area consumption between the *Bacillus* infested larva and healthy larvae. Results showed that larvae can survive for 1-4 days after they begin to consume treated foliage. However, the leaf tissue they are able to consume during this period is greatly reduced (Table 10).

Cassava Fruit Flies

Two species of fruit flies have been identified as attacking cassava in Colombia. *Anastrepha pickeli* has been collected at the CIAT farm in the Cauca Valley (altitude 1,000 m) while *A. manihoti* was collected from the coffee growing regions of Colombia (1,200 m) where cassava is also widely grown. Stem and fruit damage due to the fruit fly and the bacterial disease associated with it (see CIAT Annual Report, 1975) have been observed in several cassava growing regions of Colombia. These range from coastal area where there is minimal and sporadic rainfall to mountainous areas where rainfall is well dispersed throughout the year.

The *Anastrepha* female oviposits in the fruit of mature plants or in the tender stem, just below the growing point of younger plants. The larvae may bore upward or downward in the stem causing extensive tunneling. This provides and entrance for a bacterial pathogen (see Plant Pathology Section) which can cause severe stem rotting. The rotten stem is not a favorable environment for the larvae and can cause larval mortality (see control treatment of Table 14). This also indicates that the major population increase of the fruit fly may result from the cassava fruit or an

Table 12. **Average leaf consumption (cm²) of cassava hornworm (*Erinnyis ello*) feeding on leaves treated with *Bacillus thuringiensis* and untreated leaves, under laboratory conditions.**

Developmental stage (Instar)	Avg. untreated leaf consumption/ larvae[1] (cm²)	Treated with *B. thuringiensis* Avg. leaf consumption/ larvae (cm²)	% reduction of control	Larval duration (days)
III	347.2	48.0	86.10	2.7
IV	273.8	19.2	93.0	2.3
V	345.3	7.11	97.96	2.11

[1] Sample of 10 larvae in each treatment.

alternate host. The fruit of several other plants commonly found in areas of high fruit fly populations have been examined but no additional host to these species has yet been identified. It appears that cassava plants can recuperate rapidly from fruit fly damage given adequate, well-distributed rainfall. Plants that have been severely attacked when three months old, resulting in dead or rotted growing terminals, were compared to healthy plants over a six-month period. Plant height measurements showed that within five months the damaged plants recuperate and attain the same height as non-damaged plants (Fig. 22).

Damage to planting material

Cuttings selected from planting material that has been damaged by the fruit fly and invaded by the bacterial rot have a rotten pith area. As a result, germination of damaged cuttings is reduced by 5 percent and may be delayed by several weeks (Table 13).

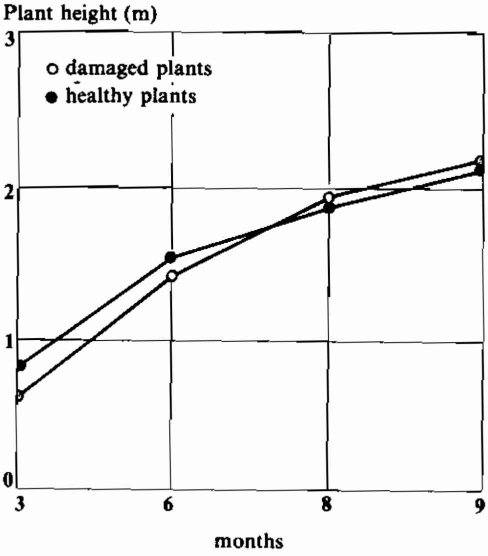


Figure 22. **Recuperation of cassava plants severely damaged by the cassava fruit fly (*Anastrepha* sp.) and bacterial rot (*Erwinia* sp.).**

Table 13. **Influence of cassava fruit fly (*Anastrepha* sp.) damage on the germination of planting material (var. Chiroza gallinaza).**

Treatment	No. of cuttings	% germination at 14 days	% germination at 28 days
Cuttings infected	100	76.8	94
Cuttings uninfected	100	84.4	99

Chemical control

Control methods using insecticide applications for both the larval and adult stage of the fruit fly were studied. For larval control, carbofuran was applied at three different doses in the soil around each plant and fenthion, in solution, was applied at three different doses to the foliage. Percentage of larval mortality caused by each systematic insecticide was recorded at 3, 8 and 16 days after application.

Results showed that fenthion gave good control three days after application and at eight days there was 100 percent larval control at all three doses (Table 14). After 16 days control was still 90-100 percent effective, depending upon the dose. Control by carbofuran was much less effective reaching only 69 percent at 16 days. Meanwhile, larval mortality in the control plants reached 40 percent, supporting the observation that the rotting stem is not a favorable medium for larval development.

Attractants

Adult fruit flies are highly mobile and difficult to control. However, trapping of adult fruit flies with the appropriate bait or attractant could result in an effective means of control, or of measuring adult fruit fly populations to determine when control measures should be employed. A

Table 14. **The effect of carbpfuran and fenthion on the control of cassava fruit fly larvae (*Anastrepha* sp.) in stems of cassava (var. M Mex 23).**

			% mortality of larvae at.		
Treatment	Dosis	Application	3 days	8 days	16 days
Carbofuran	10 g/plant	Soil	9.7	45.0	69.0
Carbofuran	20 g/plant	Soil	23.0	64.0	50.0
Carbofuran	30 g/plant	Soil	24.0	53.0	20.0
Fenthion	1.5 cc/liter H_2O	Foliage	76.0	100.0	95.0
Fenthion	2.0 cc/liter H_2O	Foliage	97.0	100.0	91.0
Fenthion	2.5 cc/liter H_2O	Foliage	77.0	100.0	100.0
Control			22.0	24.0	40.0

trial was designed to study baits or attractants that would increase the effectiveness of insecticide application. The insecticide EPN was used because of its quick knockdown effect which was necessary to get an accurate mortality count. Three bait combinations were studied—yeast, molasses, and yeast plus molasses. Yeast alone proved to be the most effective bait causing more than double the adult mortality of the insecticide used alone (Table 15). The addition of molasses had no effect on mortality and when molasses and yeast are combined mortality was greatly reduced.

In preliminary experiments, brewers yeast and hydrolized protein gave the best results as attractants for the capture of fruit flies. These were compared to three additional attractants—hydrolized yeast, hydrolized corn, and hydrolized soybean, using the McPhail trap. The hydrolized corn gave nearly three times greater capture of fruit flies than any of the other attractants (Table 16).

Table 15. **Evaluation of yeast and molasses as baits mixed with the insecticide EPN for control of cassava fruit fly (*Anastrepha* sp.) adults in field trials.**

	Adult mortality per replication				
Treatment and dosis	1	2	3	4	Avg. adult mortality
EPN (12 cc/12 liters H_2O)	25	42	43	3	28.3a[1]
EPN (12 cc/12 liters H_2O) + yeast (0.5 kg)	71	103	41	17	58.0b
EPN (12 cc/12 liters H_2O) + molasses (0.5 liter)	49	49	18	14	32.5a
EPN (12 cc/12 liters H_2O) + yeast (0.5 kg) + molasses (0.5 liter)	34	79	24	3	35.0a

[1] Averages followed by different letters are significantly different at .05.

Table 16. **Comparison of five attractants in capture efficiency of the adult cassava fruit fly (*Anastrepha manihoti*) using McPhail traps.**

Attractant	Dosis	Average no. of *Anastrepha* captured/week
Brewers yeast	40 g brewers yeast, 6 g sugar, 1 g Borax 400 cc H_2O	23.1
Hydrolized protein	50 cc/1,000 cc H_2O	17.1
Hydrolized corn	20 cc/1,000 cc H_2O	60.7
Hydrolized yeast	20 g/1,000 cc H_2O	21.9
Hydrolized soybean	20 g/1,000 cc H_2O	18.4

Biological control

Fruit fly larvae in cassava fruit are attacked by the parasite *Opius* sp. (Hymenoptera, Brackonidae). A study on the CIAT farm showed a 4.9 percent level of parasitism, while in the coffee growing region of Colombia, where fruit fly populations and damage are high, parasitism levels were 16 percent. There have been no observations of parasitism of the larvae in cassava stems.

Cassava Shoot fly

The metallic blue adult shoot fly oviposits its eggs between the unexpanded leaves in the growing terminals or in a small cavity in the tissue made by the ovipositor. After hatching, the young larvae tunnel in the soft tissue and eventually kill the growing point.

In a field where numerous plants were attacked by shoot flies yield was recorded on an individual plant basis. On plants where the attack occurred at 4.5 months of age yield reduction was 15.5 percent and when the attack occurred at 5.5 and 6.5 months there were 16.7 and 34.1 percent yield reductions, respectively. Control plants (sampled at random) yielded an average of 4.19 kg/plant as opposed to 3.54, 3.49 and 2.76, respectively, for the damaged plants. Affected plants were also shorter and may have been shaded by their healthy neighbors, hence yield losses are probably overestimated.

White Grubs

White grubs *(Phyllophaga* sp.) can cause considerable damage to planting material and roots of young plants. Germination of cuttings can be reduced by more than 90 percent under heavy attack by the grubs. In previous experiments aldrin (2.5% at 60 kg/ha) and carbofuran (3 g/m²) applied below the cutting in the soil were found to give the most effective control.

A Muscardine fungus, *Metarrhizium anisopliae,* is pathogenic to the grubs an preliminary laboratory experiments indicate that this can be an effective control method. This fungus has been found attacking grubs in their natural state in cassava fields in Colombia.

Mealybugs

Cassava plants infested with mealybugs have masses of cottony appearing insects clustered on the stem and leaves (Fig. 23). The species *Phenacoccus gossypii* has been identified as attacking cassava. There is no information available as to the extent of damage by these insects but mealybugs have been known to cause serious losses to other crops and could represent a serious

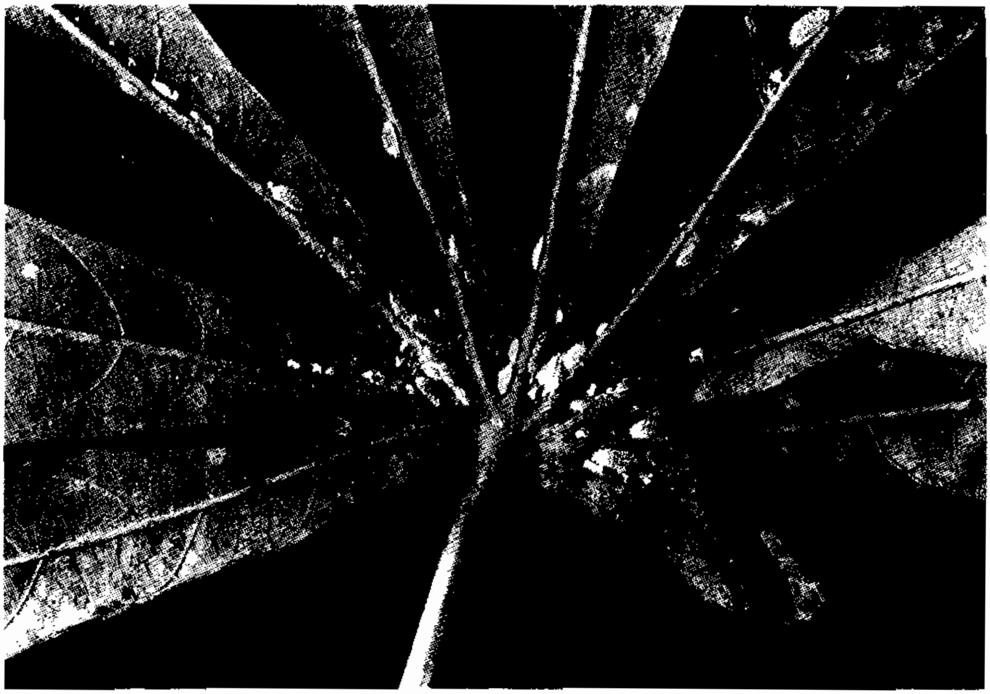


Figure 23. An infestation of mealybugs (*Phenacoccus gossypii*) on cassava.

pest of cassava. Communications from Brazil and Africa indicate that mealybugs severely defoliate cassava in these areas. They have been observed in increasing numbers this year on the CIAT farm causing defoliation and the drying of stem tissue.

Whiteflies

Very severe infestations of whiteflies (*Aleurotrachelus* sp.) were observed at the ICA experiemnt station at Nataima (Espinal) in Colombia. Leaf damage from heavy whitefly attack was observed as severe mottling or curling on susceptible varieties. These leaves had a mosaic-like effect with splotches of light green leaf tissue on the dark green leaves. The presence of sooty mold was also evident on the lower leaves of those plants with heavy infestation.

The black pupae covered with a white waxy excretion was easily observed on the

Table 17. **Evaluation of 12 varieties of cassava for resistance to the whitefly *Aleurotrachelus* sp.**

	Resistance grade[1]			
	Replicate			
Variety	1	2	3	Avg.
CMC 40	3	3	3	3
CMC 72	1	1	2	1.3
M Col 673	3	3	3	3
M Mex 52	1	2	2	1.7
CMC 86	3	3	3	3
M Ven 119	2	3	2	2.3
CMC 84	3	3	3	3
CMC 137	2	3	2	2.3
M Ecu 159	1	3	2	2
CMC 57	1	1	1	1
M Mex 59	2	2	3	2.3
M Col 22	3	3	3	3

Grade 1: Few or no pupae on leaves, no mottling of leaves;
Grade 2: About one half of leaves with many pupae and some mottling of foliage but no curling;
Grade 3: Most leaves with pupae and severe mottling and curling of leaves.

leaf undersides. The undersurface of heavily infested leaves were almost completely covered with pupae, giving a glistening white effect. Infestation was observed on nearly all leaves (upper as well as lower ones) but mottling and curling were primarily present on upper leaves.

A preliminary evaluation of 12 varieties was made for resistance/susceptibility to the whitefly.

The variety CMC 57 appeared to have good resistance in all three replicates. CMC 72 and Mex 52 gave moderate resistance while CMC 40, M Col 22, M Col 673, CMC 86 and CMC 84 were highly susceptible (Table 17).

PATHOLOGY

During 1976 emphasis was placed on research related to selecting and protecting vegetative propagating material. Losses caused by some major diseases were also determined, as well as new methods for a more accurate evaluation of resistance to certain diseases. Evaluations of resistance to cassava bacterial blight (CBB), Phoma leaf spot, *Cercospora* spp. leaf spots and the superelongation disease were done routinely on the promising material produced by the breeding program. Furthermore, the investigation related to identifying the causal agent of some syndromes observed in several commercial plantations was continued.

Bacterial Diseases

To date, three bacterial diseases of cassava have been defined according to the symptomatology, cultural and taxonomic characteristics of their causal agents. These are bacterial blight *(Xanthomonas manihotis),* bacterial stem rot *(Erwinia cassavae)* and bacterial angular leaf spot *(Xanthomonas cassavae).* However, the etiological and epidemiological knowledge of *X. cassavae* and the disease it causes is still in the preliminary phase.

Cassava bacterial blight (CBB)

Research on this disease was concentrated on: (a) determining those factors that may induce variability in the reaction of cassava cultivars inoculated by the clipping method for resistance screening to CBB (CIAT Annual Report, 1975); (b) determining the pathogenic variability of the causal agent; (c) evaluating resistance of F_1 hybrids obtained by controlled pollination; and, (d) determining losses caused by the disease on plantations infected monthly after germination, under conditions of the Cauca Valley of Colombia.

Inoculation procedure. Various trials were done to establish the optimum inoculation procedure for CBB screening. This procedure is summarized as follows. Plants should be grown in 11-cm diameter x 10-cm high pots since bigger pots do not allow plants to express symptoms as strongly as do smaller ones. Six young leaves around the stem should be inoculated using 10^8 cells/ml or more in sterile distilled water when the plants are 45-70 days old. Inoculation is best done on cloudy days or in the evening. Relative humidity should be greater than 70 percent and plants kept in pots at field capacity. This may require twice daily watering when temperatures are above 25ºC since higher temperatures accelerate symptom formation. Final evaluation, on five plants 45 days after inoculation, can be made visually.

Pathogenic variability. The virulence of 52 strains of *X. manihotis* collected from plantations in Africa, Asia, and America during the last four years was determined.

The cultivars M Col 113, Llanera, and M Col 647, previously rated as susceptible, tolerant and resistant, respectively, to certain Colombian strains were clip-inoculated with each of these strains. The 52 strains were classified into four virulence groups as shown in Table 18.

These results suggest the presence of groups of the pathogen differing in virulence. Of particular importance to CIAT's breeding strategy is whether these groups interact differently with various cassava genotypes. If so, the screening system should include as much diversity of pathogen groups as possible. If, on the other hand, the groups do not include interaction with cassava genotypes, screening by using the most virulent strains would be the most efficient, although less virulent strains (groups 1, 2 and 3) are more common.

Table 18. **Evaluation of virulence of 52 CBB strains from Africa, America and Asia, using the clip inoculation technique.**

		Virulence[1]			
Source of strains	No. of strains tested	Group 1	Group 2	Group 3	Group 4
Africa	13	2	8	2	1
America	35	8	12	10	5
Asia	4	2	1	1	—
Total	52	12(23%)	21(41%)	13(25%)	6(11%)

Group 1: Low virulence; it was able to induce lesions only on the clip inoculated leaves of the three cultivars.

Group 2: Induced dieback and/or death of susceptible cultivars. Tolerant and resistant cultivars showed lesions only on the inoculated leaves.

Group 3: Induced dieback or death of susceptible and tolerant cultivars. The resistant cultivar showed only foliar lesions.

Group 4: Induced death of the susceptible and tolerant cultivars and dieback (80%) and/or death (20%) of the resistant cultivar.

Disease losses related to crop age. The evaluation of losses caused by CBB in plantations infected at different ages was determined by monthly plantings of the cultivars Llanera (tolerant), and M Col 113 and M Mex 23 (susceptible). Yields were not reduced when plots were infected between the seventh and the tenth month of growth (Fig. 24), but in plots infected between the first and the sixth month, yield was significantly reduced in the two susceptible cultivars. Yield of the tolerant cultivar was only reduced when CBB infection occurred between the first and third month of growth. No correlation was found between yield and rainy or dry periods during this experiment.

These results suggest that disease losses may be reduced with disease-free planting material in areas where the disease is endemic. When "clean seed" (produced to insure that it doesn't carry CBB) is planted in an affected area, the plantations will be clean initially if the land has not been planted to cassava previously or has been rotated for a six-month period (CIAT Annual Report, 1973). Since CBB dissemination over short distances is generally related to environmental conditions and insect populations, the possibility that these plantations become fully infected within 3-4 months is low. Consequently, the risk of losses caused by CBB could be reduced by using clean propagating material or minimized if clean material of resistant or tolerant cultivars is used.

Evaluation for resistance. Evaluation of promising high-yielding material produced by the breeding program was of high priority. Other nonpromising lines were also included to obtain more information on the genetic control of this disease. Results (Table 19) were similar to those found previously (CIAT Annual Report, 1975). Selfing of resistant cultivars produc-

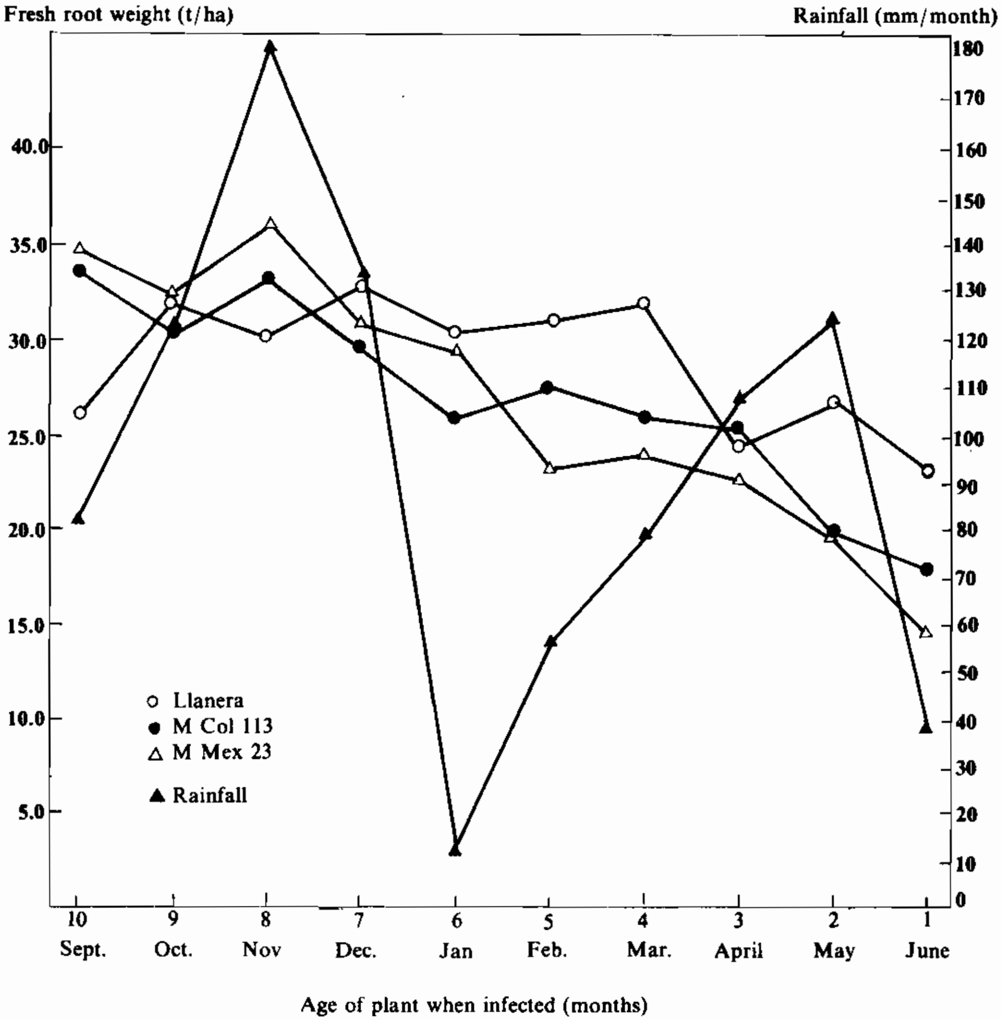


Figure 24. Effects of cassava bacterial blight infections at various growth stages on fresh root yields of three cassava varieties.

ed a high proportion of resistant types (52.2%). Similarly, by controlled pollinations of resistant x resistant or susceptible x resistant crosses, the percentage of resistant hybrids was considerably higher (14.8% and 10.6%, respectively) than crossing susceptible cultivars (2.1%) or by using open pollination (4.0%). With controlled hybridization resistant hybrids with other desirable characters can be obtained. Based on these methods, promising hybrids resistant to CBB have already been identified.

Bacterial stem rot

Etiological studies showed that the causal agent of this disease belongs to the *carotovora* group of the genus *Erwinia.* This pathogen also seems to belong to the variety *carotovora.* Taxonomically, therefore, this organism appears to belong to *Erwinia carotovora* var. *carotovora.* Erwinia *(E. cassavae* [Hansford] Burkholder 1948) is included in Bergey's *Manual of Determinative Bacteriology* (8th ed.) in the *herbicola* group. It is

Table 19. **Greenhouse evaluation of resistance to CBB of F_1 crosses from cultivars with different degrees of resistance.**

Cross type	Total no. of F_1's	Disease rating[1]		
		1	2	3
Self-pollinated (resistant)	19	10(52.6%)[2]	3(15.8%)	6(31.5%)
Open-pollinated lines	50	2(4.0%)	6(12.0%)	42(84.0%)
Control pollinated lines (susceptible x susceptible)	375	8(2.1%)	40(10.7%)	327(87.2%)
Control pollinated lines (susceptible x resistant)	530	56(10.6%)	194(36.6%)	280(52.8%)
Control pollinated lines (resistant x resistant)	27	4(14.8%)	10(37.0%)	13(48.2%)

[1] Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

[2] Percentage related to the total number of lines tested per cross type

suggested that its epithet be maintained but that the species be changed to the *carotovora* var. *carotovora* group. Since the type culture of this species is not available, it is impossible to make comparative studies; nevertheless, symptoms induced by *E. cassavae* are similar to those induced by the present pathogen.

The pathogen penetrates the host via plant wounds, generally caused by fruit flies *(Anastrepha* spp.; see Entomology Section). The pathogen was isolated in small numbers (1%) on adults and high numbers (90%) on/in larvae collected from infected stems; the pathogen was found only on the body surface of the adults whereas it was also found within the larvae when there was a bacteria/insect relationship in the stem. The pathogen was able to survive epiphytically for 132 hours, when relative humidity was near 100 percent and its concentration increased more than 100-fold.

Insect adults generally live and feed on fermenting organic debris, common in those cassava-growing areas where the vectors and the disease are endemic. Thus, it is possible that in these locations the adult flies become infested and later spread the pathogen on the surface of the plant when they oviposit in the stem. When the larva emerges, it bores through the stem, causing a wound where the pathogen, which has survived epiphytically on the plant surface, penetrates into the stem tissues of the host. This is corroborated by the presence of plants attacked by the insect only during the rainy periods and by the fact that the insect/bacterium association during dry periods is nil, even though the presence of insect and damage caused by insect vectors is common.

With artificially inoculated plants, disease severity is greater at 100 percent relative humidity than at 70 percent relative humidity during incubation (Fig. 25). In the field, disease incidence (infected plants/total plants) and severity are high during the rainy season. During the dry season, external symptoms (total stem rot) disappear, but the pathogen continues to invade the pith tissues of the infected plants. Since no significant differences in

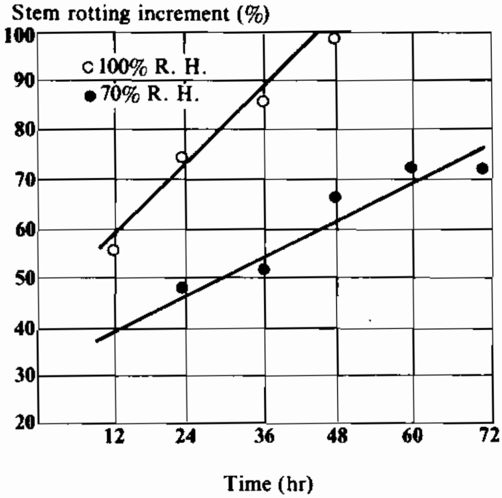


Figure 25. **Disease progress of bacterial stem rot of cassava at two humidity levels.**

the degree of stem rotting were found among artificially inoculated cultivars, best control is to identify cultivars resistant to the insect or direct control of insects.

Bacterial angular leaf spot

This disease was described in Africa (Uganda) in 1956, but no other report of the disease has been published. This year, some cultivars were found to be affected by the disease in Carimagua (Llanos Orientales, Colombia) during the rainy season. The disease, caused by *X. cassavae* (a parenchymatous pathogen), is observed only on the foliar system of cassava as angular, water-soaked lesions, very similar to those induced by CBB. The angular spots, however, are smaller, with a pale yellowish exudation in the center of the lesions on the leaf undersurface. The spots are surrounded by a diffuse pale yellow halo, which eventually extends over the whole leaf lamina, causing leaf abscission within 20 days after infection.

The pathogen grows well but slowly in sugar media, producing yellow colonies; these two characteristics (slow growth and yellow colonies) separate it from *X. manihotis,* which is a fast-growing organism producing white mucoid colonies on sugar media. First symptoms appear 8-9 days after spray inoculation with a bacterial suspension of 10^9 cells/ml, followed by 24 hours of incubation at 100 percent relative humidity and 25°C. Small, swollen, water-soaked, reddish brown dots appear, which enlarge and become surrounded by a yellow halo as described above.

Fungal Diseases

Superelongation disease

Cultural studies on *Sphaceloma manihoticola,* the causal agent of superelongation, and on *S. poinsettiae* (CIAT Annual Report, 1975) showed that these two organisms can mutate on artificial media relatively easily, producing colonies phenotypically different from the original cultures. Frequently, black, mucoid colonies appear which can sporulate more intensely than the original ones and remain stable even after inoculating/isolating several times on a susceptible cassava cultivar. Such mutants were observed to be more virulent than the original cultures affecting the same cultivar. This suggests the possible existence of physiological races in nature and/or the possibility of forming new biotypes or races in relatively short periods, an important point for a breeding program to control this disease.

In general, three field-resistant types have been observed: (a) complete immunity, characterized by the absence of disease lesions on certain cultivars; (b) disease occurrence with foliar lesions in a 12-month cycle, but without elongation and/or leaf distortion; and, (c) complete immunity during the first four months of plant growth and then tolerance, shown by the presence of lesions on leaves, petioles and green stem, and elongation only on the very young portions of branches.

The severity of this disease depends on the occurrence of prolonged periods of rainfall but yield reduction is almost nil when plantations are infected after five months of growth (CIAT Annual Report, 1975). Since it is likely that physiological races exist which interact with different cassava genotypes, especially in the case of type (a), importance will also be given to other types of resistance.

Disease resistance evaluation is carried out using plots surrounded by heavily attacked susceptible cultivars. From the results it is evident that there are very good sources of resistance to this disease in CIAT's germplasm bank (Table 20). The resistant cultivars have remained resistant for a year under continuous exposure to high inoculum potential.

Dissemination. The effect of the causal agent of this disease on germination of cuttings, as well as its dissemination by the use of infected cuttings, was determined by planting cuttings (var. M Col 310) taken from clean and infected plantations. Of cuttings from infected plantations 50 percent did not germinate, and all sprouts were infected.

When diseased cuttings were treated with the fungicide captafol (80%) at 8,000 ppm the disease was eradicated. Captafol (80%) at this concentration did not show any inhibitory or toxic effect on the treated cuttings. Stake treatments could also reduce yield losses tremendously during the early growth stages.

Phoma leaf spot

When the evaluation of 1,139 cultivars of CIAT's collection was completed, it was found that only 1.7 percent were resistant, 85.4 percent were susceptible and 12.9 percent showed some tolerance.

Comparing the yields obtained 15 months after planting, resistant cultivars yielded 190 percent of the regional average and the susceptible cultivars yielded 60 percent less (Table 21). This suggests that in areas where the disease is endemic (areas with low temperatures and high relative humidity), growers have unconsciously selected cultivars resistant to the disease and to the environmental conditions. If this resistance is increased, yields could be doubled in these areas (Table 21). However, the resistance evaluation of the first 200 hybrids showed that the heritability of resistance to this disease is quite low (Table 22).

Cercospora spp. leaf spots

The effect of *Cercospora henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot) on leaf longevity and yield of the susceptible cultivar Llanera was determined under CIAT environmental con-

Table 20. **Field evaluation of 488 cultivars and F crosses for resistance to *Sphaceloma manihoticola* (superelongation disease of cassava).**

No. of cultivars or hybrids tested	Disease rating[1]		
	1	2	3
418 cultivars	7.2[2]	24.9	67.9
70 hybrids	10.0	18.6	71.4
Avg.	7.6	24.0	68.0

[1] Disease rating: 1=resistant, 2=tolerant, 3=susceptible

[2] Percentage of the total number tested.

Table 21. **Average yield (at 15 months) of 1,139 cassava cultivars grouped according to their reaction to Phoma leaf spot.**

Disease reaction	Average yield (kg/plant)	% yield related to regional yield
Regional yield	1.2	100 a[1]
Resistant	2.3	190 b
Tolerant	1.0	80 a
Susceptible	0.5	40 b

[1] Numbers followed by the same letter were not significant at .01 level (F test).

Table 22. **Field evaluation of resistance of F_1 crosses to *Phoma* sp. from cultivars with different degrees of resistance.**

Pollination system	Total F_1 crosses	Disease rating[1]		
		1	2	3
Self-pollinated (resistant)	26	1(3.8%)[2]	15(57.7%)	10(38.5%)
Open pollinated	52	0(0.0%)	6(11.5%)	46(88.5%)
Control pollinated:				
(susceptible x susceptible)	81	0(0.0%)	2(2.5%)	79(87.5%)
(resistant x resistant)	41	2(4.9%)	31(75.6%)	8(19.5%)

[1] Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

[2] Percentage related to the total number of lines tested per cross type

ditions by applying fungicides and stickers at 1, 2 and 3 week periods in a split-plot design.

Longevity of healthy leaves was 85 days and for infested leaves untreated with fungicide, 68 days (Table 23). Fungicide treatments reduced infected leaf numbers by 60 percent but only increased leaf life of infected leaves by two days. The fungicide treatment every week reduced the level of infestation and increased leaf life. Yield was increased by 14 percent (Table 24) by this treatment at CIAT. It is interesting to note that increased leaf life is suggested (Physiology Section) as a means of increasing yield. Higher yield in this case is apparently associated with greater leaf longevity.

Field evaluation for resistance to *C. henningsii*, *C. vicosae* and *C. caribae* (Table 25) showed results similar to those reported previously (CIAT Annual Report, 1975). A high percentage of F_1 lines showed resistance to *C. henningsii* and *C. caribaea*, but resistance to *C. vicosae* was very low. Resistance to *C. henningsii* and *C. vicosae* together was even lower (Fig. 26) with the resistance to each *Cercospora* species being independent and not correlated.

Table 23. **Longevity of healthy leaves of Llanera and those infected with *Cercospora henningsii* and/or *C. vicosae*.**

Sanitary condition	Longevity (days)	No. of leaves
Infected leaves, no fungicide treatment	68	367
Infected leaves treated with fungicide	70	4,732
Healthy leaves, treated every week	85	2,062

Table 24. **Yield of cassava (var. Llanera) according to the frequency of application of either mancozeb, Vitigran, benomyl and Macuprax plus sticker (Triton or Tween 20).**

Frequency of application	Yield (t/ha)
Every week	33.1 a[1]
Every two weeks	28.1 b
Every three weeks	29.2 b
Control	28.5 b

[1] Numbers followed by different letters were significantly different at the .05 level.

Table 25. **Field evaluation of resistance to *Cercospora henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot) in F_1 crosses from cultivars with different degrees of resistance.**

	Disease rating[1]		
Cercospora spp.	1	2	3
C. henningsii	616(46%)[1]	210 (15%)	518 (38%)
C. vicosae	53(4%)	208 (15%)	1,083 (81%)
C. caribaea	141 (34%)	154 (37%)	118 (29%)

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

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

Cassava rusts

The studies on cassava rusts in cooperation with ICA, the Universidad Nacional and CIAT (1975 Annual Report), were continued. A taxonomic analysis was made of *Uromyces* spp., pathogenic to *Manihot* spp. A total of 72 samples were analyzed after being obtained from the following European and American herbaria and/or museums: Royal Botanic Gardens, Kew; Naturhistoriska, Riksmuseet, Stockholm; Botanischer Garten und Botanisches Museum, Berlin-Dahlem; Instituto Agronomico, Campinas; Micoteca Nacional, ICA.

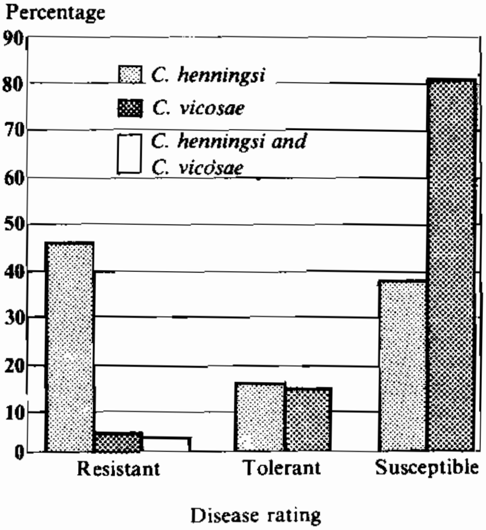


Figure 26. **Field resistance to *Cercospora henningsii* and *C. vicosae* of F_1 crosses from cassava cultivars with different degrees of resistance.**

As a result 42 samples were reclassified. The samples were characterized by comparing each sample with the type or isotype species. The identification of rust species included studies on: ornamentation and thickness of the cell wall, color, size and shape of teliospores and uredospores, and the pedicel characteristics of the number and position of the germinative pores on uredospores.

Six *Uromyces* spp. have been reported pathogenic to *Manihot* spp. in Latin America, of which *U. manihotis* Henn. is most widely distributed (Fig. 27).

The highest percentage of germination of uredospores of *U. manihotis* takes place at 20-25ºC, 36 hours after incubation on agar. At 1ºC and 35ºC uredospores do not germinate. Germination is delayed when light intensity is greater than 12,917 lux (1,200 ft-c). When relative humidity is lower than 81 percent, uredospores do not germinate but when relative humidity was between 95 and 100 percent, germination was 18 and 68 percent, respectively. Satisfactory infection was obtained when plants were spray inoculated and incubated for 12 hours at 100 percent relative humidity. The optimum concentration of inoculum was 25 mg of uredospores/40 ml of water plus Tween 20 at 0.1 percent; first symptoms appeared 12-15 days after inoculation. The highest disease rating was obtained on four-week-old plants. The pathogen penetrates the host via stomatal cavities, 4-5 hours after inoculation.

Under field conditions (at Mondomo, Cauca, Colombia) *U. manihotis* produced only uredospores. After evaluating 72 cultivars, it was found that only 8 percent appeared to be susceptible, but the disease incidence was only moderate. However,

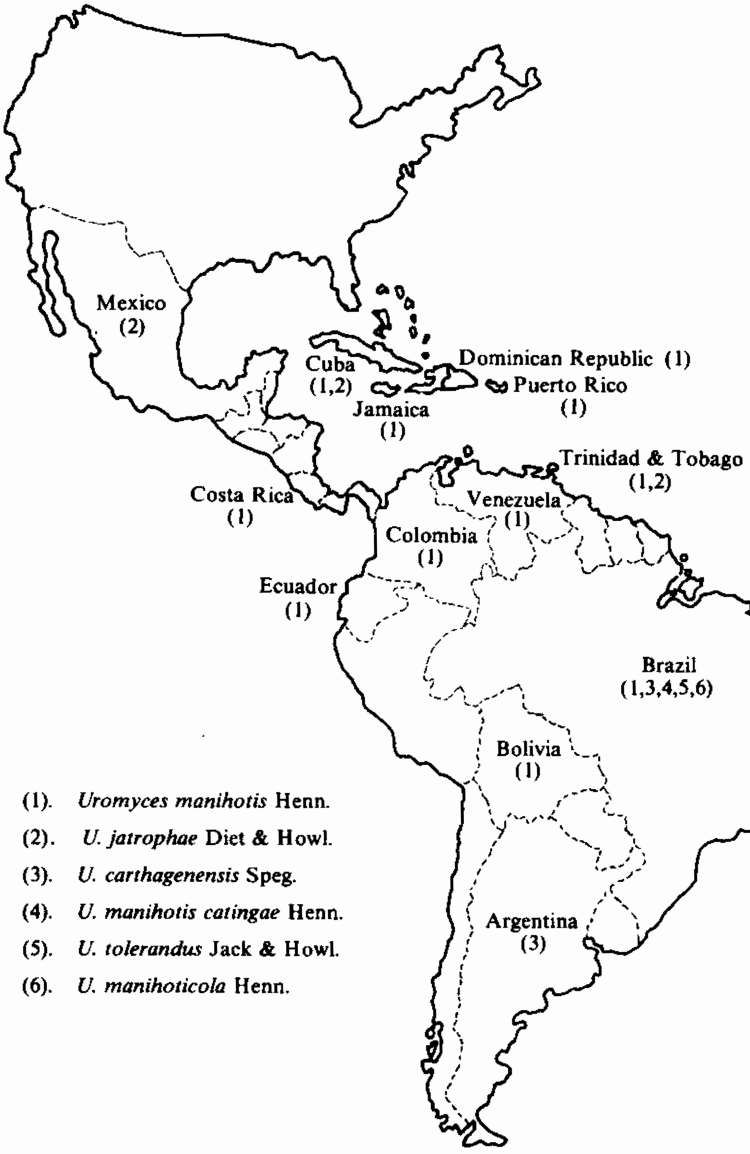


Figure 27. **Geographical distribution of** *Uromyces* **spp. in** *Manihot* **spp.**

after inoculation under greenhouse conditions, M Col 113 and 146, which showed high tolerance under field conditions, were rated as susceptible.It appears that the high incidence of the microparasite *Darluca filum* (Biv.) Cast. on pustules of *U. manihotis* in Mondomo plantations restricts the dissemination and incidence of this cassava rust and limits the production of uredospores because it invades the entire fruiting structure of the rust.

When the pathogenicity of *D. filum* was tested under controlled conditions, it was found that after 10-12 days of incubation at 70 percent relative humidity and 25ºC, the parasite invades rust lesions. *D. filum* on mature sori restricts sporulation of *U.*

manihotis almost completely. Since *U. manihotis* has been found infecting cassava at different altitudes (Nariño, 1,700 m; CIAT, 1,006 m), possibilities exist for ecological races of the pathogen.

Other Diseases of Cassava

The frog skin disease

This disease was first described in 1974, (CIAT Annual Report, 1975). It causes tremendous losses when present (see Economics Section) and attempts have been made to determine the cause of the disease, the identification of the causal agent and its transmission. Nutritional studies made by adding major and minor elements to the soil of heavily infected plantations showed that this disease was not due to any nutritional deficiency or toxicity. Similarly, in experiments using heat- or chemically-sterilized soil, it was found the disease is not caused by a soil-borne pathogen. Further investigation showed that the syndrome was due to an infectious agent transmitted through infected cuttings taken from infected plantations. Of the cuttings taken from infected plantations, 87 percent produced diseased plants, but none of the plants obtained from healthy cuttings taken from healthy plantations produced plants in the same site (Table 26). Diseased cuttings showed no necrosis or symptoms induced by fungal or bacterial organisms and attempts to isolate fungi or bacteria from infected cuttings were also negative. The causal agent of this disease is still unknown.

Yields of plants infected with this disease may decrease by 50 percent; the harvest index of diseased plants is extremely low because they produce few swollen roots and aerial development is more vigorous than in the healthy plants. By using healthy plant propagating material taken from diseased or healthy plantations, the disease can be eradicated and yields can be increased more than three times the average expected under conditions of the disease.

Table 26. **Dissemination, losses and yield index of the frog skin disease through the use of infected planting material taken from diseased and healthy plantations.**

Origin of the Cuttings	Healthy plants	Diseased plants
Cuttings from infected plantations: [1]		
No. of harvested plants	50(13%) [2]	326(87%)
Yield (kg/plant)	1.40	0.70
Harvest index	0.63	0.33
Cuttings from healthy plantations: [1]		
No. of harvested plants	360(100%)	0.0(0.0%)
Yield (kg/plant)	1.0	—
Harvest index	0.84	—

[1] Cuttings were planted in a field where the previous crop was 92% infected

[2] Percentage related to the total number of plants harvested.

Anthracnose

This disease had been reported to be caused by *Colletotrichum manihotis* Henn; however, it has been found that other species of *Colletotrichum* and *Gloeosporium* can also cause anthracnose on cassava. The following species have been identified as causal agents of anthracnose: *C. manihotis, C. dematium, C. gloeosporioides* and *Gloeosporium* sp.

Symptoms induced by these pathogens are similar to those of foliar blight, butt rotting, die-back and stem cankers. However, specific symptoms have not yet been identified to specific pathogens. Generally, these pathogens attack more frequently during prolonged periods of rainfall.

Periconia leaf spots

In some cassava plantations necrotic leaf spots different from those induced by

Cercospora caribaea and other known foliar pathogens of cassava were observed. They are of variable sizes, light brown in color, with well-defined margins. They commonly coalesce, forming large irregular necrotic lesions frequently found at the end of the rainy season. The lesions are induced by a fungus of the genus *Periconia*. Taxonomic studies show that the fungus may belong to the species *P. shyamala* because the conidophores are similar to *P. byssoides* but its conidia are only 17.5u (16 to 20u) in diameter. So far the disease is unimportant because of its low severity and incidence.

Selection and Treatment of Planting Material

Losses almost always occur during the establishment of cuttings due to the attack of soil-borne pathogens (CIAT Annual Report 1972, 1973). These losses were reduced by a five-minute dip treatment of cuttings in some fungicide solutions.

Thirty-five fungicides and mixtures were tested (Table 12) and the following conclusions were reached: (1) Some fungicides are effective in protecting the cuttings against most of the soil-borne

Table 27. **The effect of five of the most promising fungicides or mixtures on early performance of cassava propagation material using a five-minute dip treatment of cuttings in the fungicide suspension.**

		Greenhouse test [2]		Field test [2]	
Treatment [1]	Rate (ppm)	Shoot height [3] (cm)	Germinated buds (%)	Shoot height [3] (cm)	Wt/plant (g)
chlorothalonil	2,000	14.4	44.4	12.7	251
	4,000	12.4	57.1	12.2	215
	8,000	11.6	44.4	12.2	213
maneb	2,000	11.7	61.7	12.6	242
	4,000	12.1	56.6	12.2	225
	8,000	14.3	62.2	12.0	212
captan	1,000	11.7	56.2	12.3	232
+ BCM	2,000	14.8	58.5	13.8	261
	4,000	14.5	67.6	12.7	246
	8,000	12.2	54.0	12.8	231
chlorothalonil	4,000	14.4	40.0	11.9	211
+ maneb	8,000	12.0	68.4	12.1	207
chlorothalonil	4,000	12.9	47.8	12.2	210
+ captafol	8.000	12.5	65.7	12.6	215
Control		7.8	40.6	10.6	160

[1] Treatments consisted of a five-minute dip of cuttings in the fungicide suspension

[2] Average data of three replications with nine cuttings each

[3] A significant difference (at the .01 level) existed between treatments and the control.

pathogens of cassava and their effect can last up to 60 days; (2) By treating the cuttings with certain fungicides, bud germination takes place more quickly and is higher than in the untreated controls; and, (3) Some fungicides induce faster rooting and growth of sprouts than the control.

Even though the effect of fungicide treatment of cuttings on yield has not been determined, these promising results and the low cost of the treatments suggest that it is wise to treat the cuttings with fungicides before planting. Moreover, strict selection and care during preparation, handling and planting must be given to the cuttings to assure good establishment and to avoid further disease problems.

It was also demonstrated that by selecting healthy cuttings taken from plantations free of systemic causal agents (causal agents of bacterial blight, bacterial stem rot, the superelongation disease, the frog skin disease, viruses and mycoplasma, and of cankers, rotting and/or any vascular or epidermal necrosis) it was possible to avoid disease dissemination and to assure a high percentage of germination and crop development.

VARIETAL IMPROVEMENT

During the past year CIAT lines, both selected germplasm materials and hybrids, outyielded local cultivars both in and outside CIAT. Results indicate that high yielding genotypes can be produced relatively easily by hybridizations and selections. Tens of thousands of hybrids were made and evaluated in observational yield trials and replicated yield trials in and outside CIAT. Thousands of hybrid and open-pollinated seeds were distributed to breeders in Latin America, Asia and Africa. Several lines were passed for multiplications and regional trials (Table 28).

It was determined that root starch content and post-harvest root durability

Table 28. Cassava genotypes produced, evaluated and selected at four sites in Colombia during 1976.

	Site			
	CIAT	Carimagua	Caribia	Popayán
Germplasm collection	2,269			
Hybrid seeds produced (not including open-pollinated seeds)	30,007			
Hybrid seeds sown	22,482			
Hybrid plants harvested (planted in 1975)	16,196			
Hybrid plants selected	1,558			
Lines planted in observational yield trial	2,057	490	463	230
Lines harvested in observational yield trial (planted in 1975)	1,268	300	370	388
Lines planted in replicated yield trial	483	78	90	
Lines harvested in replicated yield trial (planted in 1975)	63	20	36	
Lines selected for multiplication	30			
Hybrid seeds distributed to other programs	6,628 (+ some 30,000 open-pollinated seeds)			

are highly heritable characteristics whose relative genetic values are stable over a wide range of environmental conditions. Groups of valuable genotypes were newly identified for CBB, superelongation, and Phoma leaf spot resistance. It was also found that high cassava yields can be obtained even on very acid infertile soils such as those of the Llanos Orientales of Colombia. Finally, the same high yielding genotype can give good yield over environmental variations of soil pH 4.5-7.8 and annual average temperatures of 24°-28°C.

Yield Trials

Several thousand hybrids were developed in 1973 with little knowledge as to which parents were useful. The resulting hybrids were planted in the observational yield trial of 1974 with no selection at the seedling stage. The hybrids were first selected at this stage, and therefore, passed only one step of selection before they entered replicated yield trials. (Presently new hybrids pass three steps: selection of parents, selection at seedling stage, and selection in observational yield trials).

Of these hybrids, 150 were planted in replicated yield trials in CIAT during 1975. However, only 58 were harvested during 1976 because the others were lost as a result of salt spots and poor drainage of the field.One hybrid yielded more than 50 t/ha and eight yielded more than 40 t/ha. Many outyielded the local cultivar (Table 29). Results have been promising and suggest that by simple selection high yielding hybrids can be produced relatively easily.

In Carimagua, in the Llanos Orientales, M Col 1684 yielded 36.8 t/ha (11.8 t/ha in dry matter) and many yielded more than 20 t/ha (Table 30). The soil in this area is very infertile and acid (pH 4.5) and the level of aluminum is so high that most field crops simply cannot grow even with a fairly heavy application of fertilizers. This indicates that cassava is a highly efficient crop in producing carbohydrate on poor acid soils. There is an immediate possibility of varietal selection of cassava for this kind of soil.

In Caribia, (pH 6.5, mean temperature 28°C) M Col 1684 was again the top yielder with 44.2 t/ha (Table 31). Seven cultivars

Table 29. **Results of Replicated Yield Trial during 1975/76 crop year at CIAT.**[1]

Line	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yield (t/ha/yr)
SM1-150	52.2[2]	.310[2]	16.2[2]
SM1-162	45.8	.326	14.9
CM192-1	45.3	.358	16.2
SM1-211	44.4	.324	14.4
CM104-3	43.6	.332	14.5
CM156-3	42.5	.356	15.1
SM1-193	41.9	.322	13.5
SM1-223	40.3	.346	13.9
CM192-5	38.9	.350	13.6
CM208-10	38.3	.318	12.2
M Col 22 (control)	35.3	.372	13.1
M Col 113 (local)	27.2	.306	8.3
Llanera (control)	25.3	.304	7.7

[1] Soil pH 7.8; annual average temperature 24°C; no fertilizer applied

[2] All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 spacing, eliminating two rows of borders.

Table 30. **Results of Replicated Yield Trial during 1975/76 crop year at Carimagua.**[1]

	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yiel (t/ha/yr)
M Col 1684	36.8[2]	.320[2]	11.8[2]
CM 180-5	26.1	.358	9.3
M Col 710	25.0	.353	8.8
M Mex 59	24.8	.357	8.9
M Col 1468	24.7	.310	7.7
M Col 638	24.3	.324	7.9
M Ven 326	23.4	.350	8.2
M Col 22	23.2	.349	8.1
M Col 655A	23.2	.373	8.7
M Col 5	23.1	.342	7.9
Llanera (control)	23.0	.339	7.8

[1] Soil pH 4.5; annual average temperature 26°C, fertilizer applied 100 kg/ha N, 200 kg/ha P_2O_5, 200 kg/ha K_2O, 115 kg ha Ca, 52 kg/ha Mg.
[2] All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 m spacing, eliminating two rows of borders.

selected at CIAT and ICA yielded more than 30 t/ha and many outyielded the local cultivars quite significantly. M Col 1684 was also one of the 11 cultivars yielding more than 50 t/ha in 1975 at CIAT. The pH of CIAT's soil is around 7.8 and the soil is generally regarded as highly fertile. This suggests that a wide range of soil pH's (from 4.5 to 7.8), temperature's (24°-28°C) and fertility can be covered by the same high yielding genotype. The major part of the world's cassava grows within these

Table 31. **Results of Replicated Yield Trial during 1975/76 crop year at Caribia.**[1]

	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yield (t/ha/yr)
M Col 1684	44.2[2]	.296[2]	13.1[2]
M Ven 307	37.5	.344	12.9
M Col 1468 (CMC 40)	35.0	.269	9.4
M Mex 59	32.8	.337	11.1
CMC 180	32.2	.315	10.1
CMC 144	30.6	.302	9.2
CMC 151	30.6	.315	9.6
M Ven 326	29.4	.306	10.0
M Ven 318	29.2	.344	10.0
CMC 74	27.2	.357	9.7
M Col 22 (control)	26.9	.350	9.4
Majetera (local)	23.1	.360	8.3
Llanera (control)	19.4	.291	5.6
Manteca (local)	17.5	.350	6.1
Montero (local)	13.6	.370	5.0

[1] Soil pH 6.5; annual average temperature 28°C; no fertilizer applied
[2] All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 m spacing eliminating two rows of borders.

ranges. Thus, the data suggest not only that cassava can be grown successfully under wide range of environments, but also that a single high yielding genotype can cover the major part of this wide range.

In CIAT, there was a highly significant correlation between harvest index and root yield with a slight tendency for the types with too high a harvest index to yield less (Fig. 28). This correlation was also significant both in Carimagua (Fig. 29) and Caribia (Fig. 30). Last year (CIAT Annual Report, 1975) it was demonstrated that the harvest index was a highly efficient and reliable character in selection for root yield throughout the selection of cross parents and the selections at seedling stage and in single-row trials. Results this year further suggest the validity of harvest index as a selection character for high yield over a wide range of environmental variation.

Evaluation of Hybrids

About 16,000 hybrids from several hundred crosses were harvested during the year. From this population, about 1,500 hybrids were selected and planted in observational yield trials and some 500 selected lines are being evaluated in replicated yield trials in CIAT and in observational yield trials outside CIAT (Table 28).

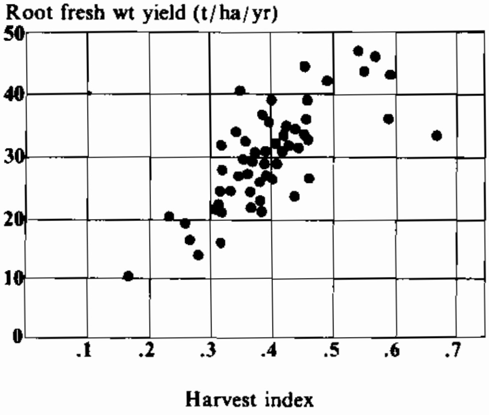


Figure 28. **Relationship between harvest index and root yield of cassava at CIAT, 1976.**

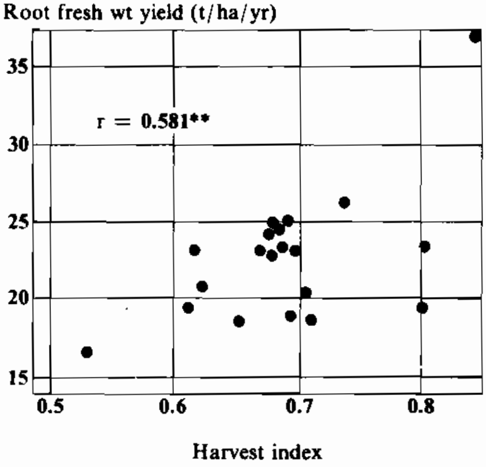


Figure 29. **Relationship between harvest index and root yield of cassava at Carimagua, 1976.**

All the hybrid seedlings at CIAT are selected for productivity mainly using harvest index. At this stage, stem cuttings of some genotypes are prepared for disease evaluation. After the observational yield trial is harvested at CIAT the superior lines are screened for different characters. The CIAT farm is kept free from two of the most important diseases, i.e., CBB and superelongation since the pathology group eradicated CBB from the farm four years

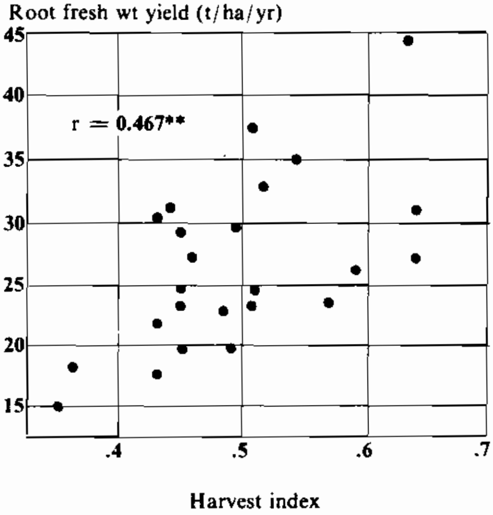


Figure 30. **Relationship between harvest index and root yield of cassava at Caribia, 1976.**

ago. Hence, hybrids can be evaluated for high yielding capacity *per se*. A brief summary of the scheme is presented in Table 32.

Hybridization

Enough data has been given to show that high yielding hybrids with wide adaptation can be produced and selected relatively easily. The strategy of hybridization and selection is then to produce hundreds, or thousands, if possible, of recombinations which yield more than 50 t/ha at CIAT from as many diverse parents as possible and to evaluate these hybrids under great environmental diversity, and at the same time, incorporating as much disease and pest resistance as possible into the whole population.

General productivity and wide adaptation.

From the original germplasm collection, such cultivars as M Col 655A, M Col 1292, M Col 1684, M Mex 17, M Mex 59, M Ven 168, M Ven 185, M Ven 218, M Ven 270, M Pan 70 and M PTR 26 remain as important parents in the list of hybridizations. After one cycle of hybridization and selection, high harvest index genotypes with other favorable agronomic characters are available by the hundreds. All these materials were crossed among themselves and with disease resistant genotypes, etc.

An example is given by the case of M Col 1684. Due to the extremely high harvest index of M Col 1684, it was decided to include this cultivar in hybridizations more than a year ago, so that some 5,000 hybrid seeds of M Col 1684 have been produced up to now.

CBB resistance

Among the four CBB resistant genotypes, i.e., M Col 197, M Col 638, M Col 647 and M Col 667, which have been used as sources of resistant genes M Col 647 has proven to be outstanding. After

Table 32. Scheme of cassava hybrid evaluation according to locations and research discipline.

	Major characters being evaluated
Location	
CIAT	Productivity, starch content, root durability, HCN content, thrips.
Carimagua	Productivity, tolerance to poor acid soil, superelongation, CBB, tolerance to dry season, starch content, root durability.
Caribia	Productivity, CBB, superelongation, *Cercospora* diseases, growth under hot dry climate, starch content, root durability.
Popayán	Productivity under cool temperatures, Phoma disease.
Discipline	
Pathology (I)	CBB
Pathology (II)	Superlongation
Pathology (III)	Phoma disease
Entomology	Spider mites
Physiology	Photosynthetic activity

one cycle of crossing with M Col 647, dozens of high harvest index hybrids with CBB resistance resulted. CBB resistance is apparently multigenic. Even in Taiwan M Col 647 progenies have shown high levels of resistance (Leu, personal communication) suggesting that CBB resistance may be relatively stable.

Superelongation resistance

There are two kinds of resistance sources (see Pathology section) one kind includes cultivars such as M Col 803 and M Mex 52 which up to the present have been completely resistant and have not shown disease symptoms even under heavy innoculation, and the second kind, including cultivars like Llanera, M Col 22 and M Col 638 which are basically susceptible to the disease although it develops slowly on these cultivars during the first months of growth. The breeding strategy against this disease will depend on the future investigations by the pathology group as to which of the two types of resistance is better.

Phoma disease and cold tolerance

A joint effort among the Pathology, Physiology, Agronomy and Breeding groups revealed that selected cassava genotypes gave high yields even under an annual average temperature of 20°C or at an altitude of 1,800 meters near the equator where Phoma disease is prevalent. It was also found that Phoma resistance was genetically independent of cold tolerance. Popayan and several other cultivars have been identified as having an acceptable level of Phoma resistance and cold tolerance so that several thousand hybrids were made with Popayan in an attempt to combine high harvest index and other desirable agronomic characters with Phoma resistance and cold tolerance.

Higher dry matter content

M Col 22, the most frequently used parent in CIAT hybridizations during 1973 because of its very high harvest index and dry matter and starch content, was frequently crossed with M Col 655A, M Col 1292 and M Ven 270, also high in dry matter content and many lines with very high dry matter content, resulted. Twelve lines which have constantly shown more than 40 percent root dry matter content are kept for hybridizations. However, several lines such as M Col 670A and M Col 1468 which have some favorable characters were dropped from the list of cross parents because of their very low dry matter content.

Post-harvest durability

One cultivar from the original germplasm and eight hybrids are in the list of hybridizations (see Root Durability Section).

Male-sterile lines

Since the occurrence of self-pollination is unexpectedly high with normal flowering types and the self-pollinated offsprings are generally useless (CIAT Annual Report, 1974), the use of male-sterile lines is highly recommendable in collecting openpollinated seeds. The following male-sterile lines are being used: M Col 113, M Col 755, M Col 882, M Col 884, M Col 1052 and M Mex 1. However, male-sterile hybrids with more desirable agronomic characteristics are being sought.

Dry Matter and Starch Content

In three varietal experiments done during 1975 and 1976 in CIAT, the relationship between root specific gravity and dry matter content of the roots was analyzed (Fig. 31). The regression of root dry matter content on the specific gravity was highly significant ($r^2 = 0.839^{**}$)and there was not much difference between different years. The deviation from the regression is considerable but is small when compared to the dry matter variation of

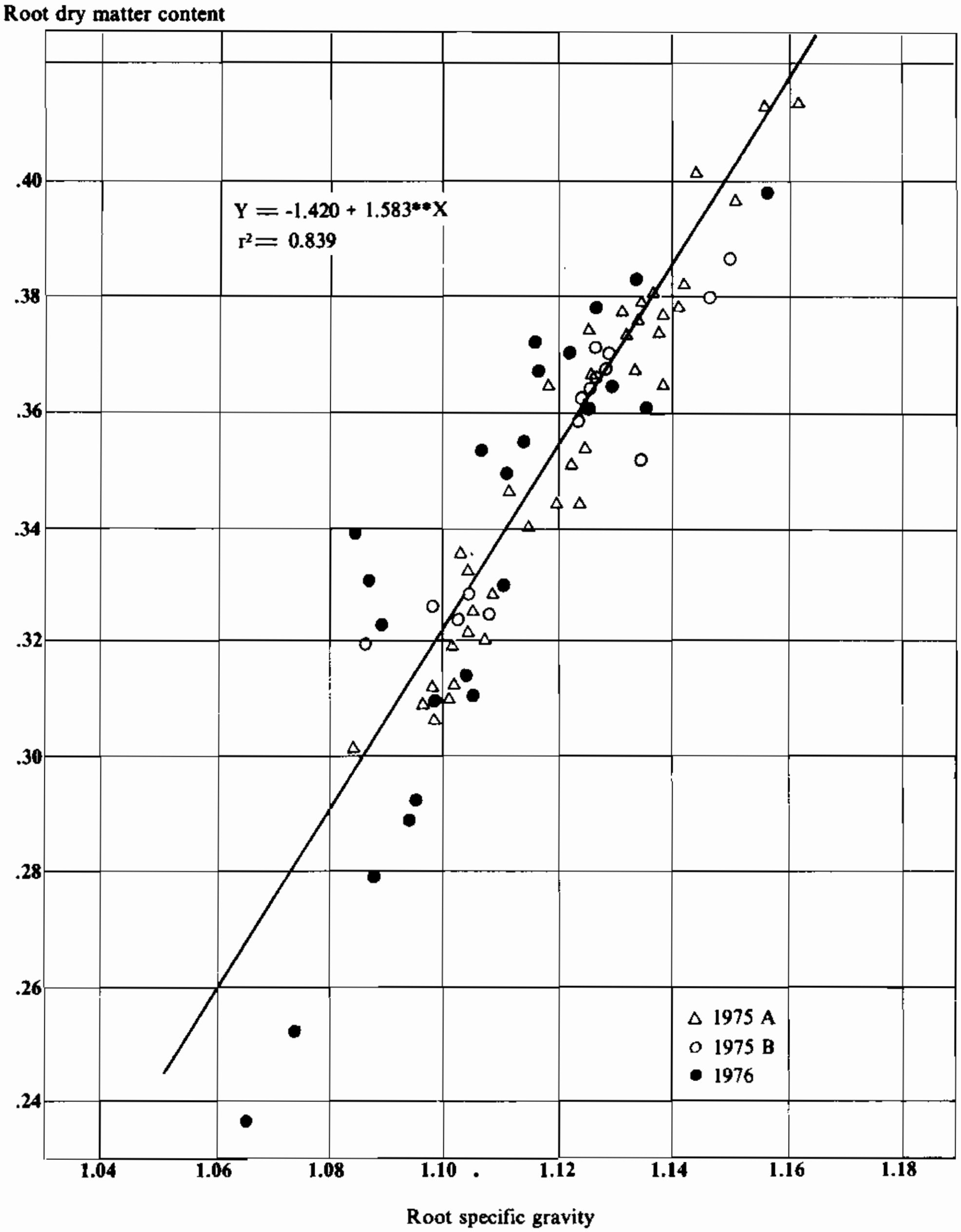


Figure 31. **Regression of cassava root specific gravity and dry matter content of the root in three trials.**

0.23-0.41 found in CIAT collections. Hence, this method can safely be used for selection.

Varietal root dry matter content in the 1974 experiment showed high correlation with that in the 1975 experiment (Fig. 32,

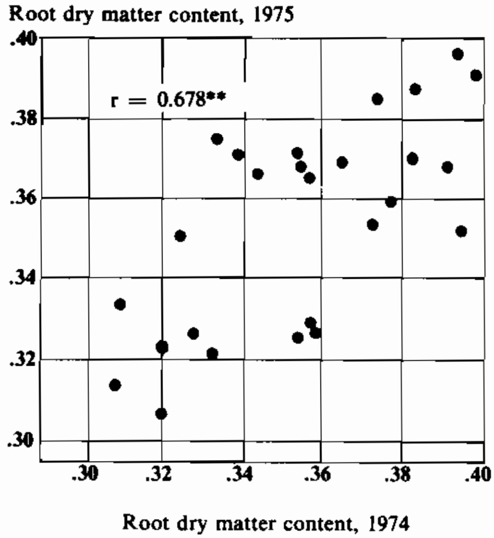


Figure 32. **Relationship between cassava root dry matter contents in 1974 and 1975.**

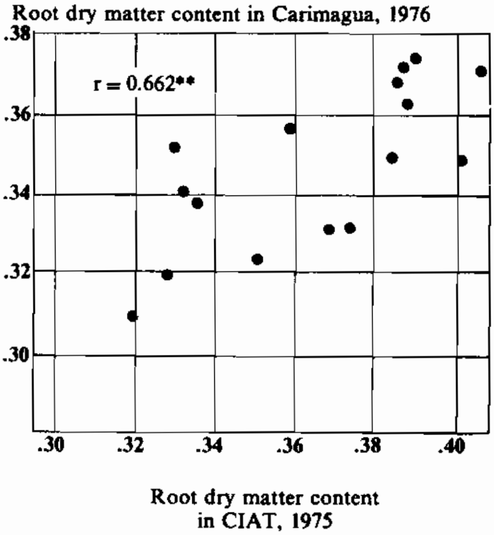


Figure 34. **Relationship between root dry matter contents of cassava at CIAT and Carimagua.**

r=0.678**) which was highly correlated with the 1976 experiment (Fig. 33 r = 0.695**). The varietal root dry matter content in CIAT was highly correlated that in Carimagua (Fig. 34, r = 0.662**) and Caribia (Fig. 35, r =0.641**). These data indicate that root dry matter content, which is almost parallel with starch content (CIAT Annual Report 1975) is a genetic character which is highly stable over a wide range of environmental conditions.

An analysis with 37 different crosses showed that in root dry matter content the regression of parental value on the average

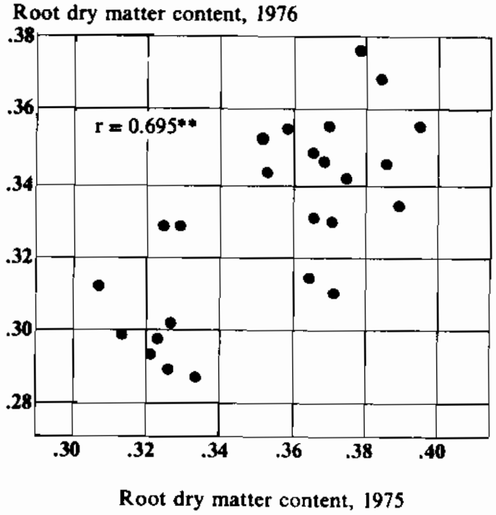


Figure 33. **Relationship between root dry matter content in cassava in 1975 and 1976.**

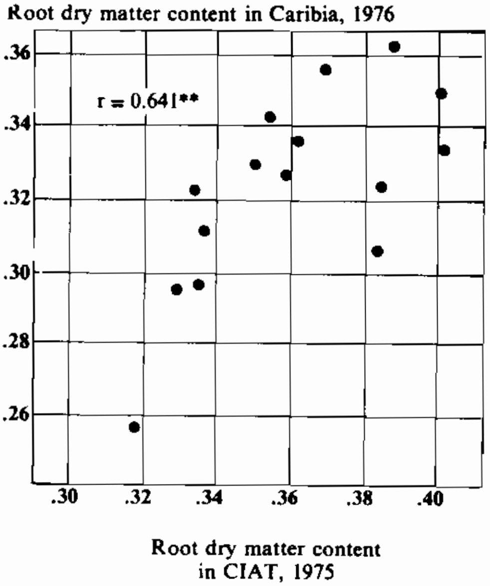


Figure 35. **Relationship between root dry matter contents of cassava at CIAT and Caribia.**

of corresponding F_1 population was highly significant (Fig. 36). The effect of additive genes must be significant and high dry matter content of some genotypes is expected to be transferred to other favorable genotypes without much difficulty.

In one of the varietal experiments in CIAT, the relationship of root dry matter content with root fresh weight yield, root dry matter yield and HCN content of the roots were analyzed. The root dry matter content was not correlated with the root fresh weight yield but significantly correlated with the dry matter yield (Fig. 37, r=0.407**). The same analysis was also made with F_1 populations of several crosses. In all of these populations, the correlation between root dry matter content and dry matter yield tended to be positive, although in some of these populations, the correlation was not as strong as in the varietal population. Nevertheless, the data indicate that improvement in root dry matter content never leads to a reduction in root yield both in fresh weight and dry matter basis. There was no sign that root dry matter content was associated with HCN content (Table 33). It is known (CIAT Annual Report, 1973) that HCN content is not correlated with insect resistance (thrips and hornworm), with disease resistance (Cercospora leaf spot) or starch content; the popular legend that bitter cassava is disease and insect resistant, and good for starch production has to be challenged.

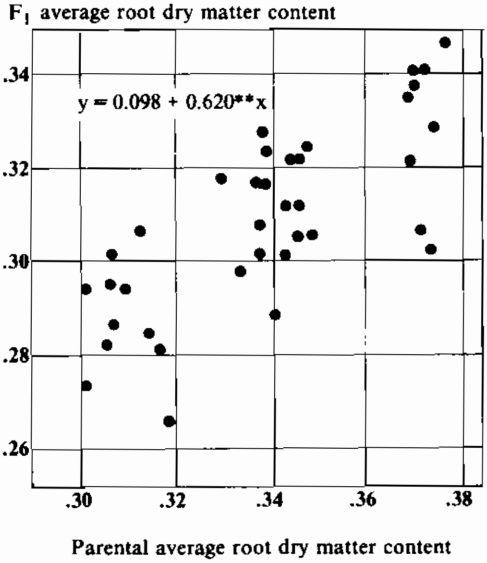


Figure 36. **Regression of F_1 average (measured at 10 months) on the parental average root dry matter content of cassava.**

Twelve new hybrid lines have been included in the list of hybridizations for higher dry matter content.

Post-Harvest Durability of Roots

Observations of harvested cassava roots reveal that there are at least two phases of root deterioration after harvest, a vascular streaking and a general, total root decay. The vascular streaking occurs 2-7 days after harvest. This does not necessarily lead immediately to the total rotting of the root. However, there is no doubt that the vascular streaking drastically affects the quality of the roots especially when cassava roots are consumed directly as human food. The general and total decay usually occurs 1-2 weeks after harvest on roots already affected by vascular streaking when the internal root condition turns from anaerobic to aerobic.

M Col 22 is highly susceptible to vascular streaking (Fig. 38) but fairly resistant to general rotting (Fig. 39). M Col 670A is resistant to vascular streaking (Fig. 38) but susceptible to general rotting (Fig. 39). Llanera, like the majority of genotypes, is susceptible to both (Fig. 38 and 39). M Col 1816 is resistant to both (Fig. 12). The root of M Col 1816 can be eaten even two weeks after harvest. These suggest that root durability is a genetic character and that vascular streaking and general rotting are independent of each other.

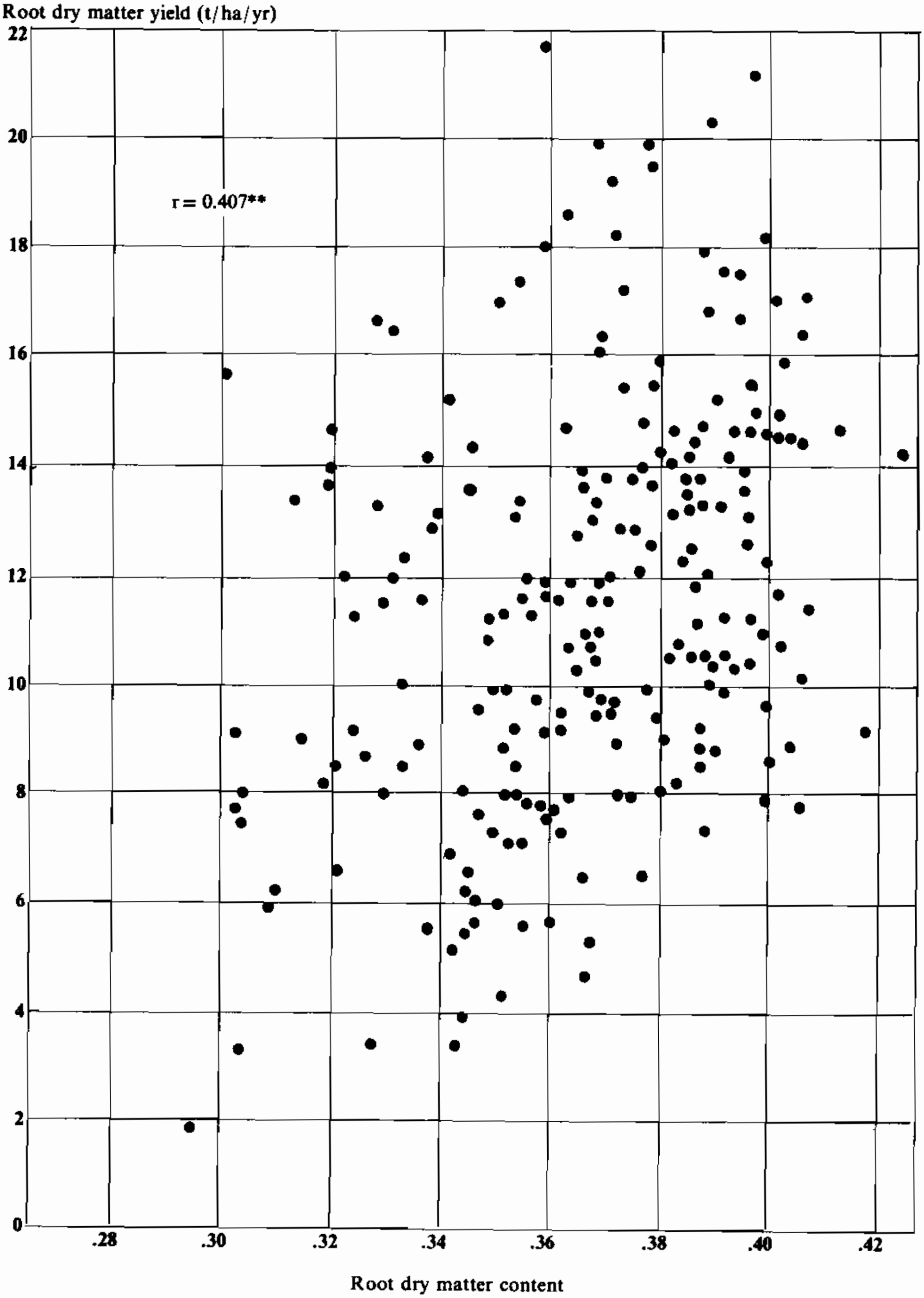


Figure 37. **Relationship between root dry matter content and dry matter yield of cassava.**

Table 33. HCN content in cassava roots and root dry matter content.

HCN rating (at 12 months)	No. of cultivars	Average root dry matter content (at 12 months)	Minimum root dry matter content within rating class	Maximum root dry matter content within rating class
1	5	.369	.349	.387
2	32	.362	.243	.417
3	87	.370	.302	.455
4	82	.362	.295	.406
5[1]	10	.356	.319	.395

[1] Usually unfit for direct human consumption.

Two ways of evaluating genotypes for root durability were adopted: (a) a quantitative rating of vascular streaking on the roots kept under shade for a week after harvest, and (b) a quantitative rating of the combination of vascular streaking and general rotting of the root kept under the sun in the field for two weeks after harvest.

Varietal rating in vascular streaking was fairly constant in 1975 and 1976 (Fig. 40, r=0.671**). The CIAT rating was significantly correlated with Carimagua (Fig. 41) and Caribia. However, the correlations were rather low between CIAT and Carimagua (r = 0.344**) and between CIAT and Caribia (r = 0.262**).

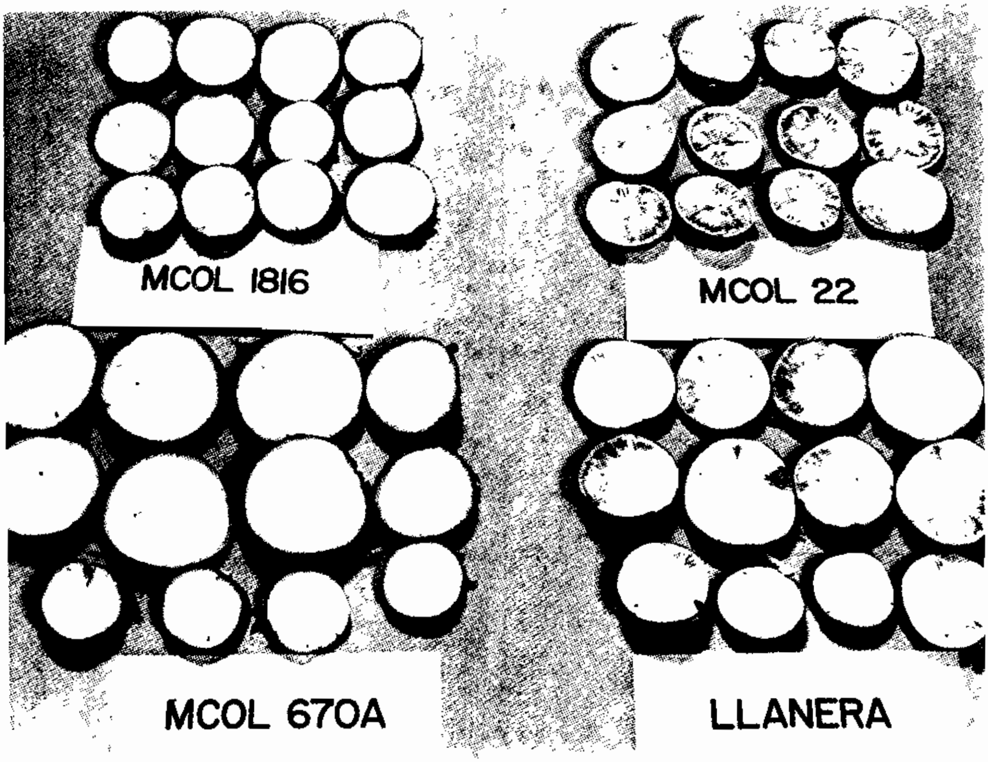


Figure 38. Roots of four cassava cultivars one week after harvest.

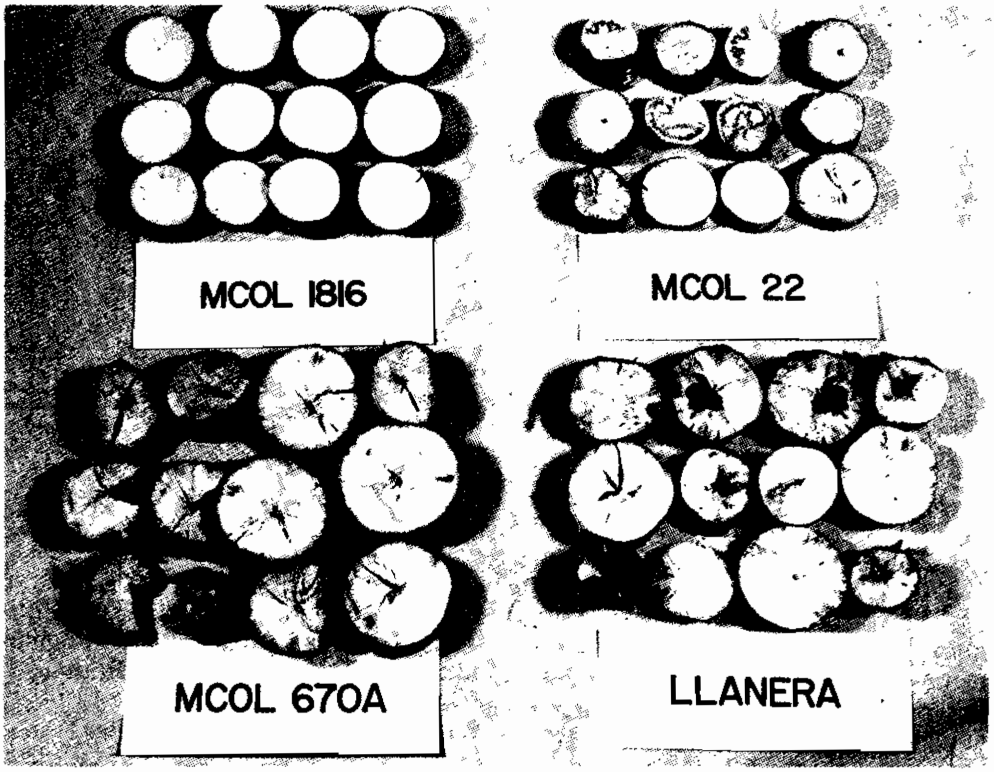


Figure 39. Roots of four cassava cultivars three weeks after harvest.

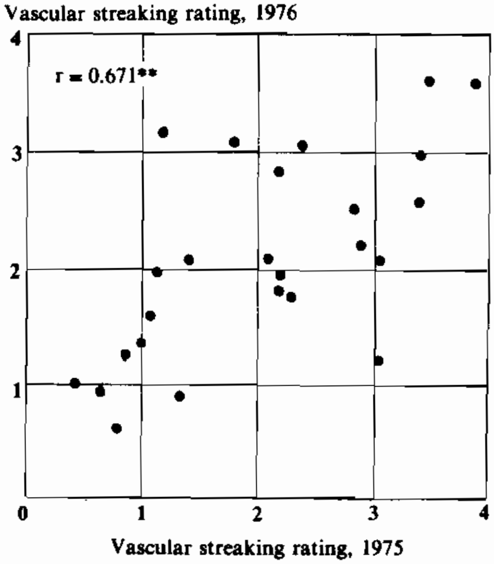


Figure 40. Relationship between varietal vascular streakings of cassava in 1975 and 1976.

This suggests that genotype x environment interaction may be significant in post-harvest durability.

An analysis with 43 different crosses showed that in vascular streaking the regression of parental values on the average of corresponding F_1 populations was highly significant (Fig. 42). Another analysis with 56 crosses in a field evaluation of root rotting two weeks after harvest indicated that the regression of parental values on the F_1 average was also highly significant (Fig. 43). The data demonstrate that the effects of additive genes are highly significant in root durability.

In one of the varietal experiments at CIAT, an analysis was made on the correlation of root durability with yield characters. The vascular streaking was

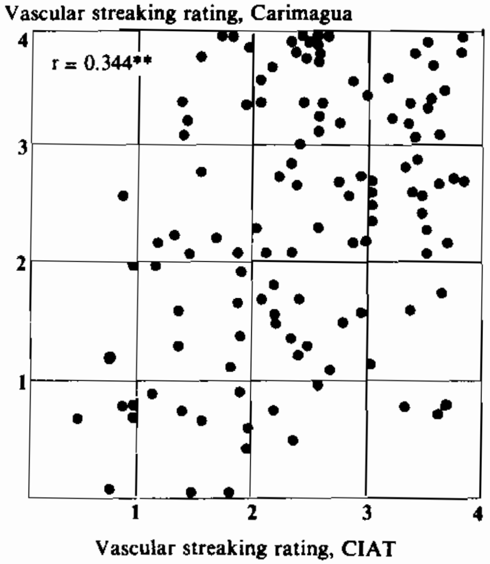


Figure 41. **Relationship between vascular streaking of cassava in CIAT and Carimagua.**

positively correlated with the root dry matter content (Fig. 44). Athough there is a fair amount of variability left after the limitation imposed by the correlation, there may be some difficulty in combining good root durability with high dry matter content.

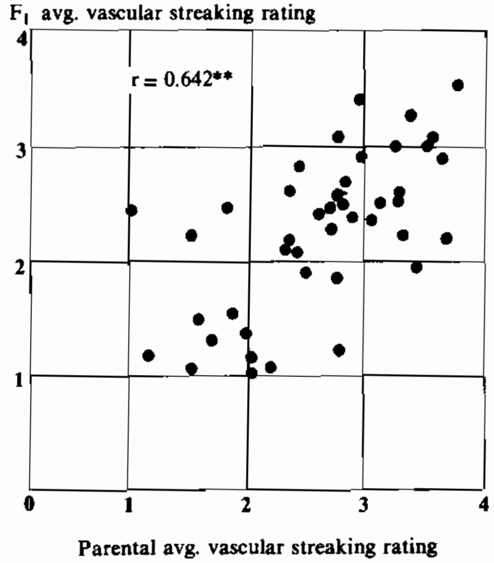


Figure 42. **Regression of F$_1$ average on the parental value for vascular streaking of cassava, 1976.**

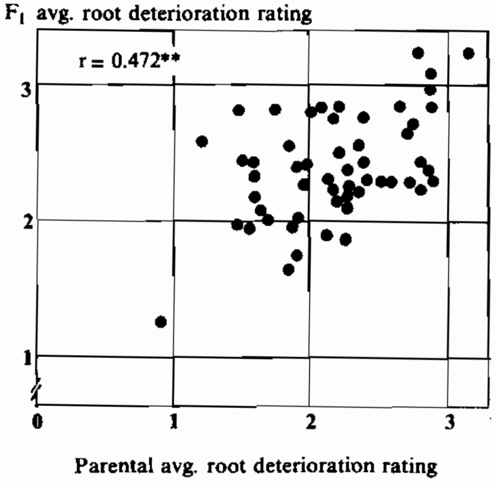


Figure 43. **Regression of F$_1$ average on the parental value of cassava root deterioration in the field.**

Nine genotypes have been identified as sources of genes for good root durability and are actively used in hybridization.

Distribution of Genetic Material

Since the beginning of the cassava breeding program, there have been numerous requests for genetic materials

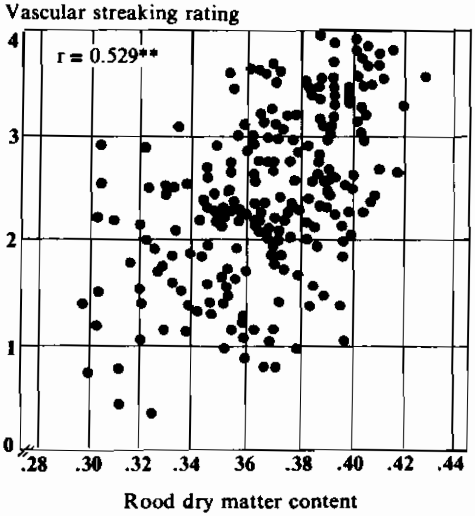


Figure 44. **Relationship between root dry matter content and root rotting in cassava.**

from many parts of the world. A total of 21,750 hybrid seeds and 50,100 open-pollinated seeds have been distributed to 28 countries (Table 34).

Table 34. **Summary of the distribution of cassava genetic materials, 1973-76.**

Country	Hybrids	Open-pollinated seeds	Stakes
Brazil	4,400	2,000	20
Mexico	200		160
Venezuela			200 (Entomology)
Ecuador			20 (Agronomy)
Nicaragua			6
Dominican Republic			6
Trinidad	600		6
Jamaica			6
Bahamas			6
India	1,300		
Thailand	3,900	4,500	
Malaysia	900		
Philippines	1,450		12
Indonesia	900		
Taiwan	1,200		6
Japan	2,000		12
Australia	900		50
New Zealand	300		
IITA (Nigeria)	1,550	41,500	
Kenya	400		6
Tanzania	1,000		
Tonga	350		
Samoa	350		
Seychelles	250		6
Hawaii			6
United States		1,000	
Canada		100	
United Kingdom		1,000	
Total	21,750	50,100	528

AGRONOMY

The agronomy program has continued to emphasize the propagation and testing of promising lines over a wide range of ecological conditions (Table 35). Selected

Table 35. Sites in Colombia and their main soil and climatic characteristics where the second cycle of promising ICA-CIAT varieties were planted during the 1975/76 cycle.

Locations	Altitude (m)	Mean temperature (°C)	Rainfall (mm)[1]	Relative humidity (%)	Soil type	pH	Organic matter (%)	P (Bray II) (ppm)	K (meq/100 g)
Media Luna (Magdalena)	10	27.2	887	77.6	Sandy	6.6 (N)[2]	0.7 (L)[2]	4.8 (L)[2]	0.08 (L)[2]
Carimagua (Meta)	200	26.1	2,323	75.2	Sandy Loam	4.9 (VA)	1.9 (M)	1.1 (L)	0.04 (L)
Nataima (Tolima)	430	27.8	1,064	69.0	Loam	7.1 (Al)	1.2 (L)	77.5 (H)	0.23 (M)
Rionegro (Sant. del Sur)	480	26.6	1,746	79.5	Clay Loam	5.1 (A)	2.0 (M)	4.9 (L)	0.17 (M)
El Tambo (Cauca)	900	26.0	850	75.0	Clay	4.9 (A)	6.0 (H)	1.8 (L)	0.15 (M)
CIAT (Valle del Cauca)	1,000	23.5	901	74.5	Clay	6.4 (N)	3.3 (M)	36.2 (H)	0.47 (H)
Caicedonia (Valle del Cauca)	1,100	22.7	1,214	80.7	Silt Loam	5.6 (A)	2.9 (M)	7.1 (L)	0.20 (M)
Pereira (Risaralda)[3]	1,480	19.0	3,817	80.0	Silty Clay	5.1 (A)	8.2 (H)	8.2 (L)	0.08 (L)
Popayán (Cauca)[3]	1,760	18.0	2,998	85.0	Loam	5.0 (A)	7.5 (H)	2.4 (L)	0.44 (H)

[1] Rainfall data corresponds to actual rain during growth period

[2] Fertility codes: (N) neutral; (Al) alkaline; (VA) very acid; (A) acid; (L) low; (M) medium; (H) high.

[3] Pereira and Popayán sites correspond to 1974/75 cycle.

lines have continued to outyield local lines in Colombia and the first results from outside Colombia have shown these selected lines to be superior in Guyana.

Regional Trials

The regional trials test new selected lines under technology which demands low cost inputs and which farmers can readily accept. Special emphasis is placed on low levels of chemical inputs. The details of this "low level technology" were described last year (CIAT Annual Report, 1975). This year two trials were planted in cooperation with ICA, three with Federación Nacional de Cafeteros, two with Integrated Rural Development Projects, and three with local Secretariats of Agriculture, with the remaining nine trials being under CIAT's direct supervision and control.

The major problems experienced in the field this year were a heavy attack of CBB and superelongation disease in Media Luna, a severe white fly attack in Nataima, and very heavy infestations of thrips in Caicedonia.

Table 36 shows the resistance of the promising varieties to some important insects and diseases. Because of the susceptibility of many varieties to a few of these pests, the improved cultural practices discussed below should be used.

Some agronomic and commercial characteristics of these varieties are shown in Table 37. Plant height and strong winds may affect lodging, while ease of harvest affects labor efficiency.

Mean starch content of the promising varieties varied from 30 to 36 percent with a minimum of five trials for variety mean. Furthermore, site means varied from 22 to 36 percent. However, the relative varietal values to the site mean were stable (see Varietal Improvement Section). Where the best regional variety produced 36 percent starch in one site, the best promising line produced 38 percent. In all trials, except for the Media Luna site, the starch content of the best promising line was greater than that of the best local variety.

A similar analysis can be done regarding dry matter content. The mean dry matter content of the promising varieties varied from 32 to 38 percent with a minimum of five trials for variety mean. Furthermore, site means varied from 24 to 38 percent. However the relative varietal values to the site mean are stable. Where the best regional variety produced 38 percent dry matter the best promising had 40 percent. In all sites, except Media Luna, the best promising cultivar had a greater dry matter content than the best regional line.

Of the nine trials so far harvested, the average of the best local line in all sites was 16.3 t/ha (Table 38), or nearly double the national average yield of 8.5 t/ha. These results suggest that simple improved cultural practices can considerably increase yields. The most important practices are: (a) using selected stakes free of CBB and superelongation; (b) good soil preparation; (c) timely weed control; and, (d) adequate plant population at harvest (10,000 plants/ha).

When the best promising line in each site is used, the yield shows a further increase up to an average of 26.8 t/ha (Table 38), showing that the combination of improved cultural practices with selected varieties can increase national average yield 3-4 times. The two varieties M Mex 59 and CMC 40 consistently yield more than the local varieties in all sites below 1,200 m msl. CMC 40 showed tremendous yield stability over a very wide range of soil conditions giving 35.5 t/ha in the fertile soils of CIAT and 23.2 t/ha in the infertile Llanos Orientales. This variety, however, is very susceptible to thrips and has very low starch content (Tables 36 and 37). Nevertheless the data support the hypothesis presented in previous sections that a single genotype may be adapted to a

Table 36. **Resistance of promising cassava varieties to some important insects and diseases in regional trials during 1975/76 cycle.**

	Resistance to[1]						
					Leaf spots		
Varieties	Thrips	White fly	Bacteriosis	Super-elongation	*Phoma* sp.	*C. henningsii*	*C. vicosae*
M Col 22	T	S	S	R	S	R	T
M Col 113	R	—	S	S	S	T	S
M Col 673	S	S	S	T	S	R	S
M Col 677	S	S	S	—	T	T	T
M Mex 23	R	—	S	T	S	T	S
M Mex 52	R	T	S	T	S	T	T
M Mex 55	T	—	S	S	S	S	S
M Mex 59	S	S	S	T	S	R	R
M Ven 119	S	T	S	S	S	T	T
M Ecu 159	S	T	S	S	—	—	—
CMC 9 (M Col 1438)	T	—	T	R	S	S	S
CMC 40 (M Col 1468)	S	S	S	S	S	R	T
CMC 57	T	R	S	S	S	—	—
CMC 72	T	R	S	S	S	—	—
CMC 76 (M Col 1505)	S	—	S	S	S	R	T
CMC 84 (M Col 1513)	S	S	S	S	S	R	T
CMC 86	T	—	S	S	S	S	S
CMC 92	T	—	S	S	R	S	S
CMC 137	T	T	S	S	S	S	S

[1] (R) Resistant; (S) Susceptible; (T) Tolerant; (—) Not evaluated.

Table 37. **Some agronomic and commercial characteristics of the promising varieties used in regional trials during 1975/1976 cycle.**

Varieties	Plant height[1] (m)	Ease of harvest[1]	Starch[2] (%)	Dry matter[2] (%)
M Col 22	1.50	easy	31.9	34.0
M Col 113	1.98	difficult	31.1[3]	33.2[3]
M Col 673	2.00	moderate	32.1	34.2
M Col 677	2.00	moderate	31.2	33.3
M Mex 23	2.23	difficult	36.2	38.4
M Mex 52	2.20	moderate	32.0	34.1
M Mex 55	1.70	easy		
M Mex 59	1.85	moderate	31.5	33.7
M Ven 119	2.00	moderate	30.5	32.5
M Ecu 159	2.20	moderate	26.0[3]	28.0[3]
CMC 9 (M Col 1438)	2.00	moderate	33.1[3]	35.3[3]
CMC 40 (M Col 1468)	2.35	easy	29.8	32.0
CMC 57	2.50	moderate	27.8[4]	29.8[4]
CMC 72	2.80	moderate	27.1[3]	29.1[3]
CMC 76 (M Col 1505)	2.25	easy	34.5	36.7
CMC 84 (M Col 1513)	2.35	easy	33.8	35.9
CMC 86	3.00	easy	24.8[4]	26.7[4]
CMC 92	3.00	easy	—	—
CMC 137	3.00	easy	19.5[4]	21.4[4]
Chiroza Gallinaza	—	—	34.4[4]	36.6[4]
Best Regional[5]	—	—	36.1	38.3

[1] Under CIAT's conditions

[2] Average of 1976 regional trials.

[3] Mean value from less than five location

[4] Data from only one site

[5] Among all regional varieties used as the controls in all trials.

wide range of soil and climatic conditions when temperature is above 22ºC.

In the two cooler sites, Popayán and Pereira, the highest yields were obtained by CMC 92 and M Col 113 respectively. CMC 92 is very tolerant of Phoma and M Col 113 is reasonably tolerant of cooler conditions when Phoma is not present. The yield of 24 t/ha after 14 months in Popayán suggest that with carefully selected lines high yields can be obtained in cooler areas (Table 38).

This year was much drier than the previous one and yields in many sites were reduced; the overall mean yield of the same five trials was reduced from 26.4 to 18.1 t/ha as rainfall decreased from 1,502 to 1,162 mm/yr. (Table 39).

International Regional Trials

Yield data from the first two international regional trials has been collected. These were planted in Guyana by Dr.

Table 38. Fresh root yield of the ICA-CIAT promising varieties from nine locations in Colombia.

Locations	Media Luna	Carimagua	Nataima	Rionegro	El Tambo	CIAT	Caicedonia	Pereira	Popayán
Days to Harvest	333	335	337	326	335	367	363	400	428
Varieties	Root yield fresh weight (t/ha/yr)								
M Mex 59	18.8**	25.6*	26.7**	24.5**	18.7	—	23.7**	10.5*	0.9
CMC-40 (M Col 1468)	19.2**	23.2*	35.3**	16.1**	22.8*	35.5**	—	16.7*	3.8
CMC-84 (M Col 1513)	15.0**	26.8*	16.3**	18.2**	25.9*	24.6**	—	18.1	1.0
CMC-76 (M Col 1505)	—	21.8	—	20.5**	17.1	29.7**	—	20.8*	0.5
M Col 22	10.5**	15.5	23.2**	—	11.1	25.1**	—	8.8	0.3
M Col 113	—	21.9	—	—	—	—	—	20.7*	5.0
M Col 673	—	13.8	4.8	20.1**	10.3	—	22.2	—	—
M Ven 119	8.5	18.4	16.9	14.3	15.3	23.7	—	—	—
M Ecu 159	—	—	15.9	—	—	22.8	18.3	—	—
M Mex 23	—	18.3	—	—	10.4	24.5**	17.3**	17.0	1.0
M Mex 52	4.6	19.8	16.8	11.1	13.0	23.0	20.7	—	—
M Col 677	8.4	—	6.3	20.8*	—	27.5*	29.2*	—	—
Other varieties									
Maximum	—	24.4 (1)	23.4*(2)	—	9.6(4)	—	11.0(3)	13.1(4)	23.8*(5)
Minimum	—	—	4.7 (3)	—	—	—	—	—	0.8(4)
Regional varieties									
Maximum	4.0(9)	22.9(4)	—	11.7 (8)	22.3(6)	22.1(6)	15.8(1)	16.9(6)	14.5(7)

* & ** Respectively, varieties approved for second and third year evaluation at the same location

(1) Chiroza Gallinaza. (2) CMC 57, (M Col 1486). (3) CMC 72, (M Col 1501). (4) CMC 9, (M Col 1438). (5) CMC 92, (M Col 1522). (6) M Col 113. (7) Amarilla. (8) Colombiana and Torama Negrita. (9) Blanca Mona.

Table 39. **The effect of rainfall on cassava fresh root yield at five locations[1] in Colombia during two growing cycles.**

Cycle	Mean rainfall (mm/cycle)	Yield average (t/ha)
1974/75	1,502	26.4
1975/76	1,162	18.1

[1] Locations: Media Luna, Rionegro, Nataima, CIAT and Caicedonia..

Abdul Wahab, of the Guyana Sugar Corporation. They have kindly made their data available to CIAT.

Both trials were planted at Enmore, one on Anira peat No. 20 and the other in Inki clay No. 100. Both soils are extremely acid, pH 3.4 and 4.1, respectively. The main edaphic and climatological data of the site are shown in Table 40.

Of the 12 varieties tested, seven were from Guyana, one (Del Pais) was introduced from Puerto Rico, and four (Llanera, M Col 673, M Mex 23 and M Mex 59) came from CIAT's cassava collection.

Standard cultural practices were used. Plant population was about 12,000 plants/ha. Lime was applied in the form of aragonite at 6.7 t/ha. Nitrogen, P_2O_5 and K_2O, at rates of 200, 67 and 134 kg/ha, were split-applied in bands. Secondary and micronutrients were also applied to prevent any possible deficiencies. Weeds were controlled manually and hornworm and shoot fly attacks were chemically controlled.

Yield data of both trials are shown in Table 41. On Anira peat, M Mex 59 yielded 30.5 t/ha, significantly higher than all other varieties. However, on Inki clay No 100, M Mex 59 produced a fresh root yield (23 t/ha) which was similar to Uncle Mack and Del Pais, which yielded 22 t/ha. On both soils, the average of the introduced varieties was significantly higher than the average of the regional varieties.

Highest producer of root dry matter was M Mex 59 with 25 kg/ha/day on Anira Soil, and both M Mex 59 and Uncle Mack on Inki Clay soil with 21 kg/ha/day (Table 41).

Rapid Propagation

The vegetative cassava propagation method used commercially gives a slow rate of plant multiplication. Development of techniques for rapid propagation initiated at CIAT in 1971 have shown that it is possible to produce more than 36,000 normal plant cuttings after one year from one adult plant. However, it has been pointed out that this method is mainly suitable for use at research stations producing planting material.

This year, a root yield of plants originating from the rapid propagation

Table 40. **Main edaphic and climatological characteristics for two Guyana sites used in International Yield Trials for cassava during the 1975/76 cycle.**

Soil type	Altitude (m above msl)	Mean temperature (°C)	Rainfall (mm/year)	Relative humidity (%)	Soil classification	pH	Organic matter (%)	P ruog (ppm)	K (meq/100 g)
Anira Peat No. 20	0	26.4	3,310	82.9	Silty clay	3.4(VA)[1]	32.0(H)	26.3(M)	0.45(H)
Inki Clay No. 100	0	26.4	3,310	82.9	Clay	4.1(VA)	7.5(H)	1.1(L)	0.3(M)

[1] Fertility codes: (N) neutral; (A) acid; (VA) very acid; (L) low; (M) medium; (H) high.

Table 41. Fresh root yield and dry matter production of 12 cassava varieties grown in Guyana.

		Anira Peat No. 20				Inki Clay No. 100	
Variety	Ranking	Fresh wt. yield[1] (t/ha)	Dry matter (kg/ha/day)	Variety	Ranking	Fresh wt. yield[1] (t/ha)	Dry matter (kg/ha/day)
M Mex 59	1	30.5	25.2	M Mex 59	1	23.0	21.3
M Mex 23	2	19.3	16.7	Uncle Mack	2	22.0	21.4
Del Pais	3	19.3	18.6	Del Pais	3	22.0	18.1
M Col 673	4	18.2	19.5	M Mex 23	4	17.6	16.8
Twelve Month	5	16.4	16.5	Four Month	5	17.4	15.1
Llanera	6	15.2	14.9	Llanera	6	16.8	18.3
Uncle Mack	7	15.2	15.6	M Col 673	7	16.4	19.6
Brancha Butterstick	8	14.2	14.8	Brancha Butterstick	8	15.2	15.1
R. Singh	9	13.0	14.6	R. Singh	9	14.7	15.5
Four Month	10	12.0	11.3	Twelve Month	10	12.3	12.0
Bitter Stick	11	11.7	11.2	Bitter Stick	11	11.0	9.5
Chinese Stick	12	7.6	6.0	Chinese Stick	12	9.0	7.0
Avg. introduced varieties		20.5	18.9			19.1	18.8
Avg. regional varieties		12.8	12.9			14.5	13.6
Avg. best introduction		30.5	25.2			23.0	21.3
Avg. best regional		16.4	16.5			22.0	21.4

[1] Harvested at 12 months.

system was compared to yields from plants started as stem cuttings as normally used, after a similar growth period.

These five cassava propagation techniques were tested:

(1) Rooting in peat pots (8-cm diameter) filled with clay loam soil for 18 days and subsequent transplanting to the field without removal of the pots.
(2) Rooting in waxed paper cups (5-cm diameter) filled with clay loam soil for 18 days and subsequent transplanting to the field after careful removal of the cups
(3) Rooting in flasks (25-ml glass flasks) filled with sterile water for 18 days and subsequent transplanting to the field at the long root stage (1-cm long).
(4) Rooting in flasks (25-ml glass flasks) filled with sterile water for 8-10 days and subsequent transplanting to the field at the callus formation stage.
(5) Planting 20-cm long stem cuttings directly to the field as a control treatment.

Planting distance in the field was on 1 x 1-meter ridges. The plantules were transplanted into holes and buried to the base of the lowest leaf, taking care not to damage the roots. Plants were watered daily for the first 27 days.

Yield, and components of yield of the cassava plants harvested at 10 months are shown in Table 42. Fresh root yield of the five treatments was not different at P=0.05, proving that root yield of plants originating from the rapid propagation

Table 42. **Yield and yield components of cassava plants planted by five systems and harvested at 10 months, CIAT, 1976.**

Treatment	Root yield (t/ha)	Total plant fresh wt. (t/ha)	Harvest Index	Total roots /plant	Thickened roots/ plant
Peat pots	29.2 a[1]	73.7 a	0.40 a	10.5 c	7.3 ab
Waxed paper cups	26.3 a	63.9 a	0.41 a	11.2 bc	7.1 abc
Long roots	20.8 a	59.6 a	0.34 a	12.8 ab	5.8 c
Callus	22.7 a	57.5 a	0.40 a	9.5 c	6.1 bc
Stakes	21.1 a	81.2 a	0.26 b	13.6 a	7.4 a
C.V. (%)	25.0	18.0	13.0	11.4	8.0

[1] Values in the same column with the same letter are not significantly different at the .05 level according to Duncan's new multiple range tes

methods are at least as good as the standard stake planting method and even showing a tendency to produce higher yields than with the traditional method. Plant roots from the peat pot treatment are not damaged at transplanting while those transplanted at the long root stage are probably the most affected in the process, consequently showing the two extremes in yield. Harvest index was less (P=0.05) for the stake planting method, and although it had one of the higher total number of roots per plant, the number of thickened roots was the same for stake, peat pots, and waxed paper cups treatments (Table 42).

The favorable yield of plants from rapid propagation techniques would therefore enable such plants to be utilized under the following circumstances:

(1) For the establishment of new farms where problems of insufficient planting material in the form of stakes are encountered.

(2) When a disease outbreak occurs and there is a need for destruction and elimination of diseased plants, replanting can then be done with disease-free material.

(3) Rapid propagation techniques save the time required in the multiplication of plants to be used as stakes when releasing new varieties or evaluating new varieties in regional trials.

Improved Rapid Propagation

The CIAT rapid propagation system for cassava as developed and recommended called for shoots growing on the two-node stem sections to be cut and rooted in flasks containing sterile water. The rooted cuttings were then planted in the field. An improved technique is now being used at CIAT and a few other locations. Shoots are cut at the same stage as previously (when they are about 8 centimeters long) and planted directly into the field. Water is supplied to provide adequate moisture during the first two weeks. This improvement makes the system even simpler, faster and less expensive, however losses can be great if management is not first class.

SOILS

Among tropical food crops cassava is uniquely adapted to acid soils of rather low fertility status. During 1976 major emphasis was directed to determining the crop's nutritional requirements under these conditions.

Fertilization of Acid Soils

Fertilizer experiments were conducted in Carimagua, which has an extremely acid and infertile soil representative of many oxisols and ultisols where cassava is frequently grown in Latin America. Under these conditions cassava response to nearly all essential elements as well as to their interactions could be studied. The most economic levels, sources, times and methods of application were also determined.

The 1975/76 cassava trials in Carimagua suffered considerably from CBB infections. Eight trials seeded in early 1975 became infected and all were destroyed. In late 1975 many of these were replanted at an isolated location (Tabaquero), 17 kilometers from the main Carimagua headquarters site. These trials remained free of CBB and only at a later stage were they affected by superelongation, which seemed to have a minor effect on yield (see Pathology Section). The highest yield obtained was 36 t/ha with the variety M Col 1684, while most trials with the variety Llanera gave top yields between 20 and 25 t/ha.

All trials received a uniform lime application of 500 kg/ha as dolomitic limestone (115 kg Ca and 52 kg Mg/ha). Except for the elements under study the constant fertilization consisted of 100 kg N/ha as urea (50 kg at seeding, 50 kg at 120 days), 100 kg P_2O_5/ha as triple superphosphate (TSP) at seeding, 100 kg K_2O/ha (50 kg as K_2SO_4 at seeding, 50 kg as KCl at 120 days) and 10 kg Zn/ha as $ZnSO_4$, all applied in short bands 5-10 centimeters from the stake. All trials used Llanera as the test variety, and were harvested at 11.5-12 months after planting.

Phosphorus fertilization

To establish the phosphorus requirement of cassava and the most economical method of applying it, two trials were planted in Carimagua using different levels and sources of phosphorus. In the first trial (conducted in cooperation with the International Fertilizer Development Center), six rock phosphates from various parts of the world and of highly variable citrate solubility, were compared with TSP and basic slag at four levels of phosphorus application: 0, 50, 100 and 400 kg P_2O_5/ha. Average yields increased from 7.5 t/ha without applied phosphorus to 13.9, 17.1 and 19.9 t/ha with applications of 50, 100 and 400 kg P_2O_5/ha.

The most soluble phosphorus sources, TSP and basic slag, gave highest yields (Fig. 45). However, the more soluble rock phosphates from Gafsa (Morocco) and North Carolina (U.S.A.) also gave very good responses, while the less soluble rocks from Huila and Pesca (Colombia) and Florida (U.S.A.) gave lower but not significantly different yields. Only yields obtained with the least soluble rock from Tennessee (U.S.A.) were significantly lower from those obtained with TSP and basic slag.

In the second trial the effectiveness of TSP was compared with that of a number of other phosphorus sources including simple superphosphate (SSP), basic slag,

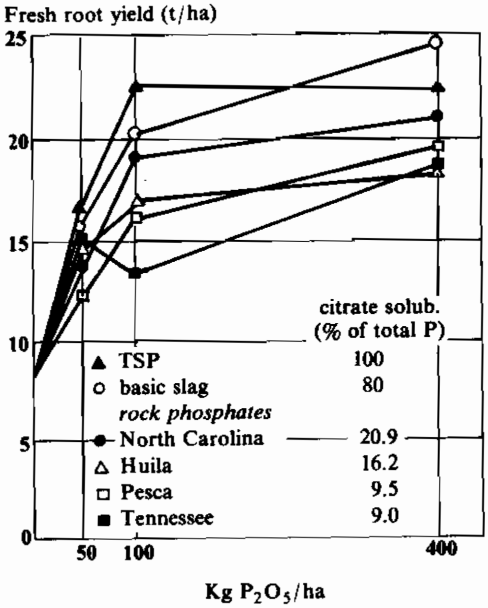


Figure 45. Cassava response to various levels of phosphorus applied as triple superphosphate (TSP), basic slag and various rock phosphates, in Carimagua.

and Huila rock phosphate, either by itself, mixed with elemental sulfur or sulphuric acid (20% acidulated). The highest yields were obtained with band-placed TSP and broadcast basic slag (Fig. 46). When the basic slag was band-placed plants suffered from severe phosphorus deficiency and yields were about half those obtained with broadcast basic slag. The SSP of local manufacture was only 43 percent citrate soluble (% of total phosphorus) and when band-placed was much less effective than TSP and slightly inferior to broadcast rock phosphate. The Huila rock phosphate was a good phosphorus source for cassava, but its effectiveness was considerably improved by partial acidulation or mixing with elemental sulfur (Fig. 46); the latter mixture gave yields equal to TSP. Although 37 kg/ha of sulfur had been applied to all treatments in the form of K_2SO_4, plants may have responded to the sulfur in SSP, and in the acidulated or sulfur-mixed rock phosphates; the high rate of application of these sources resulted in sulfur contents of the leaves above 0.32 percent which is approximately the critical content at five months of age.

Root yield showed a quadratic response while foliage yielded a linear response to phosphorus application (Fig. 47), indicating that foliage production is more responsive to phosphorus than root production. The harvest index increased to the level of 100 kg P_2O_5/ha and then decreased with higher phosphorus applications indicating that at rather low levels of phosphorus the plant utilized the absorbed phosphorus most efficiently for root production. Neither the percentage of the dry matter (33%) nor starch content (31%) were changed by phosphorus application.

The relation between cassava yield and phosphorus in the leaf blade at five months of age is shown in Figure 48. It is clear that

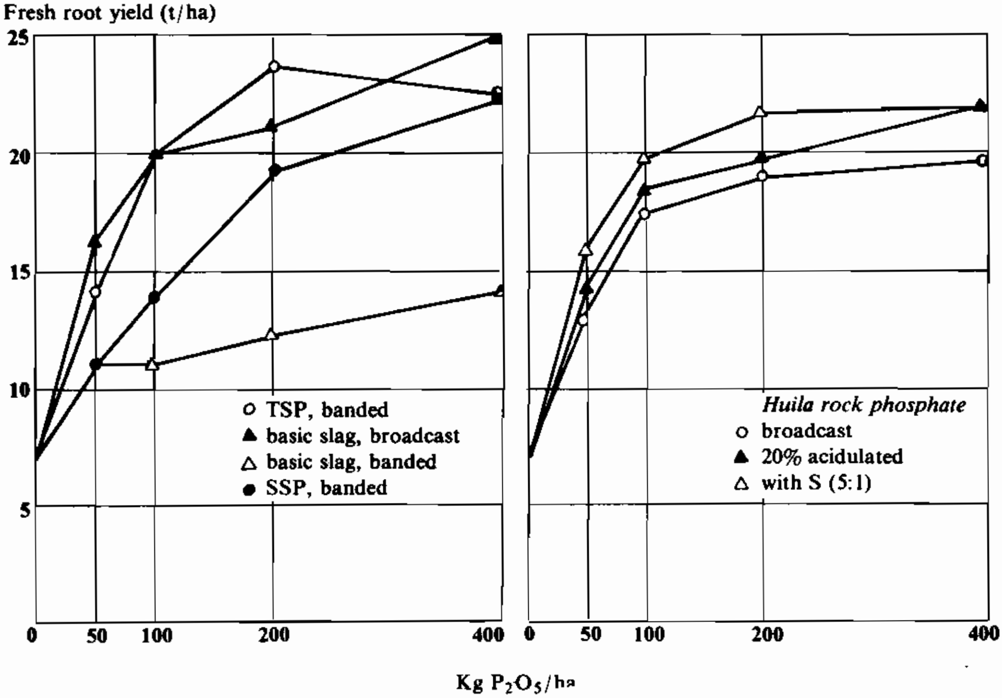


Figure 46. Cassava response to various levels and sources of phosphorus, applied either banded or broadcast, at Carimagua.

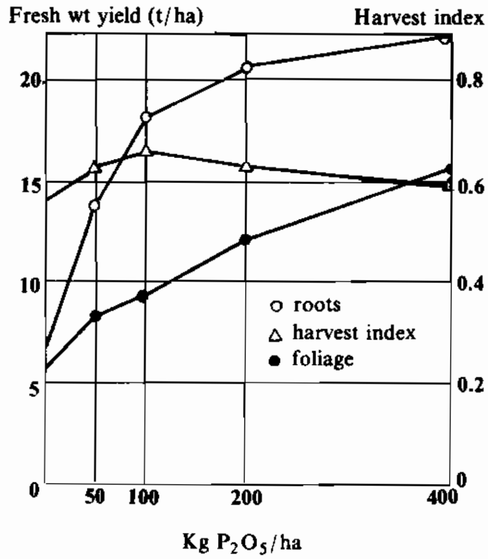


Figure 47. Effects of phosphorus (avg. of six sources) on yields of cassava roots and foliage and on the harvest index.

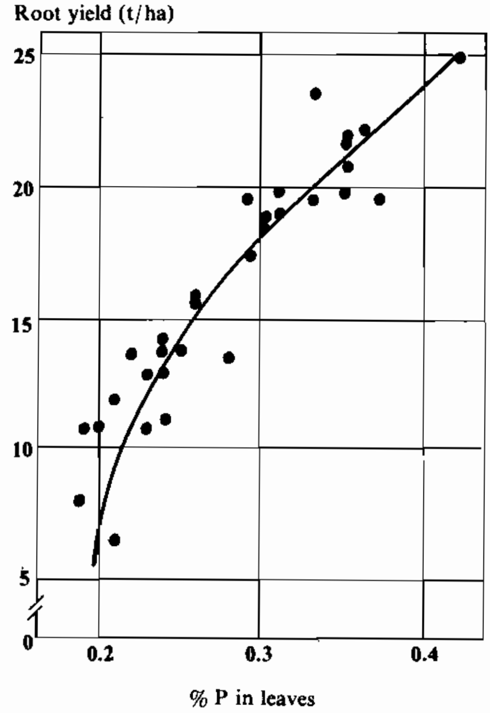


Figure 48. Relation between cassava yield and phosphorus content of leaves five months after planting.

cassava production is directly correlated with leaf phosphorus content and that plants require at least 0.35 percent phosphorus in the leaves for optimum yield. Since the curve does not reach a maximum, it is likely that elements other than phosphorus limited yield (zinc content was depressed from 47.6 to 37.2 ppm by high phosphorus-application) and the critical phosphorus content is above 0.4 percent.

The net return from applying phosphorus at current fertilizer prices and a value of Col. $2,000/t cassava for a starch extraction plant is shown in Figure 49. Highest returns were obtained with basic slag due to its high agronomic effectiveness and low cost. Production of this material is limited but the rock phosphates-sulfur mixture would be a good alternative source (Fig. 49).

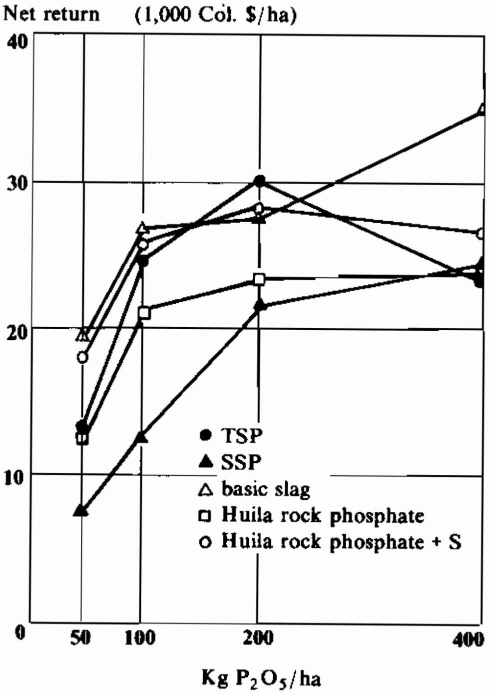


Figure 49. Net return from fertilizing cassava with various levels and sources of phosphorus, at Carimagua.

The use of TSP gave the highest return at the 200 kg P_2O_5/ha level but the lowest return at the highest application rate. SSP was the least economic source, but broadcast application might improve this.

Nitrogen fertilization

The best level and time of applying nitrogen was studied in Carimagua, using levels of 0, 50, 75, 100 and 150 kg N/ha, band placed as urea in various fractions at 0, 30, 120 and 150 days after planting. Because of dry weather no fertilizer could be applied between 30 and 120 days. The treatment with zero nitrogen still yielded 16.4 t/ha, indicating that of the three major elements, nitrogen, phosphorus and potassium, lack of nitrogen is of least importance in limiting yield (see Soils Section in CIAT Annual Report, 1975). Nevertheless, there was a definite response to nitrogen rates as high as 150 kg/ha (Fig. 50). Only when all nitrogen was applied at planting was there a negative response to the highest application rate, probably because of fertilizer burn during the dry season following planting.

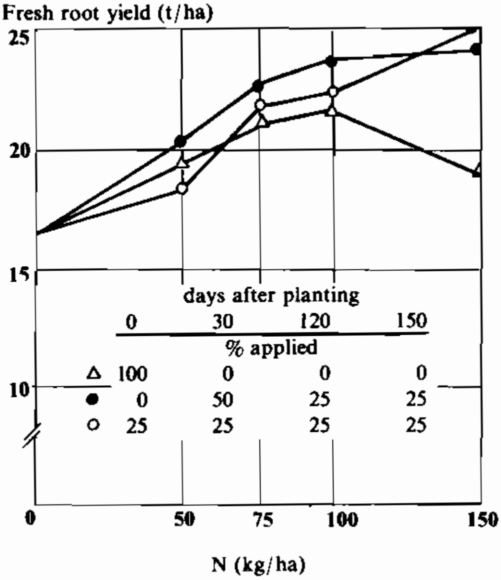
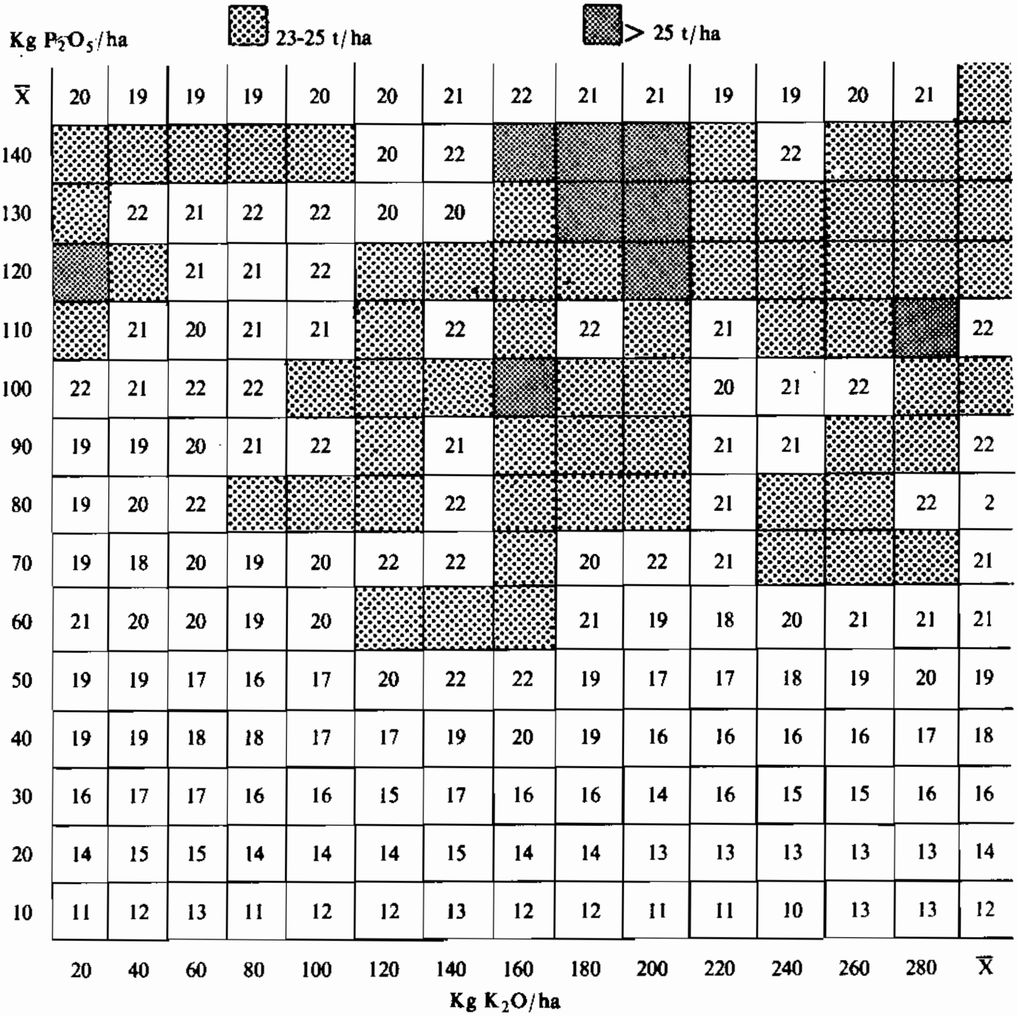


Figure 50. **Response of cassava to various levels and times of application of nitrogen, at Carimagua.**

The best fractionation was that of 50 percent applied at 30 days and 25 percent each at 120 and 150 days. There was no significant difference between other fractionation methods used. However, a similar trial planted at the begining of the rainy season (destroyed at two months because of CBB) showed a definite lack of vigor at two months in any treatment in which the initial nitrogen application was delayed to 30 days after planting. Thus, it appears that nitrogen should be fractionated with the initial doses at planting if this occurs at the beginning of the wet season or at 30 days if planting occurs at the end of the wet season.

Phosphorus x potassium interaction

To determine the interaction between phosphorus and potassium a systematic design experiment was established with 15 levels of each element in all possible combinations. Levels of the two elements increased in increments of 10 kg P_2O_5/ha and 20 kg K_2O/ha in perpendicular directions. Each plant was one treatment, and treatments were replicated four times. The yield of each treatment was considered to be the average yield of the plant with the treatment and its eight surrounding neighbors. Figure 51 shows the effect of phosphorus and potassium on yield. Highest yields were obtained with 140 kg P_2O_5/ha and 180-200 kg K_2O/ha. At lower levels of P_2O_5 the optimum K_2O application was about 140-160 kg K_2O/ha. Figure 52 shows the average phosphorus and potassium response. It is clear that cassava responds markedly to phosphorus and that maximum yields were not yet obtained with the highest application rate of 140 kg P_2O_5/ha. There was relatively little response to potassium but maximum yields were obtained with 160 kg K_2O/ha, above which yields declined. Since potassium was applied as K_2SO_4, the decline was not due to sulfur deficiency (CIAT Annual Report 1975), but was possibly due to a potassium induced calcium deficiency, since the calcium level



Kg P_2O_5/ha ▨ 23-25 t/ha ■ > 25 t/ha

	20	40	60	80	100	120	140	160	180	200	220	240	260	280	X̄
X̄	20	19	19	19	20	20	21	22	21	21	19	19	20	21	▨
140	▨	▨	▨	▨	▨	20	22	■	■	■	▨	22	▨	▨	▨
130	▨	22	21	22	22	20	20	▨	■	■	▨	▨	▨	▨	▨
120	■	▨	21	21	22	▨	▨	▨	▨	■	▨	▨	▨	▨	▨
110	▨	21	20	21	21	▨	22	▨	22	▨	21	▨	▨	■	22
100	22	21	22	22	▨	▨	▨	■	▨	▨	20	21	22	▨	▨
90	19	19	20	21	22	▨	21	▨	▨	▨	21	21	▨	▨	22
80	19	20	22	▨	▨	▨	22	▨	▨	▨	21	▨	▨	22	2
70	19	18	20	19	20	22	22	▨	20	22	21	▨	▨	▨	21
60	21	20	20	19	20	▨	▨	▨	21	19	18	20	21	21	21
50	19	19	17	16	17	20	22	22	19	17	17	18	19	20	19
40	19	19	18	18	17	17	19	20	19	16	16	16	16	17	18
30	16	17	17	16	16	15	17	16	16	14	16	15	15	16	16
20	14	15	15	14	14	14	15	14	14	13	13	13	13	13	14
10	11	12	13	11	12	12	13	12	12	11	11	10	13	13	12

Kg K_2O/ha

Figure 51. Root yields of cassava (t/ha) in Carimagua as affected by the interaction of various levels of applied phosphorus and potassium.

of the soil was extremely low (0.24 meq/100g after liming).

Method of fertilization

The efficiency of fertilizers depends to a great extent on methods of application. Fertilizers of low water solubility are generally more effective when broadcast and incorporated to secure good soil-fertilizer contact, while highly soluble fertilizers are more efficiently used when banded or otherwise placed in concentrated form.

Without N-P-K fertilization (only lime and zinc applied) cassava yielded 5.8 t/ha. Yields increased to 14.7, 20.0 and 23.4 t/ha after applying 250, 500 and 750 kg/ha of complete fertilizer (10-20-20). Since the response curve did not reach a maximum it is likely that higher yields could be obtained with higher rates.

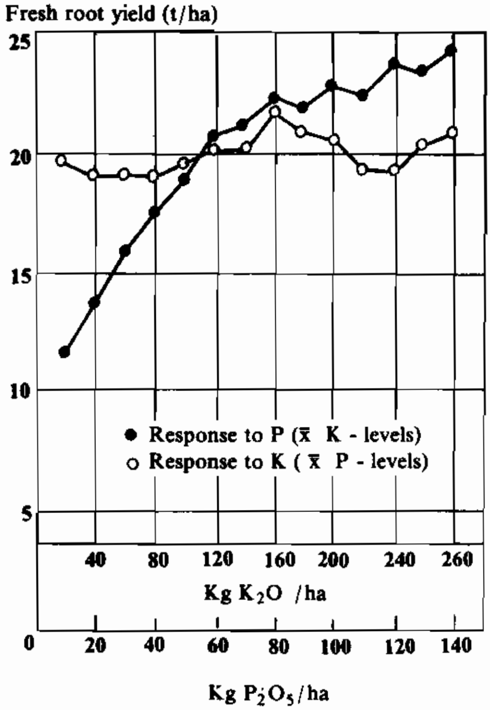


Figure 52. **Average response of cassava to the application of phosphorus and potassium, in Carimagua.**

Although there were no significant differences among methods of application (P = 0.05), placement of the fertilizer in the planting hole gave a slightly higher average yield but also the greatest variability in yield, due to loss of stand caused by fertilizer burn of the stake. This effect was most pronounced when the dry season followed planting, but when planted before the wet season no loss of stand occurred. During dry season planting, broadcast application was comparable to other methods (Fig. 53), while in the wet season planting this method reduced initial plant growth and encouraged excessive weed growth. The commonly used and very labor intensive circle application was equal or less effective than other methods. Fertilizer application in a hole 15 centimeters from the stake was the least effective method.

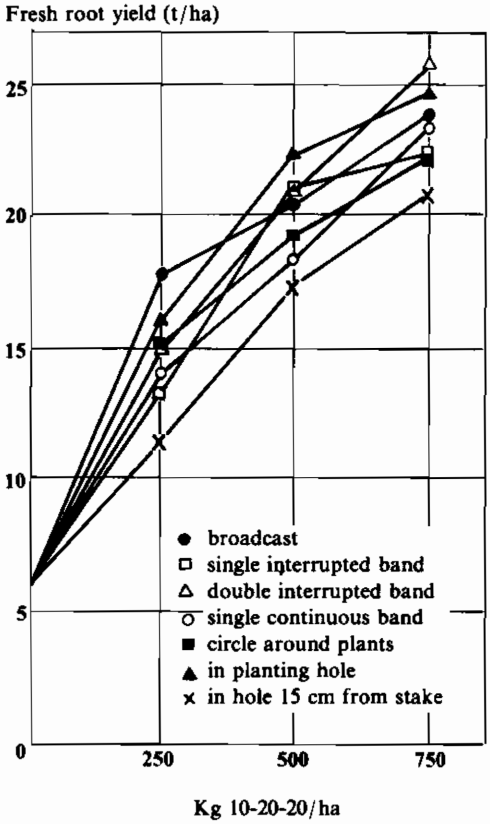


Figure 53. **Effects of various levels and methods of 10-20-20 fertilizer application on yields of cassava, in Carimagua.**

Management of Saline/Alkaline Soils

Although cassava is well adapted to acid soils, it appears quite sensitive to high pH and saline soil conditions. Large varietal differences in sensitivity have been observed on the high pH soils of the CIAT farm (Fig. 54). The uniform yellowing of leaves and die-back of the growing point is generally due to a combined effect of high pH, salinity, alkalinity, poor drainage, and sometimes deficiency of minor elements, especially zinc.

Various soil treatments to overcome one or more of these problems were established in a field of high pH, and three cassava cultivars of different sensitivities were

Figure 54. Effect of soil salinity on cassava growth; in the foreground is the susceptible cultivar Llanera, in the background, the tolerant cultivar M Col 22.

grown in each treatment. Figure 55 shows the effect of soil treatments on cassava yield. It is clear that the treatments had little effect on the yield of the two tolerant cultivars M Col 22 and 113. However, in the susceptible cultivar, Llanera, whose yields increased from 5 to 35 t/ha with the application two tons of elemental S/ha. The application of 1 or 2 t/ha of sulfur or sulphuric acid increased yields considerably. However, soil treatment effects were greatly masked by extreme soil variability within the lot and results must be considered as preliminary.

Figure 56 shows the relationship between yield and pH, percent sodium saturation and electrical conductivity of the soil. The critical pH for Llanera was 7.8 and for M Col 22 and 113 between 8.0 and 8.1. Above these pH's yields declined markedly. Similarly, yields were severely affected by excess sodium when the percent of sodium saturation was above 1 percent for Llanera and 4-5 percent for the other varieties. Yields were affected by salinity when the conductivity was above 0.5 mmhos/cm for Llanera and 0.7 for M Col 22 and 113. Thus, while many other crops are not affected by excess sodium until the percentage saturation is above 15 percent and by salinity until the conductivity is above 2 mmhos/cm, cassava is seriously affected at much lower values, and thus more susceptible to soil salinity and alkalinity. Under these conditions it would

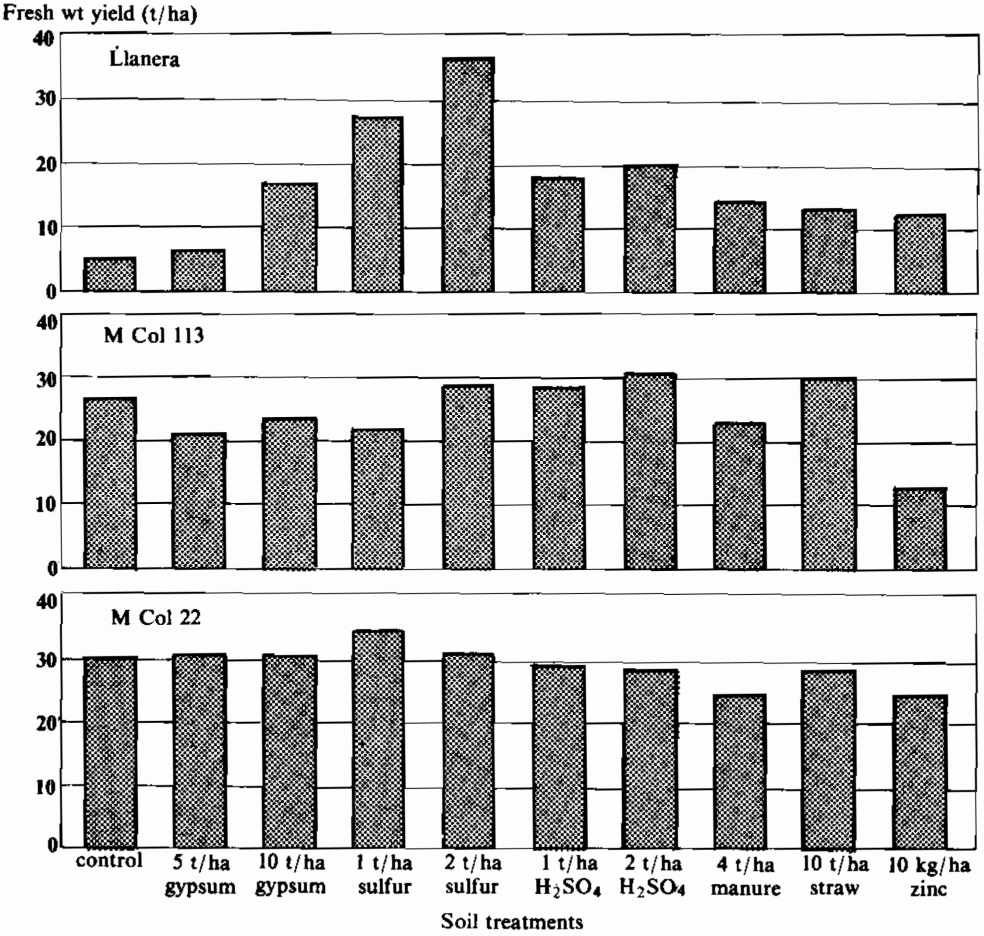


Figure 55. **Effects of various soil treatments to a high pH, saline soil in CIAT on the yield of three cassava cultivars.**

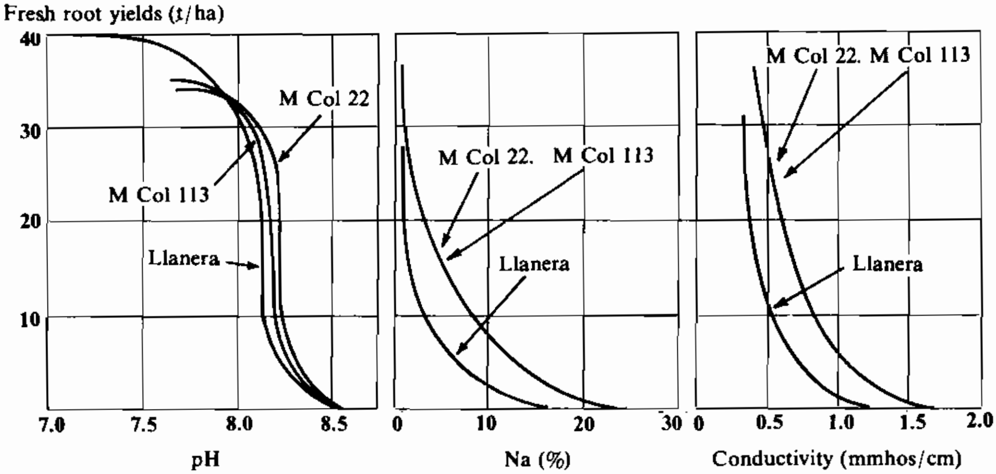


Figure 56. **Relation between yields of three cassava cultivars and the pH, percent sodium saturation, and electrical conductivity of the soil, at CIAT.**

be recommended to select a highly tolerant cultivar of cassava rather than modify the soil with rather expensive acidifying agents.

MULTIPLE CROPPING

Multiple cropping is widespread throughout the world and it is commonly practiced in Latin America by small farmers who grow cassava. Beans, maize, yams, potatoes, tomatoes and other crops all are frequently grown with cassava. The multiple cropping methods used appear to be based on tradition and the criteria for agronomic decision-making are poorly understood. It is known that intercropping cassava with beans, for example, will reduce yields of both crops. But, on the other hand, multiple cropping may be an efficient way to reduce weeds, diseases and insects and hence increase farmers' net returns (CIAT Annual Report 1975). During its early growth cassava does not tolerate shading, however, neither does it intercept much light. Hence, much light apparently is not utilized by the cassava. This light could be used for another crop such as beans.

Experiments on intercropping cassava with beans were begun early in 1976. The main objective of these experiments was to understand crop interactions so as to define more efficient multiple cropping methods.

Planting Date Experiment

The cassava variety M Mex 11 and the bean variety P302 were planted with 11 different bean sowing dates relative to a single planting date for the cassava. Beans were sown at 250,000 plants/ha and cassava at 10,000 plants/ha according to the pattern shown in Figure 57. Control plots of beans only and cassava only were also planted.

Due to climatic conditions the bean yield in monoculture tended to decrease with advancing planting dates but the mean

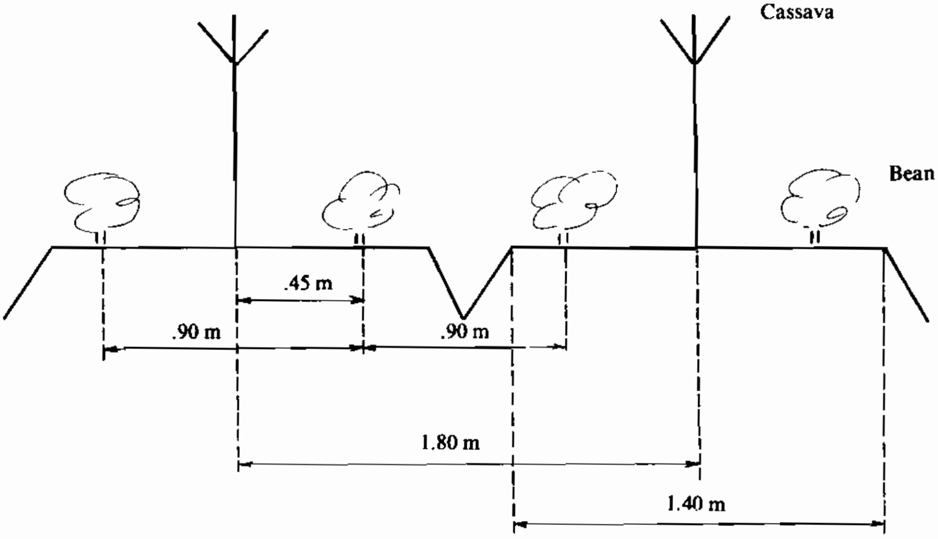


Figure 57. **Planting pattern for intercropping studies of cassava and beans.**

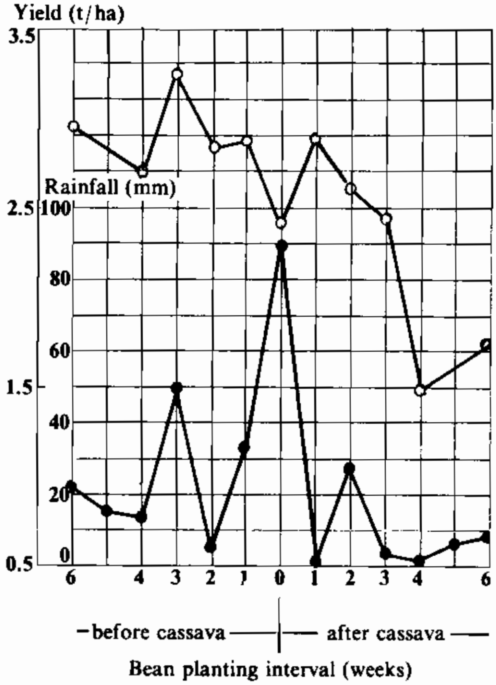


Figure 58. **Monoculture yields of beans showing influence of rainfall patterns on yields in intercropping experiment with cassava and beans.**

yield was still 2.9 t/ha (Fig. 58). Bean yields were not severely reduced when beans were planted earlier than the cassava but yields decreased when planted after the cassava (Fig. 59). When cassava was planted six weeks before beans, bean yields were reduced to 53 percent of their monoculture level.

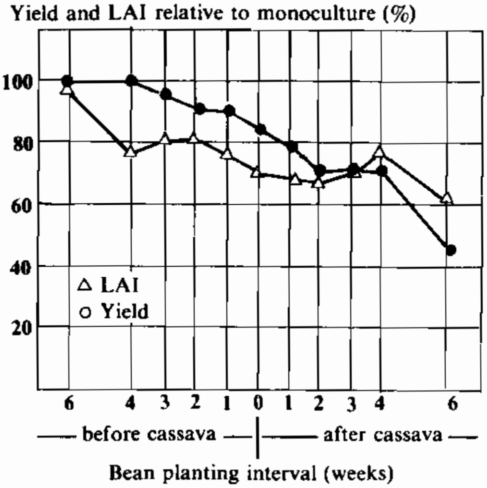


Figure 59. **Yields and leaf area index (LAI) maximum of intercropped beans planted before, at the same time and after cassava.**

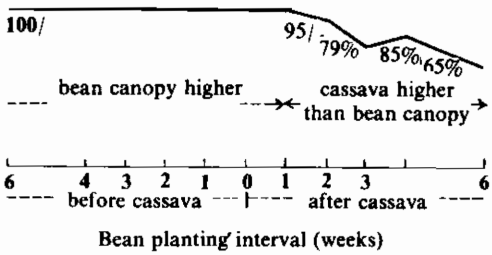


Figure 60. **Percentage of light available to beans intercropped with cassava and planted before, at the same time and after cassava.**

The light intensity at the top of the bean canopy five days after maximum LAI is shown in Figure 60. Marked yield depression only occurs when the cassava canopy is above the beans suggesting that the main competition is for light.

Cassava has been harvested at 100 and 180 days and there will be further harvests at 260 and 340 days. Figure 61 shows the total biomass curve of cassava as affected by the different bean planting dates. The fact that cassava does not tolerate any competition during the early growth stages

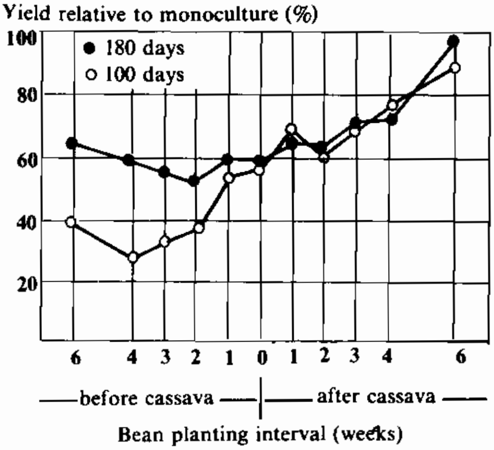


Figure 61. **Biomass yield of cassava at 100 and 180 days when beans were planted before, at the same time and after cassava.**

(CIAT Annual Report, 1973) was again proven; the later the bean was planted the greater the cassava yield. The 80 days between the first and the second cassava harvest gave time for the cassava to recover, especially when the total biomass was low at the 100 days harvest (Fig. 61).

These preliminary results suggest that by planting beans 0-2 weeks after the cassava, 75 percent of the bean monoculture level can be obtained and after 180 days an average of 50 percent of the cassava monoculture level can be obtained (Fig. 62). From 100-180 days the intercropped yield of cassava relative to control increased so that by 300 days the relative yields may be even more promising.

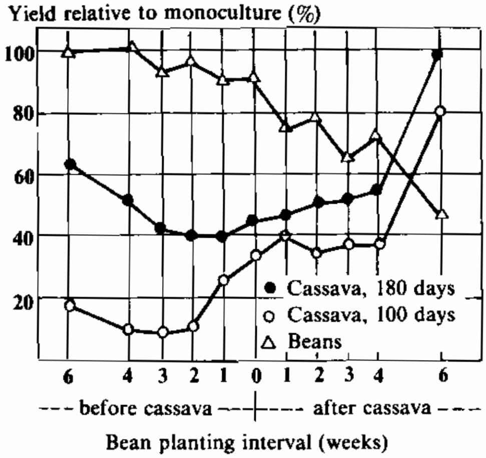


Figure 62. **Root dry matter yield of cassava at 100 and 180 days and yield of beans at maturity when beans were planted before, at the same time and after cassava.**

ECONOMICS

In the 1973, 1974, and 1975 CIAT Annual Reports the methodology and preliminary results of an agro-economic survey were presented. The survey was made in five zones of Colombia: (I) Cauca, (II) Valle and Quindio, (III) Tolima, (IV) Meta and (V) Magdalena and Atlántico. Analyses of all data have now been completed.

Economic Data

Average yields from the survey were less than 7 t/ha although a great range was observed from near zero to more than 40 t/ha. Yields tended to be greater on large farms than on smaller ones, 7.9 and 4.3 t/ha, respectively. The effect was particularly noticeable in Valle and Quindio zone with 14 and 8 t/ha for large and small farms, respectively.

Although yields are low, very much labor is used to produce cassava an average of 86 man-days/ha and varying from 66 in zone IV to 106 in zone I. About half this labor input was for weed control with land preparation, planting and harvesting using another 30 percent of the total (Fig. 63).

The variable cost of cassava production was estimated as almost Col. $4,000/ha or Col. $640/t of cassava produced. The variable production costs per hectare varied from Col. $3,000/ha in zone I to Col. $ 5,000/ha in zone II. The weeding of the crop accounted for about 50 percent of the variable costs while purchased inputs accounted for only 8 percent of variable costs (Fig. 64).

The average total costs are about Col. $6,000/ha or Col. $1,000/t (Table 43). The costs on large farms are greater per hectare due to higher land value (rent estimated at 10 percent of land value), administration costs, security and packing. Nevertheless, cost per ton of cassava is lower as a result of greater production. In zone III, with lowest yields, costs per ton were greatest, (slightly greater than Col. $1,600/t) and in zone II with highest cost and

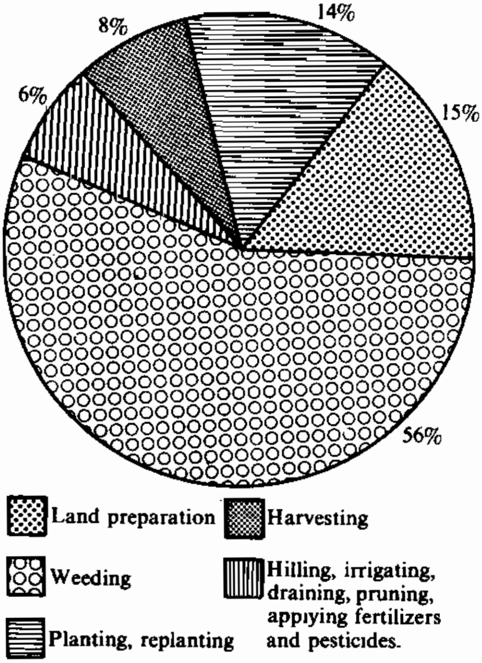


Figure 63. **Estimated percentages of the total labor required for producing cassava that are allocated to the various production activities.**

greatest yields, cost per ton was lowest (Col. $850/t).

The total value of the production was greatest in zone II, over Col. $25,000/ha.

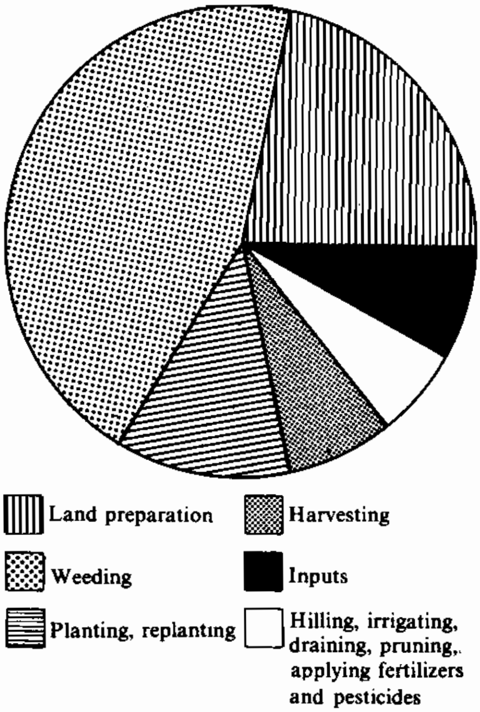


Figure 64. **Estimated percentages of the total variable production cost per hectare of cassava that are allocated to the various production activities.**

and lowest in zone V, about Col. $4,000/ha. The net return to farmers after paying for estimated rent was Col.

Table 43. **Average total production costs of cassava per hectare and per ton in each of two zones in Colombia.**

	Zone I		Zone II		Total	
	Col. $/ha	Col. $/t	Col. $/ha	Col. $/t	Col. $/ha	Col. $/t
Average variable costs	3,068	694	5,019	397	3,968	640
Administration			199	16	62	10
Technical assistant	8	2	9	1	4	1
Surveillance	39	9	263	21	96	15
Packing	52	12	126	10	123	20
Interest (12% of variable cost)	368	84	602	48	476	77
Total cost excluding land rent	3,535	803	6,218	494	4,729	763
Land rent (10% of land value)	278	63	4,511	358	1,318	212
Total cost	3,813	866	10,733	852	6,047	975

Table 44. Yield losses due to different factors affecting cassava production in Colombia.[1]

	Loss in affected plot (t/ha)	Total area affected (%)	Avg. yield loss over total area (t/ha)
Phoma	3.45	4	0.13
Superelongation	3.45	4	0.13
Low phosphorus	2.21	63	1.39
Associated crops	1.89	31	0.59
High pH (>5.5)	1.74	58	1.01
Ants	1.20	2	0.02
CBB	0.75	5	0.04
Total			3.31
Excessive rain	0.77	48	0.37
Heavy soil texture	1.46	75	1.09

[1] Calculated on basis of an average yield of 6.2 t/ha.

$19,000/ha in zone II but returns were negative in zone V.

Share-cropping occurs in some zones with farmers giving one-third of the production to the owner. In zones III, IV and V net returns to the share-cropper were negative.

The average price received by farmers was Col. $1,540/t, however prices in zones II, and III were almost double those of zone V. The difference is probably due to the proximity of large fresh markets in zones II and III. Although individual farmers received very different prices, there was no tendency for the large farmer to obtain better prices.

Yield Losses

A multiple regression analysis was used to analyse limiting factors on yield. When Phoma and superelongation were present yield losses were tremendous (Table 44); superelongation was present on only a small area of the total but potential losses are tremendous if this disease spreads. Using associated cropping systems also markedly reduced yields (see Multiple Cropping Section). Low phosphorus in the soil was also apparently a major limiting factor on cassava production. High soil pH (>5.5) also apparently reduced yield, although other factors are likely to be involved. Excessive rain and heavy soil texture are also associated with reduced yields, however, unlike the other factors, it is difficult to see how these can be ameliorated. The correction of the other limiting factors would increase yields by 3 t/ha (35%).

CASSAVA DRYING

Following earlier studies (CIAT Annual Report, 1973) work has been continued on improved methods of drying cassava naturally. Cassava chips produced by a Malaysian type chipper (Fig. 65) have been dried in horizontal and inclined mesh trays raised above the ground (Fig. 66) with comparative trials on plain and black concrete.

The Malaysian chipper produces moderately uniform chips, 0.4-0.6 centimeters thick and 1-8 centimeters long, and separates from the chips a large part of

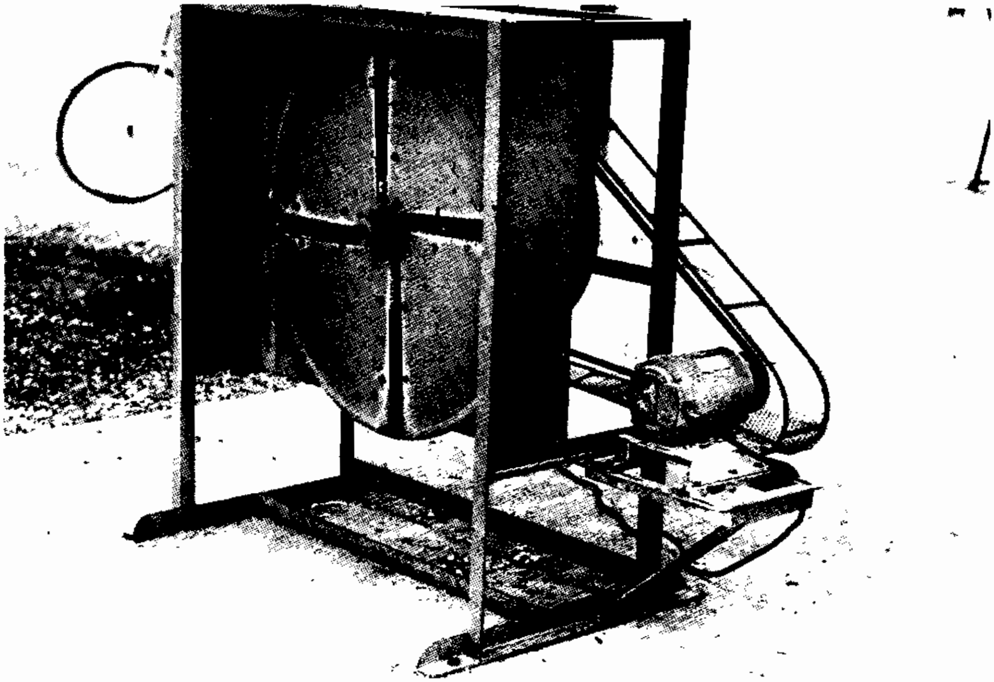


Figure 65. Malaysian type cassava chipper used in CIAT's studies of cassava drying.

Figure 66. Different treatments used in cassava drying studies at CIAT.

the cassava skin together with particles smaller than the chips. The fine material mixed with the chips apparently doesn't affect the drying rate, either on concrete or in trays, but does cause losses of up to 8 percent dry matter during drying and storage in fiber sacks. Modifications are being made to the blades and feed hopper to try to reduce the production of fine material.

Trials over a three-month period at CIAT have shown that the traditional method of drying cassava on concrete can be improved by placing the chips in horizontal or inclined mesh trays (Table 45). The increased drying rate is achieved by better circulation of air around the chips and, in inclined trays, better used is made of the drying power of the wind. The maximum angle of inclination of a tray has been found to lie between 25 and 30⁰.

Drying on black concrete gives a marked improvement over plain concrete at a fresh cassava loading of 5 kg/m², but at 10 kg/m² the layer of chips is too thick and the black surface is almost totally obscured. The higher loading rate does not require a proportionally greater number of drying hours and hence gives a greater capacity per unit area of drying surface. In practice it is difficult to achieve loading rates higher than 7 kg/m² using wooden rakes to spread and turn the chips; in this respect the design of the rake is important and requires more attention. Drying on black concrete has the disadvantage of cassava dust collecting in the cracks and reducing the absorption of solar radiation; therefore the concrete should have a smooth finish with a black pigment incorporated into the final layer to give a permanent color. For the same number of drying hours the capacity of inclined trays is double that of concrete, and if the cassava is spread evenly over the trays no turning is necessary, thus cutting labor costs during drying.

If inclined trays are used a further reduction in drying time is achieved by starting chip drying in the late afternoon. Cassava chipped at 0800 hours and placed in inclined trays at 10 kg/m² does not always dry below 14 percent moisture content, wet basis (w.b.) in one day. If the moisture content of the chips falls below 20 percent absorption of moisture can occur during the night. However, cassava chipped at 1700 hours continues to dry throughout the night and heat of the next day reduces the moisture content to below 14 percent. Figure 67 shows typical drying curves for sunny and cloudy days. Even under poor conditions, when drying starts at 1700 hours the chips reach 14 percent moisture in one complete day thus allowing the trays to be loaded again.

Stacking inclined trays one on top of the other with gaps of 30 centimeters between the trays (Fig. 68) does not appreciably

Table 45. Hours required to dry cassava to 14 percent moisture (wet basis), at CIAT, June-August 1976.[1]

Method of drying	Density of chips (kg/m²)	Number of trials	Drying time (hrs)	
			Total hours	Hours between 0800-1800
Plain concrete	5	6	26	12
Black concrete	5	6	20	10
Plain concrete	10	4	34	19
Black concrete	10	4	32	18
Horizontal trays	10	5	29	15
Inclined trays	10	8	20	11

[1] Drying conditions: horizontal trays 30 centimeters above ground; inclined trays at 28⁰. Drying began at 0800 and chips were covered between 1600 and 0800.

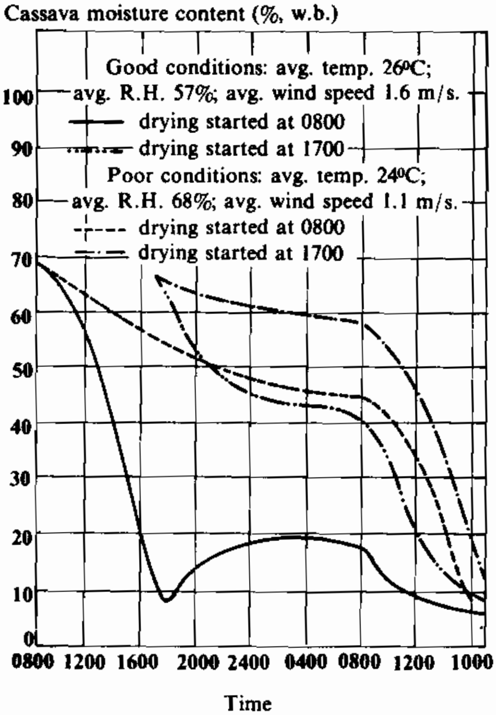


Figure 67. **Drying curves for cassava at a density of 10 kg/m² in inclined trays according to weather conditions.**

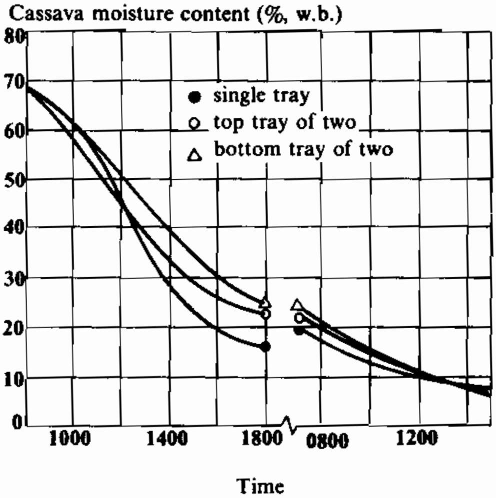


Figure 69. **Drying curves for cassava chips at a density of 10 kg/m² in inclined trays according to tray placement.**

affect the drying rate (Fig. 69). Therefore, it might be possible to increase the loading rate per square meter of ground area to 40-60 kilograms by placing 3-4 trays on top of each other, thereby justifying a roof or cover to protect the cassava at night and during rain.

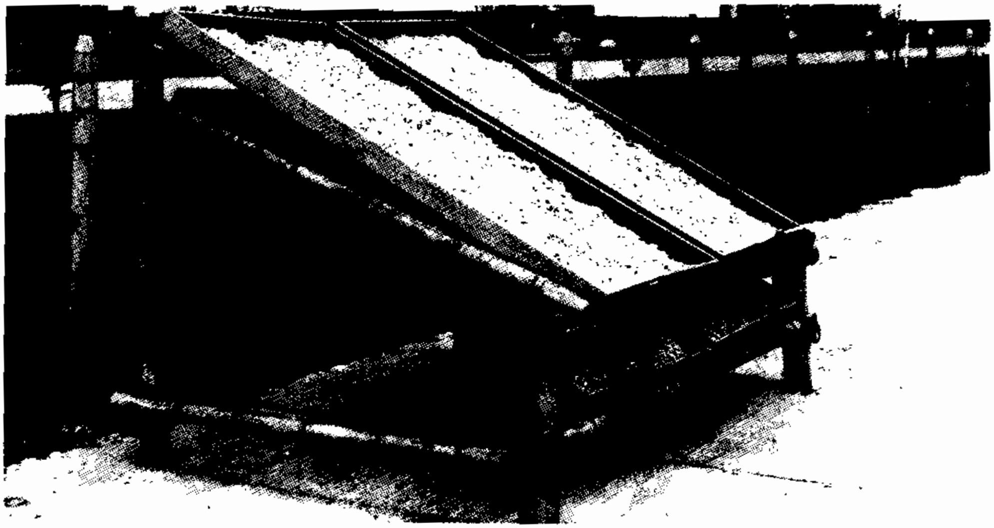


Figure 68. **When inclined trays are stacked in this way with a 30-centimeter space between them, drying rates for the chips are not appreciably affected.**

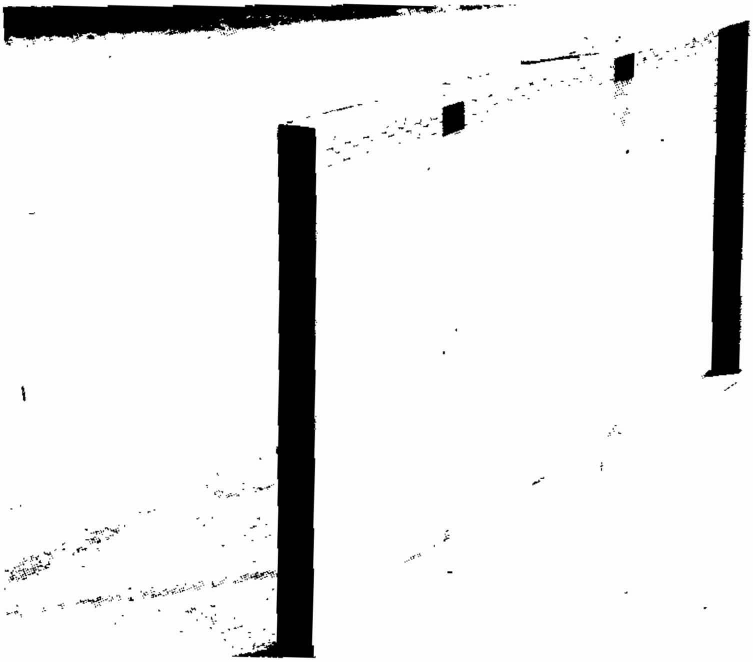


Figure 70. **Drying trays constructed in this manner are sturdy and can carry 15 kg of moist chips m².**

Various materials are being tested for constructing the drying trays and their supporting frames. The latter can be made simply from bamboo posts and rails arranged to support the trays at an angle of 25-30⁰ and positioned to make the greatest use of the prevailing wind. Wooden framed trays, 0.90 x 1.70 meters by 5 centimeters deep with a base of plastic mosquito screen supported by chicken netting have proved sturdy and capable of carrying 15kg/m² (Fig. 70); higher densities require deeper frames and a more substantial mesh.

The material costs per square meter of drying area are given in Table 46. Labor costs are not included as a farmer could build the trays or lay the concrete himself. The trays may be built of readily available materials and the cost of transporting them may not be as great as compared with cement, sand, gravel and hard-core. However, trays will have a shorter life and need greater maintenance than a concrete

Table 46. **Material costs for tray and concrete drying of cassava.**

	Col. $/m²
Trays	
Bamboo frame	15
1" chicken netting, 0.90 m wide	22
Plastic mosquito netting, 0.90 m wide	16
Wood frame for trays 0.90 x 1.70 m	45
Total cost of materials:	98
Concrete	
10-cm thick concrete floor	45
Foundation	15
Black pigment or paint	10
Total cost of materials:	70

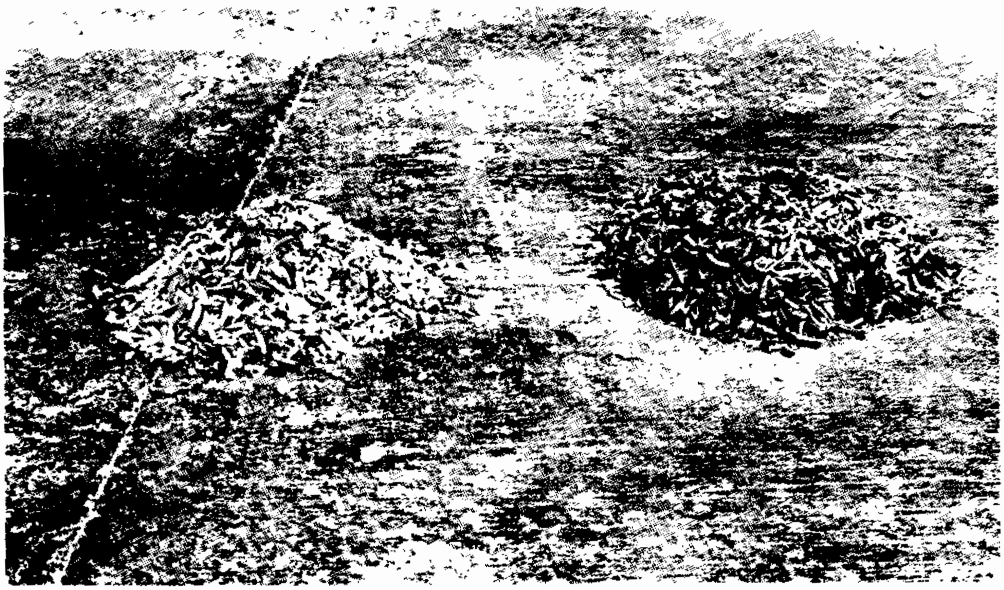


Figure 71. Chips on the left were dried under good conditions and have an excellent appearance; those on the right have deteriorated in quality during extended drying periods.

floor, these being the major disadvantages of this method of drying.

The visual quality of cassava chips depends on the drying rate, Chips dried rapidly under good conditions either on concrete at 5 kg/m² or in trays at 10 kg/m² are a brilliant white. When the drying period extends for two or more days the quality of chips produced by both methods deteriorates and there is a greater proportion of dust and fine particles in the concrete dried product due to repeated sweeping up and spreading of the cassava (Fig. 71).

TRAINING

Intensive Course on Cassava Production

Thirty-two agronomists from nine Latin American countries participated in a 31-day Intensive Course on Cassava Production funded by the Canadian International Development Research Center. During the 24 instruction days, 176.5 hours of training were given with 37.4 percent devoted to theory and 62.6 percent to practice.

Twenty-nine CIAT technicians, assistants and senior staff provided the direct instructional input. Teaching materials were compiled and printed as preliminary editions of two books in Spanish: "Course on Cassava Production" (432 pages) and "Management and Control of Weeds in the Tropics" (132 pages).

Effectiveness of the course and progress of the trainees were measured by two examinations — at the beginning and at the end of the course. Every student improved his knowledge; the average score of the initial test was 44 percent while the group averaged 79 percent on the final test.

Figure 72 shows the distribution of scores on the two tests.

These newly trained agronomists will form important links between their respective countries and CIAT's expanding cassava outreach activities.

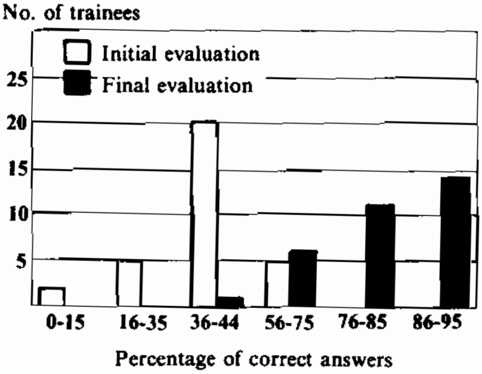


Figure 72. **Comparison of initial and final knowledge evaluation of 32 trainees participating in the CIAT Cassava Production Course, 1976.**

PUBLICATIONS

COCK, J.H. Characteristics of high yielding cassava varieties. **Expl. Agric.** 12:135-143. 1976.

LOZANO, J.C. and TERRY, E. Enfermedades de la yuca y su control. **Noticias Fitopatológicas** 1:38-44. 1976.

NESTEL, B. and COCK, J.H. Cassava: the development of an international research network. IDRC-059e. Ottawa, Canada, International Development Research Centre, 1976. 69 pp.

ROSAS, C., COCK, J.H. and SANDOVAL, G. Leaf fall in cassava. **Expl. Agric.** 12:395-400. 1976.

Beef production program

Beef production program

HIGHLIGHTS IN 1976

Agronomic assessment of a wide range of accessions of *Stylosanthes* spp. has been initiated in a search for adapted disease and stemborer resistance genotypes. Promising materials are the fine stemmed biotypes which appear to have better resistance to stemborer attack than the robust, woody growth forms. Particularly interesting is *S. capitata,* a free-seeding perennial which shows tolerance to high exchangeable aluminum and low available soil phosphorus levels. This species is also fairly resistant to anthracnose and stemborer attacks.

Species of *Zornia, Desmodium* and *Macroptilium* also contain ecotypes adapted to allic soils and possess resistance to diseases and pests. The new introductions are being tested in duplicate sets in space planted nurseries and in small sward plots at Santander and Carimagua.

Seed yields of 69 kg/ha acid scarified pure seed were recorded at Palmira from combine harvested areas of *S. guyanensis* (CIAT 136). The Carimagua crop was virtually a failure from disease and insect damage. Some 700 kilograms of pure seed were produced at the two locations.

New areas of a wide array of legume accessions were established at Santander where a lower incidence of stemborer and weeds should favor more consistent yields and longer stand life. Experiments have been initiated to define the responses of particular legume species to levels of phosphorus, defoliation and in the case of *Centrosema* sp. to support systems.

A seedbed preparation trial at Carimagua includes conventional as well as minimum tillage land preparation methods. The use of stubble mulch sweeps to undercut the savanna vegetation without turning the sod proved highly effective for controlling native vegetation, and at the same time, resulted in satisfactory sown species establishment. Band seeding and application of fertilizer in bands show distinct advantages over broadcast application.

Phosphorus application had a large effect on the phosphorus content of *S. guyanensis* and *Brachiaria decumbens* and broadcast application was much more efficient in increasing plant phosphorus contents than band application. Tropical Kudzu. Para and Tanner grasses responded strongly to potassium application and Kudzu showed marginal response to magnesium application.

Characterization of *Rhizobium* strains available in CIAT's collection indicated superior efficiency for use with *Stylosanthes* of two South American isolates over the commercially available culture. A large collection of *Rhizobium* strains is being screened in pot culture in sterilized site soil to assess tolerances to low pH, low phosphorus availability and high aluminum level.

Applications of nitrogen fertilizer on irrigated Pangola grass pasture at rates of 168 and 672 kg/ha/year gave 690 and 1,803 kilograms liveweight gain per hectare, respectively.

Brachiaria decumbens provided better dry season grazing than *Melinis minutiflora, Hyparrhenia rufa* and *Paspalum plicatulum.* Animals grazing on native savannah burned at the end of the rainy season gained 57 kg/year while animals on pasture burned at the beginning of the rainy season gained only 27 kg/year.

In the Herd Systems Project, giving minerals consistently improves the calf crop (three years) by increasing conception rate and reducing the number of abortions. The most dramatic improvement in calf crop is caused by early weaning which removes a great lactation stress from the cow. Preliminary work on raising three-month-old weaned calves at Palmira has been successful, with liveweights at 9 and 18 months as good as normal weaned calves in the Llanos.

Cattle trypanosomes *(T. vivax* and *T. evansi)* have a wider distribution, in tropical areas of Central and South America, than was previously believed. In some areas the disease has a significant economic impact

Leptospirosis is emerging as the most prevalent reproductive disease in the tropical savannahs. Two preventive medicine measures for this disease are being tested in a trial herd.

Studies on the prevalence of anaplasmosis and babesiosis in Colombia were completed in 1976. The results of these studies indicate a high prevalence of anaplasmosis and babesiosis within the major cattle producing areas of the North Coast, the Eastern Plains and the Cauca Valley. Immunization methods against anaplasmosis and babesiosis using a minimum infective dose procedure were tested on eight beef and dairy farms located in the Cauca Valley. A total of 285 animals were involved in these experiments. The preliminary results from one ranch demonstrated that vaccinated animals gained 27 kilograms more per head than the nonvaccinated control, 18 weeks after field exposure.

The Acarology Unit's tick species checklist for Colombia was expanded to include 32 hosts and 23 tick species. The tick collection is extensively used for taxonomic training. Although good nutrition increased cattle tick resistance and tolerance, it appears that relatively low tick loads still directly caused significantly decreased blood values. Studies established that certain cattle body regions are consistently the most highly populated by *Boophilus microplus,* the tropical cattle tick. Animals grazing certain improved pastures may carry fewer ticks than those on native pastures.

A comprehensive economic survey has been initiated on 16 selected and representative farms on the Eastern Plains of Colombia monitoring each farm for 18 months.

Preliminary observations reveal the possible existence of external factors such as: transportation costs, opportunity cost of pastures in nearby regions, credit constraints and relative prices of different categories of animals which appear to be conditioning the adoption of technology. They also reveal that when certain recommended practices are introduced unilaterally, the net economic effect may even be negative.

PASTURES AND FORAGES

Plant Introduction

During 1975, CIAT directed extensive forage legume explorations under the sponsorship of the International Board for Plant Genetic Resources (IBPGR). This work was continued in 1976 with support from CIAT's core budget (Fig. 1).

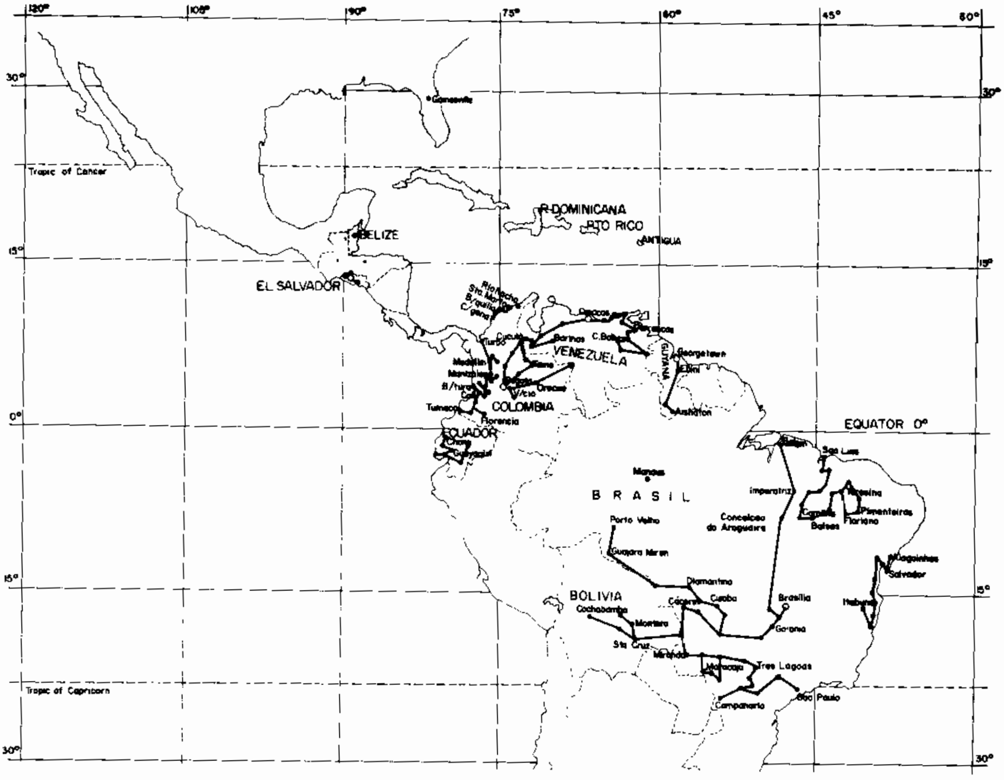


Figure 1. Routes of forage legume explorations in Central and South America during 1976.

Seed or vegetative planting material of 1,600 accessions of tropical forage species, mainly legumes, was collected to broaden the genetic diversity of germplasm stocks in CIAT's forage collection (Table 1). Emphasis was on the search for germplasm carrying resistance to pests and diseases and adaptation to low base status savannah soils.

A collaborative project was organized in El Salvador with the Banco de Fomento and the United Nations Development Programme and Food Agriculture Organization participating in the collection of forage species throughout the country. Collecting in El Salvador yielded some new accessions of browse-type *Desmodium distortum* and *D. nicaraguense*. *Teramnus, Macroptilium* and *Stylosanthes* spp. were also added to the collection.

Table 1. **Accessions in CIAT's forage germplasm bank as of November 1, 1976.**

	No. of Accessions
Stylosanthes spp.	649
Desmodium spp.	208
Centrosema spp.	144
Macroptilium spp.	95
Miscellaneous legumes:	
Calopogonium	398
Glycine	
Indigofera	
Leucaena	
Teramnus	
Vigna	
Zornia	
Grasses	106
Total accessions	1,600

One of the functions of the CIAT forage introduction center is that of preserving a source of germplasm as stored seed. New germplasm storage facilities with controlled humidity and temperature rooms are nearly completed and the forage germplasm will be housed in the new building.

Distribution of forage germplasm is another important function of the program. Seed of promising species was supplied this year to pasture researchers in 16 tropical American countries.

Forage Species Evaluation

Accessions of each of the major legume genera including *Stylosanthes, Desmodium, Centrosema, Zornia, Macroptilium* have been checked for desirable forage characters and in each genus promising new material has been identified. Some os these new species forms are scarcely known to agriculture. Species showing promise at this stage of the evaluation program are the following.

Stylosanthes. From the IBPGR project and accessions contributed by other organizations, CIAT now has 650 accessions of *Stylosanthes* in its forage legume germplasm bank, which is managed as a working facility of international caliber, to serve the lowland tropics.

Preliminary assessment of new accessions was done in the plant house where simple growth characters were measured and the stylos were tested for anthracnose resistance using artificial inoculation techniques. Of 600 stylo accessions tested for anthracnose tolerance, approximately 8 percent showed a high degree of tolerance to the disease. Appearances of resistant and susceptible reactions are shown in Figure 2.

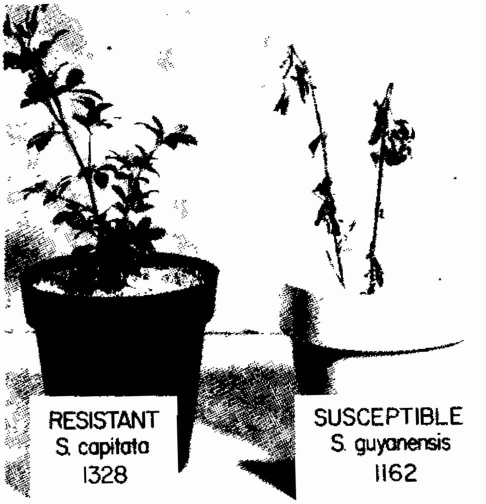


Figure 2. Comparison of anthracnose resistant and susceptible accessions of *Stylosanthes*. Varieties of *S. capitata* have exhibited strong resistance to anthracnose (*Colletotrichum* sp.).

To date, stemborer attack has not been observed outside the Colombian Llanos region, where it seriously damages stylo stands. Observations indicate that this insect favors species which have a hard woody main stem (Fig. 3). Selection for stemborer resistance is in progress and as with anthracnose, differences in tolerance within and between species have already been observed.

Agronomic assessment of a wide range of *Stylosanthes* introductions has been initiated in a search for disease and stemborer-resistant genotypes adapted to allic soil conditions. Duplicate sets of stylo introductions have been established in replicated, space-planted plots, one set at Carimagua (in the Colombian Llanos) and another at Santander (in the Cauca region south of CIAT). A total of 141 stylo introductions are now under observation. A third set of accessions has been established at CIAT for observation and initial seed increase of new stylos.

The stylo accessions showing promise as forage cultivars include fine-stemmed biotypes of *S. guyanensis* and two introductions of *S. capitata*. (Fig. 4).

S. capitata is a hardy perennial species, native to eastern Brazil and Venezuela. Its distribution is restricted in comparison to the rather ubiquitous species *S. guyanensis* and *S. humilis*. *S. capitata* is adapted to very low fertility soils, derived from sandstone. This soil type is common in the Campo Cerrado region of Brazil. Several varieties were found to be tolerant to anthracnose and stemborer attacks. This species of stylo is slow to develop in the year of establishment. It is a prolific seeder and regenerates from self-sown seed (Fig. 5) In spite of the restricted distribution of the species, *S. capitata* accessions show a great deal of ecotypical variation.

In a plant house experiment, 14 varieties of *S. capitata* were compared with three varieties of *S. humilis* and eight perennial

Figure 3. A *Stylosanthes scabra* plant severely damaged by stemborer (*Zaratha* sp.)

Figure 4. Fine-stemmed *Stylosanthes guyanensis* is well-adapted to low fertility soils and some ecotypes show tolerance to both anthracnose (*Colletotrichum* sp.) and stemborer (*Zaratha* sp.).

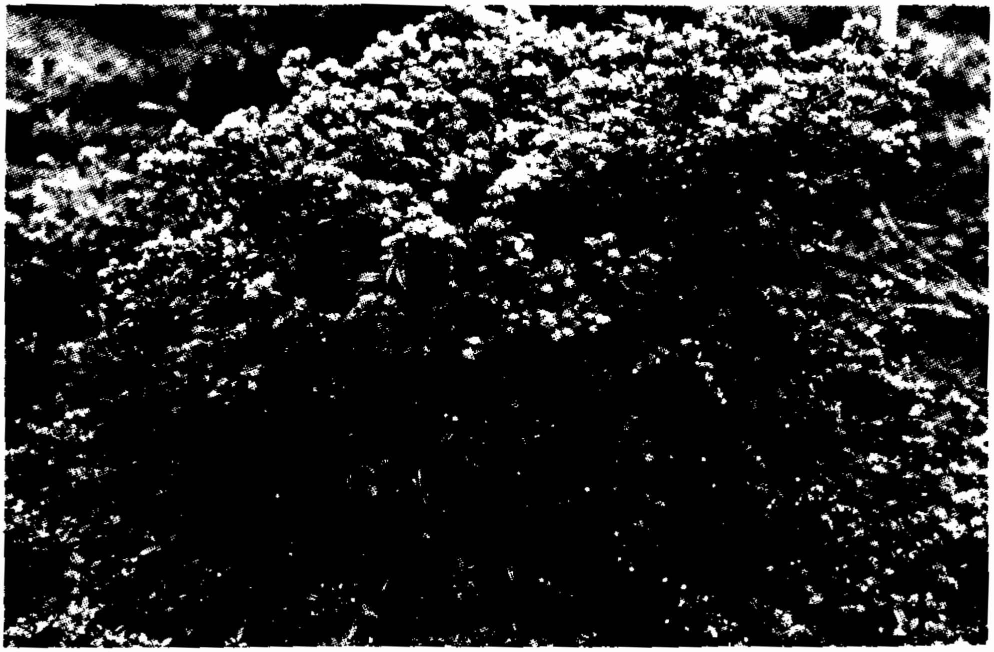


Figure 5. A *Stylosanthes capitata* plant (CIAT 1019) in full seed on the Eastern Plains of Colombia, at Carimagua.

species of *Stylosanthes*. One of the *S. humilis* varieties outyielded all 15 *S. capitata* accessions as well as all the other perennial species in the trial (Table 2).

The three highest yielding *S. capitata* accessions significantly outyielded nine other *S. capitata* varieties as well as seven other species including two accessions of *S. guyanensis* and one of *S. humilis* accessions. Slow initial growth of this otherwise very promising forage legume is one of its main disadvantages.

Table 2. **Dry matter yields of 14 accessions of *Stylosanthes capitata* and 11 accessions of other *Stylosanthes* spp.**

CIAT No.	*Stylosanthes* sp.	Dry matter yield per plant (total of two harvests) (g)[1]
1304	*humilis*	3.51a
1307	sp.	2.89b
1305	*humilis*	2.86b
1342	*capitata*	2.76b,c
1315	*capitata*	2.61b,c,d
1339	*capitata*	2.38b,c,d,e
1338	*capitata*	2.26c,d,e
1318	*capitata*	2.24c,d,e
1303	sp.	2.23d,e
1275	sp.	2.20d,e,f
1328	*capitata*	2.15d,e,f
1334	*capitata*	2.11d,e,f
1330	*humilis*	2.04e,f
1317	*guyanensis*	2.04e,f
1323	*capitata*	2.04e,f
1078	*capitata*	2.01e,f
1093	sp.	1.97e,f
1007	*capitata*	1.94e,f
1322	*capitata*	1.89e,f
1298	*capitata*	1.89e,f
1191	*capitata*	1.70f,g
1257	sp.	1.27g,h
1255	sp.	1.13h
1335	*guyanensis*	1.00h,i
1350	*capitata*	0.59i

[1] L.S.D. at .05 = 0.53 and at 01 = 0.70

A series of grass/legume sward trials has been established at Santander. In each trial, stylo varieties were included as standards for comparison. Four grass species, *Andropogon gayanus, Panicum maximum, Hyparrhenia rufa* and *Brachiaria decumbens* were used in the various grass/legume combinations. In one experiment a mixture of legumes—*Macroptilium* sp. (CIAT 535), *Centrosema* hybrid (CIAT 1733) *Stylosanthes guyanensis* (CIAT 184), and *Desmodium* sp. (CIAT 336)—was planted with each one of the grass species.

This experiment was harvested three times during the year of establishment; yields are shown in Table 3. Of the three harvests, two were taken during the unseasonable and exceptionally long dry period experienced in the Cauca Valley. Dry weather reduced the *Desmodium* in the sward with a corresponding increase of stylo. *Macroptilium* showed moderate tolerance to extreme dry conditions.

Several one-grass/one-legume associations have been established at Santander. In general, stylo varieties displayed good early vigor and gave the best dry matter yields in the various grass/legume combinations. *Centrosema* and *Macroptilium* were slower to establish but their contribution to the sward increased with time. In each case, the nitrogen content of *Centrosema* hybrid exceeded that of the other legumes in these trials.

Drought tolerance was exceptionally good in *A. gayanus* and *B. decumbens* while guinea grass was the least tolerant to adverse weather conditions. *Hyparrhenia* also suffered seriously from dry conditons.

Table 3. **Dry matter yields and nitrogen and phosphorus content of four grasses and an associated legume mixture grown at Santander, 1976.**

Species	Dry matter yield[1]			Sward composition[2]		Nitrogen content[2]		Phosphorus content[2]	
	Grass	Legume	Total mixture	Grass	Legume	Grass	Legume	Grass	Legume
	(kg/ha)			(%)		(%)		(%)	
Guinea grass, Legume mixture	7,256	1,683	8,939	81.17	18.83	1.73	2.64	0.13	0.19
Andropogon gayanus, Legume mixture	5,808	1,811	7,619	76.23	23.77	1.36	2.53	0.15	0.19
Brachiaria decumbens, Legume mixture	2,630	4,225	6,885	38.37	61.43	1.67	2.63	0.16	0.17
Hyparrhenia rufa, Legume mixture	4,931	1,776	6,707	73.52	26.48	1.42	2.68	0.13	0.19

1 Total of three harvests during the year of establishment

2 Average of three harvests during the year of establishment

S. guyanensis is well-adapted to soil and climatic conditions in the Santander area. Growth rates of two accessions, CIAT 184 and 136 are being studied under two frequencies of cutting in pure legume stands. CIAT 184 is native to the Santander area and CIAT 136 is from the Llanos of Colombia. Both varieties have robust growth forms, produced high yields of dry matter in the year of establishment and displayed very good resistance to drought. Table 4 shows establishment yields, and phosphorus and nitrogen concentrations for these accessions at Santander.

CIAT's germplasm bank contains over 200 accessions of *Desmodium*. Two species, *D. canum* and *D. barbatum*, are particularly common in the savanna. They are usually associated with short grass pastures of *Paspalum notatum* and *Axonopus* spp. and colonize low fertility soils. A great deal of variability was observed

Table 4. **Establishment yields and phosphorus and nitrogen contents of two lines of *Stylosanthes guyanensis* grown at Santander, 1976.**

Lines	Dry matter yield[1] (kg/ha)	Mineral composition[2] Phosphorus	Nitrogen
		(%)	
S. guyanensis (CIAT 184)	11,250	0.16	2.22
S. guyanensis (CIAT 136)	9,762	0.16	2.64

1 Total of two yields

2 Average of two yields.

within each species, and some attractive forage types have been selected. Tables 5 and 6 show some of the growth characteristics of several *Desmodium* accessions.

The accessions of *Zornia* in the collection vary considerably in morphological characters and forage production. The genus contains a number of species and several of them are native in the Llanos and in the Campo Cerrado. A Brazilian and a Colombian ecotype have been selected for further studies.

One species of *Macroptilium* from the Venezuelan Llanos appears to be well-adapted to allic soils.

Table 6. **Rate of leaf appearance in seven *Desmodium* spp. accessions.**

Species and CIAT accession no.		Avg. no. of trifoliate leaves/day
D. canum	3037	1.95a[1,2]
D. heterophyllum	349	1.58b
D. barbatum	3010	1.52b
D. scorpiurus	3022	1.49b
D. barbatum	3031	1.37bc
D. canum	3005	1.19c
D. canum	3042	0.85d

[1] L.S.D. at .01 = 0.2098 and at .05 = 0.1594

[2] Values followed by different letters are significantly different at .01 by Duncan's Multiple Range Tests.

One of the grasses recently added to CIAT's collection, *Andropogon gayanus*

Table 5. **Rate of growth of *Desmodium* spp. on two Colombian soils.**

Species and CIAT accession no.		Soil location and plant growth: Carimagua	Santander	Avg. for both soils: Accession	Plant growth
		(mg dry matter/plant/day)			(mg dry matter plant/day)
D. canum	3029	47.32[1]	51.53[1]	3035	49.95a[2]
D. barbatum	3031	46.99	52.08	3031	49.53a
D. canum	3035	46.44	53.44	3029	49.43a
D. canum	3044	45.82	46.06	3045	47.29ab
D. canum	3013	43.66	46.40	3028	45.98abc
D. canum	3041	43.47	44.14	3030	45.96abc
D. canum	3028	43.20	48.76	3044	45.95abc
D. canum	3030	42.75	49.16	3039	45.55abc
D. canum	3045	42.07	52.51	3042	45.19abc
D. canum	3036	41.93	44.26	3013	45.03abc
D. canum	3042	41.66	48.71	3041	43.81abc
D. canum	3032	41.44	43.42	3036	43.09bc
D. canum	3039	41.02	51.07	3032	42.41bc
D. barbatum	3061	35.08	37.62	3053	40.91cd
D. adscendens	3053	34.64	47.42	3015	36.64d
D. canum	3003	34.62	37.62	3061	36.38d
D. canum	3015	33.64	39.65	3003	36.12d
D. barbatum	3054	32.20	26.64	3054	29.47e

[1] L.S.D. between soils at .01 = 1.85 and at .05 = 1.38. L.S.D. between varieties at .01 = 4.95 and at .05 = 3.76

[2] Values followed by different letters are significantly different at .01 by Duncan's Multiple Range Test.

has very good forage characteristics. It is drought and fire-resistant and well-adapted to soil conditions of the Colombian Llanos. There it seeds prolifically and spreads rapidly as the light seeds are disseminated by wind and water.

Advanced selections of forage legume cultivars are being tested under actual grazing conditions prior to release to national forage programs. Potential release material includes: one *Centrosema* hybrid (CIAT 1733), one *Desmodium* sp. (CIAT 336) and one *S. guyanensis* (CIAT 136).

Pasture Seed Production

The production of seed of potentially useful accessions has continued as the main objective of this unit during 1976. New seed production areas, involving two new locations and a wider array of legume species and experimental lines, have been established. In general, legumes have been concentrated at Santander and Restrepo, environments with more favorable soil and weed conditions than at CIAT (Palmira). Experiments have been initiated at these locations to investigate responses to various levels of phosphorus and defoliation and to evaluate support systems to assist in determining management systems appropriate for expanded production areas in the future. Grass seed production plots are located at Palmira and Santander. Seed harvested in the last year was predominantly *S. guyanensis* (CIAT 136).

Stylosanthes spp.

Twenty-five hectares of mature *S. guyanensis* (CIAT 136) planted at Palmira and Carimagua were directly combined in January and February 1976 (Fig 6). Table 7 provides details of these harvests. At Palmira, yields from different lots ranged from 35 to 139 kg/ha of acid scarified, pure seed. The average yield was 69 kg/ha. Yields at Carimagua were much lower, with individual lots ranging from 2 to 31 kg/ha and a location average of 3 kg/ha. Some 700 kilograms of pure seed were produced from these two locations.

Table 7. **Description of seed harvest and major yield determinants of *Stylosanthes guyanensis* (CIAT 136) at two locations.**

Factor	Location	
	Palmira	Carimagua
Seed harvest		
Crop area (ha)	10.3	15.0
Crop height (m)	1.5	0.8
Combine rate (ha/hr)	0.12	0.26
Yield (kg/ha)[1]	69	3
Yield determinants[2]		
Weed competition	+++	+
Anthracnose	+	++
Stem borer	-	+++
Bud worm	++	+++

[1] Acid scarified, pure seed

[2] - not present; +, present; ++, problem; +++, serious problem.

The rate of harvest with the combine was determined by the height, density, stickiness, seed yield and moisture content of the standing mature crop and relative humidity conditions on harvest days. At Palmira, a minimum forward speed and partial width of cut were necessary to assure effective separation and recovery of seed bearing fractions from a tall, dense, sticky, high-yielding crop. The harvest rate at Carimagua was higher due to both lower crop density and seed yield and, also, lower relative humidity conditions.

The major yield determinants at Palmira were weed competition *(Ipomoea* spp., *Amaranthus debius, Commelina diffusa, Sida* sp., *Cynodon dactylon)* and a bud

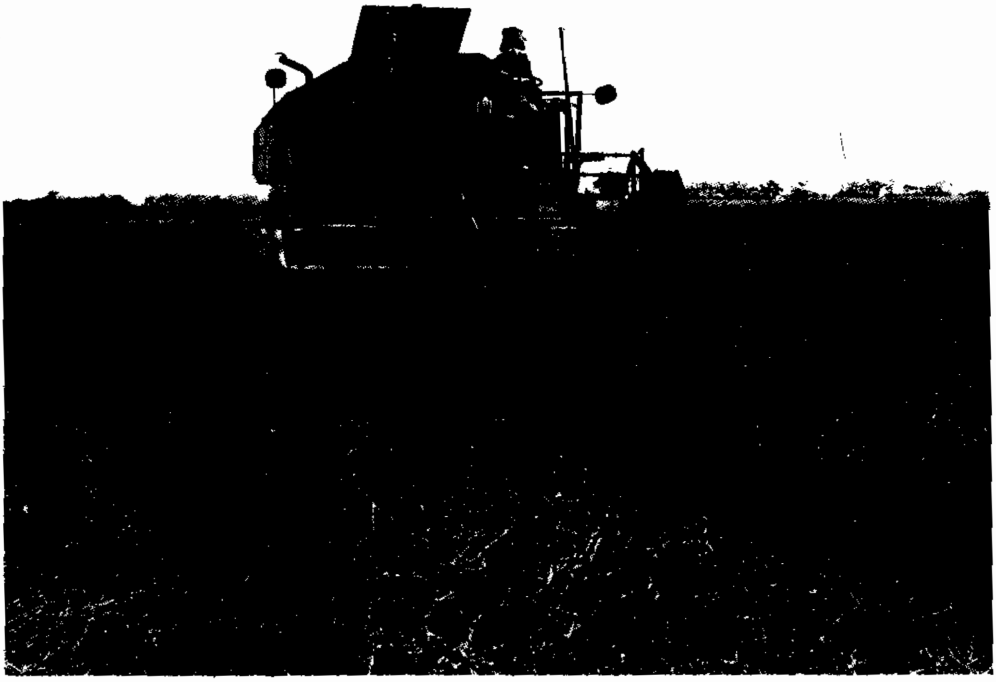


Figure 6. Combine harvesting of *Stylosanthes guyanensis* at CIAT, Palmira

worm, *Stegastra bosqueella* (Chambers) (Lepidoptera, Gelechidae). During seed processing with a conventional air screen cleaner, weed seeds of *C. diffusa* and *Sida* sp. caused separation problems. Weeds generally restrict the productive life of a stand to one, or at the most, two harvests.

At Carimagua, the combined and sequential effects of anthracnose, *Colletotrichum gloeosporioides* Penz; a stemborer, *Zaratha* sp. (Lepidoptera, Blastodanidae); and the *Stegastra* bud worm, were devasting. Future seed production of *Stylosanthes* lines susceptible to the stem borer and anthracnose will therefore be located elsewhere.

C. gloeosporioides is now regarded as being seed transmitted but sulphuric acid scarification of pods and seeds was shown to reduce the amount of seed-borne inoculum.

Small areas of 26 new accessions of *S. guyanensis, S. scabra, S. sympodialis* and *S. capitata* have been established at Santander.

Desmodium spp.

A stand of *Desmodium* sp. (Ciat 336) was harvested at Palmira by direct combining in early March 1976. Yield of scarified pure seed was 47 kg/ha. The development of an April 1976 planting at Santander has been severely retarded by a prolonged dry season. The seed yield potential of this line is also being investigated at Restrepo (altitude 1,400 meters, average annual temperature 20°C and annual rainfall, 1,020 milimeters).

Small areas of *D. heterophyllum* have recently been established at Palmira, Santander and Restrepo, to compare seed production characteristics in three contrasting environments. Twenty new accessions of various species of *Desmodium* have been established at Santander.

Centrosema sp.

Two F_7 lines of the hybrid *C. brasilianum* x *C. virginianum* are established on a bamboo and wire trellis system at Palmira. Flowering in 1976 was sparse and confined to early February as subsoil moisture promoted continued vegetative growth. Hand harvesting was completed by late March. Seed yields were very low, averaging only 16 kg/ha of pure seed. Yield potential is now being investigated at Santander, both with and without support systems.

Grass species

New areas of *B. decumbens, B. humidicola, A. gayanus* and *P. maximum* have been planted at Santander and Palmira. The prolonged dry period from May to September reduced seed yield and quality at first harvest and negated responses in two nitrogen rate experiments. Seed quality studies have been initiated comparing *P. maximum* seed harvested by hand and by direct combining.

Pasture Establishment and Maintenance

The objective of research in pasture establishment and maintenance is to develop low-cost systems for efficiently establishing legumes and grasses alone and in association on the allic soils of the tropical savannahs of South America. Studies include seedbed preparation, different aspects of planting including band versus broadcast seeding and fertilizer application, compaction, nutrient requirements, the interaction between species and fertilizers, sources and methods of applying phosphorus, fertilizer requirements for establishment under different drainage regimes and fertilizer maintenance requirements for grasses under grazing management.

Seedbed preparation

Most improved pastures are established in savannah regions after conventional plowing and disking or using heavy offset discs to completely destroy existing vegetation, leaving a reasonably smooth, weed-free surface and a plow layer 10-15 centimeters deep. With experience and quality seed, excellent pasture stands can be obtained with this type of seedbed preparation. It is, however, costly in terms of power and machinery required and it exposes the soil to extreme erosion hazards. A seedbed preparation trial was established in 1974 but discontinued for several reasons. It was established again in 1975 and includes the following treatments: (a) no tillage, with and without herbicide control of vegetation; (b) minimum tillage in which a fluted coulter is used to work up a very narrow band (approximately two centimeters) into which the introduced species are seeded, with and without herbicide; (c) the use of stubble mulch sweeps to undercut the savannah vegetation at a very shallow depth to separate the plant crown from the root system. The sweeps are used to cultivate 30-centimeter strips leaving 30 centimeters of undisturbed savannah between cultivated strips. In an additional treatment (d) the sweeps are used to cultivate the entire surface, thus destroying most of the native vegetation. This method of cultivation leaves the surface well-protected with all of the crowns and top growth remaining on the surface of the soil. The last treatment (e) is the conventional method of seedbed preparation involving a light plowing and subsequent disking.

Figure 7 shows the effects of tillage and herbicides on plant density of native species, population of introduced species and production of forage. Almost complete control was achieved with conventional seedbed preparation and this system resulted in the highest average yields for the species planted. Good control of native vegetation was achieved with the stubble mulch sweeps with or without herbicide treatment and stands of most species were adequate for these treatments, along with the no-tillage herbicide control treatment. However, yields at six months were very much affected by degree of control of native species. Yields decreased in the order of conventional> sweep strip tilled with herbicide control > sweep tillage of entire surface > strip tillage without herbicide control > no tillage with herbicide control>no tillage with no herbicide control. It was not possible to measure the influence of tillage treatment on soil loss or run-off losses. However, it is almost certain that the erosion hazard would be much greater for conventionally tilled seedbeds than with any of the other seedbed preparation systems. The stubble mulch sweep system provides excellent ground cover during the establishment phase for the seeded pasture.

A major advantage of the stubble mulch sweep is its low power requirement. It is estimated that stubble mulch tillage of the entire surface would cost approximately one-quarter as much as conventional tillage and stubble mulch tillage of strips would cost correspondingly less depending on the fraction of the total surface tilled. Another advantage of the sweep is that it should be well-adapted to animal draft implements and possible to manufacture locally. The first year's results of this trial indicate the need for more extensive testing of alternative systems of seedbed preparation, to replace or modify the conventional systems.

Planting systems

Most pastures in developing savannah regions are seeded manually either with seed or vegetative material. Stands are very erratic due to seed of unknown quality as well as to other factors. Grasses are usually surface-seeded with no covering after conventional seedbed preparation. Ranchers usually wait for a few hard rains to settle the surface of the soil before seeding, otherwise, small-seeded species like *Melinis minutiflora* and *H. rufa* will be covered too deeply with almost certain loss of stand. The most important factors in obtaining a good, uniform stand appeared to be: (a) proper compaction of the seed to assure good seed-soil contact and capillary flow of moisture from below to the surface where the seedling is struggling to survive; and, (b) adequate fertilizer in the seedling zone to assure good seedling vigor, especially important with the very small-seeded species which have hardly any nutrient reserve in the seed. Phosphorus is especially important in assuring seedling vigor in allic savannah soils that are almost universally extremely low in available phosphorus.

Compaction. In this trial, three different associations were planted with three systems of compaction consisting of: (a) a no-compaction check; (2) compaction in the band only; and, (3) compaction of the total surface. Band compaction was accomplished with an Allis Chalmers

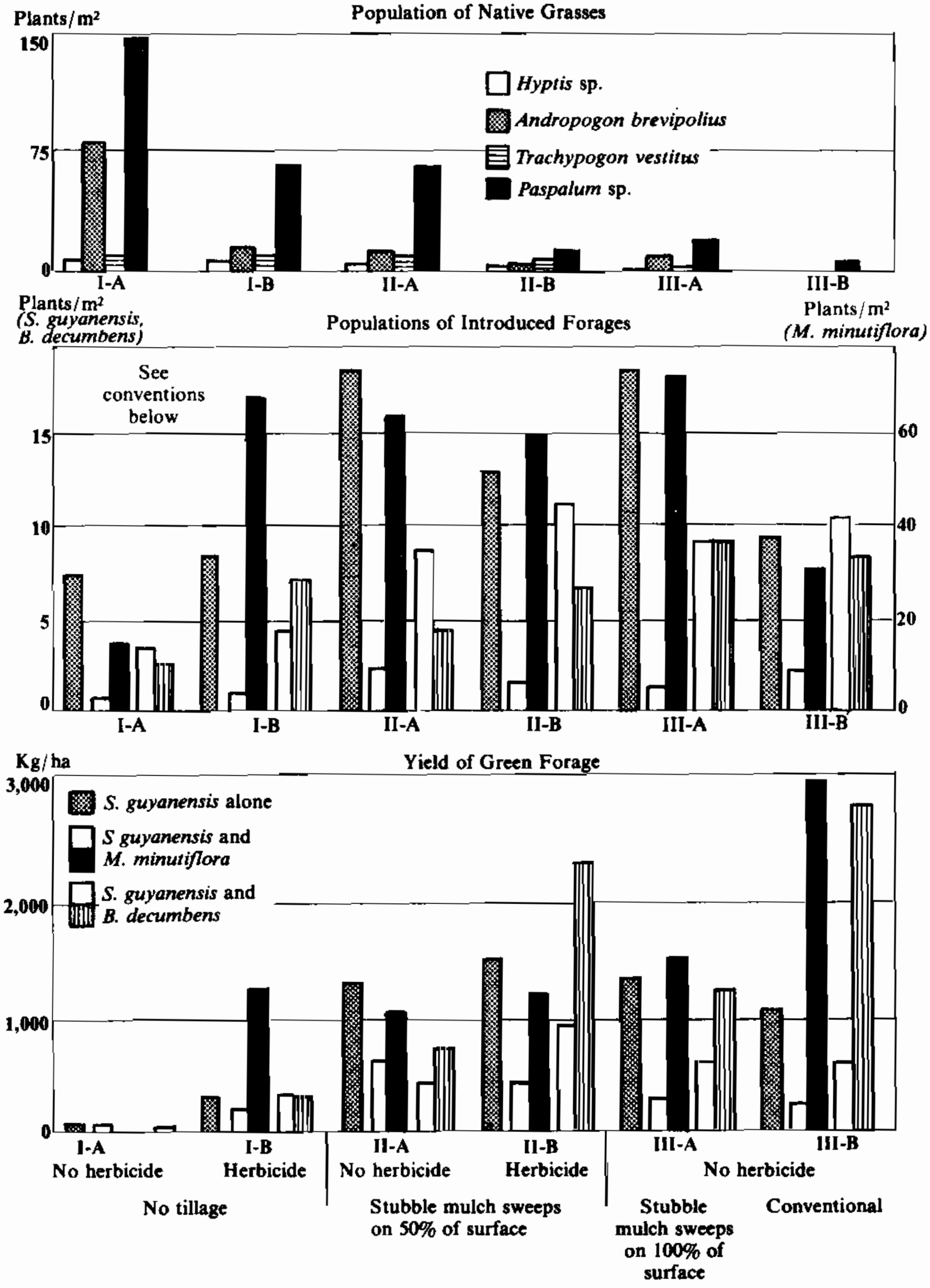
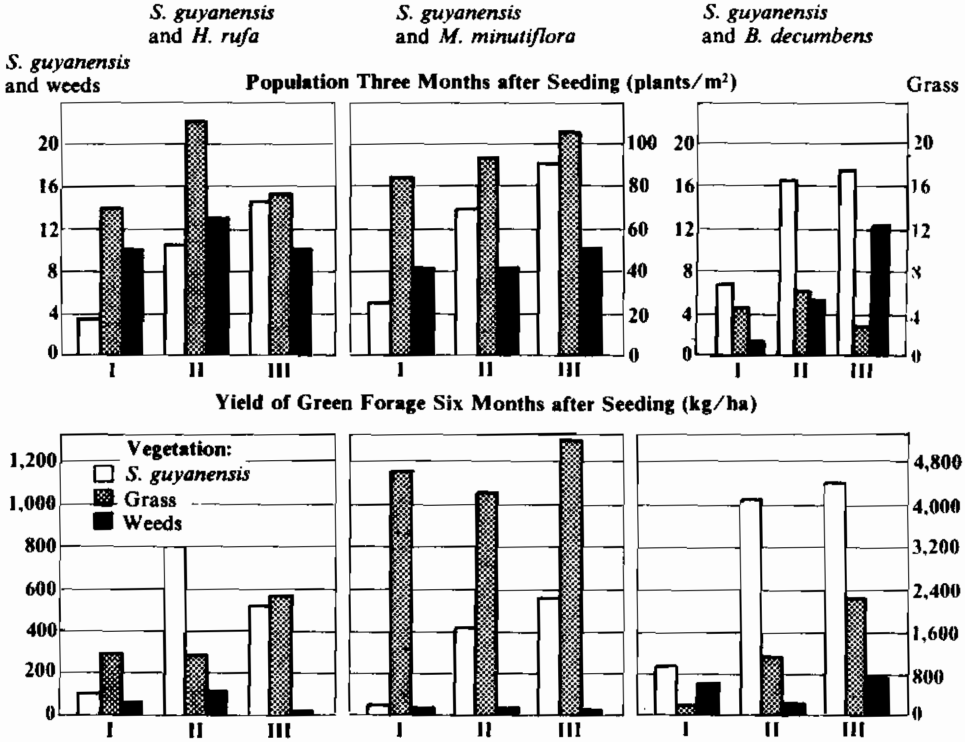


Figure 7. **Effects of different methods of preparing the soil and of controlling native vegetation on populations of native grasses and populations and yields of introduced forages, at Carimagua, 1975-76.**

planter press wheel directly over the seeded band. Total surface compaction was obtained with a compactor built of old automobile tires, with approximately the same weight per unit surface area as the band compactor.

Figure 8 shows the effect of compaction treatments on stands and forage yields of association of *Stylosanthes* with *H. rufa*, *M. minutiflora* and *B. decumbens*. Stand counts and yields are shown for the legume and grass components of the mixtures as well as weeds. Compaction, both in the band and over the entire surface, greatly enhanced the establishment of *Stylosanthes* in all mixtures, which was reflected in *Stylosanthes*, yields for all mixtures.

There was considerably less effect of compaction on stands of the associated grasses. However, compaction did have a very favorable effect on yields of *H. rufa* and *B. decumbens*. *M. minutiflora* is one of the easiest of the grass species to establish. This may account for its popularity in many savannah regions. Although weed counts were rather high in all associations, weed yields were almost insignificant, reaching their lowest level in the *Stylosanthes-Melinis* association. Note that in some cases, the scale is different for the grass component and legume component of the different associations.



Treatments: I No compaction
II Compacting in bands
III Compacting total surface

Figure 8. Effects of compacting treatments on the stablishment and performance of three forage associations at Carimagua, 1975-76. In all graphs, *S. guyanensis* and weed populations are on the left vertical scale and the respective grass populations are on the right vertical scale.)

The compaction trial was conducted on a conventionally-prepared seedbed. As progress is made with alternative systems for seedbed preparation, additional work will be required to determine the need for compaction. It appears that it may be less essential with sweep tillage than with conventional tillage since the seedbed is less disturbed and surface mulch tends to buffer the soil against rapid changes in soil moisture, promoting better seedling development than on conventionally prepared, bare land.

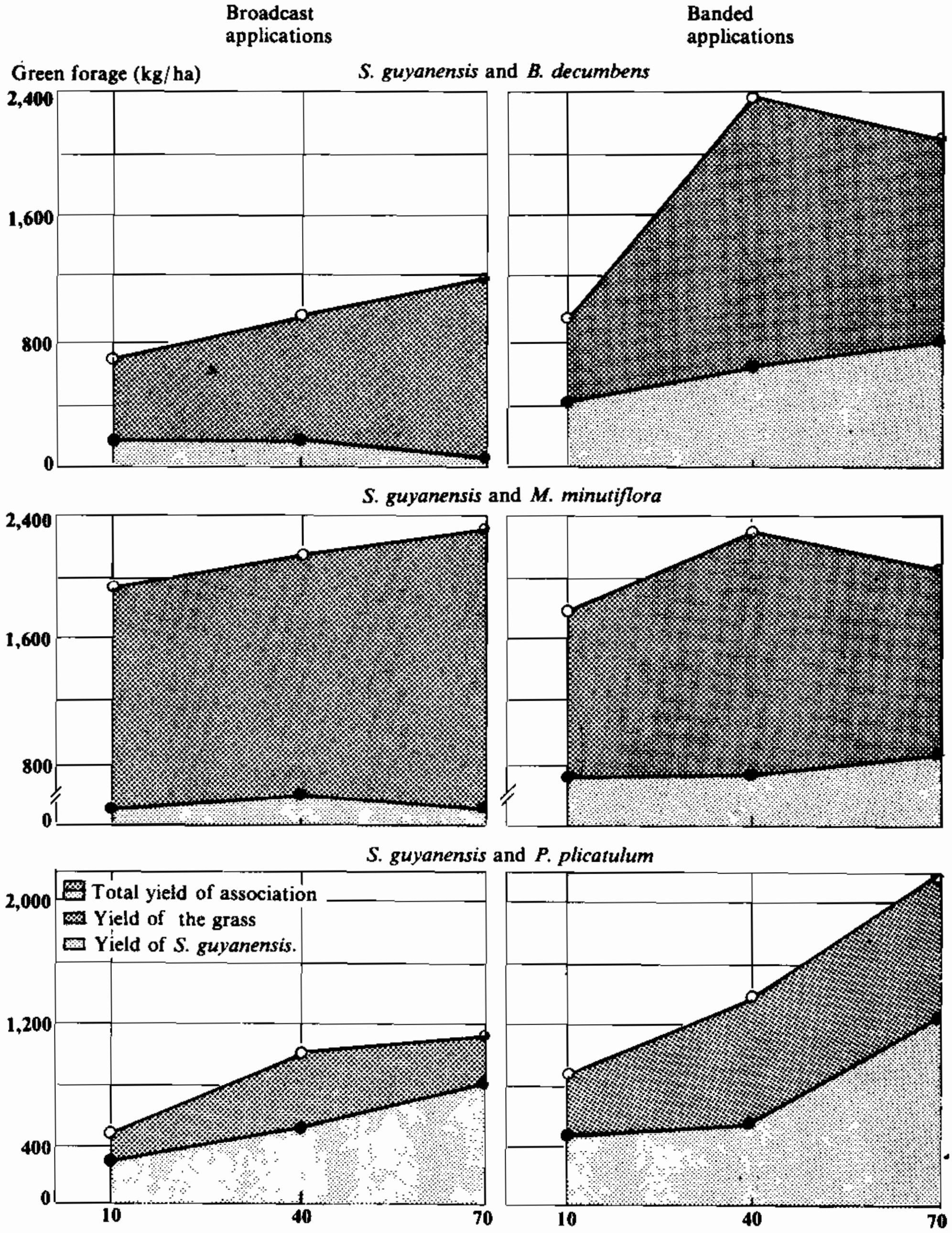
Phosphorus levels and systems of application. Three levels of phosphorus — 10, 40 and 70 kg P_2O_5 /ha — were applied broadcast and in bands, using basic slag as the source. The slag was mixed directly with seeds, thus seed was also broadcast or banded depending on how the phosphorus fertilizer was applied.

Figure 9 clearly shows that there is a definite advantage to band seeding and fertilizer application. It appears to be more important for the legume than for the grass. Stand counts fail to explain the yield differences. On the average, there were slightly better stands of *Stylosanthes* when it was bandseeded but there was no significant nor consistent difference in total stands and grass stands. Band seeding and fertilizer application apparently create a more favorable fertility environment for the developing seedling than do broadcast applications. The fertilizer is concentrated in the seedling zone and phosphorus availability is greater during the seedling stage when it appears to be especially critical for small-seeded forage species.

Figure 10 shows effects of phosphorus and method of application on phosphorus content in *S. guyanensis* and associated grasses when they were cut the first time after five months and the second time after 10 months. The first cut was at the end of the rainy season and the second cut was after the dry season as another rainy season was beginning. Phosphorus rates had a marked effect on the phosphorus content of *Stylosanthes* and *Brachiaria* and broadcast application was much more efficient than band application at the first cutting after five months. This effect tends to disappear in the second cutting. There is very little effect on the phosphorus content of *M. minutiflora* or *Paspalum plicatalum*. Figure 11 shows the effect of phosphorus rates and method of application on nitrogen content of the four species in this trial. At the first cutting there was a slight indication of greater effect of broadcast-applied phosphorus in *Stylosanthes* and *Brachiaria* but the major effect appears to be one of dilution with nitrogen levels generally decreasing with increasing levels of applied phosphorus which resulted in increased dry matter yields.

Brachiaria is generally considered to have relatively low fertility requirements and it is used widely throughout South America in allic soil regions. However, during the establishment phase on an oxisol at Carimagua it was extremely responsive to phosphorus, as can be seen in Figure 12. Response to potassium was less striking. This experience is in line with other observations and experiences at Carimagua where most forage species respond very strongly to applied phosphorus during the establishment phase.

A trial was established in early 1976 to evaluate three grass species associated with Kudzu *(Pueraria phaseoloides)* in a poorly-drained low area. The grasses included were Tanner, Pará and Alemán *(Brachiaria rugulosa, B. mutica* and *Echinochloa polystachya).* In Figure 13 there is a very strong interaction between phosphorus and potassium. Kudzu, Pará and Tanner yields were extremely low



P_2O_5 (kg/ha)

Figure 9. The effects of three levels of phosphorus and two methods of applying phosphorus and seeding on yields of three forage associations, at Carimagua, 1975-76.

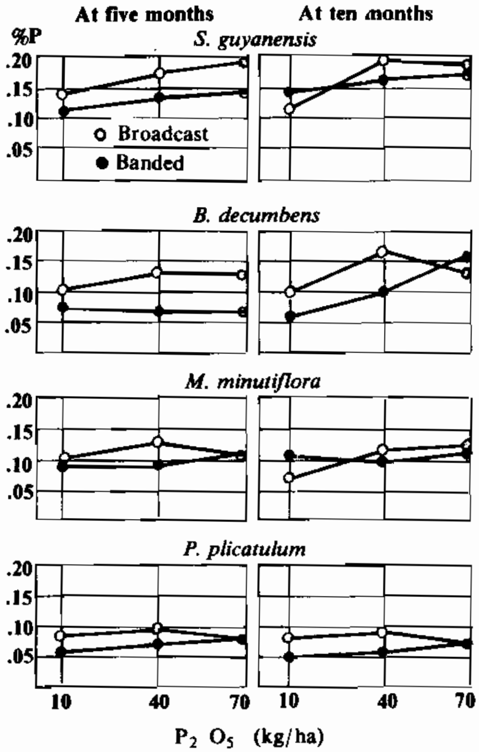


Figure 10. Effects of three levels of phosphorus and two methods of applying phosphorus and seeding on the phosphorus content of four forage species at five and ten months after seeding, at Carimagua, 1975-76.

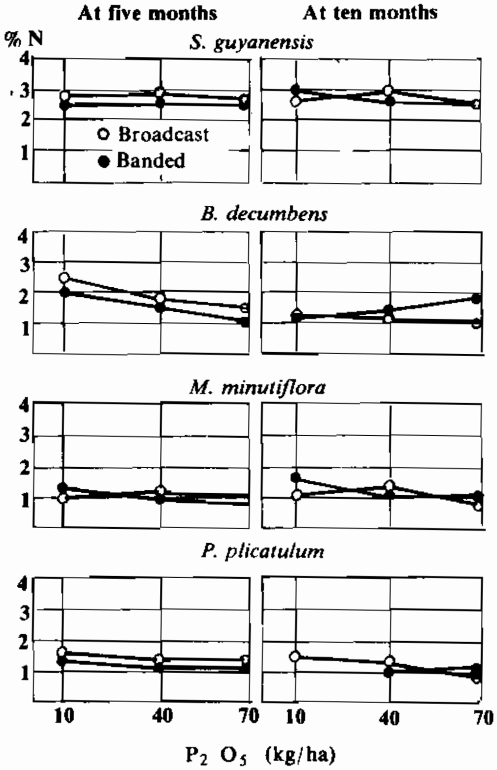


Figure 11. Effects of three levels of phosphorus and two methods of applying phosphorus and seeding on the nitrogen content of four forages at five and ten months after seeding, at Carimagua, 1975-76.

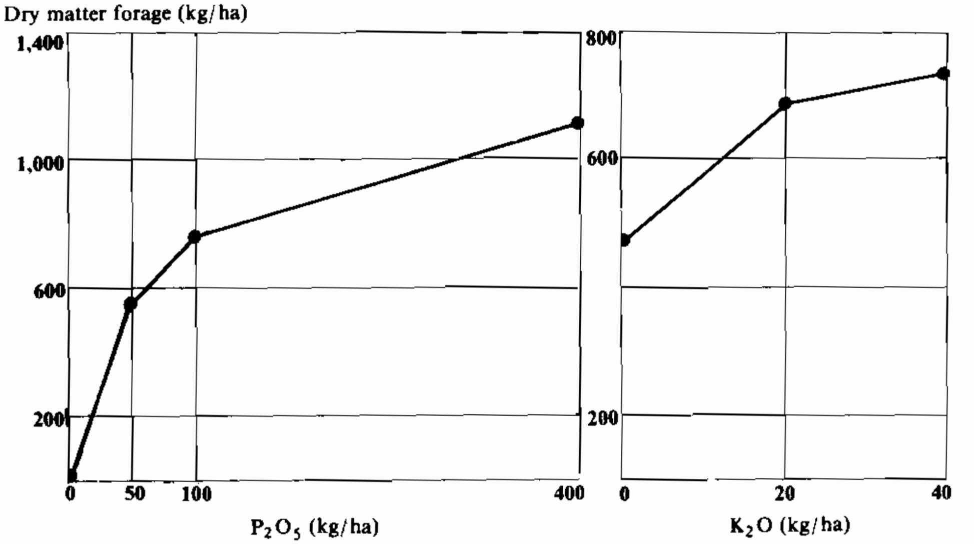


Figure 12. Effect of phosphorus and potassium on the dry matter yield at first cutting of *B.decumbens*, at Carimagua, 1976.

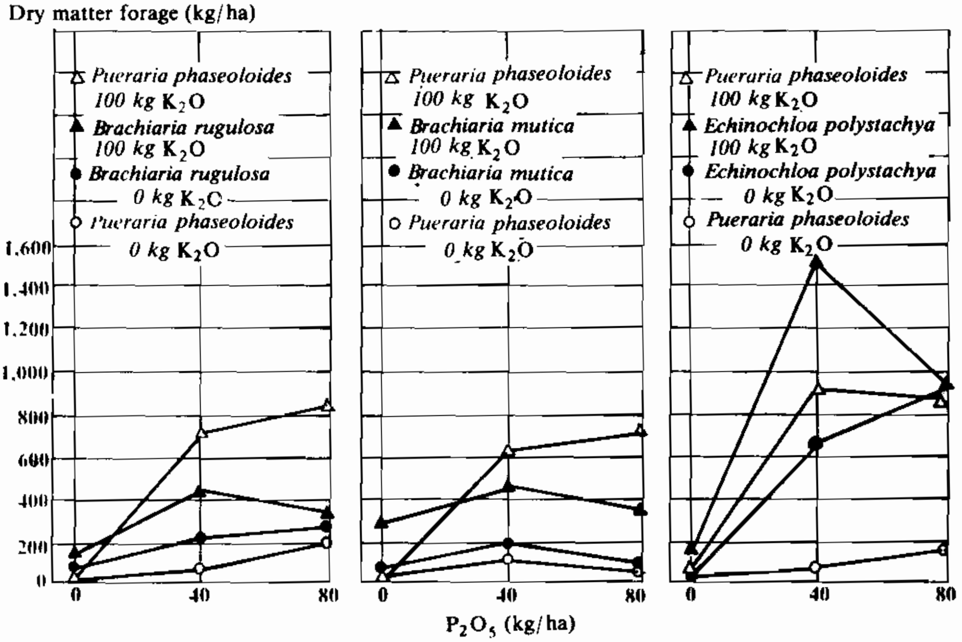


Figure 13. Effect of phosphorus and potassium on the yields of three grass-legume associations in poorly drained soil at Carimagua, 1976.

without added potassium fertilizer. Alemán is strikingly different in response pattern. Kudzu and Alemán were especially responsive to phosphorus. These species may have promise for poorly drained, low areas for accumulating high quality forage for summer grazing when these soils remain moist while the higher savannahs become extremely dry.

Field experience with Kudzu in Carimagua revealed nutritional problems. A greenhouse trial was initiated in early 1976 to study these problems. Figure 14 shows the effect of potassium and magnesium on yields of Kudzu in a greenhouse trial using Carimagua soil. The response to potassium is clear. There was also an apparent visual response to

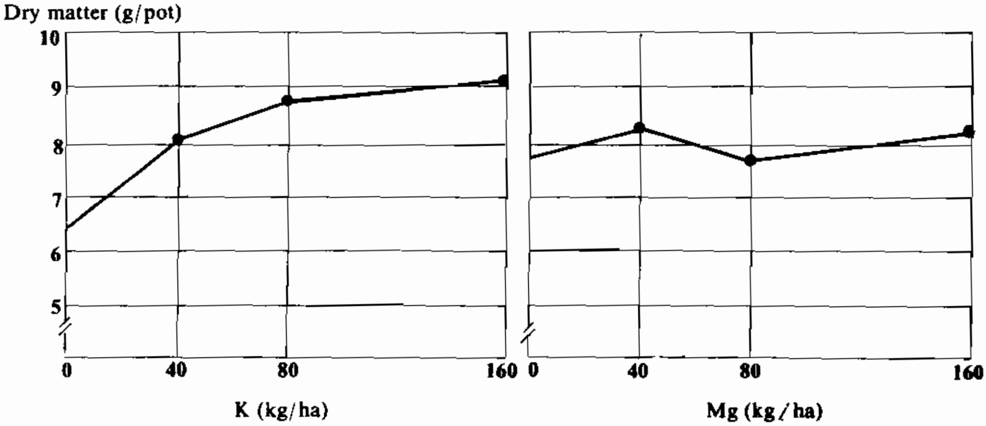
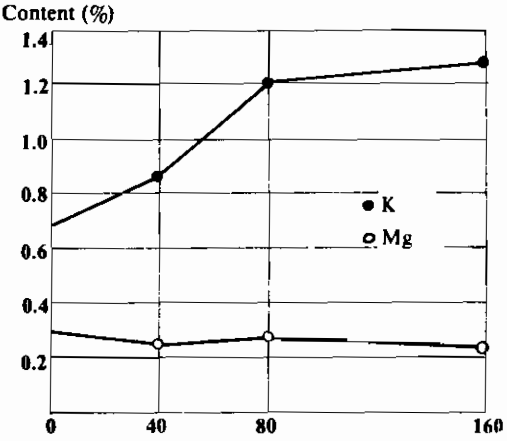
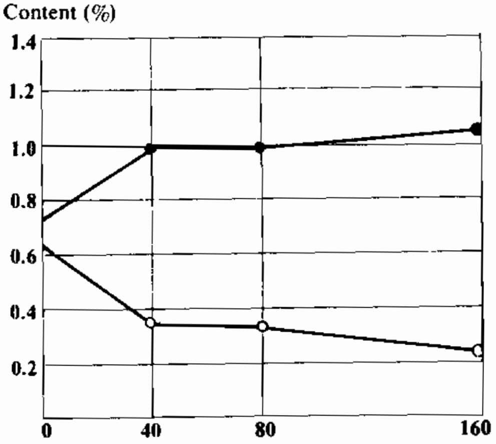


Figure 14. Effect of potassium and magnesium on dry matter yield of *P. phaseoloides* in Carimagua soil, in greenhouse tests, 1976.



K (kg/ha) without added Mg



K (kg/ha) with Mg constant at at 80 kg/ha.

Figure 15. Effect of potassium and magnesium on percentage content of those elements in young leaves of *P. phaseoloides* in Carimagua soil, in greenhouse tests, 1976.

magnesium but this was not borne out by dry matter yields. Magnesium deficiency symptoms which appeared, especially in treatments with high calcium and/or potassium applications, disappeared with application of magnesium. In Figure 15 the effects of potassium and magnesium are shown. Tissue content of magnesium was much higher when it was applied at low levels of potassium fertilization, but at 80 and 160 kg/ha of potassium, the difference in magnesium content due to added magnesium was very slight.

Soil Microbiology

Characterization of an extensive collection of *Rhizobium* strains against promising host plant forage accessions (mainly *Stylosanthes* spp.) is being pursued on three levels. First, aseptic tube culture permits large scale screening for compatability of host and bacterium. Culturing effective associations in Leonard jar assemblies allows strains to be ranked in order of efficiency. CIAT 79 (CB 756), a strain commonly used for inoculating *Stylosanthes,* performed poorly in these tests, averaging only 17th in efficiency order, whereas a local isolate (CIAT 71) is frequently high on the list (Table 8). However, the results emphasize the specificity of host-strain interaction. CIAT 71 failed to nodulate one of the accessions, so that although less efficient, the wider spectrum strain CIAT 308 (isolated at Cali, Colombia) has more potential as an inoculant. A collection program to search

Table 8. **Relative symbiotic nitrogen fixation efficiency[1] of *Rhizobium* strains with *Stylosanthes* accessions.**

	Stylosanthes Accession[3]					
Strain[2]	184	136	107	64A	1152	1053
CIAT 71	1	4	6	4	NN[4]	4
CIAT 301	6	5	5	22	NN	NN
CB 756	12	14	24	23	16	13
CIAT 308	3	8	7	13	2	1
CIAT 693	11	1	8	6	11	26
CIAT 530	NN	NN	NN	NN	NN	3

---

[1] Value is place of strain in list of 35 strains ranked in order of efficiency

[2] Only 6 of the 35 strains are included

[3] All *S. guyanensis* except 1053 which is *S. scabra*

[4] No nodulation.

for highly effective, wide-spectrum strains continues to be an important part of forage soil microbiology work.

At the third level of testing, the most efficient strains are screened in pot culture in sterilized site soil to assess their tolerance to low pH, low phosphorus availability and high aluminum level. Pot culture confirms that CIAT 71 and CIAT 301 (isolated from nodules of *Stylosanthes* collected in Brazil) are consistently better than CIAT 79 (Fig. 16).

It remains to be seen whether the superior efficiency of these and other strains is maintained in the field when they are subjected to the additional stress of competition for infection sites from inefficient, naturally-occurring *Rhizobium* populations.

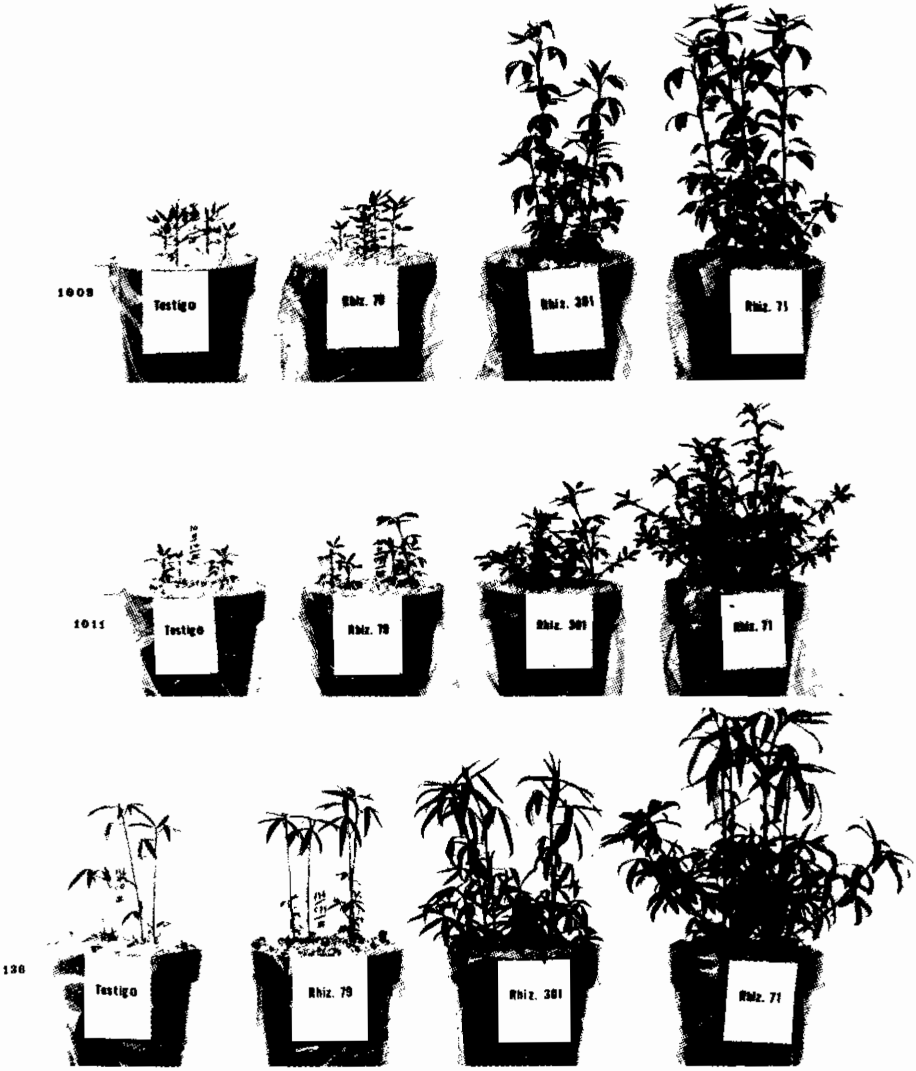


Figure 16. Response of three *Stylosanthes* accessions to inoculation with *Rhizobium* isolates 71 and 301 compared with the recommended strain 79 (CB 756) and uninoculated control plants. Accession 1009 is *S. scabra;* 1011 is *S. viscosa;* and 136 is *S. guyanensis.*

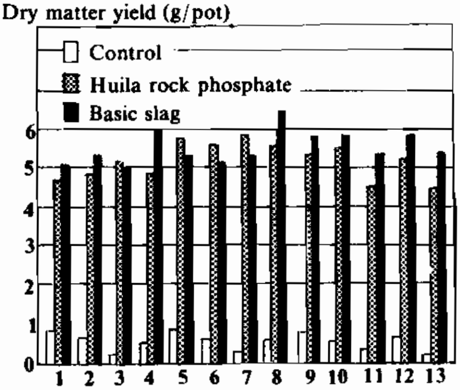
Efficient Use of Phosphorus on Tropical Soils

Phosphorus fertility management is very difficult in the allic soils of the tropics because of their low phosphorus fertility status and high fixation of fertilizer phosphorus. Recent research results indicate a number of possible new approaches to phosphorus management in tropical soils in order to improve phosphorus fertilization efficiency. Given the urgent need for more agricultural opportunities and increased food production in the tropics, a comprehensive research project was initiated in which laboratory, greenhouse and field research efforts of a team of specialists are coordinated and focused on improving phosphorus efficiency and increasing the productivity of tropical soils.

The Phosphorus Project was initiated in October 1975 as a special project. It is funded by the International Minerals Corporation and the World Phosphate Institute; some of the project's work is cooperative with the International Fertilizer Development Center. Research activities not discussed in the Annual Report of the Bean Program are summarized in this section.

Stylosanthes responses to phosphorus sources on allic soils

Greenhouse experiments for screening *Stylosanthes* species and ecotypes in an oxisol (Carimagua) for tolerance to low levels of phosphorus and for responses to low (rock phosphates) and high (basic slag) available phosphorus sources were initiated. Average yields of two cuts (Fig. 17) showed that all the 13 species and ecotypes studied responded well to 200 kilograms of P_2O_5/ha, independently of the sources. Only with *S. scabra* 1009 was there a significant difference in yield between the treatments with Huila rock phosphate and basic slag. Basic slag at 200 kilograms of P_2O_5/ha produced 23 percent more dry matter than the Huila rock treatment. On the other hand, Huila rock phosphate produced more dry matter than basic slag in the case of *S. guyanensis* 136 and 1073, and *S. scabra* 1050 and 1053. It was impossible to obtain good growth of this legume in the Carimagua soil without adding phosphorus, at least for establishment.



Stylosanthes species and CIAT No.

1	64A	*guyanensis*
2	184	"
3	136	"
4	1009	*scabra*
5	1073	*guyanensis*
6	1050	*scabra*
7	1053	"
8	1092	"
9	1057	"
10	1058	"
11	1082	"
12	1091	*montevidensis*
13	1019	*capitata*

Figure 17. *Stylosanthes* **and ecotypes screened in an oxisol (Carimagua) for tolerance to low (rock phosphate) and high (basic slag) available phosphorus sources, (average of two cuts).**

Dissolution of various phosphorus sources

Laboratory experiments were initiated on the dissolution of rock phosphates: Huila and Pesca from Colombia, Tennessee from U.S.A. and Gafsa from Morroco, and two other phosphorus sources (triple superphosphate (TSP) and basic slag) applied to an Oxisol from Carimagua and a volcanic ash soil from Popayán. In general, the results show a drastic reduction in available phosphorus extracted with Bray I and II solutions after 16 days of incubation at greenhouse temperature with only a slight further decrease after 35, 66 and 186 days.

Figure 18 shows the effect of incubation time on phosphorus availability in Carimagua soil, measured by Bray I and Bray II, when 300 ppm of phosphorus was applied from six different sources. Apparently, for soils fertilized with TSP or basic slag it is possible to use either Bray I or II to determine plant-available phosphorus. but when phosphorus is added as rock phosphate, the Bray I method seems to give a better measure of the available phosphorus in the soil. Bray II extractant solution is strongly acid and partially dissolves the rocks, showing high soil phosphorus concentrations that generally do not correlate with plant response.

Phosphorus status and fixation capacity of tropical acid soils

The phosphorus status and chemical characteristics of 14 acid soils from Colombia were studied. Table 9 shows

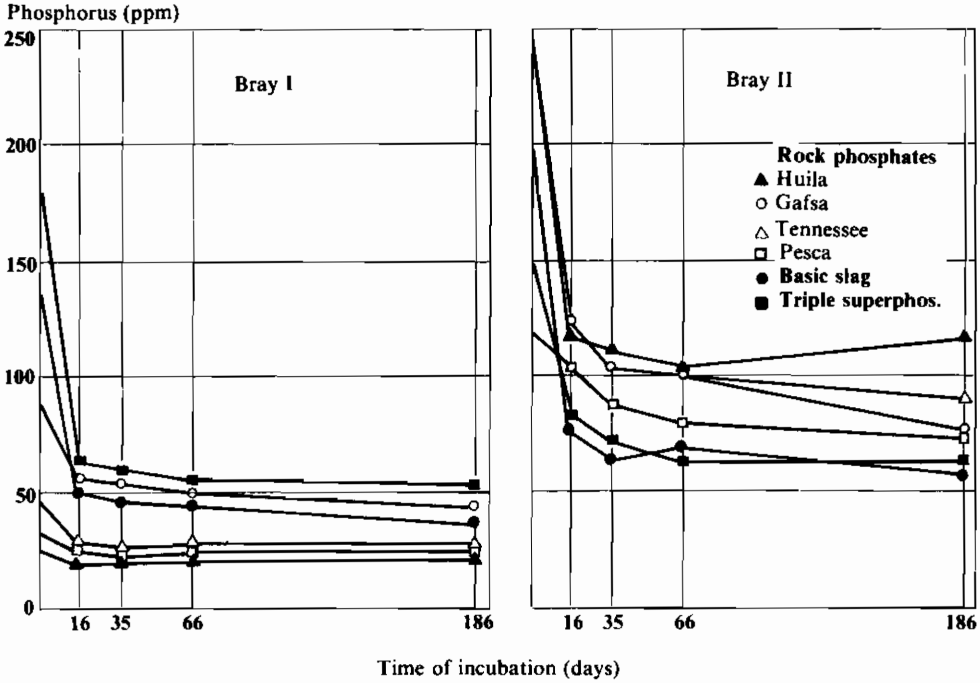


Figure 18. **Effect of incubation time on the solubility of 300 ppm of phosphorus from different sources applied to an Oxisol from Carimagua.**

Table 9. Phosphorus fixation capacity and some chemical characteristics of 14 acid soils from Colombia.

Soil	P fixation capacity		pH H_2O	Organic matter (%)	Extr. Al pH 4.8	Reac. Al $MgCl_2$	Exch. Al KCl	% Al Satur. (%)	Total acidity	Titrat. acidity to pH 8.2	Mn		P Bray I (ppm)
	(%)	(mg P/100 g)			(meq/100 g)				(meq/100 g)		KCl	HCl + H_2SO_4	
											(ppm)		
Bermeo	74.0	370.0	5.5	28.8	14.2	10.8	1.4	32.7	54.0	146.8	2.7	17.7	2.1
El Meson	72.0	360.0	5.0	16.5	15.2	11.8	1.3	76.9	31.8	162.5	1.5	10.1	1.4
La Selva	71.8	358.8	5.0	22.5	13.7	10.8	1.5	47.2	38.2	144.8	9.7	14.6	2.6
Facatativá	69.0	345.0	5.3	22.5	15.7	8.9	2.0	40.4	44.6	134.9	12.4	24.6	2.6
Unidad 10	45.5	227.5	5.5	11.8	6.2	13.7	0.5	14.1	45.6	108.3	8.9	14.8	2.8
Pamplona	33.5	167.5	5.1	9.2	6.2	11.8	4.2	38.2	42.8	51.9	6.4	11.7	2.3
Andes	33.0	165.0	5.1	6.2	1.9	6.9	0.8	6.7	6.4	14.8	92.1	136.0	1.6
Cachimbalito	29.5	147.5	4.3	9.5	4.4	6.5	3.4	62.9	43.2	45.5	16.8	23.3	3.0
Carimagua	22.0	110.0	4.2	4.3	4.1	5.5	3.1	92.0	28.4	29.2	1.5	5.9	2.1
Melendez	18.0	90.0	5.3	6.3	1.2	7.0	0.2	2.5	4.8	31.0	61.6	116.9	1.4
Platanares	16.5	82.5	4.9	4.0	2.9	5.9	1.9	56.2	14.6	22.1	13.5	20.9	1.6
La Libertad	15.5	77.5	4.9	2.9	4.2	4.4	3.3	90.2	26.1	23.5	14.4	18.1	3.7
Lebrija	15.5	77.5	4.5	4.2	5.7	4.9	6.2	96.1	24.5	21.6	0.3	5.8	1.4
Abrego	11.0	55.0	4.6	2.9	1.5	2.9	1.7	42.4	21.6	14.7	2.7	24.8	0.7

some of the chemical characteristics which largely determine the phosphorus fixation capacity. The soils have fixation capacities between 11 and 74 percent. Phosphorus retention was very high for andosols and relatively low for kaolinitic soils high in iron hydroxides.

The influence of organic matter, aluminum extracted with NH_4OAc at pH 4.8, reactive aluminum titrated between pH 8.2 and 8.5 with $MgCl_2$, and total acidity titrated to pH 8.2 in $MgCl_2$, on the phosphorus fixation capacity is evident. Soils with more than 10 percent organic matter showing high reactive and extractable aluminum have a high phosphorus fixation capacity. Exchangeable aluminum does not correlate with phosphorus retention indicating that perhaps much phosphorus fixation is due to other forms of aluminum and probably to iron hydroxides, in the case of ultisols and oxisols.

Effect of soil amendments on phosphorus availability

The effect of soil amendments such as lime and silicate on the availability of phosphorus, both native soil phosphorus and different sources of fertilizer phosphorus was studied.

Lime

In January 1976, a greenhouse experiment was initiated using four levels of $CaCO_3$, and three levels of phosphorus form different sources. Soils from Carimagua and Popayán were used, and beans (*Phaseolus vulgaris* L.), cowpea (*Vigna sinensis*), and Guinea grass (*Panicum maximum* L.) were planted successively in that order. The results for beans are discussed in the Annual Report of the Bean Program.

Guinea grass was used as an indicator plant to detect the residual effect of both lime and phosphorus applications, after beans and cowpea were harvested. Figure 19 shows that this grass responded very well to phosphorus applications, regardless of source, and that liming the soils has a negative or no effect on dry matter yields. In a recent, unpublished study by Spain, Andrew and Vanden Berg, common guinea was one of the tropical grass species that showed a marked yield increase with increasing aluminum concentration (up to 2.0 ppm) in solution culture. It is possible that in the case of the soil from Carimagua, the highest percentage

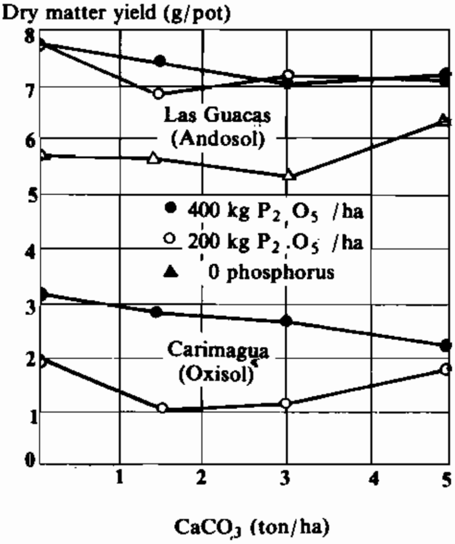


Figure 19. Effects of level of application of lime and phosphate on the yields of tops of Guinea grass (*Panicum maximum*) (average of three phosphorus sources). No yield was observed at zero level of phosphorus on the Carimagua soil.

aluminum saturation (73%) in unlimed soil coresponded to an optimum level of aluminum in the soil solution for guinea grass. These results also indicate the possibility of using rock phosphate instead of water soluble phosphorus sources in allic soils when tropical grasses like common guinea are established. The main effect of lime may be to supply calcium to the plant.

Silicates

Two greenhouse experiments were initiated to study the effect of silicate slag on the availability of phosphorus applied as water soluble phosphate to soils from Carimagua and Popayán. Figure 20 shows the effect of applying Tennessee Valley Authority (TVA) calcium silicate slag and high furnace slag from Paz del Rio (Colombia) on dry matter yields of guinea grass when 400 kg P_2O_5/ha were applied as monocalcium phosphate. For Carimagua soil, yields increased with the first increment of the two silicate slags used (one ton SiO_2/ha). With Popayán soil, the yield increase was not significant for any of the levels of silicate applied. Both silicates increased soil pH and decreased percentage aluminum saturation of the soil. Phosphorus extracted by Bray I and II increased with increasing rates of TVA silicate and slightly decreased with the high furnace slag application. In general, the plants were low in phosphorus but apparently not in calcium when silicates were applied. Increased yields were associated with improved plant phosphorus and calcium nutrition. Calcium silicate treatments did not decrease the phosphorus fixing capacity of the soils (20% for Carimagua and 45% for Popayán). When silicate slags are utilized, application 15 days prior to planting appears to allow sufficient reaction time (Fig. 21).

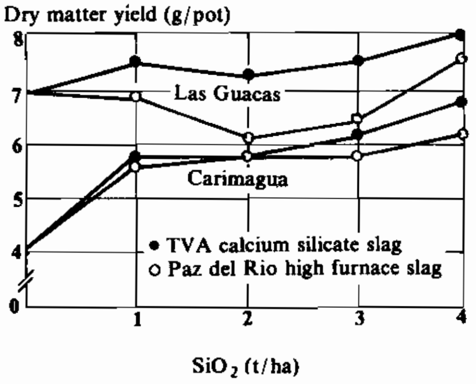


Figure 20. Effect of application of Tennesse Valley Authority (TVA) calcium silicate slag and Paz del Rio high furnace slag on dry matter yield of Guinea grass (*Panicum maximum*) (average of three cuts).

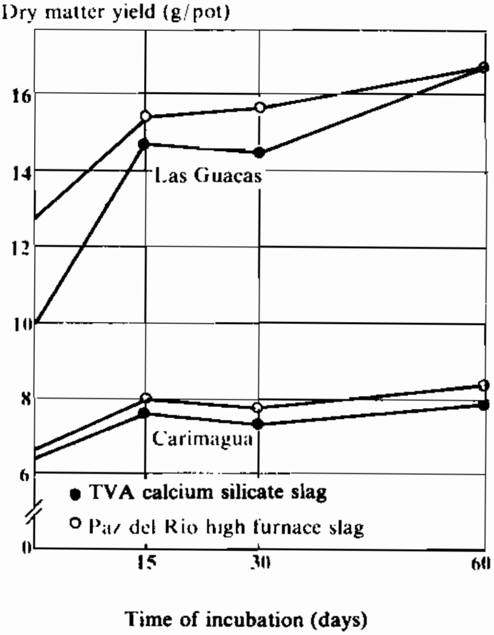


Figure 21. Effect of time of incubation of Tennessee Valley Authority (TVA) calcium silicate slag and Paz del Rio high furnace slag before planting, on dry matter yields of Guinea grass (*Panicum maximum*) (average of three cuts).

PASTURE UTILIZATION

Carimagua

Research has continued in Carimagua to determine the effects of burning as a management practice on the productivity of the savannah. The experiment was designed to compare burning the savannah at one time at the beginning of the dry season with sequential burning through both dry and wet seasons. The experiment was modified this year to allow the animals access to the sequentially/burned pastures, 15 days after burning rather than one month afterward. Table 10 presents the results of liveweight changes obtained for the year November 1975-November 1976. Animal growth was higher this year in all treatments, and the gains observed during the dry season are particularly interesting. It appears that the savannah is improving with time although improved gains during the dry season can also be associated with a milder dry season in 1976.

The introduced grasses, *M. minutiflora, H. rufa* and *B. decumbens* and the native *P. plicatulum* were grazed for the second year. The results obtained this year are presented in Tables 11 and 12. *Brachiaria* appears in a separate table since one additional set of pastures was added during the year, and also because the management of this grass was different during the dry season; the three grasses in Table 11 are rested during the dry season and *Brachiaria* (Table 12) is grazed. Previous years' results indicate that animals at all stocking rates lose weight, in some cases severely, during the dry season. However, results with *Brachiaria* last year indicate that animals gained some weight, which was confirmed this year.

The productivity of *M. minutiflora, H. rufa* and *P. plicatulum* was disappointing. Weight gains per animal per year are very similar to those obtained on savannah burned at the end of the rainy season, and the gains per hectare are no more than doubled. *Brachiaria,* however, provides good dry season grazing. Weight gains during the rainy season are not high, but the high stocking rate obtained during the rainy season makes it a useful choice, provided its productivity can be sustained over time, without high fertilizer inputs.

Table 10. **Seasonal and yearly weight changes of steers grazing the tropical savannah in Carimagua, November 1975-November 1976.**

	Weight changes					
	Dry season		Rainy season		Year	
Management treatment	(g/day)	(kg/animal)	(g/day)	(kg/animal)	(g/day)	(kg/animal)
Burning the total area:						
0.20 steers/ha	337	38	251	53	282	91
0.35 "	228	26	273	57	257	83
0.50 "	116	13	188	40	164	53
Sequential burning:						
0.20 steers/ha	306	35	385	81	359	116
0.35 "	79	9	357	75	260	84
0.50 "	-107	-12	296	62	155	50

Table 11. **Weight gains of steers grazing three tropical grasses during the rainy season in Carimagua, May to November 1976.**[1]

Treatment	Gain per animal		Gain per hectare
	(g/day)	(kg/176 days)	(kg/ha/176 days)
Melinis minutiflora			
0.7 steers/ha	325	57	41
1.0 "	269	47	49
1.4 "	148	26	35
Hyparrhenia rufa[2]			
0.7 steers/ha	194	34	29
1.0 "	166	29	32
1.4 "	139	24	39
Paspalum plicatulum[3]			
0.7 steers/ha	369	65	47
1.0 "	248	44	45
1.4 "	293	52	70

[1] Pasture was rested during the dry season

[2] Stocking rates were 0.9, 1.3 and 1.7 from the beginning of grazing in November 1975 until August 1976 when they were decreased

[3] An attack of "false army worm" occurred this year (as in 1975), but it was not necessary to remove the animals from their paddocks

The management trial with *M. minutiflora*, comparing year-round grazing with and without nitrogen supplementation (urea+molasses), and grazing during the rainy season only, was continued for one more year. This year's results are presented in Table 13. For the second consecutive year nitrogen supplementation positively affected the total annual gain per animal, and the compensatory gain in unsupplemented animals was very small. If good results of supplementation are sustained, then it may be economical to use *M. minutiflora* during the dry season.

Table 12. **Weight gains of steers grazing *Brachiaria decumbens* in Carimagua.**

Stocking rate in dry/rainy season	Dry season		Rainy season		Weight gain per ha per year (kg)
	(g/day)	(kg/animal)	(g/day)	(kg/animal)	
Second year of grazing:[1]					
0.9/0.9 steers/ha	254	44	322	57	95
1.3/1.3 "	258	45	289	51	130
1.7/1.7 "	199	34	182	32	118
First year of grazing:[2]					
0.9/1.6 steers/ha	123	21	391	69	137
1.3/2.3 "	145	25	336	59	179
1.7/3.0 "	44	8	326	57	198

[1] Pasture planted in 1974

[2] Pasture planted in 1975

Table 13. Weight changes of steers grazing *Melinis minutiflora* under three systems of management at Carimagua, December 1975-November 1976.

Treatment	Dry season (g/day)	Dry season (kg/animal)	Rainy season (g/day)	Rainy season (kg/animal)	Year (kg/animal)
Grazing all year:					
0.44 steers/ha	-225	-26	535	112	86
0.88 "	-182	-21	458	96	75
Grazing all year + urea + molasses during the dry season:					
0.44 steers/ha	298	34	492	102	137
0.88 "	208	24	289	61	84
Grazing during the rainy season only:					
0.44 steers/ha	-	-	599	104	-
0.88 "	-	-	292	51	-
1.3 "	-	-	268	46	-

Nevertheless, resting the pasture during the dry season is the most attractive way of utilizing this species, if the farmer has a good native pasture for the animals during the dry season.

Twelve paddocks of 25 hectares each were prepared in a new trial this year to study new alternatives for the management of tropical savannahs during the dry season and their effects on animal production. This area will be used over the next few years for a series of experiments which will include nitrogen and mineral supplementation during the dry season and supplementary grazing with tropical legume-grass mixtures.

Beginning in 1976 for a two-year period, the use of nitrogen (urea + cassava meal) at different levels will be tested and the interaction of nitrogen supplementation and minerals in different seasons of the year will be determined. As part of the first-year trial the interaction between urea + cassava supplementation during the dry season and mineral supplementation (phosphorus and calcium) administered throughout the year, only during the rainy season or not al all, was investigated. Figure 22 presents the results of this trial. Treatment or interaction effects were not significant because of high variability within the treatments caused by uneven consumption of the supplement. Cassava meal was chosen as the carrier for urea rather than cane molasses because of its better availability in most of the savannah areas. Although differences were not significant there was a clear tendency for animals with year-round mineral supplementation to gain more weight, while nitrogen supplementation had an additive effect on those animals which received minerals.

Weight gains of animals grazing savannah burned either at the end of or the beginning of the rainy season were compared. Animals grazing on savannah

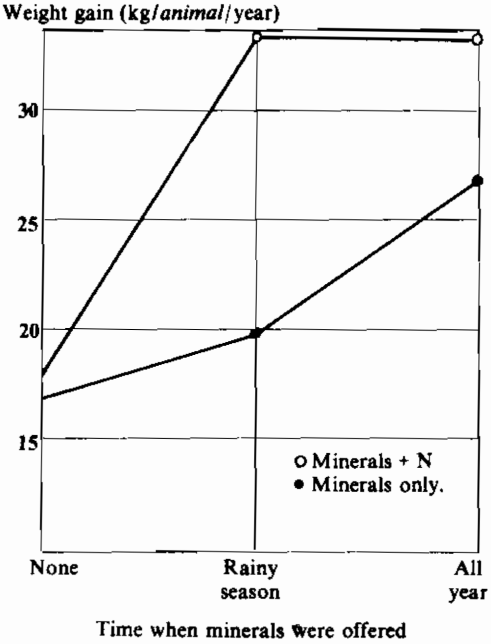


Figure 22. **Relationhip between nitrogen supplementation during the rainy season and mineral supplementation at different times in the year on the tropical savannah at Carimagua, November 1975-November 1976.**

burned at the end of the rainy season gained 57 kilograms of weight during the year while those on pasture burned at the beginning of the rainy season gained only 27 kilograms. This result supports the customary practice of farmers in the area who normally burn the savannah at the beginning and during the dry season, as opposed to burning at the beginning of the rainy season — a common practice in other savannah areas of the world.

In the two trials on native savannah weight gains were always superior in the "systems of burning" experiment (Table 10). This may be due to the fact that burning is done at the beginning of the dry season or throughout the year, and that the prevailing vegetation of the savannah used in the first trial is dominated by *Trachypogon vestitus;* in the new experimente, the dominant species is *Leptochoryphium lanatum*. In interpreting the significance of the results, it must be noted that burning the savannah at the beginning of the dry season is incompatible with dry season supplementation with nitrogen, and with the requirements of stocking rate increases.

Palmira

On the same area on which a pasture experiment was conducted to measure the response of Pangola *(Digitaria decumbens)* pasture to nitrogen and irrigation (CIAT Annual Report, 1975) another experiment was established for 240 days with steers to measure the net efficiency of energy and nitrogen transformation.

Figure 23 shows the relation between animal stocking rate and beef yield per hectare. Stocking rates ranged from 3.33 to 9.17 animals/ha; nitrogen fertilization levels were the same as in the previous experiment — 168, 332, 500 and 672 kg/ha/year. The combined response to

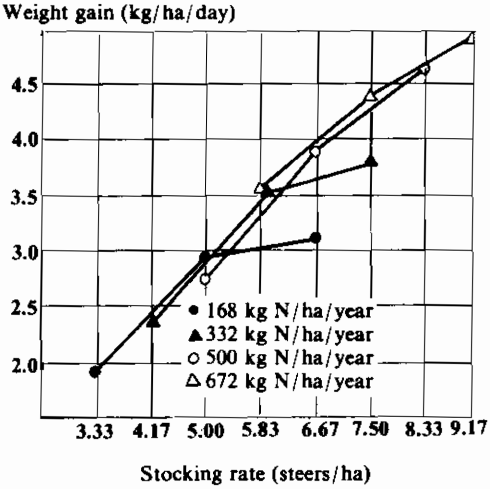


Figure 23. **Weight increase per hectare on Pangola pasture (*Digitaria decumbens*) fertilized with nitrogen and irrigated (for 240 days of pasturing).**

increasing both the level of applied nitrogen and the animal stocking rate was essentially linear. Gains were from 1.89 to 4.94 kg/ha/day with nitrogen and stocking combinations from 168 kg/ha and 3.33 animals to 672 kg/ha and 9.17 animals. Extrapolating these weight gains to a full year, gains would equal 690 and 1,803 kg/ha, respectively.

At nitrogen levels of 168 and 332 kilograms, gains at the highest stocking rate did not continue in a linear form. This was expected because at some level of stocking, gain per hectare should decrease. At levels of 500 and 672 kg of nitrogen, stocking rates were not high enough to show this effect and the increases were therefore linear.

The response of Pangola to fertilization was satisfactory at all nitrogen levels. The number of kilograms of weight gain obtained per kilogram of applied nitrogen was above 1 in all treatments.

The increase diminished as the level of nitrogen increased from 168 to 672 kilograms and increased as the stocking rate increased. Figure 24 shows these relationships base on an estimated production of Pangola without fertilization or irrigation of 330 kg/ha/yr. The response, therefore, corresponds to the combined effect of nitrogen and irrigation; irrigation, however, was the same for all treatments. treatments.

If other production factors are constant, weight gain of an animal on pasture should increase according to the increase of forage available for consumption, up to a point at which the gain is not limited by the amount of forage but by the genetic capacity of the animal. This relationship is presented in Figure 25.

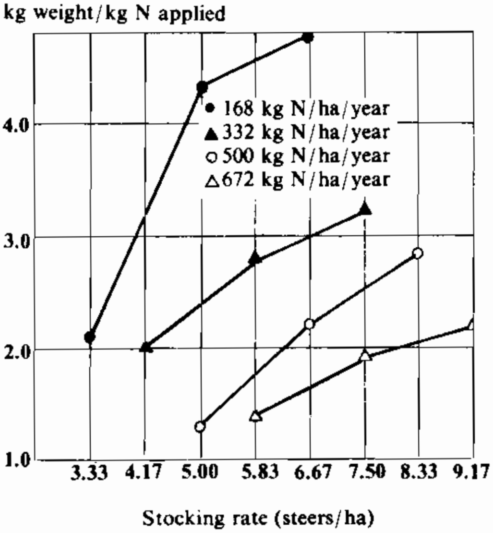


Figure 24. Increase in the weight gains of steers on Pangola pasture *(Digitaria decumbens)* for each kilogram applied. It is assumed that each hectare provides 330 kilograms of gains without fertilization or irrigation.

When up to 25 kilograms of dry matter was available per animal (grade crossbreds of native x Zebu breeding, weighing an average of 300 kilograms), the quantity of forage available limited the weight gain. However, as more total dry matter became available, the animal through selective grazing, would be able to consume a more nutritions diet. According to Figure 25 this maximum point when available forage

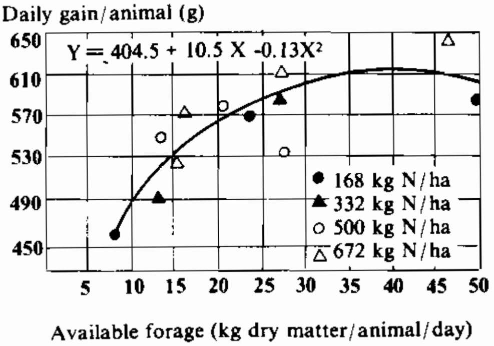


Figure 25. Relationship between available forage in a Pangola pasture *(Digitaria decumbens)* and weight gains of steers.

becomes unlimiting should have come at 40-45 kilograms of forage. In tropical forages, in contrast to temperate species, plant selection by animals is very active, even in low-growing pasture species like Pangola. The maximum point of forage availability for maximum consumption, after selection, is therefore high and is important to know for planning of pasture management.

PRODUCTION SYSTEMS

Herd Systems I Experiment At Carimagua (ICA-CIAT)

The herd systems project is a relatively large experiment designed to study the effects of certain management factors on production and reproduction during the life cycle of beef cattle in the Eastern Plains of Colombia. This zone is similar in many respects to other large areas in the interior of South America where beef cattle production is the major enterprise.

Treatment variables between herds include pasture systems, mineral supplementation, and protein (urea) supplementation during the dry season. Within herd treatments include early (84 days) versus normal weaning, and alternate use of Zebu and San Martinero bulls in each herd.

Pasture treatments

The pasture treatments are: native pasture throughout the year, native pasture during the dry season and molasses grass *(M. minutiflora)* in the rainy season, and molasses grass throughout the year.

For 1976 there were no significant differences ($P<.05$) in calving percent and no abortions were recorded among the three different pasture systems (Table 14); however, cows grazing native pasture plus molasses grass in the dry season tended to have higher calving rates than cows on molasses grass the entire year (81.4, 82.3

Table 14. Reproductive performance of cows during the third calving year (June 1975-June 1976) in Herd System I.

		1976					1974-76	
Treatment[1]	Herd	No. of cows	No. of births	No. of abortions	Calving (%)	Abortions (%)	Total births	Total abortions
Control (native pasture)	1	28	14	10	50.0	35.7	33	22
Native pasture	2	33	10	3	30.3	9.1	39	6
and salt	3	32	18	4	56.2	12.5	47	5
Native pasture	4	32	23	0	71.9	0.0	65	0
and minerals	5	33	28	0	84.8	0.0	67	0
Native pasture, minerals	6	35	26	0	74.3	0.0	72	2
+ molasses grass	7	35	31	0	88.6	0.0	72	0
Molasses grass	8	35	28	0	80.0	0.0	69	0
and minerals	9	33	28	0	84.8	0.0	67	2

[1] In addition to the pasture treatments, all herds receive salt; herds 4-9 also receive complete minerals; and herds 2,4,7 and 9 receive a protein supplement during the dry season of 0.5 kg molasses, 80 g urea and 4 g sulfur/head/day.

and 78.4%) respectively. The same trend prevails when the three-year results are averaged; however, two abortions each were recorded in the native plus molasses grass and in the molasses grass pasture groups in previous years (Table 15).

The calving interval was significantly ($P<.01$) less for cows on native plus molasses grass (15.7 months) than for cows on molasses grass alone (17.7 months) or native grass (16.6 months). This was probably due to a better supply of forage throughout the year which allowed the cows to recover more quickly from the stress of lactation.

The reproductive performance of cows permanently on molasses grass varies with the length of the dry season as the quality and quantity of this grass are greatly reduced during this period (Table 16). In 1976, two cows were lost apparently due to a lack of forage during the dry season. However, the major effect of that severe dry season will probably manifest itself in 1977 reproductive performance.

Mineral supplementation

One of the treatments that consistently gives positive results is feeding a complete mineral mix free choice. In 1976, 82.1 percent more births were recorded in the herds receiving minerals (51 births) than in those herds receiving only salt (28 births). Six abortions were observed in herds receiving salt as compared to no abortions in cows receiving minerals (Table 14). Calving rate for cows receiving minerals was almost double that of cows not receiving minerals. While abortions account in part for the low calving percentage, there is still a 26 percent reduction in calving rate caused by the lack of minerals, perhaps due to a type of anestrous or undetected early abortions.

The three-year average reproductive performance of herds with and without minerals parallel 1976 results. Calving rates were 71.9 versus 47.7 percent; abortions 0 versus 10. percent; average births per cow 2.13 versus 1.43; and the calving interval was 1.4 months less in cows receiving minerals. This is partially explained because they did not abort — a factor which lengthens the calving interval. The fact that cows receiving minerals had more conceptions per cow (2.13) than cows receiving salt alone (1.58) indicates that mineral supplementation is important in fertility as well as in maintaining pregnancy in cows on mineral deficient soils.

Urea-molasses supplementation

A molasses-urea-sulfur (500-80-4 g/head/day) mixture is fed daily in the dry season to herds 2, 4, 7 and 9. The supplementation period is determined by the dry season which varies somewhat in duration and severity. As in previous years, in 1976 there was no increase in reproductive performance due to supplementation (69.2 versus 74.1% calf crop with and without supplementation, respectively). The three-year averages (Table 15) show a slight disadvantage for cows receiving supplementation, a phenomenon which should be investigated further since it persists year after year and is contrary to the expected effect.

Early weaning

At the beginning of the experiment, five cows from each herd (2-9) were selected to have their calves weaned early at 84 days of age. Calves from all other cows in each herd are weaned normally at eight months.

The reproductive performance of the early weaned group (14 % of all cows in the trial) is significantly better than the other

Table 15. Calving interval, conceptions, abortions and births in Herd System I, May 1973-June 1976.

Treatment	Herd	No. of cows	Calving interval[1] (mo)	Total conceptions	Average conceptions per cow	Total abortions	Average abortions per cow	Total births	Average births per cow	Calf crop (%)
Minerals										
Salt	2,3	65	18.0	103	1.58	11**	17**	93	1.43	47.7
Salt + minerals	4,5	65	16.6	132	2.13	0	0	132**	2.13	71.9
Pasture										
Native grass	4,5	65	16.6	132	2.03	0	0	132	2.13	71.0
Native grass + molasses grass	6,7	70	15.7**	146	2.08	2	.03	144	2.06	68.6
Molasses grass	8,9	68	17.7	138	2.03	2	.03	136	2.00	66.7
Supplementation										
None	3,5,6,8	135	16.6	268	1.98	6	.04	262	1.94	64.7
Urea + molasses	2,4,7,9	133	16.8	251	1.88	8	.06	243	1.83	60.9
Weaning										
Normal	2-9	225	17.4	403	1.79	13	.06	390	1.73	57.8
Early	2-9	40	13.7**	103	2.56**	2	.05	101	2.52**	84.2

[1] Calculated from cows having calved two or more times, one calving of which occurred after June 1975.

Table 16. **Percent calf crop by years for 1974-1976 in Herd Systems I.**

Treatment	Herd	Calving rate (%)			3-year average[1]	
		1974	1975	1976	Calving rate (%)	Calving interval (mo)
Control	1	51.8	18.5	50.0	39.3	18.4
Native pasture	2	33.3	54.5	30.3	39.4	20.2
and salt	3	18.7	74.2	56.2	49.0	17.2
Native pasture	4	59.4	71.9	71.9	67.7	16.0
and minerals	5	60.6	57.6	84.8	67.7	17.2
Native pasture and	6	54.3	77.1	74.3	68.6	15.5
minerals + molasses grass	7	51.4	65.7	88.6	68.6	16.2
Molasses grass	8	65.7	51.4	80.0	65.7	17.6
and minerals	9	78.8	39.4	84.8	67.7	18.2

[1] Calculated from cows having calved two or more times, one calving of which occurred after June 1975.

cows (Table 15) Over three years, early weaned cows had a 27.3 percent shorter calving interval (13.7 months); 43 percent more conceptions per cow (2.56); and 45.7 percent more births per cow (2.52) than normal weaned cows.

There are no early weaned cows which have not had at least one calf while 10.9 percent of those cows without minerals and 3.4 percent of those on molasses grass (with minerals) but weaned normally have never calved. Number of calves produced by early- and normally-weaned cows are shown in Table 17. The results indicate that a combination of early weaning plus mineral supplementation on native pasture would consistently give a 70 percent calf crop.

Table 17. **Percentage of cows producing none, one, two or three calves during three calving years (1973-1976) in Herd Systems I.**

Treatment	Herd	No. of calves							
		0		1		2		3	
		Weaning treatment							
		Normal	Early	Normal	Early	Normal	Early	Normal	Early
Minerals									
Salt	2,3	10.9	0	60.0	30.0	29.1	30.0	0	40.0
Salt + minerals	4,5	0	0	19.2	0	73.1	30.0	7.7	70.0
Pasture									
Native	4,5	0	0	19.2	0	73.1	30.0	7.7	70.0
Native + molasses	6,7	0	0	13.3	0	78.3	30.0	8.4	70.0
Molasses	8,9	3.4	0	8.6	0	82.8	40.0	5.2	60.0
Weaning	2-9	3.6	0	24.9	7.5	66.2	32.5	5.3	60.0

Converting the average births per cow (normal weaned, 1.73 and early weaned, 2.52) over a three-year period to calving percentage demonstrates that 26 calves/100 cows can be gained each year (58 versus 84% calf crop) with early weaning. This practice, in effect, partially solves the problem of nutritional stress on the cow during her most critical period (lactation).

Mineral analyses

In a special collaborative project with the University of Florida and the U.S. Agency for International Development (AID), a PhD candidate carried out detailed analyses in 1976 to determine the mineral compositions of the pastures and selected blood parameters for cows in the Herd Systems Project.

Pastures. The results of the pasture analyses are summarized in Tables 18 and 19. Nitrogen content of native grass increased with decreasing rainfall while that of molasses grass dropped significantly (P<.01) in the dry season. There were no significant differences in the values of *in vitro* organic matter digestibility between periods, however molasses grass showed a slight but significantly (P<.01) higher value than native grass. Phosphorus content of native grass was lower (P<.01) than that of molasses grass in the rainy season. In the dry season both grasses had similar phosphorus contents, due to an increase in the phosphorus content of the native grass and a decrease of phosphorus in molasses grass. In both grasses, calcium and magnesium decreased in the dry season. Molasses grass had a higher calcium content (P<.01) than native grass in the rainy season. Potassium and sodium values increased in the dry season in both grasses. Copper and cobalt values were higher in the dry season than in the wet (P<.01). Molasses grass had a higher copper content than native grass (P<.01). The values of iron, manganese, zinc and molybdenum did not differ between periods. Iron and manganese contents of native grass were higher than those of molasses grass, while zinc was higher in molasses grass (P<.01).

The concentration of most of the nutrients in native grass increased during the dry season, probably due to the effect of rotational burning during those periods which permitted regrowth of higher quality grass.

Blood parameters. The levels of serum inorganic phosphorus are shown in Table 20 and Figure 26. Complete mineral supplementation increased serum phosphorus levels at all bleeding times (P<.01), and the effect was more prominent in the rainy season. In both treatments, serum phosphorus level was lowest in the early rainy season when the cows were gaining weight rapidly and highest in the dry season when cows were losing weight. Cows receiving the urea-molasses-sulphur supplement during the dry season had reduced serum phosphorus levels in herds on salt only (6.76—4.54 mg%) but increased serum phosphorus level in herds on complete minerals (5.81-6.48 mg%) The physiological status of the animals also influenced serum phosphorus. The average value for lactating cows was 4.46 mg% compared to 5.05 mg% for dry cows (P<.01). Complete mineral supplementation did not affect serum calcium levels, but calcium level was influenced by season. As indicated in Table 21. serum calcium was higher in the beginning of the rainy season than in the other seasons (P<.01). Complete supplementation increased serum magnesium (P<.01) in the dry season (Table 22), even though the complete mineral supplement did not include

Table 18. *In vitro* organic matter digestibility (IVOMD) and average nitrogen, phosphorus, calcium, magnesium, potassium and sodium content of native and molasses grasses.[1]

Grass	Period[2]	No. of obs.	Variable (%)						
			IVOMD	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium	Sodium
Native	Early rainy season	20	44.33a[3]	1.31b	.10a	.15b	.19c	.85a	.009a
	Late rainy season	16	43.60a	1.42bc	.11a	.12a	.14b	78a	.009a
	Dry season	24	45.52a	1.52c	.15b	.12a	.14b	1.01b	.016b
Molasses	Early rainy season	12	47.78b	1.43c	.21c	.23d	.20c	1.10c	.006a
	Late rainy season	16	48.94b	1.50c	.24c	.20c	.18c	1.17c	.007a
	Dry season	8	49.34b	1.21a	.17b	.13a	.13a	1.19d	.011b

1 Values for all nutrients expressed on a dry matter basis
2 Early rainy season, May-August; late rainy season, September-December; dry season, January-April
3 Means in the same column bearing different letters are different ($P \leq .01$)

Table 19. **Average microelement content of native and molasses grasses.**[1]

			Element (ppm)					
Grass	Period[2]	No. of obs.	Iron	Manganese	Zinc	Copper	Cobalt	Molybdenum
Native	Early rainy season	20	555b[3]	161b	15.7b	1.5a	.07a	.44a
	Late rainy season	16	618b	156b	9.4a	1.5a	.09a	.50a
	Dry season	24	540b	227c	14.2b	2.0b	.13b	.68a
Molasses	Early rainy season	12	326a	92a	18.5c	2.6c	.06a	.50a
	Late rainy season	16	308a	106a	18.6c	2.4c	.06a	.51a
	Dry season	8	646a	78a	17.9c	3.0d	.15b	.43a

1 Values for all nutrients expressed on a dry matter basis

2 Early rainy season, May-August; late rainy season, September-December; dry season, January-April

3 Means in the same column bearing different letters are different ($P < .01$).

magnesium. Urea-molasses-sulphur supplements also increased serum magnesium levels ($P < .01$). Serum copper (Table 23) was increased by complete minerals ($P < .01$) in the rainy season but not in the dry season, when the value was lower than that of the rainy season. Serum zinc level (Table 24) was affected by season and physiological status of the cows. Dry cows had higher serum zinc (109.9 µg%) than lactating cows (101.9 µg%) ($P < .01$).

Comparison between cows on different pastures. Pasture treatments were native (herds 4 and 5), combinations of native and molasses grass (herds 6 and 7) and molasses grass (herds 8 and 9). For herds 6 and 7 grazing native pasture during the dry season and molasses grass during the rainy season, serum mineral values were generally similar to those of the herds on the corresponding pastures. Cows grazing molasses grass pastures showed higher

Table 20. **Serum inorganic phosphorus levels of cows on native pastures supplemented with salt or complete minerals.**

		Sampling date				
Treatment[1]	Herd	Apr. 1975	Jun. 1975	Oct. 1975 mg %	Dec. 1975	Mar. 1976
Salt	2	5.21 (33)[2]	2.98 (33)	3.45 (32)	4.59 (33)	4.54 (33)
	3	3.03 (33)	3.57 (32)	5.02 (32)	3.26 (29)	6.76 (32)
Complete minerals	4	5.13 (32)	4.96 (32)	5.98 (31)	5.17 (31)	6.48 (31)
	5	4.77 (32)	4.00 (33)	5.83 (33)	6.32 (32)	5.81 (32)
Means herds 2 and 3		4.12ay (66)[3]	3.27ax (65)	4.24ay (64)	3.97ay (62)	5.63az (65)
Means herds 4 and 5		4.95by (64)	4.44bx (65)	5.91bz (62)	5.75bz (63)	6.14bz (63)

1 Herds 2 and 4 received urea-molasses-sulfur supplement during dry season

2 Numbers in parenthesis are number of observations from which the mean was calculated

3 Means bearing different x, y, z letters on the same line and different a, b, c letters in the same column are different ($P < .01$)

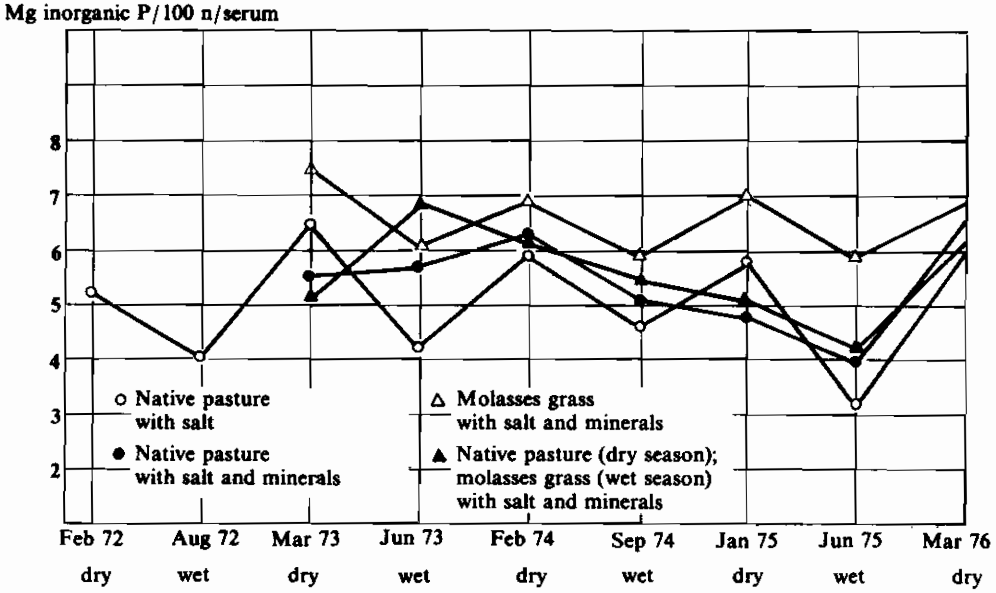


Figure 26. Mean serum inorganic phosphorus levels of grade zebu famales from before first mating to six years of age in the Llanos of Colombia.

serum phosphorus levels than those on the native pasture, except in the October sampling (Table 25). High serum phosphorus levels in June indicated that molasses grass could maintain serum phosphorus during the period of rapid gain for the animals in the early rainy season. Urea-molasses-sulphur supplementation increased serum phosphorus levels in cows on native grass but decreased this level in cows on molasses grass ($P<.01$). The effect of physiological status appeared again in this comparison. As in the first comparison, serum calcium levels were lower ($P<.01$) in the dry season (Table 26).Cows grazing molasses grass tended to have higher serum calcium ($P<.05$) but lower serum magnesium levels ($P<.01$) Table 27.

Table 21. Serum calcium levels of cows on native pastures supplemented with salt or complete minerals.[1]

Treatment	Herd	Sampling date		
		Apr. 1975	Oct. 1975 mg %	Mar. 1976
Salt	2	9.80 (33)	10.01 (32)	9.95 (33)
	3	10.67 (33)	9.39 (32)	9.01 (32)
Complete minerals	4	10.32 (32)	9.43 (32)	9.11 (31)
	5	9.58 (30)	9.35 (32)	9.56 (32)
Means of all herds		10.12y (128)	9.55x (128)	9.41x (128)

[1] See footnotes to Table 20.

Table 22. Serum magnesium levels of cows on native pastures supplemented with salt or complete minerals.[1]

Treatment	Herd	Sampling date Apr. 1975	 Oct. 1975 mg %	 Mar. 1976
Salt	2	2.38 (33)	2.17 (32)	2.37 (33)
	3	2.42 (33)	2.25 (32)	2.61 (33)
Complete minerals	4	2.31 (32)	2.26 (32)	2.71 (31)
	5	2.32 (30)	2.07 (32)	2.73 (32)
Means herds 2 and 3		2.40ay (66)	2.21ax (64)	2.49ay (65)
Means herds 4 and 5		2.31ay (62)	2.17ax (64)	2.72by (63)

1 See footnotes to Table 20.

also indicates that urea-molasses-sulphur supplementation decreased serum magnesium levels of cows on molasses grass pasture ($P < .05$). In the rainy season, the cows which grazed the native pasture year-round had higher serum copper levels than the other herds even though the serum copper value was higher in the rainy season than in the dry season in all pasture groups (Table 28). Serum zinc levels of the cows grazing on native pasture were higher in the dry season ($P < .01$) as in the previous comparison (Table 29). Molasses grass pasture did not show any effect on serum zinc. Dry cows had 110.5 µg% serum zinc, which was higher than that of lactating cows (103.6 µg%) ($P < .01$).

Toward the end of the year, a more detailed analysis of the blood constituents was started by employing the metabolic profile test which will assist in the interpreting the production performance data by relating of metabolic status of the cow to her performance. More details of this work are given in the Animal Health section of this report.

Table 23. **Serum copper levels of cows on native pasture supplemented with salt or complete minerals.**[1]

Treatment	Herd	Sampling date Oct. 1975	 Mar. 1976 µg %
Salt	2	80.3 (31)	68.1 (33)
	3	84.4 (32)	61.1 (32)
Complete minerals	4	86.7 (32)	58.8 (31)
	5	113.0 (32)	59.6 (32)
Means herds 2 and 3		82.4ay (63)	64.7ax (65)
Means herds 4 and 5		99.8by (64)	59.2ax (63)

1 See footnotes to Table 20.

Table 24. **Serum zinc levels of cows on native pasture supplemented with salt or complete minerals.**[1]

Treatment	Herd	Sampling date Oct. 1975	 Mar. 1976 µg %
Salt	2	100.9 (30)	112.1 (33)
	3	98.4 (31)	113.2 (32)
Complete minerals	4	102.7 (32)	124.8 (31)
	5	95.1 (32)	107.2 (32)
Means of all herds		99.2x (125)	114.2y (128)

1 See footnotes to Table 20.

Table 25. **Inorganic phosphorus levels of cows on native and molasses grass or molasses grass pastures.**

Pasture[1]	Herd	Sampling date Apr. 1975		Jun. 1975		Oct. 1975 mg %		Mar. 1976	
Native	4	5.13	(32)[2]	4.96	(32)	5.98	(31)	6.48	(31)
		4.77	(32)	4.00	(33)	5.83	(31)	5.81	(32)
Native +	6	5.18	(35)	4.72	(33)	5.37	(34)	5.66	(35)
Molasses	7	4.93	(34)	4.37	(35)	4.98	(35)	6.15	(35)
Molasses	8	5.44	(35)	6.20	(33)	5.47	(33)	7.66	(35)
	9	5.67	(33)	5.60	(32)	5.29	(33)	5.94	(32)
Means herds 4 and 5		4.95ay	(64)[3]	4.44ax	(65)	5.91bz	(62)	6.14az	(63)
Means herds 6 and 7		5.06axy	(69)	4.54ax	(68)	5.17ay	(69)	5.91az	(70)
Means herds 8 and 9		5.55bx	(68)	5.90by	(65)	5.38ax	(66)	6.84bz	(67)

[1] Herds 6 and 7 in Oct. 1975 bleeding period were on molasses grass pastures, and in the other periods were on native pastures. Herds 4, 7 and 9 received urea-molasses-sulfur supplement during dry season

[2] Numbers in parenthesis are number of observations from which the mean was calculated

[3] Means bearing different x,y,z letters on the same line and different a,b,c, letters in the same column are different ($P \leq .01$)

Early weaning project at CIAT

In an early weaning trial initiated on three private ranches in the Eastern Plains of Colombia in 1975 an average increase of 600 percent in the pregnancy rate of cows (four months post-weaning) was recorded when their calves were weaned 90 days postpartum, compared to cows still nursing thir calves. The early weaned calves were brought to CIAT in March 1975, where they were assigned to one of four rearing regimes (Table 30) for 55 days (Period 1). After Period 1, all calves were pastured together on Pará grass (*Brachiaria mutica*) (Period 2) until they were 18 months of age (Table 30 and Fig. 27). As reported last year (CIAT Annual

Table 26. **Serum calcium levels of cows on native and molasses grass or molasses grass pastures.**[1]

Pasture	Herd	Sampling date Apr. 1975		Oct. 1975 mg %		Mar. 1976	
Native	4	10.38	(32)	9.43	(32)	9.11	(31)
	5	9.38	(30)	9.35	(32)	9.56	(32)
Native +	6	10.33	(35)	10.42	(34)	9.50	(35)
Molasses	7	9.88	(33)	9.82	(35)	9.73	(35)
Molasses	8	10.50	(35)	10.01	(34)	9.19	(32)
	9	9.97	(33)	9.80	(32)	9.62	(32)
Means of all herds		10.12c	(198)	9.81b	(199)	9.46a	(197)

[1] See footnotes of Table 25.

Table 27. **Serum magnesium levels of cows on native and molasses grass, or molasses grass pastures.**[1]

Pasture	Herd	Sampling date Apr. 1975		Oct. 1975 mg %		Mar. 1976	
Native	4	2.31	(32)	2.26	(32)	2.71	(31)
	5	2.32	(30)	2.07	(32)	2.73	(32)
Native +	6	2.32	(35)	1.98	(34)	2.29	(35)
Molasses	7	2.21	(33)	2.10	(35)	2.52	(35)
Molasses	8	1.94	(35)	2.16	(34)	2.26	(32)
	9	2.13	(33)	1.76	(32)	2.10	(32)
Means herds 4 and 5		2.31by	(62)	2.17bx	(64)	2.72cz	(63)
Means herds 6 and 7		2.28by	(68)	2.04ax	(69)	2.41bz	(70)
Means herds 8 and 9		2.03bx	(68)	1.97ax	(66)	2.18az	(64)

[1] See footnotes of Table 25.

Report, 1975), calves receiving concentrate gained faster (P<.01) than calves without concentrate, during Period 1 of the experiment.

In Period 2 of the experiment, all groups previously without concentrates increased in average daily gain (ADG). Although ADG was similar in all groups in Period 2, the greatest improvement over Period 1 was noted in the groups previously on *Stylosanthes guyanensis* and Pará which gained 134 and 90.5 percent faster, respectively, in Period 2 than they did in Period 1. It must be noted that *Stylosanthes* was finely chopped before feeding which prohibited any selective eating and partially explains the poor performance of the calves on that diet.

Table 28. **Serum copper levels of cows on native, native and molasses grass or molasses grass pastures.**[1]

Pasture	Herd	Sampling date Oct. 1975		Mar. 1976 µg %	
Native	4	86.7	(32)	58.8	(31)
	5	113.0	(32)	59.6	(32)
Native + Molasses	6	87.7	(34)	62.7	(34)
	7	83.8	(34)	63.8	(35)
Molasses	8	86.6	(34)	75.7	(32)
	9	87.7	(31)	66.9	(32)
Means herds 4 and 5		99.8by	(64)	59.2ax	(63)
Means herds 6 and 7		95.8ay	(68)	63.2ax	(69)
Means herds 8 and 9		87.1ay	(65)	66.3ax	(64)

[1] See footnotes of Table 25.

Table 29. **Serum zinc levels of cows on native, native and molasses grass or molasses grass pastures.**[1]

Pasture	Herd	Sampling date Oct. 1975		Mar. 1976 µg %	
Native	4	102.7	(32)	124.8	(31)
	5	95.1	(32)	107.2	(32)
Native + Molasses	6	108.6	(34)	105.7	(34)
	7	100.7	(32)	104.2	(35)
Molasses	8	124.8	(25)	112.9	(32)
	9	99.5	(31)	103.1	(32)
Means herds 4 and 5		98.0a	(64)	115.8b	(63)
Means herds 6 and 7		104.8a	(66)	105.0a	(69)
Means herds 8 and 9		110.8a	(56)	108.0a	(64)

[1] See footnote of Table 25.

Table 30. **The effect of type of forage and concentrate on growth performance of early weaned calves from four to 18 months of age.**

Forage	Liveweight gain (kg)					
	Concentrate					
	None		750 g/head/day (period)[1]		Avg.	
	Wt. gain	Avg. daily gain	Wt. gain	Avg. daily gain	Wt. gain	Avg. daily gain
Grass (Pasture)						
Cynodon nlemfuensis (Star)						
Period 1[1]	21.7	.394ab[3]	27.6	.502c	24.6	.448a
Period 2[2]	147.7	.339	152.0	.411	149.8	.405
					174.4	.410
Brachiaria mutica (Para)						
Period 1	11.7	.200a	16.7	.304	13.8	.252
Period 2	141.0	.381	126.3	.341	133.6	.361
					147.4	.347
Legume (Hand-fed)						
Desmodium distortum						
Period 1	19.0	.345ab	27.7	.504c	23.4	.424a
Period 2	143.0	.386	142.3	.384	142.6	.386
					166.0	.390
Stylosanthes guyanensis						
Period 1	8.7	.158	17.0	.309	12.8	.233
Period 2	137.0	.370	147.0	.397	142.0	.384
					154.8	.364
Average, Period 1	15.1	.274	22.2	.404		
Period 2	142.0	.384	141.8	.383		

[1] Period 1 = 55 days (4th to 6th of month of calf's life)

[2] Period 2 = 370 days (6th to 18th month of calf's life; all calves in Para pasture)

[3] Figures in columns with same latters are not significantly different ($P \leq .01$).

The groups receiving concentrates in Period 1 gained an average of 47.4 percent faster than those without concentrates (274 versus 404 g/day, for no concentrate and with concentrate, respectively). The two fastest gaining groups on concentrate (calves grazing *Cynodon nlemfuensis* and *Desmodium distortum)* gained at a slower rate when they were put on Pará pasture while the two slower growing groups on concentrates gained faster during Period 2 when no concentrate was offered.

It is apparent from the weight gain data

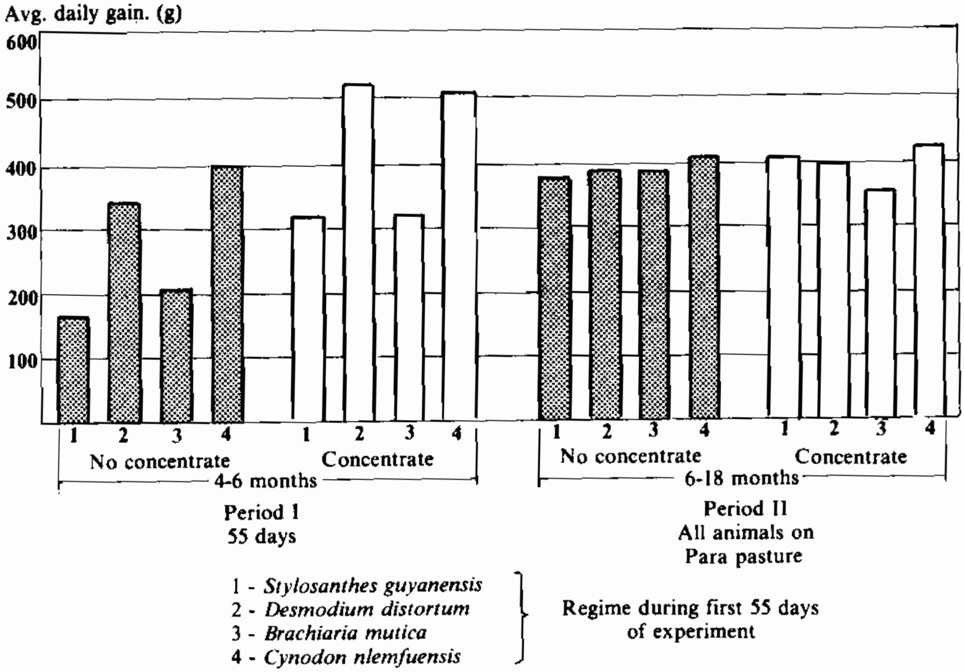


Figure 27. **Effect of type of forage (with and without concentrate) on performance of early weaned calves from four to 18 months of age.**

(Table 31) that the star grass in this experiment provided the best forage. Animals initially on Star grass gained 8.6 percent better than the average for the experiment while animals initially on Pará gained 8.9 percent less than the average. Since there was a 92.2 percent difference between the highest and lowest gains in Period I and only a 12.1 percent difference in gains in Period 2, it appears that the feeding regime during the first two months influenced the difference in final weight

Table 31. **Effect of pasture regime during the first two months post-weaning on animal performance to age 18 months.**[1]

	Pasture for first 55 days				
No. of animals	*Cynodon nlemfuensis* 6	*Desmodium distortum* 6	*Stylosanthes guyanensis* 6	*Brachiaria mutica* 6	Average
Initial weight (kg) (4 months)	59.6	66.2	67.5	61.6	63.7
Weaning weight (kg) (9 months)	146.7	151.7	120.7	128.0	136.8
Final weight (kg) (18 months)	234.0	232.2	222.3	209.0	224.4
Wieght gained (kg) (4-18 months)	174.4	166.0	154.8	147.4	160.6
Percent weight change from average for experiment (%)	+8.6	+3.4	-3.7	-8.9	

[1] All groups were pastured on Para grass from 6-18 months.

more so than that during the Period 2.

Since, at the end of the experiment, the weight difference among groups caused by the Period 1 feeding regime still exist, growth retardation due to the feeding regime during the first months of the calf's life was not apparently offset by compensatory growth on Pará pasture by 18 months of age.

It was not possible to compare the final (18-month) weight of these animals with their normally weaned counterparts in the private ranches from which they came; however, their 18-month weights are as good as those of 18-month-old animals in the Herd Systems Project at Carimagua. Future early weaning projects are necessary to establish a pasture and animal management regime that can be adapted to a cow-calf program in areas where early weaning is needed to improve reproduction by relieving the lactation stress from the cow.

Evaluation of Intensively Grown Forages

Cassava tops left after the root harvest are occasionally fed to ruminants in certain parts of the tropics; however, little attention has been given to cassava as a forage crop. Results of an earlier trial (CIAT Annual Report, 1973) showed that large quantities of dry matter (DM) (20 t/ha/yr) and protein (4 t/ha/yr) can be produced when cassava is planted especially to produce forage.

Analysis of the aerial part of the plant (Table 32) shows that the leaves are especially high in protein (28%) and that the entire plant contains approximately 20 percent protein when harvested at 90-day intervals. The fact that the high quality leaves make up more than half of the plant enhances its potential as a forage crop.

Table 32. **Proximate percentage analysis of cassava forage harvested at 90 days, CIAT, 1976**

	Plant part (%)		
	Leaf	Petiole	Stalk
Percent of total plant	52	15	33
Dry matter content	29	18	15
Nitrogen	4.38	1.65	1.76
Protein (N x 6.25)	28.0	11.3	11.0
Ether extract	15.3	14.3	13.0
Crude fiber	9.0	21.9	25.2
Ash	8.1	8.5	7.8

To evaluate the general performance of cassava forage in ruminant diets, 24 grade Zebu steers were randomly assigned to one of the three treatments described in Table 33. All forages were cut and chopped fresh daily and fed *ad libitum* allowing for approximately 10 percent refusal. Sugar cane (whole plant) was harvested in a rotation pattern so that the cane was always about one year old. All animals were fed individually so that each treatment had eight replicates.

The cassava stakes were planted in beds (1.2 meters wide) with a .3 meter spacing within and between rows giving approximately 100,000 plants/ha. The forage was cut 20 centimeters above the ground every 90 days. Seven cuttings were made during an 18-month period before regrowth was substantially reduced. *Desmodium distortum* was sown in rows 60 centimeters apart and harvested every 60 days. Production was markedly reduced after the third cutting as flowering occurred earlier after each successive cutting.

Average daily gain, feed efficiency and dry matter consumption were not significantly affected by the different sources of protein (Table 33). Due to an unexpected low intake of cassava and *Desmodium*, the animals in group 1

Table 33. **Performance of 18-month-old steers fed three different sources of protein, plus freshly chopped sugar cane for 112 days.**[1]

	Treatments		
Parameters	Cane + 1.6 kg cottonseed meal	Cane + cassava forage	Cane + *Desmodium distortum*
No. animals	8	8	8
Initial weight (kg)	230	241	241
Final weight (kg)	303	311	306
Avg. daily gain (kg)	.657	621	.584
Avg. daily consumption cane (kg)	3.67	4.03	3.31[2]
Avg. total daily consumption (kg)	5.29	5.55	5.25
Feed efficiency	8.00	8.90	9.00
Kg protein/kg gain	1.13	.74	.74
Percentage protein of supplement	46.0	22.1	16.8
Percentage protein in diet consumed	14.0[3]	8.0	8.2

[1] All feed data is on a dry matter basis

[2] Significantly ($P < 05$) less than treatment 2

[3] Significantly ($P < 01$) greater than 2 or 3.

consumed significantly ($P < .01$) more protein/head/day. Since animal performance between groups was not different, it appears that an excessive amount of protein which was inefficiently utilized by Group 1. Groups 2 and 3 received approximately the same amount of protein; however, group 2 ate significantly more sugar cane which was reflected in slightly better gains. Because of the lower consumption of protein per unit gain the same two groups were 52.7 percent more efficient in converting protein into liveweight gain.

Cane production

Approximately 0.28 hectare of mature cane (13,250 kilograms DM) was harvested during the trial, providing most of the energy for 1,664 kilograms of liveweight gain. On an annual basis, cane production would be 47,321 kg DM/ha, providing sufficient energy for 5,423 kilograms of liveweight gain. Thus, one hectare of well managed sugar cane in the Cauca Valley, providing 70 percent of the DM requirements, would be sufficient to feed approximately 30 growing-fattening steers under local conditions.

The trial indicates that fresh cassava forage can be successfully fed to ruminants and could be competitive nutritionally with other sources of plant protein. No signs of HCN toxicity or other adverse affects were noted from feeding the freshly cut cassava.

Future investigation in this area should be directed to defining cassava forage quality and efficient utilization in various stages of the beef production system.

ANIMAL HEALTH

Introduction

The animal health group consists of two units, animal pathology and animal microbiology whose goal is the development of economic preventive medicine programs in beef cattle, emphasizing the complex interaction of disease and nutrition. Accordingly, studies continued on the epidemiology of trypanosomiasis, leptospirosis and the economics of animal disease.

Complementary to this, work was initiated on metabolic profiles of Zebu cattle to provide insight into the condition known as wasting disease or "secadera" complex.

Trypanosomiasis (Trypanosoma vivax, T. evansi)

Work carried out by thesis students gave significant results and the investigations were extended for another year involving collaboration with the Instituto Colombiano Agropecuario (ICA), the International Center for Medicine (ICM), the University of Antioquia and the London School of Hygiene and Tropical Medicine.

T. vivax is an important tsetse-transmitted pathogen in Africa. It has also been reported at various times in this century from all the Latin American countries with an Atlantic coast line between Panama and the Amazon mouth in Brazil. There are also reports from the two West Indian islands of Guadalupe and Martinique. However, the number of observations in the literature are fragmentary and the lack of a serological means of diagnosis has delayed work in several basic areas. These are: confirmation that the trypanosome is identical with the tsetse-transmitted *T. vivax* of Africa; definition of the true geographical distribution of the infection in the Americas; definition of prevalence and incidence within the geographic distribution; identification of the means of transmission in the Americas in the absence of tsetse; investigation into the possibility of a sylvatic cycle of transmission; and, lastly, the estimation of the economic significance of the infection.

A trainee in the pathology unit set up an indirect fluorescent antibody test (IFAT) for the parasite in CIAT in 1973. Another student made further modifications during 1976 applying the test to the situation in the Cauca Valley of Colombia where clinical episodes associated with trypanosomes were known to occur. It was concluded that the entire valley was endemic for the infection, a situation previously unsuspected. The means of transmission was not identified but characteristics of the vector were established. Clinical episodes of disease were demonstrated as having important economic impact on individual farmers. There were similarities to riverine tsetse situations in Africa. However, there is diagnostic confusion in the field between trypanosomiasis, anaplasmosis and babesiosis.

These results were the basis for an expanded investigation. A lysate was prepared from a Colombian isolate and sent to the London School of Hygiene and Tropical Medicine for analysis of enzyme patterns and comparisons with isolates from Africa. Present serological results from 197 farms in eight Colombian regions (departamentos) indicate the probability of the trypanosome being endemic in all tropical areas of Colombia where there is a cattle industry. Serum samples have also been obtained from Brazil, Ecuador, El Salvador and Paraguay and others have been promised from Costa Rica, Panamá and Perú. These will be used to investigate the possiblity of a greater geographical distribution than previously realized. However, interpretation of these results requires confirmation of the specificity of IFAT in the field. There is no cross fluorescence occurring among anaplasmosis, babesiosis or *T. evansi*, but *T. theileri* and toxoplasmosis require final elimination as potential causes of error. Under Colombian conditions the test appears to reliably diagnose *T. vivax* on a herd basis.

The International Center for Medicine in Cali is collaborating in the search for a vector and a check list is being prepared of all arthropods biting cattle on farms where transmission is occurring.

Although *T. evansi* is not an important pathogen for cattle in South America, disease epidemics in horses can seriously hinder the management of range cattle. It is commonly believed that the epidemiology of the infection involves only domestic animals. Evidence collected in 1975 indicated that the capybara (*Hydrochoerus hydrochoeris)* is a wild animal reservoir for the trypanosome in the Colombian Llanos. In 1976, a research trainee using a cloning technique and a slide agglutination test demonstrated that isolations made from dogs, horses and capybara in the same location were antigenically similar.

Leptospirosis

Previous work (CIAT Annual Report, 1975) showed that 63.5 percent of the animals in the Colombian Llanos had a serological reaction to various *Leptospira* types. *L. hardjo* and *L. sejroe* were the more prevalent types, with *L. hardjo* giving the greatest number of intensive reactions (1:400 or more).

To extend these studies, a herd was selected on one of the farms that had been observed closely because of elevated abortion rates and a high prevalence of leptospirosis. The herd consists of 100 breeding cows and seven bulls grazing 400 hectares of native savannah with salt and bonemeal supplementation. The farm is located 65 kilometers from Puerto López on the road to Puerto Gaitán in the Departamento of Meta.

The basic objective of this study was to obtain a thorough understanding of the pathogenesis, epidemiology and effect on productivity of these major *Leptospira* types while at the same time developing a practical, preventive medicine approach.

The initial test for leptospirosis resulted in 70.5 percent reactors for one or more serotypes. Sera were examined for 15 different serotypes known to occur in cattle, and *L. hardjo* and *L. sejroe* were the most prevalent, with *L. hardjo* giving the highest titers. Two additional serum samplings were collected and examined using the microscopic agglutination test (MAT) with standard strains obtained from the Panamerican Zoonosis Center, Buenos Aires. Table 34 shows the animals in this herd with titers to *L. hardjo* compared with the number of abortions detected for each animal. *L. hardjo* antibodies are being used as indicators to monitor the pathogenesis of infection since this serotype is being reported as the most pathogenic for cattle in similar areas of the world.

Six animals with high serological titers (1:800 for *L. hardjo)* were necropsied. They all had gross kidney lesions characterized

Table 34. **Cows from the Colombian Llanos trial herd that had recorded abortions during a ten-month interval, and their *Leptospira* titer.**

Cow No.	No. of abortions	*L. hardjo* titer	Cow No.	No. of abortions	*L. hardjo* titer
1	1	200	16	1	400
2	1	800	17	1	200
3	2	100	18	1	0[1]
4	1	50	19	2	200
5	2	50	20	1	200
6	2	50	21	1	1,600
7	1	0[1]	22	1	200
8	1	50	23	1	1,600
9	2	1,600	24	1	0[1]
10	2	100	25	1	100
11	2	100	26	2	400
12	1	400	27	1	800
13	1	100	28	1	100
14	1	100	29	1	0[1]
15	1	50	30	1	800

[1] Four cows with no antibodies detected.

by necrotic areas in the cortex and atrophic kidney lobules. Microscopically, these lesions reflected a chronic interstitial nephritis compatible with leptospirosis. A *Leptospira* strain was isolated from these cows and the bacteria isolated is being classified and typed.

Kidney function tests could provide insight as to the evolution of the disease. Four clinical-pathology tests have been used. Eight cows from the trial herd that had high *Leptospira* titers were tested for urine specific gravity and pH, and for creatinine in the blood serum. The results were compared with those from cows with low titers. The averages shown in Table 35 indicate a lower specific gravity in infected cows. The kidney, in this case, cannot concentrate the urine sufficiently and as a

Table 35. **Comparison of blood serum and urine parameters in cows with different *Leptospira* titers from Colombian Llanos trial herd.**

			Urine[1]		Blood[2]
	No. of cows	Average of *L. hardjo* titers	Specific gravity	pH	Creatinine
High titer animals	8	800	1.008	6.28	2.36
Low titer animals	8	50	1.019	6.42	2.00

[1] Average of 3 samples (consecutive days).

[2] Average of 2 samples 10 weeks apart.

consequence specific gravity is lowered. Creatinine is also used to measure kidney function. It is elevated when kidney function is impaired. Serum creatinine seems to be a reliable diagnostic test because it is not affected by dietary protein catabolism or exercise. The group with high *Leptospira* titers had slightly elevated serum creatinine values.

Even though the herd is actively infected with *Leptospira* (21 animals have titers to *L. hardjo* of 1:400 or higher) not all animals with significant titers had detected abortions in the last 10 months (Table 34) Moreover, abortions have been reported from cows that do not have detectable antibodies for *Leptospira*. This could mean that animals infected with *Leptospira* do not always abort and that abortions due to other unknown causes are also occurring in the herd. The interaction between nutrition and disease under such circumstances is worth exploring and metabolic profiles (discussed later in this section) may be useful for this purpose.

Knowledge of the *Leptospira* transmission pattern will be helpful in formulating a preventive medicine approach for control. Wild rodents are common reservoirs for *Leptospira*. Eighty wild rodents were captured in the forest to which the 100-cow trial herd has access and four *Leptospira* isolations were made by culturing kidney tissue. There were three isolations from *Proechymis* sp. (spiny rat), all classified as *L. australis** and one isolation from *Caluromys philander* (Philander opossum) classified as *L. tarassovi*. Cattle on this farm have significant serological reactions to *L. hardjo* and *L. sejroe*. Therefore, if wild animals are not disseminators or carriers of the same *Leptospira* that affect cattle under the lowland savannah conditions the bacteria is probably being perpetuated by carrier cattle. This opens up the possibility of controlling the spread of infection by treating carrier animals. Moreover, if leptospirosis is the main cause of abortions, productivity could be increased by reducing the disease infection rate. Two preventive medicine measures are being tested in this herd for immediate application. Animals in the herd have been assigned to three groups: one group of 35 cows for antibiotic treatment; a second group of 35 vaccinated with specific vaccine types; and the remaining untreated 30 cows as controls.

The first group is being treated with Streptomycin to reduce the excretion of *Leptospira* through the urine of carrier animals. Two doses are being applied 12 weeks apart with the second dose scheduled for the end of this year.

The second group of animals is being treated with a commercial bacterin that contains *L. pomona*, *L. hardjo* and *L. grippotyphosa*. There are no commercial vaccines that include the *Leptospira* prevalent in the tropical savannahs.

The isolation of a *Leptospira* from affected cattle points to the possibility of producing experimental infections and carrying out a more detailed study of the pathogenesis, pathogenecity and evolution of the disease under controlled conditions.

Economics of Controlling Foot and Mouth Disease

Studies on the economic impact of foot and mouth disease in beef cattle continued. A collaborative project with ICA, was started, to obtain reliable field data that can be used to measure the impact of foot and mouth disease and the returns on

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* These classifications were confirmed by the Panamerican Zoonosis Center, Buenos Aires.

investment in its control. The methodology developed in collaboration with the CIAT Economics group will utilize the data collected to guide national institutions in planning future control strategies. Data are being collected from an area in the Urabá regions of Colombia and a survey has been designed for the Córdoba region as well (see the Economics Section of this report).

Studies on Metabolic Profiles and "Secadera" Complex

In the lowland tropical savannahs of Latin America, efforts are being made to increase beef production at minimum cost. However, some of the improved technology and new management practices add to existing stresses of production, and may introduce hidden factors that endanger the metabolic health of the animals, thus exacerbating the general debilitating effect of noxious agents not often significantly important with adequate nutrition. It is hoped that the study of metabolic profiles will be a valuable tool for monitoring the health of the animals on a herd basis as well as predicting and diagnosing the nature of existing problems.

Metabolic profiles monitor the adequacy of dietary intake for production and are based on the assessment of blood clinical parameters. The method depends on the fact that imbalances between feed input and production output are reflected in abnormal concentrations of key metabolites in the blood, leading to negative balance and disease. The Metabolic Profile Test (MPT)* uses blood clinical parameters in a special combined analytical system, basing the identification of pathological abnormalities on statistical deviations from the population mean.

The Herd Systems Project experiment at the Carimagua Station has provided a satisfactory site for testing the method with beef cattle. In this context, the MPT is being used on Zebu breeding cows to identify the development of critical pathological situations arising from various management practices and production inputs.

Due to the original experimental design, the effects of mineral ssupplementation and pasture type on the profiles can not be measured simultaneously. In order to overcome this, and for the purpose of statistical analysis, the herds have been divided into two major groups. Group I comprises herds (2, 3, 4, 5) on native grass against which the effect of mineral supplementation is being measured. Group II comprises herds (4, 5, 6, 7, 8, 9) with mineral supplementation against which the effect of pasture type is being measured. Effects of lactation status are being considered between and within groups.

Herd 1 is under conventional management and serves as a negative control. The performance of cattle under natural conditions was taken in the original design of the Herd Systems Project as a base line against which to measure the effect of improved management practices in the other herds.

The effect of reproductive status of cows on blood parameters, weight and weight gains, is being analyzed. Four reproductive conditions of breeding cows are included in the test model: (a) lactating-pregnant; (b) dry-pregnant; (c) lactating-open; and, (d) dry-open. Further details of the experimental design of metabolic profiles on the Herd Systems Project are given in the Biometrics section of the Annual Report.

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* Payne and others, Compton (1970)

As an example of the analytical mechanism of the test, Table 36 gives comparative mean values for metabolic profiles, weight and weight gains, for different pastures and mineral treatments. Samplings were in June and August 1976.

Several blood parameters were influenced by pasture type in both months. Significant differences were found for packed cell volume (PCV), glucose, urea, phosphorus, albumin and hemoglobin levels.

In June, PCV, glucose and urea mean values were significantly higher in herds grazing native + molasses grass (6, 7) than in those grazing native grass alone (4,5) ($P<0.01$), and molasses grass alone (8,9) ($P<0.01$). In contrast, blood phosphorus mean values were higher in June in animals grazing molasses grass, than in those grazing native + molasses grass ($P<0.01$), and native grass alone ($P<0.01$). Albumin levels in the same month were higher in animals on native grass and native + molasses grass, than in those grazing molasses grass alone ($P<0.01$). This parameter followed essentially the same trend as urea, with which it is closely related since both reflect protein intake.

In August, which was a drier month in the Llanos mean blood values for urea and albumin were significantly higher ($P<0.01$) in herds on native grass (4,5) than in herds on molasses grass (8,9). PCV and hemoglobin values in the same month were higher ($P<0.01$ and $P<0.05$, respectively) in cattle on native + molasses grass (6,7), than in those on native grass alone. Glucose mean values, perhaps following the same trend as urea and albumin, were higher for those animals grazing native and native + molasses grass, than for those grazing molasses grass alone ($P<0.01$). Phosphorus mean values in August continued to be higher ($P<0.01$) in those animals grazing molasses grass (8,9) than in those on native grass.

The effect of mineral supplementation on the metabolic profiles of herds grazing native savannah is also shown in Table 36. In June, mean values for PCV, glucose, urea, calcium and hemoglobin were higher ($P<0.01$) for herds 2 and 3 with no supplement, than for herds 4 and 5 receiving mineral supplementation. However, mean values for phosphorus were higher ($P<0.05$) for herds 4 and 5 with supplement, than for herds 2 and 3 without supplementation.

In August, mean values for urea, potassium and hemoglobin were higher ($P<0.01$) in herds 2 and 3 with no minerals than in herds 4 and 5 with mineral supplement. Mean values for phosphorus, as in June, continued to be higher ($P<0.01$) in herds 4 and 5 with minerals. Magnesium and globulins also showed higher mean values ($P<0.01$) in herds 4 and 5, than in 2 and 3. The interpretation of these early results should be done cautiously since many more estimates are needed. It is especially important that year-round data be available to reflect seasonal changes in forage quality and quantity.

As reported last year, the condition known as "secadera" appears to be an important problem occurring in the lowland tropical savannahs of Colombia, and possibly, in similar beef producing areas in other Latin American countries. Of 37 ranches surveyed last year in the Llanos, 13 (35%) reported the condition. A common opinion among veterinarians working in the Llanos is that nutritional stress in animals which are carriers of anaplasmosis causes a recrudescing clinical infection. Other infectious and parasitic diseases such as leptospirosis,

Table 36. Comparative mean values of metabolic profiles, weight and weight gains under different variables independent of herd distribution, Herd Systems I (June and August of 1976).

					Blood parameters												
Treatment	Herd	Month	No. of cows	PCV[1] (%)	Glucose (mg/100 ml)	Urea (mg/100 ml)	P (mg/100 ml)	Ca (mg/100 ml)	Mg (mg/100 ml)	Na (meq/Liter)	K (meq/liter)	Total protein (g/100 ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Hemoglobin (g/100 ml)	Weight (kg)	Weight gains (kg)
Control	1	June	26	37.42	67.18	29.12	3.26	10.62	2.48	137.01	5.73	7.99	2.64	5.35	14.17	324.08	10.92
		August	26	43.15	76.73	29.58	2.92	10.78	2.26	140.13	5.63	8.45	2.48	5.97	14.58	311.65	-12.42
Minerals (Group I)																	
Salt	2,3	June	63	34.16	93.11	36.51	3.93	10.34	2.14	150.63	6.34	7.40	2.66	4.74	14.53	322.03	19.35
		August	63	42.35	77.37	28.33	2.08	10.57	2.16	137.66	5.61	8.14	2.60	5.55	15.59	311.62	9.38
Salt + minerals	4,5	June	64	32.68	59.38	30.95	4.53	9.50	2.25	147.98	6.54	7.65	2.75	4.91	13.45	338.33	20.53
		August	64	41.41	81.18	19.84	4.51	10.91	2.41	141.07	5.21	8.39	2.52	5.86	14.11	334.39	-2.25
Pasture (Group II)[2]																	
Native grass	4,5	June	64	32.68	59.38	30.95	4.53	9.50	2.25	147.98	6.54	7.65	2.75	4.91	13.45	338.33	20.53
		August	64	41.41	81.18	19.84	4.51	10.91	2.41	141.07	5.21	8.39	2.52	5.86	14.11	334.39	-2.25
Native grass + Molasses grass	6,7	June	68	34.59	67.00	34.46	4.68	9.48	1.98	148.36	5.99	7.80	2.67	5.12	13.43	337.44	31.38
		August	67	43.24	77.39	14.68	5.41	10.38	2.24	146.29	5.55	8.19	2.57	5.64	14.63	337.87	-0.25
Molasses grass	8,9	June	61	32.13	48.79	29.40	6.34	9.64	1.76	151.71	6.05	6.96	2.46	4.45	13.33	312.36	23.44
		August	61	42.95	68.03	12.63	5.55	11.15	2.38	141.06	5.42	8.00	2.41	5.58	14.47	308.15	-4.21
Supplement (Dry season)[3]																	
None	3,5,6,8	June	126	32.89	64.96	34.07	4.66	9.69	2.09	149.93	6.42	7.48	2.66	4.82	13.61	321.73	19.00
		August	126	42.03	73.24	17.73	4.16	10.53	2.35	136.91	5.39	8.01	2.50	5.50	14.42	312.76	-8.15
Urea + molasses	2,4,7,9	June	130	33.92	69.32	31.72	5.03	9.78	1.97	149.35	5.04	7.43	2.22	4.80	13.74	333.86	20.65
		August	129	42.29	78.18	19.95	4.62	10.95	2.24	146.13	5.49	8.34	2.54	5.80	14.96	333.78	-19.10
Weaning																	
Normal	2,3,4,5,6,7,8,9	June	219	33.36	67.29	33.12	4.86	9.72	2.03	150.25	6.27	7.43	2.63	4.79	13.67	324.55	24.41
		August	217	42.38	76.39	19.30	4.42	10.75	2.30	141.83	5.47	8.18	2.54	5.63	14.68	321.58	-2.50
Early	2,3,4,5,6,7,8,9	June	37	33.78	66.54	31.46	4.82	9.85	2.05	145.73	5.98	7.64	2.66	4.97	13.73	347.68	20.30
		August	38	43.18	74.42	16.35	4.38	10.73	2.28	140.34	5.33	8.23	2.43	5.80	14.83	332.82	-12.26

[1] Packed cell volume or hematocrit.

[2] L.S.D. between mean values at .01 and .05 levels

[3] From December 1975 through March 1976

trypanosomiasis and babesiosis have also been incriminated as contributing factors to the complex. Most cases of secadera occur in cows 3-11 years old, with an average age of 5.5 years. Affected animals walk with difficulty, suffer from ataxia and severe anemias and often end up starving to death.

Malnutrition is rampant in cattle in allic tropical savannahs of Colombia and other countries due to the low nutritional value of native grasses, especially in the dry season. Animals at a low plane of nutrition are constantly in a delicate metabolic balance. This balance is easily upset by changes in input and output. The stress of calving and lactation is so great in the Llanos, as repeatedly observed with the cows in the Herd Systems Project experiment, that without proper nutritional input before and after calving, the metabolism of the animals is thrown totally out of balance. Animals fall into a negative balance state that may eventually lead to the wasting disease.

The data already obtained by applying the MPT to the Herd Systems Project experiment supports the hypothesis that the condition is caused by malnutrition, often leading to inanition and death.

If wasting disease or secadera in the Llanos is due to the low plane of nutrition and lactational stress on cows as is now speculated, the calving rate of Zebu cows in the region is important for a better understanding of the disease complex. If annual calving rates in the Llanos range from 42 to 52 percent, it can then be assumed that at any given time several females of breeding age will be subjected neither to the stress of pregnancy nor to the stress of lactation. This must account for reports of secadera cases among groups of apparently healthy cows, all under the same management regime.

International Cooperation

A collaborative project was developed with the Empresa Brasilera de Pesquisas Agropecuarias (EMBRAPA) research station at Campo Grande, Mato Grosso, in Western Brazil. The objective was to establish the prevalence of five major diseases in the area directly influenced by the National Beef Cattle Center. The information obtained will be used as a basis for planning future research in animal health. A survey was designed and executed in cooperation with the EMBRAPA animal health group and the CIAT Biometrics and Animal Health units.

Six-hundred and twenty animals from 62 farms were sampled. This size sample estimates prevalence with a confidence level of 95 percent. The mean prevalence of hemoparasites was significantly lower than the figures reported for the Llanos of Colombia. In relation to reproductive diseases, the mean prevalence for leptospirosis (72.8%) is similar to that found in Colombian Llanos and merits further investigation of the importance of this disease to reproductive performance.

CIAT staff have studied the results of this survey with the beef team at Campo Grande, and suggestions been given for future research activities in animal health. Management practices have been suggested and further collaborative projects, including training, are being discussed.

SPECIAL PROJECT FOR RESEARCH ON ANAPLASMOSIS AND BABESIOSIS

From November 1975 to November 1976, the work program of the Texas A&M University Group at CIAT is financed by AID and oriented toward developing more efficient economic control of hemoparasitic diseases of cattle in the tropics. Research activities were focused on: (a) development of more practical diagnostic methodology; (b) epizootiology of hemoparasitic diseases; (c) evaluation of immunization systems for control of anaplasmosis and babesiosis, and (d) training.

Development of Diagnostic Methodology

A rapid latex agglutination test (RLA) for diagnosing *Babesia argentina* infection was developed. Although complement fixation (CF) and indirect fluorescent antibody (IFA) tests are routinely used as diagnostic tests for *Babesia* spp. infections in cattle, there is a need for a more rapid and reliable test for these infections.

The agglutination test, utilizing latex particles (0.82 microns in diameter), sensitized with *B. argentina* antigens, proved to be effective in the diagnosis of *B. argentina* in natural and artificial infections. Comparisons among visual reactions for the test are shown in Figure 28.

In experimental infections with *B. argentina* the first detectable positive agglutination reactions coincided with the appearance of parasitemia. Positive reactions were noted with known positive sera which had been stored for up to 18 months. Animals with natural infections of *B. argentina,* proven by blood smears and IFA and CF tests, also showed reactions to the latex agglutination test.

Antibodies to *Babesia* spp. were detected in dried blood samples using the IFA test. It was confirmed that blood dried on filter paper can be used as a source of antibody to *Babesia* spp. infection in cattle. There was good correlation between the antibody titer of duplicate serum and dried blood samples collected from animals infected with Babesia spp. The use of dried blood samples in the IFA test is more practical and economical than using serum samples in diagnosing bovine babesiosis

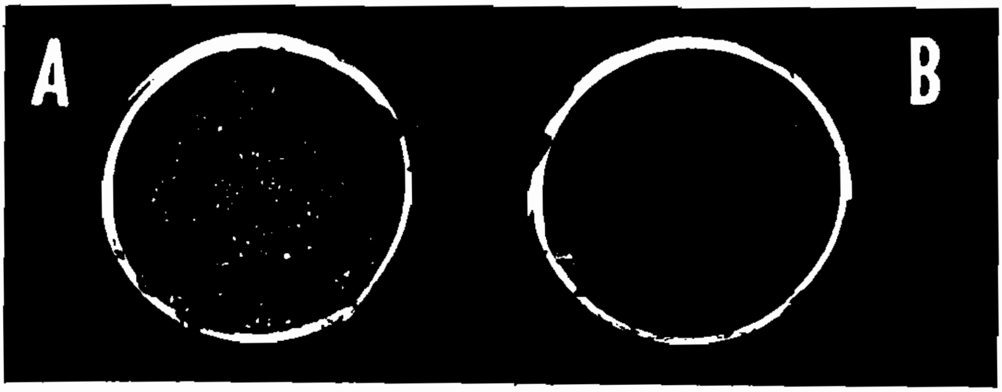

Figure 28. Agglutination pattern observed in the rapid latex agglutination test (RLA) to diagnose infection with *Babesia argentina*. (A) shows a positive reaction with serum of an animal infected with *B. argentina;* (B) is a negative reaction with serum from a non-infected animal.

under field conditions in the tropics.

The CF and IFA tests were used to determine the *Babesia* spp. antibody response in calves before and after ingestion of colostrum from cows immune to babesiosis in comparison with antibody response in calves artificially infected with *Babesia* spp. Both the CF and IFA tests were approximately equal in their ability to detect colostral antibodies. Serologic titers were positive for *B. bigemina* and *B. argentina* during the first week of life and persisted for as long as 20 weeks. The protection of calves from clinical babesiosis was believed to be due to protective antibodies in the colostrum from immune cows.

Epizootiology

During the year additional data were obtained on the prevalence of anaplasmosis and babesiosis among beef and dairy cattle herds in the Cauca Valley of Colombia. These data, combined with the results of previous epizootiological studies conducted in the North Coast region and in the Eastern Plains of Colombia, are presented in Table 37. The high prevalence of reactors indicates that anaplasmosis and babesiosis are endemic within the major cattle producing areas of the North Coast and Eastern Plains as well as within the Cauca Valley. The wide range of reactors among herds within these endemic areas indicates that a large population of noninfected and thus susceptible indigenous cattle is present and substantiates reports by ranch owners that anaplasmosis and to a lesser extent babesiosis are among the major cattle diseases in the areas.

Immunization against Anaplasmosis and Babesiosis

An immunization procedure using the minimum infective dose was evaluated last year using stabilates stored in a dry ice chest at -60°C. Since it was observed that organisms lost viability after eight months of storage, new stabilates were prepared and stored in liquid nitrogen at -196°C. Stabilates were titrated using different dilutions, doses and routes of infection in order to find the best practical method under field conditions.

Ten-fold, serial dilutions of *Anaplasma marginale* stabilate were tested for infectivity. All dilutions were infective when given intravenously (IV) and subcutaneously (SQ) except for dilution 10^{-3} when administered SQ. A direct correlation was found between amount of inocula and antibody response but clinical reactions were observed more frequently when

Table 37. Average percentage prevalence and range of *Anaplasma* and *Babesia* reactors in Colombia.

	Species		
Region	*A. marginale*	*B. bigemina*	*B. argentina*
Caribbean Coast	93 (63-100)	77 (56-90)	n.a.[1]
Eastern Plains	72 (18-91)	59 (38-92)	12 (0-43)
Cauca Valley (dairy)	62 (16-98)	60 (24-94)	44 (12-69)
Cauca Valley (beef)	63 (0-89)	23 (0-58)	26 (0-75)
Total	72 (0-100)	55 (0-90)	19 (0-75)

[1] Not available.

using lower dilutions. For practical purposes a dilution of 10^{-2} administered SQ was chosen for immunization of animals on commercial farms.

Babesia spp. stabilates were used undiluted and diluted ten-fold to 10^{-2}. The 10^{-2} dilution was found infective only for the *B. argentina* stabilate. Inoculations of stabilates administered SQ. did not give consistent results in both *Babesia* species. Dilutions of 10^{-1} administered IV provided a more uniform response without severe clinical reactions and it was chosen for immunization of animals on commercial farms. Hematological and serological responses of dilutions presently used in the field are presented in Table 38.

Attempts to Attenuate *Babesia argentina*

Because of severe *B. argentina* reactions suffered by some of the animals in the previous field experiments, attempts to attenuate the pathogenicity of the existing isolate were made following the method described by Callow and Mellors in Australia. Twelve splenectomized calves were used for this purpose. A group of ten calves was used to evaluate the vaccine in comparison with a non-attenuated vaccine. After field challange, all animals were found resistant to natural infection from *Boophilus microplus* ticks.

In the field, several groups of calves have been immunized with this passaged strain. None of the calves have required specific treatment. The information obtained so far indicates that a degree of alteration has occurred. More evaluation is required under laboratory and field conditions before this strain can be considered to be attenuated.

Field Immunization Program

Eight commercial dairy and beef farms located in the Cauca Valley are being used to evaluate, under field conditions, the applicability and economics of the immunization system against anaplasmosis and babesiosis using the minimum infective dose procedure. Up to now 285 calves have been included in the experiment, half were vaccinated and half used as controls. After vaccination, routine samplings of blood and weight measurements were made in each group to determine the response to vaccination under field

Table 38. **Mean results of hematological and serological response from titration of stabilates stored in liquid nitrogen.**

Organisms[1]	Dilution	Dose/ route[2]	Animals infected/ total used	Incubation parasitemia (days)	Maximum parasitemia (%)	Maximum CF titer	PCV decrease	No. of animals treated
Anaplasma marginale	10^{-2}	2cc/SQ	10/10	28	2.5	1/80	-9%	6/10
Babesia bigemina	10^{-1}	2cc/IV	10/10	7	0.9	1/40	-7%	2/10
Babesia argentina	10^{-1}	2cc/IV	6/6	15	0.01	1/20	-4%	1/6

[1] ***A. marginale*** **stabilate contained 1.2 x 10^9 organisms per ml.**

B. bigemina **stabilate contained 2 x 10^8 organisms per ml.**

B. argentina **stabilate contained 4 x 10^8 organisms per ml.**

[2] **SQ = subcutaneously; IV = intravenously.**

challenge. Evaluation of the immunization program is still in progress on seven of the farms. Preliminary results from one farm are presented in Figures 29 and 30.

This farm is representative of the cattle farms located on the marginal areas of the Andean mountains and the Cauca Valley. Cows and unweaned calves are kept on tick-free pastures at elevations above 2,200 meters. When calves are weaned they are moved to the lower tick-infested valleys where farmers have reported serious losses among weaned calves due to anaplasmosis and babesiosis.

A group of 20 grade crossbred calves, 7-8 months of age were selected for immunization. The calves were weighed and divided into two groups, equal with respect to body weight. One group of 11 calves were immunized while the second group of nine calves left as controls. A nonsignificant difference in weight gains was observed between the immunized and control calves at the end of the 12-week post-immunization period (Fig. 29).

Following recovery from immunization, the remaining 19 calves were exposed to field challenge. Between the second and third post-challenge weeks, the control calves started to develop acute signs babesiosis. By the third week, the PCV's of the controls had decreased an average of 15 percent. All of the controls required specific treatment for babesiosis and one calf died in spite of treatment. The immunized calves developed low *Babesia* parasitemias and small decreases in PCV's but did not require treatment.

All of the immunized and control calves developed detectable *Anaplasma* parasitemias during the seventh post-challenge week. All of the control and

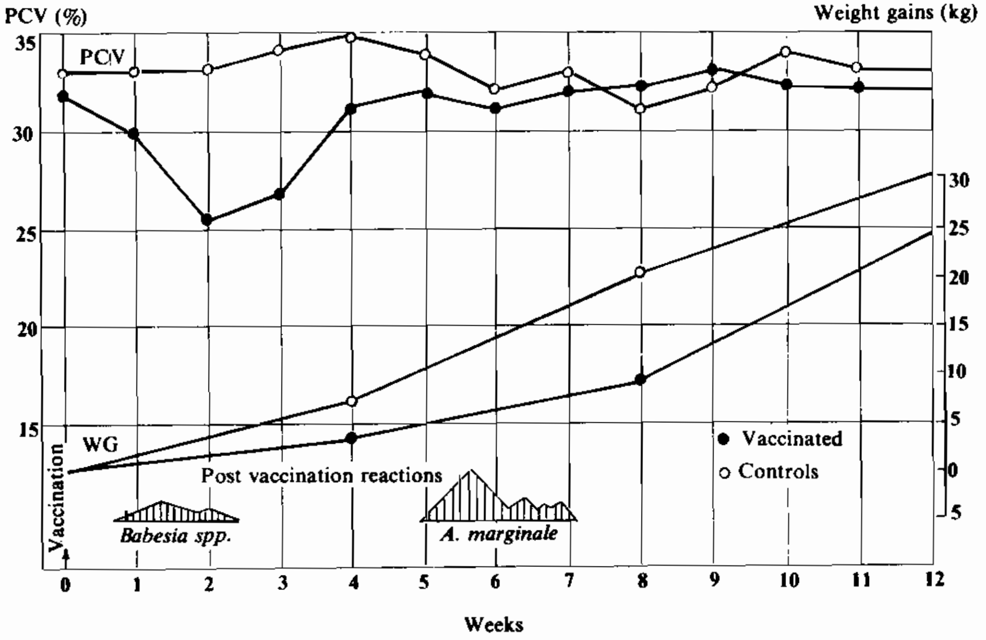

Figure 29. Effect of vaccinations against *A. marginale* and *Babesia spp.* and their relationships to anemia (PCV) and weight gains (WG) in 19 calves before field exposure - San Julián farm.

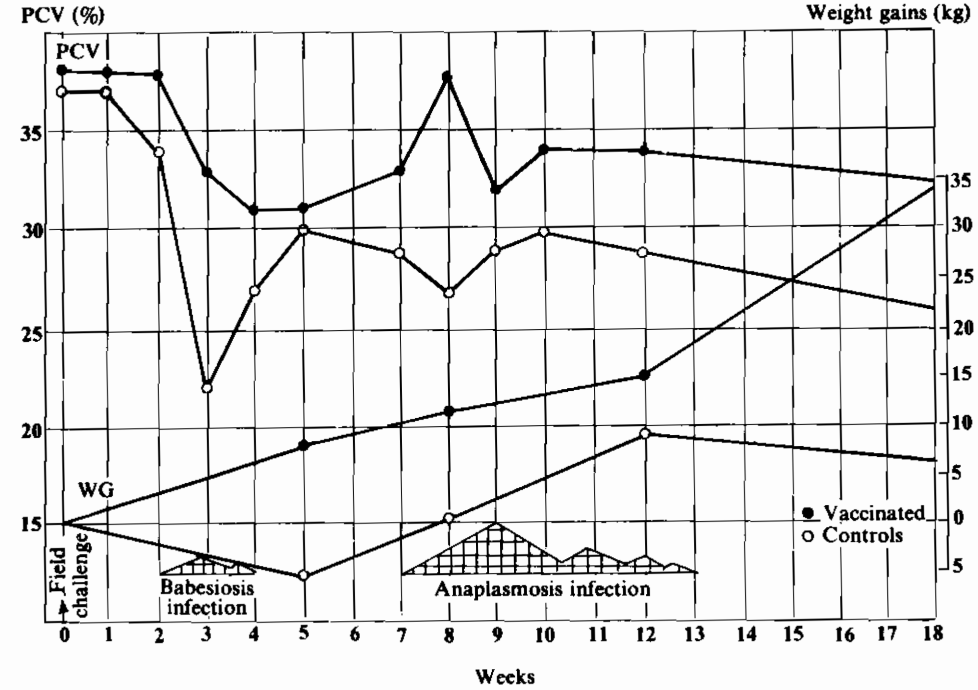

Figure 30. Effect of field challenge with *Boophilus microplus* ticks infected with *Babesia* spp. and *A. marginale* on anemia (PCV) and weight gains (WG) in 19 calves - San Julián farm.

some immunized calves required specific treatment for anaplasmosis.

At the end of the field challenge period (18 weeks) the inmmunized calves had gained an average of 27 kilograms more per head than had the control calves, a statistically significant difference (Figure 30).

Collaborative Project

A collaborative project between the University of Illinois and Texas A&M University, (USA), ICA and CIAT for the evaluation of immunization methods against bovine anaplasmosis, was organized during a meeting of the collaborating groups at CIAT in March 1976. The project began in July with the assembly of 130 experimental Normandy calves at ICA's Tibaitatá station near Bogotá (2,600 meters elevation, mean temperature 14°C). The calves are being periodically examined and various parameters monitored to establish base line information prior to beginning immunization procedures early in 1977. The immunization methods employed will be evaluated under field conditions in an anaplasmosis endemic area when the calves are moved to the ICA Turipaná station near Montería, (elevation 50 meters, mean temperature 27°C).

Training

During 1976, training of veterinarians primarily from Latin America continued. Special emphasis was given to recent advances in the serologic diagnosis and control of anaplasmosis and babesiosis. Nine professionals received training in

CIAT: two were North Americans working on advanced degrees from Texas A&M University while seven were Latin Americans receiving postdoctoral trainig in hemoparasitology as Postgraduate interns in CIAT. The Latin American professionals included representatives from Colombia, Perú, Brazil and the Dominican Republic. Requests for training in hemoparasitology were also received from the Governments of Bolivia, Brazil, Ecuador and Venezuela.

SPECIAL PROJECT IN ACAROLOGY

Activities of the Acarology Unit in CIAT are conducted as a special project in the Center. Funding for the unit is through the Ministry of Overseas Development in the United Kingdom.

Serious production losses from tick infestations have been recorded on all tropical continents. In the Americas, approximately 70% of the total cattle population is found in tick-infested areas (between the 32nd north and south latitudes with a few foci found as far as the 35th latitudes). Ticks are not only important vectors of disease but also reduce weight gains and otherwise affect host performance through direct parasitic effects. Ticks transmit every class of infectious agent known (protozoa, rickettsia, fungi, bacteria, spirochaetes and viruses) and infest amphibians, reptiles, birds and mammals.

In 1976, the research program has concentrated on studies of tick identification and distribution, disease transmission and ecology on and off the host. Information dissemination and training activities were integrated with research work. The unit assisted in identifying ticks taken from 45 species of birds which were collected as part of a non-CIAT-related survey on the Carimagua station. Of special concern is the fact that migratory birds found in Colombia may be introducing new tick species and/or diseases infecting man and/or animals.

Tick Identification and Distribution

The Unit's tick species checklist was expanded to include 32 host and 23 tick species. The major area of collection was the Eastern Plains of Colombia with minor collecting being done in the North Coast region, the Cauca Valley, and Tolima and Cundinamarca regions of Colombia. The tick collection is extensively used for taxonomic training.

Disease Transmission

The common belief that *Boophilus microplus* is the principal transmitter of *Anaplasma marginale* is not supported by experimental evidence. After a series of eight *B. microplus* tick transmission trials, the only successful modes of *A. marginale* transmission were found to be trans-stadial (transference of infection between developmental tick stages on one host) and intra-stadial (transference of infection to other hosts using developmental tick stages). Transovarial transmission (transference of infection through the tick egg to the next generation) never occurred during these trials. In the field, intra-stadial transmission between animals by *B. microplus* would seem possible only if management practice allowed the close apposition of animals. Such mechanical transmission would appear more likely with ticks requiring two or three hosts to complete their cycles than with *B. microplus* which need only one.

On- and Off-host Ecology

A doctoral candidate continued ecological studies of ticks economically important to the Colombian cattle industry. This work stresses three areas of tick control improvement: (a) the provision of localized ecological data for greater efficiency of traditional chemical acaricide application; (b) the greater current attention to mechanisms, assessment and utilization of naturally tick resistant cattle; and, (c) the continued need for revolutionary biological tick control techniques.

Natural seasonal incidence studies of *B. microplus* on *Bos taurus* and *B. indicus* cattle, untreated with acaricides, have covered 17 of the 20 months of the program (four dry and three wet seasons) in the Cauca Valley. The distinct seasonality of parasitic tick numbers was compared with the success and longevity of ticks reared in field vials from 1,000 meters (enzootic) to 2,500 meters (epizootic), and under control conditions. The non-parasitic ticks were limited geographically and seasonally by low temperature inhibition of egg development, and seasonally by egg and larval dessication. Tick load tolerance of cattle under various environmental conditions was concurrently observed by monitoring changes in hemoglobin and packed cell volume values of the field-infested cattle, and of experimental cattle on high and low nutrition planes with single and repeated artificial infestations. Hemo- and endoparasitic effects were largely eliminated by regular use of drugs. Although good nutrition increased cattle tick resistance and tolerance, it appears that relatively low tick loads still directly caused significantly decreased blood values.

Field, corral and barn studies established that certain cattle body regions were consistently highly populated by *B. microplus*. Ticks migrate to these regions irrespective of the point of larval application, and were associated with distinct skin-surface temperature regimes. Thus, micro-environmental stress may operate on ticks in conjunction with immunological host resistance. This work is currently focussing on possible differential tick mortality rates in various host body regions from microclimatic and tick feeding-density aspects.

Ticks may alternatively or additionally exhibit such highly contagious on-host distribution by differential attraction to the various body regions for successful engorgement. Preliminary studies on the validity of such "feeding-site predilection" concepts have begun for *B. microplus* and *Anocentor nitens* on cattle and horses, and will be emphasized in early 1977. Such behavior could exploit the already vulnerable pre-feeding tick phases on cattle and increase their natural parasitic mortality even more.

Reports from cattlemen in Colombia indicate that animals grazing molasses grass (*M. minutiflora*) carry fewer ticks than those on other improved or native pastures. In a preliminary trial in the dry season, 40,000 *B. microplus* larvae were placed at the base of molasses grass plants. All larvae had died after 34 days, while the control, a bermuda grass (*Cydodon dactylon)* had viable ticks for more than 70 days after infestation, when the trial ended. This trial is presently being repeated during the rainy season and a full-sacale field grazing trial is proposed to complement existing data and add the dimension of observations on the interaction between ticks, grass and grazing cattle. The ideal would be to observe the tick/cow/grass triangle through a minimum of two full seasons (two wet and two dry) to observe changes in the tick population, cattle weight gain and durability of pasture. Likewise a variety of improved pastures with native species as controls would be advantageous.

Information Dissemination and Training

During 1976, staff of the CIAT acarology unit assisted in training five veterinarians, one PhD candidate and two special trainees. Assistance was also given in laboratory training courses. The unit's staff met with some 50 visitors. A tick study set of 78 color and black/white slides (with Spanish commentary) was prepared for training purposes. A literature review (CIAT Annual Report, 1975) was extended to include the geographic distribution, hosts and authors for 200 tick species of the neotropical faunal region.

ECONOMICS

In 1976 the Economics Unit of the Beef Production Program concentrated in three major areas: (a) economic evaluation of different alternatives in the control of foot and mouth disease; (b) productive behavior of the cattle industry in Colombia; and, (c) microeconomic evaluation of beef cattle production in the Colombian Llanos and of factors internal and external to the farm, conditioning the adoption of technologies.

Economic Evaluation of Alternative Control Strategies of Foot and Mouth Disease

An epidemiological model of foot and mouth disease for endemic situations was designed and reported in 1975 as part of the methodology developed in collaboration with the Animal Health and Biometrics Units of CIAT. The model simulates the annual incidence and prevalence of foot and mouth disease on a long-term basis by means of semi-Markov stochastic processes.

Objectives

On the basis of this epidemiological model, a methodology was developed in 1976 to evaluate different alternatives corresponding to: no disease control, different vaccination levels, and finally, eradication. In this way, the optimum economic level of control for a given region or country may be derived.

The model is also designed to evaluate the "externalities" present in the control of foot and mouth disease. The private optimum level of control is inferior to the social optimum level since each producer only considers those benefits internal to the farm, underestimating the total social benefit by ignoring spillover benefits to the other farms from reducing their probability of contagion. The latter constitutes what is known as externalities.

To verify the validity and applicability of the methodology the North Coast of Colombia was chosen for a case study not only because it is an important cattle raising area but also because it borders on the disease-free zone extending from Panama northward.

Methodology

In order to estimate economic losses from the disease, two microeconomic models were formulated in FORTRAN (for computer use): one for breeding, and the other for fattening farms. In these models the development and production of the herd, and the cash flows of the farms were simulated. In both models, the point of departure is a stabilized herd whose production parameters reflect technology prevailing in the region. The economic losses considered were: morbidity, mortality, and the cost of additional resources required to manage sick animals. These losses were measured as the difference between the farm income flows over time with and without the disease. The benefit from each level of control is the reduction achieved in economic losses from disease. In turn, a comparison of costs and benefits associated with each level of control allows the identification of the optimal economic strategy.

Breeding model

The gross annual income of the stabilized herd without foot and mouth disease was determined on the basis of the number of predicted animals sold and of milk production. The net income was obtained by deducting variable costs. To derive the farm's gross income flow considering the probability of an outbreak of foot and mouth disease, the morbidity values (measured as incidence) and the increase in mortality rate, estimated by means of the epidemiological model, were used. These values depend as much upon vaccination levels on the farm as vaccination levels in the region. During a year of a foot and mouth disease outbreak, lower production parameters are used in relation to each sick animal. These are: lower milk production, lower birthrate, lower weight in calves and culled cows sold during the year, and greater management costs. Also, the model accounts for changes in size and composition of the herd during the year of the outbreak and in subseqent years. The control variable for returning to the pre-outbreak stabilized herd, is the number of calves on the farm for future cow replacement as these cannot be bought outside the ranch due to the risk of reintroducing the disease. Also, the number of calves available for replacement is limited by the existing birthrate[1].

Fattening model

On the fattening farms, net income is estimated monthly from information on age and weight of unfattened calves at purchase, an average weight gains curve according to age, average mortality rate, purchase and sale prices, and average expense per calf. The selling age and weight of the calves were determined by maximizing the discounted value of expected net income. In making sales and purchases calculations it was assumed that these transactions take place throughout the year[2]. In order to generate farm income flow with foot and mouth disease, morbidity and mortality data for the disease, and a weight gains curve for animals with the disease was used[3]. The model calculates the new optimum selling age of sick animals since it is not possible to replace them immediately with healthy animals due to the required quarantine. Hence, the demographic component of the simulation model projects subsequent herd development in which healthy animals are sold at one age and sick ones at another. The

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[1] This assumption is not needed at the farm level, but it is necessary at the aggregate level since purchase for replacement is not feasible.

[2] This assumption at the farm level allows generalization of results at the regional level.

[3] The production parameters with foot and mouth disease were taken from: Animal Health Project - "The Battle against Foot and Mouth Disease and Control of Brucellosis", Document No. 16, ICA, November, 1970.

income flow with foot and mouth disease is projected up to the month in which the last animal affected left the herd.

Results

Results are presented for a cattle population of 4.4 million head. This total approximately corresponds to the existing cattle population of the Departamento of Córdoba on the North Coast of Colombia.

Table 39 presents morbidity results and Table 40 shows the annual mortality from foot and mouth disease in a steady-state situation, for in-farm and regional vaccination levels varying from 0 to 100 percent. These results are based on the previously described epidemiological model. The results obtained at the ranch level were weighted by the proportion of total stock represented by each type of cattle farm in order to obtain regional estimates.

Table 41 presents the annual private and social costs and benefits for the region in a situation of long run equilibrium, for different vaccination levels. It is assumed that the annual unit cost of control is constant and independent of the vaccination scale. Annual social net benefits are maximized at 90 percent vaccination, which is thus the optimal vaccination strategy from society's point of view. The optimum vaccination strategy from the private point of view is only 60 percent; i.e., definitely inferior to that of society (Table 41, column 3). This difference, due to the existence of externalities, justifies governmental actions or campaign to control the disease.

In order to analyze the optimal strategies when unit cost of vaccination increases, net benefits were evaluated at costs 50 and 100 percent higher than the original values. In both cases, the optimum private strategy was reduced to 40 percent while the

Table 39. Annual morbidity from foot-and-mouth disease over the long run as a function of the vaccination level on the farm and in the region (Percentages)

Vaccination level on the farm (%)	Vaccination level in the region (%)										
	0	10	20	30	40	50	60	70	80	90	100
0	19.0	17.7	16.3	15.1	14.1	12.2	10.6	5.5	4.7	3.3	2.5
10	18.2	16.4	15.2	14.1	13.2	11.5	10.0	5.3	4.5	3.1	2.3
20	16.6	15.1	14.0	13.0	13.1	10.6	9.3	4.9	4.3	3.0	2.2
30	15.1	13.7	12.7	11.9	11.1	9.7	8.5	4.5	3.9	2.7	2.1
40	13.5	12.3	11.4	10.7	10.0	8.8	7.7	4.1	3.6	2.5	1.9
50	11.6	10.6	9.9	9.2	8.7	7.7	6.7	3.7	3.2	2.2	1.7
60	8.9	8.2	7.7	7.2	6.8	6.0	5.3	3.0	2.6	1.8	1.4
70	5.4	5.0	4.8	4.5	4.3	3.8	3.4	2.0	1.7	1.2	1.0
80	2.9	2.8	2.6	2.5	2.4	2.2	2.0	1.2	1.1	0.8	0.6
90	1.17	1.12	1.08	1.05	1.01	0.95	0.9	0.6	0.54	0.41	0.33
100	0.162	0.159	0.157	0.155	0.153	0.15	0.14	0.12	0.11	0.09	0.08

* Refers to annual average coverage, with 3 vaccination cycles.

Table 40. **Annual mortality rate from foot and mouth disease over the long run as a function of the vaccination level on the farm and in the region (x 1,000)**

Vaccination level on the farm (%)	Vaccination level in the region (%)										
	0	10	20	30	40	50	60	70	80	90	100
0	4.75	4.42	4.07	3.77	3.51	3.05	2.65	1.37	1.17	0.82	0.62
10	4.18	3.77	3.49	3.24	3.02	2.64	2.3	1.2	1.03	0.72	0.53
20	3.48	3.16	2.94	2.73	2.54	2.22	1.94	1.03	0.89	0.62	0.46
30	2.87	2.6	2.41	2.25	2.1	1.85	1.61	0 85	0.74	0.52	0.40
40	2.02	1.84	1.71	1.6	1.5	1.32	1.15	0.62	0.54	0.37	0.28
50	1.16	1.06	0.98	0.92	0.86	0.77	0.67	0.37	0.32	0.22	0.17
60	0.62	0.57	0.54	0.5	0.47	0.42	0.37	0.21	0.18	0.13	0.10
70	0.27	0.25	0.24	0.22	0.21	0.19	0.17	0.1	0.09	0.06	0.05
80	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0

optimum social strategy fell to 70 percent of vaccination coverage[4].

In the absence of reliable primary information, the simulation results were based on secondary data sources and on data from other countries adapted to conditions on the North Coast of Colombia. Therefore, results must be cautiously interpreted. Given that epidemiological

[4] This would be the case, if for example, the costs per vaccinated animal in the anti-foot and mouth disease campaign in Urabá were charged to the private costs of caccination.

Table 41. **Annual private and social costs[1] and benefits corresponding to different vaccination levels on North Coast of Colombia[2] in millions of $Col. of 1975.**

Vaccination level	Annual costs (1)	Gross private benefits (2)	Net private benefits (3) (2)-(1)	Gross social benefits (4)	Net social benefits (5) (4)-(1)
0	-	(430.1)[3]	(430.1)	(430.1)	(430.1)
10	11.5	35.2	23.7	64.4	52.9
20	22.9	61.9	38.9	122.3	99.4
30	34.4	85.5	51.1	173.0	138.6
40	45.8	110.4	64.5	220.7	174.8
50	57.3	122.4	65.1	274.2	216.9
60	68.8	135.8	67.0	323.2	254.4
70	80.3	85.7	55.4	386.6	306.3
80	91.7	85.4	-6.3	404.1	312.4
90	103.2	65.8	-37.3	415.8	312.6
100	114.7	54.0	-60.6	421.5	306.8

1 It is assumed that there are no discrepancies between the social and private costs. A cost of $Col. 25/head/year was used
2 With a total cattle population of 4,410,372
3 The annual cost from foot-and-mouth disease in an endemic situation according to the adopted assumptions.

parameters are location specific, in order to obtain valid estimates for the region, an agreement was signed with ICA to obtain primary information relevant to the Urabá and Córdoba regions on the North Coast of Colombia. This agreement involves the Animal Health, Biometrics and Economics units at CIAT, and the departments of Economics, Cattle Production, and Biometrics at ICA. The objective is to compare losses from the disease at two vaccination levels and to estimate cost and benefits on moving to higher levels. For this purpose, a survey of ranches without foot and mouth disease is being conducted in Urabá, where periodic measurements are taken. Parallel measurements are also taken on farms with outbreaks of foot and mouth disease. A sampling of farms in the Córdoba region was also designed to determine the frequency of outbreaks, the rates of attack and the lethatlity of the disease. This study will be completed during 1977.

At the same time, other strategies such as eradication through slaughter, and through a vaccination-slaughter sequence are being economically evaluated.

Productive Behavior of the Cattle Industry in Colombia

Continuing the study of the cattle industry in Colombia, the aggregate behavior of stocks and slaughter from 1940-75 was evaluated.

In Colombia, beef is the most important product in the family budget, representing between 10 and 12 percent of a worker's budget. From 1940 to 1975 its consumption per person varied according to slaughter cycles, tending to decline slightly. This is due to production increases which were counterbalanced by increases in population and in exports.

Available information is not sufficient for designing a policy to induce significant production increases. This would require the identification and quantification of the fundamental economic relationship to predict the effects of the different variables and policy instruments on investment behavior, cattle sales, and on meat consumption. This study represents a first attempt to begin such an analysis.

Once the inventory series by age and sex from 1940-75 were estimated, a supply, demand and inventory model was developed including such economic variables as cattle prices, crop prices, disposable incomes, and such explanatory policy variables as the agrarian reform, credit and price controls. This model allows for the identification and quantification of the fundamental parameters over short run. It is based on similar theoretical models on aggregate production behavior which have been successfully applied in Argentina, Brazil and Chile.

Preliminary results

In general, the results of the econometric model agree with the theoretical model. The aggregate demand for cattle was estimated as being relatively inelastic with respect to price and income.

Estimates obtained for the price parameters in the supply function (slaughter) in terms of both magnitude and sign, were as expected on the basis of the theoretical model. The aggregate slaughter of females reacts inversely to price (Figure 31) which implies that as the price of beef goes up producers retain females to generate future supply, and as a consequence, sales are reduced over the short run. These results are consistent with observed behavior of beef cattle inventories during price fluctuations; that is,

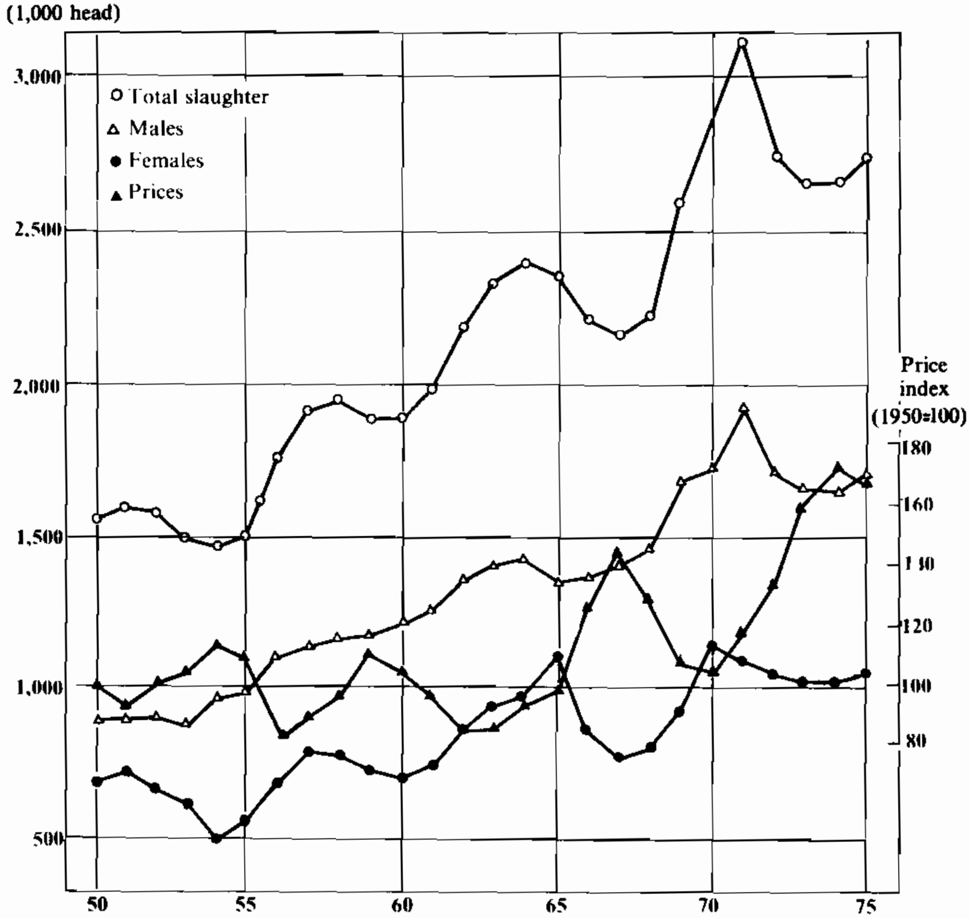

Figure 31. Slaughter, including unregistered and exports on foot, and real prices of beef cattle in Colombia, 1950-75.

price elasticities in the inventory functions are positive indicating that when prices rise, inventories of both males and females increase. On the other hand, when the prices of cotton, rice, maize and beans rise there is a decrease in inventories.

The behavior of milk prices in the short run supply functions, as well as inventories, indicates that when milk prices rise, sales of females decline, consequently increasing the breeding herd.

The volume of credit granted by the Caja Agraria and the banking system in general, does not appear to significantly influence slaughter supply, even though this variable was introduced with different lags (1-5 years). However, credit from the Fondos Ganaderos, and granted under Law 26, had a significant effect (P .01) on female inventory behavior[5]

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[5] It must be noted that credit from the Fondos Ganaderos and under Law 26 is supervised credit.

Price control, expressed as a binary variable, did not significantly explain either slaughter supply or domestic demand. In the case of the supply function, however, price control was already reflected in the series of wholesale cattle prices. At the consumer level, the price controls have been generally inoperative, therefore no significant relationship was expected.

Generally, the estimated values for the fundamental parameters of the functions of supply and demand, and their respective elasticities over the short run, represent a preliminary approximation of their true magnitude and value.

It must be noted that the model only measures short term effects; this representing a serious limitation since some policy effects manifest themselves only in the long run. Smuggling was excluded from the analysis for lack of data. Climatic conditions were also excluded due to difficulties involved in constructing a representative climatic index. Such an exclusion seriously limits the study since the scarcity of pasture resulting from droughts can seriously restrict production and cause slaughter variations. While these and other macroeconomic aspects were excluded due to lack of data, nevertheles they merit research.

Cattle Production Systems in the Llanos

Relatively little is known about the economics of cattle production systems in the savannas of Colombia and about those economic restraints which might condition adoption of existing technology. Therefore, the objective of the study is to characterize the region according to: (a) the present systems of production; (b) factors internal to the farm (natural resources and management) and external factors (credit policies, prices, input availability) which represent current restictions on technology adoption; and (c) the economics of practices such as using minerals, early weaning, and improved pastures.

The study is being carried out in the Carimagua region in order to complement and document with primary information, data obtained from prior studies (CIAT Annual Report 1975).

On the basis of agrological, climatic and natural vegetation studies conducted by the Food and Agriculture Organization (FAO), and road maps, a zone of 300,000 hectares was selected for study. A census of farms in the region was obtained from the census office and complemented with aerial photographs and field work. The principal criteria for selecting farms were: (a) scale of operation; (b) location and distance to supply centers and markets; (c) specialization in breeding or fattening; and (d) the use of mineral supplements.

From 200 farms which met the typical conditions of poor soil and less than 20 percent lowland, 16 farms were selected; of these, six of them have been analyzed as the first contacts in the area. For each of the farms selected, monthly visits were planned for a period of 18 months, beginning in April 1976. At present, the farms' natural resources have been studied, the cattle numbered, and monthly overall farm records have been kept for the last six months. The animals have been weighed in order to measure different technological parameters.

The principal external factors considered are: (a) price of cattle, (b) transportation costs, (c) level of utilization (opportunity cost) of natural pastures in nearby regions (piedmont), and in general, those external factors which may condition the degree of intensification, specialization and location of cattle production in the area. The principal internal factors considered are: (a) natural resources as farm size, proportion of high and low lands, soil quality, pasture and infrastructure; (b) management practices —division, rotation and carrying capacity of the pastures, fire control, sanitary practices, marking, use of minerals, early weaning, forms of transportation, age and season of sales; (c) production— birthrate, mortality, weight increase, breeding season, weight losses; and, (d) expenses and income, —purchase and sale price of inputs and outputs, and wages.

Preliminary observations

Several principal observations have been made:

(a) A high degree of specialization exists in the piedmont in fattening operations and in the savannahs in cowcalf operations. In 1975, 131,459 head of fat cattle were extracted from the Department of Meta (police check point, "retén", of Bogotá) of which only 3,000 head came from the savannah region ("retén" of Pt. López). Through this last "retén" 30,000 cattle passed to be fattened and finished in the piedmont.

(b) In the more fertile lands of the piedmont non-capital intensive technology is available that increases carrying capacity without reducing the daily weight gains per animal.

(c) In the savannah, the cost of truck transportation has increased in real terms, approximately 10 and 25 percent respectively in each of the last two years. The cost per animal per kilometer from Villavicencio (piedmont) to Bogotá is only half the cost per kilometer in the Llanos.

(d) Cattle movements from the savannah to lands of the same owner in the piedmont have been observed. In 1976, three of six farms transferred and average of 30 percent of their animals to the piedmont; under normal production conditions, these farms would not extract more than 15 percent of their animals. None of the farms studied reported a uniform extraction during the last three years.

(e) In none of the three farms which have obtained credit, did the loan institution accept savannah land where the investment was made as collateral.

(f) On the four farms which had some mechanization (forage seeding, building of dams, road construction), the machinery was also used by the same owners on other enterprises or lands in the piedmont.

(g) In areas near the farms under study, there are farmers with good land who have seeded improved pastures and charge a pasturage fee substantially lower than in other areas (Col.$45-80/animal/mo.)

(h) The stocking rate is much lower than what is technically feasible on the savannah. The average stocking rate is one animal on 5.5 hectares in the dry season and 7.1 hectares per animal in the rainy season.

(i) On the three farms where early weaning is being practiced, the age of the early-weaned animals varied from 7 to 15 months, depending on the size and condition of each calf.

(j) On one farm, mineral supplementation for the first three years increased the birthrate to 62 percent and have considerably reduced abortions However, the slow recovery of nursing cows resulted in increased cow mortality because they were unable to pull themselves out of the bogs near watering points in their weakened condition. In 1976, 6 percent of the nursing cows on the ranch died in this manner.

(k) The average weight of nursing cows under savannah conditions and supplemented with minerals was 273 kilograms in the rainy season (weighed six months after the rains began); however, individual weights varied between 210 and 400 kilograms. The average weight of the heifers at breeding was 235 kilograms with a range between 210 and 286 kilograms.

(l) In 1976, the average sale price of finished animals in the Llanos was approximately Col.$14/kg while the average price of feeders and heifers was Col.$16/kg. Average price of pregnant cows was Col.$18/kg.

Working hypotheses

Observations to date suggest the following working hypotheses.

(a) While present conditions of low opportunity cost of pastures in the piedmont and the high cost of transportation from the savannah are maintained, piedmont farms will continue to specialize in fattening and, the savannah in cow-calf operations.

The low opportunity cost of pastures in the rainy season in the piedmont creates a high demand for feeder cattle. This would explain the difference found in the prices of fat and lean animals. It explains why farmers transfer more animals from the savannah to the improved pastures in the piedmont than the normal annual extraction rate, even though the savannah has maximum carrying capacity during the same season (rainy season). This may be attributed (in the case of steers) to greater daily weight gain in the piedmont (600 grams compared to 350 grams on savannah pasture), and in the case of cows, for reasons of ease of management. However, the stocking rate in the piedmont is still inferior to its potential which would explain the slow adoption of available, low-cost and easily applied technology, in the area.

The cost of road transportation has risen in real terms during the last two years; hence the price of cattle as well as specialization of production in each area is more dependent upon transportation costs. Feeder cattle cost less to move on foot, than by truck in terms of cash outlay This contributes to the specialization on finishing in the piedmont and breeding in the savannah.

(b) The low cost of land in the savannah limits the possibility of using it as collateral to adopt capital-intensive technologies, i.e. extensive use of improved pastures. This restricts the adoption of capital intensive technology even on the supposition of profitability.

(c) The adoption of improved management practices in an isolated manner —use of minerals, division of pastures, and early weaning in the savannah,— does not seem to greatly increase productivity over traditional systems. On the farms analyzed, "early" weaning occurred on the average at 12 months, which is almost the age of natural weaning. The use of minerals alone appears to stimulate some cows to reproduction levels above biologically safe levels for present savannah conditions. This would contribute to the death of the most productive cows due to calving and lactation stresses.

In relation to the use of minerals, the difference found with experimental results in Carimagua (see discussion on page 35 Herd System Project I) appear to be due to the age, initial condition and the composition of the breeding herd. The experimental herd was originally formed by heifers with an average weight at breeding of 280 kilograms while the average weight at breeding observed in the study was 235 kilograms. Another difference between ranch and experimental systems is that ranch savannahs are burned in a less controlled way than the experimental station. In 1975, two of the six farms observed had accidental fires on 50 and 100 percent of their savannah. Although mineral supplementation increases the pregnancy rate accidental fires appear to increase the number of abortions due to poor nutrition of first pregnancy heifers. Also, water on the experiment station is provided by wells while on the savannah, the only sources of water are the watering holes along natural streams. This notably increases the risk of death in bogs of those cows weakened by calving and lactation.

In 1977, information will continue to be collected in order to evaluate some of these hypotheses and to obtain empirical information on the different parameters involved.

TRAINING

In 1976, 12 postgraduate interns received individual training in the areas of animal health, pastures and forages and animal management. The average length of training was seven months, for a total of 84 man-months. These trainees were selected for advanced training from several different countries to better prepare them for research responsibilities in their respective national institutions.

Seven research scholars are working on their master's degrees. Three have completed academic studies and are conducting thesis research projects in the various disciplines of the Beef Production Program. The other four are at various universities completing their academic requirements and are expected to do their thesis research at CIAT.

Seven special trainees (three months or less at CIAT) received short-term training, learning specific research or analysis techniques within the various disciplines.

A two-month short course in epidemiology of animal diseases was organized and supervised in the field by members of the beef team as part of an overall course organized and funded by the Panamerican Zoonosis Center. The major portion of the course, in CIAT, consisted of a disease survey in Santander de Quilichao, in the Cauca region of Colombia. Field work was done in collaboration with the Cauca secretary of agriculture, the regional livestock association (Fondo Ganadero del Valle). the Caja Agraria, ICA and private ranchers.

The objective of the course was to teach a systematic approach for collecting and interpreting fundamental biological data within a beef cattle zone to construct an accurate description of the disease situation. Based on general information of the zone provided by the collaborating institutions, the seven trainees (two from Brazil, and one each from Chile, Honduras, the Dominican Republic, Mexico, and Guatemala) were divided into groups which surveyed 35 farms.

From the smaller herds (<120 head) blood samples were taken from 20 animals and from the larger herds (500-2,500 head) 40 animals were bled. A total of 750 animals were sampled representing a population of 12,401. A questionnaire was completed for each farm to obtain data on production and nutritional parameters. Serum samples were analyzed in the laboratory for hemoparasites and reproductive diseases. At the end of the two-month course, the trainees held a field day at one of the ranches. They presented their preliminary results and discussed with the cattlemen possible means of improving beef production in the area.

Data obtained from questionnaires and laboratory analyses is being evaluated and will be used not only for evaluating the student's performance but also as a guide for preventive medicine regimes to be established for animal experimentation which will be conducted in this area.

Eight visiting research associates either began or completed their dissertation research as the final phase of their doctoral program. All candidates are sponsored by other organizations; however, CIAT covers some of the research related costs.

Due to a lack of special project funding, no beef cattle production specialist course was offered this year. However, a course is being developed for a group, primarily from Guatemala, which will begin in January 1977. The first three-month phase of the course will be taught at CIAT and the subsequent seven-month field phase will be done under supervision by CIAT personnel on private ranches in Guatemala.

Two visits were made to Ecuador to assist personnel at Instituto Nacional de Investigaciones Agropecuarias (INIAP) in setting up a beef cattle production course for the coastal region where training programs are contemplated for workers in various levels of the livestock sector.

A detailed analysis is given in the training and conference section of the annual report.

PUBLICATIONS

Eberhard, M. L., Morales, G.A. and Orihel, T.C. *Cruorifilaria Tuberocauda* gen et sp. n. (Nematoda: Filarioidea) from the capybara, *Hydrochoerus hydrochaeris* in Colombia. **Journal of Parasitology**, 604-607. 1976.

Gonzalez, E. F., Todorovic, R. A. and Thompson, K. C. (1976) Immunization against anaplasmosis and babesiosis using a minimum infective dose of parasites. **Zeitschrift fur Tropenmedizing und Parasitologies.** 27:427-437. 1976.

Morales, G. A. and Carreño, F. The *Proechimys* rat; a potential laboratory host and model for the study of *Trypanosoma evansi*. **Tropical Animal Health Production**, 122-124, 1976.

Morales, G. A., Wells, E. A. and Angel, D. The capybara *(Hydrochoerus hydrochaeris)* as a reservoir host for *Trypanosoma evansi.* **Journal of Wildlife Diseases,** 572-574, 1976.

Todorovic, R. A. and Long, R. F. Comparison of indirect fluorescent antibody (IFA) with complement fixation (CF) tests for diagnosis of *Babesia* spp. infections in Colombian cattle. **Zeitschrift fur Tropenmedizin und Parasitologie,** 27:169-181, 1976.

Todorovic, R. A. Bovine babesiosis: recent advances in diagnosis and control. **Proc. V. Jornadas en Medicina Veterinaria y Protección Animal,** Colegio de Médicos Veterinarios Zootecnistas de Caldas, Manizales, Colombia, 1-12. 1976.

Swine nutrition unit

Swine nutrition unit

HIGHLIGHTS IN 1976

In 1976 the Swine Nutrition Unit concentrated on training activities and international cooperation as well as on nutritional research.

The most important training activity was the First Postgraduate Swine Production Course which lasted six months and provided some 930 hours of training to the 20 participants. Practical tasks at the level of commercial production were emphasized; the initial cycle of conferences included an analysis of the limiting factors on efficient production in Latin America.

In addition, CIAT collaborated in the organization and development of the first Central American Seminar on Swine Production, held at the University of Costa Rica in San José. The seminar was attended by 120 persons from five Central American countries. In the future, these types of regional seminars will be considered very important as a complementary activity to CIAT training courses as a way of maintaining contact with former trainees and technicians of national swine production programs in Latin America.

International cooperation activities in swine production continued to develop with national institutions in Bolivia, Colombia, Costa Rica and Perú. The swine units in Santa Cruz (Bolivia) and Pucallpa (Perú) have begun swine production on a regional level. In Bolivia, the Cooperative Project of the Universidad Gabriel René Moreno-CIAT-Heifer Project has initiated research (for example, evaluating some simple, local products as feedstuffs for swine), training producers including small farmers, and developing swine production activities.

In Perú, CIAT assessed the Swine Unit of the Instituto Veterinario de Investigaciones Tropicales y de la Altura (IVITA); this unit already has foundation breeding stock and research and production activities have begun.

In Costa Rica, modifications were made in the initial plans of the University of Costa Rica-CIAT Cooperative Project in order to broaden the range of project activities. Improved financing has been secured as has increased assistance from the university, the United States Agency for International Development (AID) and from national agencies such as the Ministeries of Government and Agriculture. Construction is scheduled to begin in early 1977.

In La Victoria (Colombia), a cooperative technical assistance project for small swine producers was initiated with the Instituto Colombiano Agropecuario (ICA), the Caja

Agraria and the Concentración de Desarrollo Rural. Ten small swine producers were selected to be financed as a group. The small production units are cheap and easy to construct, and local by-products will be used as the basic swine diets. This first project will be used to study transfer to techniques for different aspects of swine production activity and for teaching CIAT trainees.

Research has continued on nutritional studies, especially on the substitution of rice polishings, cassava meal, and sugar cane for cereal grains during growing and finishing periods.

A pilot plant was installed at CIAT to study the production of microbial protein using cassava as the energy substrate. The process appears to offer a potential solution to the growing problem of the shortage of protein sources for human and animal consumption.

TRAINING

Postgraduate Swine Production Course

The first Postgraduate Swine Production course was taught between March 15 and September 19 of this year. It was financed by the International Development Research Centre (IDRC) of Canada, the U.S. Agency for International Development (AID), Banco de Mexico, Asociación de Crédito y Asistencia Rural del Amazonas (ACAR) in Brazil, the Government of the Federal Republic of Germany and CIAT. The 20 professionals attending the course were selected from institutions concerned with swine production, teaching, extension and research in Latin America (Table 1).

A total of 930 course hours were directly related to training as shown in Figure 1. Practical activities of commercial production were emphasized. In addition, an initial cycle of conferences was taught to analyze the various aspects of efficient swine production (nutrition, management, production costs, swine breeding and health) and the principal limiting factors on swine production in Latin America. The theoretical-practical phase of the course was coordinated by specialists in swine production, swine health, economics, training and information services of CIAT with the collaboration of professionals from the Instituto Colombiano Agropecuario (ICA), Caja de Crédito Agrario and other Colombian organizations.

The practical training in swine production was initially carried out in CIAT's swine production unit (Figure 2) and later on small farms and commercial enterprises. Work groups of three or four professionals were formed for supervised practical work and short research projects. One day of the week was designated for visits to agro-industrial companies concerned with swine production in the Cauca Valley in order to analyze in an integrated manner the current and future swine production potential in the region. A one-

Table 1. **Professionals participating in the First Postgraduate Course in Swine Production.**

Trainee's name	Country	Institution	Financing
Asunción Méndez	Mexico	Banco Nacional	CIAT
Roberto Silva	Mexico	Banco Nacional	Banco Nacional
Olegario García	Mexico	Universidad Nacional	CIAT
Bartolomé Manjarrés	Mexico	Secretaria Agricultura	Banco Nacional
Leonel Berducido	Guatemala	Instituto de Ciencia y Tecnología Agrícola	CIAT
Braulio Fajardo	Honduras	Banco Nacional	IDRC
Carlos Blanco	Nicaragua	U. Centroamericana	IDRC
Adán Ruiz	Nicaragua	Banco Nacional	CIAT
Manuel Padilla	Costa Rica	Ministerio Agricultura	IDRC
Juan Gómez	Panamá	Universidad de Panamá	IDRC
Alvaro Alvarez	Colombia	Universidad Nacional	CIAT
Luis F. Ramos	Colombia	Universidad Nacional	CIAT
Jairo A. Venegas	Colombia	Caja Agraria	Government of West Germany
Nilton C. Ataide	Brazil	ACAR	ACAR
Luis Pablo Boutier	Bolivia	Comité de Obras Públicas	IDRC
Antonio Gonzales	Bolivia	Comité de Obras Públicas	IDRC
Blas V. Oddone	Paraguay	Ministerio Agricultura	IDRC
Andrés Gonzales	Paraguay	Ministerio Agricultura	IDRC
Blas Aguilera	Paraguay	Ministerio Agricultura	AID
Carlos Florentín	Paraguay	Ministerio Agricultura	AID

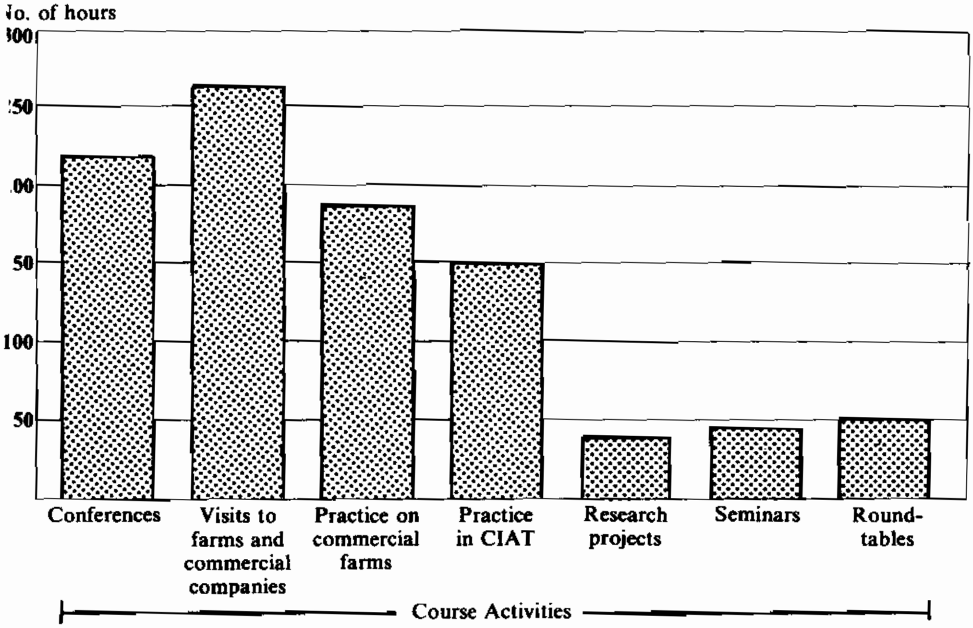


Figure 1. **Distribution of programmed activities in the First Postgraduate Course in Swine Production.**

Figure 2. **A group of trainees studies management of hogs on pasture in CIAT's Swine Unit.**

month study trip was organized to tour pig farms and experimental stations in order to evaluate various systems of swine production on the basis of existing resources in different ecological situations in Colombia.

During the last month of training, all the trainees were paired and each pair of trainees remained on commercial pig farms to work directly in routine activities. Under the continuous supervision of instructors, trainees analyzed farm problems and solutions to help orient producers toward modern systems of swine production.

In an evaluation at the end of the six-month course, trainees indicated great satisfaction in their achievements. A 100-point scale measured their general level of satisfaction according to the level of expectations realized during each two-week period. Figure 3 shows the

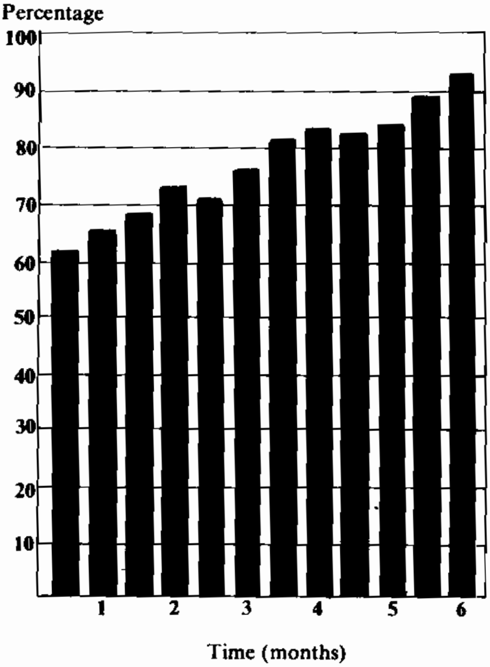


Figure 3. **General satisfaction level of trainees participating in the First Postgraduate Course in Swine Production.**

progressive increase in general level of satisfaction with the course.

The principal positive factors mentioned by trainees were:

- The human relations between the trainees and CIAT personnel directing the course
- The surpassing of trainees' goals
- Ability of the instructors
- High level of knowledge attained
- Availability of the specialists responsible for the course

In Table 2 complementary information is presented on some points judged by the trainees as the most positive aspects of the training program. High value was assigned to the applicability of knowledge acquired indicating a good program balance. The practical focus of the training also received high marks.

Finally, all trainees considered that their participation in the course gave them training equivalent to 1-3 years of professional experience.

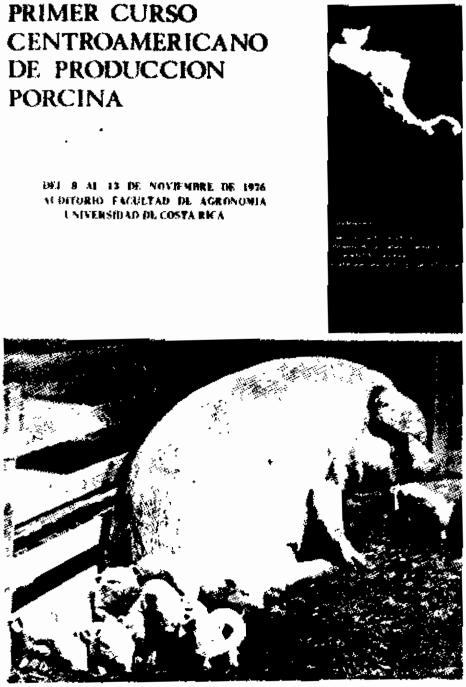
First Central American Seminar on Swine Production

The first Central American Seminar on Swine Production took place November 8-13, 1976 in San José, Costa Rica (Figure 4). The seminar was coordinated by the Universidad de Costa Rica, Ministerio de Agricultura y Ganadería, Banco Central de Costa Rica and CIAT. It was financed by the Banco Central de Costa Rica and the Inter-American Development Bank (BID). Approximately 120 persons participated in the seminar; most were professionals from Central American institutions working on swine production and development.

Table 2. **Satisfaction ranking about several important aspects of the First Postgraduate Course in Swine Prodution, as rated by the participants.**[1]

Aspects analyzed	Percentage
Degree to which expectations were attained:	
For the most part	61
Totally	39
Little or none	0
Degree to which the course will be applicable to future work in the country:	
To a high degree	89
To a medium degree	11
Little or none	0
Equivalency of the course training in relation to professional experience:	
About three years	25
About two years	47
About one year	25
Less than one year	0
Time dedicated to conferences and practices in CIAT:	
Adequate	65
Excessive	23
Short	12
Very short	0
Time spent on farms:	
Adequate	56
Excessive	0
Short	39
Very short	5
Time devoted of study travel through Colombia:	
Adequate	89
Excessive	11
Short	0
Very short	0

[1] Average figures from surveys completed by 19 trainees.



PRIMER CURSO
CENTROAMERICANO
DE PRODUCCION
PORCINA

DEL 8 AL 13 DE NOVIEMBRE DE 1976
AUDITORIO FACULTAD DE AGRONOMIA
UNIVERSIDAD DE COSTA RICA

Figure 4. Announcement for the First Central American Course of Swine Production.

During the conferences, CIAT swine specialists presented information on nutrition, feeding programs, production and management. Other lecturers from Chile, Colombia, Nicaragua and Costa Rica analyzed aspects of planning, economics, breeding and swine health.

Due to the interest and support for this first seminar, special priority will be given to developing future seminars which are useful for expanding the training programs offered at CIAT and maintaining close ties between former trainees and professionals of swine production programs in Latin America.

INTERNATIONAL COOPERATION

Bolivia

The Gabriel René Moreno-CIAT-Heifer Cooperative Project initiated, on schedule, the research, training and swine development activities in Santa Cruz. A breeding herd of 45 purebred females and 15 males from Duroc, Yorkshire and Hampshire breeds were imported from the United States through the Heifer Project. In 1976, two farrowings were obtained from the foundation herd with high reproductive efficiency. Some 130 purebred gilts and 70 boars of different breeds have been distributed as part of the development program for pig farmers in the region.

At present, the Cooperative Project has 210 pigs available for development and research. Experiments have been initiated to evaluate some local products as feed sources for pigs, such as cottonseed meal, rice meal and sugar cane by-products. Five short (one-week) training courses, in which 121 persons have participated, have been offered to swine producers in the region.

The Swine Project of Monteagudo at Chuquisaca, coordinated by the Comité de Obras Públicas and BID, increased its information interchange and cooperation with CIAT. Two professionals who participated in the Monteagudo program completed the Postgraduate Course in Swine Production at CIAT in 1976.

Perú

The construction of facilities for the Swine Unit of the Instituto Veterinario de

Investigaciones Tropicales y de Altura (IVITA), in Pucallpa, was finished early in 1976 with technical assistance provided by the Swine Program at CIAT and an IVITA specialist who had previously participated in the swine training course. Foundation breeding stock was also acquired permitting the initiation of research and swine development on a regional level. Presently, a professional from the IVITA Cassava program is participating in training efforts, as a point of departure for developing an integrated program of production and utilization of cassava in animal feeding adaptable to the Amazon basin in Perú.

Costa Rica

Initial construction plans for the Cooperative Project of the Universidad de Costa Rica-CIAT were modified to broaden the activities of the project due to increased financing and support on the part of the university, AID and other national institutions (Ministerio de Gobierno y Ministerio de Agricultura). Construction has not yet been initiated due to legal requirements necessary for the final approval of the project, but will begin in early 1977.

The project site is located one hour from the University of Costa Rica, with good routes of communication and adequate water and electricity. Local feed resources (rice and sugar cane by-products) are available for swine feeding. The favorable location will provide thorough integration with the teaching plans of the university and greater support to the research work. Training courses for pig farmers in various regions of the country have already been organized in cooperation with the Ministerio de Agricultura.

Colombia

In collaboration with ICA, Caja de Crédito Agrario and the Rural Development Project, a Swine Production Project for small pig farmers was initiated in La Victoria (Valle del Cauca) with permanent logistic support. Preparation of feed concentrates, daily supervision and training for swine producers is offered with periodic assistance by ICA and CIAT swine specialists. Ten small producers

Figure 5. View of the growing and finishing houses in the swine unit of the Gabriel René Moreno-CIAT-Heifer Cooperative Project in Bolivia.

were selected for group financing from the Caja de Crédito Agrario. Small swine units were constructed with locally available materials, including bamboo, wood, and straw. At the same time, a feed program was designed based on the local products which are mixed under the technical control of the ICA and CIAT Swine Programs.

The initial project focused on the production of fattening and finishing pigs but later it was decided to implement swine reproduction as an integrated and self-sufficient program. During the first year, a monthly net profit of 7.3 percent (Table 3) was obtained providing some additional income to the farmers using simple production techniques. The value of feed (50%) and the initial cost of the pigs (34%) represent the largest production costs since as little investment as possible was spent on building the units and on other nonfeeding resources. By using low-cost materials, the value of the construction mortgage and equipment was only 1.6 percent of the total production costs. The participation of the whole family was encouraged in all aspects of swine management, preparation of diets, acquisition of raw materials, bookkeeping, preventive sanitation, marketing and commercialization.

Table 3. Economic study for the establishment of a family swine unit.[1]

Items		Value (Col. $)
Expenses:		
Animals		8,016
Feed		11,905
Labor[2]		1,242
Electricity		450
Drugs and other expenses		110
Interest, insurance		1,734
Amortization of construction and equipment[3]		392
Total		23,849
Income:		
Sale of hogs		29,197
Net profit:	**Total**	**Monthly**
Colombian pesos	5,348	1,783
Percent	22	7.3

[1] Each owner received financing for his herd of 10 hogs in each cycle (92 days)
Two cycles are programmed per year. Average results are presented for one cycle

[2] Labor was calculated on the basis of two hours daily in the unit

[3] Construction and equipment are completely amortized in six cycles.

The project has also served as an excellent training ground for those persons with a special interest in swine production at the small production level.

Other Countries

Training in production, and swine health was offered to professionals from the following national institutions: Banco Nacional de Crédito Rural and the Universidad Autónoma de México, Instituto de Ciencia y Tecnología Agrícola de Guatemala (ICTA), Banco Nacional de Fomento de Honduras, Banco Nacional and Universidad Centroamericana de Nicaragua, Ministerio de Agricultura de Costa Rica, Universidad de Panamá, Caja de Crédito Agrario and Universidad Nacional de Colombia, Asociación de Crédito y Asistencia Rural del Amazonas (ACAR) de Brasil, Comité de Obras Públicas de Bolivia and Ministerio de Agricultura y Ganadería de Paraguay.

Evaluation of Energy Feedstuffs

During recent years the Swine Program has dedicated a large part of its activities to evaluating energy ingredients which are not conventionally used in great quantities, in order to completely replace cereal grains in swine diets. In selecting these energy feedstuffs, their potential crop importance for Latin America, and particularly for the tropical or subtropical regions, must be taken into account. Consequently, the swine feeding experiments have been restricted to nutritional evaluations of agro-industrial by-products such as rice meal or polishings and sugar cane molasses, in view of the importance of the rice and sugar cane crops in Latin America. Furthermore, the potential increase both in the area and yield of the cassava crop makes feasible the increased utilization of these roots for animal feeding, in general, and for swine, in particular

Experimental results from using these feedstuffs have been reported in previous Annual Reports. High levels of rice meal or polishings generally result in lower weight gains for growing and finishing pigs than those obtained with control diets based on yellow maize and soybean meal. However, experience gained with these experiments suggests that daily weight gains do not necessarily constitute the most adequate parameter for the integral evaluation of the feeding program. For this reason, experiments in 1976 were extended until the pigs reached slaughter weight of at least 90-95 kilograms.

A limiting factor of diets based on rice polishings for growing-finishing pigs has been the reduced consumption of the diets. This may be due to: (a) some physical aspects of the diets, such as consistency, density and palatability; (b) to nutritional aspects related to the reduction of energy in the diet as the levels of rice polishings are increased; (c) or to other factors previously mentioned such as supplementary protein quality (CIAT Annual Report, 1975). To study the additional aspects of energy reduction and palatability, an experiment was initiated utilizing diets based on 60 percent rice polishings with the addition of increasing levels of tallow (for high energy) and sugar cane molasses (to improve palatability). The treatments studied were: (a) a control diet based on yellow maize; (b) a diet based on 60 percent rice polishings and 4.5 percent tallow; (c) a diet based on 60 percent rice polishings, 6.5 percent tallow and 10 percent molasses; and, (d) diet based on 55-60 percent rice polishings, 7.5 percent tallow and 15 percent molasses. In all the diets soybean meal was used as the protein ingredient to balance the crude protein rations at 16 and 14 percent for growing and finishing periods, respectively.

The results of these experiments are shown in Table 4. Animals fed diets based on rice polishings reached final weight one week later than the pigs on the control diet. Adding 4.5 percent tallow did not result in greater consumption of the diet but the higher levels of tallow(6.5 and 7.5%) and molasses (10.0 and 15.0%) produced increments in diet consumption resulting in greater weight gains.

Feed conversion (feed consumption/weight gain) is expressed in Table 4 and the quantities of the basic ingredients in the diet compositions which contribute to total weight gain are summarized in

Table 4. **Results during the growing-finishing period of utilizing molasses and tallow in swine rations based on rice polishings.**

		Diets		
	Control	Rice polishings		
Parameters	Maize	+4.5% tallow	+ 6.5% tallow +10.0% molasses	+ 7.5% tallow +15.0% molasses
No. of days on trial	119	126	126	126
No. of pigs/group	5	7	8	8
Average live weight:				
Initial (kg)	18.1	17.6	17.8	17.6
Final (kg)	97.8	89.6	95.5	96.8
Total weight gain (kg)	79.9	71.6	77.7	79.2
Total diet consumed (kg)	256.6	210.9	246.3	262.7
Feed/gain	3.22	2.95	3.17	3.32

Table 5. The animals with the control diet required, on the average per pig, 206.7 and 37.9 kilograms of maize and soybean meal, respectively, to achieve a final body weight of 97.8 kilograms. Increasing the amounts of tallow and molasses in diets based on rice polishings resulted in progressive increases in total diet consumption per animal and in a reduction of the quantity of the maize required. Thus, the diet based on rice polishings with 7.5 percent tallow and 15 percent molasses required no maize; instead, 151.6, 19.7, 39.4 and 39.2 kilograms of polishings, tallow, molasses and soybean meal, respectively, were required per animal. The substitution of rice polishings, tallow and molasses was nutritionally satisfying but the price of

Table 5. **Total consumption of diets and basic ingredients during the growing-finishing period when utilizing molasses and tallow in swine rations based on rice polishings.**

		Diets		
	Control	Rice polishings		
Parameters	Maize	+4.5% tallow	+ 6.5% tallow +10.0% molasses	+ 7.5% tallow +15.0% molasses
Total diet consumed (kg)	256.6	210.9	246.3	262.7
Ingredients consumed (kg):				
Yellow maize	206.7	42.6	13.4	-
Rice polishings	-	126.5	147.8	151.6
Tallow	-	9.4	16.0	19.7
Molasses	-	-	24.7	39.4
Soybean meal	37.9	22.0	32.5	39.2
Minerals and vitamins	12.0	10.4	11.9	12.8

tallow tended to be expensive for practical use. However, the results suggest that molasses could be used in increasing amounts if acceptability or palatability of the diets based on rice polishings were the only problem.

The possibility of utilizing high levels of sugar cane molasses as a partial and progressive substitute for basic energy ingredients has the advantage of improving diet acceptability and consumption to produce rapid weight gains. Molasses improves the physical appearance of diets based on cassava meal by lessening its powdery appearance. To study various combinations of rice polishings and cassava meal with increasing levels of molasses, an experiment was undertaken with weaned pigs through the growing-finishing periods up to market weight (approximately 95 kilograms). In order to facilitate feed management and to avoid making periodic adjustments with each increase of molasses, two basal diets were prepared containing 18 percent crude protein and based on either rice polishings with soybean meal, or cassava meal with soybean meal. The compositions of these diets and the control diet based on common maize are presented in Table 6. Since weanling pigs are more sensitive to drastic diet changes, the periods requiring 5 percent increments of molasses were longer during the initial part as compared to the final weeks of the experimental period. Based on this program the protein content was progressively reduced from 18 to 12 percent throughout the growing-finishing period and levels of molasses were increased from 5 to 35 percent of the total diet.

The pigs fed a diet based on cassava meal and increasing levels of molasses reached final liveweight one week before the control group, and those fed a diet based on rice polishings and molasses reached final liveweight one week later than the control (Table 7). The addition of molasses resulted in increased consumption of the experimental diets as compared to the control. Consumption data of the principal ingredients indicate that it is feasible to efficiently use rice polishings as well as cassava meal with increasing levels of

Table 6. **Percentage composition of experimental diets utilizing rice polishings and cassava meal for swine during the growing-finishing period.**

Ingredients	Common maize		Rice polishings[1]	Cassava meal[1]
	Growing	Finishing		
Common maize	77.7	85.3	-	-
Rice polishings or cassava meal	-	-	77.6	59.5
Soybean meal	17.6	10.0	16.2	34.3
Bone meal	4.0	4.0	5.0	5.0
Commercial premix	0.2	0.2	0.3	0.3
Iodized salt	0.5	0.5	0.6	0.6
DL-methionine	-	-	0.3	0.3
Crude protein	16	13	18	18

[1] Cane molasses were added in increasing levels (5-35%) to the basal diets.

Table 7. **Results of utilizing rice polishings and cassava meal with increasing levels of molasses in swine diets during the growing-finishing period.**

	Diets		
	Control		
Parameter	Maize	Rice polishings + molasses	Cassava meal + molasses
No. of experimental days	119	126	112
No. of pigs/group	8	8	7
Total gain/animal (kg) [1]	76.4	77.6	80.7
Total consumed/animal (kg)			
Diets	227.8	251.6	264.7
Maize, rice polishings or cassava meal	188.6	151.8	120.5
Molasses	-	56.0	62.1
Soybean meal	28.4	31.7	69.5
Feed/gain	2.98	3.24	3.28

[1] Average initial and final weights for the three groups: 17.3 and 93.7 kilograms; 17.3 and 94.9 kilograms; and, 16.9 and 97.6 kilograms, respectively.

molasses. A notable difference in the consumption of the basic ingredients is the elevated quantity of soybean meal required in the diets based on cassava meal owing to the limited amount of protein in cassava as compared to maize or rice polishings.

In an attempt to economically evaluate the swine feed systems, the Swine Nutrition Unit collaborated with the Biometrics Unit to analyze experimental data obtained using common maize, opaque-2 maize and cassava meal in different periods of the swine life cycle. These calculations suggest that the relative prices of maize/cassava meal must be equal or greater that 2/1 in order for cassava meal to be economically feasible. In addition, the use of cassava meal in swine diets depends not only on the relationship of its price to the energy ingredients it replaces but also on the prices of the protein ingredients.

Microbial Protein Production

Prior reports (CIAT Annual Reports, 1974 and 1975) have demonstrated the need to provide a greater quantity of feed or protein ingredients necessary to adequately balance diets based on cassava meal or fresh cassava. High quality animal protein sources such as fish meal have limited use because of high prices. Soybean meal also constitutes a possible protein source. However, the growing interest in soybean meal for human consumption would limit its availability as animal feed. The by-products of other oilseed crops like cottonseed meal have certain restrictions which limit their use in the large quantities required for diets based on cassava meal.

One future possibility is the production of microbial protein from starchy roots like cassava. To study this possibility, CIAT's Cassava and Swine Programs and the University of Guelph (Canada), with support from IDRC of Canada, have begun a cooperative project for producing microbial protein. Scientists from Guelph developed a laboratory scale model, selecting the microorganisms to be employed and designing the machinery required for a pilot plant. CIAT is responsible for installing and operating the pilot plant. Sufficient quantities of the final biomass will be produced to enable nutritional and toxicological evaluations with domestic animals, primarily swine, and the entire process will be economically evaluated.

The pilot plant for producing the microbial protein has been installed at CIAT (Fig. 6). It consists of two fermenters with capacities of 200 and 3,000 liters. A harvester for recovering the microbial biomass is expected to arrive from Guelph in early 1977. The 200-liter fermenter is now operating and the larger unit will begin functioning continuously when the harvester arrives.

The microbial protein process is graphically shown in Figure 7. After fresh cassava roots are thoroughly washed, they are mechanically shredded and placed in the fermenter which has been half-filled with water. The water temperature is raised to 65-70ºC to gelatinize the starch from the roots and accelerate the fermentation process by the microorganisms. More water is added to almost fill the fermenter; this reduces the temperature of the medium to 45ºC and dilutes the carbohydrate concentration to about 4 percent. After stabilizing the temperature at 45ºC, sulfuric acid is added to reduce the pH to 3.5 and urea and potassium phosphate are added to supply nitrogen and phosphorus, respectively. Other minerals required for the process are supplied by the cassava.

The microorganism selected at the University of Guelph and currently used in the pilot plant is the *Aspergillus fumigatus* I-21A. This fungus is an asporogeneous mutant, thus practically eliminating the problem of aspergillosis (invasion of spores in the respiratory tract). The selective conditions of the medium (45ºC and pH 3.5) for optimum development of this fungus prevents contamination with bacteria and yeasts, reducing the necessity of asepsis. The filamentous nature of the

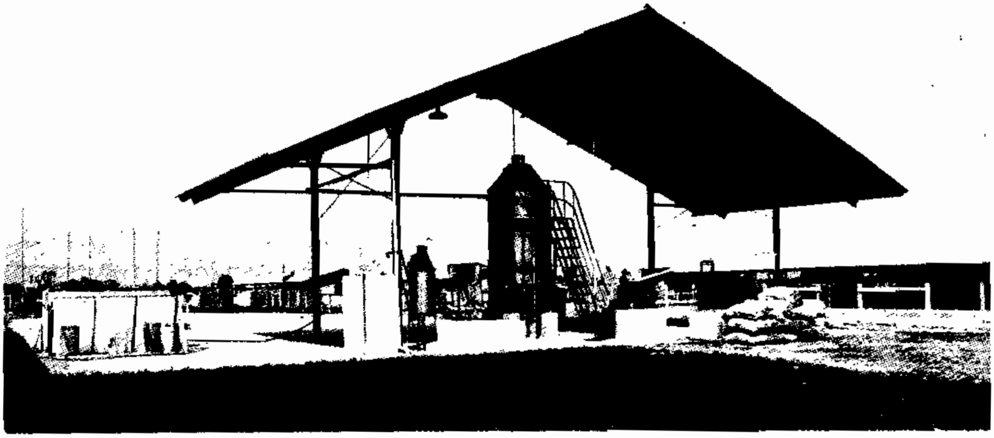


Figure 6. View of the pilot plant in the CIAT Swine Unit for producing microbial protein utilizing cassava roots as the energy substrate.

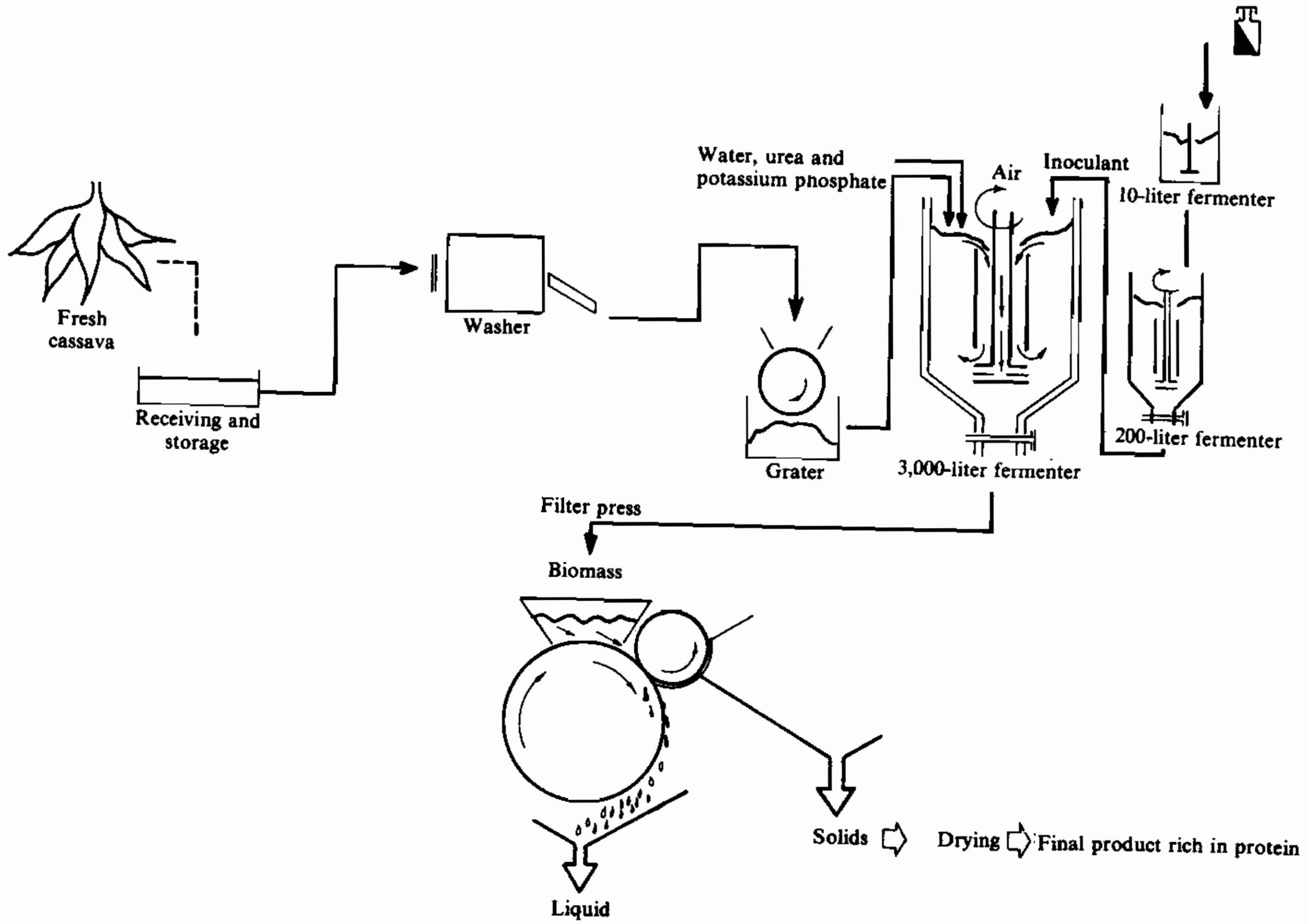


Figure 7. **Diagram of the process for producing microbial protein by the fermentation of cassava roots.**

fungus does not require centrifuging at high speeds for its recovery. Instead, a press and filter system for partially extracting the water is used to hasten the drying of the final biomass. These and other characteristics of the process and of the microorganism permit optimism for the practical application of the process.

Table 8 summarizes preliminary data from 10 fermentations in the 200-liter fermenter using fresh cassava roots. The final biomass obtained at this scale contained about 29 percent crude protein compared with 35 percent obtained in laboratory tests at Guelph. The conversion efficiency of fresh cassava or of its dry matter equivalent to the final sun-dried biomass is about 17 percent, expressed in terms of fresh root weight, and 48 percent, in terms of the dry matter content of cassava. In each of the 10 fermentations an average of 25.3 kilograms of fresh cassava was used; this amount produced an average 4.3 kilograms of final sun-dried biomass. The nutritive value of the sun-dried biomass fed to growing rats has given a protein efficiency ratio (weight gain/protein consumed) of 1.8 compared with 2.5 for casein. These results are now being verified under more standardized conditions.

Table 8. Average results from the production of microbial protein (using *Aspergillus fumigatus* I-21A) with cassava roots in the pilot plant at CIAT[1]

Parameters	Values
Quantity of fresh cassava (kg)	25.3
Quantity of final sun-dried biomass (kg)	4.3
Percentage weight yield of biomass in relation to:	
Fresh cassava	16.9
Cassava dry matter	48.5
Crude protein in final biomass (%)	28.6
Comparative nutritive value of biomass in rat feeding:[2]	
PER of casein	2.5
PER of dry biomass, without methionine	1.8

[1] Averages of 10 fermentations in the 200- liter fermentor.

[2] Protein efficiency ratio (PER); average from 10 growing rats fed for 28 days.

PUBLICATIONS

GOMEZ, G., CAMACHO, C. and MANER, J.H. Utilización de yuca y harina de yuca en alimentación.

Paper presented at Seminario Internacional de Ganadería Tropical. Acapulco, México, 8-12 March 1976.

GOMEZ, G., CAMACHO, C. and MANER, J.H. Utilization of diets based on yuca meal, without supplemented methionine, during the life cycle of swine.

Paper presented at IV International Symposium on Tropical Root Crops. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 2-7 August 1976.

GREGORY, K.F., MEIERING, A.G., AZI, F.A., SEDGWICK, J.A.D., CUNNINGHAM, J.D., MacLEAN, S.J., SANTOS, J. and GOMEZ, G. Establishment of a pilot plant for the production of fungal protein from cassava.

Paper presented at IV International Symposium on Tropical Roots Crops. Centro International de Agricultura Tropical (CIAT), Cali, Colombia, 2-7 August 1976.

Regional andean maize unit

SUMMARY OF ACTIVITIES IN 1976

During 1976 the Maize Program at CIAT evolved into the planned collaborative effort between CIAT and the Centro Internacional de Mejoramiento de Maize y Trigo (CIMMYT), in Mexico. This new program has been designated as the CIMMYT-CIAT Regional Andean Maize Unit. During the year, work at CIAT on maize breeding has been reduced while international cooperation activities and crop promotion have been increased, consistent with the objectives of the unit. Specifically, activities of the unit during 1976 may be summarized as follows.

Work at CIAT included three categories of trials for maizes: (a) experiments with materials originating at CIMMYT; (b) experiments with material from CIAT; and, (c) Andean Zone regional trials.

In addition, selection of materials for poorly drained areas continued as did the observation, selection and breeding of materials with reduced plant height and materials carrying the opaque-2 gene and having vitreous endosperm.

Some seed was multiplied for distribution and testing in the Andean Zone national programs.

During the latter half of 1976, much effort was directed to organizing the CIMMYT-CIAT cooperative project in maize. Activities included visits to countries in the region for purposes of planning future cooperative work and to observe progress of trials. Assistance was given to a region-wide maize scientists meeting in Ecuador.

Five professionals from the Andean Zone were sent to CIMMYT for training. Plans were developed for short, extension-type courses to be conducted early in 1977 in Bolivia.

ACTIVITIES AT CIAT

Yield Trials

Trials with CIMMYT materials

In the second semester of 1976 four trials called the International Progeny Testing Trials (IPTT) were planted at CIAT. These included IPTT-23, for white crystalline maizes; IPTT-27, for yellow crystalline materials; IPTT-31, for brachytics; and IPTT-42, for ETO x Illinois materials. Each of the trials was seeded in a simple 16 x 16 lattice design with 256 entries and two replications. On the basis of the results obtained, the technical personnel of CIMMYT will produce an experimental variety from each of the four IPTT trials, recombining the ten best families.

Three Experimental Variety Trials (EVT) from CIMMYT were also planted. Two consisted of normal maize (EVT-14B and EVT-16) and one had opaque materials (EVT-15). These trials include experimental varieties developed by CIMMYT on the basis of results obtained in the IPTT trials on an international scale. The most promising varieties will then be placed with the national maize programs in the Andean Zone.

Trials with CIAT materials

The CIAT Maize Program has emphasized the incorporation of the brachytic-2 gene in many experimental materials. The action of this gene is manifested in a shortening of the stem internodes, resulting in short plants which are more resistant to lodging. However, this gene also produces some undesirable characteristics such as lack of uniformity of plant height and excessively wide leaves. This last condition can reduce yield since the wide leaves cover the female inflorescence which results in deficient pollination. These problems may be eliminated or reduced through selection and recombination.

In the first semester of 1976, brachytic materials developed at CIAT were seeded to determine their utility and to make the best families available to national programs in the Andean Zone. Results obtained indicate there are promising materials of high yield and short plant type which could be useful for the Andean Zone (Table 1).

Regional trials

The Tropical Andean Zone Trials are part of a regional project whose objective is to promote germplasm interchange among the Andean countries. The material included is a sample of the best tropical varieties from the national breeding programs throughout the region.

In the first quarter of 1976, two Tropical Andean Zone Trials were seeded at CIAT. The materials tested included three varieties from Bolivia, and six each from Ecuador, Peru, Venezuela and Colombia. Control materials from CIAT and CIMMYT were also planted.

The results (Table 2) indicate that the varieties with the highest yields were Simeto, from Venezuela (10.0 t/ha); La Posta, from CIAT (11.5 t/ha); and Mezcla Tropical Blanco, from CIMMYT (10.44 t/ha). All are tall plant types (300, 290 and 300 centimeters, respectively). However, the existing genetic variation within these varieties makes them useful as basic material in the different breeding programs in the Andean Zone.

Regional trials designated as Highland Andean Zone Trials have been planted but results are not available yet.

Table 1. **Summary of results from three yield trials of brachytic materials developed at CIAT.**

			Yield (kg/ha, 15% moist.)		Plant height (cm)		Days until 50% of female flowers	
Trial	Material	Origin	Avg. of population	Avg. of selected families	Avg. of population	Avg. of selected families	Avg. of population	Avg. of selected families
C76 A-3[1]	Br2 whites and yellows, full sibs.	C75 B-3	7,944	8,793	202	198	64.5	65
C76 A-5[2]	Br2 yellows, half sibs.	C75 B-4	6,931	7,852	218	208	65	64.4
C76 A-6[3]	Br2 whites and yellows, half sibs.	C75 B-2	6,958	8,280	206	192	64	64

[1] Best test material: PAL 7435 — 9,597 kg/ha, 245 cm high, 62 days to flowering

[2] Best test material: ICA H256 — 7,464 kg/ha, 170 cm high, 63 days to flowering

[3] Best test material: ICA 7431 — 10,397 kg/ha, 200 cm high, 66 days to flowering.

Special Projects

Selection of materials for poorly drained areas

This project, which was initiated in 1974, was continued. Selection of the variety La Posta was made in a poorly drained plot at CIAT, taking into account: plant height, ear size, ear rot, and early maturity of the plant. Some 147 ears were selected and seeded in the second quarter of 1976 on a plot with half-sibs in order to continue the selection process for materials resistant to poor soil drainage conditions..

Table 2. **Highest yielding varieties in Tropical Andean Zone Trials at CIAT, 1976.**

		Yield (kg/ha)	
Country or place or origin	Variety	January seeding	March seeding
Colombia	H-302	6,714	—
	H-154	—	8,090
Venezuela	Var. Simeto	6,988	10,000
Peru	PMC-747	6,585	9,215
CIAT	P.B. Blanco	7,744	—
	La Posta	—	11,149
Ecuador	Var. 13	6,975	—
	Var. 2	—	8,396
Bolivia	Sint. 10 Lin. PD. (MS-6)	6,532	—
CIMMYT	PD. (MS-6)	5,004	—
	Mezcla Trop. Bl.	—	10,439

Observation and breeding of short-statured materials

It has been observed that short statured materials (plantas bajas) developed by CIMMYT, when they are planted in the Valle del Cauca of Colombia behave differently, growing 50-100 centimeters higher than in their place of origin. This phenomenon also occurs in other parts of the world, so that the selection done at CIAT of material generated by CIMMYT, would help to develop materials with plant height stability. In the second semester of 1976, a plot with crosses from 212 families of the variety Tuxpeño Planta Baja was planted. Short families were selected at flowering time and crossed among themselves in order to recombine characters. A 50 percent selection pressure will be used. The resulting seed will be sent to CIMMYT for the next cycle of selection and new families generated at CIMMYT will be planted again at CIAT. The procedure will continue until plant height is stabilized.

Selection and breeding of materials with the opaque-2 gene and crystalline endosperm

The experimental variety VE-21 from the Instituto Colombiano Agropecuario (ICA), selected by the ICA-CIAT Cooperative Project from the opaque CIMMYT variety Veracruz 181 x Antigua Gr 2 x Venezuela 1-0 , has various undesirable characteristics. The most important is excessive height, and therefore, susceptibility to lodging. In order to correct this, ears were selected from a seed multiplication plot planted at CIAT. Short plants without evidence of lodging were selected. A sample of each ear was analyzed to determine the quantity and quality of protein and the best families on a plot of half-sibs were seeded again to continue the breeding process.

Increase in seed availability

In order to fill the frequent requests from breeding programs in the Andean Zone, various seed multiplication plots have been established with seed from promising varieties.

REGIONAL ACTIVITIES

CIMMYT-CIAT Cooperative Project

The CIMMYT-CIAT Cooperative Projects was initiated in May, 1976 with a team of two CIMMYT specialists in maize. This team is dedicated to reinforcing national maize programs in the Andean Zone, operating from a headquarters at CIAT.

The principal responsibilities of the CIMMYT-CIAT maize team are; (a) to assist the national programs in their problems of production, research and transfer of technology for maize cultivation; (b) to promote trials of maize varieties on a regional level (from materials generated by the national programs) and international level (with materials from CIMMYT) and to analyze the results obtained; (c) to collaborate in organizing a workshop for maize specialists in the Andean Zone, every two years; (d) to identify candidates for future training in production and breeding of maize in CIMMYT or CIAT; (e) to promote the interchange of genetic material among the national programs in the Andean Zone and between these, and CIMMYT and CIAT; (f) to stimulate cooperation between different countries, taking the steps necessary for scientists from one country to assist those of its neighbors; (g) to promote training in production at a national and international level for specialists in technology transference; (h) to produce an annual report on maize breeding in the Andean Zone, taking into consideration the specific necessities of the different countries in the zone.

In order for the CIMMYT-CIAT team to carry out its coordinating function between the two centers and the national programs in the Andean Zone, the team must orient its activities toward close collaboration with the maize specialists and the governments in the zone through frequent visits to the different countries to promote the interchange of ideas, materials, techniques and identification of training needs of the technicians at different levels (trainees, masters' and doctoral candidates). Therefore, the CIMMYT—CIAT team will have to reduce research on maize at CIAT and further increase visits to national programs.

The regional activities of the CIMMYT-CIAT team from May through the end of 1976, have been developed by one person with the other team member to arrive in January, 1977.

Activities for 1976 included the following.

Consultation was provided during the revision of breeding and production programs in Ecuador and Bolivia. In Peru, the staff from the Programa Cooperativo de Investigaciones en Maíz designed an integral development project for the jungle zone in the departments of Junín and Pasco. Trials of progenies and experimental varieties were visited in Bolivia, Perú, Ecuador and Colombia, however, it was not possible to establish such trials in Venezuela due to climatological conditions.

Table 3. **Regional maize trials distributed in the Andean Zone in 1976.**

Country	No. of Tropical Andean Zone Trials	No. of Highland Andean Zone Trials
Bolivia	1	2
Brazil	3	—
Colombia	2	3
Ecuador	2	2
Peru	4	2
Venezuela	2	—
	14	9

Tropical varieties from national programs were promoted in the Andean Zone Regional Trials; these trials were designed with the leaders of the breeding programs of the different countries. The trials included open-pollinated varieties and hybrids with an open pedigree. It was requested that the materials from the national programs be of open pedigree since the purpose of these trials is the exchange of materials among countries. In 1976, 14 trials for the Tropical Andean Zone Trials and nine Highland Andean Zone Trials were sent (Table 3). By the end of the year, six trials had already been planted.

Meeting of Maize Producers in the Andean Zone

Technicians of Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador cooperated in the organization and financing of the seventh meeting of maize producers in the Andean Zone, in Guayaquil, Ecuador during October 18-23. Of 64 participants from seven countries, 40 made presentations. On the last day of the meeting, participants visited the experimental plots established at the Pichilingue Experimental Station of INIAP. It was also decided to: (a) organize the next meeting in Lima, Peru in 1978; (b) procure studies presented at this meeting which were of regional relevance, excluding those with a strictly local focus; (c) to establish norms for the elaboration and presentation of the studies; (d) to establish uniform trials for highland zone varieties in order to find sources of resistance to the corn ear worm *Helicoverpa zea* (this trial is to be planted in Ecuador, Bolivia, Perú and Colombia); and, (e) to continue for another year both the Tropical and Highland Andean Regional Trials.

TRAINING ACTIVITIES

An important part of the activities of the CIMMYT-CIAT team is the promotion of training at all levels. The CIMMYT-CIAT team is committed to promote training for as many maize specialists as possible. Four professionals from the Andean Zone, (two Ecuadorians, one Peruvian, and one Venezuelan) have been sent to CIMMYT for training in breeding and production.

Also one Peruvian staff member was invited to CIMMYT as a visiting scientist to become familiar with studies being carried out at this international center.

In order to oversee the collaboration of specialists from one country in the training course of neighboring countries, an agreement was reached with the recently formed Instituto Boliviano de Tecnología Agropecuaria (IBTA) to collaborate in organizing a short extension training course on maize production. This course will be carried out in Santa Cruz, Bolivia during the last half of February 1977. 1977.

CICA 9

Rice improvement program

HIGHLIGHTS IN 1976

In 1976, the evaluation of six promising rice lines was completed. Basic seed of lines 4421 and 4461 was multiplied and later these lines were named as varieties CICA 7, and CICA 9 respectively. Another promising line (4440) was selected for multiplication of basic seed and for possible designation as a variety in 1978.

Seed of CICA 7 and CICA 9, and of other lines, was distributed to national programs in several Latin American countries. As a result of this international collaboration, line 4444 — a sister line to 4440 — was named INIAP 7 by the National Program of Ecuador. Also, line 4422 — a sister line of CICA 9 — was named Tikal 2 by the Instituto de Ciencia y Tecnología Agrícolas (ICTA), in Guatemala.

Progeny selection continued to be directed to forming new varieties with multiple resistance to rice blast disease. Resistance is being provided by the Tetep, Dissi Hatif, C46-15, Colombia 1 and Carreón. From 587 multiple crosses produced in 1975, some 24,000 F_2 plants were selected during 1976 for resistance to rice blast and for other desirable characteristics. These materials were evaluated in the laboratory for grain quality and in infection beds for their resistance to the blast. Part of the material evaluated was transplanted to the field to continue the selection process in advanced generations.

A second focus of the progeny selection process continued to be the incorporation of multiple resistance to blast through backcrossing to produce multi-line varieties. During 1976, individual F_1 combinations showing resistance to blast were recrossed two times with the lines 4414 and 4421 that serve as recurrent parents.

A Program of International Rice Trials for Latin America was initiated to accelerate the development, the evaluation and dissemination to farmers of a continuous flow of improved varieties with wide adaptation to diverse zones and systems of cultivation. To develop guidelines for the trials and to establish nurseries of lines and varieties, the first conference was convened in August 1976. Thirty-five delegates from 14 Latin American countries attended the meeting. It was agreed that the nurseries should be formed with materials especially adapted to Latin America, taking into account the grain type, and the milling and cooking quality of the rice.

Three nurseries were established: a yield nursery, a rice blast nursery and an observational nursery. Some countries asked that other nurseries be formed for specific cases of acid or saline soils, and for low temperature and deep water conditions; these may be developed later as general needs arise. The yield nursery was formed with 24 varieties nominated by delegates from 11 countries. In November 1976, 28 sets of this nursery were sent to national programs in 18 Latin American countries.

Since September 1976, the problem of a foliar burning on rice has been studied in Panama and Colombia. Preliminary results from pathogenetic studies indicate that the symptoms correspond to those of the bacterial blight of rice, caused by *Xanthomonas oryzae*.

In close collaboration with the Training and Conferences Program at CIAT, training has been provided in rice production and improvement for seven professionals (two each from Honduras and Perú, and one each from Colombia, Brazil and Guyana). These trainees participated in producing basic and certified seed of CICA 7 and CICA 9, conducted transplanting trials for the control of volunteer rice and estimated grain losses during harvesting trials.

Engineering studies on water control continued during 1976. Water losses in dikes and reservoirs were calculated in order to design an appropriate water supply model for irrigated rice.

Testing of a pump that can be easily manufactured and installed was continued. The unit has a pumping capacity of one cubic meter per second. Information was developed from pumping trials when the water level varied between 75 and 200 centimeters. In 1977, designs of a more economical pump for use in irrigated rice crops will be made available by CIAT.

An econometric model was developed based on studies of the economics of rice production and demand in Colombia. From this model, it was estimated that low-income consumers, for the most part, have received the major benefits from farmers planting of the new high-yielding rice varieties: rice prices were maintained at levels much lower than they would have been in the absence of the higher-yielding varieties.

Latin American countries, with the exception of Brazil, have adopted the semi-dwarf rice varieties with high production capacity in about 40 percent of their areas, especially in the irrigated areas and in upland rain-fed zones where mechanization is possible. In other rice areas, the new varieties have not been adopted, possibly due to unfavorable environmental conditions including long droughts, deep waters, low temperatures, serious insects, diseases or soil problems. Other reasons may be due to consumer preferences for a specific type of grain or simply lack of greater collaboration between the international agricultural research centers and national programs.

INTERNATIONAL COLLABORATION

The fundamental objective of the CIAT Rice Program is to increase national yields per unit area in Latin American countries. Since 1968, a broad spectrum of activities has been oriented to improving production. These include identifying factors limiting yields, collaborating with rice technicians from national institutions, training of specialists in research and production, and cooperation in establishing international trials of improved lines and varieties. Collaboration has been particularly close among the Central American countries, Colombia and Ecuador. On a lesser scale, CIAT cooperated with technicians from Brazil, Venezuela, the Dominican Republic, Jamaica, Perú and Paraguay.

In Colombia, results from the CIAT-ICA cooperative rice program have contributed to the increased national production of paddy rice to 1,622,230 tons in 1975 and exports of 166,000 tons; previously Colombia exported very little rice. It is considered that 80 percent of this production is due to the new high yielding varieties. This fact indicates the great potential to transfer the technology generated in Colombia to similar rice areas in Latin America.

International Rice Testing Program

In 1975, the International Rice Research Institute (IRRI) initiated an International Rice Testing Program in several countries. Coordination with national programs has been done by IRRI and other international centers.

This year, the International Rice Testing Program for Latin America was begun because the consumer needs, production systems and other factors are different in Latin America compared to other parts of the world. This program is sponsored by IRRI and CIAT and responsibility for coordination with national institutions rests with CIAT. Basically, the program evaluates and distributes for subsequent use, the best varieties of rice obtained in other countries based on the environmental conditions of each country. Thus, development, evaluation and availability of improved varieties will be accelerated and farmers will receive a continuous flow of new materials that have good adaptation to diverse rice areas and different cultivation systems.

Establishment of International Nurseries

The first of a series of conferences was organized at CIAT in August 1976 to define the purposes of the International Rice Testing Program for Latin America and to establish the methods of coordinating and setting up nurseries for lines and varieties. Leaders of national rice programs in Latin America were invited to the conference; Table 1 shows the participating countries and the number of delegates from each. Delegates presented useful information on the amount of land under cultivation, the number of rice researchers, crop problems, and present and future levels of production (Tables 2 and 3). Figure 1 shows this data consolidated for each country.

Delegates to the conference agreed that all materials in the nurseries should have good grain type and milling and cooking qualities. It was decided to begin with three nurseries. One— an International Yield Nursery for Latin America (VIRAL)–was established with 24 varieties nominated by delegates from several countries. Twenty-eight sets of this nursery were distributed to national institutions late in 1976. Varieties in this trial and their source countries are shown in Table 4. Materials for the other two nurseries — an International Rice Blast Nursery for Latin America (VIPAL) and an International Observational Nursery for Latin America (VIOAL) — will be distributed in early 1977. If other objectives, needs or specific problems

Table 1. **Countries participating in the first conference of the International Rice Testing Program (IRTP) for Latin America, 1976.**

Country	No. of delegates
Brazil	6
Colombia	11
Costa Rica	2
Ecuador	1
El Salvador	1
Guatemala	1
Guyana	1
Honduras	2
México	1
Panamá	2
Perú	1
Dominican Republic	2
Surinam	2
Venezuela	2
United States	1*
Philippines (IRRI)	4*

* Program speakers

Table 2. **Area, production and yield of rice in Latin America, 1975[1]**

	Area (1,000 ha)		Production (1,000 ton)		Yield (t/ha)	
Country	Irrigated	Upland	Irrigated	Upland	Irrigated	Upland
Brazil	1,050.0	5,950.0	2,860.0	7,140.0	2.7	1.2
Colombia	285.0	95.5	1,471.1	151.1	5.1	1.6
Costa Rica	—	87.1	—	195.6	—	2.2
Ecuador	45.5	84.5	300.0	—	—	2.4[2]
El Salvador	—	11.1	—	32.1	—	2.9
Guatemala	—	31.0	—	45.5	—	1.5
Guyana	120.0	—	282.0	—	2.3	—
Honduras	—	15.0	—	19.2	—	1.3
Mexico	119.5	119.5	501.9	216.1	4.2	1.8
Panama	—	115.0	—	185.0	—	1.7
Peru	107.1	25.0	610.5	37.5	5.7	1.5
Dominican Republic	84.0	—	260.0	—	3.1	—
Surinam	29.0	—	173.0	—	3.7	—
Venezuela	65.0	105.0	292.0	262.5	4.5	2.5
Subtotal	1,905.1	6,638.7	6,750.5	8,284.6	3.5	1.3
Total	8,543.8		15,035.1			

[1] Figures supplied by delegates attending the first conference on the International Rice Testing Program for Latin America. Delegates did not attend from Argentina, Belize, Bolivia, Chile, Cuba, Nicaragua, Paraguay and Uruguay; however, these countries total about 280,000 hectares of rice.

[2] National average for irrigated and upland rice.

Table 3. **Potential new rice areas and number of rice scientists in Latin America[1]**

Country	Potential new area (1,000 ha)	No. of scientists
Brazil	20,000	44
Colombia	3,000	17
Costa Rica	30	4
Ecuador	200	8
El Salvador	5	12
Guatemala	50	11
Guyana	—	7
Honduras	100	6
Mexico	100	12
Panama	20	8
Peru	200	29
Dominican Republic	—	19
Surinam	—	3
Venezuela	360	6
Total	24,065	186

[1] Figures supplied by delegates attending the first conference on the International Rice Testing Program for Latin America.

arise, future nurseries could be established to evaluate materials for such conditions as high salinity, low temperatures or drought tolerance.

Evaluation and Multiplication of Seeds from International Nurseries

In mid-1976, eight international nurseries were received from IRRI: two yield nurseries (early and medium maturing varieties for irrigated conditions); two for upland conditions; one for rice blast; one for sheath blight (caused by *Thanatephorus cucumeris* or *Corticium sasakii*); one of deep water varieties; and, one for high soil salinity. These nurseries, with the exception of the deep water varieties, were planted at CIAT between July and November 1976 to evaluate the materials and multiply the seed of the

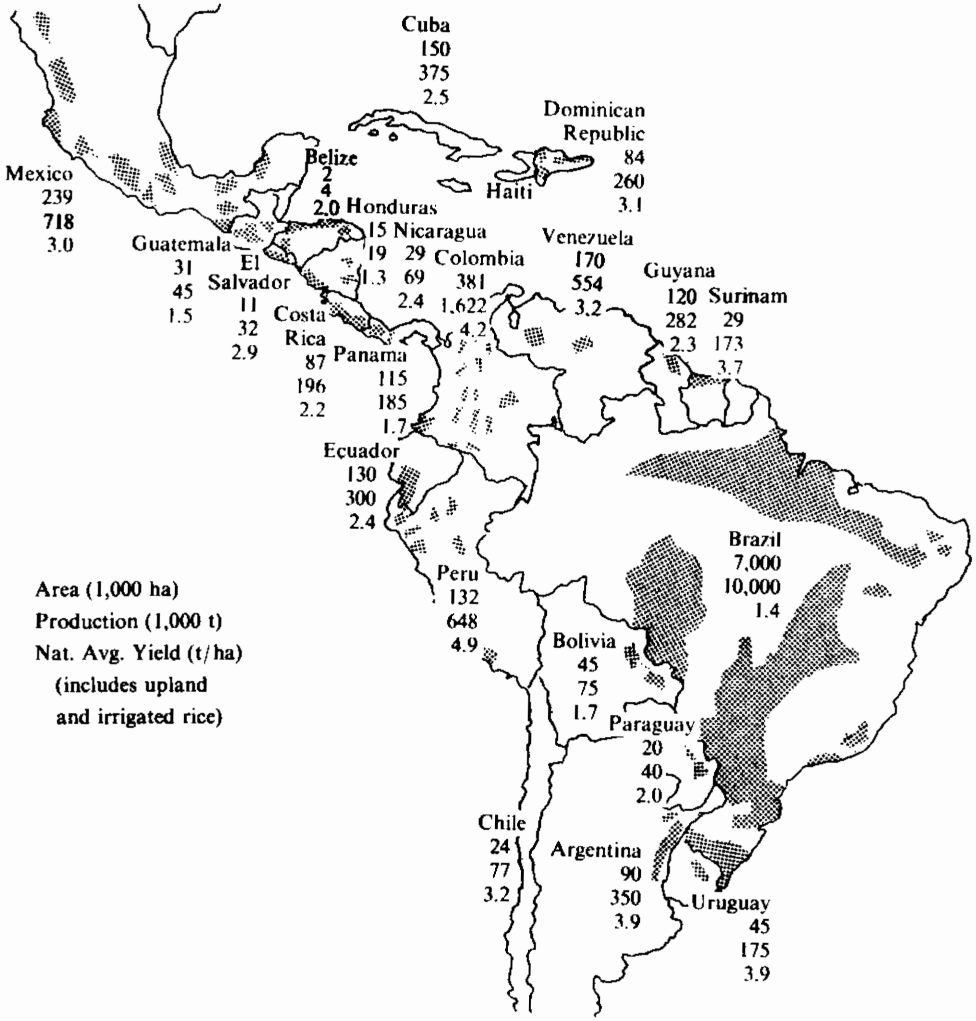


Figure 1. Distribution of rice-producing areas in Latin America.

superior performing varieties (Figures 1, 2 and 3). These superior materials will form the basis of the international nurseries that are to be distributed in Latin America in 1977. In June 1976, a demonstration nursery with 12 promising varieties was planted. Its purposes are seed multiplication and, at the same time, demonstration of varietal characteristics to trainees and CIAT visitors. All of this material was evaluated under laboratory conditions for the mechanical damage of the rice plant hopper, *Sogatodes oryzicola;* it was determined that many varieties are resistant to such damage.

The deep water rice nursery was planted in July at the ICA Experimental Station at Palmira and data are still being evaluated.

Table 4. **Rice varieties nominated for the first International Rice Yield Nursery in Latin America (VIRAL), 1976**

Line or variety	Nominating country
CICA 4	ICA-CIAT, Colombia
CICA 6	ICA-CIAT, Colombia
CICA 7	ICA-CIAT, Colombia
CICA 9	ICA-CIAT, Colombia
4440	ICA-CIAT, Colombia
4444	ICA-CIAT, Colombia
CR 1113	Costa Rica
118	INIAP, Ecuador
IR 2058-78-1-3-2-3	IRRI, Philippines
IR 2823-399	IRRI, Philippines
IR 2853-38	IRRI, Philippines
IR 1529-680-3	IRRI, Philippines
Tikal 2	Guatemala
N	Guyana
77916	Guyana
Macuspana 75	INIA, Mexico
Bamoa A 75	INIA, Mexico
Inti	PNA, Peru
Juma 57	Dominican Republic
Juma 58	Dominican Republic
Bg 90-2	Sri Lanka
Apani	Surinam
Camponi	Surinam
Ceysvoni	Surinam

Cooperation with National Rice Programs in Latin America

The CIAT Rice Program has collaborated with different national institutions on two fundamental activities — seed distribution and evaluation of promising lines.

Seed distribution

Seed of the new varieties CICA 7 and CICA 9 as well as of several promising lines was distributed to different national programs and to all national institutions in Latin America cooperating with the CIAT Rice Program. Table 5 presents the list of countries which received seed in 1976 and the quantities dispatched.

Evaluation of promising lines

The six promising lines evaluated in regional trials in Colombia were also observed in other Latin American countries. Table 6 presents the yields in several Central American countries compared with those from Colombia.

Yields of all six were satisfactory,

Figure 2. **Participants in the First Conference on the International Rice Testing Program for Latin America observe demonstration plots of several outstanding varieties.**

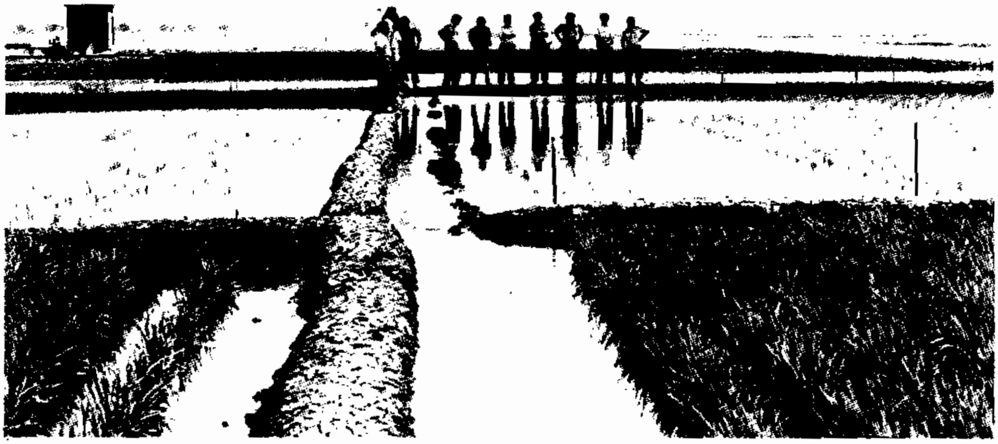


Figure 3. Participants in the First Conference on the International Rice Testing Program for Latin America observe the International Rice Yield Nurseries of Early and Medium Maturity.

Figure 4. CIAT Rice Program trainees seeding the International Upland Nurseries for Yield and for Observation.

Table 5. **International distribution of rice seed materials, 1976.**

	Varieties and lines (kg)							
Country	Colombia 1	CICA 6	CICA 7	CICA 9	4422	4440	4444	4462
Argentina			1.2	1.2				
Belize				50.0				
Brazil			322.0	322.0		5.0	5.0	
Costa Rica			100.0	100.0				
Ecuador			20.0	70.0		10.0		
El Salvador			20.0	50.0				
Guyana	0.05							
Holland			0.01	0.01		0.01		
Honduras			50.0	50.0				
Solomon Islands			0.1	0.1		0.1		
Mexico			51.0	151.0	1.0	1.0	1.0	1.0
Nicaragua			50.0	50.0				
Panama			150.0	100.0				
Paraguay				240.0				
Peru	0.05	0.1	0.7	1.7		0.6	0.6	
Surinam		0.05	1.5	1.5				
Sri Lanka		0.05	0.05	0.05		0.05		
Venezuela			105.0	105.0		1.0	1.0	
United States			150.0	150.0				
Total	0.1	0.2	1,321.56	1,442.46	1.0	17.76	7.6	1.0

Table 6. **Yields of six promising lines and three commercial varieties in Central America and Colombia, 1975.**

	Country and yield (t/ha)[1]					
Line or variety	Costa Rica	Honduras	Guatemala	Nicaragua	Panamá	Colombia[2]
4421	7.9	6.4	5.4	8.2	5.2	6.9
4422	9.2	5.6	5.6	7.7	5.4	6.8
4440	6.8	6.7	5.9	7.1	4.4	6.9
4444	7.7	4.4	5.4	6.7	4.1	6.8
4461	8.5	4.8	4.6	5.0	5.6	5.5
4462	7.2	3.9	5.8	5.9	6.1	6.0
CICA 4	5.9	4.3	4.7	6.9	6.5	6.2
CICA 6	4.2	4.0	5.2	6.7	3.3	5.5
CR1113	5.4	—	—	5.3	6.0	—

[1] Under upland conditions, except in Nicaragua, Panama and Colombia which are irrigated.

[2] Average of 34 regional trials in Colombia; all other countries are the average of two replications in one trial.

although a high incidence of rice blast affected various lines. Line 4461 (named later as CICA 7), demonstrated resistance to this disease in Central America, except in Guatemala. Line 4421 (named later as CICA 9) showed resistance in Guatemala but was susceptible in Panamá.

As a result of this international cooperation, the Instituto de Ciencia y Tecnología Agrícolas (ICTA) in Guatemala selected line 4422 (a sister line of 4421) and named it Tikal 2. Also, the National Rice Program in Ecuador selected line 4444 (a sister line to 4440), naming it INIAP 7.

The Universidad de Panamá and CIAT collaborated in selecting promising material planted at the university's Experimental Station at Tocumen. Sixty promising lines were selected in the F_8 generation for yield trials. This material had been sent by the CIAT-ICA cooperative program as F_4 material and originated from the following crosses: IR x F_1 (IR 930 x Colombia 1); IR 665 x F_1 (CICA 4 x Colombia 1); IR 665 x F_1 (IR 665 x Tetep); CICA 4 x F_1 (IR 665 x Tetep); CICA 4 x F_1 (IR 841 x Dissi Hatif); and CICA 4 x F_1 (IR 841 x C46-15). The 60 lines were selected for their good plant type, long grains, and resistance to the following diseases: rice blast, leaf scald (*Rhynchosporium oryzae*) and sheath blight (*T. cucumeris* or *C. sasakii*). For these lines, it was recommended that technicians of that country to conduct yield trials; with four lines showing superiority, it suggested that regional tests be done to determine their true potential and then to proceed with basic seed multiplication.

BREEDING

As in past years, the CIAT Rice Program collaborated closely with ICA in selecting progenies and high-yielding varieties with resistance to rice blast and to the rice plant hopper, *S. oryzocola.*

Release of Two New Varieties

In 1975, 14 promising lines were evaluated in 22 regional trials under irrigated conditions in the principal rice zones of Colombia. Six of the most promising lines were selected for high yield and resistance to rice blast, *S. oryzicola,* lodging and shattering, and for their good milling and cooking qualities.

During the second semester of 1975 another cycle of regional trials was conducted in Colombia with these six lines. In Table 7 several characteristics are listed such as: flowering; rice blast incidence, lodging; and yield of the two cycles of regional trials.

Based on the results of these trials, lines 4461 and 4421 were named as commercial varieties CICA 7 and CICA 9, respectively Final selection was done in cooperation with rice technicians of ICA and the Federación Nacional de Arroceros (FEDEARROZ).

CICA 7 resulted from a cross of IR 22 x F_1 (IR 930 x Colombia 1) made in 1970. It was selected as a pure line with the pedigree P881-19-24-12-1B and was then included in the regional testing program. CICA 9 originated from a cross between IR 665 x F_1 (IR 841 x C46-15) made in 1971. It was

Table 7. **Comparison of the results of two semesters[1] of regional trials for rice, 1975.**

Line or variety	Days to flowering[2]		Blast reaction		Lodging (%)	Yield (t/ha)	Average Yield (t/ha)
	A	B	Leaf [3]	Neck (%)			
4421	103-105	96- 94	R-R	5- 2	10- 2	7.1-6.7	6.9
4422	100-103	92- 92	R-MR	8- 6	16-10	7.2-6.5	6.8
4440	112-117	102-100	R-R	2- 3	23-32	7.6-6.2	6.9
4444	116-119	103-101	R-MR	3- 3	27-30	7.0-6.6	6.8
4461	100-101	97- 88	R-R	3- 2	0-0	5.9-5.1	5.5
4462	104-101	97- 89	R-R	3- 3	2-0	6.5-5.6	6.0
CICA 6	103-106	89- 93	MS-S	16-18	3-0	5.9-5.2	5.5
CICA 4	104-109	94- 97	S-S	22-25	5-0	6,2-6.3	6.2
IR8	108-101	97-101	S-S	23-10	4-0	5.8-6.3	6.0
IR22	100-103	97- 90	S-S	18-17	0-0	5.4-5.7	5.5
Bluebon.50	107-112	96- 91	MR-MR	13- 4	0-0	4.2-3.9	4.0

[1] The first number in each column corresponds to the first semester growing season.

[2] Days from seeding to flowering: A, zones 700-1,000 m.a.s.l.; B, zones 0-700 m.a.s.l.

[3] Reactions: (R) resistant, scale 0-2; (MR) moderately resistant, 2-3; (MS) moderately susceptible, 3-4; (S) susceptible, greater than 4.

isolated in the F_6 generation as a pure line with the pedigree P901-22-2-6-1-1B and was then evaluated in the regional trials. Both crosses were made in the CIAT-ICA cooperative program.

Among the other four lines, 4422 and 4462 were discarded but it was decided to continue the purification of lines 4440 and 4444 for later multiplication and, also, to complete their evaluation under upland conditions. It is possible that one of them may be named as a variety in the future.

CICA 7 and CICA 9 are tolerant to rice blast and moderately resistant under field conditions to brown leaf spot (*Helminthosporium oryzae*) and stem rot (*Leptosphaeria salvinii*). They are moderately susceptible to stem borer, (*Diatraea saccharalis*) and to the white rice stem borer *Rupella albinella*, and to sheath blight *T. cucumeris* or *C. sasakii*. CICA 7 is moderately susceptible to leaf scald and CICA 9 is tolerant. Both varieties are resistant under field conditions to hoja blanca and moderately susceptible under laboratory conditions. Both are resistant in the laboratory and the field to mechanical damage from the rice plant hopper *S. oryzicola*.

Tables 8 and 9 show the milling and cooking qualities of CICA 7 and CICA 9 compared to four other commercial varieties. The milling and cooking quality of CICA 9 is similar to that of CICA 6. CICA 7 has excellent milling quality, the milled rice having a translucent appearance equal or superior to that of Bluebonnet 50. CICA 7 is similar to CICA 6 in cooking quality.

The semi-commercial milling results for the new varieties are presented in Table 10. The yields of CICA 7 and CICA 9 obtained in regional trials in Colombia, are summarized in Table 7. On the average, CICA 9 yielded 0.7 t/ha more than CICA 4, 0.9 t/ha more than IR 8 and 1.4 t/ha more

Table 8. **Milling quality of CICA 7 and CICA 9 compared with four other commercial varieties.**

Variety	Total yield of milled rice[1] (%)	Head rice[2] (%)	Grain width (mm)	Grain length (mm)	White belly[3]
CICA 7	67.8	59.5	1.9	7.2	0.4
CICA 9	72.5	69.1	2.0	7.0	0.6
CICA 4	70.5	66.7	1.9	6.8	0.6
CICA 6	71.8	69.0	2.1	6.8	0.6
IR22	73.0	66.4	1.9	6.8	0.2
Bluebonnet 50	69.2	58.5	2.0	7.0	0.4

1 Based on five-kilogram samples of paddy rice.
2 Whole milled rice and three-quarters size.
3 Appearance of milled rice on a 0-5 scale: (0), absence of white belly; (5) white belly throughout the grain.

than CICA 6 and IR 22. The average yield of CICA 7 was equal to that of CICA 6 and IR 22.

Selection of Progenies

New progeny selection continued with the objective of forming new varieties with multiple resistance to rice blast, originating from the varieties Tetep, Dissi Hatif, C46-15, Colombia 1 and Carreon. Using ten promising lines possessing resistance from these sources, 45 single crosses and then 587 multiple crosses were produced in 1975. F_1 plants from the multiple crosses were evaluated for resistance to blast in infection beds. Some 6,000 seedlings showing resistance were transplanted to the field in November 1975. Plants were discarded before harvesting that showed lack of vigor, sterility and late maturity. Some 3,600 plants were harvested in February of 1976; these were planted in May in the ICA Experimental Station La Libertad in Villavicencio. The incidence of rice blast on the neck of the panicle under field conditions was severe at this station and permitted the differentiation between the F_2 resistant progenies and the susceptible ones. Based on rice blast resistance and other desirable characteristics, some 24,000 F_2- plants were harvested between September and October 1976. Seed from these plants was transferred to the ICA research station at Palmira for laboratory analysis of grain quality and appearance, and resistance to rice blast in infection beds.

Table 9. **Cooking quality of CICA 7 and CICA 9 compared with four other commercial varieties.**

Variety	Gelatinization temperature[1]	Amylose content (%)	Gel consistency[2]	Total protein (%)
CICA 7	low	29.0	high	8.9
CICA 9	low	31.0	high	8.5
CICA 4	intermediate	28.0	intermediate	7.0
CICA 6	low	29.0	high	7.0
IR22	low	30.0	high	8.5
Bluebonnet 50	intermediate	18.0	intermediate	7.5

1 Low or intermediate indicates the rice is dry and separated after cooking.
2 High indicates the rice has a tendency to harden when it cools after cooking; intermediate indicates no hardening.

Table 10. **Results of semi-commercial milling tests of CICA 7 and CICA 9 compared with three other commercial vareities, 1976.**

Variety	Quantity milled (kg)	Yield of milled rice (%)	Yield of head rice[1] (%)	Broken grains (%)	Brewers grains (%)	Bran (%)	Broken kernels in brown rice (%)	Hulls (%)
CICA 9	2,000	68.0	60.3	5.7	2.0	8.7	2.5	23.3
CICA 7	2,000	66.7	52.1[1,2]	13.4	1.2	8.4	7.2	24.9
IR22	2,500	66.3	42.1[1,2]	20.4	3.8	8.8	17.8	24.9
CICA 6	2,655	65.6	50.6[2]	13.6	2.9	9.2	9.1	23.7
CICA 4	2,045	66.1	55.8	8.1	1.7	10.4	4.8	24.0

[1] Head rice are whole and three-quarters size of grain with up to 5% breakage.

[2] Head rice yields of CICA 7, IR 22 and CICA 6 were low. In the case of CICA 7, this was probably because the grain over-matured in the field; many grains of IR 22 and CICA 6 were cracked, possibly because of poor drying.

Part of the material was evaluated and some 3,000 selected progenies were planted at the end of October; the rest of the material was planted in November and December 1976.

A secondary focus in the selection of progenies has been the incorporation of multiple resistance to rice blast by backrossing to produce multiline varieties.

In 1975, the lines 4414 and 4421, both highly productive and well-adapted to tropical Latin America, were crossed with six lines possessing good plant characteristics and resistance to rice blast. In 1976, the individual F_1 combinations were backcrossed twice with the 4414 and 4421 lines that serve as recurrent parents. Backcrossing was done with F_1 plants resistant to rice blast in the seedling stage. Three or four backcrosses will be necessary to recover the characteristics of the recurrent parents in the segregating generations.

Cooperation also continued with ICA in evaluating F_4-F_9 material in the laboratory. A total of 984 progenies were evaluated for resistance to *S. oryzicola* In the evaluations both CICA 7 and CICA 9 were observed to have higher than normal percentages of plants affected by the insect. Meanwhile, Mudgo (the resistant check) continued to be resistant. These observations may indicate that: (a) the resistance source of CICA 7 and CICA 9, coming from IR 8, is not sufficiently reliable to continue using it in future crosses; (b) that the resistance genes of Mudgo are more stable than those of IR 8; and, (c) that the insect colonies multiplied in the laboratory for several generations became more severe with time. All of this suggests the necessity of incorporating the resistance of Mudgo and other sources into the new crosses. Also, insect colonies should be changed frequently to achieve better representation of field conditions for evaluations of genetic materials.

Basic Seed Multiplication

In the second semester of 1975 seed from 500 selected panicles of each of the lines 4421 (CICA 9) and 4461 (CICA 7) was planted in a 1.5 x 60-meter seed bed. Seed from each panicle (approximately 5 grams) was planted independently in the bed. The seedlings from each panicle were transplanted at 30 days of age to individual plots at a distance of 30 x 30 centimeters. When the plants had 6-10 tillers (15 days after transplanting) a second transplanting was made. Tillers of each plant were separated and again transplanted at 30 x 30 centimeters. This second transplant was done to produce a greater number of seeds of each line within a short time. Only the plots with uniform populations typical of the line were harvested. Line 4421 produced 1,600 kilograms and line 4461, 420 kilograms.

To accelerate the planting of this seed, dormancy was broken by soaking the seed for 16-24 hours in a solution of 0.5 percent nitric acid. Treated seed was dried and stored in the shade for four days then seed from each line was divided between the ICA and CIAT rice programs.

The seed available to CIAT was used to begin multiplication. In the first semester of 1976, 7.7 hectares were seeded with line 4421 and 16.0 hectares, with 4461. The seedings, in puddled lots, were planted by hand in rows 50 centimeters apart. Pregerminated seed was used at a density of 19 kg/ha.

In May 1976, 86.5 tons of seed of line 4461 and 51.0 tons of line 4421 were harvested. At this time, the two lines were named as varieties (CICA 7 and CICA 9, respectively).

When the varieties were named, the ICA Seed Certification Program approved the seed produced as basic seed. This seed was then delivered to the ICA Rice Program in June 1976 for distribution to producers of certified seed and these, in turn, will produce the registered or certified seed for commercial planting. It is hoped that, by the first semester of 1977, the new varieties will be in the hands of farmers for commercial production.

PATHOLOGY

Bacterial Blight in Latin America

The presence of rice bacterial blight caused by *Xanthomonas oryzae* had not been confirmed in Latin America until 1975. According to Dr. S. H. Ou, phytopathologist at IRRI, it has been observed in all tropical countries of Asia and in some countries of Africa.

In 1976, before attending the first conference on International Rice Trials for Latin America, Dr. Ou visited the rice experiments of the Universidad de Panamá, in Tocumen Experimental Station, and also some commercial rice crops in the area. He observed a foliar burning or blight on the rice plants and on some weeds in Tocumen and in the rice zone of Bayano, and suggested that this might be related to bacterial blight.

Since September 1976, scientists of the CIAT Rice Program and Dr. Carlos Lozano, phytopathologist in CIAT's Cassava Program have studied the problem and identified the symptoms of the blight in Panamá and in Colombia as corresponding to the bacterial blight caused by *X. oryzae*.

In Panamá, the symptoms were initially observed on semi-irrigated crops of the Nilo 2 variety and Gayote (a native variety) in the Tocumen Experimental Station and on upland crops of Nilo 2 in the Bayano zone. In these same zones, symptoms similar to the disease were observed on red rice, wild rice (*Oryza latifolia*), jungle rice (*Echinochloa colonum*), raoulgrass *Rottboellia exaltata*, pará grass (*Panicum mutica*), crabgrass (*Digitaria* sp.) and angelgrass (*Paspalum* sp).

In Colombia, the symptoms of the disease were observed at the ICA Experimental Station in Palmira and in CIAT on experimental plots of various rice lines and varieties, at the ICA Experimental Center at Turipaná (Cereté, Córdoba) and in Maria La Baja (Bolivar). In these last two sites, the symptoms were observed in upland plantings established with CICA 4 and the native varieties Miramono and Macao.

It is possible that the disease also exists in other Latin American countries and even in other parts of Panamá and Colombia. However, where the disease was observed, severity was light and dissemination appeared to be limited to certain varieties.

According to information from observers in Panamá and Colombia, it appears that the syndrome has been present for several years but has been overlooked, perhaps due to fluctuations in its appearance, and its light incidence associated with climatic changes (temperature and rain), varietal resistance or the occurrence of slightly pathogenic biotypes.

Some preliminary isolations of the pathogen, done by Dr. Lozano, have yielded pure cultures originating from individual colonies coming from a bacteria which due to the coloration in the medium and slow growth appear to belong to the genus *Xanthomonas*. Preliminary pathogenic experiments have demonstrated symptoms characteristic of those induced by *X. oryzae*.

The establishment of this disease on the American continent, based on the field observations, suggests an introduction dating back many years. It may possibly have been introduced through infested seed — grass as well as rice seed — since both can be hosts of the pathogen. Nevertheless, on the basis of reliable research, the survival of the pathogen on the seed is relatively short, although some controversy exists on this point.

Because bacterial blight in Asia is principally disseminated by typhoons and irrigation water and its development and incidence are favored by high relative humidity with elevated temperatures, it may be possible that the disease will not be of economic importance in America, particularly in the rice zones with moderate climates or in those with high temperatures and low relative humidity and where upland rice is grown. Probably these climatic conditions unfavorable to the disease have not permitted the occurrence of epiphytotics; this may be the reason that its presence has been overlooked for several years.

Presently, research into this disease has been intensified, not only with rice but also with weeds in which similar symptoms have been observed, in order to further understand its hosts and methods of dissemination.

CONTINUOUS PRODUCTION OF RICE

In August 1975, the Rice Production and Training and Conferences programs and the Station Operations Unit began a joint effort to seed 2-3 hectares of rice weekly at CIAT. The effort was planned to: (a) complement the varietal improvement program by multiplying seed; (b) to assist research by validating agronomic and engineering production practices on a field scale; and, (c) to assist in training of rice agronomists for national programs with a basic understanding of all factors of production.

It is hoped that in each of the principal rice-producing areas of the American tropics an extensive network of pilot centers could be established for multiplying seed and for rice production and training. If such pilot centers were to be established in future irrigation and drainage projects, they could serve as nuclei around which the projects could develop. At the same time, they would form a contact point through which varieties and production practices from IRRI and CIAT could be introduced, validated under local conditions, demonstrated in the field, and finally, made available to farmers in the region. This approach could assist in the rapid adoption of improved varieties and practices.

Rice that was seeded under this system in August 1975 was harvested in January 1976. Table 11 summarizes all data obtained from harvests in the continuous production system from January through October 1976. A total of 733 tons were harvested from 122 hectares for an average yield of 6 t/ha of paddy rice with moisture content ranging from 16-25 percent.

Over a five-year period, the average yield of rice at CIAT has varied between 5.8 and 6 t/ha, across more than 80 seeding dates. This confirms the feasibility of continuous seeding of rice and indicates that the establisment of diseases and insects is not a serious problem. The principal advantages of this system of production are: the even distribution of work throughout the growing cycle which allows a better utilization of labor and machinery, and at the same time, a favorable opportunity for trainees to learn all phases of production.

The principal disadvantage is the scarcity of water during the dry season and the difficulty of harvesting and drying the crop during wet periods. However, a long harvest period reduces the quantity of rice to be handled at any one time. In addition, a more beneficial average price is received without having to maintain large drying and storage facilities.

An Asian rice production system, with some variations, is used at CIAT. This method is described in a CIAT publication which will be revised during the coming year.

Table 11. **Data on continuous rice production system at CIAT in 1976**

Harvest date	Variety or line	Area (ha)	Total yield (kg)	Average yield (kg/ha)	CIAT thresher			IRRI thresher		
					total (kg)	Man-days	Kg/man-day	total (kg)	Man-days	Kg/man-day
7/I/76	CICA 6	4.5	26,921	5,982	26,921	330	81			
13/I/76	CICA 6	3.4	19,342	5,689	19,342	160	120			
19/I/76	CICA 6	4.6	21,712	4,722	21,721	280	78			
25/I/76	CICA 6	4.5	23,359	5,191	23,359	220	146			
30/I/76	CICA 6	4.2	25,171	5,993	25,171	240	105			
14/II/76	CICA 6	3.9	19,061	4,886	19,061	180	106			
18/II/76	CICA 6	4.3	25,483	5,926	25,483	180	142			
23/II/76	4462	3.7	29,075	7,858	29,075	180	162			
9/III/76	IR5	4.2	19,342[2]	4,605		combined				
5/IV/76	CICA 6	4.3	18,850	4,384		no data on men				
25/III/76	CICA 6	3.3	20,020[2]	6,067		combine harvested				
4/IV/76	CICA 9	7.7	60,959	7,917	60,959	234	260			
25/IV/76	CICA 7	8.4	62,374	7,425	62,374	208	300			
5/V/76	CICA 7	4.5	29,539	6,564	29,539	100	300			
10/V/76	CICA 7	4.5	33,787	7,508	33,787	164	206			
14/V/76	4422	2.25	11,874	5,277	11,874	57	208			
20/V/76	4422	1.12	4,790	4,276	4,790	48	100			
1/VI/76	4440	6.56	20,729[2]	3,160	20,408	95	214			
24/VI/76	4422	4.0	23,308	5,827	20,475	152	125	2.797	12	233
6/VII/76	4422	2.31	19,774	8,560	12,272	63	195	7,502	24	313
14/VII/76	4422	2.14	16,298	7,615	7,333	31	236	8,965	30	299
21/VII/76	4462	4.6	30,768[2]	6,687	12,363	71	174	9,834	42	234
6/VIII/76	4462	4.2	29,956[2]	7,132	6,830	34	201	6,973	24	290
13/VII/76	4462	3.7	21,427[2]	5,791	10,554	67	158	5,446	30	181
24/VII/76	CICA 9	4.0	26,055	6,514[3]	26,055	116	225			
3/IX/76	CICA 9	4.0	21,596	5,399[4]	21,596	97	223			
10/IX/76	CICA 9	3.0	16,535	5,543[4]	16,535	79	209			
16/IX/76	CICA 9	4.0	22,057	5,531[3]	22,057	92	240			
25/VII-20/IX/76	CICA 9	4.0	21,277	5,319[3]	21,277.	95	224			
20/X/76	4421	2.0	11,864	5,392		combined				
		121,88	733,312	6,017	591,210	3,573	165[5]	41,517	162	256

[1] Harvested weight at 17-25% moisture.

[2] Partially or totally harvested with combine

[3] Transplanted at 35 x 35 centimeters.

[4] Direct-seeded with 450 kilograms of seed (7 ha).

[5] Average rate was 107 kg/man-day for CICA 6 and 222 kg/man-day for all other lines.

Mechanical Preparation of Land for Seeding

During 1976, a total of 32 hectares were developed and planted for basic seed production. Most of the fields were developed directly from cattle pastures by building leaves and leveling in water.

After leveling, the fields were flooded before seeding. The high pH of 7-9 in fields at CIAT requires that this method be used to prevent iron and zinc toxicity problems. This method also reduces weed problems and water and nitrogen losses.

Volunteer and Red Rice Control

Harvest losses of 100-500 kg/ha are common due to shattering of ripened grains. This seed germinates over a period of months or years and can be a serious problem when changing to a new rice variety or when red rice from a previous crop shatters in the field. Several control methods have been tried with varying results.

Wetland preparation

When wetland preparation — flooding and puddling for several weeks — was tried, volunter rice did not germinate in areas where the water cover was constantly maintained. However, as soon as the soil was exposed, the CICA 6 seed remaining from the previous harvest germinated and grew profusely (Fig. 5).

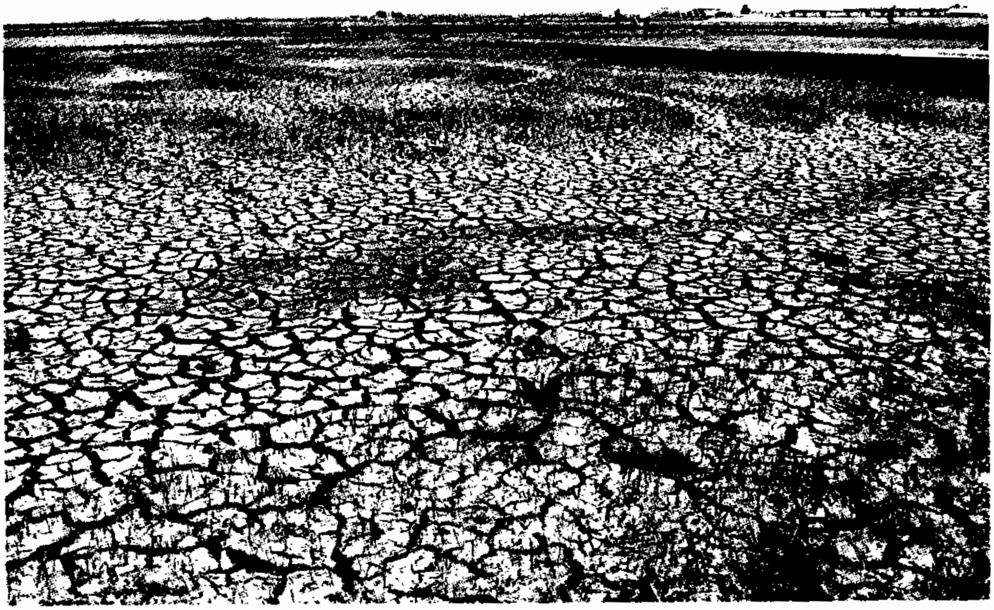


Figure 5. Survival of volunteer rice plants after the land was prepared under water and then flooded and two applications made with paraquat. Note that the best control is on the lower lying areas.

Chemical control

Paraquat was tried as a chemical control on germinating volunteer seedlings with very poor results. While the existing seedlings were killed, many more germinated immediately so that where the new crop was seeded there was a mixture of IR 8, CICA 6 and line 4462. Figure 4 shows seedlings that survived after three types of control during land preparation: land cultivation under water, subsequent flooding of the land, and two applications of paraquat. It is evident that the control is poor.

Sowing of pregerminated seed

Sowing pregerminated seed in rows immediately after puddling of the soil was attempted. Seedlings from the pregerminated seed had an advantage of 3-5 days over volunteer seedlings and could be distinguished well enough by their location so that hand weeding was possible. Nevertheless, the volunteer rice was almost as thick between the rows as the good seedlings in the rows.

Transplanting of seedings

Two trials were done with transplanted seedlings. In the first, seedlings from a Dapog nursery were transplanted when they were 12-16 days old; it was possible to distinguish volunteer plants in the first two weeks but became more difficult later. In a second trial, after the failure of puddling, flooding and application of paraquat, transplanting of 25- to 40-day-old seedlings was attempted. Seedlings of line 4422 were planted at random, spaced about 35 x 35 centimeters or 8 plants/m^2.

One light hand weeding was necessary in the non-puddled areas where paraquat was used but no weeding was needed in the remaining area. The excellent results in this field led to the transplanting of three other plots to eliminate CICA 6 volunteer rice from previous crops. These areas were also transplanted at about 8 plants/m^2 and were weeded several times to eliminate any volunteer CICA 6 plants.

The intention was to grow a commercial crop on these plots. However, an inspection team from FEDEARROZ and ICA approved the field for production of certified seed. CIAT sold the seed of CICA 9 to FEDEARROZ on the condition that it be used only for commercial rice production on farmers's fields and not for multiplication.

Many farmers visiting CIAT and seeing the transplanted fields have adopted the practice in 20- to 40-hectare fields on their farms where red and volunteer rice are problems. Observations on a large field severely infested with red rice indicate that transplanting 30-day-old seedlings and hand weeding constitute a practical and economical method of controlling red and volunter rices. The adoption of seeding in rows allows mechanical weeding; in addition, the recommendation of IRRI to apply granular 2,4-D four days after transplanting appears to be a promising practice.

Planting Methods

Four plots were transplanted at approximately 8 plants/m^2. Three others were planted in rows 50 centimeters apart with about 18 kg/ha of pregerminated seed. The other plots were broadcast seeded with about 100 kg/ha of pregerminated seed. It is obvious that the seed rates and methods are not the most important factors in rice production and their importance is often over-emphasized. Good stand establishment, weed and water control, and adequate fertility are most important for good yields. When seeds are in limited supply, as in the case of basic seed multiplication, then 4-20 kg/ha of seed are adequate for yields of 5-8 t/ha.

This statement is supported by the results from the seeding of eight kilograms of line 4440 seed which were used to establish a seed bed. Less than half the seedlings were used for transplanting in another lot while the remainder in the bed produced 700 kilograms of seed. Seedlings from about four kilograms of line 4440 were transplanted into plots totaling 6.5 hectares. At first seedlings were transplanted at 1/m^2, later transplanting in the same plots was done at four and 10 plants/m^2, as the seedlings increased in age from 25 to 50 days of age. The average high-moisture yield for the 6.5 hectares was 3.2 t/ha and several plants produced more than 600 g/m^2 of clean, dry seed.

Fertilizer Application

Usually, 20-25 kilograms of zinc sulfate were incorporated in the soil with the last operation of final leveling and puddling, one or two days before seeding. The first application of urea at 100 kg/ha was usually applied 25-40 days after seeding depending upon the color of the plants. Irrigation was stopped and the nitrogen applied in standing water on undrained fields. A second application of urea was made at panicle initiation stage at 55-65 days. All applications were hand-broadcast with a labor requirement of about 2.33 man-hours to apply 100 kg /ha.

Insecticide Application

Carbofuran was hand broadcast in the 3 percent granular form at 22.5 kg/ha as needed. Usually, two applications were applied to control *Hydrellia*. The control was poor in many cases, possibly due to old or poor quality granules or to flowing water. The effectiveness increased by stopping water movement for two or three days after application.

Weed Control

Propanil was applied at a rate of 5 liters/ha at 6-8 and 13-16 days after seeding. In case of severe weed problems, a third application of 10 liters/ha of propanil was given, Hand-powered knapsack sprayers were used with the propanil diluted in water to give 200 liters/ha of liquid. The labor required averaged 3.6 man-hours/ha.

In the transplanted areas, an observational trial was made by the trainees on the application of the herbicide 2,4-D, four days after transplanting as recommended by IRRI. The granular form of 2,4-D is not available in Colombia so urea was used as a carrier. Liquid 2,4-D was sprayed uniformly over urea spread on a canvas. The small quantity of liquid did not dissolve the urea but gave a yellow color which aided in estimating the uniformity of coverage. The urea was immediately broadcast onto the water standing in the fields and the oil based 2,4-D floated on the water. The tillering ability of the large 25- to 35-day-old transplanted seedlings was apparently not damaged by the 2,4-D, and weed control was better in the treated plots. These results may lower the cost of weed control and, also, may help to control red and volunteer rice. Further studies are planned next year as part of the training program.

HARVESTING

Mechanical Harvesting

Combine harvesting is the most common method in the Americas, especially for large commercial farmers. Combines are most efficient and economical when harvesting large fields during the dry season with good soil conditions, good access roads, and good dryer facilities. However, for small farmers, small fields, rainy weather, poor soil conditions, poor access roads, and poor dryer facilities, the combine loses much of its efficiency.

Contract harvesting of rice by combines is available in Colombia for approximately US$16 per metric ton when there is sufficient harvest area to utilize the combine for several days. Areas of less than 10 hectares or harvests of less than 50 tons are probably not sufficiently attractive for the contractor.

CIAT has a medium size combine with a 360-centimeter cutter bar which was purchased for harvesting forage grass and legume seeds, but it is also used to harvest sorghum and rice when convenient and available. Approximately 100 tons of rice were harvested with the combine in 1976. Six time studies were made by the rice production trainees when the combine harvested three plots for a total of about 30 tons of paddy rice. The weather, soil and grain were dry and ideal for combine harvest. The average harvesting rate for the combine was 2,800 kg/hr harvested. Grain losses from the combine were between 60 and 100 kg/ha which were very low when compared with the hand harvest methods described later, or when compared with the average 4.46 percent losses reported by workers in California (USA).

The 360-centimeter width combine at CIAT presently costs about US$42,000 locally, and has an estimated life of 2,000 hours with a 60 percent repair cost and 18 percent interest charges. This indicates that at a 500 hr/yr and a four-year life, the depreciation, repairs and interest costs alone would be over US$40/hr or about US$15/t. Sample costs of rice production in Butte County, California in March 1975, estimated combine costs of US$14.90/t for interest, depreciation, labor, fuel and repairs. Bank out costs were estimated at US$7.19/t. The US16/t contract price is probably just enough to cover costs.

Manual Harvesting

Manual harvesting by contractors using the CIAT-designed, portable hand thresher has been used for the last five years at CIAT. In 1976, the standard labor rate was US$16/t, or the same as the contract rate by the combine. Over 610 tons were harvested and threshed manually at CIAT during 1976; 3,573 man-days were required to thresh 591 tons. The overall average was only 165 kg/man-day due to a low rate of only 107 kg/man-day while harvesting and threshing CICA 6 (Table 11). However, a later analysis showed a rate of 222 kg/man-day for harvesting and threshing CICA 7, CICA 9, and their sister lines 4462 and 4422. Several contractors consistently harvested 240 to 300 kg/man-day in less than eight hours. The minimum wage rates in Colombia are less than US$1.60 per day, thus the contract harvest wage from U.S. $1.60 to over $3.50 has been attractive and has created work for the otherwise unemployed, unskilled workers in the area.

A study by the rice production trainees on grain losses during harvest is reported in Table 12. Losses averaged 578 kg/ha or about 9.63 percent of the crop which is over double the average losses (4.46 percent) for a combine in California. The approximate difference of 50 kg/t in grain losses indicates a value of US$7.50/t contract rate in favor of the combine at the producer level if employment, farm size, foreign exchange, harvest weather, access roads, etc. are not considered.

IRRI Thresher

Tests were carried out with an IRRI thresher and results are in Table 11 and 13. A total of 41.5 tons were harvested and threshed by six men using the 7-hp, axial flow thresher. In Table 13, a direct comparison is made between the IRRI thresher and the CIAT portable hand thresher. In both cases, plants were manually cut by sickles, gathered, carried and fed to the IRRI thresher, while the CIAT thresher was moved within the plots to the grain which was beaten by hand on the metal drum so that the grain fell into the box below. The values in Table 13 indicate that 378.5 man-hours out of 847, or 44.7 percent of the labor, was used for cutting and 468.5 man-hours or 55.3 percent for threshing. The IRRI thresher averaged 546 kg/hr with a range of 182-854 kg/hr. Tests were carried out for several hours with freshly cut straw; capacity was less than the 1 t/hr reported by IRRI from dry straw in tests of less than one hour. It should be noted that for the first eight tests, both the IRRI and CIAT thresher rates per man-day were higher than average. It should also be noted in Table 11, that other CIAT thresher tests for over 223.7 tons before, and 107.5 tons after the comparative tests, averaged 246 and 224 kg/man-day respectively. The output per man-day when using either the IRRI or CIAT threshers depends upon the experience of the laborers and the condition of the machine.

The IRRI machine was down for repairs for seven days out of the 26-day test period and for over 30 days following the last test period reported. It is doubtful that the difference of 71 kg/man-day or US$1.14/man-day and US$6.82/thresher day will pay depreciation, interest, repairs and fuel. Repair costs for the 26-day period were just about paid. However, experience should reduce repair costs.

The grain was clean from both threshers; the IRRI thresher left fewer unthreshed

Table 12. **Grain losses in the field at CIAT with three methods[1] of harvesting, 1976.**

Type of loss	Combine	IRRI thresher	CIAT thresher
		(kg/ha)	
Shattered before harvest		17	17
Shattered during cutting		65	66
Threshing losses		176	305
Unthreshed grain		110	190
Total		368	578
Percentage loss based on yield of 6 t/ha	1.67	6.13	9.63

[1] Combine losses were measured as 60-100 kg/ha at CIAT in six tests and reported to average 4.46 percent in California by Cervinka and Chancellor.

Table 13. Comparisons of yields from the IRRI and CIAT threshers. (Plants were cut in the field with sickles).

			IRRI thresher with six men									CIAT thresher		
			Man-hours											
Harvest date 1976	Line	Grain moisture (%)	Cutting	Threshing	Total	Man-days	Thresher hours	Liters of gasoline	Total paddy rice (kg)	Yield/ Man-day (kg)	Rice threshed/ hour (kg)	Total paddy rice (kg/)	Man-days	Yield Man-day (kg)
July 6	4422	23	15.0	24.0	39.0	6	4.0	9.0	2,314	386	578	2,080	6	347
July 7	4422	26	13.0	21.0	34.0	6	3.5	8.5	1,966	328	562	1,981	6	330
July 8	4422	—	15.0	22.0	37.0	6	3.67	7.5	1,957	326	533	335	3	112
July 12	4422	—	9.0	16.0	25.0	6	2.67	5.5	1,591	265	596	1,138	6	190
July 13	4422	—	12.0	25.0	37.0	6	4.16	7.5	2,148	358	516	1,797	6	300
July 14	4422	23	12.0	20.5	32.5	6	3.42	8.0	2,311	385	675	1,753	6	292
July 15	4422	23	10.5	16.5	27.0	6	2.75	6.0	2,055	342	746	1,491	6	248
July 16	4422	23	4.5	7.5	12.0	6	1.25	3.0	860	143	688	1,154	6	192
July 19	4462	26	9.0	21.0	30.0	6	3.5	5.0	1,488	248	425	884	6	147
July 21	4422	23	12,0	24.5	36.5	6	1.83	4.0	1,290	215	705[1]	1,041	6	174
July 22	4462	25	13.5	20.5	34.0	6	3.42	5.5	1,639	273	479	1,175	7	167
July 23	4462	22	13.5	18.5	32.0	6	2.5	5.5	1,352	225	541[1]	1,174	7	167
July 26	4462	—	13.0	11.0	24.0	6	1.83	4.0	1,017	170	556	1,252	11	114[2]
July 27	4462	20	16.5	20.5	37.0	6	3.42	5.0	1,652	275	483	2,069	12	172
July 28	4462	20	16.5	20.5	37.0	6	3.42	4.0	1,396	233	408	1,378	9	153
July 29	4462	—	34.0	—	34.0	6	—	—	—[1]	—	—[1]	1,983	11	180
July 30	4462	—	19.5	19.0	38.5	6	3.16	6.0	2,086	348	660[1]	1,629	11	148
Aug. 2	4462	17	—	—	—	—	—	—	—	—	—[1]	620	6	103
Aug. 3	4462	23	27.0	9.0	36.0	6	1.5	3.0	714	119	476[1]	1,782	6	297
Aug. 4	4462	21	12.0	19.5	31.5	6	3.25	10.0	2,777	463	854	1,388	8	174
Aug. 5	4462	24	13.5	24.0	37.5	6	4.0	7.0	1,322	220	330	1,580	8	198
Aug. 6	4462	—	13.5	21.0	34.5	6	3.5	9.0	2,160	360	617	1,888	11	172[2]
Aug. 9	4462	22	15.0	9.0	24.0	6	0.5	1.0	91[1]	15	182[1]	1,182	12	98
Aug. 10	4462	17	15.0	20.0	35.0	6	1.5	3.0	907	151	605	2,355	13	181
Aug. 11	4462	—	14.0	17.0	31.0	6	2.83	9.0	2,001	334	707	2,567	14	183
Aug. 12	4462	—	16.5	19.5	36.0	6	3.25	6.0	1,404	234	432	2,552	14	182
Aug. 13	4462	—	13.5	21.5	35.0	6	3.58	4.0	1,043	174	293	1,898	14	136
			378.5	468.5	847.0	156	72.41	146.0	39,541	—	546	42,126	231	
			14.6	18.0	32.6	6	2.78	5.58	1,521	253	546			182

[1] Theresher was damaged

[2] Operator were not experienced

grains and had fewer grain losses as shown in Table 12. The difference of 3.5 percent in grain losses in favor of the IRRI thresher is 19 kg/hr of thresher time. If the thresher has a 1,000-hour life, then the 19 tons of grain saved would be the major factor in favor of the IRRI thresher. The development and use of harder to thresh, non-shattering varieties would be more favorable for the axial flow thresher which would compare well with the combine.

GRAIN WEIGHT LOSSES

The weight losses from drying and cleaning are an important consideration in determining the farm price of freshly harvested paddy rice. Basic seed from line 4421 was harvested during the dry season with a grain moisture content of 20-23 percent. The conversion factor from fresh paddy to dry clean seed was 0.84 (Table 14). Later harvests of basic seed for line 4461 occurred during periods of both dry and rainy weather with seed moisture contents ranging from 17-23 percent. However, there were occasional days with saturated bags and grain, due to rainfall. The conversion rate of 0.743 was very low for the entire seed lot (86.5 tons of clean dry seed from 116.4 tons of fresh paddy). This difference in conversion factors of basic seed of two varieties resulted in a search for a possible 11 additional tons of basic seed without any results. It was then decided to keep detailed weights of future harvests. The freshly harvested paddy was weighed in the field, at the silos, from the silos, and weighed either as clean dry seed or as products from the rice mill. These detailed weights were kept by farm operations personnel, farm management training associates and the trainees. Results are given in Tables 14 and 15.

Table 14. **Determination of weight losses during drying and cleaning of paddy rice, at the farm level.**

Line	Weight with 18-24% moisture (kg)	Weight of clean grain 12-13.5% moisture (kg)	Conversion factor
4421	60,969	51,200[1]	0.840
4461	116.455	86,550[1]	0.743
4440	15,368	12,199[1]	0.793
4421	21,580	19,108[2]	0.907
4422	60,108	50,023[2]	0.832
4462	73,150	63,798[2]	0.872
Total	347,360	282,878	Avg. 0.814

[1] Dry and clean basic seed, in 50-kg sacks.

[2] Dry and clean paddy rice to be threshed in the single-pass rice mill (Satake SB-2B) at CIAT.

MILLING RECOVERY

Table 15 gives the milling recovery for lines 4421, 4422 and 4462. A 3-hp rice mill with a milling rate of 160 to 210 kg/hr of paddy was operated by farm operations to mill the rice not to be sold as seed. This gave excellent data on milling, an income to CIAT, and control of seed which did not leave CIAT. CICA 9 and line 4422 are sister lines with almost identical plant and grain types. Both lines gave an average of about 60 percent first head rice with some lots as high as 67 percent. However, there

Table 15. **Data on harvested paddy, dry paddy, and milling recovery for rice lines 4421, 4422 and 4462.**

Lines	Harvest wt (kg)	Moisture %)		Dry wt (kg)	Milling recovery from CIAT mill												
					Conversion factor	Grade 1		Grade 2		Grade 3		All Grades		Bran		Total (kg)	Recovery (%)
		Wet	Dry			(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)		
4421	1,012	23.3	12.2	812	0.802	538	66.2	57	7.0	1	0.1	596	73.4	81	9.9	677	83.3
	2,873	18.7	12.0	2,576	0.897	1,659	64.4	186	7.2	-	-	1,845	71.6	254	9.8	2,099	81.5
	1,058	18.9	12.0	962	0.909	505	52.5	117	12.2	-	-	622	64.6	108	11.2	730	75.9
	1,059	21.2	12.2	939	0.887	541	57.6	112	11.9	-	-	653	69.5	97	10.3	750	79.9
	434	16.6	12.0	402	0.926	221	55.0	63	15.7	-	-	284	70.6	33	8.2	317	78.9
	1,672	25.7	12.5	1,361	0.814	911	66.9	143	10.5	-	-	1,054	77.4	217	15.9	1,271	93.4
	345	19.6	12.1	319	0.925	197	61.7	32	10.0	-	-	229	71.8	37	11.6	266	83.4
	606	17.3	12.0	531	0.876	317	59.7	63	11.9	-	-	380	71.6	46	8.7	426	80.2
	609	16.9	12.0	538	0.883	324	60.2	60	11.2	-	-	384	71.4	59	10.9	443	82.3
	651	18.5	12.5	582	0.894	357	61.3	57	9.8	-	-	414	71.1	56	9.6	470	80.8
	1,531	16.0	12.8	1,407	0.919	799	56.8	195	13.9	-	-	994	70.6	147	10.4	1,141	81.1
	7,871	21.5	13.6	6,959	0.884	4,061	58.4	670	9.6	65	0.9	4,796	68.9	775	11.1	5,571	80.1
	1,859	22.0	13.2	1,720	0.925	881	51.2	225	13.1	53	3.0	1,159	67.4	218	12.6	1,377	80.1
Total	21,580			19,108	0.885	11.311	59.2	1,980	10.4	119	0.6	13,410	70.2	2,128	11,1	15,538	81.3
4422	4,909	23.1	12.9	4,177	0.851	2,638	63.1	270	6.4	65	1.5	2,973	71.2	543	12.9	3,516	84.2
	6,781	22.6	12.6	5,680	0.838	3,338	58.7	600	10.5	149	2.6	4,087	72.0	597	10.5	4,684	82.5
	5,300	26.0	12.6	4,330	0.817	2,921	67.5	199	4.6	3	0.1	3,123	72.1	411	9.9	3,534	81.6
	2,302	24.3	12.8	1,949	0.847	1,258	64.5	128	6.5	4	0.2	1,390	71.3	193	9.5	1,583	81.2
	3,937	25.2	13.6	3,083	0.783	1,616	52.4	486	15.8	22	0.7	2,124	68.9	417	13.5	2,541	82.4
	2,002	23.1	12.7	1,685	0.842	1,000	59.3	147	8.7	37	2.2	1,184	70.3	210	12.4	1,394	82.7
	7,533	23.1	13.0	6,389	0,848	3,637	56.9	770	12.0	142	2,2	4,549	71.2	927	14.5	5,476	85.7
	5,227	28.9	13.2	4,326	0.828	2,860	66.1	243	5.6	4	0.1	3,107	71.8	331	7.7	3,438	79.5
	4,177	25.0	13.2	3,464	0.829	1,909	55.1	423	12.2	44	1.3	2,376	68.6	424	12.2	2,800	80.8

Table 15. Continuation

					Milling recovery from CIAT mill												
		Moisture (%)				Grade 1		Grade 2		Grade 3		All Grades		Bran			
Lines	Harvest wt (kg)	Wet	Dry	Dry wt (kg)	Conversion factor	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)	Total (kg)	Reco-very (%)
4422	7,127	23.3	12.8	5,832	0.818	3,801	65.2	410	7.0	5	0.1	4,216	72.3	559	9.6	4,775	81.8
	2,718	27.0	11.6	2,094	0.770	1,241	59.2	185	8.8	3	0.1	1,429	68.2	231	11.0	1,660	79.3
	3,539	23.8	12.7	2,949	0.833	1,745	59.2	225	7.6	93	3.2	2,063	70.0	334	11.2	2,397	81.3
	1,323	22.0	13.0	1,166	0.881	618	53.0	157	13.4	-	-	775	66.4	114	9.7	889	76.2
	561	16.5	12.0	477	0.850	207	43.3	47	9.8	-	-	254	53.2	50	10.5	304	63.7
	2,197	19.0	12.8	2,023	0.921	1,153	56.9	244	12.0	-	-	1,397	69.1	212	10.4	1,609	79.5
	475	18.5	12.4	409	0.861	221	54.0	44	10.7	-	-	265	64.8	53	12.9	318	77.8
Total	60,108			50,033	0.832	30,163	60.3	4,578	9.1	571	1.1	35.312	70.6	5,606	11,2	40,918	81.8
4462	8,430	21.2	12.3	7,585	0.908	4,265	56.2	972	12.8	13	0,1	5,250	69.21	809	10.6	6,059	79.9
	2,900	23.8	12.6	2,442	0,842	1,458	59.7	279	11.4	25	1.0	1,762	72.2	294	12.0	2,056	84.2
	4,030	19.3	12.5	3,406	0.845	2,006	58.8	148	4.3	6	0.1	2,160	63.4	392	11.5	2,552	74.9
	8,867	22.6	12.3	7,872	0.888	3,967	50.3	1,263	16.0	17	0.2	5,247	66.7	921	11.6	6,168	78.4
	9,874	19.6	13.2	8,482	0.859	4,207	49.6	1,613	19.0	32	0.4	5,852	69.0	971	11.4	6,823	80.4
	2,374	26.2	13.0	1,965	0.828	1,185	60.3	193	9.8	-	-	1.378	70.1	190	9.6	1,568	79.8
	4,625	16.7	13.0	4,388	0.949	1,282	29.2	1,609	36.6	231	5.3	3,122	71.1	564	12.8	3,686	84.0
	621	16.7	12.7	552	0.889	250	45.3	134	24.3	-	-	384	69.6	49	8.9	433	78.4
	7,660	23.3	12.7	6,415	0.837	4,175	65.0	359	5.5	5	0.1	4,539	70.8	578	9.0	5,117	79.8
	2,342	17.5	13.0	2,304	0.984	894	38.8	750	32.6	22	1.0	1,666	72.3	227	9.8	1,893	82.2
	4,762	19.4	12.3	4,157	0.873	2,270	54.6	601	14.4	11	0.2	2,882	69.3	534	12.8	3,416	82.2
	10,960	22.2	13.0	9,402	0.858	5,416	57.6	975	10.3	34	0.3	6,425	68.3	936	9.9	7,361	78.3
	5,705	17.6	12.0	4,828	0.846	2,831	58.6	481	10.0	5	0.1	3,317	78.5	541	11.2	3,858	91.2
Total	73,150			63,798	0.872	34,206	54.1	9,377	14.7	401	0.6	43,984	68.9	7,006	11.0	50,990	79.9

were some low recoveries due to (a) moisture below 18 percent at harvest; (b) and, the fact that line 4421 was a ratoon crop with uneven maturity. Line 4462, a sister line to 4461 or CICA 7, was discarded due to lodging and poor milling recovery even though it is a better yielding line than 4461. The low average milling recovery of 53.2 percent was largely due to some overmature plots with low moisture grain which was harvested after a heavy rain. Milling recovery was good for lots harvested earlier at higher grain moistures.

AGRICULTURAL ENGINEERING

Pump Drainage and Irrigation

A major part of the agricultural engineering effort in the CIAT Rice Program was devoted to the continuous rice production system and later harvesting and processing as previously reported. The numerous practical problems in land preparation and water losses were stressed and some of the research results given. The importance of pump drainage and irrigation, however, is treated separately in this section.

There are millions of hectares of fertile alluvial flood plains in the American tropics which are flooded with water to depths of less than two meters. During the dry season, these same areas normally have water in the drains which are less than two meters below the field surface. Protective levees, floodways, drains, roads, culverts and pump stations, can be designed as an integrated system to turn these flood plains into rice fields. In this design, the earth from the drains would serve as a road bed and protective levees which in turn, would serve as limits to wider floodways. The drains would concentrate the water to be pumped for drainage or irrigation, as required. The culverts would permit the water to flow under the roads or levees by gravity or by pumping and these same culverts would serve as low cost foundations and sump pits for large axial flow portable pumps.

Pump design and installation must be included as an integral part of the overall project design of drains, roads, levees and culverts if maximum benefits are to be gained at a minimum cost. Since levees and drains under two meters are adequate in most areas, easier to construct, and less expensive, an efficient economical pump with less than a two-meter head differential should be used. Although electrical power is limited on most floodplains, diesel farm tractors of over 50 hp with 540 RPM on the power takeoff (PTO) are necessary for other farm operations such as land preparation and transportation so that the original capital investment can thus be reduced by using the tractor PTO as a power unit of the pump when the tractor is not otherwise in use. In addition, an old tractor or a marine engine may be used as a stationary power unit. The use of a culvert and drain crossing under a road bed levee as a pump installation site completes an integrated set of design criteria as previously illustrated.

An axial flow pump was designed, constructed and tested at CIAT during 1976. Table 16 summarizes the results obtained with the pump. Two hectare-meters (20,000 m^3) is adequate for water control during a crop season. The diesel fuel required would range from 15-60 liters/ha/crop season and the tractor pumping time would be from 4-6 hr/ha during a 120-day period. On a 100-hectare

Table 16. **Maximum efficiency relationship of head differential, discharge, revolutions per minute and fuel requirements per hour and per hectare-meter of water pumped for a 70-hp-tractor, PTO-driven axial flow pump.**

Head differential (cm)	Discharge (liters/sec)	PTO speed (rpm)	Diesel fuel consumed	
			(liters/hr)	(liters ha-m)
75	770	308	3.85	13.89
100	890	356	5.68	17.72
125	992	387	7.32	20.50
140	1,100	440	9.01	22.75
175	1,190	476	10.51	24.53
200	1,270	508	11.90	26.03
225	1,355	542	13.34	27.35

area, one tractor and pump should easily maintain water control by 4-6 hours of operation during the night and/or 24-hour periods during extreme flood conditions. Since the pump is portable, one or more pumping sites may be used as needed for best use of a drain and canal system for irrigation and drainage. The direction of pumping is reversed by lifting out the pump and reinstalling it in the opposite direction.

Irrigation and Water Control

Insofar as was possible, the desired water control in the CIAT fields was maintained at a 1-5 centimeter depth throughout the growing season, as this is of maximum importance for good rice yields. The fields were deliberately drained only (a) to permit stand establishment in the first week, (b) for the application of herbicides, and (c) for harvesting after physiological maturity. The desired water control, however, was not always possible, and fields were frequently not flooded due to water shortages and losses through the border levees.

All water in CIAT is pumped from wells 10 to 30 meters deep by turbine electrical pumps which require about 0.22 KWH/m^3. The total pumped water requirement is estimated as 15,000 to 20,000 m^3/ha or 3,300 to 4,400 KWH/ha of electrical energy.

Water Losses

Storage reservoir water losses from deep percolation were measured in order to estimate the cost of the losses and to determine if the reservoirs were needed. The losses from the storage reservoirs through deep percolation ranged from 7.4 to 10.3 liters/hr/m of reservior perimeter. Two reservoirs each of about 20,000 cubic meters capacity and 600 meters of perimeter are used to store water from four deep wells. The wells and pumps have a combined pumping rate of 835 m^3/hr. Thus the reservoirs have the capacity to store water from 48 hours of pumping; this permits their full use during nights, weekends, holidays and when rain is scarce. The storage capacity also permits simultaneous use on several fields during normal work hours when irrigation efficiency is higher. The measured percolation losses (less than 12 m^3/hr or 1.5 percent of pumping capacity) are easily recovered by better use of the wells, pumps, electrical power facilities, and by higher

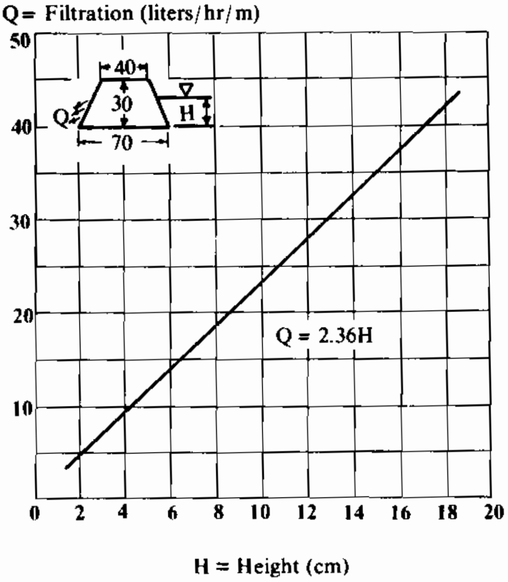


Figure 6. Water losses by filtration through boundary levees on CIAT rice fields.

irrigation efficiency in the application of large flows during daylight hours.

Field perimeter losses through the boundary levees were observed and measured as flows into roadside ditches. Some of this flow could be re-used in lower fields by blocking the ditches but large amounts were lost in runoff outside CIAT. An effort was first made to reduce and re-use these surface losses as much as possible and then a series of measurements was initiated to detdrmine the factors involved in the losses from existing perimeter levees and how to prevent these losses through better design. Measured losses from CIAT field boundaries averaged about 16 liters/hr/m with a range of 0-70. A prediction equation was derived from the observations made on levee dimensions and water depth with an $R^2 = 0.87$ (Fig. 6). This research will be published as a technical article since perimeter levee losses are a major factor in the water requirements of flooded rice fields.

IRRI Agricultural Machinery

Agricultural machinery manufactured from IRRI designs was donated to CIAT and received in May 1976. The set consisted of two single axle 7-hp tractors, one axial flow thresher, one bin-type dryer with 3-hp gasoline engine and a kerosene burner, one bellows pump, power weeder, and one multihopper seeder.

The axial flow thresher and single axle tractor have been used in the rice program for as many hours as possible. The 7-hp gasoline engines and power tiller transmissions have required major repairs. The reliability of these machines must be improved before recommending them for sale to small rice farmers in the Americas. Producers and local manufacturers have shown great interest in obtaining and reproducing machinery for rice production. The IRRI machinery program has referred about 100 inquires to the CIAT Rice Program as their Latin American coordinator. CIAT does not have an adequate budget or technicians to give adequate technical assistance to the local manufacturers or to handle the referrals. However, CIAT has assisted IRRI and a German technical mission to arrive at an agreement by which the technical mission will assist local manufacturers in producing prototypes of IRRI designs.

ECONOMICS

Colombia

An econometric model of rice production and demand was developed to measure the impact of the new high-yielding rice varieties. In this model, the

Table 17. **Size and distribution of benefits and costs[1] of high yielding rice varieties in Colombia, 1957-74.**

Item		Producers			Consumers	Total in Colombia	International cooperation
		upland	irrigated	total			
Gross benefits		-3,542.1	-5,292.9	-8,835.0	14,939.3	6,104.3	-
Costs of	FEDEARROZ	8.4	29.9	38.3	-	38.3	-
research	ICA	0.7	1.7	2.4	22.1	24.5	-
	Total	9.1	31.6	40.7	22.1	62.8	18.8
Net benefits		-3,551.2	-5,342.5	-8,875.7	14,917.2	6,041.5	-

[1] All data are (1,000,000) Col. pesos, 1970.

gross benefits, research costs and the net benefits were estimated and distributed by groups of producees and consumers (Table 17). Producer gross and net benefits are negative for both upland and irrigated sectors, indicating that the return on land and entreprenurial skills would have been much higher in the absence of high-yielding varieties. This lost income would heavily affect small upland producers since the new varieties were developed for irrigated culture, giving these sectors a comparative advantage over the upland sector where no technological change has occurred. Table 18 shows the changing structure of the rice industry.

The absolute and relative benefits were greatest for low income consumers. For the three lowest income groups the benefits were 12.8, 7.1 and 3.5 percent of their income levels in 1970. Since the additional production was sold on the domestic market, prices were much lower than they would have been in the absence of high-yielding varieties due to the relatively inelastic domestic demand. Producers currently have problems marketing their rice since per capita consuption has apparently reached its maximum level (this figure has almost doubled). As a consequence, two alternatives arise: (a) the exportation of the national surplus to the Caribbean countries; or (b) to search for alternative domestic uses for rice such as the substitution of barley with rice for brewing or as animal feed.

Table 18. **Yield and production of the upland and irrigated rice growing areas in Colombia (selected years).**

Year	Upland		Irrigated	
	yield (t/ha)	production (1,000 t)	yield (t/ha)	production (1,000 t)
1954	1.1	124	2.7	171
1960	1.2	187	3.9	263
1965	1.1	276	3.0	396
1968	1.7	251	4.2	536
1972	1.6	161	5.2	883
1975	1.6	152	5.4	1,480

The benefits of expanded output of food crops brought about by technological change would be captured by the consumer and tend to favor lower income groups if the crop does not enter export markets. Industrialization polices which protect the manufacturing sector maintain the price of foreign exchange lower than it would be in the absence of such protection, thus contributing to a cheaper food policy. When technological change generated by public investment in agricultural research shifts the supply of food crops, producers have less incentive to export because of the lower exchange rate. Hence, the expanded output must be absorbed by the domestic market where demand elasticity is low. Thus, prices fall substantially and consumers benefit. This result occurs when there is a dynamic situation in agriculture. In a static situation, protection of the manufacturing sector raises input prices for the farm sector, *reduces* farm output, and *raises* food prices. If the exchange rate policy had been more favorable toward potential exporters, Colombia could have competed favorably in export markets. If Colombia becomes a significant exporter of rice, the producers will capture more of the benefits in the future (and consumers less).

TRAINING

During the second semester of 1976, eight professionals from six countries were trained in all aspects of rice production by the Rice Program in collaboration with the Training and Conferences Program. Five of these trainees from Honduras, Perú and Colombia received "full time" training while the remaining two from Guyana and Brazil received "part-time" training.

Using the system of continuous production, it was attempted to instill in the trainee the scientific aptitudes, techniques, and economics of the small farmer and communication agent which are related to the practical methods involved in rational irrigated rice production.

As basic objectives, by the end of the course the trainee was expected to be able to:

(a) Validate new rice production technology;
(b) Apply new and existing technology within the economic context of rice production;
(c) Plan, develop and direct efficient exploitation of rice;
(d) Transfer the technologies to the rice producers to achieve economically valid gains in production at the regional or national level; and
(e) Plan, develop and direct regional trials of varieties.

The training period varied between four and six months. Approximately two hectares per week were seeded in continuous production and the trainees had the opportunity to work and be trained in all phases of the crop cultivation. These phases were grouped in the following four divisions so that the trainee could be trained, for at least a month, in each one of the divisions.

(a) *Soil preparation* which included: elimination of residues from the previous crop; soil analysis; construction, cleaning and reconstruction of levees; plowing or harrowing with a rototiller; flooding for puddling; leveling with a shovel; and use of a grading rake.

(b) *Seeding* which included: choosing good quality seed; pregermination; seed bed establishment; seeding; and draining.

(c) *Cultural practices* which included: irrigation; weed control; fertilization; and insect control.

(d) *Harvesting and processing* which included: manual and mechanical threshing; drying; milling; and treatment of the seed.

(e) *Planning and economic evaluation*

(f) *Breeding*

(g) *Observational trips*

Essentially, the trainees received practical training during which they were in daily and permanent contact with rice production tasks. This training was reinforced with discussions and conferences on topics which interested the trainees.

In addition to the biological and agronomic understanding of the crop, the trainees received ample information on the economic and administrative aspects of production. Two hours per week were dedicated to exercises and conferences on administration.

A very important part of the course was that dedicated to breeding, with emphasis on establishing regional trials and the planning, development and evaluation of the International Yield Trial Nurseries for lowland and upland rice, resistance to salinity, and disease.

The trainees were taken on observational trips through the rice zones in Valle del Cauca, Tolima and Huila in Colombia and through the Rio Guayas zone in Ecuador, so they could compare different cultivation techniques in diverse ecologies. These trips gave the traineees new judgement criteria for their professional formation.

In the future, it is hoped that the course will last six months, four of which would be dedicated to production and two to breeding.

TECHNOLOGY ADOPTION

In 1976, rural sociological research was initiated to explore factors related to the adoption of new technology in Colombia. The work is in collaboration with the Colombian Land Reform Agency (INCORA). The project has two objectives: (a) to obtain information on the socio-economic aspects of traditional rice production by small farmers; and, (b) to assess changes in the farmer's level of living and in the socio-economic structures in which he operates after he adopts new technology.

This information will be important know the needs of the small rice producer and to help understand how new rice technology improves or changes the rural welfare of these farmers.

The research is being done in a representative lowland tropical area on the Northern Coast of Colombia. Thirty percent of Colombia's rice is produced in this section and a major potential exists for expanding rice production there in the future. Farmers of the region use many rice production systems — from shifting cultivation combined with eventual pasture establishment to double-cropping in irrigation districts.

To help accomplish the first objective of the project, two surveys have been made. In the first survey professionals involved with rice production in the region were surveyed by letter and about 50 responded. Information was obtained on the relative importance of: various rice growing systems; production levels; occurrence of rice as a frontier crop for opening of new pasture land; land tenure systems; marketing; production costs; labor use; changing values for tillable land; and, problems perceived upon adoption of new rice varieties.

One important finding sometimes overlooked is the huge number of small subsistence farmers who grow rice. These contribute only marginally to the national market, but they may be the biggest group in terms of numbers of producers. In the political departamentos of Bolívar, Sucre, Córdoba and a small part of Antioquia, the survey revealed a lower limit of about 21,000 farmers who grow rice under traditional methods. This involves no land preparation except using a stick to open planting holes for the seed. About one-third of these farmers then transplant their rice.

Rice plots average 1.8 hectares for farmers sowing seed directly, and 1.2 hectares for those who transplant. Average yields for the two systems are 2.3 t/ha and 2.5 t/ha, respectively. For many subsistence farmers of this region, rice is a typical frontier crop. The farmer opens the virgin land and plants rice for one two seasons; then the land is sown to pasture. This becomes the land rent or payment to the owner, who is frequently a cattle rancher.

The survey showed that one of the most important changes occurring after the introduction of new rice technology, was the sharp increase in land values for the region (Table 19).

These data indicate that where new technological opportunities boosted land prices beyond the normal inflationary increase, the demographic pressure in the subsistence areas and the importance of rice as a staple food helped force land values even higher.

In the second survey, rice farmers in about 20 important rice-growing communities in the region participated in structured, open-ended interviews; these will be fully analyzed in 1977.

During field visits one important socio-economic consequence of new rice varieties

Table 19. **Rice land prices[1] in Northern Colombia[2] in 1968 and 1976.**

Production system	Price, 1968 (Col. $)	Price, 1976 (Col $)	Rate	Inflated Rate
Mechanized, irrigated	5,030	24,700	4.7	1.7
Mechanized, upland	2,660	10,800	4.1	1.4
Manual, upland	1,700	8,160	4.8	1.6
Manual, transplanted	1,290	7,000	5.4	1.8

[1] Not adjusted for inflation

[2] Number of observations range from 11 to 32.

was observed throughout the region. The traditional manual harvesting system, consisting of cutting the rice panicle by panicle is not used with dwarf, high-yielding varieties. This rice is harvested with a sickle if manual labor is employed. This is an important direct effect of the new plant types and involves the entry of the farmer-laborer more and more into the monetary economy, since under the new system he is no longer paid in rice but in money.

To accomplish the second objective of sociological research in rice, a comparative study among three different communities was designed. A survey among 112 farmers in the three communities provided information on: different rice growing methods used; costs of production; use of family and hired labor; harvesting methods; production and consumption of rice; tenure arrangements; varieties sown; changes in family size; health; education; and the future expectations of the farmers.

The communities were selected according to the levels of technology used to grow rice. In one community, all farmers grew traditional varieties.In another, most farmers grew CICA 4 (an improved variety) and used irrigation, mechanization and other modern inputs; in some years these farmers produced two crops. The third community of growers used an intermediate level of technology; new varieties were grown but with little mechanization.

The surveys were completed late in 1976 so only preliminary data are available for some of the factors studied. Compared with estimates from the first survey and results from the other two communities, farmers in the community using traditional methods had very low yields. In 1976, the farmers in that community obtained only 892 kg/ha from their transplanted plots and 1,050 kg/ha from direct-seeded plots. This was probably due in large part to the dry year. Also, when these data are compared to estimates from the first postal survey, production averages for traditional rices may have been overestimated by the professionals interviewed. Some farmers in the community, however, produced yields of more than 2 t/ha with the traditional varieties. Fifty percent of these farmers used herbicides, 10 percent used insecticides, but none used chemical fertilizers.

Among the other two communities an average of 3.9 t/ha of CICA 4 was produced. Mechanized farmers produced an average of 4.4 t/ha while those in the intermediate technology group produced only 3.1 t / ha. The former group have more experience with producing irrigated rice, having used this method for about six years; farmers in the intermediate froup only began to grow improved varieties this year.

In the traditional community, all rice was cut by hand with 92 percent of the farmers paying for this service with rice — from each five bundles cut, the harvester keeps one. Two-thirds of the farmers claimed they would prefer to pay for labor with money, but on the other hand, 91 percent said they would prefer to be paid in shares of rice if working for someone else. Fewer than half the farmers using intermediate technology harvested by hand and only two of 37 modernized farmers still harvested by hand. The total amount of labor necessary to produce a hectare of rice under the three technological systems varied sharply (Table 20).

Table 20. **Labor use (in man-days) for growing one hectare of rice in three different systems, Colombian North Coast, 1976.**

	Production system					
	Manual, Upland		Manual,Transp.		Mechanized irrigated	
Type of labor	Family	Hired	Family	Hired	Family	Hired
Land preparation, sowing, irrigation	13.0	14.9	7.7	14.7	7.7	16.7
Transplanting	0.0	0.0	3.6	8.1	0.0	0.0
Manual weeding	7.8	17.9	3.4	6.3	0.5	9.1
Aplying inputs	0.0	0.0	0.5	0.5	1.6	2.2
Protecting from birds	34.2	32.2	0.0	20.7	2.0	4.0
Harvesting	6.5	18.1	3.8	14.7	0.2	0.2
Others	0	0	1.0	0	0	0
Total	61.5	83.1	20.0	65.0	12.0	32.2
Total labor	144.6		85.0		44.2	

Training and conferences

As CIAT's commodity research programs evolve and generate new technologies, training takes on added importance, and the need for a systematic reorganization of its resources and methods is increasingly felt.

The year 1976 marked a turning point for the Training and Conferences Program; the program's strategy and actions were adjusted in the directions of decentralizing training activities to put them more into the realm of each one of the commodity programs. This was justified, and essentially induced, by several reasons.

(a) CIAT's commodity research thrusts have evolved rapidly in the last five years to the point where each could carry a greater responsibility in training both for research and for production related to the commodity.

(b) The same evolution and the technologies it generated have made it necessary to direct increasing attention from each program to training-related outreach activities.

(c) A six-year special project series of six combined-commodity, crop-production training courses and four livestock production training courses, largely financed by a grant from the Inter-American Development Bank, was completed at the end of 1975. It become evident then that production training would be better individualized on a single commodity basis, to serve the purposes of each program.

(d) CIAT has developed a sound international reputation parallel to that of its research, for the quality and scope of its training activities among its clientele of national institutions.

(e) There appears to be an increasing awareness in national research institutions of the advantages of vertically integrated, single-commodity research and production programs in place of the traditional, disciplinary departmentalization across commodities.

Training and conference activities are an intrinsic part of each commodity program. They are based on the CIAT research function and as part of the Center's international cooperation activities, they provide support to commodity research at national levels as a component of the technology transfer chain.

As a result, training is conducted parallel to research. Every staff member has the responsibility and commitment to the same standards of excellence and sense of urgency since training produces the scientific and technical manpower indispensable for achieving CIAT's objectives of assisting national institutions to increase production in their countries. For these reasons, then, the training program has been revised as a center-wide activity at CIAT rather than a separate program.

All trainees at CIAT are now with a commodity program or unit; the few exceptions include those training in management of experiment stations, library and documentation, and special studies (for example weed control) and some research scholars. The discipline orientation that once was accepted in the training program has practically disappeared giving place isntead to a concentration on a single commodity by individual trainees or groups of trainees.

The training coordinator for Animal Sciences was transferred halftime to the Beef Program as a Production Specialist. The outreach specialist in the Swine Program devotes half his time to training. One training associate position for production training was assigned to an outreach scientist in each of the commodity programs.

Postgraduate Training

CIAT selects candidates from among the best available university graduates working in national programs. Few exceptions are made only when a specific country does not have sufficient numbers of college graduates in agriculture employed by the national institutions or when the training of para-professionals, technicians, as special trainees is essential for the success of a country-CIAT cooperative project.

CIAT in its training efforts aims at the scientific leadership ranks of the national institutions. Therefore, CIAT prefers candidates that already hold graduate MSA and PhD degrees or who are in the process of obtaining them. This has become increasingly evident through the evolution of CIAT's training program, during which both the number and the proportion of research scholars and visiting research associates has increased yearly. The category of postdoctoral fellows, created in 1975, has expanded in number from three to eight in 1976. However, the availability of candidates at the higher academic levels is still very limited from developing countries, so that some of these positions are filled by professionals from developed nations.

Nevertheless, in seeking and selecting candidates for training, CIAT is very conscious of the needs of each country and accepts for training professionals at various academic levels. This is especially true with the numerous university graduates without advanced degrees who come to CIAT as postgraduate interns.

During 1976, 18 visiting research associates conducted PhD dissertation research or post-MS research at CIAT; 19 research scholars pursued MSA degrees at several universities, with most scholars doing their thesis research at the Center. In 1976, the universities that agreed to conduct thesis or dissertation research at CIAT included the following: Nacional-ICA (Colombia); La Molina (Peru); Florida, Illinois, Michigan State, Minnesota, Cornell, Wisconsin and Texas A&M (USA); the University of London (England) and the University of Bonn and the Technical University of Berlin (Germany).

Sixty-one professionals were trained as postgraduate interns in research and 25 in that same category specialized in production; 29 persons came for short training periods as special trainees and 28 (plus four postgraduate interns) participated in a short course on cassava production. There were a total of 188 trainees at CIAT in 1976. This figure is slightly lower than that of 1975 (201) because the two production courses on crops and on beef were not given this year. However, there was an increase in the number of postgraduate interns in research, and postdoctoral fellows. Table 1 shows the distribution of the trainees of all categories with respect to the commodity programs.

Through its training program, CIAT provided assistance to 25 developing countries in 1976 and 137 of the total of 188 trainees came from 18 Latin American countries. Tables 2 and 3 show the number of trainees from each country according to the categories of training and to the commodity programs respectively.

Training in Commodities, Research and Production

The training pertaining to commodities is reported in the respective sections of each commodity program. In addition to the training in research of postgraduate interns, research scholars, visiting research associates, and postdoctoral fellows, postgraduate interns were trained in: (a) the first six-month Course for Swine Production Specialists; (b) the four-month Rice Production Training Internship; and (c) the two-month Field Exercise on Epidemiology of Beef Cattle Diseases. Only 21 profesionals received cross-commodity training because of their academic study or the special nature of their training; among this group three were trained in Library and Documentation and seven in Management of Station Operations.

Twenty-eight professionals participated in a one-month Short Course on Cassava Production.

Table 4 shows the number of trainees in each commodity program and discipline with respect to categories of training and total man-months of training.

Training in Management of Experiment Stations

Some international centers have offered training in this area to support their commodity research activities. There are two primary reasons: (a) inefficient operation of experiment stations is too often an obstacle to research programs; and, (b) this type of training is not available anywhere in Latin America with a high level of excellence.

CIAT staff participated in a special workshop in Guatemala sponsored by the Rockefeller Foundation in which the importance of this training was stressed by heads of research and of graduate programs from several countries. CIAT has now taken preliminary steps to combine its present six-month postgraduate internship on Management of Experiment Stations with an MS program with the following graduate schools: the Universidad Nacional-ICA Graduate Program in Tibaitata (Colombia); the Management Graduate Program of the Universidad del Valle (Colombia); and the Agricultural Enterprises Management Graduate Program of the ITESM, in Monterrey, Mexico.

During 1976, seven managers of experimental stations in Brazil, Mexico, Guatemala and Colombia received 5-6 months of training in management of experiment stations. Most of the training was at CIAT but this was supplemented by two one-week visits to experimental stations in Colombia and Ecuador. Other details of this training are to be found in the Station Operations section of this report.

Training Inputs on Experiment Design and Methodology

In line with CIAT research objectives, significant instructional input is provided by the Biometrics Unit. This instruction focuses on planning and designing experiments rather than on traditional statistical analyses. The Biometrics Unit assisted with this type of training for the Swine Production Course and the Intensive Course on Cassava Production during 1976.

Table 1. **Number of professionals trained at CIAT in 1976 by each commodity program with 1975 comparisons.**

	Category of training							
Program	Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Postdoctoral fellows	Total
Beans	18			7	3	7	5	40
Cassava	19		28	3	2	1	2	55
Rice	3	5		3	1			12
Beef	11			13	6	8		38
Swine	2	20						22
Others								
Library and Information Services				3				3
Station Operations Management	7							7
Others	1				7	2	1	11
Total 1976	61	25	28	29	19	18	8	188
1975	58	45	20	27	20	21	3	201

Table 2. Professionals trained at CIAT in 1976 classified by country of origin and category of training.

	Category of training							
	Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Postdoctoral fellows	Total
Latin America and the Caribbean								
Bolivia	3	2		1				6
Brazil	9	1	8	3				21
Colombia	11	4	6	3	14	1		39
Costa Rica		1						1
Chile	1			1	1	1	1	5
Venezuela	5		3					8
Dominican Republic	3			4		1		8
Ecuador				1				1
El Salvador	3					1		4
Guatemala	1	1		2	1	1		6
Guyana				1				1
Honduras	2	3	2	1				8
Mexico	6	4	5	2	1			18
Nicaragua	1	2						3
Panamá	1	1	3					5
Paraguay		4	1					5
Perú	5	2		1	2		1	11
Puerto Rico				1				1
Other countries								
Canada						1		1
Germany						3		3
Great Britain				1		2		3
Holland				6				6
Indonesia						1	1	2
Japan							2	2
Malaysia	4							4
N. Ireland							1	1
Spain						1		1
Tanzania						1		1
Thailand	6							6
United States				1		4	2	7
Total	61	25	28	29	19	18	8	188

Table 3. **Professionals trained at CIAT in 1976 by country of origin and commodity of training.**

	Commodity or program								
Country	Beans	Cassava	Rice	Beef	Swine	Station operations	Library and Information Services	Others	Total
Latin America and the Caribbean									
Bolivia	1			2	2			1	6
Brazil	2	11	1	3	1	3			21
Colombia	10	8	3	10	3	3		2	39
Costa Rica					1				1
Chile	1	1		2				1	5
Venezuela	3	4	1						8
Dominican Republic	1	1		3			3		8
Ecuador				1					1
El Salvador	1			3					4
Guatemala	2			2	1	1			6
Guyana			1						1
Honduras	2	2	2	1	1				8
Mexico	3	9		1	4	1			18
Nicaragua					3				3
Panamá		3			2				5
Paraguay		1			4				5
Perú	2	3	2	3				1	11
Puerto Rico	1								1
Other countries									
Canada	1								1
Germany				3					3
Great Britain	1			2					3
Holland	1	1	2	2					6
Indonesia		1		1					2
Japan	2								2
Malaysia		4							4
N. Ireland	1								1
Spain								1	1
Tanzania		1							1
Thailand		6							6
United States	7								7
Total	42	56	12	39	22	8	3	6	188

Table 4. Professionals trained at CIAT in 1976 by commodity/discipline of specialization and category of training.

Commodity/discipline of specialization	Category of training Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Post-doctoral fellows	Sub-program totals, no.s and (man-months)	Total commodity programs
Beans/agronomy	3			1		3		7 (38)*	
biometrics	2							2 (7)	
economics						1		1 (1)	
entomology	2			1	1		1	5 (39)	
microbiology	1			2		1	1	5 (31)	
physiology	4				1		1	6 (35)	
plant breeding	3						1	4 (19)	
plant pathology	3			2	2	2	1	10 (55)	
seed production				1				1 (1)	
phosphorus studies						1		1 (12)	
Beans total	18			7	4	8	5	42	42 (238)
Cassava/agronomy	7				1		1	9 (59)	
entomology	1							1 (3)	
physiology	1						1	2 (17)	
plant breeding	3							3 (20)	
plant pathology	5				2	1		8 (58)	
processing	1			2				3 (20)	
production			28					28 (28)	
rural sociology				1				1 (2)	
soil microbiology	1							1 (6)	
Cassava total	19		28	3	3	1	2	56	56 (213)
Rice/agronomy	2				1			3 (14)	
plant breeding				1				1 (2)	
production		5						5 (21)	
rural sociology				2				2 (9)	
weed control	1							1 (6)	

Table 4. Continued.

	Category of training								
Commodity/discipline of specialization	Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Post-doctoral fellows	Sub-program totals, no.s and (man-months)	Total commodity programs
Beef/agricultural managment.					1			1 (8)*	
animal health	5			10	2	2		19 (87)	
economics				1	1	1		3 (30)	
pastures & forages	6			2	2	3		13 (72)	
past. weed control	1							1 (3)	
production					1	1		2 (10)	
Beef total	12			13	7	8		40	40 (210)*
Swine/production	2	20							
Swine total	2	20						22	22 (131)
Other subprograms									
biometrics							1	1 (6)	
crop production					1			1 (11)	
information services/library				3				3 (7)	
soil microbiology					1	1		2 (14)	
spec. studies/weed control					1			1 (12)	
station operations/mgment.	7				1			8 (41)	
Total other subprograms	7			3	4	1	1	16	16 (91)
	61 (326)	25 (146)	28 (28)	29 (72)	19 (161)	18 (129)	8 (73)	188	188 (935)

* ( ) Man-months

Training Inputs on Communication and on Management-Economics

Although training at CIAT emphasizes biological commodity research, and its application to field production, the Center recognizes the importance of economic and management factors. Also important are methods and strategies of communication, particularly in relation to the validation and transfer of new technologies through a chain, ranging from research workers and administrators to disseminators of technology at various levels, and finally to the farmer himself. Thus, CIAT's training program includes a specialist in management economics on the professional staff to provide production training inputs directly related to the commodities. Likewise, appropriate inputs are provided on communication for the same type of training.

Training Materials

An important step toward the systematic organization of CIAT's training resources has been the production of instructional materials which (a) would ensure better training results; (b) would free senior scientists from routine teaching responsibilities, and (c) could be made available for within -country training and on-the-job self training directly related to commodities under CIAT's responsibility.

Good-quality audio-visual sets have already been produced on livestock management practices. This effort will be considerably expanded for which a new senior staff member has been contracted.

A needs assessment conducted in 1976 revealed that both research and production training at CIAT greatly needed systematically organized training materials. Until now, this training has been characterized by extensive, time consuming inputs by CIAT research staff. Since the content of this training, once established, changes little over time and is directed to a uniform target audience, it readily lends itself to a packaged information approach. Among various alternatives, the audio-tutorial system, as originally developed in the Department of Biological Sciences at Purdue University (USA), was selected for CIAT production training needs. This approach relies on the availability of relatively self-contained training units consisting of three elements: objective-relevant content exposition, guided trainee practice, and criterion-referenced evaluation. The audio-tutorial approach allows for individualized instruction that may readily be complemented with group discussions, direct trainee-scientist interaction, and lab/field experiences.

During late 1976 a developmental model was identified that would guide future design, development and evaluation activities, relating to the individual units that will make up the audio-tutorial system. The model was developed through the actual production of 11 audio-tutorial training units, in weed control, bean breeding and development of the bean plant.

To develop a given audio-tutorial unit, the model calls for a three- to four-week team effort. The team consists of one or more content specialists and a producer who is assisted by an editor, a photographer, and a graphic artist. According to the model, the development effort must pass through a series of six steps: (a) specification of the purpose of a given unit and translation into trainee-referenced objectives; (b) selection and organization of content; (c) preparation of support material; (d) formative evaluation with representatives of target audience; (e) packaging of the unit; and, (f) final evaluation and implementation.

On the basis of this year's production experiences and the concomitant developmental model, detailed specifications for a three-year production phase for a CIAT-relevant, audio-tutorial system have been drawn up for special project funding.

Within-Country Training

Three countries received assistance from CIAT in conducting within-country training projects.

Ecuador, for a second follow-up year, received limited instructional inputs and organizational guidance for a Crop Production Training Course (primarily rice) conducted by the Instituto Nacional de Investigaciones Agropecuarias (INIAP), in Portoviejo. Also, the training coordinator for the Beef Program visited INIAP to plan for CIAT's assistance in a forthcoming training project on the Ecuadorian coast.

This year the Instituto de Ciencias y Tecnologías Agrícolas (ICTA) in Guatemala, started a Training Program in Crop Production (beans, rice and maize). in Eastern Guatemala with instructors trained at CIAT the previous year, and a training associate from CIAT stationed at ICTA for nine months. This project provided an example of an innovative approach combining in-service training and productive-validative field research. The course was based on field trials to validate new technology for the region and trained 16 participants in a two-phase, nine-month period.

The Rice Program of the Ministry of Agriculture of the Dominican Republic requested CIAT's assistance in August 1976 to conduct a series of practical short courses on rice production for extension agents in a promotion campaign among small farmers and cooperatives to rapidly transfer technology for increased production, that would help end the chronic shortage of that basic food staple in that country. New high yielding rice varieties are available in the Dominican Republic but these, and the cultural practices associated with them, have not been sufficiently adapted despite favorable markets since 1973. CIAT sent its production training staff to that country on short advisory missions and recently stationed one training associate there for six months to assist with organizing and conducting training on rice production.

Financing of Training

Of the 188 trainees at CIAT in 1976, 60 percent were financed from the CIAT core budget. Seventy-nine were supported by 31 donors including international organizations, national institutions and private firms. These donors are shown in Table 5.

Workshop on Training

In April, CIAT senior staff held a two-day Internal Workshop on Training to review and establish objectives and strategies for future activities.

Table 5. **Professionals trained at CIAT in 1976 classified by source of support and category of training.**

Source of support*	Category of training							Total
	Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Post-doctoral fellows	
National and International Interests								
ACAR, Amazonas, Brazil		1						1
Agency for International Development, USAID	1	2		3				6
Banco Interamericano Desarrollo, BID-Honduras	2							2
Banco Interamericano Desarrollo, Washington					7	1		8
Banco Central de Guatemala					1			1
Banco Nacional de Crédito Rural, México	1							1
Banco de México		1						1
Centro Panamericano de Zoonosis				7				7
Centro Internacional de Agricultura Tropical, CIAT	46	10	23	9	11	3	8	110
EMBRAPA, Brazil			3					3
Food and Agriculture Organization, FAO	1					2		3
Fundación Amparo a Pesquisas, FAPERGS, Brazil	1							1
Government of the Federal Republic of Germany		1				2		3
Gobierno Dominicano				1				1
International Development Research Centre, Canada	4	8						12
Internacional de Mercadeo, C.A., Venezuela	1							1

Table 5. Continued.

	Category of training							
Source of support*	Postgraduate research interns	Postgraduate production interns	Short course participants	Special trainees	Research scholars	Visiting research associates	Post-doctoral fellows	Total
Industrias Resistol, S.A., Mexico		2						2
Instituto de Ciencias y Tecnología Agrícolas, ICTA, Guatemala				1				1
Instituto Colombiano Agropecuario, ICA, Colombia				1				1
International Fertilizer Development Center, USA						2		2
Michigan State University, USA						1		1
National Science Foundation, USA						1		1
PROTINAL-INCE, Venezuela	1							1
The Rockefeller Foundation, USA						3		3
The Royal Society, London						1		1
Technical University of Berlin, Germany						1		1
Universidad Autónoma de México		1						1
Universidad de Puerto Rico				1				1
Agricultural University, Wageningen, Holland				6				6
Universidad Pedagógica Nacional, Colombia	2							2
University of Illinois, USA						1		1
Universidad del Tolima, Colombia	1	1						2
	61	25	28	29	19	18	8	188

* All or bulk of financial support provided by or through organization indicated

Table 6. Professionals trained at CIAT in 1976 by training category, country and field.

Name	Country	Program/Discipline	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = Completed) (P = in Process)
Postgraduate research interns				
Aguilar, Immer	Mexico	Bean/physiology	2	C
Alvarez, Eblis	Colombia	Bean/physiology	5	C
Avalos, Feliciano	Perú	Bean/entomology	6	C
Baena, Diosdado	Colombia	Bean/biometrics	3	P
Bandhukul, Rangsit	Thailand	Cassava/agronomy	5	P
Bascur, Gabriel	Chile	Bean/agronomy	3	C
Bazalar, Hernando	Perú	Beef/animal health	12	P
Calderón, Guillermo	Perú	Beef/animal health	1	C
Camarena, Félix	Perú	Bean/plant breeding-biometrics	8	C
Carbonell, Javier	Colombia	Station operations unit/management	6	C
Carrizo, Vicente	Panamá	Swine/production systems	1	C
Castellanos, Víctor H.	Dominican Republic	Cassava/agronomy	3	P
Colasante, Luiz O.	Brazil	Rice/agronomy	6	C
Chan, Seak Khen	Malaysia	Cassava/agronomy	4	C
De Sordi, Guido	Brazil	Station operations unit/management	4	C
Fernández, Héctor	Honduras	Bean/plant pathology	5	C
Freire, Wania María	Brazil	Cassava/plant breeding	8	C
Fuentes, Germán	Bolivia	Beef/pastures & forages	7	C
Fukuda, Chigeru	Brazil	Cassava/plant pathology	8	C
García, Jesús A.	El Salvador	Beef/pastures & forages	5	C
García, Rafael	Dominican Republic	Beef/animal health	8	P
Geh, Swee Lan	Malaysia	Cassava/plant pathology	5	C
Godoy, Gentil	Brazil	Station operations unit/management	4	C
Jarupat, Thanakorn	Thailand	Cassava/plant pathology	8	C
Khelikuzaman, Hussain	Malaysia	Cassava/agronomy	10	P
Kessler, Raúl	Brazil	Beef/animal health	2	C
Lamar, Raúl	Venezuela	Rice/agronomy	3	C
Linares, César H.	Colombia	Rice/weed control	6	C
López, Gustavo	Colombia	Beef/animal health	12	P
Mariot, Edemar	Brazil	Bean/physiology	6	C

Table 6. Continued.

Name	Country	Program/Discipline	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = Completed) (P = in Process)
Martínez, Rafael	Honduras	Bean/agronomy	5	C
Materón, Hernán	Colombia	Station operations unit/management	6	C
Moreno, María Teresa	Colombia	Bean/physiology	2	C
Muñoz, Jaime	Colombia	Bean/biometrics	7	C
Núñez, José Ignacio	Mexico	Cassava/entomology	3	C
Nilmanee, Sanay	Thailand	Cassava/plant pathology	5	P
Papacostas, Pablo	Mexico	Cassava/processing	4	C
Pardo, Alexis	Venezuela	Bean/plant pathology	6	C
Pastrana, Laureno	Mexico	Cassava-Bean/soil microbiology	6	C
Pettinelli, Armando	Brazil	Station operations unit/management	4	C
Ramírez, Carlos Alberto	Colombia	Bean/microbiology	5	C
Ramírez, Esteban	Venezuela	Cassava/agronomy	5	C
Reyes, César A.	Perú	Beef/pastures & forages	7	C
Ríos, Raúl	Bolivia	Bean/plant breeding	6	C
Rodríguez, Pedro	Venezuela	Bean/agronomy	5	C
Rodríguez, Roberto	Brazil	Cassava/agronomy	8	C
Rodríguez, Víctor Manuel	El Salvador	Bean/plant pathology	3	P
Rojanaridpitched, Chareinsuk	Thailand	Cassava/plant breeding	7	C
Romero, José A.	El Salvador	Beef/pastures & forages	5	C
Ropain, Jairo	Colombia	Beef/pastures & forages	4	C
Sánchez, Luis Gerardo	Guatemala	Station operations unit/management	6	C
Sánchez, Nelson	Venezuela	Bean/plant breeding	5	C
Tiraporn, Charn	Thailand	Cassava/plant breeding	5	P
Tan, Swee Lian	Malaysia	Cassava/physiology	10	P
Unterladstatter, Roberto	Bolivia	Beef/pastures weed control	3	C
Vargas, Héctor	Colombia	Bean/entomology	5	C
Vásquez, Antonio	Mexico	Station operations unit/management	6	C
Vega, Julio A.	Nicaragua	Swine/production systems	2	C
Vichukit, Vichan	Thailand	Cassava/agronomy	9	C
Wagner, Birmania	Dominican Republic	Beef/pastures & forages	6	C
Wood, Rogelio	Mexico	Cassava/plant pathology	3	C

Table 6. Continued.

Name	Country	Program/Discipline	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = Completed) (P = in Process)
Postgraduate production interns				
Aguilera, Blas	Paraguay	Swine production	6	C
Alvarez, Alvaro J.	Colombia	Swine production	6	C
Ataide, Nilton	Brazil	Swine production	6	C
Berducido, Leonel	Guatemala	Swine production	6	C
Blanco, Carlos	Nicaragua	Swine production	6	C
Boutier, Luis Pablo	Bolivia	Swine production	6	C
Fajardo, Braulio	Honduras	Swine production	6	C
Florentín, Carlos	Paraguay	Swine production	6	C
García, Olegario	Mexico	Swine production/animal health	10	P
Gómez, Juan	Panama	Swine production	6	C
González, Andrés	Paraguay	Swine production	6	C
González, Antonio	Bolivia	Swine production	6	C
Manjarrez, Bartolomé	Mexico	Swine production	4	C
Méndez, Asunción	Mexico	Swine productoin	6	C
Oddone, Blas	Paraguay	Swine production	6	C
Padilla, Manuel	Costa Rica	Swine production	6	C
Ramos, Luis Fernando	Colombia	Swine production	6	C
Ruiz, José A.	Nicaragua	Swine production	9	C
Silva, Roberto	Mexico	Swine production	5	C
Venegas, Jairo	Colombia	Swine production/beef	10	P
Castro, José H.	Colombia	Rice production	4	C
Del Castillo, Dennis	Perú	Rice production	4	C
Larios, Roberto	Honduras	Rice production	4	C
Rázuri, Antonio	Perú	Rice production	5	C
Rubí, Rolando	Honduras	Rice production	4	C

Table 6. Continued.

Name	Country	Program/Discipline	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = Completed) (P = in Process)
Short course participants				
Baena, Hugo	Colombia	Cassava production	1	C
Borges, José Eduardo	Brazil	Cassava production	1	C
Cáceres, José W.	Honduras	Cassava production	1	C
Cortés, Carlos	Colombia	Cassava production	1	C
Dos Santos, Antonio	Brazil	Cassava production	1	C
Echeverri, Manuel	Colombia	Cassava production	1	C
Fuentes, Claudio	Colombia	Cassava production	1	C
González, Fernando	Mexico	Cassava production	1	C
Guerra, Mario	Panama	Cassava production	1	C
Guevara, Arturo	Mexico	Cassava production	1	C
Jaramillo, Alejandro	Panama	Cassava production	1	C
Macedo, Manuel C.	Brazil	Cassava production	1	C
Malo, Eddy	Mexico	Cassava production	1	C
Marceno, Luis	Venezuela	Cassava production	1	C
Marquez, Marcio	Brazil	Cassava production	1	C
Mayeregger, Manuel	Paraguay	Cassava production	1	C
Muñoz, Rodián Iván	Venezuela	Cassava production	1	C
Oliveira, Fernando	Brazil	Cassava production	1	C
Olivero, Carlos	Venezuela	Cassava production	1	C
Orozco, Alvaro	Colombia	Cassava production	1	C
Pérez, Néstor	Panama	Cassava production	1	C
Pérez, Octavio	Colombia	Cassava production	1	C
Pessoa, Severino	Brazil	Cassava production	1	C
Pires, Pedro	Brazil	Cassava production	1	C
Prudot, Agustín	Honduras	Cassava production	1	C
Reyes Humberto	México	Cassava production	1	C
Ternes, Murito	Brazil	Cassava production	1	C
Yong, Carlos	Mexico	Cassava production	1	C

Table 6. Continued.

Name	Country	Program/Discipline	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C= Completed) (P= in Process)
Special trainees				
Aguilar, Catalina de	Mexico	Bean/microbiology	1	C
Becerra, María Nelly de	Bolivia	Beef/animal health	4	C
Burgos, José A.	Honduras	Beef/animal health	2	C
Da Costa, Joaquim	Brazil	Beef/animal health	2	C
De Matos, José A.	Brazil	Beef/animal health	2	C
Dorresteijn, Hans	Holland	Rice/rural sociology	6	C
Egas, Jaime	Ecuador	Beef/economics	6	C
Evans, Stuart	Great Britain	Beef/animal health	1	C
García, Alvaro	Colombia	Bean/soils microbiology	2	C
García, Omar	Colombia	Beef/animal health	1	C
Ordóñez, José Hugo	Perú	Cassava/production processing	2	C
Genao, Diana	Dominican Republic	Information Services/library	2	C
Gooren, Gerardus	Holland	Rice/rural sociology	3	P
Lotter, Donald	USA	Bean/agronomy	3	C
Marmolejo, José	Dominican Republic	Beef/animal health	2	C
Martínez, Marco Tulio	Guatemala	Beef/animal health	2	C
Maturana, René	Chile	Beef/animal health	2	C
Méndez, Marco A.	Mexico	Beef/animal health	2	C
Monllor, Amelia de	Puerto Rico	Bean/plant pathology	1	C
Pineda, Jorge	Guatemala	Bean/seed production	1	C
Rava, Carlos A.	Brazil	Bean/plant pathology	2	C
Rewinkel, Bernardus	Holland	Beef/pastures & forages	3	C
Rewinkel, Margaretha	Holland	Beef/pastures & forages	3	C
Robinson, Ana Dolores	Dominican Republic	Information services/library	2	C
Somwaru, Ramlakhan	Guyana	Rice/plant breeding	2	C
Strobosch, Peter	Holland	Cassava/rural sociology	2	C
Tolentino, Francisca	Dominican Republic	Information services/library	3	C
Trujillo, Freddy	Colombia	Cassava/processing	3	C
Van Gent, Rudolph	Holland	Bean/entomology	7	P

Table 6. Continued.

Name	Country	Program/Discipline	Institution where enrolled	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = completed) P = in Process)
Research scholars					
Acuña, Luis	Colombia	Cassava/agronomy	Univ. of Guelph, Canada	4	C
Altieri, Miguel Angel	Chile	Special studies/weed control	Prog. Graduados, ICA, Colombia	12	C
Argel, Pedro	Colombia	Beef/pastures & forages	Univ. of Queensland, Australia	12	P
Calvo, Fabio	Colombia	Beef/pastures & forages	Esc. Nal. Agricultura, Mexico	4	P
Campos, José Y.	Colombia	Beef/agric. management	Inst. Tecnol., ITESM, Mexico	8	P
Cárdenas, Moisés	Mexico	Bean/plant pathology	Prog. Graduados, ICA, Colombia	12	P
Dominguez, Carlos	Colombia	--/crop production	Univ. of Guelph, Canada	12	P
Galindo, José	Colombia	Bean/plant pathology	Cornell Univ., USA	6	P
Garcés, Carlos	Colombia	--/agric. engineering	Prog. Graduados, ICA, Colombia	4	C
García, Edmundo	Colombia	Rice/agronomy	Es. Luiz de Queiroz, Brazil	5	P
Gómez, William F.	Colombia	Beef/production	Prog. Graduados, ICA, Colombia	3	P
Hidalgo, Rigoberto	Colombia	Bean/physiology	Cornell Univ., USA	12	P
Laberry, Rafael	Peru	Cassava/plant pathology	Prog. Graduados, ICA, Colombia	12	C
Mattos, Luz Leonor	Peru	Cassava/plant pathology	Univ. Agraria La Molina, Perú	12	P
Moncada, Hemerson	Colombia	Beef/animal health	Univ. Hannover, Germany	3	P
Morales, Víctor	Colombia	--/soil microbiology	Univ. of Florida, USA	12	P
Ramírez, Luis E.	Colombia	Beef/microbiology	Univ. de Antioquia, Colombia	5	C
Samayoa, Otto	Guatemala	Beef/economics	Univ. Católica, Chile	11	C
Vargas, Octavio	Colombia	Bean/entomology	Cornell Univ., USA	12	P

Table 6. Continued.

Name	Country	Program/Discipline	Institution where enrolled	Months training completed as of December 31, 1976	Status as of December 31, 1976 (C = Completed) (P = in Process)
Visiting research associates					
Betancourt, Antonio	Colombia	Beef/animal health	Texas A&M Univ., USA	12	C
Ellis, Michael	USA	Bean/plant pathology	Univ. of Illinois, USA	4	C
Evans, David	Great Britain	Beef/animal health	Univ. of London, England	12	P
Fuentes, César	Spain	--/soils microbiology	Inst. Nal. Inv. Agr., INIA, Spain	2	C
Galway, Nicholas	Great Britain	Bean/agronomy-entomology	Univ. of Cambridge, England	3	P
Hammond, Lawrence	USA	Bean/soils phosp. rocks	Michigan State Univ., USA	12	C
Hudgens, Robert	USA	Bean/agronomy	Univ. of Florida	12	P
Martínez, Romero	Guatemala	Bean/nitrogen fixation	Michigan State Univ.	8	C
Muller, Frank	Germany	Beef/pastures & forages	Univ. of Bonn, Germany	9	P
Paniagua, César	Dominican Rep.	Bean/agronomy	Michigan State Univ., USA	7	C
Pervis, Dennis	Canada	Bean/economics	Michigan State Univ., USA	1	C
Rubinstein, Eugenia de	Chile	Beef/economics	Univ. of Minnesota, USA	12	P
Salazar, Mauricio	El Salvador	Beef/pastures & forages	Univ. of Florida, USA	7	C
Schellenberg, Rupprecht	Germany	Beef	Tech. Univ. of Berlin, Germany	12	C
Schultze-Kraft, Rainer	Germany	Beef/pastures & forages	Justus Liebig Univ., Germany	1	C
Soekanto, Lebdosoekojo	Indonesia	Beef cattle production	Univ. of Florida, USA	6	C
Teri, James	Tanzania	Cassava/plant pathology	Cornell Univ., USA	5	P
Webster, David	USA	Bean/plant pathology	Univ. of Wisconsin, USA	4	P
Postdoctoral fellows					
Castro, Abelardo	Chile	Cassava/agronomy		11	P
Eskafi, Fred	USA	Bean/entomology		9	C
Halliday, John	N. Ireland	Bean/soils microbiology		11	P
Hayakawa, Yoshihiko	Japan	Bean/physiology		8	C
Mendoza, Gastón	Perú	Biometrics		6	P
Swindell, Richard	USA	Bean/plant breeding		4	P
Thung, Michael	Indonesia	Cassava/physiology		12	P
Yoshii, Kazuhiro	Japan	Bean/plant pathology		12	C

CONFERENCES

Conference activities at CIAT are intended primarily to serve the needs and objectives of the commodity programs.

As noted in Table 7 CIAT sponsored or co-sponsored 14 events in 1976, including scientific seminars, workshops and organizational meetings. The most important, because of its size and world-wide effect, was the IV International Symposium on Tropical Root Crops, with a participation of 170 delegates, representing 44 countries.

Presentation Days, a seminar for directors of research of Latin America countries and representative donors, is the annual presentation to client institutions of research advances at CIAT. This was held April 19-20, 1976, and was followed by a round table discussion with directors of research of countries of Latin America on ways and means to facilitate international cooperation and the transfer of technologies emerging from CIAT.

The meeting of rice research workers from Latin America in August included many former trainees of CIAT's Rice Program and resulted in the consolidation of the rice research workers network that will conduct an expanded program of international trials.

In August, 65 microbiologists and soil scientists of developed and developing countries met to share advances on nitrogen fixation and to plan future research with particular attention to beans and forage legumes.

In addition to the above mentioned conferences, there were 11 scientific, single-lecture seminars given by visiting scientists.

However, since there is a large surplus of conference space and time available, CIAT hosts a number of events related to agricultural research and development, sponsored by other organizations.

Eight other seminars and workshops were held by outside organizations in the Center's facilities.

The Cassava and Swine Programs, and the Animal Health Unit held one training course each. The Public Information Office used conference room facilities on many occasions to present CIAT's programs to visiting groups. Finally, the facilities were used by all programs for internal meetings, and the social, labor and cooperative groups at CIAT. Occupancy records for 1976 show an average of 50 percent for the five meeting rooms in the conference area. Room F showed a 100 percent occupancy for five consecutive months.

Table 7. Events held in CIAT conference facilities in 1976.

Date	Event	No of particpants
CIATsponsored or co-sponsored scientific seminars and workshops		
April 19-20	CIAT Presentation Days	80
April 21	Round table with Latin American research directors	12
April 23	Panel discussion on commodity yields in Latin America	80
May 7	1st. Regional Meeting on Interaction of Weeds-Crops-Insects	80
June 14-16	Presentation to IICA Tropicos	6
Aug. 2-7	IV Symposium on Tropical Root Crops	170
Aug. 12-14	IRRI-CIAT rice trials in Latin America	50
Oct. 18-20	VIII Latin American Meetin on *Rhizobium*	65
CIAT organizational events		
Feb. 24-25	Workshop on Training at CIAT	60
March 1-2	Cooperation network planning (Rockefeller Foundation, Texas A&M Univ., Univ., of Illinois, USAID and CIAT)	20
April 24	Special Rice Program Review	60
Sept. 6-7	Bean Germplasm Advisory Committee	8
Dec. 11-14	Bean Program Advisory Committee	10
Dec. 13-17	CIAT Program Reviews	60
CIAT Short Courses		
March 15-Sept. 15	Swine Production	20
Sept. 30-Nov. 30	Cassava Production	32
Sept. 30-Nov. 30	Field training in beef cattle diseases	7
CIAT hosted events, sponsored by other institutions		
March 22-27	Workshop on Root-knot Nematodes (North Carolina State Univ.)	25
April 5-7	Rockefeller Foundation — Education for Development	20
May 14-15	INCOLDA — Marketing procedures	15
Oct. 4-6	National Academy of Sciences — World Nutrition Study	15
Oct. 20-23	INCOLDA — Rural Marketing	25
Nov. 4-6	USIS — World Food Policies	40
Nov. 15-18	Irrigation and Drainage (Venezuela)	10
Nov. 22-27	IDRC — Communication Research for Rural Development	80

Library and Information Services

The Library and Information Services Unit not only provides basic support for all research and training activities at CIAT, but also has a major function in contributing to the transfer of existing, as well as new technology developed at CIAT or elsewhere, through publications, documentation services, and public information activities.

Organizationally speaking, it is a component of International Cooperation. In this capacity, the Library and Information Services Unit has always stressed a philosophy of delivering the needed information to its immediate users. This philosophy is translated into activities that have gradually become more specialized in terms of subject matter, and personalized in terms of service.

Library and Documentation Services

The basic collection of the Library now has approximately 37,500 books (including bound journal volumes), and 1,302 journals are received regularly.

Processing of all the backlog information existing on cassava was completed in 1976. CIAT's collection of cassava documents, therefore, is probably the most complete in the world, which allows practically total coverage in all services offered by the Cassava Information Center.

In addition to the regular distribution of abstract cards and provision of specific topic searches to subscribers, a second compilation of abstracts in book form was issued. Although Volumes I and II of Abstracts on Cassava were published in English, there are plans for the publication of these two volumes in Spanish during 1977. The Center will, then, issue semiannual supplements in both languages to provide a permanent record of cassava information for scientists. The service of abstract cards, however, will be maintained as a current awareness system and as a means of answering specific topic searches requested.

The initial grant from the International

Development Research Center (IDRC) which established the Cassava Information Center at CIAT, terminated in February. Negotiations for continuing IDRC's assistance culminated in May with an expanded Phase II for this project which is characterized by a greater integration of documentation *per se* with other communication activities. These include: (a) the publication of monographs on particular aspects of cassava giving a state-of-the-art report based on existing knowledge to date, while providing the analytical views of the scientist/writer; (b) the publication of a Cassava Newsletter; (c) the continuation of the current series of Manuals such as *Field Problems of Cassava;* and, (d) the selective reproduction of published journal articles which, due to their particular importance, should reach a wider audience. This latter activity is particularly important in the developing countries where access to libraries (and thus, to standard scientific journals) is limited.

The Bean Information Center at CIAT was started in 1975 with an initial grant from the Inter-American Development Bank (BID) which partially covered the costs of this activity and enabled CIAT to apply the experience acquired through the Cassava Information Center and cover the literature on beans (*Phaseolus vulgaris* L.) under tropical conditions. The major advantage of these documentation activities as compared to the more traditional publication of only bibliographic listings is that as soon as documents are collected, the information is provided to the scientists. In addition, Volume I of Abstracts on Beans has been published.

Paralleling activities in bean and cassava documentation, CEDEAL (Centro de Documentación Económica para la Agricultura Latinoamericana) has offered similar services to agricultural economists and policy-makers in Latin America during 1976. The first volume of abstracts in this social science field was also published and distributed during the year.

Table 1 summarizes the number of abstracts processed in 1976 and their distribution in terms of countries served and recipient institutions and persons.

It should be clarified that abstract cards are an information medium specifically designed for personal use. Consequently, they are sent primarily to scientists rather than institutions (libraries). Conversely, the series of abstracts in book form receive a wider distribution to institutions without excluding persons that subscribe to the service.

In Table 2, countries having the five highest percentages of use of documentation services are presented for the three areas covered — cassava, beans, and

Table 1. **Distribution of abstracts processed during 1976 in cassava, beans, and agricultural economics and development.**

Documentation field	No. of abstracts processed	No. of countries served	Recipients
Cassava	1,037	45	318
Beans	1,475	47	420
Agricultural economics and development	750	20	603

Table 2. **Countries having the five highest user percentages of documentation services for each area covered.**

	Documentation field		
Country	Cassava	Beans	Agricultural economics
Colombia	19.18	19.76	39.00
Brazil	13.21	10.00	
Venezuela	4.40		14.30
México	3.77	3.57	
U.S.A.	3.77	6.19	7.14
Ecuador	3.77		4.54
Nigeria	3.14		
Guatemala		3.33	
Peru			5.19

agricultural economics in Latin America.

Table 3 presents figures on the distribution of the Tables of Contents service, whereby scientists receive monthly copies of tables of Contents from journals in Plant, Animal and Social Sciences, and may request photocopies of articles in which they may be interested.

The system of coupons started in 1975 for the purchase of photocopies has had wide acceptance among users of these services but, the problem of foreign exchange remained unresolved for countries with very rigid resrictions in this respect. However, in 1976, the Instituto Interamericano de Ciencias Agrícolas (IICA) agreed to collaborate with CIAT so that country representatives from that institution can transmit requests for CIAT services from users within the countries, and receive payment in local currency. Similarly, agreements with other national institutions have been made for the distribution and processing of services such as the Tables of Contents within each country. In this manner, national institutions can use the CIAT library as a backstop to fill photocopyingrequests for those materials not locally available. For example, CIAT is bulk mailing the Tables of Contents each month to the Library of the Facultad de Agronomía de Buenos Aires for internal distribution in Argentina. Requests are, then, processed through the Facultad and payment (whenever the CIAT Library is used) is effected through the IICA Office in Buenos Aires. Similar arrangements are being implemented with the Facultad de Agronomía in Paraguay and in Venezuela.

Table 3. **Journals covered and distribution of Tables of Contents in plant, animal, and social sciences.**

Field	Journals covered	Countries served	Recipients
Plant sciences	317	29	629
Animal sciences	285	27	539
Social sciences (CEDEAL)	58	34	804

Other services provided by the Library and Documentation program include short, specific bibliographies which are done on request and include as many abstracts as may be available. Sixty-two such bibliographies were produced in 1976.

A new bibliographic series called "Selecciones de Reseñas de Libros" (selected book reviews) was started. Similar in concept to the Tables of Contents, this series reproduces selected book reviews published in technical journals. Besides being a current awareness tool on new books for scientists, this publication will also aid librarians in their acquisitions activities.

Three librarians from the Dominican Republic were given in-service training for two months.

Public Information Office

Table 4 analyzes the number of visitors that came to CIAT in 1976.

In addition, the Public Information Office handled both national and international media relations. As a result, highly informative articles on CIAT have appeared in several newspapers and magazines in Latin America, and in such countries as Thailand, Malaysia and the Philippines.

Several national and international TV programs and broadcasting corporations have recorded technical information at CIAT, which appeared in various countries.

CIAT also participated in agricultural fairs such as the "Fiesta Nacional de la Agricultura" in Palmira and the "Muestra Nacional de Agricultura y Artesanías" in Bogotá, during 1976.

Information Services

Integration of documentation services with editing and printing activities has been accomplished in such a way that, in addition to the production and distribution of abstract cards, the annual compilations of Abstracts on Cassava, Abstracts on Beans, and Abstracts on Latin American Agricultural Economics and Development, were produced and distributed in December.

Over 30 publications were printed during the year. For some of these publications demand was such that reprinting was required during the year. Of particular impact and utility by scientists, as well as by extension workers and farmers, were the field manuals such as: *Field Problems of Rice* published in English and Spanish; and *Field Problems of Cassava,* in English, Spanish and Portuguese. CIAT received and approved a request from the Brazilian journal

Table 4. **Countries of origin of visitors to CIAT, 1976.**

Countries	Farmers	Students	Scientists and policy-makers	Civic groups	Other professionals	Others	Total
Colombia	357	862	95	720	63	345	2,442
North América, Europe and other overseas countries	22	60	133	19	26	18	278
Venezuela	49	86	18	-	28	31	212
Ecuador	15	93	15	-	14	7	144
Central America and the Caribbean	39	22	17	-	15	23	116
Brazil	3	-	24	2	-	-	29
Peru	3	2	14	-	3	4	25
Bolivia	-	3	19	-	1	-	23
Other South American countries		5	8		12	5	30
Total	488	1,133	343	741	161	433	3,299

Lavoura Arroceira to print Field Problems of Rice in Portuguese as well.

During 1976, the CIAT Publications Committee adopted a policy of encouraging CIAT scientists to publish their results in established scientific journals. (These publications are reported at the end of each chapter of this Annual Report). From these publications, reprints are made at CIAT for wider distribution. In 1977, translations of some of these articles will be made for publication either simultaneously with the journals or immediately after they appear in journals.

Finally, a monthly internal newspaper ARCOS began publication this year, as an efficient means of communication within the institution's various strata.

CIAT Publications

The following publications were produced by the Library and Information Services during 1976:

AS- 1	Noti-CIAT
AE- 1	Noti-CIAT
AS- 2	Noti-CIAT
AE- 2	Noti-CIAT
AS- 3	Noti-CIAT
BE- 6	Annual Report. 1975. 315 p.
BS- 6	Informe Anual. 1975. 322 p.
	(The following 12 publications, constituting the annual reports of CIAT's six commodity programs, were also issued as separates in addition to forming a part of the comprehensive annual reports.)
	Cassava Production Systems. 57 p.
	Sistemas de Producción de Yuca. 63 p.
	Bean Production Systems. 58 p.
	Sistemas de Producción de Frijol. 64 p.
	Rice Production Systems. 16 p.
	Sistemas de Producción de Arroz. 18 p.

Maize Production Systems. 10 p.

Sistemas de Producción de Maíz. 11 p.

Beef Production Program. 64 p.

Programa de Producción de Ganado de Carne. 72 p.

Swine Production Systems. 20 p.

Sistemas de Producción de Ganado Porcino. 23 p.

BE- 7 1975 Research Highlights. 80 p.

BS- 7 1975 Progresos de Investigación. 94 p.

DE- 5 **LOZANO, J. C.** and **BOOTH, R. H.** Diseases of cassava *(Manihot esculenta* Crantz). 40 p.

ES- 4 **GUTIERREZ, N.** and **BUITRAGO, J.** Cálculo de raciones de mínimo costo para cerdos en zonas tropicales. 15 p.

ES- 6 **CLAVIJO, H.** and **MANER, J. H.** El empleo del banano de rechazo en la alimentación porcina. 20 p.

ES-16 **DOLL, J.** Control de malezas en cultivos de clima cálido. 10 p

ES-17 **BOOTH, R.H.** Almacenamiento de raíces de yuca. 20 p.

EE-20 **COCK, J. H., WHOLEY, D.** and **LOZANO, J. C.** A rapid propagation system for cassava. 11 p.

ES-20 **COCK, J. H.** et al. Sistema rápido de propagación de yuca. 13 p.

EE-21 **DOLL, J. D.** and **PIEDRAHITA C., W.** Methods of weed control in cassava. 12 p.

ES-21 **DOLL, J. D.** and **PIEDRAHITA C., W.** Métodos de control de malezas en yuca. 12 p.

ES-22 **DOLL, J. D.** and **ARGEL, P.** Guía práctica para el control de malezas en potreros. 30 p.

GE-16 **LOZANO, J. C.** et al. Field problems in cassava. 127 p.

GS-16 **LOZANO, J. C.** and others. Problemas en cultivos de la yuca. 127 p.

GP-16 **LOZANO, J. C.** and others. Problemas no cultivo da mandioca. 127 p. (Port.)

HS-27 **Biblioteca.** Catálogo de publicaciones periódicas de la Biblioteca del CIAT. 78 p.

HE-28 **Cassava Information Center.** Abstracts on cassava (*Manihot esculenta* Crantz). Vol. II. 302 p.

HE-29 **Bean Information Center.** Abstracts on field beans (*Phaseolus vulgaris* L.). Vol. I. 494 p.

HE-30 **CEDEAL.** Resúmenes analíticos en economía agrícola latinoamericana. Vol. I. 394 p.

Directory of persons interested in cassava and other tropical root crops. 49 p.

Research support groups

BIOMETRICS UNIT

Introduction

During its fourth year of service, the Biometrics Unit continued to provide assistance in planning, designing, analyzing and interpreting experiments carried out by CIAT's research programs. The Biometrics Unit has five basic functions.

Statistical consulting

The Unit offers statistical assistance in every developmental stage of a project including planning, data processing, statistical analysis appropriate to the design used, and finally, an interpretation of results. These services are provided to all programs at CIAT and to other institutions such as the Instituto de Ciencias y Tecnología Agrícola (ICTA) in Guatemala, the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador, the Empresa Brasilera de Pesquisas Agropecuarias (EMBRAPA) in Brazil, and the Instituto Colombiano Agropecuario (ICA) in Colombia.

Design and maintenance of information systems

In some large research projects, the volume of data generated is large enough to justify the creation of a data base and an efficient system of access and up-dating of the data base. The Statistical Analysis System (SAS) has been used for this purpose because it is not only an excellent package for statistical analysis, but is also efficient in handling large volumes of information.

Cooperative research projects

The Biometrics Unit participates in cooperative projects with other CIAT programs to satisfy subject matter needs and to provide some opportunities for the application or development of new statistical methodology. This has contributed to a better understanding of the functions a Biometrics Unit can develop in a research center.

Evaluation of technology

The Unit collaborates with research programs on studies of the impact of new technologies developed at CIAT as compared to the techniques currently used by the farmer. These conclusions will be forwarded to the national institutions charged with the dissemination of the improved techniques.

Statistical training

The Biometrics Unit also provides

training in statistics and data processing to CIAT's scientific personnel, members of other research institutions invited by CIAT for seminars or short courses, and to trainees.

Cooperation with Research Programs

Bean Program

*The Bean Breeding Information System (SIFFRI).** In order to meet present and future needs of the CIAT Bean Program, the Biometrics Unit has developed an information system to fulfill the following basic requirements:

- Registration of all genetic material that enters and leaves the system
- Recovery of all crosses and selections from a parent
- Selection of the parents, their progeny and selections meeting the criteria combinations of interest.
- Reconstruction of the pedigree of a given cross or selection
- Registration of discarded selections (not considered promising) and the reasons for their elimination
- Classification of genetic materials according to their characteristics of taxonomic integration
- Periodic reporting of missing data and inventory control of viable seed
- Statistical analysis of the information contained in the system
- Production of labels from individual cards to be used as the field book for crosses and selection
- Finding of the similarity index between actual and potential parents
- Integration of the system information.

SIFFRI has been successfully developed in the areas of data management, recovery of information concerning parents, progeny and characteristics of the crosses. For the statistical analysis of the data system, the Unit uses SAS version 76.2 which, together with programs developed by the Unit, is also used for data handling.

SIFFRI has several data sets: the germplasm bank; the promising accessions file containing their main characteristics; the crosses file; the file of promising accessions used as parents; and several other files created to meet specific needs of the several disciplines in the Bean Program. A selections file will be incorporated in the future.

From now on, efforts will be directed toward the taxonomic integration, handling of the information relative to first generations, and to the development of a suitable methodology to fully integrate all the information from the several disciplines in the Bean Program.

Using information coming from the Bean Program files, the Unit produced the data pages for a catalogue characterizing 780 promising accessions of *Phaseolus vulgaris*. Furthermore, some preliminary statistical analyses (frequency tables, correlations between characteristics, etc.) have been performed on data from SIFFRI.

Comparisons between lattice designs

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* Sistema de Información de Fitomejoramiento de Fríjol

and randomized complete block designs for evaluating bean yield trials. In order to provide better consulting service on the planning and design of a bean yield trial, the Biometrics Unit studied the relative efficiency of a lattice design with respect to the randomized complete block design (RCBD) under several soil conditions.

When selecting an experimental design, a prime concern is to choose a design which minimizes the variance of the experimental error. The RCBD is one used to test the difference in treatment effects under heterogeneous conditions of the experimental units. Appropriate use of this design requires that the variability among blocks be as large as possible while the variability within blocks be minimized. When the number of treatments is too large (>12 according to Kempthorne[1], >10 according to Gómez, KA.[2]), the RCBD is not efficient since it is difficult to obtain a soil band homogeneous enough to be considered as an appropriate block. This situation is found in bean variety trials where large numbers of genetic materials are tested. Furthermore, the bean experiments in CIAT are carried out in soils with a high heterogeneity index. Consequently, it is necessary to use designs which control more efficiently the soil heterogeneity effect. A step in this direction is the use of the lattice design. A lattice design can also be analyzed as an RCBD if replications are considered as complete blocks. Thus, it would be possible to calculate the relative efficiency of the lattice design with respect to the RCBD. The data used for this study came from eight yield trials done by the agronomy and breeding groups of the Bean Program. Table 1 shows the results of this study.

From the results, it can be concluded that for a large number of varieties the lattice design is more efficient than the RCBD. It is standard statistical practice to justify the use of a lattice design only when its relative efficiency with respect to the RCBD exceeds 105 percent. Average

Table 1. **Relative efficiency of the lattice design compared to the complete random block design for evaluating bean yield trials.**

Site	Lattice type	No. of varieties	Average yield (kg/ha)	L.S.D. (kg/ha)		Relative efficiency[1]	RHo[2]
				RCBD	Lattice		
Popayán	5x5, triple	25	795	34	31	109	.96
Dagua	5x5, triple	25	2,222	13	10	126	.95
CIAT	5x5, triple	25	1,615	23	15	184[3]	.92
CIAT	5x5, triple	25	850	40	29	151	.75
Monteria	6x7, triple	42	872	29	25	123	.96
CIAT	7x7, simple	49	1,851	11	10	107	.98
Boliche (Ecuador)	5x5, triple	25	2,380	16	16	102	1.00
CIAT	5x5, triple	25	1,545	21	21	105	1.00

[1] Relative efficiency of design A with respect to design B as $\frac{\text{CM error below B}}{\text{CM error below A.}}$

[2] Spearman's RHo correlation coefficient, which measures the linear correlation among the ranks of the ordered means under RCBD and lattice design.

[3] The high relative efficiency observed in this experiment is partially due to the two incomplete blocks that were inundated and whose results greatly differed from the rest.

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[1] Oscar Kempthorne, **The Design and Analysis of Experiments** (Huntington, N.Y.: Robert E. Krieger Publishing Company, 1975) p. 631.

[2] Kwanchai A. Gómez, **Techniques for Field Experiments with Rice** (Los Baños, Philippines: International Rice Research Institute, 1972) p. 7.

efficiency over the eight trials was 126 percent. Another manifestation of the lattice design's superiority over the RCBD is its higher ability to detect as significant smaller differences between variety means. This may be observed from the columns indicating the least significant difference (L.S.D.) under each design.

Other cooperative programs. During 1976, CIAT established the first International Bean Yield and Adaptation Nursery, consisting of more than 100 yield trials from countries throughout the world. In order to combine statistical analyses a common experimental design was used in every trial; a lattice design (5 x 5) with four replications was chosen. The Biometrics Unit participated in the choice of the experimental design, the codes for collecting the information derived from these trials and the planning of the statistical analysis of data from the nursery. Results have been received from a few trials. In addition to the processing and statistical analyses of the data, the Biometrics Unit will use this data to extend the previously described evaluation of the lattice design.

The Unit has collaborated with the bean pathology group in developing a resistance index to bean rust applicable to all the varieties tested in the International Bean Rust Nursery.

This year, Biometrics completed the processing and tabulation of the bean production agro-economic surveys done by CIAT economists in several regions of Colombia.

Beef Program

Herd Systems Project I Experiment. The Herd Systems Project I, a cooperative activity between Biometrics and the Beef Program, began in July 1972 and will continue through April 1978. Due to the large amount of data periodically generated, it was necessary to design a system to classify, sort, and analyze the data. At present, Biometrics has processed and analyzed all the information available up to June 1976. The method used for the statistical analysis was developed by Harvey[3], by adapting for the computer the analysis technique for unbalanced designs proposed by Henderson[4]. (See Biometrics Section, 1975 Annual Report and Beef Section, 1975 and 1976 Annual Reports).

In June 1976, the animal health team of the Beef Program initiated a study to be re-evaluated in June 1977, on the practicality of the metabolic profiles test to evaluate diets based on improved pastures, and mineral and energy supplementation on beef production and fertility. The initial participation of Biometrics in this project was the planning of statistical analysis. Biometrics obtained the basic descriptive statistics for the various blood clinical parameters at two bleeding dates, June and August 1976. At each bleeding, the effects of mineral supplementation, protein supplementation, improved pastures, and early weaning on the various blood parameters were independently analyzed.

Foot and mouth disease control. This project has been carried out cooperatively by ICA and CIAT with the participation of the animal health, economics and biometrics groups of both institutions. The CIAT Biometrics Unit collaborated in two aspects. First, a semi-Markov stochastic model for determining the proportions of animals at every stage of the disease over the long run was developed. Using this

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[3] Walter R. Harvey,"Least-Squares Analysis of Data with Unequal Subclass Numbers," Agricultural Research Service, ARS-20-8 (1960).

[4] C.R. Henderson, "Estimation of Variance and Covariance Components," Biometrics, IX (1953).

model, an economic evaluation methodology was developed to compare alternative control strategies for the disease. Then, the unit assisted in developing an appropriate sampling methodology to estimate production parameters on cattle farms of the Colombian Northern Coast.

Epidemiology surveys. During 1976, the Biometrics Unit collaborated with the animal health group of the Beef Program in two epidemiology studies to establish the prevalence of five major cattle diseases, two caused by hemoparasites and three classified as reproductive diseases. The first study was performed in cooperation with EMBRAPA in the research station at Campo Grande, Matto Grosso, in Western Brazil. The second study was carried out in Santander de Quilichao (Colombia) with professionals from the Panamerican Zoonosis Center in Buenos Aires, who were invited by CIAT for a field training course. Biometrics selected the appropriate sampling methodology for both studies that would allow valid probability statements with a given confidence level. This methodology included developing and testing of the questionnaire, the choice of the sample, data quality control and electronic processing of the data.

This year, a computer simulation model for cattle farms was completed in collaboration with the Beef Program's economics group. A preliminary operation manual of this model will be published in the near future. The model is written in FORTRAN IV and allows an economic analysis of cattle farms under intensive pasturage. It has been adapted and used in regions of more intensive pasturage in Ecuador and Guatemala.

The unit completed the statistical analyses of the early weaning experiment on commercial farms in the Llanos of Colombia, and some unbalanced factorial experiments of pangola pasture (stocking rate and nitrogen fertilization) and other experiments of intensive fattening of Zebu cattle and pasture, and forage trials.

Cassava Program

Cassava ideotype model. Since last year the Biometrics Unit together with the Cassava Program has been developing a computer model that simulates the growth of a cassava plant. This was due to the lack of a quantitative model of a cassava ideotype of maximum yield which would be much more useful to the breeder than the existing qualitative models. The model simulates leaf area development and its relationship to the accumulation of dry matter and distribution of this dry matter among leaves, stems and roots. The parameters and functional relations used in the model were estimated by an experimental field program at CIAT. The model is currently being refined and after validation and testing with the available genetic material, will be used predictively (See Cassava Physiology section of this report).

Cassava varietal stability study. The central objective of the regional trials of cassava is to test cassava varieties under different ecological conditions and then to recommend stable genotypes. Data from the first cycle of regional trials done by the cassava agronomy group in 1975 was used to carry out a study of varietal stability with respect to six different response variables: fresh root yield, dry root yield, harvest index, root diameter, root length and number of roots per plant. Varietal stability is an inherited characteristic that can be quantified by the so-called "stability parameters" and provide the breeder with reliable criteria for parent selection.

The study methodology chosen by

Biometrics includes some stability criteria that have been used in maize, barley, potatoes and beans, and a new criterion which measures the contribution of a specific variety to the interaction of varieties and environment in a RCBD with four replications. Final results of this study will be published in the 1977 Annual Report.

Cassava hornworm study. The Biometrics Unit, in collaboration with the cassava entomology group has begun a long-term experiment to determine the effectiveness, through biological control, of egg parasitism by the *Trichogramma* sp. and larval predation by *Polistes erytrocephalus* on cassava hornworm populations. The population dynamics of the system and its economic impact on cassava production were analyzed under laboratory conditions where the hornworm finds an optimum living environment (since no biological control is imposed) and field conditions, under the biological control of the *Trichogramma* sp., *Polistes*, or both.

The Unit has begun to develop a stochastic model as the analysis methodology to describe the populations under a steady state situation. This model will be used to estimate the effect of the biological controls on the hornworm population.

In 1976, the Biometrics Unit completed processing and tabulation of data from cassava production agro-economic studies in Colombia and Ecuador.

Swine Nutrition Unit

The Swine Nutrition Unit asked Biometrics to process an economic evaluation of swine feed systems based on common maize, opaque-2 maize, and cassava meal, in order to compare the profitabilities of the diets. The results show that under current relative cassava prices with respect to maize prices in the Cauca Valley of Colombia, the diet using cassava meal is not competitive. However, if the maize/cassava price ratio were greater than 2.2, the diets based on cassava meal would be economically preferable to those based on common maize. Similarly, if the maize/opaque-2 maize price ratio were greater than 1.1, the diet based on opaque-2 maize would be preferable to that based on common maize.

Training Assistance

This year, the Biometrics Unit participated in the Postgraduate Course on Swine Production offered by CIAT to professionals from several Latin American institutions. Five lectures of two hours each were offered, and basic statistics and experimental design principles were presented and illustrated by real life examples. The Biometrics Unit also participated in the Intensive Cassava Production Course for Latin American agronomists, offering a cycle of lectures that covered general introduction to statistics and experimental design, frequently used designs in cassava research, and statistical methodology used in the regional trials. Finally, the Unit collaborated in the training of veterinarians from the Panamerican Zoonosis Center in Buenos Aires in October and November. Statistical consulting in the areas of sampling design, general survey methodology and data processing were provided. The objective of the field training was to determine the incidence of bovine diseases in the area of Santander de Quilichao and the use of such information to devise control strategies.

Rice Program

In 1976, the Biometrics Unit carried out preliminary evaluation studies of the honeycomb design to rank and select rice genotypes using individual plants. The CIAT Rice Program, in cooperation with ICA, performed the first cycle of experiments with a two-fold objective: (a) to determine the minimum distance between plants that guarantees the elimination of competition; and, (b) to compare the evaluation of varieties under this new design with that obtained under the randomized complete block design traditionally used in the regional rice trials.

SPECIAL STUDIES UNIT

The Special Studies Unit has initiated several activities to explore new ideas which might be helpful to traditional farmers. This work has been done on the CIAT farm in order to test and more fully develop the ideas before introducing them onto small farms on secondary lands. Four activities of the unit this year are reported.

Permanent Cover Crops

Living mulches have been used for centuries in various crops in many parts of the world and are common in some perennial crops such as African oil palm and rubber. A new approach is to use living mulches in cropping systems; the perennial peanut (*Arachis glabrata*) is being evaluated at CIAT for this purpose. As it is a leguminous plant, it can be an important source of nitrogen and because it is stoloniferous and/or rhizomatous, it will also stablize soil on sloping areas as well as conserve soil moisture and greatly reduce weed competition.

Establishment trials have shown that soil moisture at planting time is critical. Planting should only be done when the soil is at field capacity; if rainfall or irrigation does not occur frequently during the first two weeks, the survival rate is considerably reduced.

A. glabrata is slow in establishing itself (Table 1). Nearly three months were needed to achieve 50 percent ground cover, but then growth was rapid and, after five months, more than 90 percent coverage was obtained. Interestingly, there was little correlation between planting density and establishment rate. Only the highest planting rate (160,000 plants/ha) was noticeably faster in providing 90 percent ground cover.

In view of its slow establishment and the need for frequent weedings the first three months after planting, several herbicide selectivity trials were conducted. The first trial, in flats in the screenhouse, indicated that alachlor, H-22234, nitrofen, linuron, DNBP, vernolate and bentazon were selective but diuron, metribuzin and trifluralin were not sufficiently selective. A field trial confirmed these results with the combination of alachlor and linuron giving the best weed control.

Table 1. **Rate of perennial peanut (*Arachis*) establishment at five planting densities.**

Plants/ha (1,000's)	Distance (cm) between		Percentage ground cover at				
			40	77	103	127	150
	rows	plants	days after planting				
160	25	25	17	49	87	91	94
100	40	25	5	20	53	60	85
83	40	30	9	35	82	85	95
67	50	30	8	28	72	72	91
50	50	40	7	26	65	73	90

Once plants were well-established, paraquat and glyphosate were tested to determine which products and rates were necessary to kill a strip of peanuts into which another crop could subsequently be sown. Paraquat only burned the treated leaves and full recovery was observed 21 days after application. Glyphosate was much more effective with rates of 1-1.5 kg a.i./ha giving the best results.

A follow-up trial was carried out to evaluate the effectiveness of post-emergence applications of atrazine and dalapon with surfactants in killing or reducing the competitiveness of perennial peanuts. Two kg/ha of atrazine and eight kg/ha of dalapon gave 70 percent control, considered sufficiently effective.

In another trial, paraquat and glyphosate were applied in either 20- or 40-centimeter bands in perennial peanuts and 20- and 40-centimeter bands were also prepared by hoeing. Maize was planted in all plots including a check without peanuts. Three weeks later the maize was severely retarded by peanut competition and the trial was terminated by removing the maize.

One month later, glyphosate, dalapon and atrazine were applied either in 50-centimeter bands or to entire plots and a 50-centimeter band was cleared by hoeing. Maize was again planted. The best treatments were the overall application of 1.5 kg a.i./ha of glyphosate or 2.0 kg/ha of atrazine and the hand-weeded plot. All other treatments appeared to allow excessive competition, although the yields of maize to be harvested in early 1977 will confirm this observation.

Leucaena with Maize

The perennial forage legume tree *Leucaena leucocephala* is native to the Americas. It has recently been tested in cropping systems, and specifically with maize, as a source of nitrogen. CIAT has begun similar trials to evaluate the potential for the *Leucaena* maize association under Latin American conditions.

Leucaena seeds have a low germinability. A hot water treatment (80°C) for 1-2 minutes increased germination from 20 to 96 percent. Longer treatment times tended to reduce seed viability. To determine if this was a permanent effect, hot water-treated seeds were stored for up to four months. Results showed that the treatment effect is long-lasting (Table 2), indicating that seed could be treated by the distributing agency, thereby guaranteeing the farmer that he is purchasing seed with high germinability which does not require further treatment.

Two field trials with *Leucaena* are in progress. *Leucaena* (CIAT 871) was established at the beginning of 1976 and four months later was approximately two meters tall. At this time it was cut to 20 centimeters and the branches uniformly distribued over the soil surface. In one trial, maize (var. H-207) was planted at 25,000 and 50,000 plants/ha in *Leucaena* densities of 0, 10,000, 20,000 and 40,000 plants/ha. In the second trial, the maize population was 60,000 plants/ha and *Leucaena* was planted either on the same ridge as the maize (40,000 plants/ha), on

Table 2. Effects of various storage times on hot water-treated *Leucaena* seed germination.

Treatment	Germination (%)
80°C the same day	78
80°C one month earlier	97
80°C two months earlier	88
80°C four months earlier	92
Not treated	37

every ridge (20,000 plants/ha) or on every third ridge (13,000 plants/ha). Thirty days after planting the maize, the *Leucaena* was again cut to 10 centimeters as it had regrown considerably and was competing with the maize. The branches were distributed around the maize plants.

At maize planting time, the fresh weight and nitrogen, phosphorus and potassium contents of *Leucaena* were determined (Table 3). The highest plant population produced significantly more fresh weight and nitrogen, phosphorus and potassium than did lower ones. Nevertheless, all populations gave significant quantities of nitrogen and potassium. The leaves contained 27.4 percent protein and could perhaps be incorporated into animal diets.

Maize yields were only slightly different (Table 4). This is significant since it indicates that no competition occurred from the *Leucaena*. The fact that yield increases with *Leucaena* were not observed is understandable since CIAT soils are relatively high in fertility and therefore no response to the nutrients in the *Leucaena* foliage was detected. The early height reductions in the high *Leucaena* populations did not persist and did not reduce yields.

Results were similar in the second trial (Table 5). Maize yields were only slightly reduced by the highest populations of *Leucaena* and the two maize populations did not differ appreciably. It appears that *Leucaena* populations of 10,000-20,000 plants/ha are adequate to provide sufficient foliage to cover the soil and supply significant quantities of nutrients without competing with maize. Now that the *Leucaena* is well-established, further trials will be conducted.

Since *Leucaena* is very slow in establishing itself, weeds have been troublesome. To explore possible methods of control, herbicide selectivity trials similar to those with perennial peanuts were carried out. Herbicides proving selective in *Leucaena* were alachlor, H-22234, fluorodifen, nitrofen, DNBP,

Table 4. **Maize height reducion and grain yields when grown in association with *Leucaena*. (Trial 1).**

Leucaena population (plants/ha)	Planting distance (cm x cm)	Maize Height reduction[1] (%)	 Yield[2] (t/ha)
0	—	0	5.4
13,000	25 x 300	16	6.0
20,000	25 x 200	16	5.5
40,000	25 x 100	25	4.9
40,000	50 x 50	29	4.5

[1] 40 days after planting compared to check

[2] Adjusted to 15 percent moisture.

Table 3. **Fresh weight and nitrogen, phosphorus and potassium contents of the leaves and branches of four-month-old *Leucaena* plants.**

Leucaena population (plants/ha)	Fresh weight[1] (t/ha)	Nutrients released (kg/ha) N leaves	 branches	 total	 P leaves	 branches	 total	 K leaves	 branches	 total
40,000	17.8	127	45	172	7	6	13	53	46	99
20,000	9.3	66	25	91	4	4	8	28	24	52
13,000	8.2	59	22	81	3	3	6	24	21	45

[1] The leaves and branches had 64 percent moisture

Table 5. **Maize height reductions and grain yields when grown in association with *Leucaena*. (Trial 2).**

		Maize	
Leucaena population (plants/ha)	Maize population (plants/ha)	Height reduction[1] (%)	Yield[2] (t/ha)
0	25,000	0	4.6
0	50,000	0	5.2
10,000	25,000	2	4.7
10,000	50,000	11	4.6
20,000	25,000	0	4.2
20,000	50,000	12	4.9
40,000	25,000	10	3.5
40,000	50,000	15	4.9

[1] 40 days after planting, compared to check

[2] Corrected to 15 percent moisture.

linuron and bentazon; non-selective compounds included metribuzin, diuron, vernolate and trifuralin.

An exploratory trial indicates that *Leucaena* could be planted with a companion crop during establishment. This would reduce weed competition and provide income during the 3-4 months of initially slow *Leucaena* growth. Bush beans (var. Calima) were interplanted in one-meter rows without affecting early development of the *Leucaena*; beans were also unaffected by the *Leucaena*.

No-tillage Systems

Traditional farmers have peak labor demands at planting and harvesting time. The use of non-selective, non-residual herbicides makes it possible to prepare land chemically and thereby allow farmers to plant greater areas. In addition, such systems do not disturb the soil structure but do help reduce susceptibility to erosion. The dead weeds become a protective mulch and reduce surface temperatures, increase infiltration, conserve moisture and inhibit new weed growth.

A three-season trial has been initiated in which two rates of glyphosate and one of paraquat are being compared to hand weeding prior to planting. Maize. and beans are being grown as continuous or rotated monocrops or in association. Pre-emergence herbicides are applied to one-half of each plot. The first planting was done early in 1976 and the true no-tillage plantings were made late in the year. In 1977 the results of all three plantings will be available for comparison.

Germplasm Evaluation

Other international agricultural research centers were invited to send their most promising germplasm materials to CIAT for evaluation under Colombian environmental conditions. Also, several important legume species are being evaluated that are not part of any international center's program. To date, trials of soybeans, mungbeans, cowpeas, winged beans, jack beans, sword beans, Chinese cabbage and tomato have been planted.

Yield data and other characters measured in these trials (Table 6) show that several species have high yield potential and have sufficient difference in growth period and seed characteristics (e.g. in color and size) to permit selection for various environments, cropping systems and consumer preferences.

Table 6 Yield data and selected characteristics of four food legumes tested at CIAT the second semester of 1976.

Species and no. of lines tested	Line or variety	Growth period (days)	Seed color	100-seed wt (g)	Plot yield (t/ha)
Cowpea[1]					
31	(Range)	68 — 85	white, cream, maroon	8.4—18.4	0.3—3.5
	TVx 1193-0590	80	maroon	15.7	3.5
	TVx 30-1G	78	cream	15.5	3.2
	TVx 456-01F	83	ash white	18.4	3.2
	Coastal	85	white	15.1	2.6
Mung bean[2]					
65	(Range)	61 — 74	—	2.9—8.4	0.1—3.7
	1180M-239	65	bright green	5.5	3.7
	2808 local	70	dark green	6.3	3.5
	1380 Mg-50-10A	67	bright green	7.6	3.2
	2273 ML-3	65	bright green	3.9	3.1
Soybean[1]					
51	(Range)	70 — 95	—	8.7—29.7	0.3-2.7
	30211-1-5	83	—	18.7	2.7
	30101-23-8	90	—	21.3	2.5
	30096-1-9	90	—	17.6	2.4
	Acc 2120	90	—	8.7	2.4
Winged bean[1]					
66	(Range)	64 — 67	—	16—41	74 — 750[3]
	ICA	64	—	36.1	750[3]
	UPS-61	67	—	28.0	598[3]
	UPS-63	67	—	21.1	488[3]
	UPS-37	67	—	28.9	428[3]

[1] Yields are for unreplicated observational plots.

[2] Yields are means of four replications.

[3] Dry seed yield in grams for six staked plants; a significant conversion to t/ha is impossible.

EXPERIMENT STATION OPERATIONS

Personnel in the Station Operations Unit accomplished the following activities in support of commodity investigations at the CIAT farm in 1976.

General Services

Over 28 kilometers of the CIAT internal road network were covered with gravel and otherwise maintained to improve transport conditions; in addition, 2.8 kilometers were paved with asphalt in areas neavy traffic normally produced large quantities of dust.

A dike with a volume of 12,375 cubic meters of fill and 550 meters long was constructed. On top of this dike a lined canal was built to conduct water from a well situated east of the El Porvenir reservoir to fields lying higher than the well. This dike and canal have solved the problem of irrigating plots in the extreme eastern section of the station. In addition, 4.2 kilometers of existing irrigation canals were lined with a mixture of earth and cement.

In order to improve the internal drainage system of the experimental plots, 53 hectares were subsoiled with a mole drain. Ten kilometers of drainage canals were also constructed.

Leaching was carried out on 51.8 hectares of land, while producing rice, and 20 hectares of this land nave now been assigned to other research programs.

A total of 44.5 hectares of land was leveled and seeded in either rice or maize. As these lots are improved, they will be utilized by research programs or for training.

A total of 20.8 kilometers of fencing were removed and 6,953 posts and 104 kilometers of wire salvaged; 2.2 kilometers of new fence were constructed and another 11 kilometers were maintained.

On lands not being used for research, 30 tons of maize were produced (an average of 3.5 t/ha); 70 tons of sorghum (averaging 3.4 t/ha); 2.2 tons of beans (averaging 0.55 t/ha); 46 tons of cassava (averaging 14 t/ha); and, 648 tons of rice (averaging 6.2 t/ha). During the second half of the year, 94 hectares were planted to maize, 3.2 to sorghum, 9 to beans and 20 hectares of sorghym stubble were left to regrow and produce another crop.

In cooperation with the CIAT Rice Program, 152.9 tons of basic seed of the new varieties CICA 7 and 9 were produced. Also, 87 tons of certified seed were produced for the Federación Nacional de Arroceros (FEDEARROZ) and another 129 tons of paddy rice were produced from six lines or varieties.

About 325 tons of rice were processed in a mill and 148.5 tons of white rice were sold through CRECIAT, an autonomous credit entity for CIAT employees. Rice remaining in plots after research harvests was also sold through CRECIAT. Only 66.7 tons of paddy rice were sold through a commercial mill since the harvest coincided with the season of basic seed production (Fig. 1).

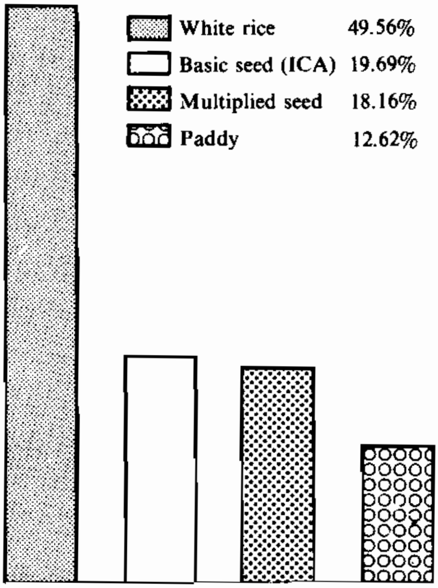

Figure 1. Forms in which rice produced at CIAT in 1976 was sold (total of 648 kilograms).

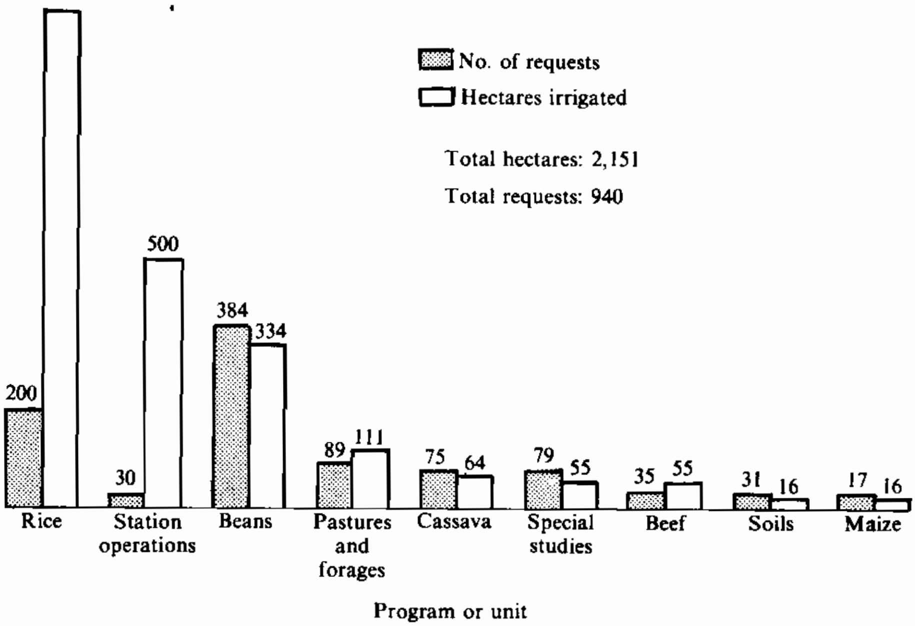

Figure 2. Irrigation services provided to research programs or units at CIAT during 1976.

Specific Services

A total of 940 requests for irrigation of research plots were answered and a total area of 2,151 hectares was irrigated (Fig. 2).

A total area of 679 hectares were prepared during the year for planting or cultivating in answer to 329 requests (Fig. 3).

Field operations arranged for laborers

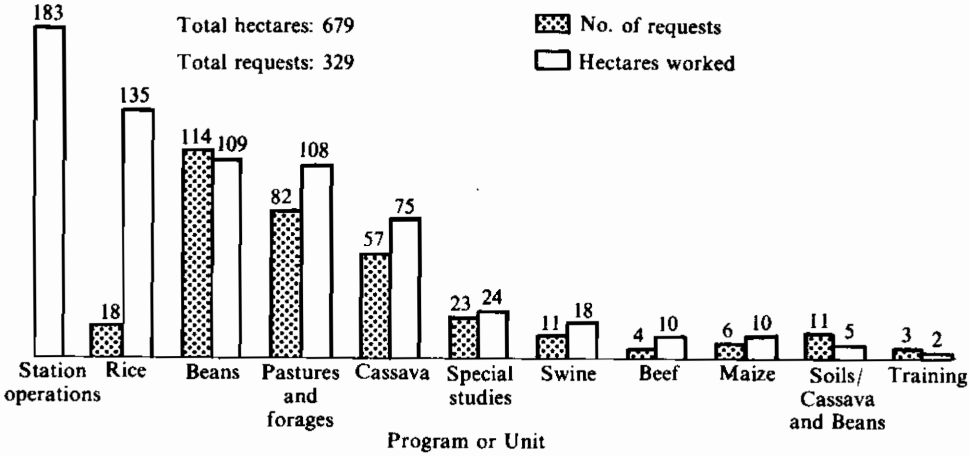

Figure 3. Machinery services fusnished to research programs or units at CIAT during 1976.

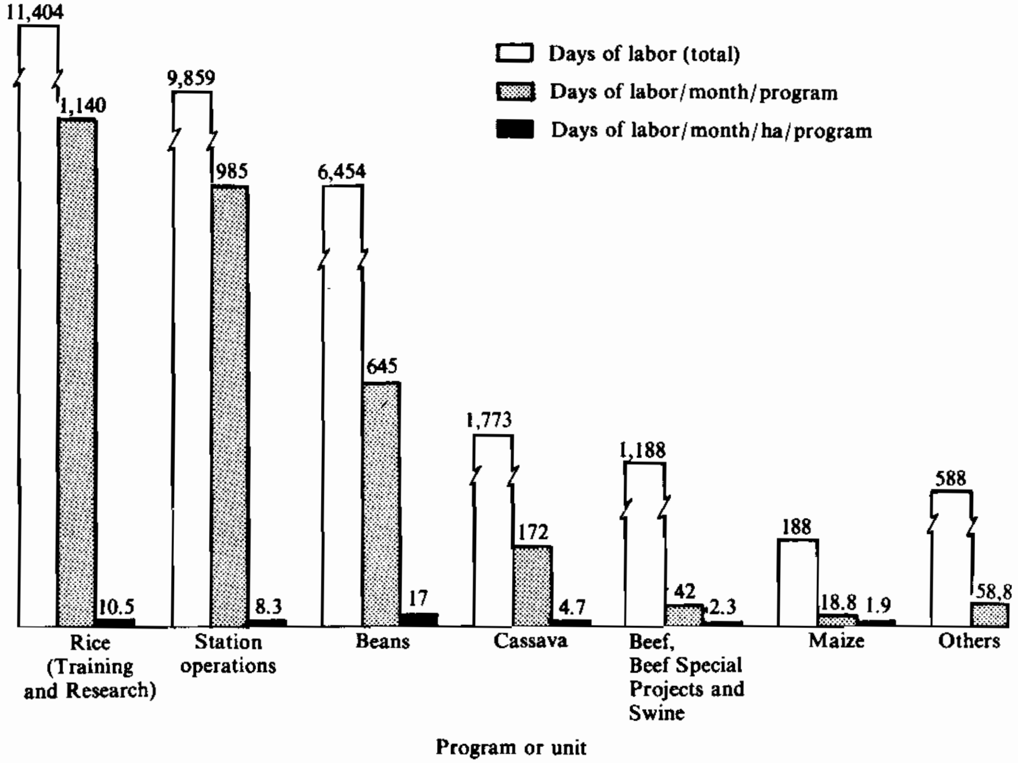

Figure 4. **Utilization of field labor personnel by CIAT research programs or units (through October 1976 and including CIAT labor pool and contracted workers).**

to work in respective research programs as needed. Through the end of October 1976, 31,769 days of labor were supplied from CIAT's own labor pool or contract laborers (Fig. 4).

Training

Two agricultural engineers from Colombia, three from Brazil and one each from Mexico and Guatemala were trained in experimental station operations.

The CIAT station superintendent collaborated with the cassava training courses, providing instruction on land preparation in the theoretical-practical phase of the courses.

To support the Continuous Rice Production System, 138 hectares were prepared and seeded in this crop.

Financial report

Price Waterhouse & Co.

APARTADO AEREO 180 · CALI, COLOMBIA

February 28, 1977

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, 1976 and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year. Our examination of these statements was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our examination also encompassed the schedules of analysis of grants and related expenditures, earned income, comparison of approved budget and actual expenditures and dates of receipt of grants for the year ended December 31, 1976, which are presented as supplementary information, and, in our opinion, these schedules present fairly the information shown therein.

Price Waterhouse & Co.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
BALANCE SHEET
(Expressed in thousands of U.S. dollars)

	December 31			
ASSETS	**1976**	1975	1974	1973
CURRENT ASSETS:				
Cash	1,481	1,152	623	139
Accounts receivable:				
Donors	1,616	607	531	497
Employees	57	66	85	69
Others	425	311	718	289
	2,098	984	1,334	855
Inventories	345	250	199	100
Prepaid expenses	11	5	8	5
Total current assets	3,935	2,391	2,164	1,099
FIXED ASSETS:				
Equipment	1,963	1,721	1,346	802
Vehicles	685	593	568	305
Vehicles (replacements) in transit	149	330		
Furnishings and office equipment	938	930	901	378
Buildings	4,773	4,495	4,429	3,950
Other	25	46	103	925
Total fixed assets	8,533	8,115	7,347	6,360
Total assets	12,468	10,506	9,511	7,459
LIABILITIES AND FUND BALANCES				
CURRENT LIABILITIES:				
Bank overdraft	18	14	317	137
Accounts payable	807	758	286	351
Others			385	152
Total current liabilities	825	772	988	640
GRANTS RECEIVED IN ADVANCE	180	250	115	117
FUND BALANCES:				
Invested in fixed assets	8,533	8,115	7,347	6,360
Unexpended funds (deficit):				
Core —				
Unrestricted	70	303	32	(37)
Working fund grant	600	600	100	100
Capital grants	1,964	185	628	175
Special projects —				
Donors	315	340	301	144
Other	(19)	(59)		(40)
	2,930	1,369	1,061	342
Total fund balances	11,463	9,484	8,408	6,702
Total liabilities and fund balances	12,468	10,506	9,511	7,459

The notes on pages G-46 and G-47 are an integral part of the financial statements.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
STATEMENT OF REVENUE AND EXPENDITURES AND UNEXPENDED FUNDS

(Expressed in thousands of U.S. dollars)

	Year ended December 31			
	1976	1975	1974	1973
Revenue:				
Core:				
Operating grants —				
Unrestricted	4,500	4,180	3,475	2,672
Restricted	1,145	1,090	1,030	790
Working fund grant		500		100
Capital grants	1,858	257	1,365	1,779
Total Core	7,503	6,027	5,870	5,341
Special projects	725	593	631	404
Earned income	339	339	310	168
Total revenue	8,567	6,959	6,811	5,913
Expenditures:				
Core programs:				
Direct research —				
Beef	831	813	724	661
Beans	698	517	374	262
Cassava	573	413	399	330
Swine	150	211	230	202
Rice	206	201	133	135
Maize		78	83	121
Small farm systems		160	185	36
	2,458	2,393	2,128	1,747
Research support	602	328	342	230
Total research	3,060	2,721	2,470	1,977
Training and conferences	634	527	520	518
Library and information services	515	438	276	139
Administration expenses	670	598	559	340
General operating costs	999	986	678	656
Total Core programs	5,878	5,270	4,503	3,630
Special projects	710	613	602	305
Purchases of fixed assets	418	768	987	2,496
Total expenditures	7,006	6,651	6,092	6,431
Excess of revenue over expenditures:				
Operating grants	(233)	271	69	
Working fund grant		500		100
Capital grants	1,779	(443)	453	(717)
Special projects	15	(20)	197	99
	1,561	308	719	(518)
Unexpended funds at beginning of year	1,369	1,061	342	889
Grants receivable for prior years written off				(29)
Unexpended funds at end of year (See balance sheet)	2,930	1,369	1,061	342

The notes on pages G-46 and G-47 are an integral part of the financial statements.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
NOTES TO FINANCIAL STATEMENTS

NOTE 1 - ACCOUNTING POLICIES:

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

Inventories -

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

Fixed assets -

Fixed assets are recorded at cost.

Depreciation -

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

NOTE 2 - FOREIGN EXCHANGE:

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

	P/$1	
Peso balances included in current assets and current liabilities	36.32	Year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	34.71	Average monthly rate of exchange applicable to sales of dollars

NOTE 3 - OPERATIONS:

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 CIATS 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:

Accounts receivable from donors as at December 31, 1976 comprised:	$000
Inter-American Development Bank:	
Balance of 1976 grant (Unrestricted Core and Capital)	525
The Rockefeller Foundation:	
Balance of capital grants	107
Special projects	19
	126
United States Agency for International Development:	
Balance of 1976 grant (Unrestricted Core)	700
Special projects	27
	727
Canadian International Development Agency:	
Balance of 1976 grant (Restricted Core)	31
Government of Belgium:	
Balance of 1976 grant	135
Government of the Federal Republic of Germany:	
Balance of 1976 grant	34
Others	38
	1.616

SCHEDULE 1

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
ANALYSIS OF GRANTS AND RELATED EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1976
(Expressed in thousands of U.S. dollars)

		Expenditures							
	Total funds available	Fixed assets	Total research	Training and conferences	Library and information services	Administration	General operating	% of library, administration and general operating to total research and training	Transfer to unexpended balance
Unrestricted Core:									
The Ford Foundation	400								
Inter-American Development Bank	1,900								
The Rockefeller Foundation	500								
United States Agency for International Development	1,700								
Balance from previous year	303								
Total unrestricted Core	4,803		2,622	351	412	544	804	59	70
Restricted Core:									
Canadian International Development Agency	845								
The W.K. Kellogg Foundation	300								
Total restricted Core	1,145		438	283	103	126	195	59	
Working fund grants:									
Balance from previous year	600								
Total working fund grants	600								600
Capital grants:									
Government of Australia	125								
Government of Belgium	135								
Government of the Federal Republic of Germany	636								
Inter-American Development Bank	200								

SCHEDULE 1 (cont.)

	Total funds available	Fixed assets	Total research	Training and conferences	Library and information services	Adminis-tration	General operating	% of library, administration and general operating to total research and training	Transfer to unexpended balance
International Development Association	250								
Government of the Netherlands	200								
The Rockefeller Foundation	15								
Government of Switzerland	140								
Government of the United Kingdom	106								
Other	51								
Balance from previous year	185								
Income applied in year	339								
Total capital grants	2,382	418							1,964
Special projects (1):									
CIMMYT (Canadian International Development Agency)	73		44	5					24
The Ford Foundation	63		5	6	44				8
Inter-American Development Bank	207		107	66	15	17	21		(19)
International Board for Plant Genetic Resources	72		12	8					52
International Development Research Centre (Canada)	218		9	53	37				119
International Fertilizer Development Center	11		11						
International Minerals & Chemical Corporation	21		11				1		9
The Rockefeller Foundation	175		96	34		3	4		38
United Kingdom - Ministry of Overseas Development	74		34			4	5		31
United States Agency for International Development	27			27					
Others	65			31					34
Total special projects	1,006		329	230	96	24	31	29	296
Total grants and expenditures	9,936	418	3.389	864	611	694	1,030	56	2,930

(1) Includes balances brought forward from previous year of US$281,000.

SCHEDULE 2

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1976
(Expressed in thousands of U.S. dollars)

Sources of earned income:	
Interest on deposits	147
Sale of farm produce and services	73
Use of CIAT facilities	119
	339
Applied to capital	339

SCHEDULE 3

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1976
(Expressed in thousands of U.S. dollars)

	Core unrestricted		Core restricted		Capital	
Programs	Approved budget *	Actual	Approved budget *	Actual	Approved budget *	Actual
Direct research:						
Beef	1,031	831				
Beans	750	698				
Cassava	371	292	285	281		
Swine	102	77	79	73		
Rice	265	206				
Research support	603	518	84	84		
Training and conferences	504	351	308	283		
Library and information services	444	412	92	103		
Administration	575	544	114	126		
General operating costs and other	892	804	183	195		
Total	5,537	4,733	1,145	1,145		
Capital						
Fixed assets					1,234	418
Total					1,234	418
Analysis of variances						
Budget surplus:						
Grants not received		734				
Transfer to unexpended balance		70				816
Total		804				816

* Revised budget approved by the Board of Trustees.

SCHEDULE 4

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
DATES OF RECEIPT OF GRANTS
FOR THE YEAR ENDED DECEMBER 31, 1976
(Expressed in thousands of U.S. dollars)

	Rec at beg. of year	1976 rec. in adv.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Rec. at yr. end	1977 rec. in adv.	Net 1976 grants
Unrestricted Core:																	
The Ford Foundation					100	33	33	34	33	33	34	33	33	34			400
Inter-American Development Bank	(349)			349							1,050		525		325		1,900
The Rockefeller Foundation			283	17	13	34	10	16	9	8	8	9	86	7			500
United States Agency for International Development						500			500						700		1,700
	(349)		283	366	113	567	43	50	542	41	1,092	42	644	41	1,025		4,500
Restricted Core:																	
Canadian International Development Agency						814									31		845
The W.K. Kellogg Foundation							300										300
						814	300								31		1,145
Capital grants:																	
Government of Australia					125												125
Government of Belgium															135		135
Goverment of the Federal Republic of Germany						197		35	97			107		166	34		636
Inter-American Development Bank															200		200
International Development Association		110			140												250
Government of the Netherlands								200									200
The Rockefeller Foundation	(179)									81				6	107		15
Government of Switzerland		140												180		(180)	140
Government of the United Kingdom								37		36				33			106
Others														51			51
	(179)	250			265	197		272	97	117		107		436	476	(180)	1,858

SCHEDULE 4 (cont.)

	Rec at beg. of year	1976 rec. in adv.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Rec. at yr. end	1977 rec. in adv.	Net 1976 grants
Special projects:																	
CIMMYT (Canadian International Development Agency)									57					16			73
Inter-American Development Bank									214	52							266
International Board for Plant Genetic Resources														25	8		33
International Development Research Centre (Canada)	(23)		3	73			58	8	24	(3)	41						181
The Rockefeller Foundation	(9)			5	80										19		95
United States Agency for International Development	(30)					30									27		27
Others	(33)		1		4	29	2		3	1	1	4	7	1	30		50
	(95)		4	78	84	59	60	8	298	50	42	4	7	42	84		725
	(623)	250	287	444	462	1.637	403	330	937	208	1,134	153	651	519	1.616	(180)	8,228

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