02E1-78
April 1979

Annual Report
1978

Centro Internacional de Agricultura Tropical (CIAT)
Apartado Aéreo 6713
Cali, Colombia S.A.

(*) CA CP

Contents

Board of Trustees

Personnel

Office of Director General

Senior staff
John L. Nickel, PhD, Director General
Alexander Grobman, PhD, Associate Director General, International Cooperation
***Kenneth O. Rachie,** PhD, Associate Director General, Research

Other professional staff
Cecilia Acosta, Administrative Assistant

Administration

Office of the Administrative Division

Senior staff
Jesús Antonio Cuéllar, MBA, Executive Administrator

Other professional staff
***Hernán Villa J.,** BS, Administrative Assistant
Germán Vargas, MS, Administrative Associate

Bogota Office
Ricardo Castañeda, Administrative Assistant

Carimagua Station
Fernando Bernal, MS, Station Superintendent

Food and Housing
Eduardo Fonseca, Head

Human Resources
Carlos R. Viana, BS, Head
Edgar Echeverri, Lawyer, Personnel Officer

Maintenance Services
Alessandro Ferrari, Superintendent
Mario Cadena, Assistant Superintendent (Electrical Shops)
Marvin Hennan, Assistant Superintendent (Motor Pool)

Personnel
Francisco Jaramillo, Assistant Superintendent (Mechanical Shops)

Purchasing
Fernando Posada, MS, Head
Percy de Castro, Administrative Assistant
Marino López, Administrative Assistant
Diego Mejía, Administrative Assistant

Office of the Controller

Senior staff
Andrew V. Urquhart, FCA, Controller

Other professional staff
Joffre A. Guerrero, Assistant Controller
Gregorio Bedoya, Accountant
Yolanda Fernández, Accountant
Mauricio Lozano, MBA, Administrative Associate
César Moreno, Cashier
Hernando Navia, Internal Auditor
Rafael Petti, Contract Assistant
Raúl Zamudio, Systems Analyst

Cassava Program

Senior staff
James H. Cock, PhD, Physiologist (Coordinator)
Anthony C. Bellotti, PhD, Entomologist (stationed in Cruz das Almas, Brazil)
Abelardo Castro, PhD, Agronomist
Reinhardt Howeler, PhD, Soil Scientist (on study leave)
Kazuo Kawano, PhD, Plant Breeder
Dietrich Leihner, DAgr, Agronomist

* Left during 1978

J. Carlos Lozano, PhD, Plant Pathologist
John K. Lynam, PhD, Agricultural Economist
Romeo R. Obordo, PhD, Regional Coordinator for Asia (stationed at SEARCA, Los Baños, the Philippines)
Julio César Toro, PhD, Agronomist

Visiting scientist
Yoshiki Umemura, PhD, Plant Pathologist

Postdoctoral fellow
Clair Hershey, PhD, Breeding

Visiting specialist
Jesús Antonio Reyes, PhD, Entomologist

Research associates
*__Jairo Castaño,__ MS, Pathology
Rafael Orlando Díaz, MS, Economics
Octavio Vargas, MS, Entomology
Carlos Domínguez, MS, Training

Visiting research associates
David Byrne, MS, Entomology
Fritz Elango, MS, Plant Pathology
Rafael Laberry, MS, Plant Pathology
Bernhard Lohr, MS, Entomology
Peter Jan Strobosch, MS, Rural Sociology
Hendrick Jan Veltkamp, MS, Plant Physiology

Research assistants
*__Nancy Acosta,__ Ing. Agr., Agronomy
Bernardo Arias, Ing. Agr., Entomology
Eitel Adolfo Buckhardt, Biologist, Soils
Fernando Calle Calle, Ing. Agr., Soils (stationed in Carimagua, Colombia)
Ernesto Celis, Ing. Agr., Agronomy
Julio Eduardo Holguín, Ing. Agr., Agronomy
Gustavo Jaramillo, Ing. Agr., Agronomy
Javier López, Ing. Agr., Cultural Practices
*__Carlos Medina,__ Ing. Agr., Soils
Sara Mejía, Ing. Agr., Physiology
Germán E. Parra, Ing. Agr., Physiology
Edgar Salazar, Ing. Agr., Soils (stationed in Carimagua, Colombia)
Ana Milena Varela, Ing. Agr., Entomology
*__Uldarico Varón,__ Ing. Agr., Economics
Ana Cecilia Velasco, Med. Tech., Pathology

Beef Program

Senior staff
Pedro A. Sánchez, PhD, Soil Scientist (Coordinator)

* Left during 1978

Eduardo R. Aycardi, PhD, Animal Health Specialist
Walter Couto, PhD, Soil Scientist, Pasture Development (stationed in Brasilia, Brazil)
William E. Fenster, PhD, Soil Fertility (IFDC Phosphorus Project)
John E. Ferguson, PhD, Agronomist, Seed Production
**__Bela Grof,__ PhD, Forage Agronomist (stationed in Carimagua, Colombia)
Jake Halliday, PhD, Soil Microbiologist
C. Allan Jones, PhD, Grasses Agronomist
Ingo Kleinheisterkamp, DAgr, Animal Scientist Management
Luis Alfredo León, PhD, Soil Chemist (IFDC Phosphorus project)
C. Patrick Moore, PhD, Animal Scientist (stationed in Brasilia, Brazil)
Gustavo A. Nores, PhD, Economist
Osvaldo Paladines, PhD, Animal Scientist, Nutrition
José G. Salinas, PhD, Soil-Plant Nutritionist
*__Kenneth D. Sayre,__ PhD, Legume Breeder
Rainer Schultze-Kraft, DAgr, Legume Agronomist
James M. Spain, PhD, Soil Scientist, Pasture Development (stationed in Carimagua, Colombia)
Luis E. Tergas, PhD, Agronomist, Training/ Regional Trials
Derrick Thomas, PhD, Forage Agronomist (stationed in Brasilia, Brazil)

Visiting scientists
Thomas T. Cochrane, PhD, Land Resources Specialist
E. Mark Hutton, DAgrSc, Breeder
Nobuyoshi Maeno, DAgr, Legume Agronomist

Postdoctoral fellows
Mario Calderón, PhD, Entomology
Jillian M. Lenné, PhD, Plant Pathology
Eugenia de Rubinstein, PhD, Economics

Visiting specialists
Rolf Minhorst, MS, Animal Management (stationed in Brasilia, Brasil)
Peter Kammer, MS, Animal Management (stationed in Maturín, Venezuela)

Research associates
Edgar Burbano, MS, Seed Production
Carlos Castilla, MS, Pasture Development (stationed in Carimagua, Colombia)

* Left during 1978
** On sabbatical leave. Transferred to Carimagua as of January 1, 1979.

*Rubén Darío Estrada, MS, Economics
Clemencia Gómez, MS, Training/Regional Trials
*Víctor H. Guzmán, MS, Animal Health
Libardo Rivas, MS, Economics
Fabio Nelson Zuluaga, MS, Animal Health

Visiting research associates
Fabio Calvo, Ing. Agr., Pasture Development
Guido Delgadillo, MS, Soil-Plant Nutrition
Jorge Luis Díaz, MS, Pasture Utilization
William F. Gómez, DVM, Pasture Utilization
Hendrik Jansen, MS, Legume Agronomy
***Herbert Jenrich,** MS, Pasture Utilization
Joel Levine, MS, Economics
***Javier Marín,** BS, Phosphorus Project
Frank Muller, MS, Legume Agronomy (stationed in Carimagua, Colombia)
Luis Fernando Sánchez, MS, Land Resources

Research assistants
Amparo V. de Alvarez, Ing. Agr., Plant Pathology
***Miguel A. Ayarza,** Ing. Agr., Soil Science
Daniel Javier Belalcázar, Ing. Agr., Plant Introduction
Francisco Bonilla, Ing. Agr., Seed Production
Raúl Botero, DVM, Animal Management (stationed in Carimagua, Colombia)
Arnulfo Carabaly, Ing. Agr., Grass Agronomy
Manuel Coronado, Ing. Agr., Legume Breeding
José Misael Cortés, DVM, Animal Health
Patricia Chacón, Biologist, Entomology
Luis A. Duque, Ing. Agr., Phosphorus Project
Martha Lucía Escandón, Ing. Agr., Legume Breeding
***Jaime Escobar,** Zoot., Pasture Utilization (stationed in Carimagua, Colombia)
Luis E. Forero, Biologist, Plant Introduction
Luis H. Franco, Ing. Agr., Pasture Development (stationed in Carimagua, Colombia)
Duván García, Ing. Agri. Seed Production
Hernán Giraldo, Ing. Agr., Legume Agronomy
Ramón Gualdrón, Ing. Agr., Soil Science (stationed in Carimagua, Colombia)
Fabio Gutiérrez, Ing. Agr., Soil Microbiology
Uriel Gutiérrez, Economist, Economics
Silvio Guzmán, DVM, Training/Regional Trials
Phanor Hoyos, Zoot., Pasture Utilization (stationed in Carimagua, Colombia)
***Jorge Leal,** Zoot., Pasture Utilization
***Orlando Lozano,** DVM, Animal Management
Henry Llanos, Ing. Agr., Soil Chemistry
Carlos Humberto Molano, Ing. Agr., Grass Agronomy (stationed in Carimagua, Colombia)
Rodrigo F. Mutis, Zoot., Animal Management (stationed in Carimagua, Colombia)
***Martha Stella Peña,** Chemist, Pasture Utilization

* Left during 1978

***Bernardo Rivera,** DVM, Animal Health (stationed in carimagua, Colombia)
Manuel Sánchez, Ing. Agr., Legume Agronomy (stationed in Carimagua, Colombia)
Roberto Sánchez, Ing. Agr., Soil-Plant Nutrition
José Ignacio Sanz, Ing. Agr., Training/Regional Trials
Gustavo Adolfo Urrea, Ing. Agr., Training/Regional Trials
Bernardo Velosa, Ing. Agr., Legume Breeding
Fernán Alberto Varela, Ing. Agr., Entomology (stationed in Carimagua, Colombia)

Bean Program

Senior staff
Aart van Schoonhoven, PhD, Entomologist (Coordinator)
Jeremy Davis, PhD, Breeding, Agronomist
Guillermo G. Gálvez, PhD, Regional Coordinator for Central America (stationed in San José Costa Rica)
Peter H. Graham, PhD, Microbiologist
Douglas R. Laing, PhD, Physiologist
Silvio H. Orozco, PhD, Plant Breeder (attached to ICTA, Guatemala)
John H. Sanders, PhD, Agricultural Economist
Howard F. Schwartz, PhD, Plant Pathologist
Shree P. Singh, PhD, Plant Breeder
Steven Ray Temple, PhD, Plant Breeder
Michael D.T. Thung, PhD, Agronomist
Oswaldo Voysest, PhD, Agronomist
Kazuhiro Yoshii, PhD, Plant Pathologist (attached to ICTA, Guatemala)

Visiting scientists
***Richard M. Riedel,** PhD, Nematologist
***Oghenetsevbuko Todo Edje,** PhD, Seed Physiologist

Postdoctoral fellows
César Cardona, PhD, Entomology
Francisco J. Morales, PhD, Virology
Richard Swindell, PhD, Plant Breeding

Research associates
Camilo Alvarez P., MS, Economics
José Ariel Gutiérrez, MS, Breeding
Luis Gonzaga Vergara, Ing. Agr., Breeding

Visiting research associates
Gustavo Arcia, MS, Economics
Stephen Beebe, PhD, Production

* Left during 1978

Anne Clark, MS, Physiology
Nicholas Galwey, MS, Agronomy
Susana García, MS, Plant Breeding
Jeffrey Wescott White, MS, Plant Physiology

Research assistants
Alfredo Acosta, Ing. Agr., Entomology
*__Carlos Bohórquez__, Ing. Agr., Agronomy
*__Ricardo Campos__, Ing. Agr., Breeding
Mauricio Castaño, Ing. Agr., Pathology
Fernando Correa, Ing. Agr., Pathology
Aurora Duque Maya, Ing. Agr., Microbiology
Jaime García, Ing. Agr., Entomology
Jorge García, Ing. Agr., Entomology
Ranulfo González, Biologist, Entomology
*__Pablo Guzmán__, Ing. Agr., Pathology
Norha R. de Londoño, Ing. Agr., Economics
Nelson Martínez, Ing. Agr., Agronomy
Carlos S. Medina, Ing. Agr., Agronomy
William Mondragón, Ing. Agr., Pathology
*__Martín Prager__, Ing. Agr., Breeding
Luz H. Ramirez, Ing. Agr., Entomology
José Restrepo, Ing. Agr., Physiology
*__Rosmira Rivera__, Ing. Agr., Pathology
*__Juan Carlos Rosas__, Ing. Agr., Microbiology
*__Luz Dary Ruíz__, Ing. Agr., Microbiology
Fernando Takegami, Ing. Agr., Agronomy
Gerardo Tejada, Ing. Agr., Agronomy
Silvio Vitery, Ing. Agr., Microbiology
*__Diego Zorrilla__, Ing. Agr., Agronomy
*__Silvio Zuluaga__, Ing. Agr., Physiology

Rice Program

Senior staff
Joaquín González, MS, Agronomist (Coordinator)
Peter R. Jennings, PhD, Regional Coordinator for Central America (stationed in San José, Costa Rica)
Manuel J. Rosero, PhD, IRRI Liaison Scientist
Hector Weeraratne, PhD, Plant Breeder

Visiting research associates
*__Annette Bernd__, MS, Plant Breeding
Diego Roldán, MS, Economics

Research assistants
Gustavo Benavides, Ing. Agr., International Trials
*__Marino Caicedo__, Ing. Agr., Breeding
Luis García, Ing. Agr., Breeding
Camilo Jaramillo, Ing. Agr., International Trials
Luis Octavio Molina, Ing. Agr., Breeding
Carlos Otero, Ing. Agr., Agronomy

* Left during 1978

Swine Unit

Senior staff
Guillermo Gómez, PhD, Nutritionist/Biochemist
Julián Buitrago, PhD, Nutritionist

Research associate
Jorge Santos, MS

Research assistants
Luis Enrique Beltrán, DVM
*__Elkin Tabordá__, Zootecnista
Mauricio Valdivieso, Zootecnista

Genetic Resources Unit

Senior staff
Robert A. Luse, PhD, Biochemist (Coordinator)
Leonard S. P. Song, PhD, Germplasm Specialist
William M. Roca, PhD, Physiologist

Research associate
Rigoberto Hidalgo MS, Germplasm

Visiting research associates
Daniel Debouck, MS, Germplasm
Paul Gepts, MS, Germplasm

Research assistants
James García, Ing. Agr., Germplasm
Hember Rubiano, Ing. Agr., Germplasm
*__José Tinoco__, Ing. Agr., Germplasm

Special Studies Unit

Senior staff
Kenneth O. Rachie, PhD, Associate Director General, Research and Coordinator, Special Studies Unit

Postdoctoral fellow
Bodo Hegewald, PhD, Plant Production

Visiting research associate
Judith M. Lyman, MS, Horticulture

Research assistant
Guillermo Giraldo, Ing. Agr.

Research Support Groups

Data Services Unit

Senior staff
* **David Franklin**, MS, Systems Engineer/Biometrician (on study leave)

* Left during 1978

Postdoctoral fellow
Gastón Mendoza, PhD, (Acting Coordinator)

Computer Services

Research associate
Jorge A. Porras, BS

Research assistants
Adolfo Gordillo, Ing. Elec.
Gerardo I. Hurtado, Ing. Agr.

Statistical Services

Research associate
María Cristina Amézquita de Quiñónez, MS

Visiting research associate
* **Christoph Plessow,** MS, Biometrics

Research assistants
Juan Ospina, Ing. Agr.
Jaime E. Muñoz, Ing. Agr.

Experiment Station Operations

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

Research assistants
Xavier Carbonell, Ing. Agri.
Ricardo Cruz, Ing. Agri.
Ramiro Narváez, Ing. Agri. (at CIAT-Quilichao Substation)

Laboratory Services

Research assistant
Charles McBrown, BS

Training and Conferences

Senior staff
Fernando Fernández, PhD, Plant Scientist (Coordinator)

Training

Training associates
Carlos Domínguez, MS (Cassava)
Carlos Flor, MS (Beans)
Clemencia Gómez, MS (Beef)
Marceliano López, MS, (assigned to CENTA, El Salvador)
Eugenio Tascón, Ing. Agr. (assigned to INIAP, Ecuador)
Cornelio Trujillo, MS (Swine)
Gustavo Villegas, MS, (Rice)

Training assistants
Antonio Acosta, Zootecnista
Silvio Guzmán, DVM, (Beef)
Carlos Suárez, BS

Conferences

GAS staff
David Evans, Conference Administrator

Documentation Services

Senior staff
Fernando Monge, PhD, Communication Scientist (Coordinator)

Library and Documentation

Visiting specialist
Trudy Brekelbaum, MA, Editor

Associate
Hernán Poveda, BA

Assistants
Stella Gómez, BA
Marilú O. de Hensel, BA, Documentalist
Sonia Laverde, BA, Head, Public Services
Jorge López S., Documentalist
Piedad Montaño, Head, Acquisitions
Julia Emma de Rodríguez, Ing. Agr., Documentalist
Himilce Serna, BA, Head, Technical Services

Communications Support Unit

Senior staff
Fritz Kramer, PhD, Communications Scientist (Coordinator)

Message Development

Original Publications
Senior staff
Mario Gutiérrez, Ing. Agr., Editor

Standard Publications
Senior staff
Charles E. Bower, BSJ, Editor

Associate
Francisco Motta, MS, Agronomy, Editorial

* Left during 1978

Assistants
Alejandro Jiménez, Ing. Agr., Editorial
Dorothy Muller, BA, Editorial

Audiotutorial

Research associate
Alfredo Caldas, MS

Associate
María Lucía de Posada, MS, Editor
Gabriel Robayo, MS

Assitants
Luis Fernando Ceballos, Ing. Agr.
Cilia Fuentes, Ing. Agr.
Héctor Fabio Ospina, Ing. Agr.

Graphic Arts Production

GAS staff
Walter Correa, PhD, Head, Graphic Arts

Associate
Manfred Hirsh, Photographer

Assistants
Didier González, Graphic Designer
Carlos Rojas, Graphic Designer
Fanny Rodríguez, Graphic Designer
Carlos Vargas, Graphic Designer

Public Information Office

Associate
Fernando Mora, BA, AHA, Head

Assistants
José Fernández de Soto, Ing. Agr.
Jorge Enrique Paz, Ing. Agr.

Seed Unit

Senior staff
Johnson Douglas, MS, Seed Specialist (Coordinator)

CIMMYT/CIAT Andean Regional Maize Unit

Senior staff
Gonzalo Granados, PhD, Entomologist (Coordinator)
James Barnett, PhD, Plant Breeder

Research assistant
Edgar Castro, Ing. Agr.

International Program

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

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

Foreword

In 1978 CIAT completed a year of solid progress — both in the generation and the inter-institutional transfer of technology. After several years of external and internal reviews, program modifications and staff changes, 1978 was a year of stability with the various interdisciplinary research teams building on the solid foundation of clearly defined objectives and sharply focused strategies established in previous years.

The results now beginning to emerge from our various programs have created a sense of wonder and excitment. Many of these research results attack basic problems of food production and resource use; they are meant to provide broadly based solutions; and we have indications to believe they are valid and adaptable at all economic levels of production and usually over extensive geographic areas. Our excitement, then *is* justified, especially when we begin to think of what these results can mean in improved human welfare when they are applied by farmers throughout our areas of influence.

While we are optimistic and excited about our developments in technology generation, we are aware of the important gap between developing new technology and applying it to increase food productivity by a large number of farmers. In past years we have directed considerable efforts toward strengthening national programs and increasing their capacity to adapt and utilize new technology under locational conditions. We have vigorously moved in this direction by out-posting regional service program staff and by increasing numbers of participants in our training programs. Not only do we expect a better technology transfer mechanism from these strategies, we also know they will provide an important feedback connection assuring us that our technology is broadly applicable and as useful as possible under real farming conditions in our areas of concern.

Our research programs themselves are increasing their efforts to insure that technology under development is appropriate to varied climatic, edaphic and socio-economic conditions in the countries served. Programs also are doing their utmost to help disseminate new technology as effectively as possible. Consequently, you will note certain themes running through activities reported this year. Among the most important ones are a minimum input philosophy, expanded work in regional collaborative testing and on-farm validation of technology.

The minimum input philosophy directly relates to our statement of objectives which identifies producers and consumers with limited resources as major beneficiaries of our technology. If consumers are to benefit, it is important that increases in production be achieved at lower unit costs. Low unit costs can be achieved through biologically based technology, which is usually scale-neutral. To assure that producers with limited resources have access to benefits of this technology, it should not depend on large amounts of purchased inputs. Increased fertilizer use will probably be essential to meet growing food requirements; however, other factors are of greater relative importance as production constraints on the non-cereal commodities represented by our major programs.

Among such other important constraints are diseases, insects and adverse soil conditions. We have made great progress in finding genetic solutions to these problems, not only through narrowly focused solutions to single problems, but solutions which provide insights into entire complexes of insect-disease-environmental relationships. We have reason to believe that genetic differences exist and can be exploited for efficient use of important elements such as phosphorus and potassium. Two of our programs involve legumes; increased efficiency of biological nitrogen fixation can reduce the need for nitrogenous fertilizers and we have made important strides in obtaining this efficiency. All of these efforts and results will contribute to decreasing the dependence on pesticides and relatively expensive, frequently scarce fertilizers and still provide optimum yields with reduced risks.

Our reports this year also document a quantum jump in the amount and quality of collaborative testing of CIAT's technology in regional and international networks utilizing procedures worked out by mutual agreements in various workshops. Continuing back-up support and guidance are provided by the extensive travel of the home-based staff and out-posted program staff.

CIAT programs are also rapidly increasing their collaboration with national programs in establishing on-farm trials for technology validation. This level of testing is an essential component of our technology generation strategy; in addition, it provides a logical beginning for technology transfer. One of the important problems is the large difference between yields on experiment stations and in farmers' fields. We must know for a given technology whether this difference can be removed under the constraints of real farmers and whether they will adopt the new technology; only if we have positive answers to both questions can we be certain we have produced improved technology. Because this stage of generation is so critical, we have worked this year to increase our involvement in it and expect to continue expanding and learning from it.

The results and progress we are reporting are encouraging. This, however, is only the beginning. Most of our programs are only five to eight years old, but old enough that the exciting results are emerging at an accelerating rate. These results are moving into the hands of national programs, many of which are managed at various levels by professionals who have completed some stage of their training in CIAT's own training programs. Until now, the Center and its programs have not been sufficiently mature that many of the results of CIAT's past efforts are being applied by farmers.

Now, however, the Center is ready to begin demonstrating its maturity, a maturity to be measured by the quantity and, ultimately, the degree to which the new technologies are included in the adaptive/validative research endeavors by our national program clients and are finally adopted by their farmers. We are fully confident that in the next several years we can report important progress in this essential phase.

John L. Nickel
Director General

Cassava Program

The cassava program has three major objectives: (1) to develop a simple technology to increase production in areas where cassava is already widely grown; (2) to develop technology for cassava production on the acid, infertile soils; and, (3) to assist national agencies in their efforts to adapt this technology to local conditions and increase cassava output.

The first objective is rapidly being reached and in the North Coast of Colombia, representative of a large proportion of the world's cassava growing areas, the CIAT-developed technology package has been tested by farmers. The use of improved varieties, stake selection and treatment, optimum plant population and good weed control tripled yields. It is important to note that this was done without the use of any purchased inputs, except for the very cheap (US$ 3/ha) stake treatment. Although yields were spectacularly increased, certain marketing problems were encountered due to the low starch content of the CIAT-selected lines. This knowledge has led us to concentrate on methods of increasing starch content, mainly by selecting lines with higher levels.

In the acid, infertile soils the technology is not yet as far advanced due to the very serious disease problems encountered in these areas. Research in this area has been greatly increased and, on experimental plots, yields of over 30 t/ha have been consistently obtained. However, in this area problems still have to be overcome, particularly those associated with the production of large quantities of high-quality planting material and improved disease resistance.

The measure of success in the transference of technology is always difficult to define, nevertheless, it appears that progress is being made. CIAT-produced seeds have been planted in several countries and the selected lines are now being grown in advanced yield trials. International yield trials have been planted in more than ten countries and material has been multiplied in Asia to start the Southeast Asian trials early next year.

Continued contact with the large number of former trainees suggests that within national agencies there is a growing interest in cassava and that due to collaboration with CIAT and the dissemination of CIAT-developed technology, increased production may soon become a reality in certain countries.

PHYSIOLOGY

The Physiology Section has continued to evaluate characters associated with high yield potential of cassava. In 1978 emphasis was on determining the branching characteristics of different clones, how branching habits are affected by different growing conditions and on obtaining a firmer basis for recommending extended leaf life to attain high yields.

Earlier physiology studies were directed to determining the ideal cassava plant type for near ideal conditions, including monoculture production. Much of the world's cassava, however, is grown on poor soils with limited fertilizer and in mixed culture. Work was intensified to define how cassava responds to different fertility levels and the plant type required for multiple cropping.

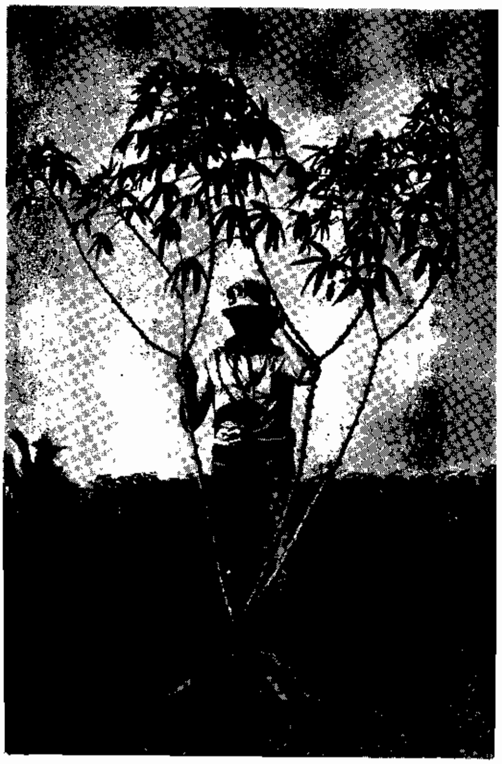


Figure 1. Mature cassava plant showing typical branching pattern.

Branching Pattern of Cassava

The predominant form of branching in cassava occurs when the main apex produces an inflorescence. Once this occurs the apical dominance is apparently broken and two to six of the axillary apices immediately below the main apex develop into approximately equal sized branches (Fig. 1). The most common number of branches is two or three at each branch point, however, some clones produce four.

It has been shown that changing the branching habit can markedly affect yields and that optimal branching patterns for high yields exist (CIAT Annual Reports, 1975, 1976 and 1977). Therefore, it is important to determine the genetic variability in branching habit and how this is affected by ecological conditions. The time for forming the first branch, under conditions at CIAT-Palmira, depended on the variety (Fig. 2). Variety M Col 72 did

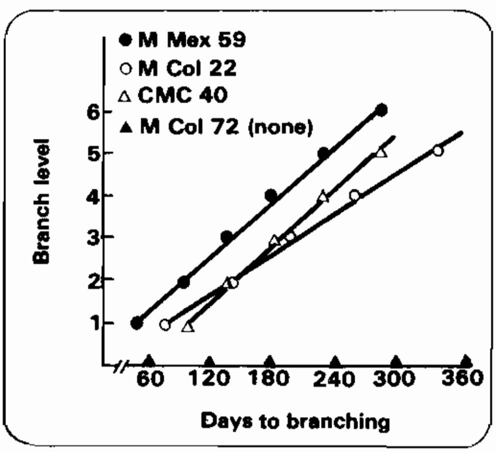


Figure 2. Time to branching for four cassava varieties at CIAT.

not branch in the one-year trial while M Mex 59 branched first about 60 days after planting. The time interval between branch formation appeared to be constant for a variety but differed between varieties (Fig. 2). This constant interval between branching points is important in determining the ideal plant type; for example, from this data it would appear impossible to obtain a variety that branched solely at 20 and 30 weeks and then stopped. Further studies with a computarized simulation model, employing a constant branching interval, suggest that optimal yields can be obtained with types that branch at 30 weeks or at 30 and 45 weeks.

The variety M Col 113 tends to produce four branches at each branch point. The time interval between branch points tended to increase at higher branch levels. When the number of branches at each branch point was restricted to one, the constant time interval was maintained (Fig. 3). This suggests that when branching is very profuse, some internal competition mechanism delays the branching at higher levels.

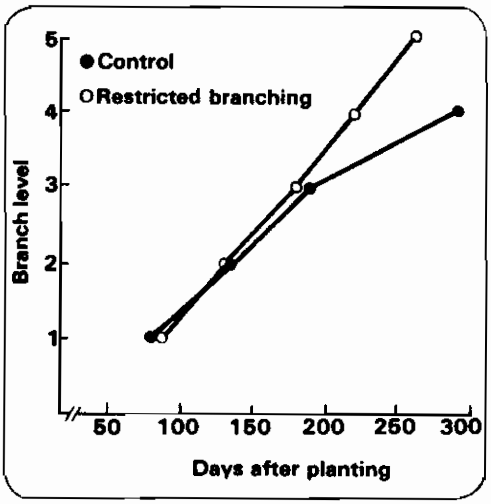


Figure 3. Effects of restricting number of branches at each point on time to branching of variety M Col 113.

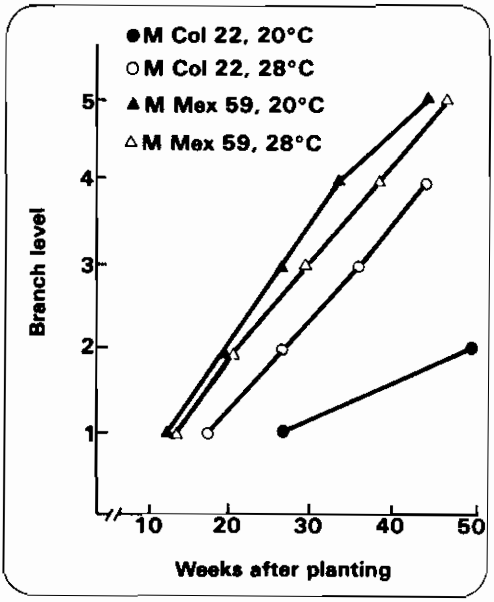


Figure 4. Effects of mean air temperature on time to branching for two cassava cultivars.

At cooler temperatures branching in M Col 22 was delayed and the interval between branches increased (Fig. 4). Hence, it appears possible to select varieties that are insensitive, in terms of branching habit, to a broad temperature range.

Three varieties were grown at CIAT-Quilichao at low, medium and high fertility levels. The time to first branching and the time interval between branches was little affected by the fertility level. However, at lower fertility the plants produced fewer branches per branch point and the percentage of plants branching at the higher points was much reduced or no high-level branches were formed. The net effect of fertility on the number of active apices per plant differed for each variety (Fig. 5). M Col 22 did not respond to changing fertility levels and CMC 40 responded slightly. With M Mex 59, however, the final active apex number per plant was four times greater at high than at low fertility levels.

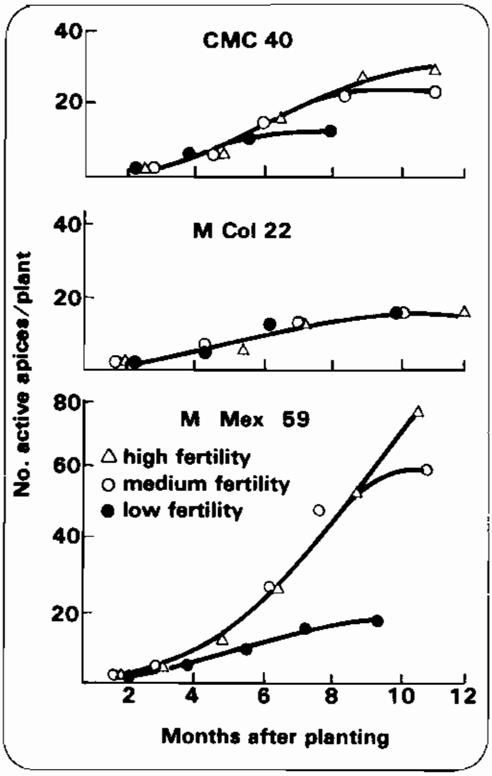


Figure 5. Effects of three fertility levels on the number of active apices per plant in three varieties of cassava.

Leaf Life

Last year it was suggested that a long leaf life was advantageous for high yields and results were presented on the effects of changing leaf life on yield up to nine months after planting (CIAT Annual Report, 1977). The one-year harvest data show that yield increases with leaf life up to a level of 90-100 days (Fig. 6). The data suggest that yield increases of about 25% can be expected by increasing leaf life from 50 days to 100 days. The photosynthetic rate of old leaves was only slightly less than that of younger leaves, up to leaf ages of 90-100 days (Fig. 7), suggesting that older leaves continue to make very useful contributions to the total photosynthesis of the crop canopy.

Response to Fertilizer

The variety M Col 22 was grown in pots of Carimagua soil at high, medium and low fertility levels and harvested after 13 weeks. Fertilizer treatments were 300, 150 or 0 kg N/ha and 600, 300 or 0 kg of P_2O_5 and K_2O/ha; all treatments received 150 kg $ZnSO_4$/ha and 2 t/ha of dolomitic limestone.

Large differences in total dry matter per plant were found (Table 1) and these were closely related to the Leaf Area Duration (LAD) per plant during the same period (Fig. 8). This suggests that the differences in dry matter production per plant were due to differences in leaf area and not to differences in leaf efficiency. Photosynthetic rate of fully expanded leaves was measured about halfway through the experiment (five weeks). Photosynthetic rate was little reduced by low levels of potassium but was reduced

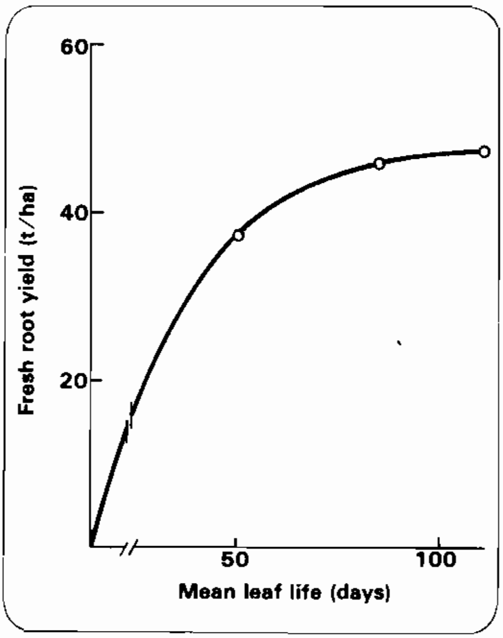


Figure 6. Effects of leaf life on yield of cassava variety M Col 72.

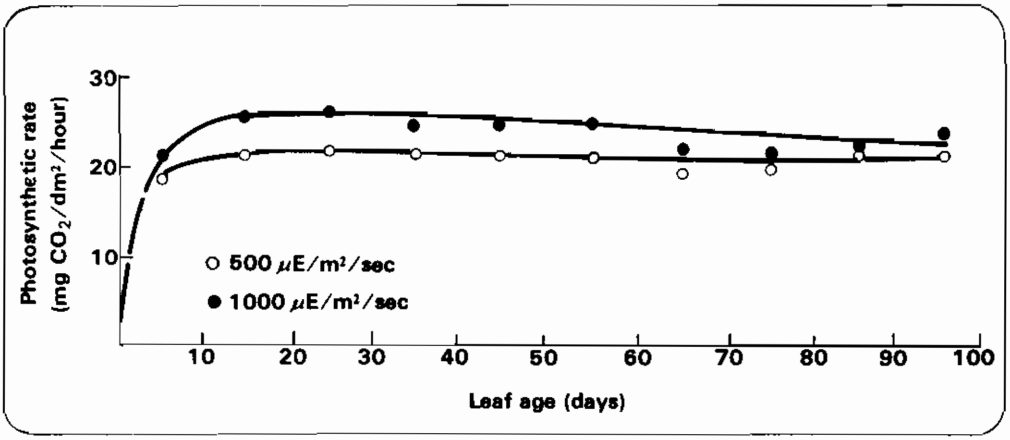


Figure 7. Photosynthetic rate of leaves of cassava variety M Col 72 at two light levels.

about 20% by low levels of nitrogen and phosphorus (Fig. 9). Reductions were small compared to the reduction in dry matter produced, hence reinforcing the hypothesis that differences in dry matter produced were due to differences in leaf area and not leaf efficiency.

Differences in leaf area per plant were mainly due to differences in leaf size. Leaf formation rate was only slightly decreased by low levels of N, P and K, with K having the smallest effect.

M Col 22, CMC 40 and M Mex 59, non-vigorous, medium and very vigorous varieties, respectively, were planted at the CIAT-Quilichao station at low, medium and high fertility levels. Applications of the three basic elements were the same as for

Table 1.

Dry matter production of cassava 13 weeks after planting in pots of Carimagua soil fertilized at different levels of N, P and K[1].

Fertilizer applied (kg/ha)			Dry matter
N	P_2O_5	K_2O	(g/plant)
0	600	600	67 bc[2]
150	600	600	73 ab
300	600	600	82 a
300	0	600	48 d
300	300	600	68 bc
300	600	0	70 abc
300	600	300	74 ab

1 Dry weight of original planting piece approximately 20 g.

2 Values followed by the same letters are not significantly different at the 0.05 level.

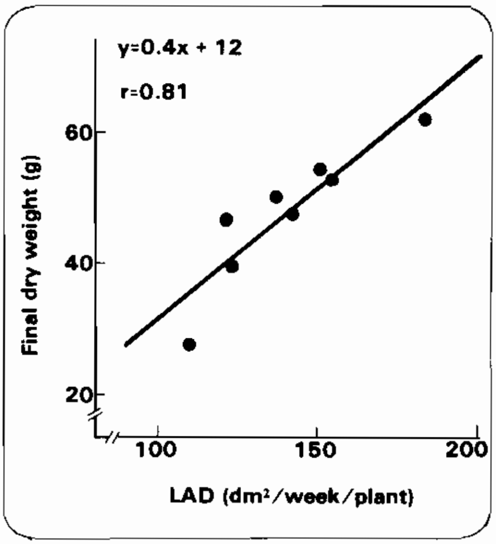


Figure 8. Dry weight of pot-grown 13-week-old plants of cassava variety M Col 22 as related to the Leaf Area Duration (LAD). (The 20-cm planting piece initially weighed 15 g.)

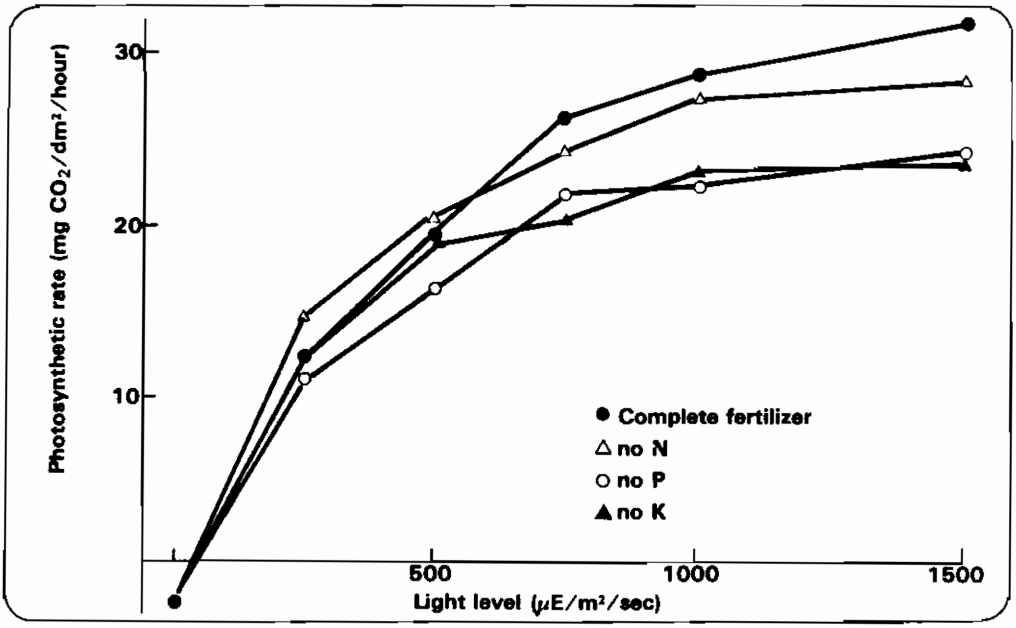


Figure 9. Photosynthetic rate of individual leaves of cassava variety M Col 22 grown under different fertilization rates.

the pot trials reported above. In addition, plots received 1.5 and 0.5 t/ha of calcic and dolomitic limestone, respectively, and stakes were treated with $ZnSO_4$ before planting.

At the final harvest 12 months after planting, there were no significant differences between varieties nor variety x treatment interactions on yield. Yields were significantly greater at the high and medium fertility levels — 13.5 and 11.9 t/ha of dry roots respectively — than at the low level, 5.4 t/ha of dry roots. At the six- and nine-month harvests there was a variety x treatment interaction significant at the 5% level. Both M Col 22 and CMC 40 approached maximum yields at all levels of fertility nine months after planting (Fig. 10), whereas at high and medium levels the yield of M Mex 59 increased markedly between nine and 12 months. M Col 22 and CMC 40 can be considered as early varieties under these conditions.

In the past a close relationship was found between root growth rate and Leaf Area Index (LAI) with an optimum LAI for root growth of 2.5-3.5. In this trial no marked optimum was obtained as can be seen in Figure 11. Root growth rate, however, tended to be less at higher LAIs. There was no tendency towards greater root growth per unit LAI at higher fertilities, suggesting that the main effects of fertility were on source size, not efficiency.

The LAIs attained by M Mex 59 at high levels of fertility were greater than those obtained in most trials. Normally, when LAI is greater than 3.5 lower leaves are shaded so much that they drop. This apparently did not occur in this trial (Fig. 12). Leaf life was only slightly less for leaves tagged from 4-8 months at high fertility where LAIs above 6 were obtained and remained above 3.5 for a long period. Thus, high fertility may prevent leaf drop;

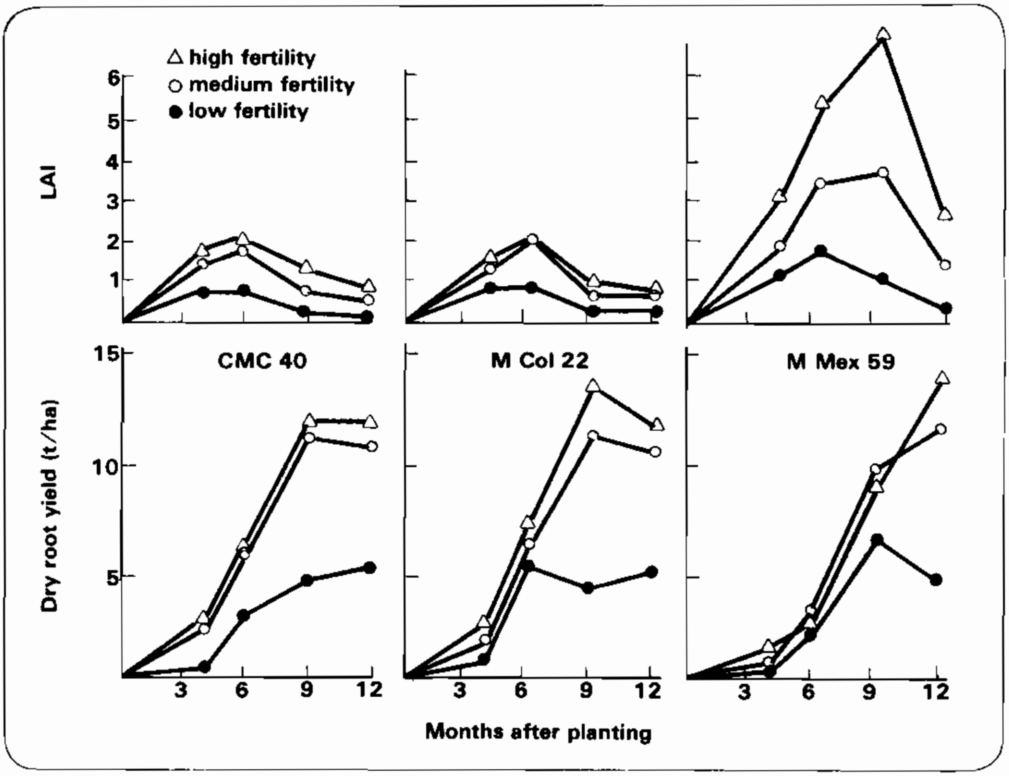


Figure 10. Effects of three fertility levels on the Leaf Area Index (LAI) and dry root yields of three cassava varieties.

nevertheless, at the low LAIs of M Col 22 there was no consistent effect of fertility on leaf life (Fig. 12).

The LAI was increased by increasing the fertility levels (Fig. 9). Higher fertility levels increased the rate of leaf formation per apex about 20% (Fig. 13), increased leaf size (Fig. 14) and increased the number of active apices (Fig. 5). In these trials cassava grown at low fertility levels restricted its leaf area development; however, the proportion of total dry matter harvested found in the roots, measured as the Distribution Index (root growth rate divided by crop growth rate) was much greater at low LAIs (Fig. 15). Thus, even with no fertilizer applied all varieties yielded more than 5 t/ha of dry roots. The lack of an interaction between variety and fertility level at the 12-month harvest suggests that varieties can be

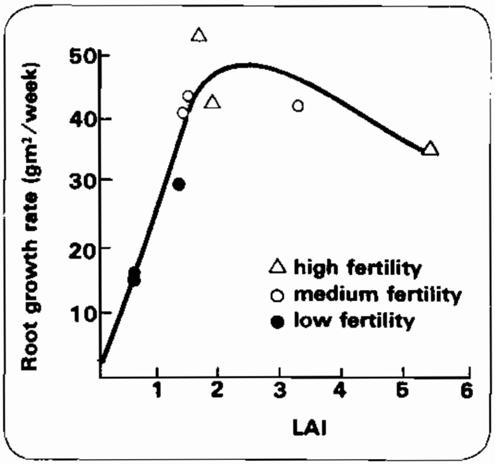


Figure 11. Cassava root growth rate in relation to Leaf Area Index (LAI) from 4 to 9 months after planting three varieties at three fertility levels.

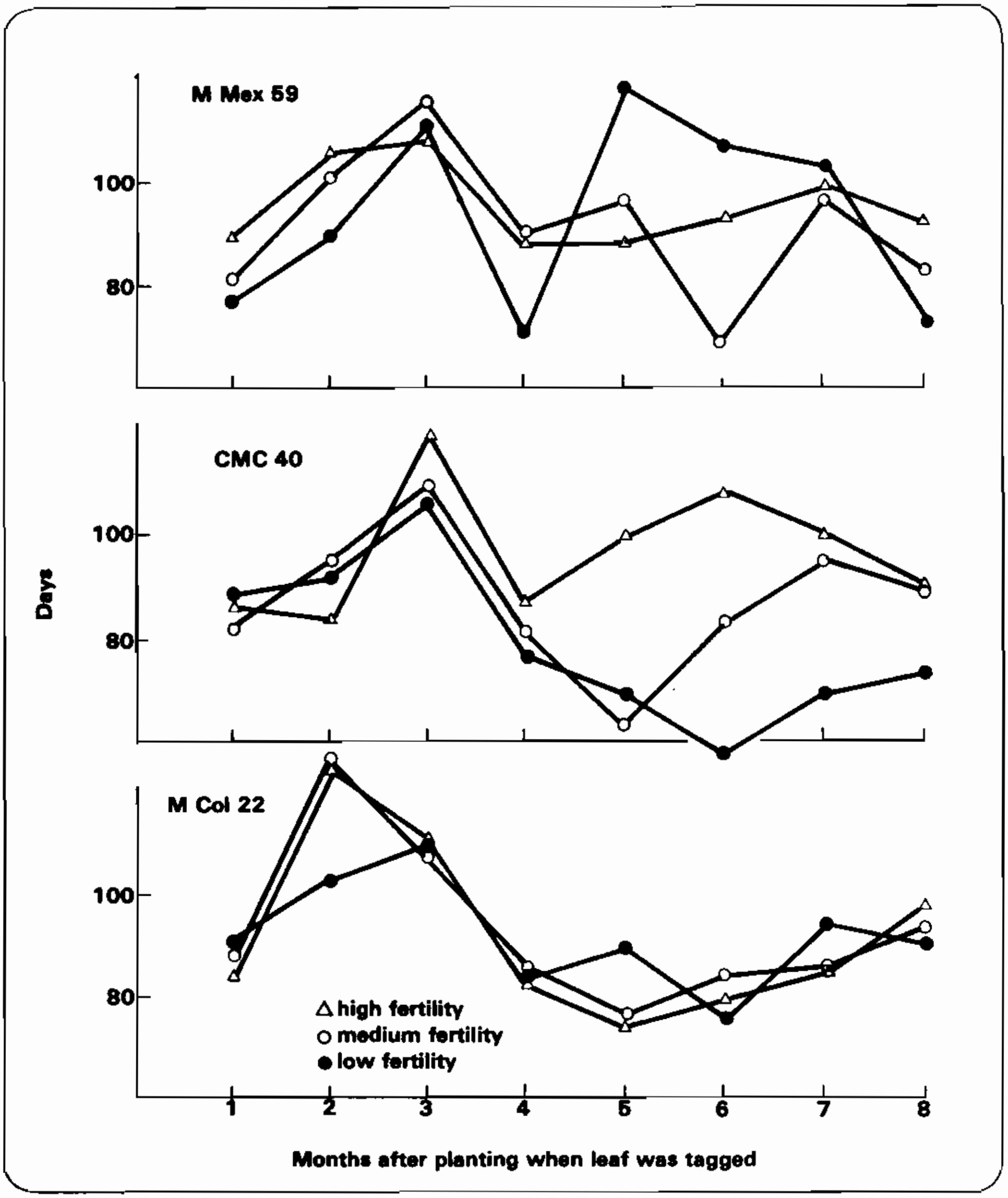


Figure 12. Leaf life of three cassava varieties at three fertility levels.

selected that yield well at low fertility but also respond to higher fertility levels, as was the case in this trial.

It is frequently stated that cassava is a crop that yields well at low fertility levels. It is also suggested it has this capacity because when the fertility level is low it tends to conserve a high level of nutrients in the leaves by reducing its LAI (Table 2). Plants with this low LAI have relatively efficient leaves in terms of photosynthesis. Furthermore, due to the restriction on leaf development, less energy is utilized to form

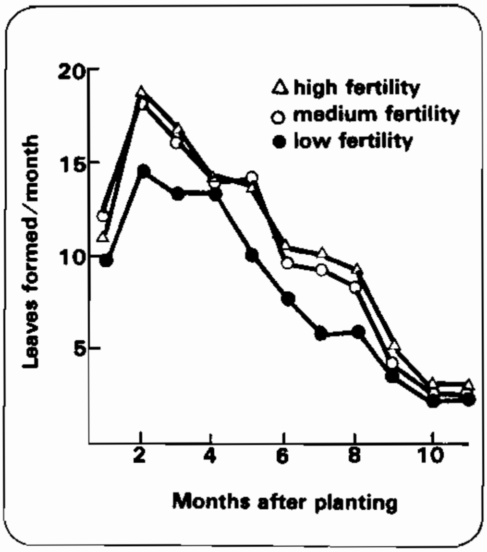


Figure 13. Cassava leaf formation rate per active apex at three fertility levels (mean of three varieties).

leaves and stems at low fertility levels giving a very high Distribution Index. Although relatively small amounts of carbohydrate are produced almost all is transported to the roots at low fertility levels.

Multiple Cropping

Last year it was shown that beans and cassava could be intercropped and high Land Equivalent Ratios (LER) obtained (CIAT Annual Report, 1977). It was also observed that higher LERs were obtained with cassava variety M Mex 11 than with M Col 113. This year the bean variety Porrillo Sintético, a black bean of indeterminate growth habit, was intercropped with 20 cassava genotypes of widely varying morphological characters. There was a strong negative correlation (r= - 0.495*) between bean yield relative to monoculture and cassava top growth three months after planting. Normally, top growth is greater in early branching types and it has been suggested that high-yielding types will be late branching (CIAT

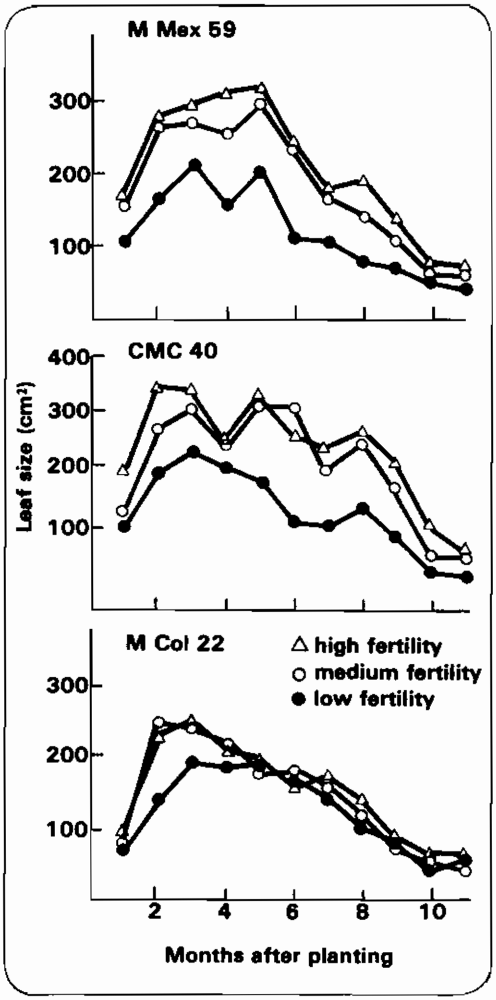


Figure 14. Leaf size of three cassava varieties at three fertility levels.

Annual Report, 1976 and 1977). In this experiment there was a nonsignificant but positive correlation between bean yield and cassava fresh root yield suggesting that it is possible to select cassava types for high yield potential in monoculture that also are suitable for multiple cropping with *Phaseolus* beans. These varieties will be late-branching.

The same 20 cultivars were planted with the soybean cultivar ICA Tunia. This soybean has a 125-day growth cycle

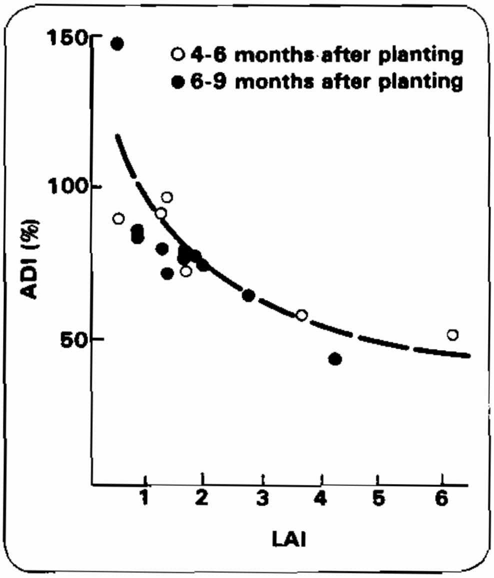


Figure 15. Apparent Distribution Index (ADI) (root growth rate/crop growth rate) as a function of Leaf Area Index (LAI) during two growth periods. (Fallen leaves not included in crop growth rate so values greater than 100% are possible.)

Table 2.

Concentration of N in leaves of cassava plants grown in the field at Carimagua at different fertilizer levels (28 to 32 weeks after planting).

Fertilizer applied (kg/ha)		Leaf area per plant (dm^2)	Leaf nitrogen (%)
N	K_2O		
0	0	76	4.2
0	300	163	5.0
100	0	94	5.3
100	300	198	5.1
200	0	119	5.0
200	300	156	5.0

whereas the *Phaseolus* beans used in previous experiments all have growth cycles of less than 100 days. Cassava and soybean yields were negatively correlated ($r = -0.347$).

It appears that the short-cycle *Phaseolus* bean can complete its growth before the cassava covers the ground and hence yields well with cassava. On the other hand, the grain-filling period of soybeans occurs when cassava needs to be reaching full ground cover if it is to yield well. Hence, the two crops compete and it is difficult to select a cassava variety that yields well and also allows soybeans to attain good yields. Planting soybeans at the same time as the cassava rather than two weeks after, as in

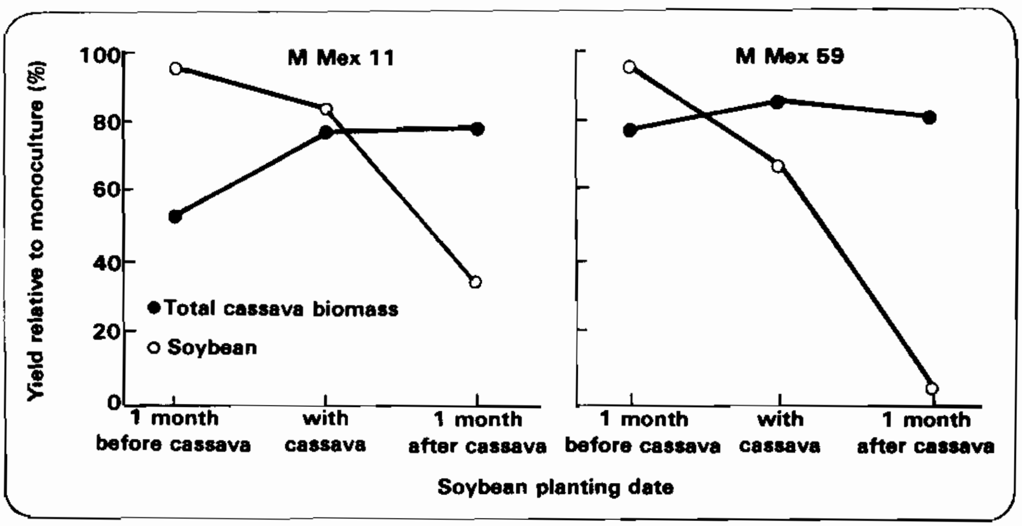


Figure 16. Relative yields of cassava and soybeans as influenced by different soybean planting dates.

this experiment, might alleviate this problem.

To study this possibility, soybeans were planted simultaneously with the late-branching M Mex 11 cassava and soybean yield was indeed little reduced (Fig. 16). The root yield in this trial was very variable; however, the total cassava biomass was not greatly reduced (Fig. 16).

Mixed cropping is most frequently utilized by small farmers using few resources. When cassava was grown with beans and no insecticides were used, populations of pests on both crops were reduced (CIAT Annual Report, 1977). Bean and cassava yields were almost the same in monoculture as in mixed culture without applied insecticides (Fig. 17), suggesting that under low input system, mixed cropping is very advantageous.

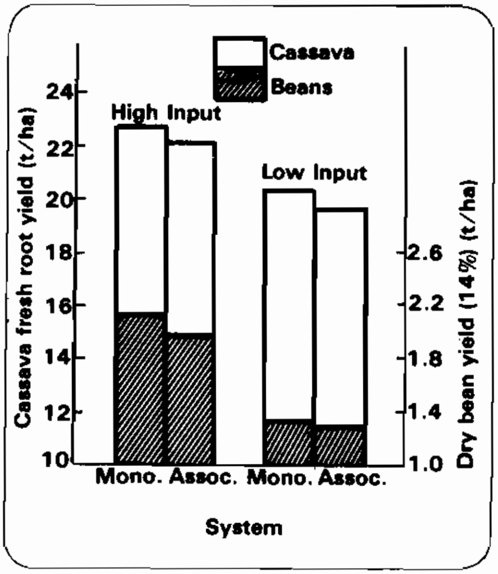


Figure 17. Effects of two input levels on yields of associated cassava and beans.

Early Growth

Cassava is highly sensitive to weed competition in the first 90 days of growth (CIAT Annual Report, 1974). This suggests that early vigor is very important in determining yield. When CMC 40 and M Col 22 were shaded for two-week periods (50% shading) during the first three months after germination final yield was reduced in all cases, although differences were rot significant. Shading at the 50% level for the first three months markedly reduced yields. This suggests that early vigor and growth are very important in determining yield and if this is true, then quality of the planting piece is vital in determining early growth and hence, final yield. When cuttings were stored for up to two weeks before planting, without any treatment, germination was greater than 90% but yield was markedly reduced.

ENTOMOLOGY

During 1978 the Entomology Section completed its studies of the biology of the cassava hornworm (*Erinnyis ello*) and intensified work to understand the biology and parasitic activities of several species which attack the hornworm.

During a two-year study in an important cassava growing area of Colombia, 57% parasitism of hornworm eggs was observed due to *Trichogramma*. Biological studies of important species of this genus were conducted. Studies were also begun with two other egg parasites — *Telenomus* sp. and *Chrysopa* sp. The hornworm larva parasite *Polistes* was studied in the field to determine optimum means of establishing colonies. Several insect species were identified which attack *Polistes*.

Screenings were done to search for host plant resistance to whiteflies

(*Aleurotrachelus* sp.), mealybugs (*Phenacoccus gossypii*), the lace bug (*Vatiga manihotae*) and mites (*Tetranychus* and *Mononychellus*). Some natural resistance was observed for each species.

Effective chemical treatments were developed to protect planting stakes against termite attack where this pest is economically important.

Cassava Hornworm

Biology

To develop an integrated control program it is necessary to understand the biology, behavior and interactions that exist between the pests and their natural enemies.

Adult longevity of the cassava hornworm (*Erinnyis ello*) was studied in field cages (25°C, 80% RH) where adults were fed a 7% honey solution. Adult females lived up to 19 days (avg. 8.6 days) while males had shorter longevities (max. 15 days and avg. of 7.0 days). The T_{50} (the time in which 50% of the population dies) was 6.6 days for females and 6.2 days for males.

The fecundity of females mass-reared on green material was determined. The pre-ovipositional period was 3-4 days. Male/female pairs in a cage produced an average of 850 eggs, but when groups of 11 pairs were caged, females laid an average of 448 eggs (Table 3). Females laid throughout their lives but laid more than 70% of their eggs in the first seven days of oviposition (Fig. 18). The maximum daily oviposition of a female was 500 eggs.

Mean egg fertility was 88% (Table 3), but this varied in the mass-reared population during the different seasons of the year. Despite a high hatching rate larval mortality was greater than 80% mainly due to a granulosis virus (Baculovirus).

Females and males were separated in the pupal stage by the position of the genital opening. The male's genital opening (gonopore) is on the ninth abdominal segment with the eighth segment being free whereas the female's genital opening reaches the eighth segment. The sex ratio (2914 pupae observed) was 1 female to 1.12 males.

Biological Control

Studies of *Trichogramma* received special emphasis because it is found parasitizing *E. ello* eggs year-round in cassava plantations and because it is easy to mass-rear and release in the fields.

Table 3.

Fecundity and fertility of the cassava hornworm (*Erinnyis ello*) under field cage conditions[1].

	No. of observations	Values		
		Max.	Min.	Avg. (SE)
Fecundity (eggs/female)	10 groups of 11 pairs	1374	132	448 (23.5)
	Individual pairs	1852	200	850 (249)
Fertility (%)	4440 eggs	98.8	77.7	88

1 25°C and 80% RH.

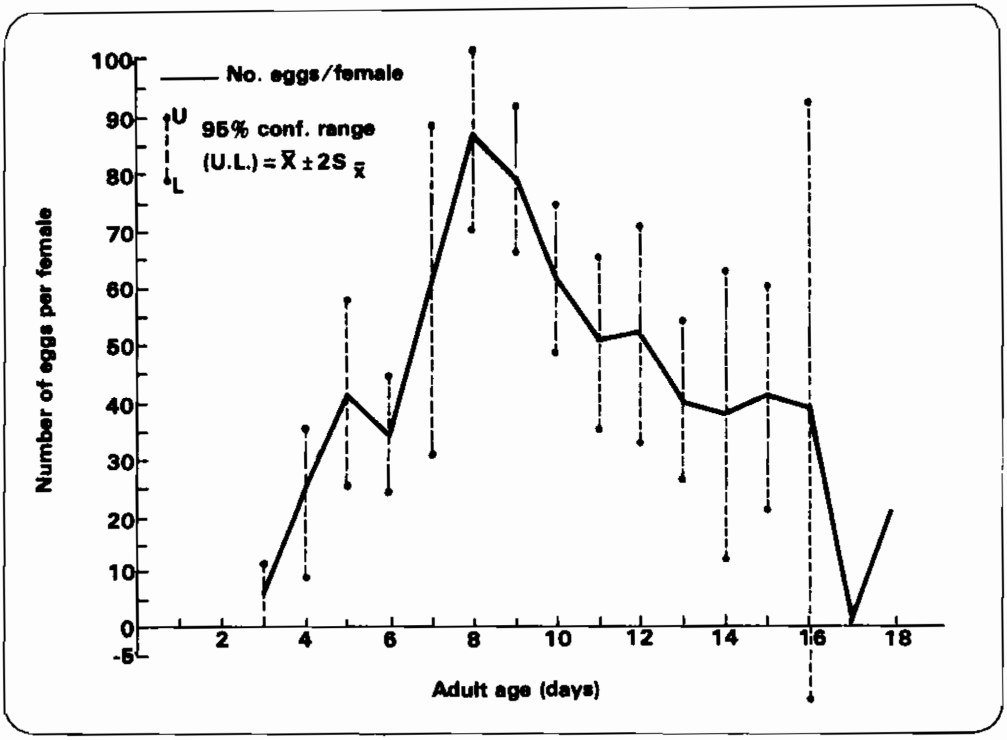


Figure 18. Average fecundity of 52 adult *Erinnyis ello* females.

Between February 1976 and March 1978, parasitized and unparasitized hornworm eggs were counted in cassava plantations in Armenia and Caicedonia, Colombia. A positive relationship was found between the total number of *E. ello* eggs and the number of eggs parasitized by *Trichogramma* (Fig. 19). Percentage parasitism remained fairly constant over the two years. Hornworm eggs and parasitism of these eggs by *Trichogramma* were found at every sampling. Average parasitism over two years was 57% (SE 0.91).

The sex ratio of native *Trichogramma* collected from four locations was determined in the laboratory. In all the locations females out-numbered males. The overall mean was 3.6 females to 1 male (range of less than 1 to 21 females per male). Natural egg mortality of *Trichogramma* was 19.5%.

The parasitic ability and sex ratio of five *Trichogramma* species were studied with adult wasps collected from liberation programs on cassava plantations to control the hornworm. All species parasitized *E. ello* eggs; the most effective species were a native *Trichogramma* (93%) and *T. australicum* (90%) and the least effective was *Trichogrammatoidea armigera* (42%).

Preliminary studies in the laboratory were conducted with two other species of particular interest in biological control because they attack the egg stage of the hornworms.

The parasite *Telenomus* sp. (Hymenoptera: Scelionidae) has a marked preference for hornworm eggs. In the laboratory (24°C, 75% RH), an average of four *Telenomus* adults emerged from each hornworm egg (400 eggs observed); the time required for adults to emerge from

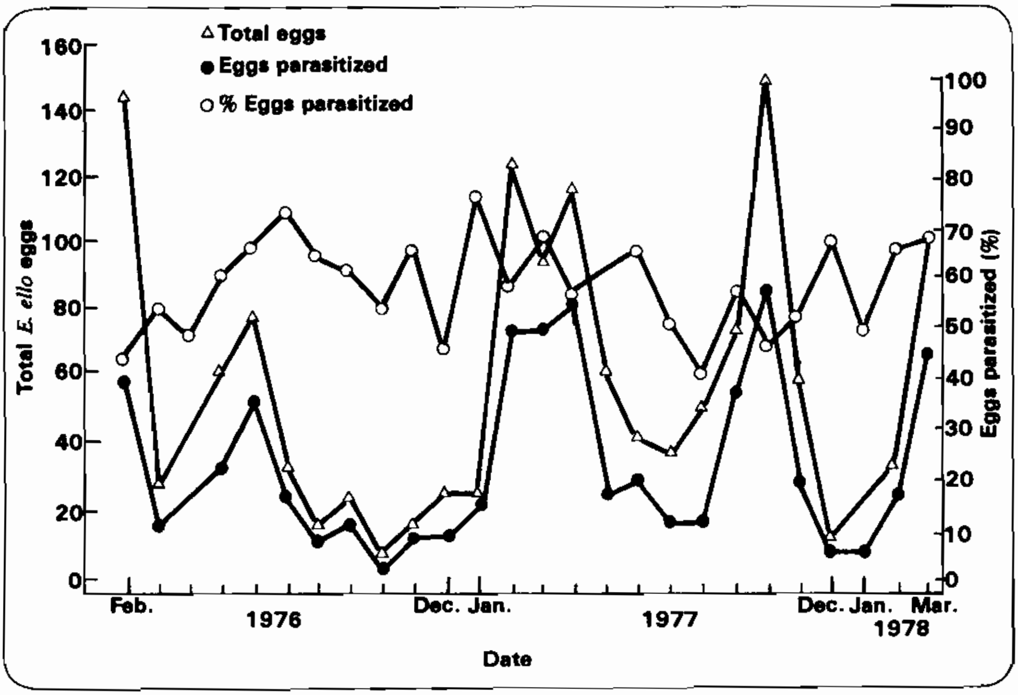


Figure 19. Relationship between numbers of eggs of *Erinnyis ello* and eggs parasitized by *Trichogramma* from 1976 to 1978 in Armenia and Caicedonia, Colombia.

Telenomus eggs was 11-14 days. Preliminary observations indicated that one female *Telenomus* can produce up to 150 offspring.

The Neuropetera *Chrysopa* sp. is a general predator in cassava fields. It has been observed eating hornworm eggs and is known to attack mites, scales and mealybugs. In a laboratory study, the last nymphal instar consumed an average of 17 hornworm eggs in 24 hours.

The predatory capacity of *Polistes* was observed to be determined principally by the number of *Polistes* larva and not the number of adults. The maximum number of *E. ello* larvae consumed by *Polistes* larvae daily was 1.1 and the minimum was 0.08 (mean of 0.47, SE=.004).

The relationship between the size of the *Polistes* nest and sex ratios of the populations was studied. Males were not found in nests having fewer than 50 cells. In larger nests males increased with increasing numbers of eggs, larvae and pupae. The *Polistes* male's function is to mate with females leaving to start new colonies. Therefore, for successful *Polistes* colonization programs in cassava fields it is preferable to introduce large nests with many cells so that these can establish strong new colonies.

Polistes populations were observed to be regulated not only by climate and insecticide applications but also by several other insects associated with their nests. Ten Hymenoptera, four Coleoptera, two Lepidoptera, two Diptera and one Psocoptera have been found associated with *Polistes*.

Of these insects, *Oxysarcodexia*, a larval and pupal parasite of *Polistes*, seems to be one of *Polistes'* principal natural enemies. This parasite has been found in several regions of the Cauca Valley of Colombia, generally attacking nests with more than 200 cells. Of 412 nests examined, 17% were attacked by *Oxysarcodexia* This insect in turn is parasitized by several natural enemies including *Pachyneuron* sp. and *Brachymeria conica*.

Podisus sp. (Hemiptera: Pentatomidae) (soldier bug) are also predators of *E. ello*. In the laboratory (24.5ºC, 75%RH) *Podisus* females survived up to 82 days (avg. of 42.8 days) (Table 4). The female lays a maximum of 1400 eggs during her lifetime with an average fecundity of 715 eggs/female.

The egg fertility was 79.4%. The egg incubation period was 4-5 days and the nymphal period was 20-24 days. Preliminary observations showed that each *Podisus* consumes an average of 100 *E. ello* first or second instar larvae in its lifetime. Colonies of *Podisus* were maintained and increased on larvae of *Galleria mellonella*, a species easily and cheaply raised.

Of 1200 of *E. ello* collected in the Caicedonia, Armenia and Cartago areas of Colombia, 70% mortality was observed, chiefly due to an unidentified disease and three Dipterous parasites: *Belvosia* sp. (Tachinidae), *Sarcodexia innota* (Sarcophagidae) and *Thysanomyia* sp. (Tachinidae) (Fig. 20).

In Caicedonia, Armenia and Palmira, eggs and larvae of another hornworm species, *Erinnyis alope* (Drury), have been found on cassava. This species was previously recorded in Colombia on *Carica papaya* L. but not on cassava.

The life cycle of *E. alope* is very similar to that of *E. ello;* the two can be easily differentiated in the egg, larval or adult stages (Fig. 21). The most notable difference is in the adults. *E. ello* adults have light grey front wings and reddish-orange back ones while *E. alope* have dark brown front wings and yellow back wings.

Table 4.

Biological cycle, fecundity and fertility of *Podisus* sp. (Hemiptera: Pentatomidae) under laboratory conditions[1].

	No. of observations	Avg.	SE
Duration of nymphal (five instars) period (days)	150	20-24	
Longevity of female adults (days)	16	42.8	10.7
Fecundity (eggs/female)	16	715.4	97.8
Eggs per cluster	1463	26	1.25
Egg incubation period (days)	1463	4-5	
Egg fertility (%)	1092	79.4	2.25

1 25°C and 75% RH.

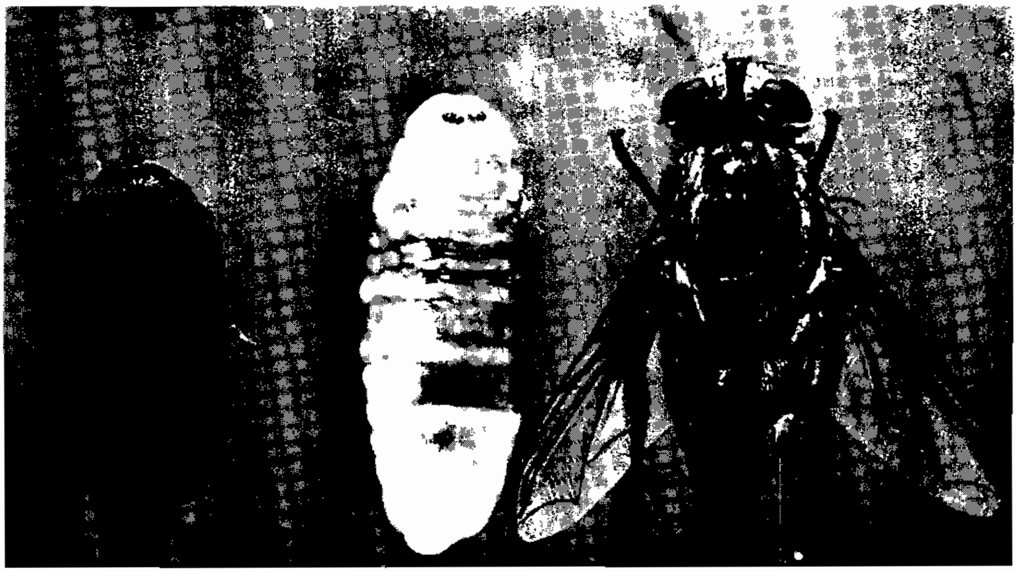


Figure 20. Pupal, larval and adult stages of *Thysanomyia* sp. (Tachinidae), a parasite of the larvae of the cassava hornworm *(Erinnyis ello)*.

Observed populations of *E. alope* in cassava have been low.

Termites

Termites are sometimes a problem in certain cassava-growing areas where they attack stored planting material and growing plants. The species found in Colombia is probably *Coptotermes niger,* a species from Asia.

Thirty-one combinations of stake treatments were tested to determine their

Figure 21. Adult stages of two species of the cassava hornworm: on the left, *Erinnyis alope* (Drury), on the right, *Erinnyis ello* (L.). The latter have light grey front wings and reddish-brown back ones while *E. alope* have dark brown front wings and yellow back wings.

effectiveness in controlling termites. The best combination was captan and carbendazin 2 g a.i. of each/liter of water in a 10-minute stake dip and later application of 0.025 g of aldrin dust around each stake. For this treatment stake death was 5% and the termite attack after 150 days was 5%. The five best treatments did not differ significantly.

The effectiveness of a fungicide/insecticide combination can be seen in the following examples. When only aldrin was dusted on the ground at planting, termite attack after 150 days was only 13% but stake death was 34%. When only captan and carbendazin were applied, stake death from pathogenic attack was only 1% but after 150 days 37.4% of the plants were attacked by termites. Stake death after applying maneb and mancozeb was 14% but the termites had attacked 64% of the stakes after 150 days.

Whiteflies

Yield Reduction

Whiteflies (*Aleurotrachelus* sp.) cause leaf yellowing and deformation of the growing points and a sooty mold grows in the sugar excretions of the insect.

In the Espinal, Tolima area of Colombia where whiteflies are numerous throughout the year, CMC 57, CMC 40 and M Mex 59 were treated with monocrotophos (E.C. 1.5 cc a.i./liter of water) every 20 days until the harvest at 10 months.

Treated plants showed lower grades of infestation and fewer pupae and yielded more than the untreated ones (Table 5). Yield loss due to whiteflies depended on the variety planted.

Host Plant Resistance

In another trial at Espinal, 300 cassava cultivars were evaluated for field resistance to whiteflies. Although there were high populations on all cultivars some did not show chlorosis or deformation of apical leaves. These tolerant cultivars were M Col 336, M Col 339, M Pan 70, M Ecu 72 and M Bra 12.

Biological Control

Two new pupal parasites of *Aleurotrachelus* sp. were found - *Eretmocerus* sp. (Hymenoptera: Eulophidae) and *Amitus* sp. (Hymenoptera: Platygastridae). Both were observed at CIAT-Palmira, Armenia and the Caicedonia regions of Colombia. The percentage of pupal parasitism was 56.1% among almost 6000 pupae observed.

Mealybugs and Scales

Studies of the biology of *Phenacoccus gossypii* and the search for resistance and natural enemies continued.

Under greenhouse conditions (29ºC, 50% RH), 2-month-old plants of 12 varieties were infested with two egg sacks (300 eggs/sack). The rate of population development of *Phenacoccus* varied on different varieties. Varieties with the lowest populations after 70 days (M Ven 208, M Col 689 and Bra 27) can be considered more resistant than those with high mealybug populations.

Female *P. gossypii* are parthenogenic and produce males as well as females (10 females observed). An ant, *Brachymyrmex* sp., is associated with mealybug populations; the ant feeds on sugary excretions of mealybugs and protects them from some natural enemies.

Table 5.

Yield reduction from whitefly *(Aleurotrachelus* sp.) attack on three cassava varieties grown at Espinal, Tolima, Colombia.

Variety	Treated[1] Fresh root yield (kg/plot) (SE)	Treated[1] Infestation grade[2] Population (SE)	Treated[1] Infestation grade[2] Pupae (SE)	Untreated Fresh root yield (kg/plot) (SE)	Untreated Infestation grade Population (SE)	Untreated Infestation grade Pupae (SE)	Yield loss (%)	% Difference in infestation grade between treated and untreated plots Population	% Difference in infestation grade between treated and untreated plots Pupae
CMC 57	3.31 (0.41)	0.57 (0.19)	0.28 (0.12)	0.77 (0.27)	3.92 (0.27)	3.17 (0.23)	76.7	85.5	91.2
CMC 40	5.35 (0.60)	0.82 (0.23)	0.21 (0.10)	2.57 (0.43)	4.75 (0.17)	4.87 (0.08)	52.0	82.7	95.7
M. Mex 59	3.63 (0.74)	0.71 (0.21)	0.17 (0.07)	2.41 (0.67)	4.70 (0.16)	4.65 (0.10)	33.6	84.9	96.4

1 With monocrotophos at 1.5 cc a.i./liter of water.

2 Infestation grades: Population (adults, nymphs and pupae), 0 = no infestation; 1 = less than 20% of leaves infested; 2 = 21-40% of the leaves infested; 3 = 41-60% of leaves infested; 4 = 61-80% of leaves infested; 5 = 81-100% of leaves infested. Pupae, 0 = no pupae; 1 = fewer than 5 pupae/leaf; 2 = 6-10 pupae/leaf; 3 = 11-25 pupae/leaf; 4 = 26-50 pupae/leaf; 5 = more than 51 pupae/leaf.

Biological Control

In CIAT-Palmira several new parasites and predators of *Phenacoccus gossypii* were found (Table 6) (Fig. 22).

Black Scale

The natural populations of *Saissetia miranda* were low in the cassava growing areas of Armenia, Caicedonia and Palmira, due to the high rate of parasitism (79.1% of 3000 observations) by *Anagyrus* sp. and *Surtellista* sp. (Hymenoptera: Pteromalidae).

Lace Bug

In May and June, 1978 populations of *Vatiga manihotae* were high at CIAT-Palmira. During this period 2203 varieties in the cassava germplasm bank were evaluated for resistance. The results are presented in Table 7. All of the varieties were attacked and 59.8% of the materials had ratings of 3 or more.

Mites

Varietal Resistance

Screening for resistance to three species of mites continued under screenhouse, greenhouse and field conditions. To date, 2120 varieties have been evaluated under screenhouse conditions for resistance to *Tetranychus urticae*. In the first cycle (unreplicated), 96 varieties were selected. Replicated trials of these 96 materials

Table 6.

Predators and parasites of *Phenacoccus gossypii* observed in CIAT-Palmira, 1978.

Order	Family	Species	Association
Coleoptera	Coccinellidae	*Olla* sp. *Curinus colombianus* *Cicloneda sanguinea* *Cryptognatha auriculata* *Hippodamia convergens* *Pentilia* sp. *Prodilis* sp. *Azya* sp.	Predators of eggs, nymphs and adult females
Hymenoptera	Encytidae	*Anagyrus* sp.	Parasite of nymphs and adult females
Hemiptera	Reuviidae	*Zellus* sp. *Emesaya* sp.	Predators of nymphs and adult females

Figure 22. Two predators of the mealybugs (*Phenacoccus gossypii*) on cassava: on the left, *Curinus colombianus*, on the right, *Azya* sp.

Table 7.

Evaluation of 2203 cassava varieties for damage by *Vatiga manihotae* during a natural infestation in the field.

Damage scale[1]	No. of varieties	% per class
0	0	0
1	277	12.57
2	607	27.55
3	920	41.76
4	309	14.03
5	90	4.09

1 0 = No *Vatiga;* 1 = few yellow spots on lower leaves; 2 = many yellow spots on lower leaves (leaves are yellow); 3 = many yellow spots on lower leaves and leaves reddish-yellow and curled; 4 = curling and drying of lower leaves and curling of middle leaves; 5 = lower and middle of plant defoliated and apical leaves are yellow.

resulted in the selection of 17 promising varieties.

Evaluation for resistance to the *Mononychellus* mite also continued in the greenhouse and field. In the first unreplicated selection cycle in the greenhouse 105 varieties were selected from the 2116 evaluated. In the second replicated cycle 15 of the 105 varieties chosen earlier were selected as promising varieties. Two cycles of field evaluations for resistance to the *Mononychellus* mite yielded 71 varieties that appeared to be resistant.

Greenhouse and laboratory studies were begun to characterize the mite resistance (*T. urticae* and *Mononychellus tanajoa*) in several varieties. The preliminary results indicated that both species generally prefer, and lay more eggs on, the more susceptible varieties.

The germplasm bank (2231 cultivars) at CIAT was again evaluated for resistance to the *Oligonychus peruvianus* mite by counting the number of webs per leaf (avg. nine leaves per variety). From this and two previous evaluations, 250 varieties were selected as promising materials.

Biological Control

A beetle, *Oligota minuta* (Coleoptera: Staphilinidae), is an efficient predator of *M. tanajoa.* The larvae and adults eat all stages of the green cassava mite. *Oligota* adults were counted at 6 a.m., 9 a.m., 1 p.m., and 4 p.m., to study the distribution of the predator population in a plant and population fluctuations throughout the day. High populations of *Oligota* did not fluctuate significantly during the day. Within the first 14 leaves (top to bottom) that were sampled, the greater predator populations were on the fifth to eighth leaves (Table 8). It is important not to apply any insecticide which reduces the population of this predator.

Fruit Fly

The major species found in the Armenia and Caicedonia cassava growing areas of Colombia is *Anastrepha manihoti.* Besides the damage caused by larvae, this fruit fly is associated with a bacterial pathogen (*Erwinia carotovora pathovar carotovora).* This pathogen reduces the quality of planting material subsequently causing reduced yields.

An experiment to assess the usefulness of two insecticdes to control this pest was done between September 1977 and October 1978 in Armenia. The insecticides (Fenthion EC 0.5 cc a.i./lt., Ometoato EC 0.4 cc a.i./lt), were applied every 15 days during the growing season. Treated plots had over 90% clean seed and damaged seed from these plots was only slightly damaged.

Table 8.

Fluctuation and distribution of *Oligota minuta* populations at four times of the day on cassava variety M Col 113 at CIAT-Palmira over 42 days.

Leaf position, top to bottom of plant	Time				Avg. adults per 48 leaves
	6 a.m.	9 a.m.	1 p.m.	4 p.m.	
1	0.9	0.3	0.6	1.1	0.69
2	7.0	1.7	2.1	2.6	3.36
3	14.4	6.5	7.7	8.8	9.36
4	14.4	11.8	12.8	15.0	13.50
5	25.0	16.3	19.2	17.8	19.58
6	21.9	18.5	19.8	20.0	20.05
7	19.5	19.8	21.0	19.8	20.03
8	13.6	18.0	18.4	16.6	16.65
9	12.8	16.4	14.4	13.6	14.30
10	10.2	12.9	12.3	10.6	11.50
11	7.1	10.2	9.9	8.2	8.85
12	4.7	8.0	5.8	5.9	6.10
13	3.5	6.7	5.5	4.8	5.13
14	2.5	5.4	3.7	4.3	3.98
Avg. adults per 48 leaves	11.3	10.9	10.9	10.7	10.93

Multiple Resistance

In cooperation with the Pathology Section, 1400 cassava cultivars were planted in two replications in Carimagua to identify materials with resistance to pests populating the ecosystem of this part of the Llanos Orientales of Colombia. The most important insect is the stem borer (*Chilomima clarkei*) (Amsel), which attacked 78% of the varieties. With respect to diseases (see Pathology Section), 14 varieties were selected as resistant to the complex of pathogens in the area. Of these 14, eight had not been attacked by *Chilomima*.

PATHOLOGY

Wide Type Resistance

Sources of resistance to all major diseases of cassava have been found. Furthermore, sources of resistance to several insects and of tolerance to adverse soil and climatic conditions have been identified. Combining these useful characters into one variety, however, poses a very real problem for the breeding program as it requires a very large number of crosses and several generations of testing before the objective can be achieved. Thus, emphasis has been on identifying lines tolerant to many factors that normally reduce yield. If such lines can be identified, the time to develop varieties that are both high-yielding and tolerant to these adverse factors can be greatly reduced.

Popayan Ecosystem

It appears almost impossible to develop single lines that are tolerant to these adverse factors in all ecological zones. Hence, work has concentrated on two regions, each one having different adverse factors that can greatly reduce yield. The first region, Popayan is not representative of large areas where cassava is grown; it does, however, illustrate that certain lines do possess resistance or tolerance to a large number of adverse factors.

The test site at Popayan has several adverse factors of which the most important are a low pH (4.4), low mean

Table 9.

Some climatic and edaphic characteristics and diseases and pests causing reduced cassava yields at Popayan, Darien, Carimagua and CIAT-Palmira, Colombia.

	Site			
Factor	Popayán	Darien	Carimagua	CIAT-Palmira
Climatic				
Mean temperature (°C)	18.0 (+)[1]	19.5 (+)	26.1 (—)	24.0 (-)
Rainfall (mm/year)	2500 (—)	1500 (—)	2031 (—)	1000 (+)
Rainfall duration (mo)	6 (bimodal) (—)	6 (bimodal) (—)	8 (unimodal) (+)	5 (bimodal) (—)
Edaphic				
pH	4.1 (+)	4.3 (+)	4.7 (+)	6.8 (—)
Al concentration	high (+)	high (+)	high (+)	low (—)
Soil fertility	good (—)	med. low (+)	low (+)	good (—)
Soil texture	clay loam (—)	silt loam (—)	sandy loam (—)	clay (±)
Diseases				
Phoma leaf spot	+	+	—	—
Anthracnose	+	+	+	—
White leaf spot	+	+	—	—
Bacterial blight	—	—	+	—
Superelongation	—	—	+	—
Brown leaf spot	—	—	+	±
Cercospora leaf spot	—	—	+	+
Pests				
Mites	+	+	+	±
Thrips	+	+	+	±
Scale insects	—	—	+	±
Stem borers	—	—	+	—

1 Factor ratings: + severe damage; ± moderate damage; - no damage.

Table 10.

Reactions of nine cassava varieties to some ecosystem characteristics that may induce yield reductions at Popayan, Colombia, and overall varietal evaluations under field conditions.

Variety	pH low (4.4)	pH neutral (6.4)	Low temperature (18.°C)	Phoma leaf spot	Anthracnose	Thrips	Mites	Overall evaluation in the field
CMC 92[1]	I[2]	R	R	R	I	R	I	R
Sata Davio[1]	R	I	R	R	S	R	-	R
R/amarilla[1]	S	R	R	R	R	R	-	R
R/negrita[1]	I	S	I	R	S	R	-	R
CMC 40	R	R	S	S	R	I	S	S
M Col 22	S	S	S	S	R	I	S	S
M Mex 59	R	R	S	S	I	I	I	S
M Col 113	I	I	I	S	R	R	I	S
CMC 39	I	I	R	S	S	R	I	S

1 Regional varieties
2 Varietal reactions: R = resistant; I = moderately resistant; S = susceptible.

temperature (18°C; min. 4°C, max. 23°C) and severe incidences of Phoma leaf spot, anthracnose, thrips and mites (Table 9). Reactions of several lines to these adverse factors are shown in Table 10 and yields of three lines over time are shown in Figure 23. The line M Col 22 is susceptible to most of the adverse factors and its yield in Popayan is always low. CMC 39 is tolerant to all factors except Phoma leaf spot and anthracnose; in general its yields are reasonable but fluctuating. In 1974, for example, rainfall was low in Popayan; Phoma leaf spot and anthracnose were not severe and CMC 39 yielded well. Cultivar CMC 92 was tolerant to all adverse factors and has shown very stable yields. These data show that at least in the Popayan ecosystem, cultivars having wide type resistance to the adverse factors can be selected. The germplasm bank was screened under Popayan conditions and seven wide-type-resistant cultivars identified.

Several cultivars were tested in both Popayan and Darien. The latter has an ecosystem somewhat similar to Popayan (Table 9). Lines yielding well in Popayan also yielded well in Darien; the correlation of yield of 15 varieties in Popayan and Darien was $r^2 = 0.94$. This suggests that although different ecosystems exist, representative sites can be used for selection and that results from one site can be extrapolated directly to sites having similar adverse factors. No significant correlation

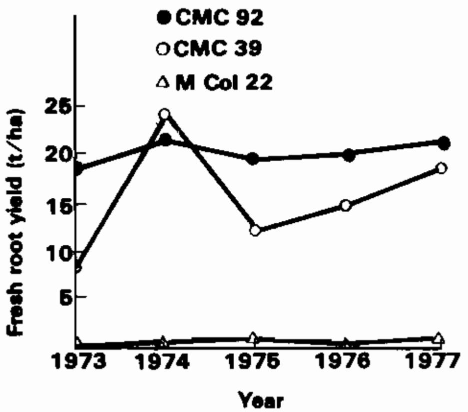


Figure 23. Yields of three cassava varieties in the Popayan ecosystem over 5 years.

was found between yields at CIAT-Palmira and Popayan, demonstrating that, at least for Popayan-type conditions, special lines are needed.

Carimagua Ecosystem

While the Popayan area represents a relatively small portion of the world's cassava producing areas, the conditions at Carimagua are representative of much larger areas under cultivation with tremendous potential for increased production. Carimagua has many factors that can adversely affect yield which are different from those in Popayan (Table 9).

Of 2200 clones of the germplasm bank grown at Carimagua, 14 showed moderate resistance to the local adverse factors (Table 9). Ten of the 14 were morphologically similar or identical, suggesting that only five morphologically different cultivars showed wide type resistance to the adverse conditions in the Carimagua ecosystem. Resistance to individual factors is much more common than resistance to all factors (Table 11). While only 0.6% of the clones were resistant to all factors, incorporating these few lines in the breeding program and combining them with lines of high-yielding potential should enable rapid progress.

From the above observations it appears that great interaction exists in *Manihot esculenta* between cultivar reaction and the ecosystem. While there are cultivars with wide type resistance, they are limited to ecosystems with similar characteristics. Nevertheless, by selecting in ecosystems with many adverse factors, selected clones may be adapted to areas with similar or fewer adverse factors. For example, all clones resistant to cassava bacterial blight (CBB) and superelongation disease in Carimagua were also resistant on the North Coast of Colombia. The clone M Col 1684 was originally selected in Carimagua, where it showed good resistance to the adverse factors of that ecosystem. In regional trials (see Regional

Table 11.

Relationship between varietal reaction to superelongation disease and other leaf and stem diseases of cassava present in the ecosystem at Carimagua, Colombia.[1]

	No. of varieties					
	Leaf and stem disease rating[3]					
Superelongation disease rating[2]	2	3	4	5	Total	%
2	3	5	19	137	164	12.17
3	1	5	19	184	209	15.50
4	2	5	36	187	230	17.06
5	2	4	43	696	745	55.27
Total	8	19	117	1204	1348	100
%	0.60	1.41	8.68	89.31	100	

1 Planting was at the beginning of the rainy season in April.

2 Superelongation rating: 2 = leaf spots (cankers); 3 = cankers on leaf and petioles; 4 = cankers on leaves, petioles and stem, and elongation; 5 = elongation and dieback.

3 Leaf and stem diseases rating: 2 = less than 30% leaf fall, leaf lesions; 3 = up to 80% leaf fall, stem injuries; 4 = total defoliation, slight dieback; 5 = severe dieback or plant death.

Figure 24. Evaluation for disease resistance in cassava at Carimagua, a severe-stress site.

Trials Section) this variety has yielded well in areas with similar or fewer adverse factors. Hence, it appears that by carefully selecting at sites that have many adverse factors, broadly adaptable clones can be obtained.

Cassava Bacterial Blight

Thirty-five physiological tests to 67 isolates of *Xanthomonas manihotis* and six of *Xanthomonas cassavae* were done. Generally, no major physiological differences existed among isolates of *X. manihotis*, except in the rate of utilization of certain carbohydrates. Few physiological differences were found between *X. manihotis* and *X. cassavae;* polysaccharides produced by both organisms appear to have different chemical compositions.

Greenhouse clipping inoculations with 50 *X. manihotis* isolates on nine cassava varieties showed differences in aggressiveness. Generally, isolates with different degrees of aggressiveness were found in most cassava growing areas affected by this pathogen.

Results of effects of temperature on disease severity indicated that widely fluctuating day/night temperatures (range of 16°-30°C) favored disease severity more than relatively steady temperatures (± 5°C). Disease severity also appeared to be positively related to water-holding capacity of the soil, possibly because the CBB causal agent is a vascular pathogen. These factors may explain moderate CBB infections in areas with sandy soils and/or stable temperatures, independent of the rainy season and total rainfall in a given period. For example, eight months after planting 312 cultivars at Carimagua (sandy loam soils, 2400 mm rainfall, 16°-29°C mean night/day temperature) and at Media Luna (sandy soil, 1320 mm rainfall and 23°-32°C temperature), all but one cultivar was susceptible at Carimagua

Table 12.

Reaction of 312 cultivars to cassava bacterial blight at eight months after planting, in the ecosystems at Carimagua and Media Luna, Colombia.

Disease rating at Media Luna[2]	No. of varieties: Disease rating at Carimagua[1] 2	3	4	5	Total	%
2	0	1	43	253	297	95.19
3	0	0	3	6	9	2.89
4	0	0	0	6	6	1.92
5	0	0	0	0	0	0
Total	0	1	46	265	312	
%	0	0.30	14.73	84.94		100

1 Disease rating: 2 = angular leaf spots and blight; 3 = leaf symptoms and stem exudation and cankers; 4 = dieback and/or total defoliation; 5 = dieback of more than one-half of the plant, or death.

whereas only six were rated susceptible at Media Luna (Table 12).

Controlled inoculations showed that isolates from both locations have a similar rate of agressiveness and that the difference in disease reaction was mainly due to climatic and edaphic effects. Studies related to the progress of CBB epidemics on susceptible varieties planted at Carimagua at the beginning of the heaviest rainy season and 32 days afterwards, showed that despite the high inoculum potential present at the later planting, (a) full expression of disease symptoms was delayed 30 days, and (b) disease progress was higher during the first planting than the second because of decreased rainfall and its distribution (Fig. 25).

From these epidemiological studies, it appears there is a strong ecological interaction with CBB severity. Consequently, when screening for CBB resistance in the field, certain environmental (rainfall duration, amount and distribution; fluctuating temperatures; and inoculum potential) and edaphic (soil moisture) conditions must be present; moreover, planting must be at the beginning of the rainy season.

Apparently the severity of diseases such as CBB and superelongation (see next section), which need long periods for the occurrence of the exponential phase, can be reduced by programming planting with the rainy season. However, since the cassava-growing cycle is about 12 months and cuttings from the previous crop are

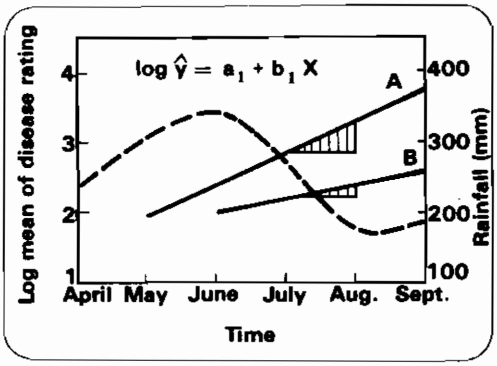


Figure 25. Development of a cassava bacterial blight epidemic at Carimagua on 100 susceptible varieties (10 plants/variety) planted in April (A) and 25 susceptible varieties planted in May (B), in relation to monthly rainfall. a_1 = y intercept - initital disease present; b_1 = rate of disease development; X = time.

generally used for the next planting, these diseases can seriously affect the stability of a variety if resistance is not present. Moderate resistance could be enough for areas (like Media Luna) where environmental and/or edaphic conditions do not favor disease establishment and development.

Superelongation Disease

The development of superelongation epidemics on susceptible varieties planted at Carimagua at the beginning of the heavy rainy season and 32 days afterwards showed the same pattern as that observed for CBB. At the second planting, there were also (a) a delay in full-symptom expression, and (b) a higher disease epidemic during the first than the second planting (Fig. 26). The rainfall effect on this disease is understandable since spores require free water for germination (CIAT Annual Report, 1976). This also suggests great disease/environmental interactions; where rainfall is scattered, disease severity is reduced. Similarly, when screening for resistance to this disease, it is very important to plant at the beginning of the rainy season.

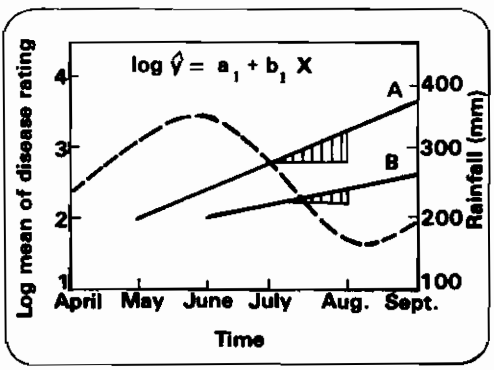


Figure 26. Development of a superelongation epidemic at Carimagua on 100 susceptible varieties (10 plants/variety) planted in April (A) and 25 susceptible varieties planted in May (B), in relation to monthly rainfall. a_1= y intercept - initial disease present; b_1 =rate of disease development; X= time.

The distribution of cultivars (1348) per disease rating, as a superelongation epidemic developed at Carimagua, showed an initital bimodal distribution in June formed by two groups —one including those rated 4-5 (susceptible) and the second group rated 1-2 (resistant). As the epidemic increased with time, the distribution became unimodal (Fig. 27). In contrast, the distribution formed by the increase in CBB epidemics was always unimodal. This behavior of superelongation epidemics could be due to: (a) the existence of an early-type of resistance present in some, but not all cassava varieties, which is broken by plant age; (b) the presence of different biotypes (races) of the pathogen with different inoculum potentials; or, (c) small differences in the rating system both between 2-3 or 3-4. Experiments to confirm any of these factors are in progress.

The possible relationship between varietal reaction to superelongation versus leaf and stem disease in the Carimagua ecosystem (Table 11) showed 12.2% of the cultivars to be resistant to superelongation (a single disease) but only 0.6% resistant to the other leaf and stem diseases (CBB, anthracnose and Cercospora leaf spots).

Frog Skin Disease

Studies on mechanical transmission of this disease within cassava varieties were undertaken using infested knives; similarly, several known viral differential plant species were inoculated by sap-rubbing inoculations. It appears that disease transmission by infected knives is relatively high; none of the differentials inoculated by sap-rubbing showed infection. Plants from open-pollinated seeds produced on diseased plants were healthy; disease transmission through pollen has not been investigated. Attempts to produce disease-

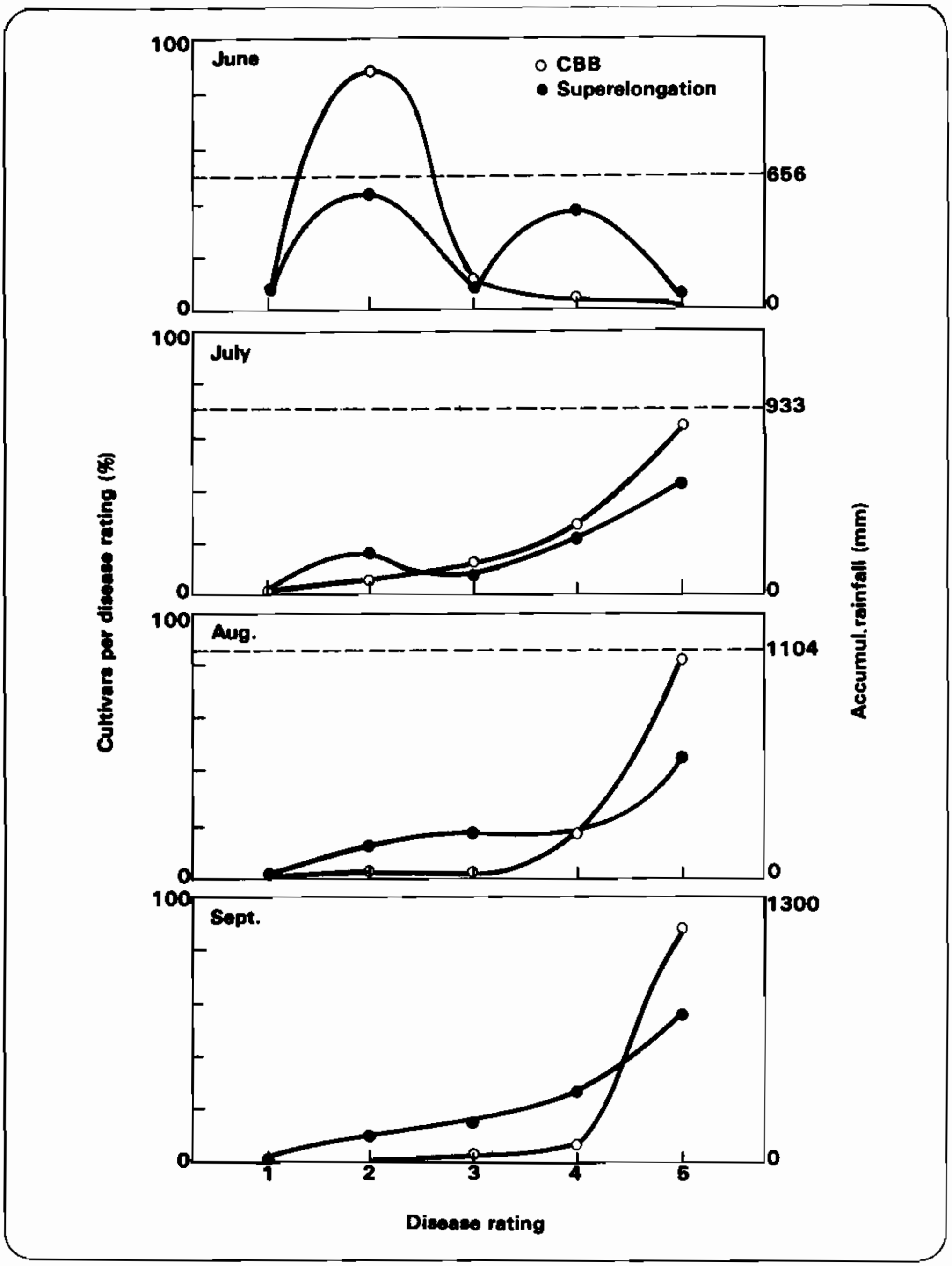


Figure 27. Distribution of cassava cultivars per disease rating according to increase in epidemics of cassava bacterial blight (CBB) and superelongation, in relation to accumulated rainfall at Carimagua.

free plants by meristem culture are under way in CIAT's Genetic Resources Unit.

Other Cassava Diseases

A *Choanephora* sp. was found associated with CBB in plots at Carimagua and Media Luna. It appeared to induce faster blight occurrence and leaf fall. Preliminary studies showed that the fungus penetrates through wounds on the plant.

Evaluations for resistance to Cercospora brown and white leaf spots were made on 373 varieties at Media Luna, where both diseases are endemic. More varieties were found resistant to white than to brown leaf spot. Moderate resistance to both diseases was also identified in several varieties.

Root Rot

The effect of plant debris from previous cassava crops on root rot incidence was determined on plots at CIAT-Palmira where cassava had been cultivated for two consecutive cycles before the experiment. After harvesting the second planting, which showed no root rotting, plant residues were removed from some plots and incorporated into the soil on others. Germination of selected cuttings of M Col 22 and CMC 94 was reduced 11 and 20%, respectively, when comparing clean plots with those containing residues. Root rot incidence in both varieties was also higher in plots with residues than in clean ones, and yields were reduced 17 and 32% for M Col 22 and CMC 84, respectively, in plots with residues (Table 13). If these plots are continually planted to cassava, infestations of these soil-borne pathogens can be expected to increase drastically. However, this depends on environmental conditions and soil characteristics. If soil is infested, it is necessary to eliminate cassava plant residues and use fallowing or crop rotation.

Protection of Vegetative Planting Materials

Tool Disinfectants

Cuttings were immersed in solutions of several disinfectants commonly used to disinfest tools to determine if these chemicals affected subsequent rooting of cuttings. None of the following common disinfectants affected rooting: formaldehyde (5%, pH 3.4); mercuric chloride (1%, pH 4.3); sodium chloride (1%, pH 5.5); alcohol (70%, pH 6.6); Inextra detergent (2%, pH 10.5); calcium hypochloride (0.5%, pH 11.7); sodium hypochloride (1%, pH 11.8); trisodium

Table 13.

Effects of plant residues from a previous cassava crop on germination, root rot incidence and fresh root yield, at CIAT-Palmira.

Variety	Plot condition	Germination (%)	Root rot (%)	Root yield (t/ha)	Yield reduction (%)
M Col 22	No residues	84.4	2.1	27.5	
M Col 22	With residues	73.4	3.5	22.8	17.0
CMC 84	No residues	70.3	4.4	28.8	
CMC 84	With residues	50.0	6.1	19.4	32.0

phosphate (19.5%, pH 12.1); Limpido soap (20%, pH 12.3); and sodium hydroxide (0.6%, pH 13.0). The chemicals with low pH are useful for preventing dissemination of fungi and bacteria with infested tools and those of high pH can prevent dissemination of viruses.

Fungicides

Several fungicides were tested alone and in mixtures, at various concentrations, to determine their protective effects as dips for cuttings. The mixture of captan (nonsystemic) and BCM (systemic), each at 3000 ppm, was the best treatment. It: (a) protected against a broad range of fungal pathogens; (b) had a prolonged effect, especially when cuttings were stored; (c) erradicated some fungal infections; and (d) had some effect in increasing plant size after bud germination.

Fungicide/Insecticide Mixtures

To integrate disease and insect control on cuttings, the captan/BCM mixture was combined with several insecticides. Combinations which provided 100% rooting of cuttings and bud germination after 60 days of storage were the following: (a) The fungicides with malathion EC (1 ml/liter of water). The malathion must be mixed with the water before adding the fungicides, to prevent incompatibility effects. When the fungicides were mixed before the malathion, a reaction occurred which totally inhibited rooting and germination of cuttings (Fig. 28). (b) A dipping treatment in a solution of malathion EC (1 ml/liter of water) and, after the cuttings dried, dipping with the fungicide mixture. (c) Dipping with the fungicides and then dusting each cutting with 1 g of aldrin 2.5.

The latter treatment was one of the best to not only ensure rooting and bud germination, but also to reduce termite attacks during an experiment at Media Luna. Because the fungicides greatly decrease or eliminate rotting of cuttings, this prevented termite attacks, which appeared to occur commonly on dead cuttings or plant stem tissue.

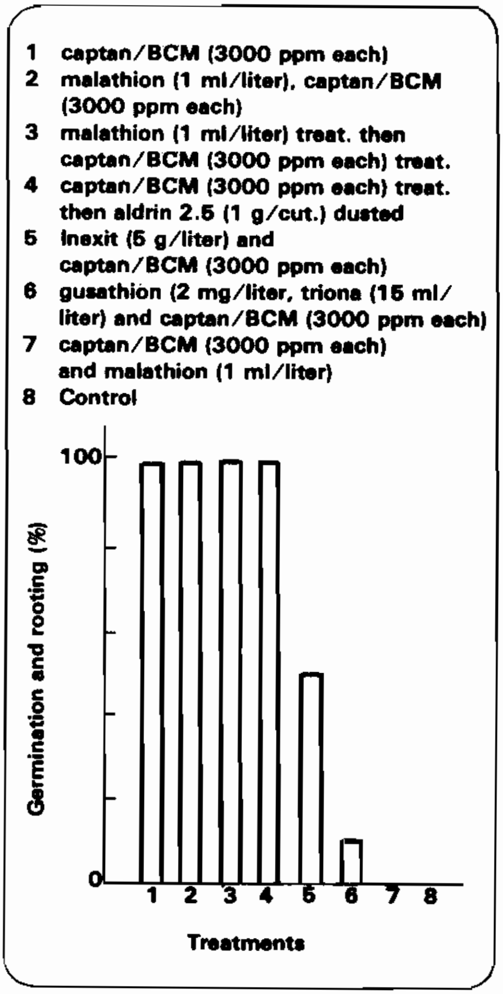


Figure 28. Germination and rooting of cassava stakes after treating with mixtures of captan/BCM plus insecticides and storing for 60 days.

Storage of Cuttings

Cassava growers commonly store cuttings for the next planting but, heavy losses occur because of poor rooting and/or bud germination and a decrease in plant vigor. These are due to: (a) dehydration of cuttings; (b) microbial or insect attack; and (c) early bud germination which wastes available nutrients. Work was done in 1978 to solve each of these problems.

Cutting Dehydration

Cutting dehydration was prevented by storing in polyethyelene bags or by treating with sodium alginate (Agricol), a water-soluble gel. A dry film of this gel allows oxygen interchange by the cutting but prevents water loss.

Disease/Insect Damage

Damages from diseases and/or insects were prevented by treating cuttings with fungicidal/insecticidal solutions before packing in polyethyelene bags or by adding sodium alginate to the solution, which made it unnecessary to store cuttings in bags.

Ninety percent of the 20-cm cuttings rooted and buds germinated after 12 weeks of storage when treated with captan/BCM and kept in polyethyelene bags at room temperature (Fig. 29). About 95% of the 20-cm cuttings from long stems (70-cm) rooted and buds germinated when stored for 10 weeks on a dry floor at room conditions (24ºC, 80% RH) after treatment with captan/BCM (2000 ppm each) (Fig. 30). Similarly, 90% of the 20-cm cuttings rooted and buds germinated after 90 days

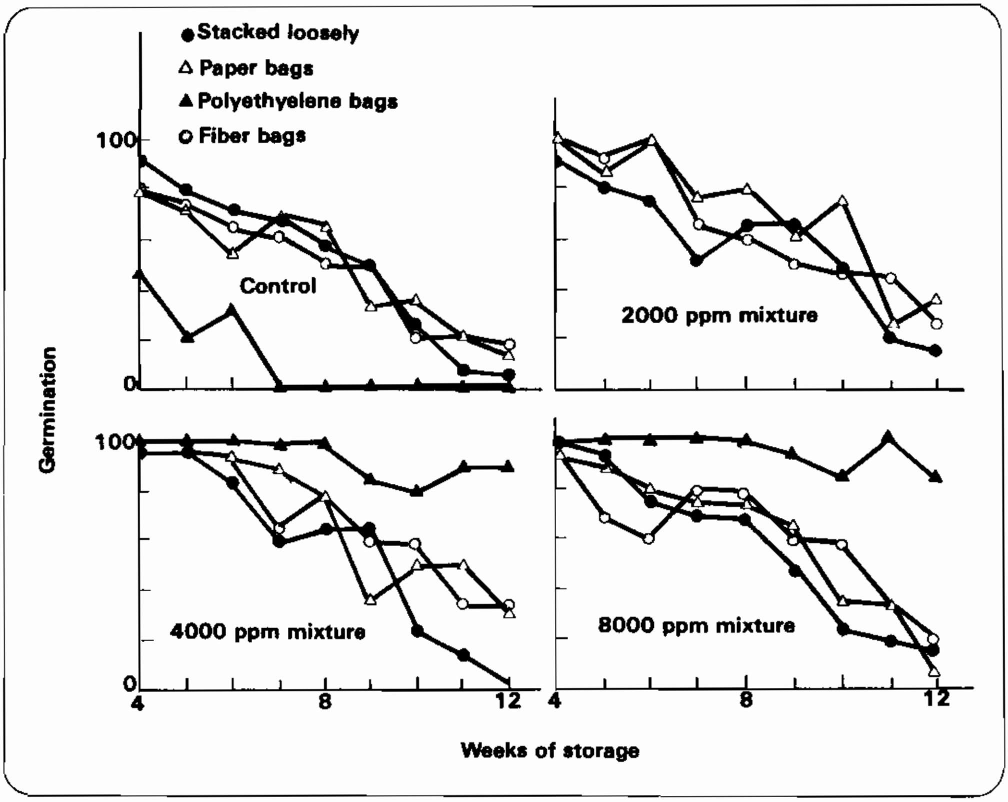


Figure 29. Effects on germination of 20-cm cassava stakes after treatment with 3 concentrations of captan/BCM mixtures and subsequent storage by different methods.

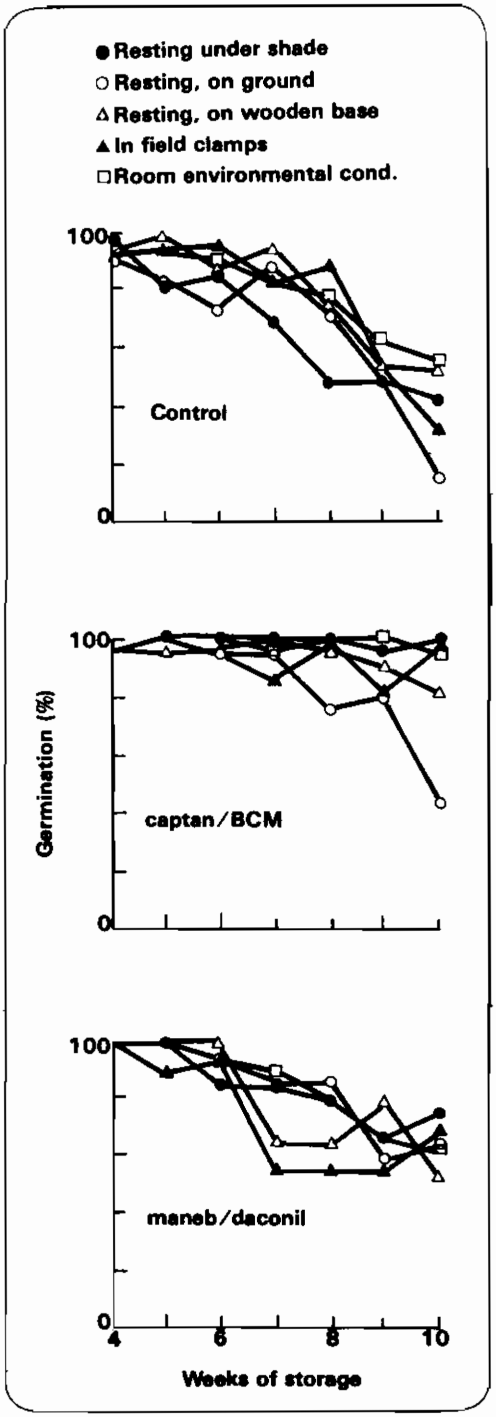


Figure 30. Germination of 50-cm cassava stakes after treatment with mixtures of two fungicides (4000 ppm) and subsequent storage.

of storage when they were dip-treated in a captan/BCM (3000 ppm) plus sodium alginate (10,000 ppm) solution and kept at room conditions.

Treating cuttings immediately after harvesting, regardless of later storage time, increased yields of fresh roots/ha (Figs. 31 and 32).

When short cuttings (20-cm long) were treated with fungicides before storage, yields were always higher than the control and the difference increased with time of storage (Fig. 31).

Effects of fungicide treatments on yield on long cuttings were not so great as with short cuttings, however, the increase was considerable (Fig. 32).

Bud Germination

Theoretically, early bud germination could be delayed or accelerated by growth regulators. Several chemicals were found that inhibited or accelerated bud germination and shoot growth. Investigations began on their use before and after cutting storage.

Ecosystem Influence on Cutting Production

In addition to the studies reported in the first part of this section on negative production factors in ecosystems, the Pathology Section also studied how these factors affect production of plant materials for cuttings. Heavy reduction in cutting production per plant and the rooting of cuttings was observed in severe NPF ecosystems like Carimagua and Popayan. Preliminary data indicate cutting production in such ecosystems appears to be related to the level of resistance to the NPF present in each ecosystem.

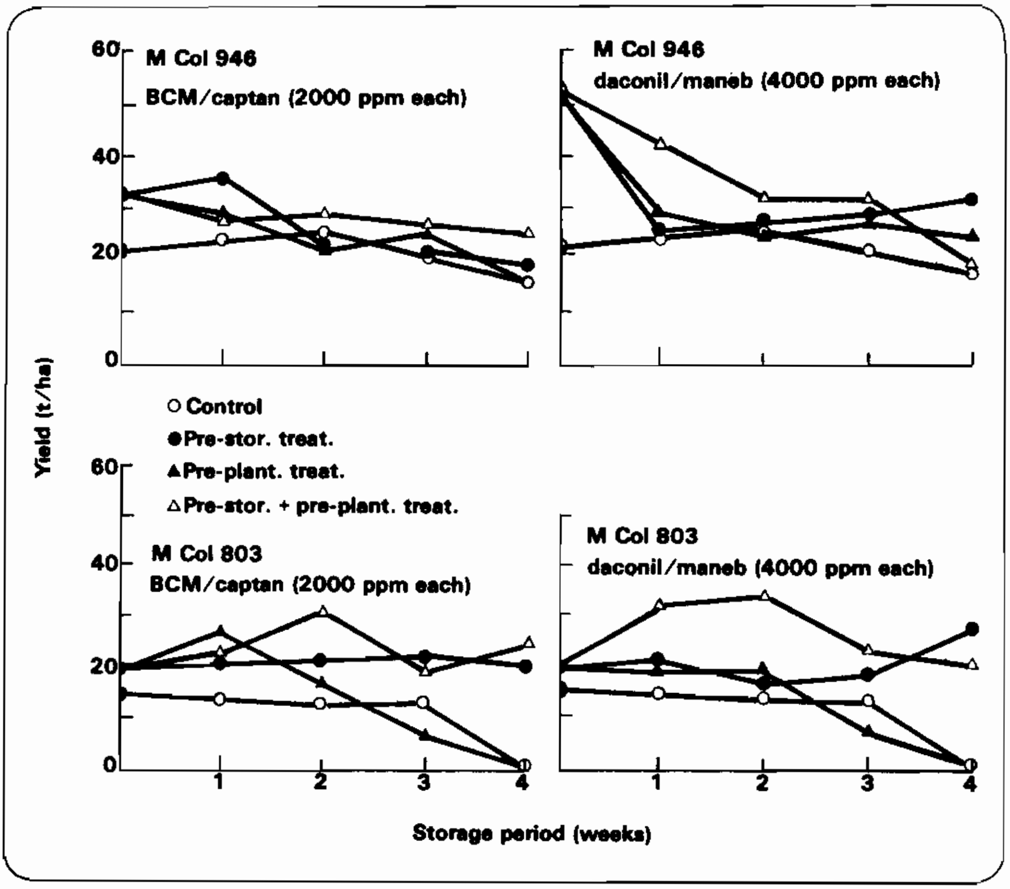


Figure 31. Fresh root yield from cassava plants obtained from 20-cm stakes treated with mixtures of two fungicides before and after storage.

Table 14.

Cutting production of several cultivars in the CIAT and Carimagua ecosystems.

	CIAT		Carimagua		
Cultivar	Cuttings /plant	Rooting (%)	Rooting [1] (%)	Cuttings /plant	Rooting[2] (%)
M Col 113	15	100	95	1	63
M Col 638	12	100	90	3	60
M Col 845A	12	100	80	1	0
M Col 1351	12	100	80	1	50
M Col 1684	10	100	98	3	83
Llanera	10	99	94	1	37
M Pan 19	8	100	100	3	80
M Ven 38	8	100	93	1	70
M Ecu 82	10	100	100	3	70

1 Rooting of cuttings from CIAT planted at Carimagua
2 Rooting of cuttings at Carimagua produced from Carimagua material after the first growing cycle.

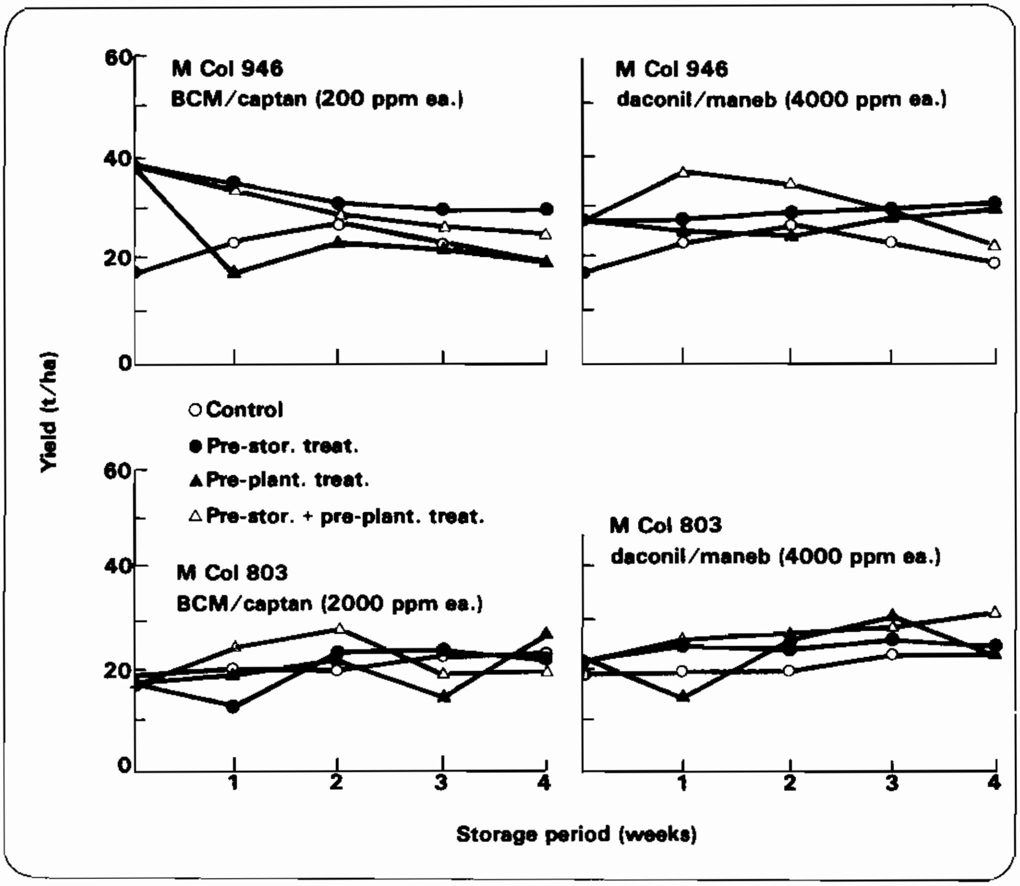


Figure 32. Fresh root yield from cassava plants of stakes from 70-cm cuttings treated with mixtures of two fungicides before and after storage.

Cutting production per plant can be reduced so much that an introduced, nonadapted variety or hybrid may disappear after a few growing cycles. Similarly, rooting of cuttings decreases considerably, suggesting that introduced cultivars could also disappear after a few growing cycles (Table 14).

Since (a) growers commonly take planting material from previous crops or from the nearby area; (b) production of certified planting material and shipping from production centers is expensive and risky; and, (c) great ecological interactions apparently exist in cassava, then cutting production/plant/variety should be considered an important factor in selecting for adaptation and stability.

VARIETAL IMPROVEMENT

Principal activities of the Varietal Improvement Section are identification of parental genotypes, hybridization, F_1 seedling selection, observational yield trials in single rows, replicated yield trials, and identification of the most promising materials for multiplication and regional trials by the Agronomy Section. All these activities are done at CIAT, and observational and replicated yield trials are also carried out at Caribia (North Coast of Colombia) and Carimagua (Llanos Orientales). A major addition to these routine activities in 1978 was the introduction of F_1 seedling selection at Carimagua.

CIAT, Caribia, and Carimagua represent a high-yield environment, a more representative cassava growing area, and a high-stress environment, respectively. Root yield at CIAT was significantly correlated with the root yield of the same genotype at Caribia (Fig. 33). Significant correlations also existed between root yield at CIAT and yield of the same genotype at Carimagua, both in the presence or absence of CBB (Figs. 34 and 35). This indicates that those genotypes observed to be low yielding at CIAT generally yield low outside CIAT. The early elimination of low-yielding genotypes at CIAT may thus

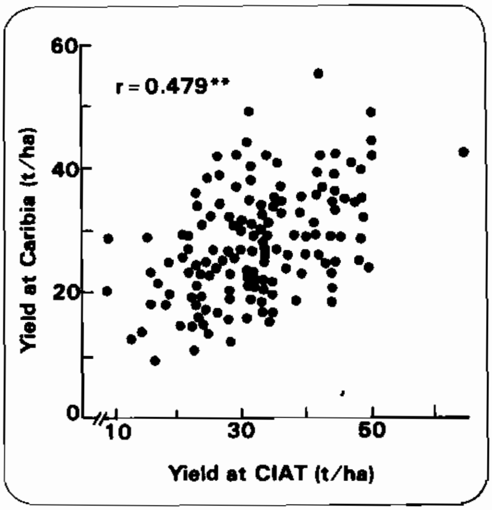


Figure 33. Relationship between cassava fresh root yields of the same genotype at CIAT and at Caribia. (Data are from 1976, 1977, 1978 replicated yield trials.)

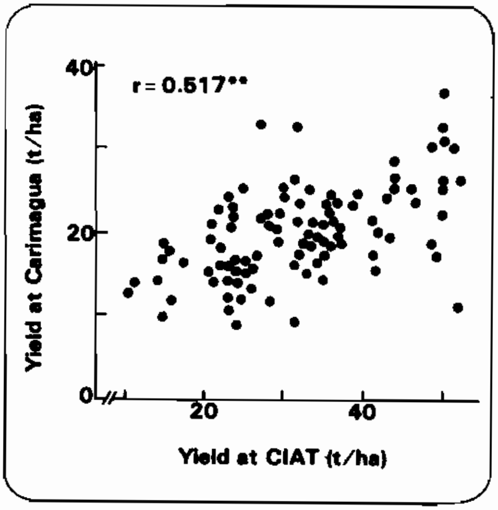


Figure 34. Relationship between cassava fresh root yields of the same genotype at CIAT and at Carimagua (with no cassava bacterial blight present). (Data are from 1976 and 1977 replicatied yield trials.)

be justified. How much of the deviation from the main correlation axes in Figures 33, 34 and 35 is due to genotype x environment interaction, and to experimental error, still needs to be clarified.

Approximately 45,000 hybrid seeds, 3800 selected lines, and 600 advanced lines

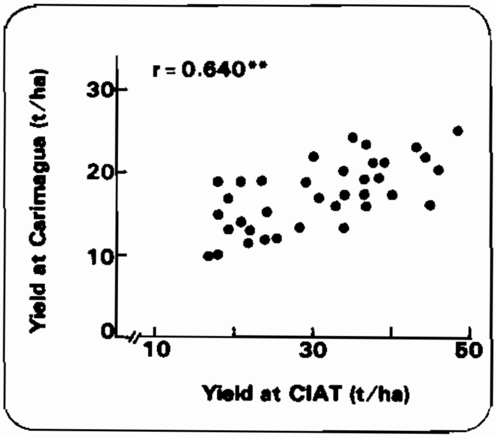


Figure 35. Relationship between cassava fresh root yields of the same genotype at CIAT and at Carimagua (with cassava bacterial blight present). (Data are from September planting 1977-78 replicated yield trial.)

were evaluated in F_1 seedling selection, observational yield trials, and replicated yield trials, respectively. Nine promising lines were delivered to the Agronomy Section for advanced testing. Approximately 32,000 seeds, of which 18,000 are hybrid seeds from controlled crosses, were given to breeder/agronomists in 18 Latin American and Asian countries.

A period of one year each is necessary for hybrid seed production, F_1 seedling selection, an observational yield trial, and a replicated yield trial. Thus, the advanced lines which were evaluated in replicated yield trials at CIAT during 1978 are mainly from hybridizations made during 1974. Lines evaluated in replicated yield trials at Caribia and Carimagua were from hybridizations of 1973. From this year onwards the Varietal Improvement Section can provide reasonably comprehensive data for the promising materials which have been sent to the Agronomy Section for multiplication.

Yield and Adaptation

In all six replicated yield trials at CIAT and Caribia, CIAT lines (F_1 lines hybridized and selected by the Varietal Improvement Section) yielded higher, as an average, than selected germplasm accessions (selected by the same section) (Tables 15 and 16). Yield levels of both CIAT lines and selected germplasm accessions were far higher than yields of local cultivars. At Carimagua, CIAT lines and selected germplasm accessions had about the same yield levels which were much higher than the local cultivar (Table 17). The best CIAT lines outyielded local cultivars by 200-350%.

CIAT lines such as CM 305-38, CM 321-188, and CM 323-375 yielded well at CIAT (more than 50 t/ha) and Caribia (more than 40 t/ha), suggesting they are not only high yielding but also widely adapted. Since the range of environmental conditions between CIAT and Caribia are

Table 15.

Results of cassava replicated yield trials at CIAT, 1977-78.

	Trials[1]					
	I		II		III	
	Fresh root yields (t/ha)	Root dry matter content	Fresh root yields (t/ha)	Root dry matter content	Fresh root yields (t/ha)	Root dry matter content
Avg., all genotypes	28.5	.340	40.3	.362	34.1	.359
Avg., local cultivar	22.8	.286	23.3	.305	18.9	.341
Avg., control cultivars[2]	18.9	.326	27.8	.338	27.6	.354
Avg., all selected germplasm accessions	24.8	.338	32.8	.345	30.2	.347
Avg., all CIAT lines	28.9	.341	41.2	.365	35.6	.364
Avg., top 10 CIAT lines	51.3	.343	58.4	.362	53.0	.370
Maximum yielder	54.2	.350	79.2	.354	67.2	.375
	(CM 440-5)		(CM 489-1)		(CM 321-188)	

1 I—223 genotypes; planted 3 May 1977, harvested 22 May 1978. II—121 genotypes; planted 24 Sept. 1977, harvested 24 Sept. 1978. III—90 genotypes; planted 15 Nov. 1977, harvested 13 Nov. 1978.

2 Llanera and M Col 22.

Table 16.

Results of casssava replicated yield trials at Caribia, 1977-78.

	Trials[1]					
	I		II		III	
	Fresh root yields (t/ha)	Root dry matter content	Fresh root yields (t/ha)	Root dry matter content	Fresh root yields (t/ha)	Root dry matter content
Avg., all genotypes	26.7	.285	30.4	.309	29.7	.286
Avg., local cultivars	16.9	.324	26.7	.366	-	-
Avg., control cultivars[2]	23.2	.261	20.6	.306	17.3	.291
Avg., all selected germplasm accessions	23.8	.287	22.0	.339	23.8	.298
Avg., all CIAT lines	27.5	.284	32.1	.305	30.6	.283
Avg., top 10 CIAT lines	39.7	.296	41.7	.311	37.9	.284
Maximum yielder	49.4	.299	51.9	.284	54.6	.302
	(CM 309-277A)		(CM 323-403)		(CM 305-38)	

1 I— at Caribia; 64 genotypes; planted with locally prepared planting stakes 17 May 1977, harvested 19 April 1878.
II— at Caribia; 30 genotypes; planted with locally prepared planting stakes 11 Oct. 1977, harvested 5 Sept. 1978.
III—on-farm field trial near Cienaga; 23 genotypes; planted 23 Nov. and 7 Dec. 1977, harvested 23 Oct. 1978.

2 Llanera and M Col 22.

representative of a major portion of cassava growing areas, these advanced lines should be candidates for future release as a recommended cultivar(s) if they perform well in regional trials.

Table 17.

Results of cassava replicated yield trials at Carimagua, 1977-78.

	Trials[1]		
	I	II	
	Fresh root yields (t/ha)	Fresh root yields (t/ha)	Root dry matter content
Avg., all genotypes	5.3	15.4	.276
Avg., local cultivar	2.5	9.8	.263
Avg., control cultivars[2]	2.2	12.3	.270
Avg., all selected germplasm accessions	5.4	13.5	.280
Avg., all CIAT lines	5.3	16.0	.268
Avg., top 10 CIAT lines	6.5	21.2	.283
Maximum yielder	12.0	24.6	.271
	(M Col 638)	(M Col 1684)	

1 I — 26 genotypes; planted 9 June 1977, harvested 18 May 1978. II — 43 genotypes; planted 20 Sept. and 28 Nov. 1977, harvested 2 Oct. 1978.

2 Llanera and M Col 22.

Selection for such characters as eating quality, starch content, and ease of harvest is highly important now that high yield capacity and wide adaptability have been demonstrated. For high stress conditions like Carimagua, the priority continues to be a combination of high yielding ability with disease and insect resistance.

Promising Lines

Table 18 provides information on several promising advanced lines. All are being multiplied by the Agronomy Section and many were planted in the 1978-79 regional trials. The first group of promising lines are from the 1973 hybridizations, when little was known about genetic resistance to diseases. These lines do not possess comprehensive resistance to diseases and may be unfit for high stress conditions such as are found in the Llanos Orientales of Colombia and Campo Cerrado in Brazil.

The second group of promising lines is from the hybridizations of 1974 and after when increasing emphasis has been given to disease resistance in the hybridization and selection program. From these materials, high yielding lines with disease resistance and favorable agronomic characters seem to be emerging (Table 18).

Genetic Resistance to CBB and Superelongation

Among the numerous diseases which attack cassava plants, cassava bacterial blight (CBB) is the most devastating and superelongation is the most conspicuous, with a possible exception of African cassava mosaic which is not reported in Latin America and most of Asia. Infection with either disease during early growth stages can severely decrease yields of susceptible cassava genotypes (CIAT Annual Report, 1973 and 1975). Genetic resistance is considered the best measure for protecting cassava against yield reductions from these diseases. While many genotypes which were originally believed to be resistant under moderate infection turned out to be susceptible under heavy infections, new genotypes have been identified as resistant. The effectiveness of presently available resistance under different field infection levels of CBB and superelongation was analyzed.

At Caribia, CBB is always present and can infect cassava plants from the early stage of growth; however, the level of infection has been low to moderate. Under these conditions, yield reductions on highly susceptible plants is about 20% and incorporation of resistance into susceptible genotypes can increase their yields 30% (Table 19). Planting stakes taken from the CBB-infected Caribia field were used in two of the three replicated yield trials there (Table 16). Yields of CIAT lines were still very superior to those of local cultivars. When CBB infection is moderate, preparation of good planting stakes may not be a problem. Moderate resistance is apparently all that is needed for this environment.

At Carimagua, cassava plants are heavily infected by CBB unless special precautions are taken. With early season planting (in April and May), heavy infection occurs in the early growth stages (three months after planting) while with late season planting (September and October), heavy infections come only after the start of the next rainy season (seven to eight months after planting). Yield reductions on highly susceptible plants are about 30 and 70% for late and early season plantings, respectively (Table 20).

Cassava plants suffer from CBB infection both in fresh root yields and in root

Table 18.

Characteristics of some promising hybrid cassava lines.

Cultivar	Cross (Year made)	Fresh root yields (t/ha/year) CIAT	North Coast	Cari-magua	Root dry matter content	Eating quality	Ease of harvest	Root skin color	Disease reactions[1] CBB	Super-elongation
Promising lines										
CM 305-38	M Col 113 x M Col 22 (1973)	34-51	55	20	medium	good	easy	brown	S	S
CM 305-120	M Col 113 x M Col 22 (1973)	39-51	39	21	low	accept.	average	brown	S	S
CM 305-125	M Col 113 x M Col 22 (1973)	37-48	42	16	medium	good	average	brown	S	S
CM 321-188	M Col 22 x M Ven 270 (1973)	61-67	42	14	medium	accept.	easy	white	S	S
CM 323-375	M Col 22 x M Mex 59 (1973)	36-63	41	7	medium	good	easy	brown	S	S
CM 376-407	M Col 22 x M Ven 307 (1973)	27-57	33	8	high	good	average	white	S	S
CM 430-37	Llanera x M Col 647 (1974)	64	-	-	medium	good	average	brown	R	MR
CM 459-5	Llanera x M Mex 23 (1975)	40	-	-	high	good	diffic.	brown	R	MR
Controls										
CM 308-197	M Col 22 x M Col 361 (1973)	44-50	33-39	3-21	low	poor	diffic.	white	S	S
M Col 1684		25-51	23-44	10-25	low	unaccept.	diffic.	white	MR	MR
M Col 638		17-31	21-31	12-22	low	unaccept.	average	yellow	R	MR
M Ven 218		27-60	21-37	3-13	medium	good	diffic.	brown	S	MR
Llanera		20-29	9-19	2-15	low	accept.	diffic.	brown	S	S
M Col 22		13-31	21-35	2-19	high	good	easy	white	S	S

[1] Ratings for cassava bacterial blight (CBB) and superelongation — S = susceptible; MR = moderately resistant; R = resistant.

Table 19.

Cassava yields at different levels of cassava bacterial blight (CBB) resistance in four replicated yield trials at Caribia.

CBB rating[1]	No. of genotypes	Avg. fresh root yield (t/ha)	Yield range (t/ha)
1	0	-	-
2	69	27.3	10.7-49.7
3	82	26.7	11.3-51.7
4	52	25.0	10.0-41.9
5	13	21.2	12.6-33.5

1 CBB field resistance rating 6-10 months after planting: 1 = no disease symptoms; 2 = disease symptoms only on leaves; 3 = infested leaves and stems; 4 = dieback in $\leq$ 50% of plants; 5 = death or dieback in 50% of plants.

dry matter content. High susceptibility reduced root dry matter content of cassava at Carimagua about 22% (Table 21). Low root dry matter content at Carimagua may be attributed to CBB infection as well as to other environmental factors such as temperature.

For late season plantings under Carimagua conditions, presently available resistance is highly effective if clean seed is used, however, with early season plantings, higher resistance levels are desirable. A series of resistant genotypes recently identified by the Pathology Section will be an important addition to hybridization schemes.

At Carimagua, cassava plants are always infected by superelongation disease. Heavy infections occur in patterns identical to those of CBB, when cassava is planted

Table 20.

Cassava yields at different levels of cassava bacterial blight (CBB) resistance in plantings at two times of the season at Carimagua.[1]

	Early planting (April-May)[2]			Late planting (Sept.-Oct.)[3]		
CBB rating[4]	No. of genotypes	Avg. fresh root yield (t/ha)	Yield range (t/ha)	No. of genotypes	Avg. fresh root yield (t/ha)	Yield range (t/ha)
1	0	-	-	0	-	-
2	2	11.1	10.2-12.0	2	19.6	17.0-22.2
3	6	6.5	4.9- 9.5	7	17.6	8.0-24.6
4	7	5.1	1.8- 9.1	19	16.1	10.4-24.0
5	10	3.6	2.5- 5.3	19	13.6	4.2-23.3

1 One replicated yield trial at each planting time.
2 Reaction to CBB evaluated 5 months after planting.
3 Reaction to CBB evaluated 8 months after planting.
4 See footnote to Table 19 for CBB ratings.

Table 21.

Cassava root dry matter content at different levels of cassava bacterial blight (CBB) resistance in a late-season-planted, replicated yield trial at Carimagua.

CBB rating[1]	No. of genotypes	Avg. root dry matter content	Avg. root dry matter content without CBB infection at CIAT
1	0	-	-
2	2	.325	.349
3	7	.285	.342
4	19	.271	.345
5	19	.253	.360

1 Evaluated 8 months after planting. For ratings, see footnote to Table 19.

early or late in the season. Yield reductions in highly susceptible cultivars are about 17 and 30% with late and early season plantings, respectively (Table 22). Superelongation does not reduce root dry matter content in highly susceptible materials as drastically as does CBB (Table 23).

Because the effects of superelongation disease on yield and quality of cassava roots are not so serious as those from CBB, presently available levels of genetic resistance are highly effective.

Selection for CBB and Superelongation Resistance

Significant improvement has been observed in the reaction to CBB among genotypes evaluated in observational yield trials at Carimagua from 1974 to 1978

Table 22.

Cassava yields at different levels of superelongation disease resistance in plantings at two times of the season at Carimagua.[1]

Super-elongation rating[2]	Early planting (May)[3]			Late planting (Oct.)[4]		
	No. of genotypes	Avg. fresh root yield (t/ha)	Yield range (t/ha)	No. of genotypes	Avg. fresh root yield (t/ha)	Yield range (t/ha)
1	0	-	-	0	-	-
2	18	22.2	12.2-33.0	5	20.6	18.1-24.3
3	10	21.6	13.9-33.0	10	22.5	15.3-36.8
4	10	17.3	9.0-32.3	14	20.7	16.0-25.0
5	12	15.2	10.4-24.0	20	17.6	10.4-24.7

1 All plantings were kept free of cassava bacterial blight (CBB) infections.

2 Rating varies slightly from that used in Pathology Section. 1 = no disease symptoms; 2 = disease symptoms only on leaves; 3 = disease symptoms on leaves of all plants and occasional stem elongation; 5 = 50% of plants show stem elongation; 5 = leaves dying of disease infection.

3 Data from one replicated yield trial evaluated 5 months after planting.

4 Data from two replicated yield trials evaluated 10 months after planting.

Table 23.

Cassava root dry matter content at different levels of superelongation disease resistance at Carimagua.[1]

Super-elongation rating[2]	No. of genotypes	Avg. root dry matter content	Avg. root dry matter content without superelongation infection at CIAT
1	0	-	-
2	18	.319	.349
3	10	.317	.342
4	10	.311	.354
5	12	.297	.338

1 Data from replicated yield trials; experiments were kept free of cassava bacterial blight (CBB) infections.
2 Evaluated 5 months after planting in May. See footnote 2 to Table 22 for ratings.

(Table 24). Since all the lines evaluated in these trials have been sent from CIAT, the only input for improving CBB resistance during this period has been the inclusion of CBB resistant genotypes such as M Col 647 and M Col 638 as parents and the elimination of extremely susceptible genotypes such as M Col 113 in the hybridization program. After one cycle of selection at Carimagua improvement was even more marked (lower row in Table 24).

The correlation of CBB rating of the same genotype between 1977 planting and 1978 planting was highly significant (r = 0.693**). Many lines have consistently shown good resistance.

Comparing CBB reactions of the same CIAT lines in Carimagua (heavy infection) and Caribia (moderate infection), many genotypes with a 2 rating at Caribia were highly susceptible at Carimagua while

Table 24.

Annual change in reactions of cassava genotypes to cassava bacterial blight (CBB) in Carimagua.[1]

Planting date	% of genotypes under each CBB rating[2]					Avg. rating of total population	Avg. rating of control cultivars		
	1	2	3	4	5		Llanera	M Col 22	M Col 638
May 1974	0	0.3	14	36	52	4.37	3.27	4.17	2.00
Oct. 1975, May 1976, Oct. 1976	All plantings were purposely kept free of CBB								
June 1977	0	3	27	64	6	3.74	3.33	3.64	2.73
Nov. 1977	0	3	20	44	33	4.06	4.35	4.50	3.18
May 1978	0	6	31	43	19	3.76	3.87	4.73	2.67
May 1978 After one cycle of selection at Carimagua	0	25	47	26	2	3.02	3.50	4.00	2.50

1 Data from observational yield trials except for selected population which is planted as a replicated yield trial.
2 See footnote 1 to Table 19 for CBB ratings.

Table 25.

Comparison of cassava bacterial blight (CBB) reactions of the same genotypes when planted in observational yield trials at Carimagua and Caribia.

CBB rating in Caribia	No. of genotypes CBB rating in Carimagua				
	1	2	3	4	5
1	0	7	8	5	0
2	0	14	39	55	40
3	0	2	18	47	60
4	0	0	3	18	52
5	0	0	0	1	39

practically all the genotypes with a 2 rating at Carimagua remained resistant at Caribia (Table 25). Genotypes with susceptible reactions at Caribia were always susceptible at Carimagua. This obviously occurred because of the difference in infection intensity rather than by racial interaction of CBB with cassava genotypes (see Pathology Section).

From these results it appears that using resistant parents field-selected at Carimagua in hybridizations is a highly efficient means for improving cassava genotypes for CBB resistance.

The same type of population improvement was observed for superelongation resistance (Table 26) as for CBB resistance. A major part of the improvement from 1974 to 1978 may be attributed to including such genotypes as M Ven 218 and M Col 1684 as parents, eliminating genotypes such as M Col 113 and M Mex 55 in the hybridizations.

Again a great improvement was made when one cycle of field selection at Carimagua was applied (lower row in Table 26). The correlation of superelongation ratings of the same genotype between

Table 26.

Annual change in reactions of cassava genotypes to superelongation disease in Carimagua.[1]

Planting date	% of genotypes under each superelongation rating[2]					Avg. rating of total population	Avg. rating of control cultivars		
	1	2	3	4	5		Llanera	M Col 22	M Col 638
May 1974	0	3	15	29	53	4.31	4.23	4.06	3.50
Oct. 1975	0	4	44	25	27	3.74	3.35	4.00	3.00
May 1976	0	6	35	21	40	3.93	3.50	3.25	2.60
Oct. 1976	0	4	9	18	69	4.54	2.75	4.50	3.25
June 1977	0	4	29	50	17	3.79	3.75	4.13	3.25
Nov. 1977	0.4	7	32	33	27	3.79	3.94	4.36	3.76
May 1978	1	13	26	34	27	3.72	3.53	3.93	3.29
May 1978 After one cycle of selection at Carimagua	0	21	43	17	19	3.34	3.00	5.00	3.00

1 Data from observational yield trials except for selected population which is planted as a replicated yield trial.
2 See footnote 2 to Table 22 for superelongation ratings.

plantings in 1977 and 1978 was highly significant (r = 0.656**). Many lines have consistently shown high resistance.

Genetic Behavior of CBB and Superelongation Resistance

In a field trial at Carimagua with six germplasm accessions in 15 replications, CBB and superelongation ratings of some accessions varied widely. For example, the CBB rating of M Col 638 fluctuated between 2 and 5 and the superelongation rating of Llanera, also from 2 to 5. On the other hand, ratings of susceptible genotypes such as M Col 113 were always 5 for both diseases.

A statistical analysis revealed that the six accessions differed from each other in the following manner: CBB (resistant to susceptible): M Col 638 > M Col 1684 > Llanera > M Ven 218 = M Col 22 > M Col 113; and, superelongation: M Ven 218 > M Col 1684 = M Col 638 > Llanera > M Col 22 > M Col 113. This suggests that the field resistance of these diseases are continuous traits and polygenically controlled.

Depending on the parental genotype, F_1 populations differed drastically in CBB and superelongation resistance (Table 27). Almost all the F_1 lines from crosses between parents susceptible to both diseases (SM 76-66 x CM 157-9, SM 76-66 x M Mex 59) were susceptible to both diseases. On the other hand, the cross between M Col 638 (resistant to CBB, moderately resistant to superelongation) and M Col 1684 (moderately resistant to both diseases) produced a high proportion of F_1 lines resistant to both diseases. Crosses of M Col 638 with M Ven 218, M Pan 70, M Pan 114, and M Mex 17 (highly

Table 27.

Difference in cassava bacterial blight (CBB) and superelongation resistance among different F_1 populations grown in observational yield trials.

Parents	No. of lines evaluated	% of lines resistant to both diseases: high[1]	% of lines resistant to both diseases: moderate[2]	% of lines resistant[3]: to CBB	% of lines resistant[3]: to super-elongation
SM 76-66 x CM 157-9	128	0	0	0	0.8
SM 76-66 x M Mex 59	76	0	0	0	5.6
M Col 647 x M Col 638	79	0	10.1	19.0	0
M Ven 168 x M Col 638	70	0	11.4	10.1	8.6
M Ven 270 x M Col 1684	88	1.1	1.1	9.1	1.1
M Col 638 x M Pan 70	118	0.8	6.8	1.7	12.0
M Col 638 x M Pan 114	124	0.8	8.9	2.4	12.9
M Col 638 x M Mex 17	64	1.6	9.4	1.6	17.2
M Col 638 x M Ven 218	112	0.9	7.1	4.5	15.2
M Ven 218 x M Col 638	67	4.5	11.9	9.0	21.8
M Col 638 x CM 309-56	37	2.7	16.7	48.6	2.7
M Col 638 x M Col 1684	137	5.1	18.2	32.1	9.5

1 Rating 2 (see footnote 1, Table 19 and footnote 2, Table 22).

2 Rating 3

3 Includes lines resistant (rating 2) to both diseases.

susceptible to CBB, resistant to superelongation) produced a high proportion of superelongation resistant F_1 lines. These crosses also included a fair number of F_1 lines resistant to both diseases. The cross between M Col 638 and CM 309-56 (resistant to CBB, susceptible to superelongation) produced an extremely high proportion of CBB resistant F_1 lines. However, most of these F_1 lines were susceptible to superelongation.

Although the resistance is obviously a continuous trait, four basic groups of germplasm accessions and F_1 populations can easily be identified and are shown in Table 28. These groupings suggest that CBB and superelongation resistances are genetically independent of each other and both can be combined.

Correlations between average ratings of parents and ratings of corresponding F_1

Figure 36. Observing breeding lines in the field at Carimagua.

Table 28.

Basic groupings of cassava germplasm accessions and F_1 populations according to their reactions to cassava bacterial blight (CBB) and superelongation disease.

Reactions	Accession or line	F_1 populations
Susceptible to CBB Susceptible to superelongation	M Col 113, M Col 22 and M Mex 59	SM 76-66 x CM 157-9 SM 76-66 x M Mex 59 M Col 113 x M Col 22 M Col 22 x M Mex 59 M Col 113 x M Mex 59
Resistant to CBB Susceptible to superelongation	CM 309-56	M Col 638 x CM 309-56
Susceptible to CBB Resistant to superelongation	M Ven 218, M Mex 17, M Pan 70 and M Pan 114	M Col 638 x M Ven 218 M Col 638 x M Mex 17 M Col 638 x M Pan 70 M Col 638 x M Pan 114
Resistant to CBB Resistant to superelongation	M Col 638	M Col 638 x M Col 1684

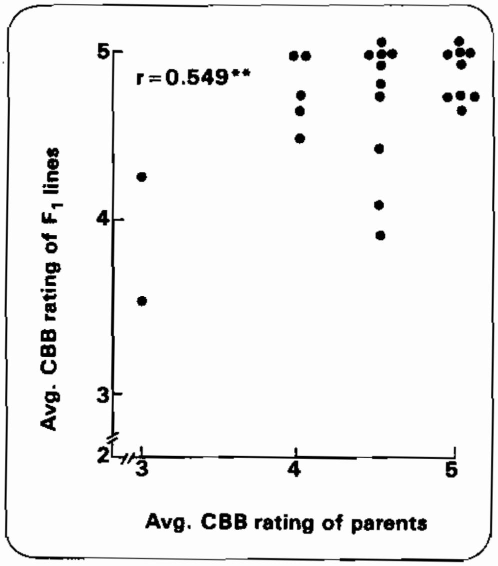


Figure 37. Relationship of cassava bacterial blight (CBB) reactions between parents and their corresponding F_1 population. (Data are from observational yield trial.)

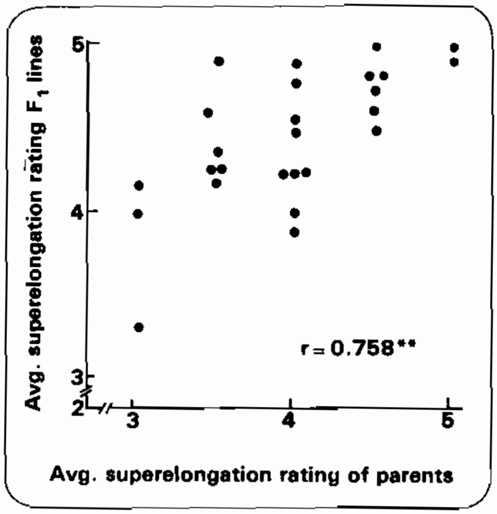


Figure 38. Relationship of superelongation reactions between parents and their corresponding F_1 populations. (Data are from observational yield trial.)

populations were highly significant for CBB and superelongation (Figs. 37 and 38). This indicates that an important portion of field resistance to CBB and superelongation is controlled by additive genes. Thus, a relatively simple scheme of hybridization will be effective.

Field Selection of Seedlings for Disease Resistance

In the May 1978 planting at Carimagua, plants suffered not only from CBB and superelongation but also from anthracnose.

The correlation between combined

Table 29.

Relationship between combined scores of parental genotypes for cassava bacterial blight (CBB), superelongation and anthracnose and survival of corresponding F_1 seedlings.

Avg. rating of 3 diseases in parental lines[1]	No. of families in each percentile group of surviving offspring seedlings						
	0%	0-10	10-20	20-30	30-40	40-50	50-100
2.0	0	0	0	1	0	2	1
2.5	0	0	8	5	4	2	0
3.0	1	8	5	7	7	2	1
3.5	6	10	10	7	4	0	0
4.0	5	13	18	7	4	0	0
4.5	12	10	12	1	0	0	0
5.0	10	8	1	0	0	0	0

1 Parental lines were planted with stakes.

Table 30.

Relationship between cassava bacterial blight (CBB) rating of parental lines and percentage of CBB-infected seedlings among offspring.

Avg. CBB rating of parental lines[1]	No. of families in each percentile group of CBB-infected offspring seedlings					
	0-50%	50-60	60-70	70-80	80-90	90-100
2	3	3	7	10	7	0
3	2	2	16	9	16	19
4	0	1	1	8	21	15
5	0	0	0	3	12	30

1 Parental lines were planted with stakes.

scores of parental genotypes for the three diseases and survival percentage of the corresponding F_1 seedlings was highly significant (Table 29).

Also highly significant was the correlation between CBB rating of parents and percentage of CBB-infected seedlings in offspring (Table 30). However, the same type of correlation for superelongation was not very significant (r = 0.168*). This may have occurred because the superelongation infection came after many seedlings had already been killed by CBB and anthracnose. These results suggest that the high correlation of data in Table 29 must have occurred mainly through inheritance of CBB resistance from parents to offspring. Field selection of seedlings may, therefore, turn out to be the simplest and most effective method of screening large numbers of genotypes for multiple disease resistance.

AGRONOMY

During 1978 regional trials were harvested on nine sites in Colombia. These trials included the first nine selected hybrids from the ICA-CIAT breeding program. At lower altitude testing sites, CIAT-selected varieties and hybrids have yielded an average of 62% more than local materials and 140% more than the Colombian average, during four cycles of testing.

Outside of Colombia, regional testing has been increasing. A second trial was harvested in Ecuador and the first cycle completed in Costa Rica. Several other countries are also conducting trials which include CIAT-selected materials.

The Rapid Propagation Unit multiplied 34 new hybrids and 19 selected varieties during the year. Part of this material was sent to 14 countries and the rest was utilized by various sections of the CIAT program.

The Cultural Practices Section completed a series of trials to define the proper management of planting materials to obtain higher yields.

Two mechanical harvesting aids for lifting cassava roots from the ground were evaluated and compared with the manual system of harvesting.

Evaluations of multiple-cropping systems with cassava and grian legumes continued with emphasis on the cassava/*Phaseolus vulgaris* system where environmental conditions are suitable and other grain legumes where conditions are too severe for *Phaseolus*.

A trapezoidal planting design was tested and found satisfactory for evaluating cassava under various plant densities.

Regional Trials

Regional Trials in Colombia

The nine regional trials in Colombia were harvested. Table 31 shows some ecological and edaphic characteristics of these sites and Table 32 shows the yields of test materials and local varieties. With the exception of results at Popayan, selected varieties and hybrids yielded considerably more than local varieties. This reconfirms the need of selecting materials for cooler regions which are of secondary priority in the Cassava Program. Of the some 2500 accessions in the CIAT cassava germplasm collection, only 9% originated from areas with altitudes over 1600 meters. Using this criterion of altitude, data on the regional trials are discussed in two groups — those from seven sites lower than 1300 meters and those from two sites above 1500 meters (Table 31).

Low-elevation Sites

The two best-yielding varieties on the low-elevation sites were M Col 1684, a bitter variety best-suited for industrial purposes, which yielded an average of 37.4 t/ha over all sites and CMC-40, which averaged 26.9 t/ha. Even though diseases were present in various severities at Media Luna, Carimagua, Nataima and CIAT-Quilichao, M Col 1684 yielded 97% more than the averages of the local varieties. At the same time the five best hybrids averaged about 27 t/ha, some 42% more than the local varieties.

The hybrids evaluated in this cycle were preliminary selections that had not yet passed all the usual requirements for final selection by the Varietal Improvement Section. The yield data indicate that much room for improvement exists within the hybrid selections before they surpass the yield of M Col 1684.

High-elevation Sites

At Pereira, variety CMC-59 produced only 8% more than the local variety and M Col 1684 and CMC-40 yielded the same as the local. In Popayan, the local variety CMC-92 has not been out-yielded by introduced varieties or hybrids.

Production Cycle

The average length of the cycle from seeding to harvest was 443 days for high-elevation sites and 345 days for low-elevation sites. The longer cycle in the former zone allows only three test cycles during four years while four cycles were possible at the lower sites.

After four years of testing the average yield at low sites has been 72 kg/ha/day compared to 62 kg/ha/day at the two higher sites. Over the four testing cycles at

Table 31.

Main climatological and edaphic characteristics of sites of cassava regional trials, 1977-78 cycle.

Site	Location	Altitude (masl)	Mean temp. (°C)	Rainfall[1]	Days to harvest	Soil texture	pH	Organic matter (%)	P Bray II (ppm)	K (meq/ 100 g)
Caicedonia, Col.	4°20'N, 75°50'W	1200	22.2	1696	346	Silty loam	6.0	2.6	22.2	0.17
Carimagua, Col.	4°40'N, 71°24'W	200	26.2	1917	361	Silty clay	4.4	3.1	2.7	0.14
CIAT-Palmira	3°31'N, 76°21'W	1000	23.8	740	307	Clayey	7.2	3.7	41.9	0.73
CIAT-Quilichao	3°06'N, 76°31'W	1070	23.0	1771	359	Silty clay	4.2	7.5	3.5	0.44
Media Luna	10°33'N, 74°30'W	10	27.2	857	333	Sandy	6.5	0.6	6.9	0.08
Nataima	4°10'N, 74°56'W	430	27.8	1077	308	Silty sand	5.5	1.0	67.0	0.32
Pereira	4°49'N, 75°41'W	1480	19.0	3091	439	Silty loam	5.2	8.5	3.3	0.17
Popayan	2°27'N, 76°34'W	1800	18.0	3365	519	Sandy loam	4.8	4.7	76.0	0.44
Rionegro	7°15'N, 73°09'W	250	27.0	1422	361	Silty clay	6.6	2.0	27.6	0.06
Santa Clara, Costa Rica	10°00'N, 83°42'W	180	22.0	3779	345	Silty loam	5.3	5.8	3.8	1.04
Pichilingue, Ecuador	1°06'S, 79°29'W	100	25.0	995	265	Loamy	6.5	5.8	51.9	1.03

1 Total rainfall during the actual growing cycle.

Table 32.

Yields of promising ICA-CIAT varieties and hybrids at nine locations in Colombia, 1977-78 cycle.

Varieties and hybrids	Sites								
	Media Luna	Carimagua	Rionegro	Nataima	CIAT-Palmira	CIAT-Quilichao	Caicedonia	Pereira	Popayán
	Fresh root yields (t/ha)								
M Col 1684	25.6[1]	36.1[1]	40.1[1]	31.2[2]		52.0[1]	39.3[1]	39.9[1]	11.1
CM 308-197	15.9[1]	30.1[1]	23.5[1]	36.7[1]	29.9[1]		37.3[1]		
CM 192-1	9.3	28.3[1]	9.7	31.8[1]	30.9[1]	46.7[1]	37.2[1]		
CM 323-87	19.0[1]	24.4	27.2[1]	30.5[1]	19.4	32.6	26.9		
HMC-2	15.6[1]	30.4[1]	18.1[1]	24.0	30.3[1]	37.7	26.3		
CM 309-41	12.2[1]	24.0[1]	21.9[1]	18.3	30.1[1]	42.1[1]	36.2[1]		
CMC-40 (M Col 1468)	22.4[3]	26.3[3]	21.7[3]	27.8[3]	30.1[3]	36.9	23.5	40.4[3]	
CMC-84 (M Col 1513)	13.2[3]	22.3[3]	29.4[3]		31.3[3]	36.8	25.8		
M Mex 59	23.5[3]	15.9[3]	33.5[3]	29.2[3]	14.0	25.1	18.7[3]		
M Col 22	6.9[3]			19.5[3]	22.1[3]		22.6		
HMC-4	13.7	20.1	14.8	24.4	28.6	31.5	33.3		
CM 314-58	11.3	18.3	21.2	19.6	24.8	32.9	25.6		
CM 333-19	10.8	18.3	17.8	15.0	24.0		25.3		
CM 314-66	9.1	14.0	12.6	25.0	18.0		30.6		
SM 1-150	9.4	25.7[1]	6.9	15.7	27.2	38.3			
M Ven 218	14.8[1]		7.8	22.5[2]	31.3[1]	43.2	14.8[2]		
MPTR 26				26.8[2]	27.3[2]			33.0	9.6
M Pan 70				20.9[2]	22.7[2]		15.3[2]	32.6	8.7
M Mex 17				22.2[2]	17.9[2]		13.8	29.2	6.0
M Ven 156	13.8[2]		21.9[2]		26.2[2]			40.0	11.2
M Col 1686				23.1				30.6	15.9

(continued)

Table 32. (continued)

Varieties and hybrids	Sites: Media Luna	Carimagua	Rionegro	Nataima	CIAT-Palmira	CIAT-Quilichao	Caicedonia	Pereira	Popayán
	Fresh root yields (t/ha)								
Other varieties and hybrids		19.0 (15)[3]	32.1 (3)[2]		28.0 (14)[1]	51.6 (4)[1]	19.7 (2)[3]	43.4 (8)[3]	32.7 (11)
			15.2 (1)[2]			46.1 (5)	18.6 (7)[2]	40.7 (10)[2]	31.2 (9)[1]
			12.1 (2)[3]			27.9 (6)		38.5 (9)	6.5 (12)
								35.3 (8)	
								33.3 (11)	
								26.1 (12)	
								17.5 (13)	
Regional varieties	5.6 (16)	10.1 (17)	12.9 (18)	22.0 (23)	24.2 (20)	45.7 (20)	12.1 (21)	40.1 (21)	40.0 (22)
			10.0 (19)						
Average, including regional varieties	14.0	22.7	19.5	24.3	25.6	39.2	25.1	34.7	17.2
Best promising variety or hybrid	25.6	36.1	40.1	36.7	31.3	52.6	39.3	43.4	32.7

Length of the growing season at each site is given in Table 31.

1 and 2 Varieties and hybrids approved for the second and third year of evaluation, respectively, at the site.

3 Varieties that completed three years of evaluation in the same site.

Underlined figures denote that promising materials were used as checks at these locations.

Other varieties and hybrids: (1) M Ven 77; (2) M Col 677; (3) CMC 99 = M Col 1529; (4) HMC-7; (5) HMC-1; (6) CM 337-7; (7) M Col 1292; (8) CMC-59 = M Col 1488; (9) CMC-57= M Col 1486; (10) M Ven 168; (11) M Col 561; (12) M Col 655A; (13) M Col 673; (14) CM 323- 375; (15) Chiroza

Regional varieties: (16) Secundina; (17) CMC-9 = M Col 1438; (18) Colombiana; (19) Venezolana; (20) M Col 113; (21) Chiroza Gallinaza; (22) CMC-92 = M Col 1522; (23) CMC-84 = M Col 1513.

Table 33.

Average yields of the three best promising varieties at eight sites in Colombia under 1300 m altitude, compared with the best local variety, during four testing cycles.

	Cycles									
	1974-75		1975-76		1976-77		1977-78		Avg./Site	
Site	Promising	Local	Promising	Local	Promising	Local	Promising	Local	Promising	Local
Caicedonia	37.3	32.3	25.0	15.8	51.2	41.2	38.0	12.1	37.8	25.3
Carimagua	6.2	3.8	25.6	22.9	23.9	17.3	32.2	10.1	21.9	13.5
CIAT-Palmira	40.6	26.8	30.9	22.1	42.6	22.5	31.1	24.2	36.3	23.9
CIAT-Quilichao	-	-	-	-	-	-	50.3	45.7	50.3	45.7
El Tambo	-	-	22.4	22.3	28.4	26.2	-	-	25.4	24.2
Media Luna	26.7	17.7	17.6	4.0	17.1	5.7	23.9	5.6	21.3	8.2
Nataima	41.1	33.6	28.4	16.3	33.6	8.0	33.2	22.0	34.0	19.9
Rionegro	29.7	15.7	21.9	11.7	45.2	16.1	35.2	12.9	33.0	14.1
Avg./Cycle	30.3	21.7	24.5	15.9	34.6	19.6	34.8	18.9	31.1	19.2

lower sites selected varieties and hybrids have yielded 62% more than local materials and have averaged 140% more than the national yield (Table 33). At the higher sites the advantage of introduced over local materials is only 4% (Table 34).

Consistency of the data over four years of regional trials in Colombia indicate with sufficient confidence that farmers can double the yields of local varieties using the same simple, low-cost cultural practices employed in the regional trials. These practices are:

1. Good soil preparation.

2. Planting at the beginning of the rainy season except at Carimagua where planting is done in September to reduce the severity of damages from diseases. Results of the first cycle trial (planted in June) show the low yields to be expected at Carimagua from early planting (Table 33).

Table 34.

Average yields of the three best promising varieties at two sites in Colombia above 1300 m altitude, compared with the best local variety, during four years (three testing cycles).

	Cycles							
	1974-75		1975-77		1977-78		Avg./Site	
Site	Promising	Local	Promising	Local	Promising	Local	Promising	Local
Pereira	19.8	16.9	44.5	45.8	41.5	40.1	35.2	34.3
Popayan	10.8	14.5	13.3	14.3	34.6	40.0	19.5	22.9
Avg./Cycle	15.3	15.7	28.9	30.0	38.0	40.0	27.3	28.5

3. Selection and treatment of the stakes by submerging them five minutes in a fungicidal suspension of mancozeb and maneb (2.2 and 1.25 g/liter of water, respectively).

4. Planting stakes vertically.

5. Planting at a density of 10,000 plants/ha.

6. Good weed control.

7. Planting in ridges on heavy soils where rainfall is above 1200 mm/year.

No fertilizer was used in these trials except at Carimagua and CIAT-Quilichao where soils are acid and infertile. At those two sites plots received 500 kg/ha of dolomitic lime (100-mesh), 1 t/ha of 10-20-20 fertilizer banded one-half at planting and the rest 60 days later, and 15 kg Zn/ha. Plots were not irrigated nor protected from insects or diseases.

Regional Trials Outside Colombia

In the second cycle of regional trials

Table 35.

Yields of promising ICA-CIAT cassava varieties harvested in international regional trials during the 1977-78 cycle.

	Sites	
	Santa Clara, Costa Rica	Pichilingue, Ecuador
Varieties	Fresh root yields (t/ha)	
M Col 1684	30.3	23.6
CMC-84 = M Col 1513	26.2	20.6
M Mex 59	27.9	12.5
CMC-40 = M Col 1468	22.0	26.4
M Pan 70	16.2	21.0
M Ven 168	21.1	23.4
M Col 677	13.1	13.0
M Col 655A	10.6	11.8
M Mex 17	17.9	25.0
MPTR-26		26.7
CMC-76 = M Col 1505	21.8	
M Col 22	19.7	
M Ven 218		24.3
M Col 561		21.4
M Col 1686		13.8
Regional varieties		
Valencia	14.8	
Yema de Huevo		18.6
Quintal		15.0
Average, including regional varieties	20.1	19.8
Best promising variety	30.3	26.7

completed in Ecuador, CIAT selections were again superior to local varieties (Table 35). The three best varieties — MPTR 26, CMC 40 and M Mex 17 — yielded 40% more than Yema de Huevo, the best local variety. No economically important insects or diseases affected this trial. The variety M Mex 59 which yielded best in the previous cycle (28.3 t/ha) was next to last this season due to flooding of the plots where it was planted.

The first regional trial in Costa Rica was harvested. The majority of introduced varieties from CIAT outyielded the local variety and the average yield of the best three was some 90% higher than the local. Mites, thrips and superelongation had some effects on this trial.

In both Costa Rica and Ecuador the varieties M Col 1684 and CMC 40 yielded well, indicating that the two materials could be widely adapted.

The results of all regional trials demonstrate that adequate technology exists to increase cassava production and that there are some selected varieties that can produce more than local materials. These superior varieties are being utilized as parents for selected crosses by the Varietal Improvement Section.

Cultural Practices

Management of Planting Material

Maturity of Stakes

Cassava stake cuttings were taken from the upper (youngest) middle and lower (maturest) parts of stems of 1-year-old plants of three varieties. Cuttings were planted vertically, irrigated when rainfall was deficient and replanted as necessary to provide a complete stand. Stakes from upper and middle stem sections always germinated well but lower stakes from the cultivar M Mex 52 germinated poorly (Table 36). Plants from upper stakes yielded highest in the very vigorous variety M Mex 59 due to their high harvest index. It is probable that the lower early vigor provided near-optimum Leaf Area Indices (LAIs) and hence, highest yields in this treatment. Mean results of performance of the three varieties suggest that cuttings from the upper part of the plant yield highest (Fig. 39), but that under good conditions, both upper and middle stakes from a vigorous variety can be used. Stakes from the lowest part of stems of vigorous plants are not recommended.

Planting Depth

Stakes 30 cm long from cultivar CMC 40 were planted vertically in ridges, 10, 20 and 30 cm deep. Yields and harvest indices were not significantly different because of planting depth but root formation along the buried section of the stake was affected. Roots were clumped around the base when stakes were planted only 10 cm deep, but were distributed along the stake and with peduncles if stakes were buried deeper. Due to the ease of planting and harvesting, stakes should be planted vertically only 10 cm deep.

Stake Length

Stakes 20, 40 and 60 cm long were

Table 36.

Effects of origin and maturity of planting stakes on germination, harvest index and yield of three cassava varieties.

Origin of stake on stem	Germination (%)	Harvest index	Fresh root yields total (t/ha)	Fresh root yields commercial (t/ha)
M Mex 52				
upper	93.0	0.34 a[1]	18.5 a	12.8 a
middle	91.1	0.30 a	18.1 a	13.1 a
lower	74.5	0.29 a	16.8 a	10.2 a
M Mex 59				
upper	93.6 b	0.35 a	17.4 a	12.0 a
middle	96.9 a	0.26 b	11.8 b	6.2 b
lower	98.5 a	0.26 b	12.5 b	6.4 b
CMC 40				
upper	100 a	0.49 a	28.8 a	26.3 a
middle	100 a	0.50 a	31.5 a	27.9 a
lower	100 a	0.44 a	26.4 b	22.5 b

1 Means for each variety and within columns that are followed by the same letter are not significantly different at P= 0.05.

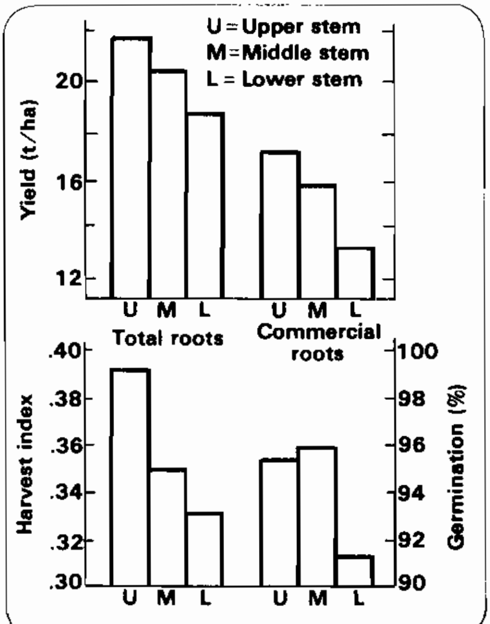


Figure 39. Effect of planting stake maturity (position on stem) on average germination, harvest index and root yields of three cassava varieties.

planted in the field at CIAT-Palmira. All stakes were carefully selected and treated. The 20-cm stakes yielded significantly more than the other two treatments (Table 37).

Planting Position

Stakes from 10 varieties were planted vertically, slanted and horizontally on different dates to cause seasonal influences on germination. Vertically planted stakes always germinated the best and the advantage was greatest when rainfall during the first 30 days was least (Table 38). When a similar trial was planted and taken to final yield at 11 months, germination was highest and yields were significantly higher for vertically planted stakes (Table 39). The rate of shoot emergence was significantly greater for

Table 37.

Effect of length of the planting stake on germination, harvest index and yield of cassava.

Stake length (cm)	Germination (%)	Harvest index	Fresh root yields total (t/ha)	Fresh root yields commercial (t/ha)
20	77.9 a[1]	0.38 a	30.8 a	27.6 a
40	78.4 a	0.36 ab	27.4 b	24.0 b
60	77.0 a	0.34 b	27.5 b	23.9 b

1 Means within columns followed by the same letter are not significantly different at P = 0.05.

stakes planted vertically or slanted than for those planted horizontally (Fig. 40).

Cutting Angle

The manner of cutting the stakes — squarely or angled— did not significantly affect yields. Roots were more uniformly distributed, however, on squarely cut stakes, suggesting that this system is best.

From these results it is recommended that carefully selected and treated cuttings, cut squarely 20 cm long, from the upper and middle parts of vigorous plants should be planted vertically 10 cm deep to provide highest yields.

Spatial Arrangements

Cassava varieties M Col 22, M Mex 59 and CMC 40 were planted at densities of 10,000 and 15,625 plants/ha, in square and rectangular patterns. Yields within the varieties did not differ significantly for the two treatments (Fig. 41), corroborating similar results observed last year (CIAT Annual Report, 1977). Planting density and selection of the best-adapted varieties appear to be more important than the planting pattern for obtaining high yields. The fact that a 2-m (between rows) x 0.5-m (within rows) pattern yields the same as a 1 x 1-m pattern has important general agronomic implications. The wider row spacings may enable easier control of

Table 38.

Effect of stake position and time of planting on germination of cassava.[1]

Planting date	Rainfall during first 30 days (mm)	Percentage germination vertical position	Percentage germination slanted position	Percentage germination horizontal position
March 29	215	97.5	98.5	98.0
May 30	5	100	100	91.5
July 29	25	91.5	88.0	54.0
Sept. 30	116	99.0	96.0	95.0

1 Average of 10 varieties.

Table 39.

Effects of planting position on germination, harvest index and yield of cassava.[1]

Planting position	Germination (%)	Harvest index	Fresh root yields total	commercial
			(t/ha)	
Vertical	89.2 a[2]	0.36 a	31.1 a	27.4 a
Slanted	85.6 a	0.36 b	27.6 b	24.2 b
Horizontal	58.6 b	0.35 a	27.0 b	23.9 b

1 Average of 2 varieties

2 Means within a columm followed by the same letter are not significantly different at P=0.05.

weeds, allow easier harvesting of mixed crops and permit uncultivated bands to be left between rows to assist in controlling erosion.

Long-term Fertility Trials

Due to serious disease and insect problems at Carimagua, long-term fertility testing was discontinued there. The second cycle trials at CIAT-Palmira and Caribia were harvested during 1978 and the third cycles planted. Results were similar to those reported last year (CIAT Annual Report, 1977). Significant differences ($P = 0.05$) in yield were found between varieties but fertilizer applications did not significantly affect yields at either CIAT or Caribia (Table 40). A planting density of 10-15,000 plants/ha tended to produce higher total yields than either 5000 or 20,000 plants/ha densities, at both locations. Similar trends were found for commercial root production (Figs. 42 and 43). There were no significant interactions between planting density and fertilizer levels. Compared to the first cycle, yields decreased at CIAT, despite more rainfall in the second year. At Caribia, yields remained fairly constant.

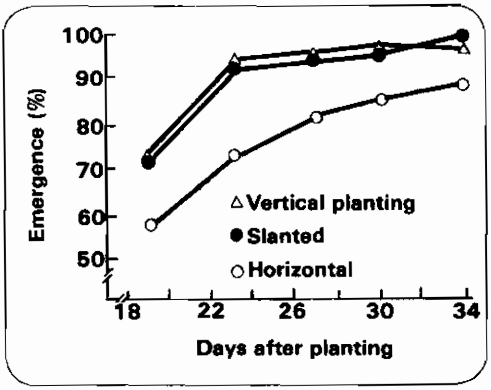


Figure 40. Effect of stake planting position on average emergence rates of 10 cassava varieties, over 4 planting seasons.

Table 41 shows changes in the soil fertility status at the two sites after the second cropping cycle. In Caribia, where no P is applied, both the fertilized (N-K-Zn) and check plots have shown the same P content in the soil; at CIAT, the P-fertilized plots show more P than in the check. However, at both sites the P content in the soil is decreasing. This study will continue for at least three more cycles.

Trapezoidal Planting Design

Planting density trials in cassava are costly because of the large areas required. Adapting the fan design of planting (CIAT Annual Report, 1974) to parallel rows with distances varying only between plants resulted in the design shown in Figure 44.

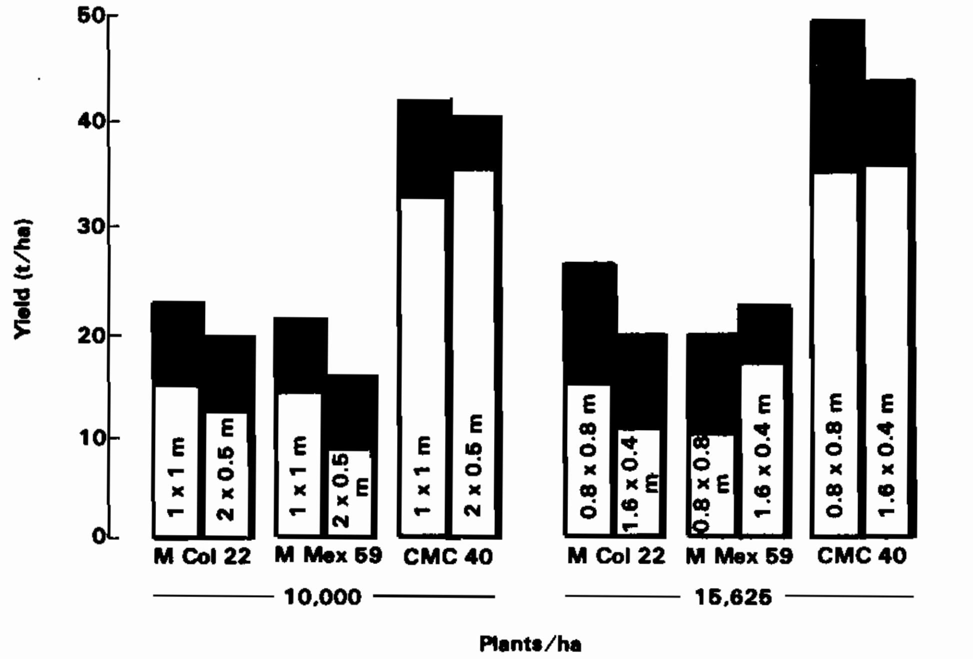


Figure 41. Effects of various square and rectangular planting patterns on fresh root yields of three cassava varieties planted at two densities. (Figures within the bars are plant spacings.)

The pattern is characterized by its simplicity of establishment. This design permits 12 planting densities between 5000 and 20,000 plants/ha to be studied with four replications, in a total area of 1200 m^2.

Table 40.

Effects of fertilization on yields of four cassava varieties grown at two locations.[1]

Treatment	Varietal fresh root yields (t/ha)			
	CMC 40	M Col 22	M Mex 59	Chiroza
CIAT				
Control	33.4 a[2]	24.8 a	20.5 a	-
Fertilized[3]	33.6 a	23.6 a	19.3 a	-
Caribia				
Control	31.9 a	31.7 a	-	18.1 a
Fertilized[4]	36.6 a	35.1 a	-	17.9 a

1 Means of 4 planting densities.
2 Means within a column followed by the same letter are not significantly different at P = 0.05.
3 50 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha.
4 50 kg N, 150 kg K_2O and 20 kg Zn/ha.

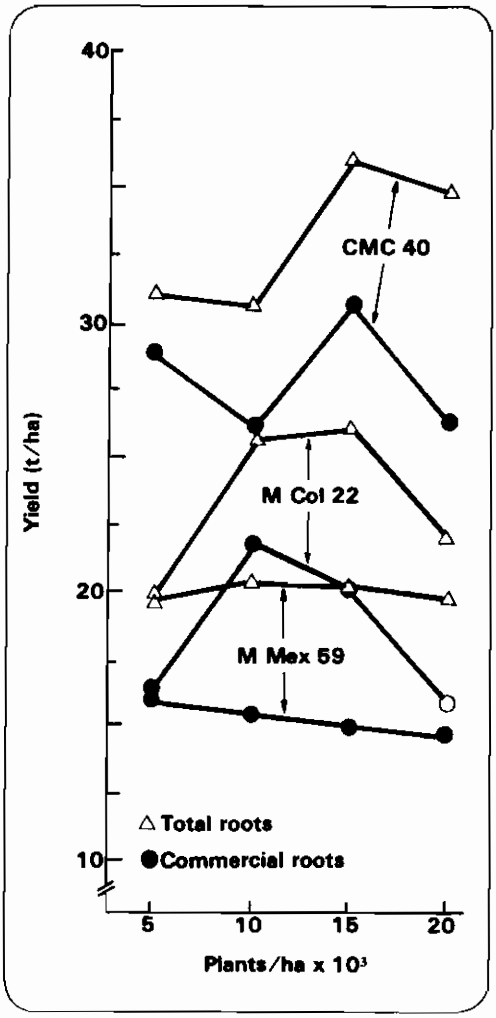


Figure 42. Effects of planting density on fresh root yields of three cassava varieties grown at CIAT.

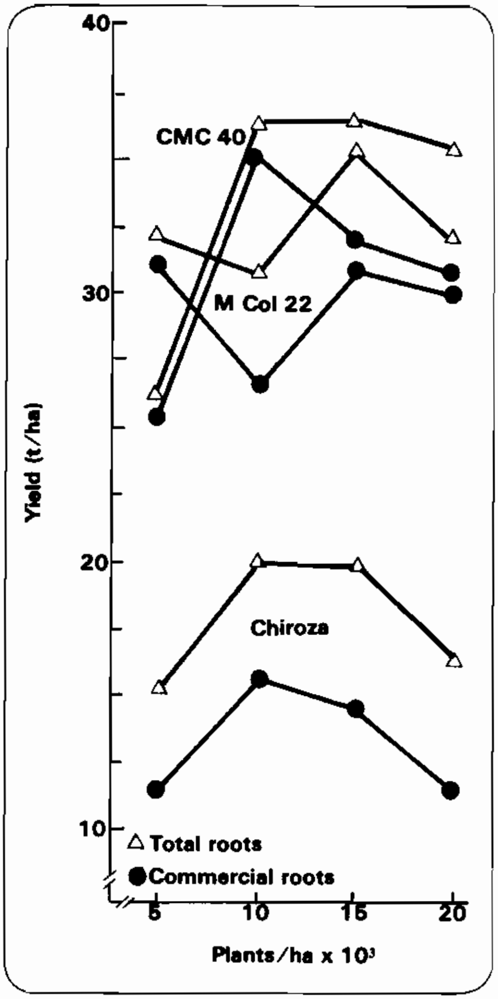


Figure 43. Effects of planting density on fresh root yields of three cassava varieties grown at Caribia.

Thirteen of these trapezoidal designs were harvested at four locations (Fig. 45). Four cassava varieties were involved although not at each location. The shape of the curve indicates that higher yields can be produced with higher planting densities. Yield data from the four locations are shown in Figure 46. At CIAT, two trials were planted with M Col 22 and one with CMC 84; in Caribia, M Col 22 and CMC 40 were the varieties used. At both locations yields decreased at densities of either 11,000 or 8000 plants/ha. The same yield decreases were observed at both sites with some of the varieties in the long-term fertility trial (see Figs. 42 and 43), indicating this may be an actual situation and not a design defect.

The other two sites, Carimagua and La Idea, showed similar yield trends, although at different levels. Yields of each variety across locations are shown in Figure 47. A variety M Col 22 was planted at the four sites in a total of six trials, CMC 40 at two

Table 41.

Soil fertility status of plots at CIAT-Palmira and Caribia initially and after one or two cassava harvests.

Location	Organic matter (%)		P, Bray II (ppm)		K (meq/100 g)	
	control	fertilized	control	fertilized	control	fertilized
CIAT[1]						
initial	3.8	3.8	36	36	0.55	0.55
after 1st harvest[2]	4.1	4.2	46	51	0.49	0.54
after 2nd harvest[2]	4.0	4.0	31	41	0.42	0.45
Caribia[3]						
initial	1.9	1.9	81	81	0.13	0.13
after 1st harvest[2]	2.3	2.4	93	96	0.12	0.13
after 2nd harvest[2]	2.1	2.0	66	67	0.12	0.12

1 50 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha applied annually.
2 Average of 12 samples.
3 50 kg N, 150 kg K_2O and 20 kg Zn/ha applied annually.

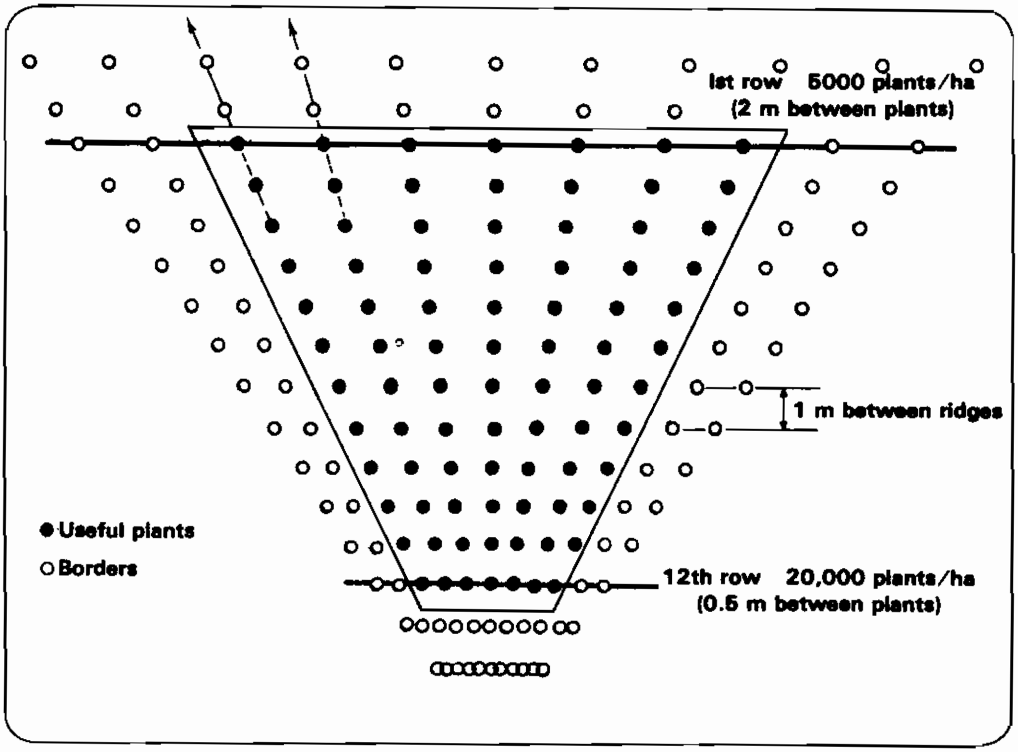


Figure 44. Trapezoidal design for the study of planting densities of cassava.

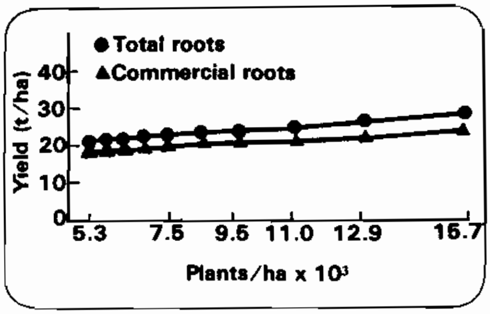


Figure 45. Effect of planting density on cassava fresh root yields. (Averages of total and commercial roots from four varieties at four locations, harvested from 13 trapezoidal plantings.)

sites in three trials, CMC 84 at two sites in one trial each and M Mex 11 in two trials at one site. Except for the latter variety, which suffered seriously from drought, all varieties responded to higher planting densities.

The results show the modified fan design can be used to obtain preliminary information where no data is available on planting density and yield response.

Weed Control

Weed control is a basic factor of cassava production technology. Chemical control is important to increase labor efficiency and reduce weeding costs. Cultural control, through intercropping, relay cropping, rotation, and growing cover crops, is — on the other hand — a low-input but labor-intensive alternative. Present research is directed to developing effective weed control systems using both chemical and cultural methods.

Screening of New Herbicides

Five pre-emergent herbicides and three experimental compounds were tested against the standard recommendation of diuron and alachlor. Herbicides were applied at the recommended, twice the recommended and four times the recommended rate to assess selectivity and weed control efficiency. Variety CMC 40 was planted at CIAT-Palmira on heavy

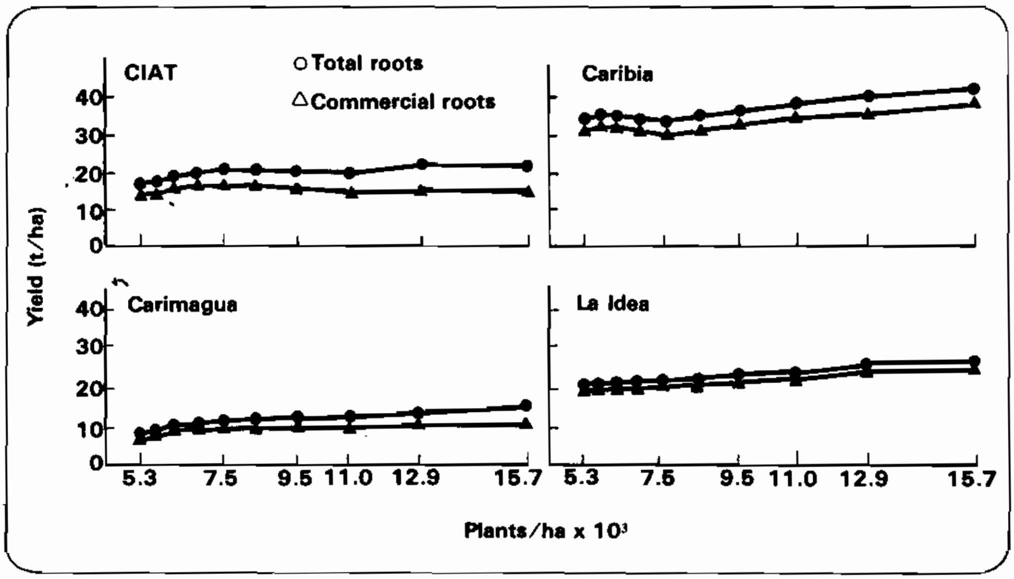


Figure 46. Effect of planting density on fresh root yields of cassava at four locations. (Averages of two or more varieties per location, using a trapezoidal planting design.)

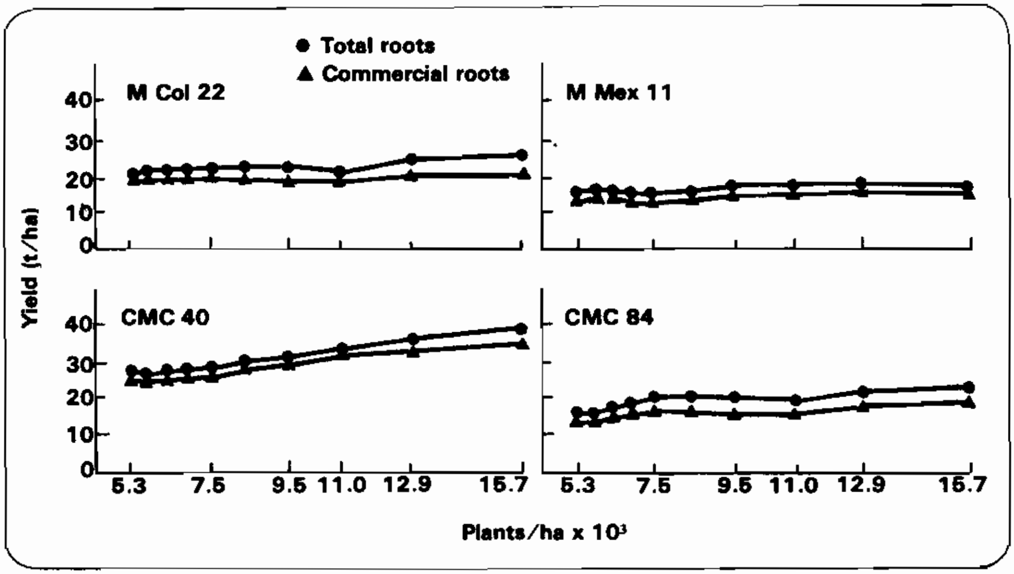


Figure 47. Effect of planting density on fresh root yields of four cassava varieties planted in a trapezoidal design.

clay-loam soil on ridges at a 1 x 1-m spacing. During the first three months after planting, the trials received a total of 257 mm of precipitation (rain and sprinkler irrigation) distributed as follows: 105 mm the first month, 88 mm the second month, and 64 mm during the third month. Control plots had heavy natural infestations of common purslane *(Portulaca oleracea)*, pigweed (*Amaranthus* spp.), balsam pear *(Momordica charantia)*, morning glory *(Ipomea hederifolia)*, goosegrass *(Eleusine indica)*, red spangletop *(Leptochloa filiformis)* and bermudagrass *(Cynodon dactylon)*.

One product caused chemical injury to cassava when applied at the recommended rate. At the higher rates, chemical injury usually peaked 3-4 weeks after application and then declined. Table 42 gives the maximum injury rating and selectivity and the recommended amounts for each product. Figures 48 and 49 show the percentage weed control at the recommended rates for broad-leaved and narrow-leaved weeds, respectively. Percentages are shown for only six products as the other four were discarded for non-selectivity (pendimethylin) or inefficiency (dichlorfop, QSC-09377 and QSC-0377).

Control of broad-leaved weeds 80 days after application (DAA) was superior with oxadiazon and oxyfluorfen and acceptable with tetrafluoron and the diuron/alachlor check, while H 26910 and metolachlor lost most of their effect one month after application.

In narrow-leaved weeds, control was efficient with the check treatment, oxadiazon, H 26910 and oxyfluorfen, the latter again providing more than 95% control at 80 DAA.

Compared to the diuron/alachlor mixture, both oxadiazon and oxyfluorfen appeared to provide longer overall weed control, but because oxadiazon ranked higher in maximum injury to cassava, only oxyfluorfen is being considered for further testing.

Table 42.

Recommended dosis, injury ratings and selectivity classifications of nine pre-emergent herbicides evaluated in cassava plantings at CIAT-Palmira.

Herbicide	Recommended dosis (kg a.i./ha)	Max. injury rating at:[1] recommended amount	2X recommended amount	4X recommended amount	Selectivity to cassava[2]
tetrafluoron	1.90	0.0	0.0	5.0 (5)[3]	mod. selective
dichlofop	1.40	0.0	0.0	0.0	highly selective
QSC-09377	1.50	0.0	0.3 (3)	0.0	highly selective
QSC-0377	0.75	0.0	0.0	0.0	highly selective
pendimethylin	1.30	2.0 (3)	3.8 (3)	8.3 (3)	non-selective
H-26910	4.00	0.0	0.3 (3)	1.0 (3)	mod. selective
oxyfluorfen	1.00	0.0	1.3 (3)	4.0 (4)	mod. selective
metolachlor	1.00	0.0	0.3	0.6 (3)	mod. selective
oxadiazon	1.50	0.0	0.7 (2)	4.7 (2)	mod. selective
diuron + alachlor	0.8 + 1.4	0.0	1.0 (3)	3.5 (3)	mod. selective

1 Scale: 0 = no injury; 10 = completely killed.
2 Selectivities: highly selective = no injury even at 4X recommended rate; mod. selective = injury only at 2X and 4X recommended rate; non-selective = injury at recommended rate.
3 Number of weeks after application when maximum injury occurred.

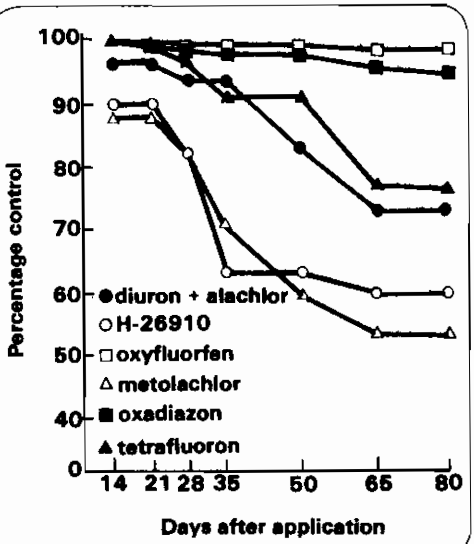


Figure 48. Broad-leaved weed control of six pre-emergent herbicides in cassava.

Integrated Weed Control

The variety M Mex 11 was planted in monoculture and associated with bush beans (variety Porrillo Sintético) to evaluate four weed control levels under monoculture and intercropping conditions.

Without any control, weeds grew vigorously in cassava monoculture and produced more than 600 g dry matter/m[2] in 45 days. In the cassava/bean association, less than one-third this amount was produced; the intercropped beans were as efficient in reducing weed growth as was the pre-emergent herbicide mixture used in the cassava monoculture treatment.[1] In the

1 The pre-emergent mixture in this trial was linuron (0.5 kg a.i./ha) and fluorodifen (2.1 kg a.i./ha). The mixture is selective for cassava and beans.

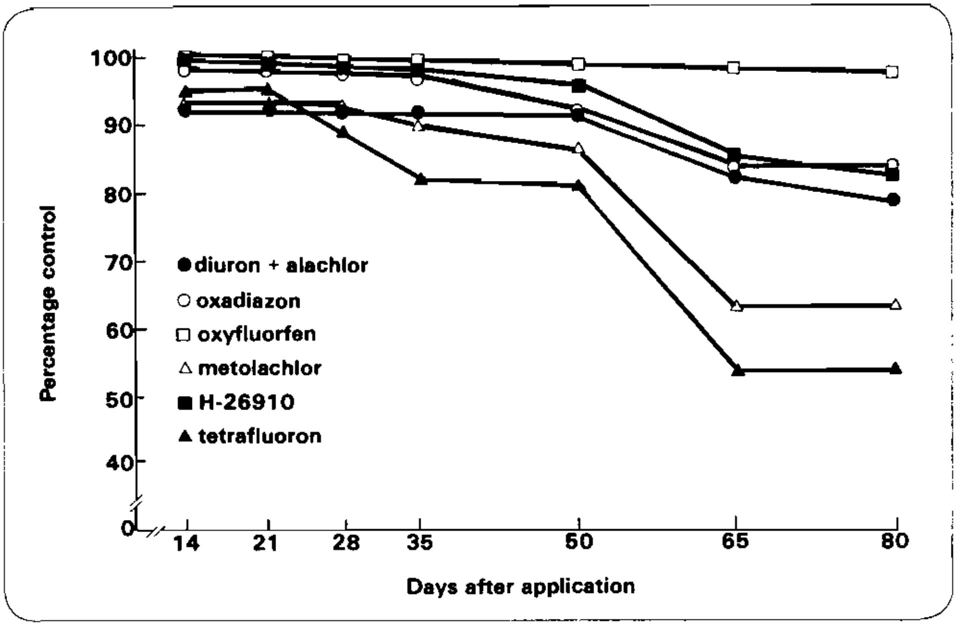


Figure 49. Narrow-leaved weed control of six pre-emergent herbicides in cassava.

continuous manual control treatment little weed growth was allowed and therefore the differences between amounts of weeds in monoculture and intercropped plots were small (Fig. 50). Weed growth two weeks before bean harvest demonstrated clearly that in the intercropping treatment a single pre-emergent application was sufficient to keep weeds at a low and economically unimportant level. In monoculture, however, a single herbicide treatment did not remain effective and weed infestation was high.

Intercropped beans not only effectively controlled weeds throughout their growth cycle, but where beans had been grown together with cassava a considerable residual depressing effect on weeds was observed 30 days or more after bean harvest (Fig. 51).

Dry bean yields increased from 2.0 t/ha with no weed control to 2.2 t/ha in the treatment with only a pre-emergent herbicide but more intensive weed control did not increase yields further. This agrees with the previous observation that in the intercropping system, one pre-emergent application was sufficient to keep weeds below an economically critical level.

Cassava yields without weed control were 44% greater when intercropped with beans than in monoculture. Yields increased in cassava monoculture as weed control was improved but remained unchanged with intercropping. With good weed control, cassava yields were 15% less in associations than in monoculture (Fig. 52). These data suggest that cultural weed control by intercropping is effective and that beans grown with cassava may have a prolonged weed-depressing effect.

Furthermore, data showed that at a low input level, greater total yields are achieved with intercropping than with monoculture. Also the yield-stabilizing effect of intercropping was clearly demonstrated. These observations undoubtedly reflect part of

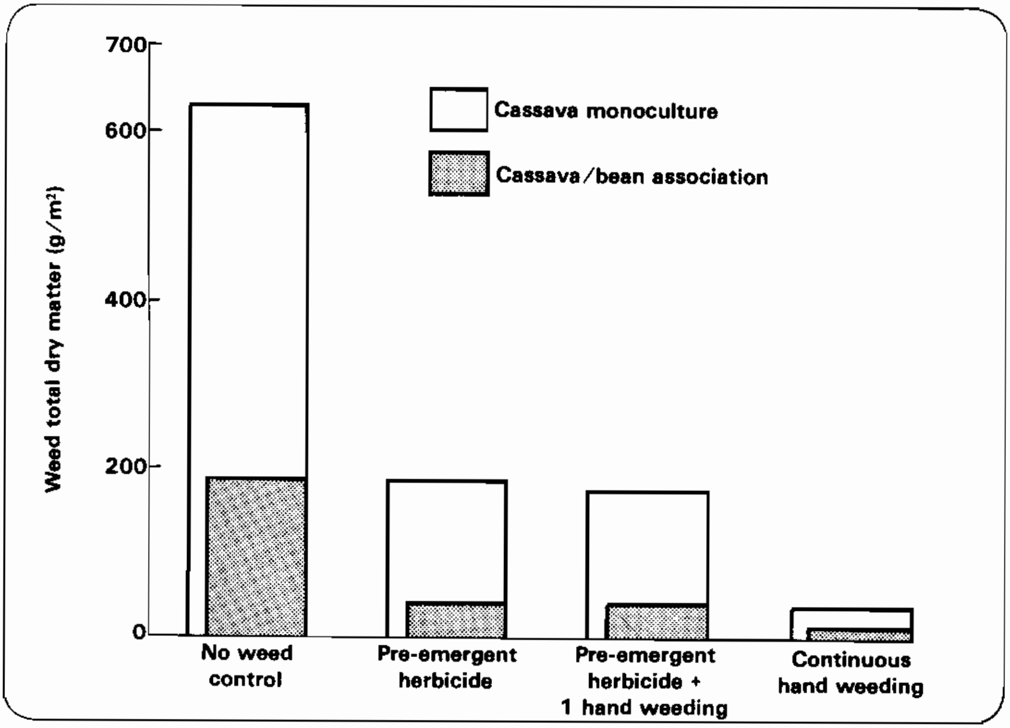


Figure 50. Weed total dry matter in two cassava cropping systems under 4 weed control systems, 45 days after planting.

the reason why small farmers may decide to adopt intercropping as a production system.

Multiple Cropping

With the advances made in defining the physiological basis of cassava/bean intercropping (CIAT Annual Report, 1976 and 1977) interest has been focused on the agronomic potential of the intercropping system. Intensification of land use by growing two bean crops with cassava in one year was attempted and an economic analysis of various intercropping options was prepared (see Economics Section). Work was begun with cassava/grain legume intercropping systems on both acid, infertile soils and under hot, humid conditions. Both are environments where the cassava/dry bean association is impractical.

Cassava/Dry Bean Intercropping

The cassava variety M Mex 11 was planted at 1.8 x 0.6-m spacing in monoculture and intercropped with beans. In intercropping treatments, the bush bean variety Porrillo Sintético was planted simultaneously with cassava and the climbing cultivar PI 313-635 was sown nine months after the cassava. The five treatments in the experiment are shown in Figure 53. The plots were fertilized by banding 30 kg N, 30 kg P_2O_5, 50 kg K_2O, 5 kg Zn and 1 kg B/ha at establishment; the same amounts were applied again when climbing beans were planted. When climbing beans germinated, the cassava plants were completely defoliated in one-half of

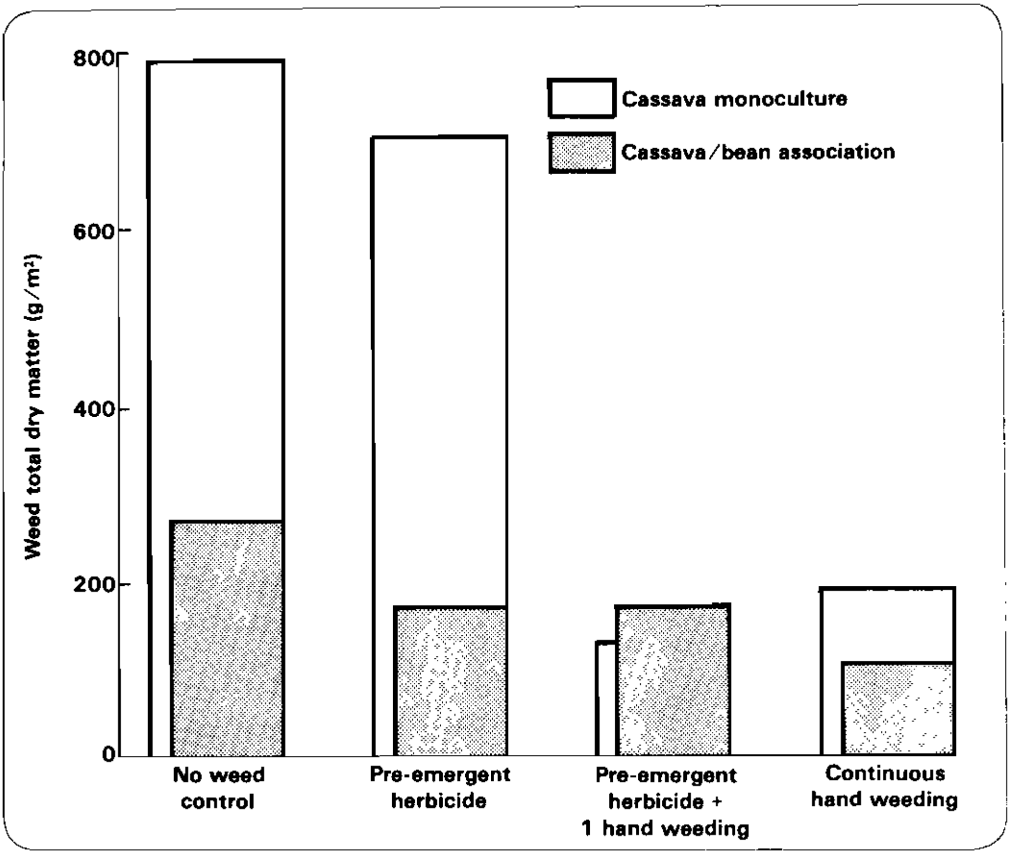


Figure 51. Weed total dry matter in two cassava cropping systems under 4 weed control systems, 135 days after planting and 30 days after bean harvest.

each plot. These same cassava plants were defoliated less intensively 34 and 68 days later..

Cassava fresh root yields were 5-10 t/ha lower in the defoliated plots than in undefoliated treatments. The effect of different cropping systems on yield was masked by the strong yield depressing influence of defoliation. Yields of undefoliated cassava reflected the normal monoculture/intercropping relation with yields from plots intercropped with bush beans being 12-18% lower than monoculture yields. When climbing beans only were intercropped, cassava yields were not reduced. Climbing bean yields were three times as high when cassava was defoliated, compared to the undefoliated treatment (Fig. 54). Yields of all systems are shown in Table 43.

Land Equivalent Ratios (LERs) — calculated from single monoculture yields of cassava and bush beans — were generally higher when cassava was defoliated. The maximum ratio of 3.04 was achieved in the intensive, three-crops-per-year system. Without defoliation yields of climbing beans were low but an LER of 2.19 was still attained by growing one crop of cassava with two bean crops (Table 43).

The results showed that intensive cassava/bean intercropping is technically

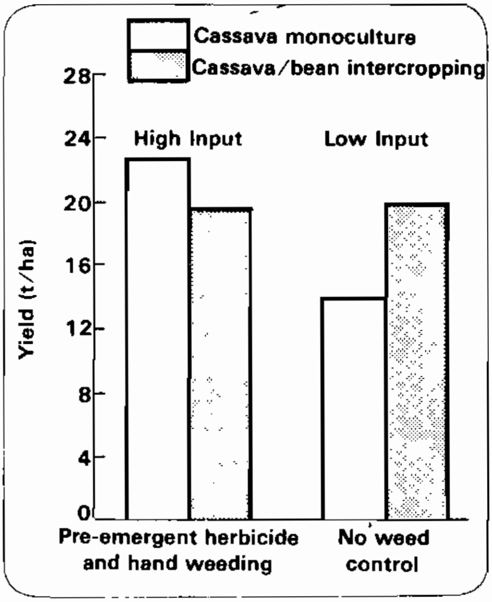


Figure 52. Effect of different weed control levels on cassava fresh root yields in two cropping systems.

feasible. The bush beans utilize light, moisture and other resources which the slow-growing cassava cannot use efficiently during early growth stages while climbing beans utilize the cassava stems for support towards the end of the cassava growth cycle.

Intercropping with Other Legumes

Cassava/dry bean associations have their well-defined area of applicability on fertile soils at intermediate elevations with mean temperatures of 18º-20ºC. However, these are not prevailing conditions in major cassava growing areas where high temperatures or poor soils, in addition to heavy disease and insect stresses, limit dry bean productivity. For these reasons, work was begun to explore the intercropping suitability and adaptation range of three other grain legumes — cowpeas (*Vigna unguiculata*), mungbeans *(Vigna radiata)* and peanuts *(Arachis hypogaea)*.

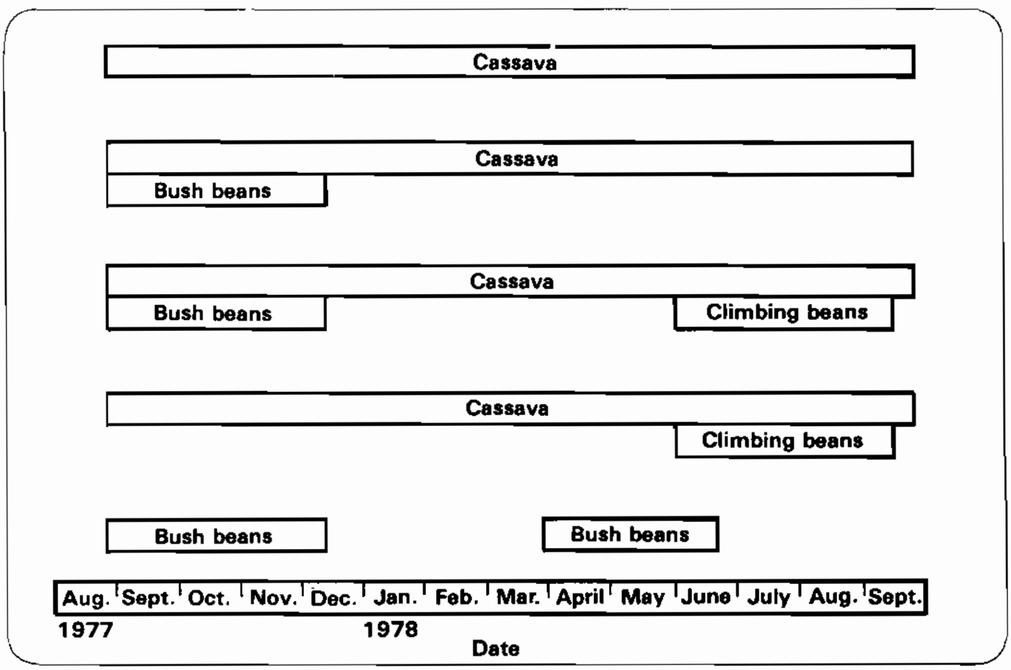


Figure 53. Chronograph of cassava/bean cropping systems trial.

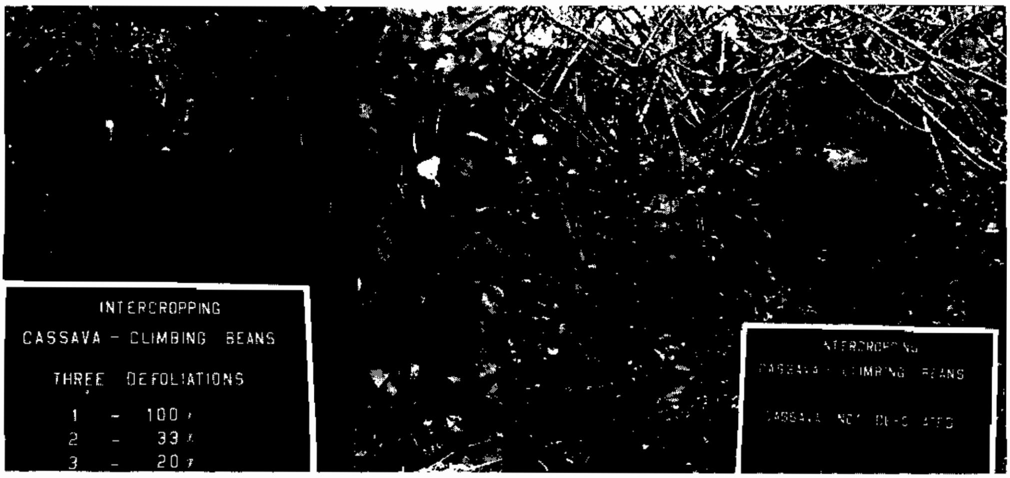


Figure 54. Effects of cassava shading on yields of climbing beans. On the left, a good 1.7-t/ha yield of beans was obtained when cassava was defoliated; on the right, in undefoliated cassava shading reduced bean yields to about 0.5 t/ha.

One cultivar of each legume species was planted in monoculture and simultaneously with cassava on the highly acid, infertile soil at CIAT-Quilichao. Plots received modest applications of amendments — 0.5 t/ha of dolomitic lime and 100 kg N, 105 kg P_2O_5, 35 kg K_2O, 3 kg Zn and 1 kg B/ha.

In monoculture, cowpeas yielded more than 2 t/ha and peanuts, almost 2 t/ha, indicating the high potential of these species under the poor soil conditions at this site. When the two were intercropped with cassava, cowpea yields dropped 9.8% and peanuts yielded 15.3% less than in monoculture. Both species can intercrop successfully with cassava without seriously depressing their yield potentials (Fig. 55). Mungbeans produced much less than the other two legumes, indicating their poorer adaptation to this environment.

Because of the poor soil conditions, crop development was expected to be much less vigorous than at CIAT-Palmira. Therefore, in addition to the standard cassava planting pattern (1.8 x 0.6 m) with legume rows 0.9 m apart, a closer spacing of 1.5 x 0.75 m for cassava, with legume rows 0.75 m apart, was planted. However, when legumes were spaced 0.9 m apart, they yielded consistently better than when closer (Table 44). Cassava is still to be harvested.

A similar trial was planted in a hot, humid climate on the Colombian North Coast. Although mungbeans showed good adaptation to these conditions with a monoculture yield of 2.3 t/ha, intercropped legume yields were disappointingly low. This could be attributed to the very vigorous growth of cassava which seriously shaded the legumes from their early development onwards. Modifying the intercropping techniques with regard to cassava genotypes, spacing and planting times appears to be necessary for achieving satisfactory results with intercropping in this environment.

Mechanical Harvesting

A commercial cassava harvester and a mechanical harvesting aid were tested on a

Table 43.

Yields of cassava and beans, Land Equivalent Ratio (LER) and Area-Time Equitalency Ratio (ATER) in various cropping systems at CIAT-Palmira.

Cropping system	Cassava fresh root (t/ha)	Bush bean yield (t/ha)[1]	Climbing bean yield (t/ha)[1]	LER[2]	ATER[3]
Cassava defoliated:					
Cassava monoculture	18.9	-	-	-	-
Cassava/bush beans	17.9	2.0	-	1.86	1.19
Cassava/bush beans/ climbing beans	19.0	2.0	1.7	3.04	1.56
Cassava/climbing beans	20.9	-	1.4	2.05	1.36
Bush bean monoculture	-	2.2	1.5[4]	-	-
CV (%)	29.8	6.2	12.7		
SD	5.7	0.129	0.198		
Cassava undefoliated:					
Cassava monoculture	28.2	-	-	-	-
Cassava/bush beans	23.0	2.0	-	1.73	1.07
Cassava/bush beans/ climbing beans	24.8	2.0	0.6	2.19	1.24
Cassava/climbing beans	31.4	-	0.5	1.45	1.20
Bush bean monoculture	-	2.2	1.5[4]	-	-
CV (%)	23.7	6.2	30.3		
SD	6.3	0.129	0.167		

1 At 14% moisture

2 Calculated on the basis of single crop yields

3 Area-Time Equitalency Ratio according to Hiebsch (1977).

$$ATER = \sum_{i=1}^{n} \frac{t_i^m}{t^I} \cdot \frac{Y_i^I}{Y_i^m} = \frac{1}{t^I} \sum_{i=1}^{n} t_i^m \frac{Y_i^I}{Y_i^m}$$

Where t_i^m = growing period of crop i in monoculture

t^I = total time of intercropping system

Y_i^I = yield (t/ha) of crop i in monoculture

Y_i^m = yield of crop i in association (t/ha)

4 Bush bean monoculture yields obtained during the period when climbing beans were grown.

friable clay-loam soil at CIAT-Quilichao. The commercial harvester, hereinafter called Lifter A (Fig. 56) was manufactured by Richter Engineering Ltd., Boonah, Australia, and the harvesting aid, Lifter B, was designed and built at CIAT.

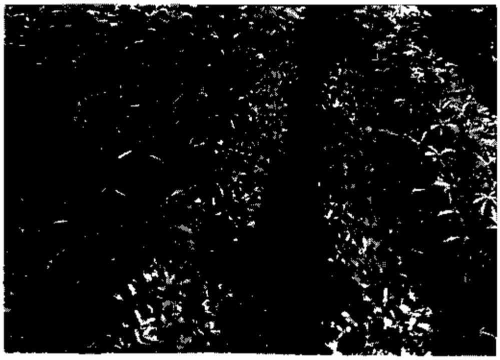


Figure 55. Cassava and peanuts growing well in association on a highly acid, infertile soil at CIAT-Quilichao.

General Performance

To evaluate the harvesters, the variety Chiroza, which is difficult to harvest manually, was planted in beds, ridges and level in 1-m rows and at different intra-row spacings to vary populations from 5000-20,000 plants/ha. In addition the two lifters were tested in level plantings of M Col 22, a variety with short, conical roots in compact arrangement, of CMC 84, with intermediate size roots, and of M Mex 11, with long, spreading roots. All aerial plant parts were removed by hand before harvest.

Performance Compared to Manual Harvesting

Lifter A left roots fully exposed on the top of the row and partially loosened the adhering soil. Lifter B did not fully expose roots in the row (Fig. 57).

Root losses were greatest with manual harvesting and least with Lifter B. Lifter A, which left almost as many roots (leavings) as the manual system, also produced the most broken roots. Lifter B penetrated the soil more deeply and loosened it more throughly than was possible with Lifter A or manually. Also the one-row design of Lifter A, with its narrow working width of 0.81 m, allowed for potential root losses on both sides of the row. Lifter B, with a

Table 44.

Yields of three grain legumes grown in monoculture and intercropped with cassava on an acid, infertile soil at CIAT-Quilichao.

Legume and variety	Cassava spacing (m)	Legume row spacing (m)	Monoculture yield (kg/ha)[1]	Intercropped yield (kg/ha)[1]
Cowpea				
(TVN 201-1D)	1.8 x 0.60	0.90	2156	1945
	1.5 x 0.75	0.75	1943	1775
Mungbean				
(1380 Mg 50-10A)	1.8 x 0.60	0.90	632	363
	1.5 x 0.75	0.75	374	125
Peanut				
(ICA Tatui 76)	1.8 x 0.60	0.90	1822	1543
	1.5 x 0.75	0.75	1420	1213

1 At 14% moisture.

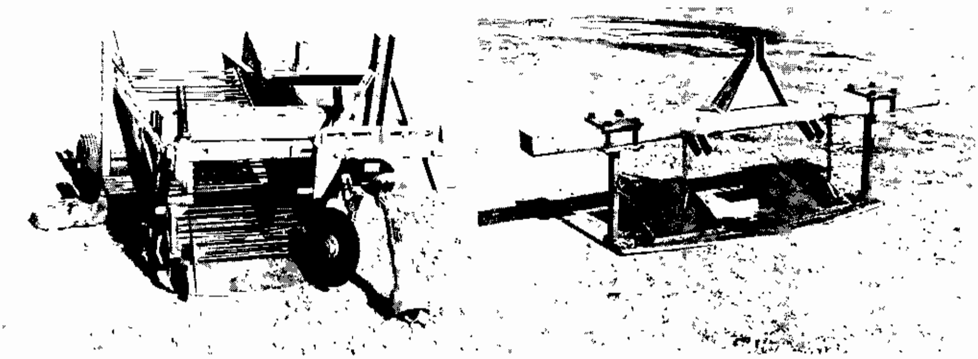


Figure 56. Two cassava harvesting devices tested at CIAT-Quilichao during 1978. On the left, a commercial unit (Lifter A) and on the right, a device designed and constructed at CIAT (Lifter B).

Figure 57. Field performance of two cassava harvesters at CIAT-Quilichao. The two rows on the left were harvested with Lifter A while the double row on the right was harvested with Lifter B.

working width of 1.92 m, harvested two rows at a time and, consequently, losses only occurred from one side of a row in each pass. This satisfactorily explains the relatively greater amount of root loss and breaking observed with Lifter A. Losses of manually harvested roots showed that without loosening the soil before harvesting, more roots were left in the ground. Occurrences of cut roots and skinning were low and apparently not influenced by any system (Table 45).

Influences of Planting System

Comparing planting systems and densities, leavings — with one exception — tended to be greatest in low-density, ridge plantings and smallest in high-density, level-planted cassava. For soil conditions at CIAT-Quilichao, level-planted cassava had the most evenly distributed root system with uniform roots expanding horizontally in all directions. Ridge-planted cassava, on the other hand, rooted more deeply, producing big, long roots along the ridges, particularly at low densities. This probably explains the greater losses in this system.

Breaking increased with total root number at higher densities but was not clearly influenced by planting systems. Planting systems and densities also did not appear to influence cutting or skinning (Tables 46 and 47).

Varietal Differences

Varieties and harvest systems affected both the amount of leavings and root damage (Table 48). With the difficult-to-harvest M Mex 11, losses from leavings were two to three times higher with manual harvesting than with mechanical systems. This agrees with results from the first trials where variety Chiroza, also difficult to harvest, showed the greatest amount of leavings when harvested manually.

On the other hand, with the intermediate and easy-to-harvest varieties, losses were low with manual harvesting but somewhat greater in the mechanical systems. Amounts of broken roots were surprisingly high in the short-rooted M Col 22, with M Mex 11 in second place. Consistency of the root tissue rather than root size appeared to influence the amount of broken roots in this trial. With one exception, no root cutting was observed. M Mex 11 appeared most susceptible to skinning while M Col 22 was almost never affected.

Table 45.

Performance of two mechanical devices and the manual system for harvesting the cassava variety Chiroza, at CIAT-Quilichao.[1]

Harvesting system	Leavings (t/ha)	Broken roots (%)	Cut roots (%)	Skinning scale (0-10)[2]
Manual	1.62	1.9	0.0	0.0
Lifter A	1.55	17.0	0.5	1.5
Lifter B	0.23	3.3	0.1	1.0

1 Cassava harvested 11 months after planting; fresh root yield of 31 t/ha; values are means of three planting systems and three densities.

2 Visual assessment on a 0-10 scale: 0 = no skinning; 10 = one-half or more of root surface damaged.

Table 46.

Effects of three planting systems with the cassava variety Chiroza on the performance of two mechanical lifting devices, at CIAT-Quilichao.[1]

Planting system	Leavings (t/ha)	Broken roots (%)	Cut roots (%)	Skinning rate (0-10)[2]
Lifter A:				
Ridged	2.1	16.8	1.5	2
Bedded	1.4	19.5	0.0	1
Level	1.2	17.7	0.0	1
Lifter B:				
Ridged	0.5	4.1	0.3	1
Bedded	0.2	2.7	0.0	1
Level	0.0	3.1	0.0	1

1 Cassava harvested 11 months after planting; fresh root yield of 31 t/ha; values are means of 10,000, 15,000 and 20,000 plants/ha densities.
2 See footnote 2, Table 45.

Work Efficiency

Net working rate of Lifter A was calculated to be about 0.2 ha/hour while Lifter B harvested 0.5 ha/hour.

Labor requirements for various stages of the harvesting operation were analyzed with and without the lifters. Cutting of stems required 25 man-hours/ha (9%) and manual lifting of roots took 44 man-

Table 47.

Effects of planting densities of the cassava variety Chiroza on the performance of two mechanical lifting devices, at CIAT-Quilichao.[1]

Density (plants/ha)	Leavings (t/ha)	Broken roots (%)	Cut roots (%)	Skinning rate (0-10)[2]
Lifter A:				
10,000	1.3	14.9	0.9	1.7
15,000	2.1	19.3	0.3	1.3
20,000	1.2	20.0	0.2	1.0
Lifter B:				
10,000	0.6	2.1	0.3	1.0
15,000	0.0	1.2	0.0	1.0
20,000	0.1	6.6	0.0	1.0

1 Cassava harvested 11 months after planting; fresh root yield of 31 t/ha; values are means of three planting systems.
2 See footnote 2, Table 45.

Table 48.

Harvest evaluations of three cassava varieties when harvested manually or with mechanical systems, at CIAT-Quilichao.[1]

Variety	Harvest system	Fresh root yield (t/ha)	Leavings (t/ha)	Broken roots (%)	Cut roots (%)	Skinning rate (0-10)[2]
M Mex 11	manual		1.03	1.5	0.0	0
	Lifter A	19.0	0.58	7.6	0.0	5
	Lifter B		0.37	2.4	0.0	2
CMC 84	manual		0.28	0.9	0.0	1
	Lifter A	20.9	0.68	6.9	0.0	3
	Lifter B		0.58	2.0	0.0	0
M Col 22	manual		0.29	0.4	0.0	0
	Lifter A	15.6	0.42	6.2	0.0	1
	Lifter B		0.44	11.2	2.0	0

1 Values are means from plot densities of 5000, 10,000 and 20,000 plants/ha.
2 See footnote 2, Table 45.

hours/ha (16%). The remaining 75% of the time (204 hours) was used to separate roots from stems, collect the crop and sort and package roots. When roots were lifted by machine, this portion of total time was saved and harvest efficiency increased 20%. These data agree well with observations during commercial manual harvesting in the Caicedonia area, where eight men harvest six tons of fresh roots in about seven hours, an efficiency of 0.85 t/man-day (eight hours).

Agronomic and Socio-economic Implications

Both machines operated easily under a wide range of crop conditions and both efficiently lifted the cassava crop. Under most conditions, leavings from mechanized lifting were less than those from manual harvesting. Although both implements work on the principle of passing a share or blade beneath the roots, no significant direct cutting damage occurred. The overall breaking and skinning damage with Lifter B was low and comparable to that of manual harvesting. Damage must be kept low in cassava for the fresh market or when roots are to be stored. Root damage was greater with Lifter A but for industrial processing of roots, this would not matter.

Harvesting cassava for fresh consumption implies a number of activities which cannot easily be mechanized if root damage is to be avoided. Therefore, labor requirements remain high. Even if stems are cut and roots lifted by machine, these two operations together would only save 25% of the total man-hours required. Therefore, workers are not displaced from jobs but using machines would relieve them of the most physical part of the work.

The working characteristics of Lifter B together with its low cost favor its use in an integrated manual/mechanical harvesting system which could be adopted even on small farms where cassava is produced mainly for fresh consumption.

On the other hand, Lifter A provides

possibilities for fully mechanizing the cassava harvesting process. A collecting device could be coupled to the lifter and a forage cutter used to remove stems prior to lifting the roots. This system appears to have potential were large-scale cassava production for industrial processing is practiced.

SOILS AND PLANT NUTRITION

High levels of Al and low levels of P in the soil appear to be the main limiting factors for cassava production on the vast, acid, infertile Oxisols and Ultisols of Latin America. The Soils and Plant Nutrition Section concentrated much of its work during 1978 on seeking to identify cultivars that tolerate these two adverse factors.

A field screening methodology was tested to evaluate materials for tolerance to soil acidity and low levels of P. In tests to find the external P requirement of cassava, the level of 0.025 ppm P in soil solution was determined to be the critical level for the crop. Experiments were also conducted to study lime/P and N/P interactions in field plantings.

Limited work was done with several cover crops to evaluate their effects on cassava yields when used to prevent erosion and for weed control. Reduced yields of cassava were generally observed when cover crops were grown, although benefits from erosion prevention, weed control and establishment of a forage crop would probably offset any reductions in cassava yields.

Screening in Nutrient Solutions

High-aluminum, Low-phosphorus Tolerance

Attempts to simultaneously screen cultivars in nutrient solutions for high levels of Al and low levels of P were unsuccessful because of the difficulty of maintaining stable Al and P concentrations in solution at a pH that the plant will tolerate. Only at pH 3.5 could the Al and P be kept from precipitating, but plant growth at that pH was very stunted and root rot problems were frequent. A preliminary trial showed that plant growth in culture solution increased markedly as pH increased from 3 to 5 and P concentration increased from 0 to 16 ppm (Fig. 58).

Rather high levels of P and Al are needed to screen varieties for tolerance to high Al and low P and these two conditions can only be combined at extremely low pH levels not normally found in the field. Thus it appears that screenings for Al and P tolerance in nutrient solutions have to be done separately if the pH is to be at a level where near-normal plant growth can be obtained.

Field Screening

Low-phosphorus Tolerance

Thirty cultivars were planted in CIAT-Quilichao at two levels of applied P, 0 and 200 kg P_2O_5/ha, to evaluate their tolerance to low levels of P. Plant height was measured at 3.5 months and final root yield recorded at 12 months to determine whether tolerance to low P could be evaluated from plant height or as total plant growth at 5.5 months, instead of waiting one year to measure root production. Unfortunately, 13 of the 30 cultivars were seriously affected by frog skin disease,

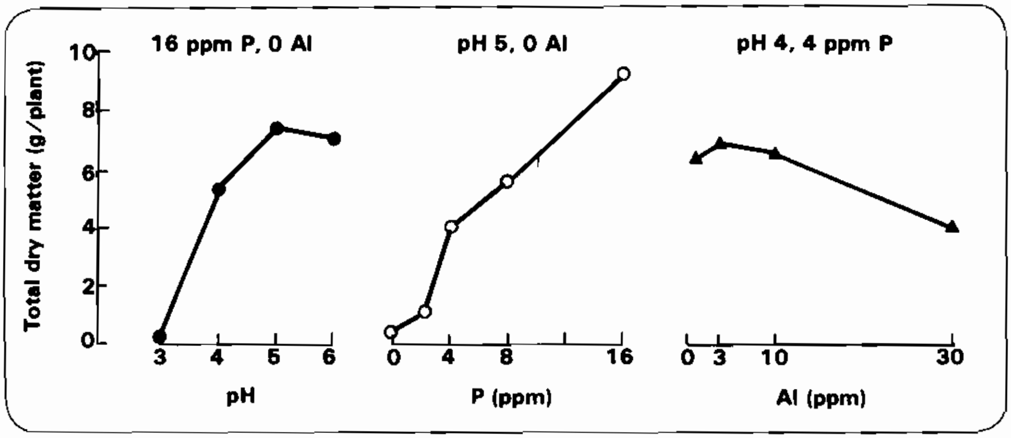


Figure 58. Effects of P and Al concentrations and pH in nutrient solution on total dry matter production of cassava plants at 35 days after treatments were established.

a problem that is only apparent at harvest. Among the remaining 17 cultivars, the P-tolerance index at 5.5 months was best correlated (r = 0.48) with the index obtained at 12 months, but the correlation was not significant. This tolerance index was calculated as follows:

$$\frac{\text{Yield at 0 P}}{\text{Yield at 200 kg } P_2O_5} \quad X$$

$$\frac{\text{Yield at 0 P}}{\text{Highest yield at 0 P}} \text{ X } 100\%$$

Correlation was much less between P tolerance determined from plant height:

$$\frac{\text{Plant height at 0 P}}{\text{Plant height at 200 kg } P_2O_5}$$

than with that determined from root yield.

The highest yielding cultivars were M Col 131, M Col 308 and M Col 676, whose single row yields were equivalent to about 50 t/ha. Cultivars with the highest P-tolerance index were M Col 458 and M Col 260.

External Phosphorus Requirements of Cassava

The external P requirement of cassava was determined by planting the cultivar Llanera at CIAT-Quilichao in plots where P (broadcast triple superphosphate) was applied at 11 rates from 0 to 2590 kg P_2O_5/ha. These rates corresponded to P concentrations in the soil solution ranging from 0.001 to 0.2 ppm, as determined from P-sorbtion isotherms. All plots were uniformly fertilized with 500 kg lime, 100 kg N, 100 kg K_2O and 10 kg Zn/ha.

Figure 59 shows the response to P in terms of root and foliage production and harvest index. Root yields increased from 26.0 to 47.6 t/ha by P application but were rather variable at the high-P levels. Foliage production increased more markedly than root yield, causing a decrease in harvest index from 0.79 to 0.66 due to P application.

Figure 60 shows the relation between root yield and the P concentration in soil solution. The external P requirement, equal to 95% of maximum yield, was estimated as between 0.015 and 0.025 ppm

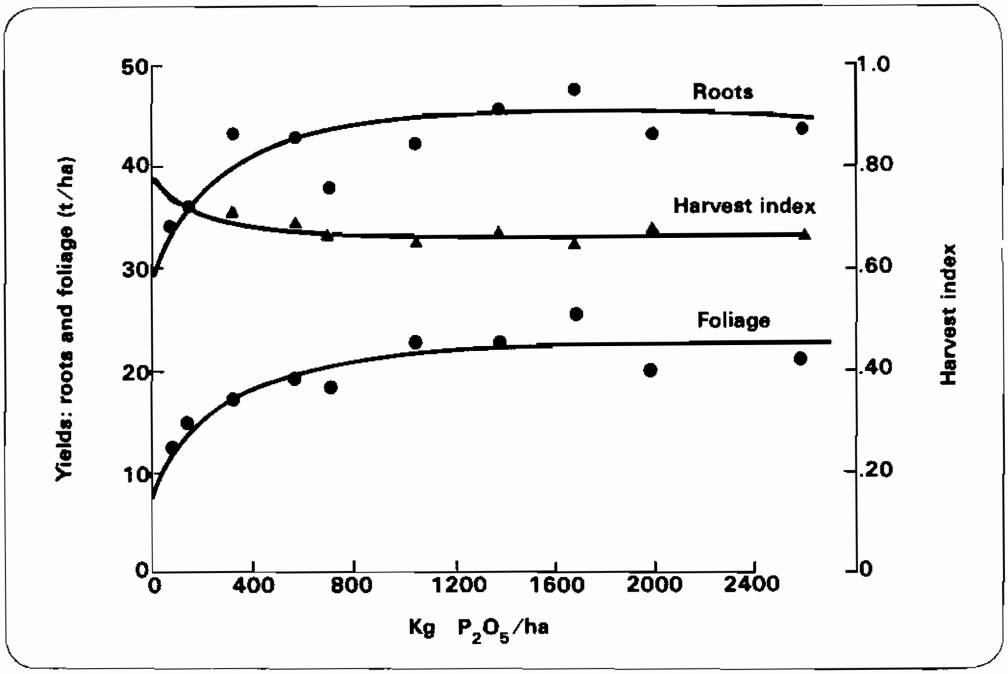


Figure 59. The effect of P application on yield of cassava roots (fresh basis) and foliage and on harvest index, at CIAT-Quilichao.

P in the soil solution. This corresponds to values obtained with cassava in Hawaii, Malaysia and Nigeria ranging from 0.006 to 0.04 ppm P. Thus the external P requirement of cassava appears much lower than that of other crops such as maize (0.06 ppm), beans (0.06 ppm) or potato (0.20 ppm). This relatively low P requirement in soil contrasts sharply to a very high P requirement in nutrient solution.

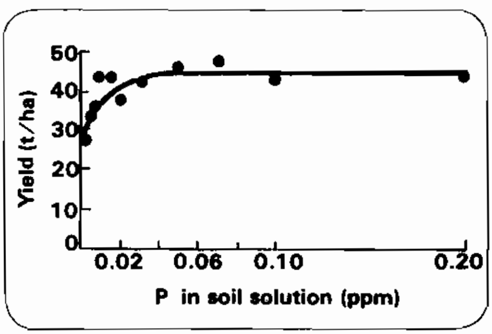


Figure 60. Relationship between cassava fresh root yields and P concentration in the soil solution for variety Llanera, at CIAT-Quilichao.

Lime/Phosphorus Interactions

Under the extremely acid (pH 4.4), low-P (2 ppm P, Bray II) soil conditions of CIAT-Quilichao, most crops respond dramatically to applications of both lime and P. To determine the response to and the interaction between lime and P by cassava, a systematic design experiment was planted in which P levels increased from 0 to 380 kg P_2O_5/ha in 20-kg increments, from row to row in one direction. Lime levels were increased along the perpendicular axis from 0 to 3600 kg/ha in increments of 200 kg. Lime was broadcast and incorporated and the P was banded along the stakes. In this design each plant is a different treatment

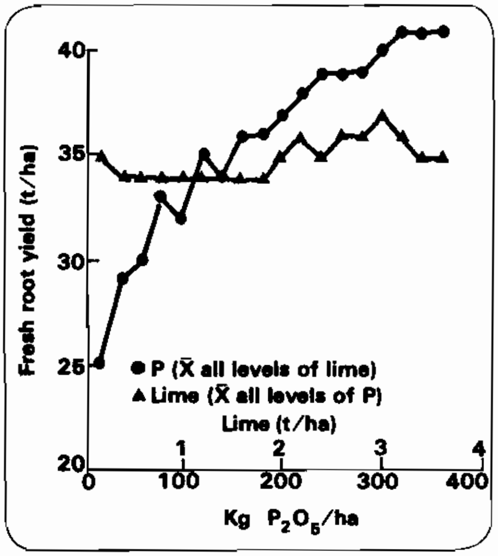


Figure 61. Average response of cassava variety Llanera to applications of lime and P, at CIAT-Quilichao.

representing a specific combination of P and lime. The trial had 324 treatments in an 18 x 18 matrix and four replications. Plants were harvested individually and yields of roots and tops were recorded.

Soil pH in the treatments increased linearly from 4.1 to 5.1 and Al decreased from 3.8 to 0.5 meq/100 g as lime levels increased. Yields increased from 19 to 45 t/ha from applying 300 kg P_2O_5/ha and 3.6 t/ha lime. Figure 61, showing the average response to P and lime, indicates that the main response was to P, with only a minor response to lime. Maximum yields both without or with lime were obtained with 300-400 kg P_2O_5/ha. This corroborates previous findings in Carimagua (Fig. 62) that on the average cassava will tolerate an Al saturation of about 80%, and Ca levels of 0.025 meq/100 g that in this case resulted in a pH of 4.7. On the CIAT-Quilichao soil (pH 4.4, 82% Al saturation and 0.48 meq Ca/100 g) cassava yields were thus not affected by either high Al or low Ca, and no significant lime response was obtained. This extreme tolerance to acid soil conditions makes cassava a very useful food crop for the extensive acid Oxisols and Ultisols of Latin America. In these soils the main limiting element would be P with minor responses to be expected to N, K and Zn (Fig. 63).

Figure 64 shows that the harvest index decreased consistently with applications of both P and lime, indicating that both materials stimulated top growth more than root growth.

Nitrogen/Potassium Interactions

A systematic design experiment similar

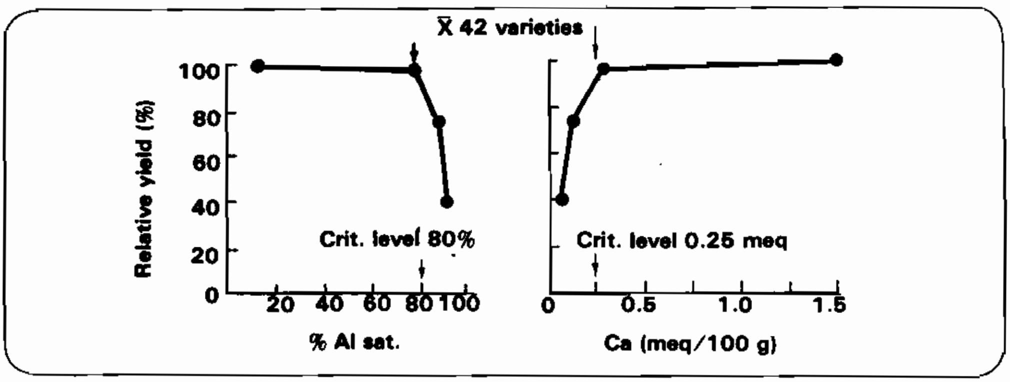


Figure 62. Relationship between the relative yield of cassava (avg. 42 varieties) and percentage Al saturation and Ca content.

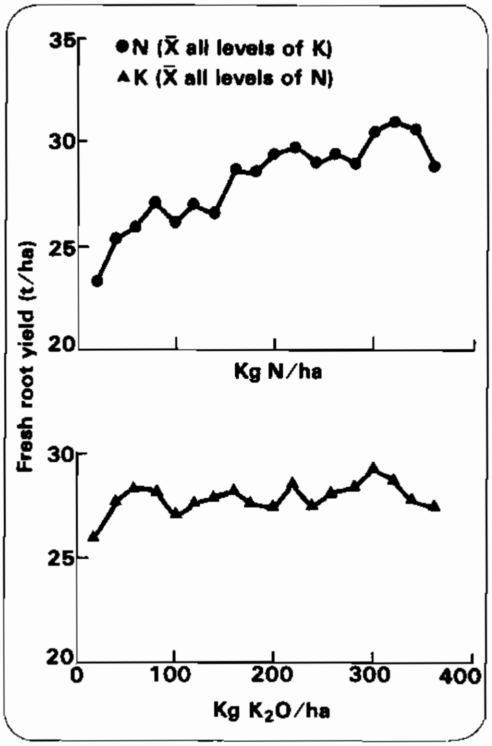


Figure 63. Average response of cassava variety Llanera to applications of N and K, at CIAT-Quilichao.

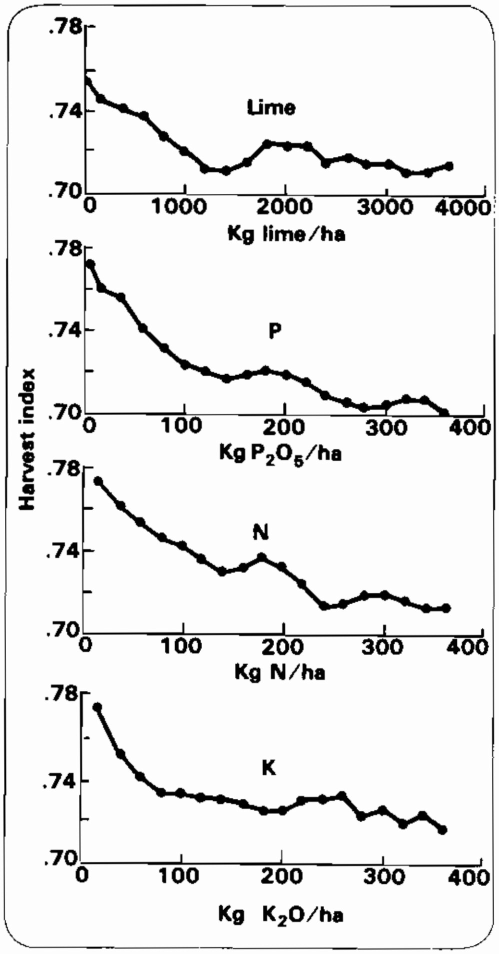


Figure 64. Effects of lime, P, N and K applications on harvest index of cassava variety Llanera, at CIAT-Quilichao.

to the one described above was planted to test the interaction of N and K. Nitrogen levels increased from 0 to 380 kg N/ha and K levels also increased from 0 to 380 kg K_2O/ha, in increments of 20 kg of each fertilizer. Both materials were banded at planting and the cultivar Llanera was seeded.

Yields increased from 22 to 34 t/ha with applications of 360 kg N and 360 kg K_2O/ha. Response to K was only minor (Fig. 63) but plants responded significantly to about 300 kg N/ha with a slightly negative response at higher rates. The rather large N response is surprising in a soil with 6.8% organic matter, but shows the very low contribution organic matter makes to satisfying the plant's N requirement. The virgin soil had a K content of 0.15 meq/100 g and no response to K would be expected. However, due to the large K removal by cassava roots (about 100 kg K_2O/25 t fresh roots), soils may become depleted in K after several croppings and some response to K applications would be expected after several crops.

Harvest index decreased with increasing applications of N and K, indicating that top growth was stimulated more than root growth. This agrees with previous data from Carimagua (CIAT Annual Report, 1977) but is contrary to the belief that applications of K stimulated carbohydrate translocation from tops to roots and would hence increase the harvest index. The latter may be true under nutrient solution conditions of extreme K deficiency, but has not been observed in the field.

Based on a price of Col.$2.00/kg of roots and a cost of Col.$17.31/kg N, 27.42/kg P_2O_5 and 14.97/kg K_2O and 750/t lime, net economic returns were calculated for each combination of lime and P and of N and K. Maximum returns were obtained with 300 kg P_2O_5 combined with 3.6 t lime/ha and with 340 kg N combined with 60 kg K_2O/ha. However, the economically optimum rates would be lower if one included risk factors, interest on capital, etc.

Phosphorus/Potassium Interactions

Studies done at Media Luna, on Colombia's North Coast, included two trials using the systematic design described earlier. Rainfall distribution for the area is shown in Figure 65 and the soil analyses of the two most common soils are shown in Table 49. Levels of applied P and K increased from 0 to 300 kg P_2O_5 and K_2O/ha, in increments of 20 kg of each, applied as triple superphosphate (TSP) and KCl. Nitrogen (urea) was applied over all treatments at a rate of 100 kg N/ha. The fertilizers were banded at planting time and the variety M Mex 59 planted.

The control treatment (no P or K applied) yielded 35 t/ha. Maximum yield of 51 t/ha was obtained with 40 and 60 kg/ha of P_2O_5 and K_2O, respectively. On the average, yields of cassava grown on the dark sand soil increased most after medium and low applications of P and K, respectively. The K content of 0.12 meq/100 g in the dark sand is above the estimated critical level (about 0.10 meq/100 g) and the P content is also above the estimated critical level of 10 ppm (Bray II), consequently explaining the moderate response. Figure 66 illustrates the average response of K and P fertilization over all P and K levels, respectively.

Figure 67 shows that both K and P applications consistently decreased the harvest index, again indicating that fer-

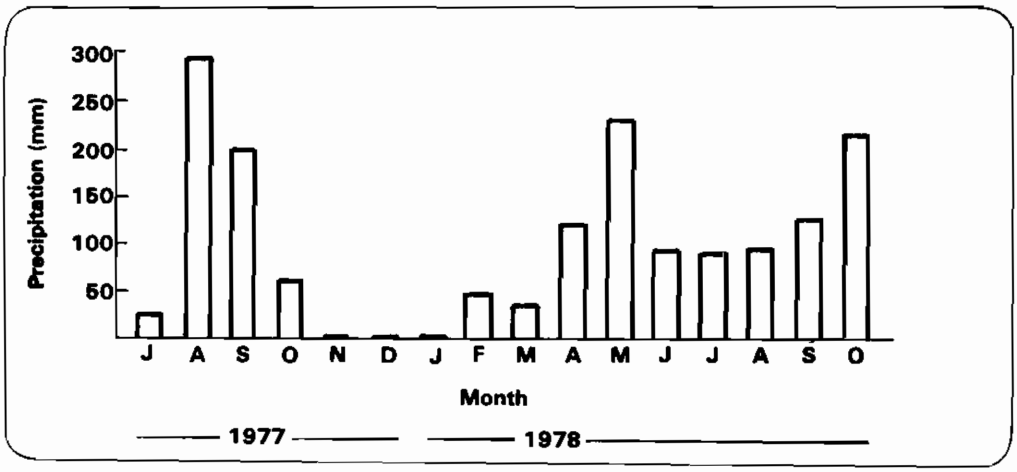


Figure 65. Cumulative rainfall at Media Luna during the cassava growing cycle (Sept.-July). (La Idea farm, altitude 10 masl, mean temp. 28°C.)

Table 49.

Chemical analyses of dark and white sand soils (coluvio-alluvial soils, series arenera) at Media Luna, Colombia.

Depth (cm)	OM (%)	P Bray II (ppm)	pH	Ca	Mg	K (meq/100 g)	Na	CEC
Dark sand soil:								
0-20	1.25	13.6	6.6	1.64	0.38	0.12	0.07	2.0
20-40	0.70	3.8	6.6	0.55	0.15	0.10	0.05	0.8
Light sand soil:								
0-20	1.05	4.0	5.8	0.62	0.18	0.05	0.05	1.1
20-40	0.75	2.2	5.6	0.38	0.11	0.05	0.04	0.7

tilization stimulated top growth more than root growth.

Figure 68 shows the negative effect of P and K fertilization on the root starch content of M Mex 59 roots.

On the white sand soil, the control treatment yielded 34 t/ha. Intermediate levels of 100-120 kg K_2O/ha produced maximum root yield increase over all levels of P and high levels of 240-280 kg P_2O_5/ha provided highest yields over all K levels (Fig. 69). A maximum yield of 59 t/ha was attained with 280 and 180 kg/ha of P_2O_5 and K_2O, respectively. This P x K fertilizer rate also produced the highest net profit of US$2728/ha, while in the dark sand soil, maximum net profit of US$2528/ha was achieved with 40 and 60 kg/ha of P_2O_5 and K_2O and a yield of 51 t/ha. Prices used were US$0.57/kg of P_2O_5, 0.70/kg of K_2O and 50/t for fresh cassava roots.

Higher yields and sound economic

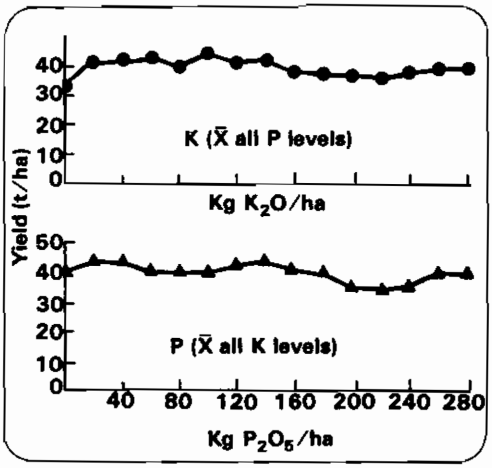


Figure 66. Effects of various levels of K and P on fresh root yield of cassava variety M Mex 59, on dark sand soil at Media Luna.

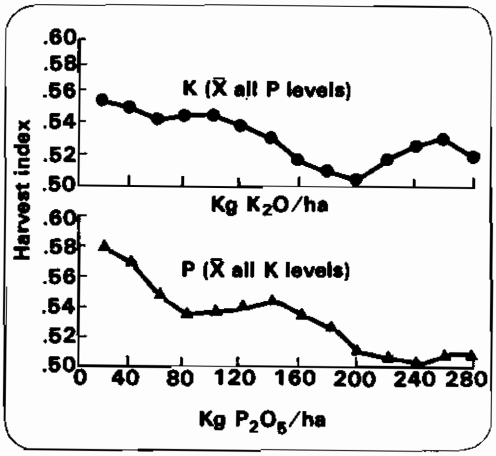


Figure 67. Effects of various levels of K and P on the harvest index of cassava variety M Mex 59, on dark sand soil at Media Luna.

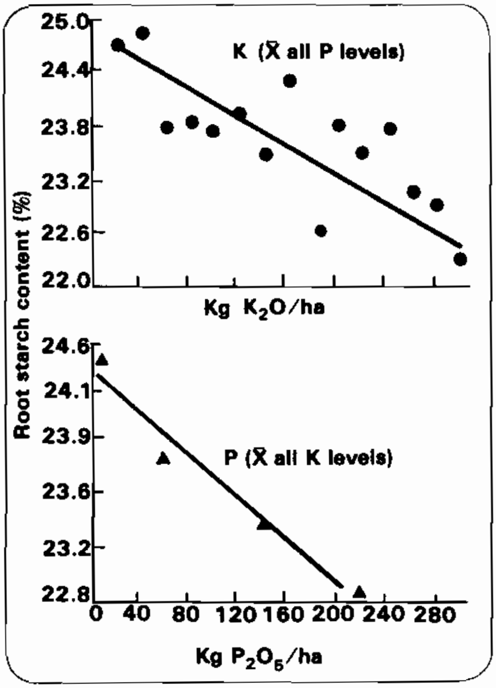


Figure 68. Effects of various levels of K and P on the root starch content of cassava variety M Mex 59, on dark sand soil at Media Luna.

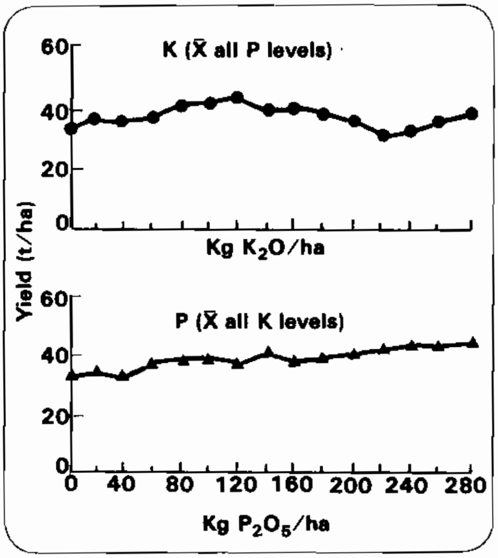


Figure 69. Effects of various levels of K and P on fresh root yields of cassava variety M Mex 59, on white sand soil at Media Luna.

responses can be produced with low levels of fertilizer on the dark sand soil while in the white sand response is found to higher levels of fertilizer.

The moderate yield response of cassava to medium levels of applied fertilizer on the dark sand soils agrees with other results reported in the Agronomy and Economics sections of this report.

Cover Crops with Cassava

Because of its wide spacing, slow initital growth and extensive soil disturbance at harvest, cassava is a crop with a high erosion index. Also, cassava is one of the few crops that will still produce on a heavily eroded soil, thus worsening a bad situation. Erosion can be reduced by protecting the soil between rows with live or dead mulches, both of which may also help reduce weed problems. In addition to erosion control, intercropping with a fast-growing grain legume can supply cash income for a farmer in 3-4 months after planting cassava while undersowing forage legumes may enable these crops to be permanently established at minimum cost. However, not all legumes are compatible with cassava; either the legume does not tolerate the acid, infertile soil conditions in which cassava is frequently grown or the legumes compete excessively for light and water.

To test compatibilities, cassava was planted with various legumes seeded simultaneously with the cassava and between the rows. At CIAT-Quilichao, highest yields were obtained without any cover crop and cassava yields declined as the competition of the cover crop increased (Fig. 70). The cover crop neither increased the N level nor decreased the P level in cassava leaves, indicating that the N contribution and nutrient competition of the legumes were minimal.

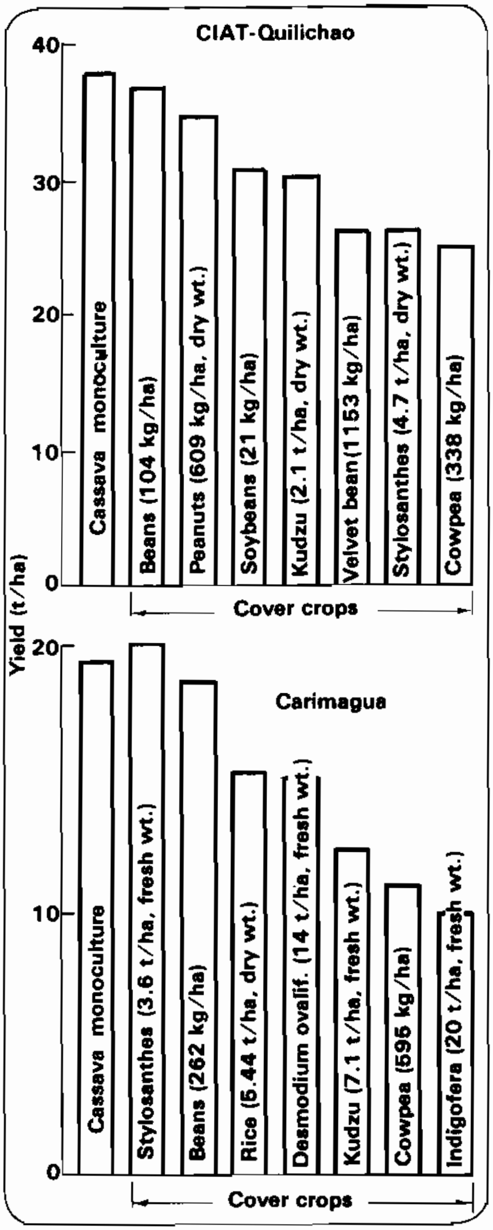


Figure 70. Effects of producing various cover crops on fresh root yields of cassava, at CIAT-Quilichao and Carimagua. (All yields of cover crops are for grain, unless otherwise indicated.)

Beans, perennial peanuts and soybeans grew poorly because of toxic levels of Al and Mn in the soil, and thus competed little with cassava. Cowpea grew very vigorously and competed for light during the critical early growth phase of cassava. Although cowpea yields were very low, the cassava never recuperated from this early competition. Kudzu *(Pueraria phaseoloides)* and velvetbean *(Stizolobium deeringianum)* grew vigorously, climbing above the cassava canopy and competing seriously for light, but at a later and less critical stage than did cowpea. *Stylosanthes guyanensis* reduced cassava yields because of its strong competition for water during the dry season. During this period it caused complete defoliation and grew even taller than the cassava.

Under the different climatic conditions of Carimagua (Fig. 70) cassava yields were not affected by *Stylosanthes* which grew poorly because of disease problems and lack of vigor. Beans produced slightly better than in CIAT-Quilichao but still did not compete seriously with cassava. *Desmodium ovalifolium* produced a dense but low soil cover, ideal for controlling erosion and did not compete much with cassava until the latter began to lose its leaves at the end of the growth period. Kudzu, cowpea and especially the extremely vigorous *Indigofera* competed excessively with cassava, reducing yields to 50-60% of normal.

It would appear that cassava seldom benefits directly from the presence of the cover crop; however, the benefits of the cover crop for erosion and weed control and establishment of a cash or pasture crop could compensate for reduced cassava yields. *D. ovalifolium* combines the favorable characteristics of easy establishment, good ground cover and minimal competition with cassava.

Maximum Yield Trial

To determine the yield potential of

cassava in Carimagua when nutritional and water restraints were eliminated, eight highly promising cultivars and hybrids were planted in a soil having considerable residual effects of previous fertilizations. Two t/ha of lime were applied and plants were fertilized with 1 t/ha of 10-20-20 and 20 kg Zn/ha, banded at planting. These fertilization rates were considered agronomically optimum, if not excessive. The effect of water stress was determined by supplying bi-weekly irrigation in the furrows to one-half the plots during the four-month dry season when rainfall was very low. Irrigation during the dry season resulted in taller plants with much better leaf retention compared with non-irrigated plants. However, these differences disappeared soon after the onset of the rainy season. At that time some varieties became infected with cassava bacterial blight (CBB) and others suffered from severe superelongation disease (Table 50). Only M Col 638 and CM 309-41 remained reasonably free of diseases and retained much of their foliage throughout the growth cycle. In contrast, CM 308-197 was seriously affected by CBB.

The root yield data, shown in Table 50, indicate that disease-tolerant varieties were not necessarily high-yielding, and vice versa. Also, the heavy fertilization rates produced very vigorous-looking plants, but with rather low root yields and low harvest indices. Under these conditions, less vigorous varieties such as M Col 1684 and CM 308-197 had the highest harvest indices and highest yields, while the more vigorous varieties such as M Mex 59, Llanera and M Col 638 were probably over-fertilized and produced excessive top but little root growth. A similar effect was observed in the regional trials at CIAT-Quilichao (Table 32, Agronomy Section) in which M Col 1684 yielded twice as much as M Mex 59 when fertilized, but was outyielded by this vigorous variety when not fertilized.

Although dry season irrigation slightly increased yields in most varieties, it decreased the yield of CM 308-197, and had no significant overall effect. Thus, under the climatic conditions of Carimagua, water stress during the four-month dry season did not appear to significantly restrain cassava production.

Table 50.

Fresh root yields and harvest indices of eight cassava cultivars grown in Carimagua with and without supplemental irrigation during the dry season.

Cultivar	Apparent reaction to:[1] cassava bacterial blight	Apparent reaction to:[1] super-elongation	Fresh root yields (t/ha) with irrig.	Fresh root yields (t/ha) without irrig.	Harvest idex with irrig.	Harvest idex without irrig.
M Col 1684	M	M	36.5	33.8	0.64	0.62
CM 308-197	S	S	27.8	31.3	0.71	0.73
M Ven 168	-	-	27.0	25.4	0.60	0.59
CM 309-41	M	S	24.0	23.1	0.55	0.54
M Pan 114	S	-	23.0	17.9	0.54	0.49
M Mex 59	S	S	22.6	20.3	0.56	0.49
M Col 638	M	M	17.1	18.3	0.45	0.45
Llanera	M	M	15.1	14.8	0.44	0.42

1 Reactions: S = susceptible; M = moderately resistant; R = resistant.

ECONOMICS

The 1974 to 1976 CIAT Annual Reports presented results of an agro-economic survey of cassava cultivation in Colombia. The objective of this study was to define and measure the factors constraining yields of cassava in Colombia. Results served as bases for establishing program research objectives. In 1977, the Economics Section moved to the second phase of assisting the technology development process by establishing on-farm trials in which different technological packages developed at CIAT would be evaluated under actual farm conditions, before their release to national institutions. Objectives of these trials are threefold: (1) to measure the productivity of improved cassava production technology under actual farm conditions; (2) to define factors limiting cassava yields that may have been overlooked in designing technology at the research station (i.e. adaptive, site-specific research); and, (3) to provide a preliminary assessment of potential constraints to adoption of the new technology.

Farm Trial Site

The first on-farm trial area for testing and evaluating CIAT cassava technology was established on the North Coast of Colombia, in the village of Media Luna. This coastal zone accounts for 33% of Colombia's cassava production. In terms of agro-climatic potential, the area is broadly representative of a large portion of Latin American cassava producing zones, including coastal areas of Colombia and Ecuador and northeastern Brazil. Finally, the area is reflective of small-farm production systems, the principal source of cassava production in Latin America.

Existing Systems

Details of the farming systems are summarized in Table 51 and Figure 71. The overall system typifies small-scale agriculture in the coastal zone. Cassava, maize, and sesame are the principal crops. Cassava is the most important crop for both on-farm consumption and cash income. The soils of the area are sandy and very low in both K and P. The low moisture retention capacity of the soil, a high evapotranspiration rate and a five-month dry season combine to make lack of moisture a major constraint on plant growth. Soil and climatic factors severely limit the variety of potential crops to those mentioned, and cowpeas. This feature is indicative of cassava growing areas in that they are usually in the more marginal zones.

The cropping pattern and, in turn, labor utilization is largely defined by the rainfall distribution (Fig. 71). The primary planting season is in April-June at the beginning of the rains when cassava and maize are planted in association. The peak for labor demand is in this period, as planting and the first two weedings overlap. Ground is prepared by hired tractor services. A second planting period follows in the August-September period, when the farmer usually plants sesame and occasionally cassava, if he has not done so earlier. This system provides employment in what would be a slack season before the cassava harvest begins in January. In the 1977-78 season the harvest period was longer than normal due to market uncertainties and limited access to the fresh food market. Farmers have a flexibility of four months in choosing when they harvest.

Table 51.

Production systems, yields and net income on nine farms in the Media Luna, Colombia area.

Farm	Size	Production system crops principal/secondary	Area (ha)	Yields principal/secondary[1] (kg/ha)	Net income from crops (Col. pesos)
1	3.7	cassava/maize	3.7	8700/177	[2]
2	10.1	cassava/maize	2.0	8350/-	19,130
		fallow	7.1		
3	4.2	cassava/maize	3.5	6598/-	46,175
		fallow	0.7		
4	2.9	cassava/maize	0.6	8000/-	16,399
		sesame	1.5	750	
		fallow	0.8		
5	12.0[3]	cassava/maize	6.9	4300/-	[2]
		cassava/sesame	4.0	5028/377	
		sesame	0.5	700	
		fallow	0.6		
6	5.8	cassava/maize	1.6	9185/-	42,028
		cassava/sesame	2.0	4550/150	
		fallow	2.2		
7	4.9	cassava/maize	4.4	6672/-	[2]
		cassava/cowpea	0.1	5180/217	
		fallow	0.4		
8	3.2	cassava/maize	0.4		
		cassava/sesame	2.1	5120/309	27,032
		sesame	0.3	200	
		fallow	0.4		
9	3.8	cassava/maize	2.8	8934/-	36,100
		cassava/sesame	1.0	5230/413	
Avg.	5.6	cassava/maize	2.8	7340/177	36,106
		cassava/sesame	1.0	5120/283	
		sesame	0.3	678	

1 In all but one case maize had already been harvested by the beginning of the survey and was therefore not observed.
2 All the cassava had not been harvested.
3 Includes 4.0 ha sown with another farmer.

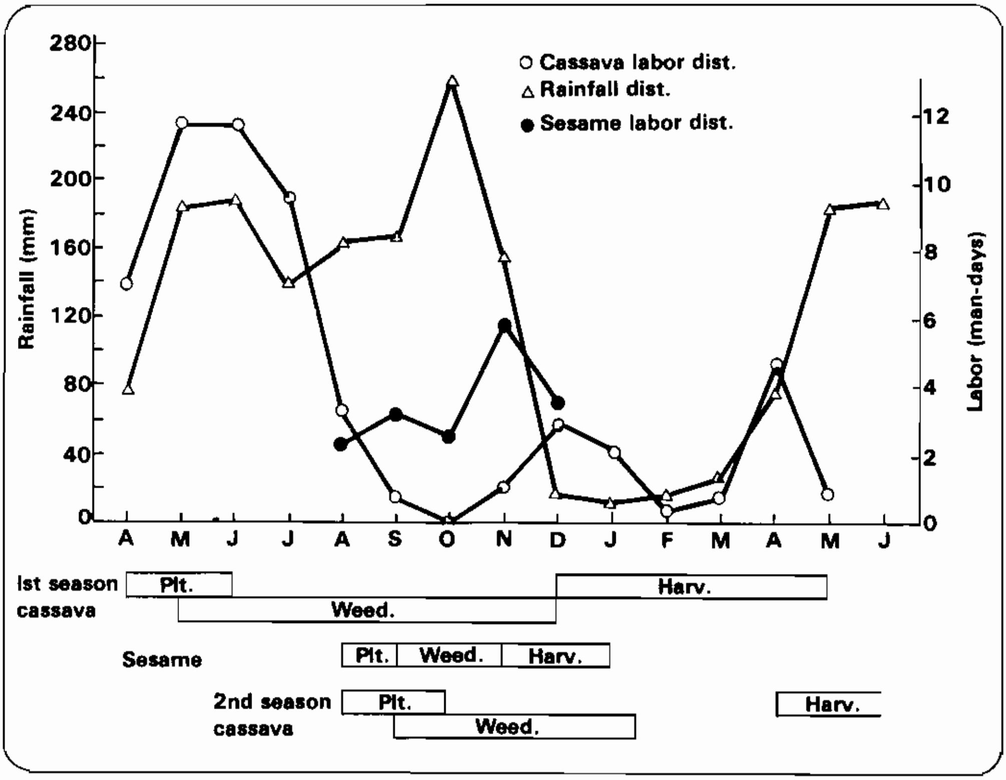


Figure 71. Rainfall pattern, labor requirements and cropping activity distribution throughout the growing season for the Media Luna region.

However, where farm size is four ha or less, due to the limited land farmers will harvest before the next planting season no matter what prices are expected.

Average yield of cassava over all systems was 6.7 t/ha. Yields were significantly lower when grown with sesame, averaging only 5.1 t/ha compared to 7.3 t/ha when grown with maize. Also, yields were much lower when sown in the August-September period and averaged 4.8 t/ha. The local variety, Secundina, yielded as high as 9.2 t/ha, a normal yield according to farmers interviewed.

Farmers have access to two markets, the fresh food markets in the major coastal cities and a large capital-intensive starch manufacturing plant. Farmer access to the food market is through trucker-middlemen residing in the village who coordinate deliveries to wholesalers in the urban markets. Prices vary from 3.0-3.5 Col. pesos/kg in the urban market, while the starch manufacturer pays a constant price of 1.9 pesos/kg. The starch manufacturer is basically a buyer of surplus from the urban market and any sub-quality cassava.

Technology Tested

The CIAT regional trials program had identified two varieties, CMC 40 and M Mex 59, that were widely adapted and yielded about 22 t/ha in the regional trials in Media Luna. The baseline survey had shown yields in the coastal zone to average only about 4 t/ha, indicating good potential for CIAT selections.

Field trials were done on 0.1/ha plots. On each of nine farms the two varieties selected by CIAT and the local variety Secundina were grown. Three farmers grew only the CIAT varieties (at 10,000 plants/ha); three farmers grew the CIAT-selected varieties, planting material of which was treated with a fungicide/insecticide mixture; and three farmers used the fungicide/insecticide treated CIAT varieties and also applied 500 kg/ha of 10-20-20 fertilizer. The first set of trials was planted in September 1977 during the secondary planting season, and results are reported here. Additional sets of trials using a revised methodology were planted in May and September 1978 and have not been harvested.

Productivity and Profitability of New Technology

Yields from the trials are presented in Table 52. The basic recommended CIAT technology — optimum plant populations, selected and treated planting material and CIAT-selected cultivars — gave a substantital yield advantage over Secundina grown with local technology.[1] However, the results would appear to indicate that stake selection and treatment are essential if selected varieties are to yield reasonably well. This implies that an effective extension and input delivery system is essential to obtain adequate yields with selected varieties. Table 53 shows that the reason underlying the low yields of CIAT varieties without stake treatment is the very low germination rates, especially for CMC 40. Low plant populations combined with increased weed growth were the primary factors responsible for the low yields.[2]

A simple gross margin calculation (Table 54) shows that CMC 40 grown with high-input levels was the most profitable. However, the advantage in using fertilizer is not conclusive. In the case of M Mex 59 fertilizer use produced a loss in income. While with CMC 40 fertilizer was marginally more profitable, one-third of the farmers would have lost money in applying fertilizer. Fertilizer application is

1 The results of the local technology are biased downward compared to yields under actual farmer management. This was because, firstly, Secundina did not germinate well and was not replanted, as farmers would have done; secondly, Secundina does not do well in the dry season and is therefore, usually planted at the beginning of the rainy season, in May; and, thirdly, the Secundina plots were not weeded on as timely a basis as farmers' fields and losses in the dry season were as much as 60% of the plants.

2 Often farmers have considerable delays between cutting and planting stakes. There was some delay between cutting and planting of the CIAT material and, in these cases, the stake treatment was highly effective in combatting low germination.

Table 52.

Fresh weight cassava root yields of three varieties grown in on-farm trials at Media Luna, according to cultural treatments.

	Varietal yields (t/ha)					
	CMC 40		M Mex 59		Secundina	
Treatment	Avg.	SD (CV)	Avg.	SD (CV)	Avg.	SD (CV)
Traditional (control)	4.6	1.7 (37)	9.3	1.4 (15)	2.0	0.7 (35)
Stake treatment	13.1	3.9 (30)	13.6	5.5 (40)	-	-
Stake treatment and fertilizer	17.4	3.4 (20)	13.9	9.5 (68)	-	-

Table 53.

Percentage plant losses of three cassava varieties grown under three treatments in on-farm trials at Media Luna.

	Losses of CMC 40 months after planting			Losses of M Mex 59 months after planting			Losses of Secundina months after planting		
	1[1]	4	11	1[1]	4	11	1[1]	4	11
Traditional (control)	55.3	63.4	74.2	30.8	38.8	49.8	4.8	21.8	64.4
Stake treatment	0.8	1.3	3.0	5.9	10.2	25.3	-	-	-
Stake treatment and fertilizer	1.1	3.4	5.8	7.2	21.2	33.5	-	-	-

1 Losses after one month were due to poor germination.

therefore, if not unprofitable, at least very risky under these agro-climatic conditions. These results highlight the fact that fertilizer recommendations for cassava are location-specific and must first be based on detailed trials for soil and climatic conditions and for varieties common to that region. Otherwise, the farmer risks substantial capital losses.

Because of the price differential between CIAT selections and the local variety (see later paragraphs on marketing constraints), the profitability advantage of CIAT-selected varieties is not clear, since Secundina combined with CIAT cultural recommendations was not tested (although subsequent trials will include this variable). This situation emphasizes the fact that quality characteristics, as they affect prices, heavily influence the relative profitability of new technology, even with a substantial yield advantage.

Yield Constraints

The Cassava Program has identified improved, high-yielding varieties as the principal means of increasing cassava productivity in Latin America. CMC 40

Table 54.

Gross margins[1] from producing three cassava varieties under three cultural treatments in on-farm trials at Media Luna.

Treatment	CMC 40	M Mex 59	Secundina[2]
		(Col. pesos)	
Traditional (control)	7130	14,415	17,500
Stake treatment	20,138	20,913	-
Stake treatment and fertilizer	22,953	17,528	-

1 Due to quality differences, a price of 1.55 pesos/kg was used for CMC 40 and M Mex 59 and 3.5 pesos/kg for Secundina.

2 A yield of 5 t/ha was used as being more reflective of on-farm yields. See Table 52 for yields used to calculate other margins.

and M Mex 59 have been identified as the most widely promising varieties, until hybrid lines are developed. As an input for the research process an evaluation of yield constraints and the means to overcome them is useful.

Yield-constraining factors of the CIAT-selected varieties planted in the September season are presented in Figure 72.[3] The major yield constraints are related to climate. Two research possibilities for

3 Figure 72 was constructed as follows: (1) Maximum yield represents the median of the average of the two highest yields in each year of the regional trials in Colombia; (2) the next lower level of yields represent the highest yields achieved at Media Luna during the four years of regional trials (planted in September); (3) the third level of yields represent this year's results from the regional trials; and, (4) the rest follows from the farm level results.

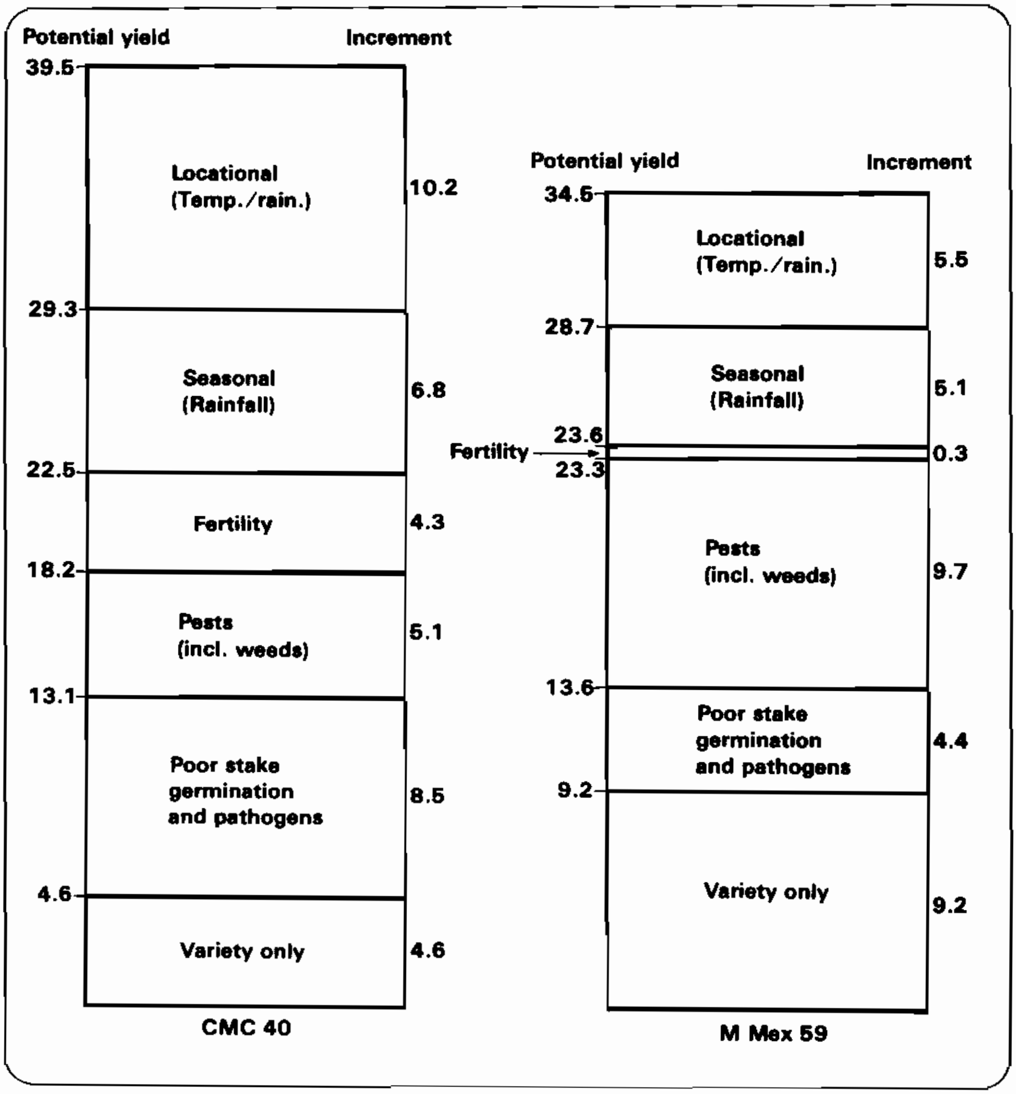


Figure 72. Constraints on yields of CIAT-selected cassava varieties during the secondary planting season at Media Luna.

overcoming these factors are better adapted varieties or more timely planting within the rainfall cycle. Using fertilizer to overcome the fertility constraint has been shown to be either risky or unprofitable. Pest control, including weeds, therefore seems to be the principal means of raising yields enough to provide adoption incentives to farmers. Stake selection and treatment are both economical for overcoming at least part of this constraint, especially for CMC 40. Yields could be increased above the 13 t/ha average for stake treatment, as the trials showed that termites caused a large proportion of the stake losses for M Mex 59 (Table 55); CMC 40, on the other hand, appeared to have some resistance. This damage can be reduced by changing the stake treatment to include aldrin (see Entomology Section). Better weed control could possibly raise yields further, but with the limited data, this effect cannot be separated from effects of pathogens and insects, particularly cassava bacterial blight and mites. Both could only be controlled with more resistant varieties.

Figure 72 also shows the striking differences in yields under optimal conditions and those obtained under typical production conditions. Cassava yields with these varieties under these conditions could be potentially raised to a maximum of 15 t/ha. Under actual farmer management, less intensive weed control and lower plant populations due to intercropping would reduce yields even below this level.[4]

Marketing Constraints

Ten families in Media Luna were given three kg each of the two selected varieties to sample for eating qualities. Variety CMC 40 was only rated fair to poor and M Mex 59 was rated poor by all.

Farmers were asked to evaluate the factors they considered most important in selecting a new variety for adoption. As primary factors, 83% mentioned high starch content and the rest mentioned high yield. As secondary factors, 17% mentioned high starch, 66% mentioned high yield and the other 17% said high germination was important.

These answers reflect two important factors about farmers' response to the marketing situation. First, quality in the fresh food market is determined principally by root starch concentration. High starch content is a necessary, but not entirely sufficient, condition for producing cassava of marketable quality. The second

4 These effects will be evaluated during the coming year when farmers plant stakes produced from these other varieties.

Table 55.

Percentages of plants of three cassava varieties that were infected by termites when grown under three cultural treatments in on-farm trials at Media Luna.

Treatment	Varieties		
	Secundina	CMC 40	M Mex 59
Traditional (control)	25.9	8.1	18.4
Stake treatment	-	0.7	4.5
Stake treatment and fertilizer	-	3.1	19.0

factor is that farmers' access to the market depends on producing cassava of sufficiently good quality. Farmers see their principal market as the fresh food market where low-starch cassava is simply not saleable, i.e. price differentials between varieties of varying quality do not exist.

However, on the North Coast, unlike the rest of Colombia, the large starch manufacturing company exists as an alternative market. In this situation the farmer can choose between higher yields and lower starch content and, therefore, many farmers planted a small section of their land to the CIAT-selected varieties.

In areas where only a fresh food market exists, these varieties will not be adopted, due to rejection by traders and wholesalers.[5] Where there is an expansive industrial market and the varieties yield about three times more than local varieties, a dual market will develop in which different varieties supply different markets. With the movement out of local varieties prices in food markets will probably increase until the two varieties become equally profitable. Although a substantial price difference between the local and industrial varieties could induce consumption of lower quality cassavas, this is not likely.

5 Because of the interaction between environmental factors and starch content (see discussion on research implications), the interesting situation arises that these varieties may produce cassava of acceptable market quality when grown at higher altitudes. Market quality is, therefore, a function of variety and the conditions under which it is grown.

Research Implications

These above results show the importance of high starch content (probably at least 30%) as a principal characteristic to be sought in new varieties, especially if there is to be a beneficial impact on the food market. All industrial uses also put a premium on high starch content. Because of its effect on prices, starch concentration becomes as important as yield in variety development.

Starch contents of the various varieties planted in the Media Luna regional and farm trials are shown in Table 56. The variety M Col 22 has been introduced in later farm trials as a potential variety having a high starch concentration. The data show starch content varies widely between varieties, with the local variety consistently having the highest concentration of root starch. Ranking of varieties by their starch content has been relatively constant through the years, indicating genetic differences for this characteristic.

Table 57 shows the average starch content for the same seven varieties across

Table 56.

Percentage starch content of four cassava varieties grown in various trials at Media Luna.

Variety	Regional trials 1975	1976	1977	1978	On-farm trials 1978
CMC 40	27	24	26	26	18
M Mex 59	25	27	28	22	24
M Col 22	33	28	30	26	-
Secundina	33	33	36	27	33

Table 57.

Average root starch content of seven cassava varieties grown in seven sites.

Site	Altitude (masl)	Mean starch content (%)	Standard deviation (%)
Media Luna	10	29.4	3.3
Nataima	430	31.7	2.4
Rio Negro	480	27.0	5.3
CIAT-Palmira	1000	33.7	2.4
La Zapata	1100	33.6	2.6
Caicedonia	1100	38.7	2.6
Pereira	1480	35.6	1.5

seven regional trial sites. Differences between sites are significant, indicating that starch content is also influenced by environmental factors. For each of three varieties, a simple linear regression was done reflecting the hypothesis that starch content was a function of average temperature and the general vigor of the plant, measured by yield in a given location.

Regression results (Table 58) showed a definite negative relationship between starch content and temperature, particularly for M Col 22, a variety exhibiting a genetic characteristic of high starch concentration. Yield, on the other hand, did not in general appear to be associated with starch concentration.

Root starch content has been shown to be a principal determinant of marketing quality, which, because it determines either access to the market or price paid, heavily

Table 58.

Linear regression results of relationship between cassava root starch content and the mean temperature at a given location, for three varieties.

Variety	Regression[1]	R-square
CMC 40	SC = 54.2 - 1.01 Temp + .001Y (1%) (NS)	.52
M Col 22	SC = 63.3 - 1.35 Temp + 0.16Y (1%) (10%)	.63
M Mex 59	SC = 44.0 - 0.61 Temp + 0.08Y (15%) (NS)	13

1 SC = starch content, Temp = temperature, Y = yield; values in parentheses are significance levels of regression coefficients.

influences farmer adoption of the variety. This characteristic is genetically determined but is also highly influenced by environmental conditions, cultural practices (see fertility results in the Cultural Practices Section), and disease attack (see the cassava bacterial blight results in the Varietal Improvement Section). To get a gross indication of the interaction between variety and environment (representing climatic, edaphic and pathogenic factors) a Spearman rank correlation was used to evaluate the ordering of varieties by starch content between eight regional trial sites in 1975.

Of the 21 possible pairings, only two correlations were significant from zero at the 10% probability level or less. While not conclusive because of the limited number of varieties in the test, this nevertheless indicates that all research disciplines in the program need to consider starch content in conjuntion with yield as a principal evaluation criterion in their trials and that each discipline has a potential role in isolating the various factors that influence starch content.

Economic Analysis of Cassava/Bean Intercropping Systems

A simple economic analysis of cassava/bean intercropping systems was done on data generated by the Cultural Practices Section. The systems may be considered relevant to a zone between 1000 and 1500 m where bean and cassava cultivation overlap. These systems are not amenable to tractor utilization and therefore are especially relevant to small-scale farmers who tend to be more labor-intensive. Nevertheless, the systems under study are relatively input-intensive, employing herbicides, fertilizers and frequent spraying of fungicides on beans.

Resources used in the various systems are presented in Table 59. Generally, as the systems become more complex both labor and input utilization intensify. There is, however, a major complementarity in the bush bean/cassava association in that weeding labor is substantially less than for monoculture because of the shading effect of the beans. This reduces the incremental

Table 59.

Resource utilization and costs for various cassava/bean intercropping systems.

System	Labor[1] weeding (man-days/ha)	Labor[1] total (man-days/ha)	Labor costs[2] ($ Col.)	Input costs ($ Col.)	Total costs ($ Col.)	Incremental cost[3] ($ Col.)
Cassava monoculture	44.5	86.5	10,650	7012	17,662	-
Cassava/bush beans	0	79.0	9900	9905	19,805	2143
Cassava/climbing bean (I)[4]	69.5	138.0	15,200	16,557	32,357	14,695
Cassava/climbing bean (II)[4]	69.5	159.5	17,950	16,557	34,507	16,845
Cassava/bush bean/ (I)[4]	25.0	132.0	15,200	19,450	34,650	16,988
climbing bean (II)[4]	25.0	156.0	17,650	19,450	37,100	19,438
Bush bean monoculture	6.0	86.0	12,600	16,031	28,631	-

1 Labor utilization reflects mechanical land preparation.
2 Includes costs of mechanical land preparation.
3 Additional cost of the system compared to cassava monoculture.
4 (I): cassava not defoliated; (II): cassava defoliated at 9 months.

Table 60.

Net profit per ha for various cassava/bean intercropping systems when cassava prices vary[1].

System	Cassava price ($ Col.)				
	0.5	1.0	2.0	3.0	4.0
Cassava monoculture	-3562	10,538	38,738	66,938	95,138
Cassava/bush beans	15,695	27,165	50,195	73,195	96,195
Cassava/climbing beans (I)[2]	-4657	11,043	42,443	74,443	105,243
Cassava/climbing beans (II)[2]	9543	19,993	40,893	61,793	82,693
Cassava/bush beans/ (I)[2]	16,150	28,550	53,350	78,150	102,950
climbing beans (II)[2]	37,200	46,700	65,700	84,700	103,700
Bush bean monoculture	15,769	15,769	15,769	15,769	15,769

1 Bean prices were constant at $ Col. 12/kg for black bush beans and $ Col. 24/kg for white climbing beans.
2 See footnote 4, Table 59.

cost of intensifying the system. There could also be an additional benefit of erosion control due to the early growth of the beans, an important aspect in mountainous zones where this system would predominate. Finally, no expenses are incurred for a support system for climbing beans which utilize the cassava stems as supports.

The high Land Equivalent Ratios and the cost complementaries would suggest a distinct income advantage for the intercropping systems. Net profitability of the various systems were calculated and are shown in Table 60. The systems were evaluated at different cassava prices to determine whether the optimal system varied according to relative prices between cassava and beans. The most intensive system — cassava defoliated at nine months in association with two crops of beans — was the most profitable system over a range of relative prices. Only at very high cassava prices was the undefoliated cassava/climbing beans association the most profitable system, reflecting the apparent positive impact of the association on increased cassava yields over the monoculture. More significantly, across a very wide range of relative prices, both monoculture systems were always less profitable than the associated cropping systems.

The incremental costs in Table 60 point out the rapid cost increases in moving from cassava monoculture to more complex associated cropping systems. Considering

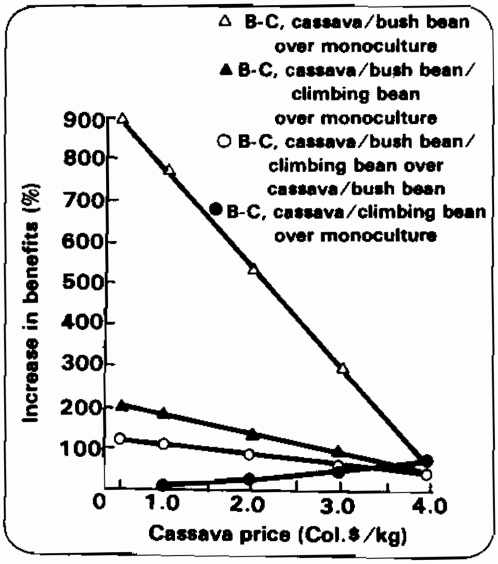


Figure 73. Benefit-Cost (B-C) ratio of investment in different intercropping systems over a cassava monoculture system.

that small-scale farmers are the primary users of associated cropping systems, risk considerations and limited capital availability require a high return on capital. Data in Figure 73 show the marginal rate of return on increased capital outlays over the cassava monoculture costs. The high productivity of the associated systems is reflected in the high rates of return. The cassava/bush bean system yields a very high rate of return on investment in the associated bean system across a wide range of relative prices, indicating the profitability of this system over monoculture. The rate of return over the cassava/bush bean system in adding a climbing bean system, the most profitable system, was substantially lower but still within an acceptable range, i.e. more than a 50% return, across all price levels except very high relative prices. These results indicate that the most profitable systems as well give a sufficiently high marginal rate of return to cover risk and high capital costs. Moreover, it would not be recommended to change to just a cassava/climbing bean system at very high relative prices. The rate of return is not that much higher and risk of price changes substantially affects both profitability and returns on capital. The importance of the bush beans in these associated systems, therefore, is crucial.

INTERNATIONAL COOPERATION

The Cassava Program's international cooperation activities are designed to link research generation and technology application through the creation of strong links between CIAT and national agencies.

Progress in Latin America during 1978 included the strengthening of existing cooperative networks, an increase in the amount of promising germplasm material moving into international testing, and extensive travel by members of the cassava team, especially the outreach specialist for Latin America.

This was the first full year in which a member of the cassava team was stationed in Asia as an outreach specialist for that region. Emphasis there during 1978 was on introducing promising clones for propagation and later distribution and testing. At the same time preparations were made to establish a research network in Southeastern Asia that will manage testing of this material.

Latin America

Scientists from the cassava team traveled during the year in Bolivia, Brazil, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador and Honduras to assist in establishing first international trials and/or to initiate or continue collaborative activities related to cassava research and production. In Colombia, close work with the Instituto Colombiano Agropecuario (ICA) has led to the extensive propagation and distribution of promising materials by ICA agronomists to local farmers. In Brazil, the entomologist from the cassava team has spent most of 1978 working with that country's national cassava program.

International Trials

After extensive evaluations in cooperation with ICA, at 10 locations in Colombia, promising materials were sent during 1978 to 14 countries in Latin America and other regions of the world for local testing. International regional trials, which included materials furnished by CIAT, were harvested in Argentina, Costa Rica, Ecuador, Mexico and Venezuela. The respective national programs are responsible for the later recommendation and multiplication of varieties.

Within-country Activities

Bolivia. Planting material for an international trial was sent and the CIAT outreach specialist assisted local agronomists in planting the experiment. One of the agronomists, from the Universidad Gabriel René Moreno, had participated in the intensive production course at CIAT, in May 1978. Relationships were also established with the Instituto Boliviano de Tecnología Agropecuaria (IBTA)to increase collaborative activities and training in cassava for agronomists of that institution.

Brazil. The network of regional trials that the CIAT agronomist assisted in planning in 1977 were planted this year throughout the country by local agronomists. Seeds from controlled crosses made in CIAT by former Brazilian trainees have been evaluated at Cruz das Almas and are being multiplied for extensive evaluations.

Plans are being made to exchange cassava germplasm grown in test tubes using the tissue culture technique. The Director of the Centro Nacional de Recursos Genéticos (CENARGEN) and the tissue culture specialist of CIAT's Genetic Resources Unit have exchanged visits to prepare for this activity.

Colombia. ICA is multiplying, distributing and selling disease-free planting material, including CIAT-selected varieties, to farmers in several regions of Colombia. Regional trials are being planted by ICA agronomists in several locations of the North Coast and other regions, using varieties recommended by ICA after joint ICA/CIAT evaluations.

Costa Rica. Work by local scientists has erradicated cassava bacterial blight from major cassava growing areas. Former trainees from CIAT are conducting the second cycle of an international trial with promising varieties sent from CIAT. Also, several regional trials were initiated with the best varieties harvested in the first testing cycle.

Dominican Republic. Agronomists who had received training at CIAT have established the first international trial in San Cristobal. One of these agronomists also arranged for the Under-secretary of Agriculture for the Moca region and several farmers to visit CIAT. The CIAT-trained agronomists are now teaching the simple improved cultural practices methodology advocated by CIAT to local farmers. The CIAT-selected variety CMC 40 (originally bred in Brazil) is widely grown in the country.

Recently, scientists from the Centro de Desarrollo Agropecuario (CENDA) have requested planting materials of promising varieties for local evaluations.

Mexico. Late in 1978 the Coordinator of Mexico's cassava program spent a week at CIAT seeking logistical support to implement the National Cassava Program, planned in 1977 with CIAT's assistance. This program, when it becomes operational, should have tremendous impact on cassava production in that country. Several former trainees from CIAT participate in this program.

Plant materials of several CIAT-selected varieties have already been sent to Mexico where they are being grown and evaluated by agronomists there.

Other countries. Planting materials have been sent to Argentina and Venezuela for international trials. In Honduras the first international trial was planted in June 1978, under the supervision of a former CIAT trainee. In Perú, a special project financed by the Canadian International Development Research Centre (IDRC) is being terminated in 1978. CIAT cassava scientists provided some assistance to this project and an evaluation of its accomplishments will determine the extent of future collaborative activities. The Cassava Program Coordinator visited Cuba and the exchange of planting material, training and other cooperation in cassava production is now in progress. Contacts were maintained with programs in Guyana and Surinam.

Training Activities

Two intensive one-month courses in cassava production technology were held during 1978 at CIAT. In the first one during January and February, participants came mostly from outside Latin America. Principal funding for participants in this course was provided by the IDRC (see Southeast Asia section).

In the second course, in May, 46 professionals from 12 Latin American countries participated. Principal funding for this course was from IDRC and the United Nations Development Programme.

Twelve agronomists from nine countries completed longer term training at the Center during the year, and another 10 were still in training at the end of the year.

Southeast Asia

Major emphasis has been placed this year on the introduction of promising clones to be distributed later throughout Asia. Material in the form of cuttings was introduced to the Philippines and multiplied in quarantine using the rapid propagation technique. Great care has been taken in the quarantine process and no problems have arisen in the process. At present, a total of 2.5 ha of promising material are in the field and ready for distribution to other countries in Southeast Asia in March 1979. While the material was being propagated preparations have been made to establish a research network that will manage the regional testing of introduced material.

Apart from the vegetative cuttings sent to Asia a large quantity of sexual seed has been sent to India, Thailand and Malaysia. Material from CIAT has shown very high harvest indices and good Cercospora resistance in India and these materials are now being used in the breeding program there. In Thailand, a number of seedling selections have been made, multiplied and are now in advanced yield trials. In Malaysia the seedlings are still in the initial selection phase.

A directory of Asian cassava workers was compiled and produced so as to determine who was working in cassava and where. National cassava programs are already established in India, Thailand, Malaysia, Indonesia and the Philippines. After careful selection a total of 25 researchers from these programs attended a one-month intensive research and production course at CIAT. All of these have returned to the national programs except for two who are receiving further training.

The outreach coordinator for Southeast Asia has visited the six countries in which CIAT is actively working, India, Thailand, Malaysia, Indonesia, Philippines and Sri Lanka. The first three programs are the largest established ones and the main emphasis has been on keeping them abreast of new advances at CIAT and providing feedback to CIAT on advances within the national programs. In the case of the Philippines, Indonesia and Sri Lanka, CIAT has helped in planning and organizing their programs, which are still very new. In the Philippines the coordinator organized a short intensive course on rapid propagation of clean plant material as lack of suitable material has been a major limitation on the increased production in that country.

Beef Program

CIAT's Beef Program became fully operational this year, with field research activities at CIAT-Quilichao, Carimagua, Brasilia and a network of 14 established regional trials throughout the target area. Following the objectives and work plan described in the 1977 Annual Report, the main accomplishments can be summarized in terms of developing germplasm, technology components and setting the stage for technology transfer activities.

Germplasm

Andropogon gayanus CIAT 621 has shown outstanding performance as a highly productive forage grass for Oxisol-Ultisol regions. It has entered the Category 5 (pre-release) stage, which includes large-scale seed production. Its principal attributes are: (1) excellent growth and dry matter production in acid, infertile soils with minimum inputs; (2) exceptional tolerance to drought stress, burning and high levels of Al saturation; (3) low P and N requirements; (4) no known disease or insect attacks; (5) excellent seed producing ability; (6) compatibility with legumes; (7) adaptability to low-cost pasture establishment systems; (8) acceptable nutritional quality and high intake due to very high palatability; (9) high animal production levels during the first year.

Its principal unknown characteristics are its tolerance to Brazilian spittlebug species, animal production during the dry season, and its weed potential in crops. The Instituto Colombiano Agropecuario (ICA) and CIAT have agreed to a joint release as "Pasto Carimagua cv. 621" by early 1980, provided the unknown questions are satisfactorily resolved and no significant negative factors are found during the 1979 experiments.

Seven accessions of three forage legume species, *Zornia latifolia* (CIAT 728), *Desmodium ovalifolium* (CIAT 350) and *Stylosanthes capitata* (CIAT 1019, 1078, 1097, 1315 and 1405) continue to show promise for potential release and have entered animal production trials at the Category 4 level. At this time it is not possible to ascertain which species is superior. All are showing good persistence during their second year under grazing pressure trials, are adapted to acid, infertile soils, have good self-propagation mechanisms, show no major insect or disease attacks, and have good nitrogen fixation potential.

In addition, *Z. latifolia* has a very high protein content and grows vigorously during the dry season. *D. ovalifolium* is aggressive enough to form good mixtures with *Brachiaria decumbens* but is susceptible to a nematode attack and its seed production potential at low latitudes is unproven. Some *S. capitata* accessions show three persistence mechanisms: abundant seedling production, regrowth from the crown nodes (like alfalfa), regrowth from axillary and terminal buds. All three legume species were found tolerant to burning, which may add to their persistence in cases of accidental burning or a need for periodic burning of some associations.

The germplasm evaluation process continues to funnel a large number of legume and grass accessions through Categories 1, 2, 3, and 4 evaluations at CIAT-Quilichao, Carimagua and Brasilia. Two browse-type, shrubby legume species have been promising under acid soil conditions: *Desmodium gyroides* 3001 and several lines of *Leucaena leucocephala* resulting from selection or breeding for acid soil tolerance, coupled with adapted acid-tolerant rhizobia. Also several late-flowering *Stylosanthes guianensis* types from the Cerrado appear to show promise for anthracnose tolerance.

Technology Components

Several sections of the Program are developing technology components to turn acid soil infertility, and plants adapted to it, into assets rather than liabilities. Low density space-planting systems provide significant savings in seed, fertilizer and machinery, and have produced pastures ready for grazing within a year. Low soil fertility inhibits weed growth while the pastures establish themselves, either from reseeding or stolon growth. Low reactivity rock phosphates, abundant in tropical America, are efficiently utilized because soil acidity dissolves the rocks rapidly and makes them available to pasture species tolerant to high levels of Al.

Carrying this thinking to the laboratory, a new acid media was developed to screen *Rhizobium* strains for acid soil tolerance. This facilitates the selection for *Rhizobium* persistence on acid soils, since lime pelleting is only effective for the first generation of nodules.

Other significant technology developments include the discovery that the type of trichoma and secretions on *Stylosanthes* stems may explain their tolerance or susceptibility to stemborer attacks, the design of simple mechanisms for estimating root length and leaf water potential in tropical grasses, the development of an *Andropogon* de-awner, the effectiveness of rock phosphate minigranules in providing better handling properties without affecting reactivity, and the verification of simulation models described last year by actual data gathered this year. In addition grass/legume pasture persistence was defined by economic analysis to be at least six years.

Putting some of the available technology together as a practical package, a breeding herd systems trial in Carimagua showed that the strategic use of improved grass legume pastures occupying 10% of the grazing area increased beef production by 250% during its first year of operation, and appears to be highly profitable.

Knowledge of the Target Area

Although the research results are most encouraging, more time is needed to determine whether the new grass/legume pastures are significantly persistent in order to be truly profitable. While research continues, advances have been made in understanding the target area both physically and production-wise, and in developing cooperative relationships with national institutions.

Interpretation of a wealth of climatic, soil and landscape data shows that the potential evapotranspiration during the rainy season effectively separates savannas from two types of forested areas. Interpretation of the target area survey strongly suggests that two evaluation sites for Category 2 and 3 germplasm should be established in jungle areas.

The in-depth study of beef production farms in the Llanos and the Cerrado (ETES project) is providing reliable quantitative data on actual production systems and excellent opportunities for validating new pasture technology at the farm level. Animal health surveys show significant differences in the extent and importance of diseases in different parts of the target area. Meetings with collaborators from many national research and development institutions helped develop a manual for forage germplasm collection and evaluation, and brought together much of the present knowledge on soil/pasture/cattle relationships in the target area. For the first time, a tropical forages research network began to function in Latin America.

Fourteen regional trials have been planted in Bolivia, Peru, Ecuador, Colombia, Venezuela and Nicaragua to test the adaptability of promising germplasm. Fifteen additional trials are to be planted in Brazil in December 1978, and additional trials in Central America and the Caribbean are projected for 1979. The first 6-month forages course trained 21 collaborators from research and development institutions of Brazil, Colombia, Bolivia, Peru, Ecuador, Venezuela, Panama, Nicaragua and Cuba. The second course is scheduled to start in February 1979.

TARGET AREA SURVEY

In mid-1977 a survey of the Beef Program's target area, the Oxisol and Ultisol regions of tropical America, was initiated in order to classify the land resources in terms of climate, landscape, and soils, and provide a geographically oriented economic synthesis of the region, which would serve as the basis for the Program's transfer of technology strategy. The methodology used and initial results were described in the 1977 Annual Report.

During 1978 the analysis of climatic data was completed, as was aerial reconnaissance and field work in South America. A total of 237 land systems have been identified so far, in the areas where work has been completed (Fig. 1). The collated data for each land system are being stored in a computerized retrieval system, which also has the capability of drawing special purpose maps.

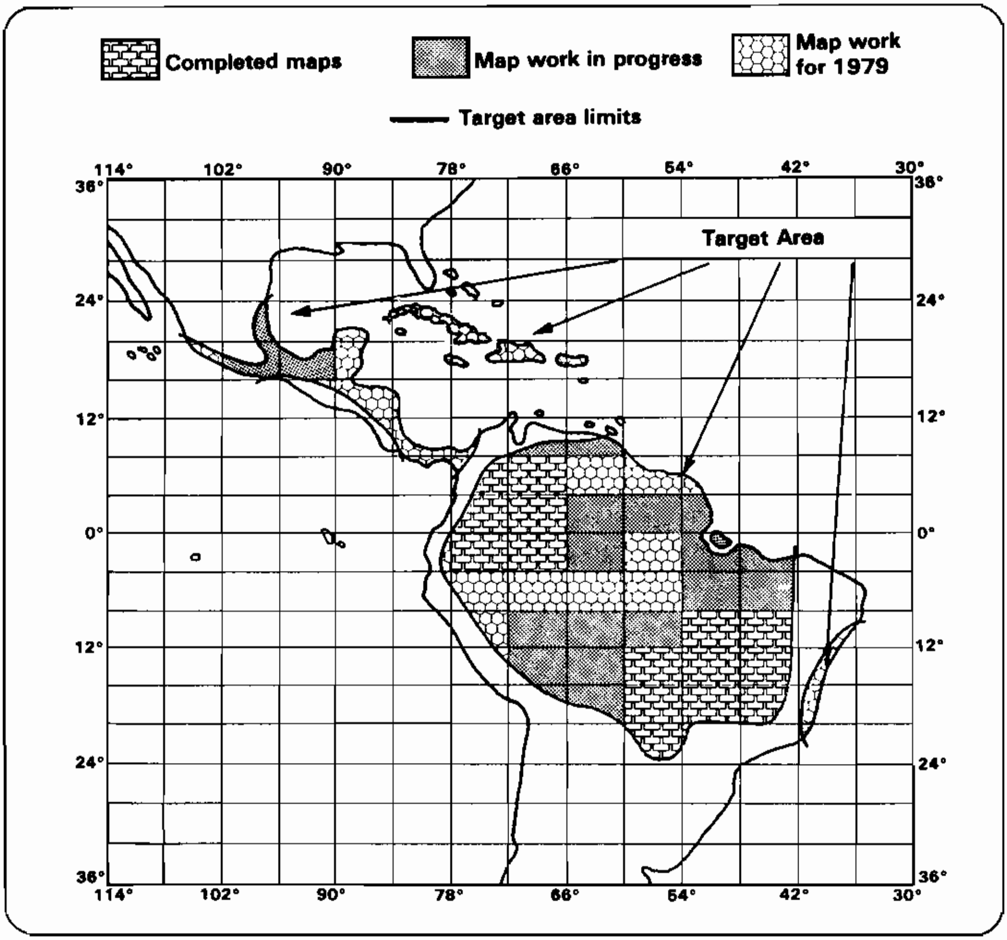


Figure 1. Status of land systems map work for the target area of the CIAT Beef Program.

Climate

Long-term climatic data of meterological stations in the target area were assembled and analyzed. Figure 2 shows the approximate locations of the stations and Figure 3, an example of the data output of one, including a definition of the parameters. The moisture availability index (MAI) predicts the probability of drought stress. When MAI < 0.34 serious drought stress is highly probable. MAI values between 0.34 and 0.67 show stress, a MAI between 0.68 and 1.0 little stress and MAI values > 1.00 no water stress.

With the completion of the water balance analyses, it was decided to map and collate climatic parameters. Data from the central savannas of Brazil showed that the total wet season (months with MAI > 0.33) potential evapotranspiration throughout that region was remarkably constant. A map of lowland tropical South America was then made where four major regions with total wet season

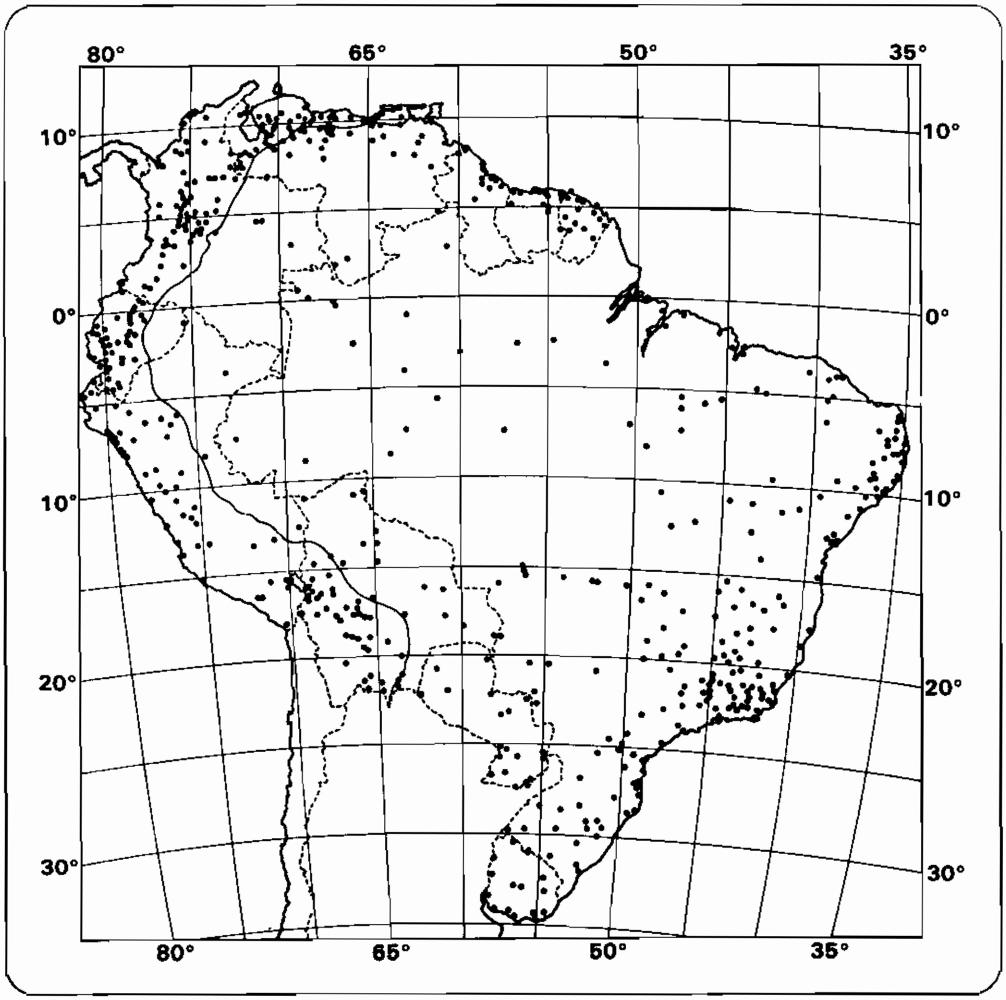


Figure 2. Locations of meteorological stations in the South American region

FORMOSA	LAT 15 32	LON 47 18	912. METROS			
	JAN	FEV	MAR	ABR	MAI	JUN
TEMP MED	22.0	22.1	21.9	21.5	20.1	19.0
H.R. MED	84.	78.	77.	64.	52.	38.
PCT SOL	44.	52.	53.	66.	76.	87.
RS MED	494.	523.	492.	486.	459.	452.
PRECIP.	252.	204.	227.	93.	17.	3.
ET POT	141.	135.	140.	132.	125.	115.
DEF PREC	-111.	-69.	-87.	39.	108.	112.
DEP PREC	176.	138.	157.	51.	0.	0.
MAI	1.25	1.02	1.12	.38	.00	.00

JUL	AGO	SET	OUT	NOV	DEZ	ANUAL
18.9	20.7	22.8	22.9	21.9	21.6	21.3
36.	41.	59.	78.	88.	91.	66.
88.	85.	61.	51.	38.	33.	61.
471.	522.	507.	510.	460.	430.	484.
6.	3.	30.	127.	255.	343.	1560.
123.	144.	143.	149.	127.	121.	1596.
117.	141.	113.	22.	-128.	-221.	35.
0.	0.	1.	78.	179.	248.	
.00	.00	.01	.52	1.41	2.04	

1 Mean temperature in °C.
2 Mean % relative humidity.
3 Mean % possible sunshine.
4 Incident mean solar radiation (Langleys/day) estimated from PCT SUNSHINE
5 Mean rainfall in mm.
6 Estimated potential evapotranspiration by Hargreaves method, in mm.
7 Precipitation deficit = POT ET - PRECIP (water balance) in mm.
8 Dependable precipitation (in mm) = (PRECIP x 0.7) - 10
9 Moisture availability index $= \frac{\text{DEP PREC}}{\text{POT ET}}$

Figure 3. Example of the computer printout of climatic data for a representative meteorological station used in land systems classification, with definitions of the parameters used.

evapotranspirations of less than 910, 910-1060, 1061-1300 and greater than 1300 mm were easily delineated, as these classes followed the natural clustering of the potential evapotranspiration figures (Fig. 4). The 910-1060 mm class had a mean of 987 mm, an SD of 54 mm and a CV of 5.5%; the 1061-1300 mm class had a mean of 1178 mm, an SD of 71 mm and a CV of 6%. The <910 mm region, encompasses areas with more than six months dry season with "caatinga" or other forms of semi-arid or arid vegetation. These are largely outside of the target area, although they include some Oxisols and Ultisols. The 910-1060 mm areas correspond neatly to savanna vegetation regions such as the Cerrado and the Llanos, with four to six months dry season. The 1061-1300 mm belt encompasses areas under semi-evergreen seasonal vegetation which experience three to four months of dry season. The areas with more than 1300 mm are the tropical rain forest regions with less than three months dry season. The similarity between the total wet season potential evapotranspiration map (Fig. 4) and the length of the dry season map (Fig. 5) is clear. This parameter, therefore, apart from equating usable energy for plant growth, provides for a broad first approximation of the length of water stress in the target area. Potential evapotranspiration during the rainy season is clearly a most useful parameter for classifying climate for growth of perennial species such as pastures.

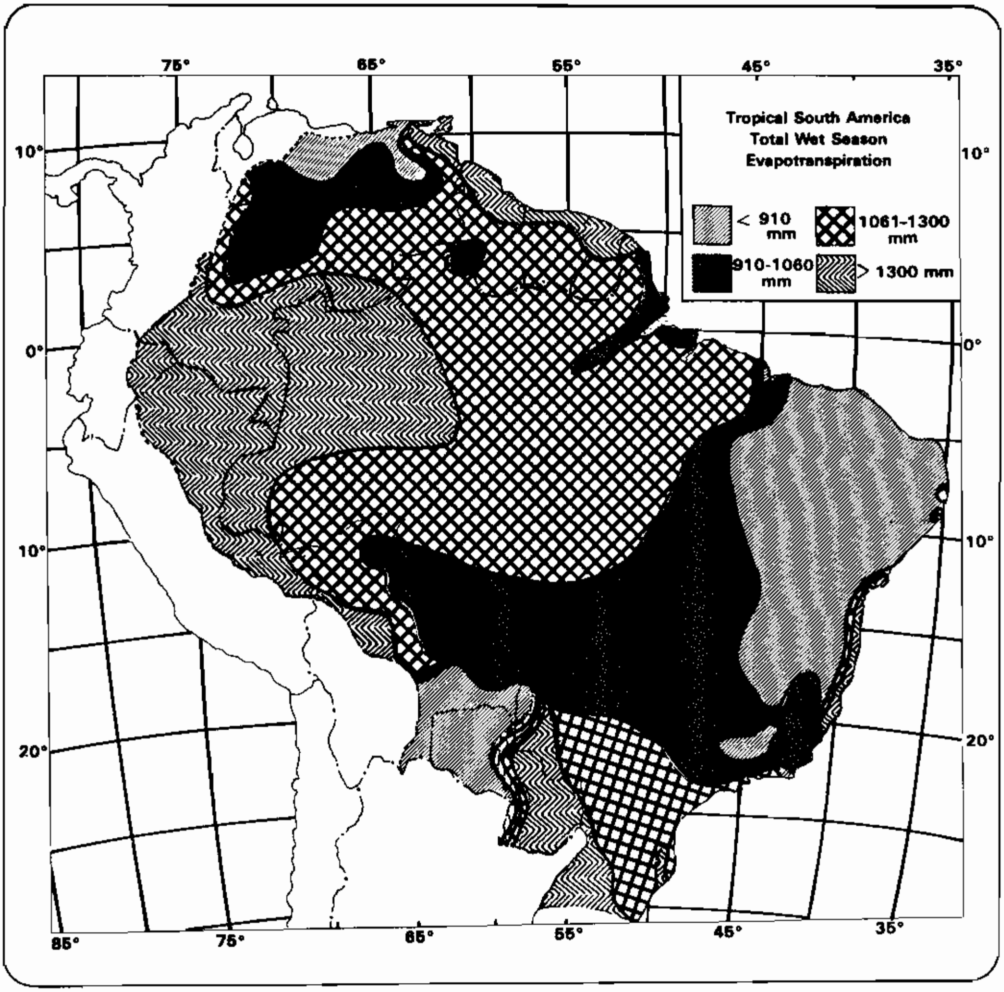


Figure 4. Total wet season evapotranspiration in tropical South America.

Landscape

It was shown that there are two completely different circumstances for cattle production in the savannas of Brazil. The first is characterized by well-drained lands, principally Oxisols, where the major limiting factor is lack of pastures during the dry season. The second is characterized by poorly drained lands, mainly Ultisols (Aquults) with flat topography. These soils have a heavy texture horizon that impedes drainage under a lighter texture topsoil. With the onset of the wet season the topsoil very quickly becomes saturated with water and the land generally inundates to the extent that cattle must be shifted to higher lands. Often the availability of higher lands within a reasonable distance is limited and a shortage of wet season pasture results. Nevertheless, at the present time, such lands carry more stock per unit area than the well-drained lands, and are well thought of by cattle producers.

In central-west Brazil, 52% or 126 million ha would classify as well-drained (mainly Oxisol) savannas, 8% or 20 million

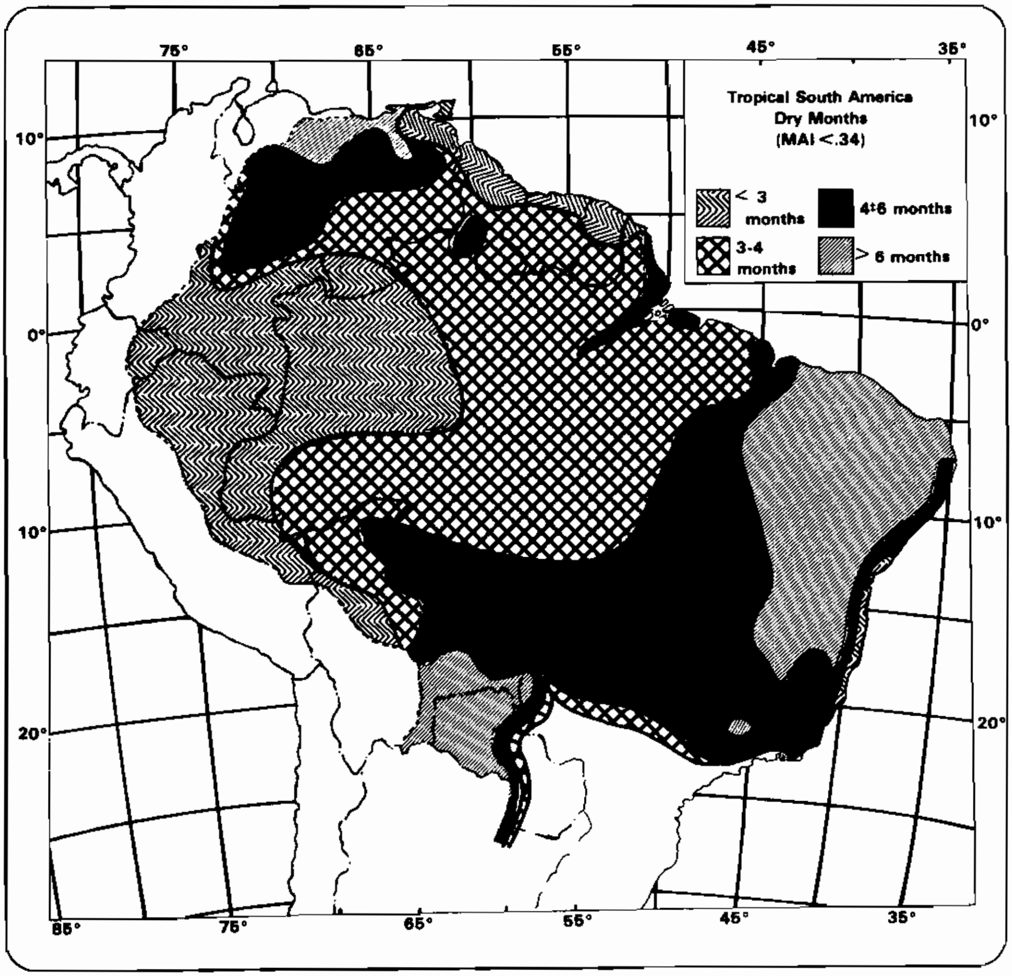


Figure 5. Dry months (Moisture Availability Index <.34) in tropical South America.

ha as seasonally flooded (mainly Ultisol) savannas and the remaining lands as other formations including 21 million ha of Entisol (sandy soil) savannas.

In lowland eastern Colombia 20% or 12 million ha would classify as well-drained (Oxisol) savannas and 7% or 4.5 million ha as seasonally flooded (Ultisol) savannas, and the remaining 46 million ha or 73% as other formations, mainly forests.

The delineation of land systems, especially in central Brazil, has emphasized the exciting contrasts between flat tablelands, hills and valleys and lowland plains. Many systems are well-watered with perennial streams dissecting the countryside at regular intervals. All contain areas of contrasting soils, and these have been summarized and separately described as land facets within land systems. This variability is clearly very important to practical farming.

Vegetation

The vegetation throughout the study region ranges from deciduous forests, to savannas, semi-evergreen seasonal forests and finally, to tropical rain forests. This gradient follows the broad classification of total wet season potential evapotranspiration (Fig. 4). However, within these areas, variations occur due to differences in soil physical and chemical properties. The physiognomic forms of Brazilian Cerrados described as "campo limpo" (grassland), "campo sujo" (grassland with occasional shrubs), "campo cerrado" (open savanna), "cerrado" (intermediate) and "cerradão" (closed savanna with continuous forest canopy) have been shown by Lopez and Cox of North Carolina State University to follow a fertility gradient. Therefore, the considerable controversy in the Brazilian literature concerning the origin of the Cerrado vegetation has been effectively resolved: the Cerrados may be considered as one climatic zone, with a constant total wet season potential evapotranspiration that ranges from 910 to 1060 mm within which the fertility gradient will determine the physiognomic form of the vegetation.

It was interesting to observe in the well-drained savannas that beef cattle actively browse shrubs and trees, especially during the dry season. Brazilian workers have shown that at the height of the dry season, over 60% of animal intake comes from shrub and tree browsing in the Cerrados. The availability of protein-rich forage during the dry season is critical on the well-drained lands, thus the attention being given to selection of grass and legume cultivars that can maintain forage quality well into the dry season is well-justified. Deep rooting species such as the grass *Andropogon gayanus* and the legume *Stylosanthes capitata* were seen to maintain forage quality during the dry season when introduced to these areas. The evaluation of total wet season as opposed to total dry season evapotranspiration will help to locate sites that will give a realistic selection pressure on forage cultivars thought suitable for improving cattle feeding. Clearly, these sites should be on representative soils from a physical and chemical point of view.

Soil

In the delineation of the land systems, soil physical characteristics have played a predominant role, particularly with respect to slope, drainage and water-holding capacity. As already noted, soils have been described separately in the land facet descriptions within a given land system. It was observed that the water-holding capacity of many clay Oxisols approaches that of sands.

In assessing soil fertility characteristics, the procedure followed was that of: (1) identifying toxicity problems, particularly Al and Mn and, (2) subsequently identifying deficiency problems.

Throughout much of the region studied, exchangeable Al levels were found to be high. In Brazil particularly, it was observed that farmers often apply massive, and costly quantities of lime assuming that the Al should be neutralized completely to overcome toxicity problems. However, crops vary in their tolerance to high levels of exchangeable Al, the degree of which may be expressed approximately in terms of the percentage Al saturation of the effective cation exchange capacity. Consequently, for many crops it is not necessary to neutralize all the exchangeable Al, but merely to apply enough lime to decrease the percentage Al saturation to levels that do not affect production. Therefore, an equation to estimate lime requirements at a specific level of Al saturation was developed:

$$\text{meq Ca/100 g soil required for liming} = 1.5[\text{Al} - \text{RAS}(\text{Al} + \text{Ca} + \text{Mg})/100]$$

The values for the elements on the right side of the equation are expressed in terms of meq/100 g soil in the original exchange complex of the unlimed soil. RAS is the required percentage Al saturation. When the estimated lime requirement using the factor 1.5 is greater than the chemical lime equivalent of the exchangeable Al, a closer agreement to measured data is obtained by substituting this by 2.

The equation can be used for estimating approximate field lime requirements by simply changing the expression meq Ca/100 g soil to tons of lime/ha and multiplying the other side of the equation by the apparent specific gravity of the soil. The use of the equation requires no special soil analyses, only a 1*N*KCl extraction for the determination of exchangeable Al, Ca and Mg. When tested against experimental data from Brazil, Colombia and the U.S., the estimated lime requirement by the equation showed correlation coefficients above 0.99** when compared with actual data. Its use could lead to considerable savings in lime applications not only in the region of interest but also in the rest of the world. It is a practical development of CIAT's stated low input philosophy.

It is possible that some areas are affected by Mn toxicity problems, but little information was available relevant to the area studied.

The most common nutrient deficiency throughout the region, apart from N, is undoubtedly P. However, for the forage species seen growing, relatively small applications of P_2O_5 (50 kg/ha or less) appear to give satisfactory response once Al toxicity problems are overcome, preferably by cultivar tolerance.

Zinc deficiency has been reported, but only with excessive lime applications. Nevertheless, Zn levels in soils are often low as are Mg, P, and S levels. Molybdenum and B levels may prove deficient in some soils for some crops. Exchangeable Na levels are often very low in the savanna regions, and this undoubtedly points to the need for common salt in helping to improve beef cattle nutrition in those regions.

In order to facilitate indentifying possible toxicity and deficiency conditions, a procedure of carrying out a regression analysis on the chemical analyses of 15 to 20 soil samples was followed wherever sufficient data could be found.

Bibliographic References

To date, some 4500 bibliographic references and abstracts of work relevant to the impact area have been incorporated into a card system.

The entire study is scheduled to be completed by mid-1979, after which additional efforts will start in the interpretation of the data collected by Program soil scientists, agronomists, animal scientists and economists.

PLANT INTRODUCTION

During 1978, this Section continued its focus on: (1) assembling germplasm through direct collection and exchange with other institutions; (2) initial increase and maintenance of germplasm; (3) preliminary evaluation of germplasm; and,(4) identification and classification of germplasm through a reference herbarium.

Collection and Introduction of Forage Germplasm

Three major germplasm collection expeditions were conducted in 1978: in Panama, in collaboration with the Instituto de Investigación Agropecuaria de Panama (IDIAP) and the Banco Nacional de Panama (Fig. 6); in Venezuela, in collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) (Fig. 7); and in Brazil, in collaboration with the Centro Nacional de Recursos Genéticos of the Empresa Brasileira de Pesquisa Agropecuaria (CENARGEN-EMBRAPA) (Fig. 8). During these systematic expeditions and several occasional collections (mainly in Colombia) a total of 1458 accessions were assembled. Furthermore, 416 accessions were acquired through germplasm exchange with other institutions (Table 1). With these additions during the year, CIAT's tropical forage germplasm collection, specializing in materials originating from regions with acid, infertile savanna and jungle soils, increased to a total of 4781 accessions (Table 1).

Initial Germplasm Increase and Maintenance

Much of the Section's work during 1978 consisted of germplasm multiplication, to produce sufficient seed or vegetative material for preservation, preliminary evaluation and distribution. Under screenhouse and field conditions in CIAT-Palmira and CIAT-Quilichao, for almost 2000 accessions seed was harvested or plants are presently still in pots or in the field (Table 2).

Preliminary Evaluation of Germplasm

Preliminary evaluations in CIAT-Quilichao during the year since October 1977 provided the following results.

From among 53 *Zornia* spp. accessions, seven were selected which proved to be more vigorous than or as vigorous as the control (CIAT 728) (Table 3). All seven ecotypes are native to and were collected in the Colombian Llanos Orientales. Selected

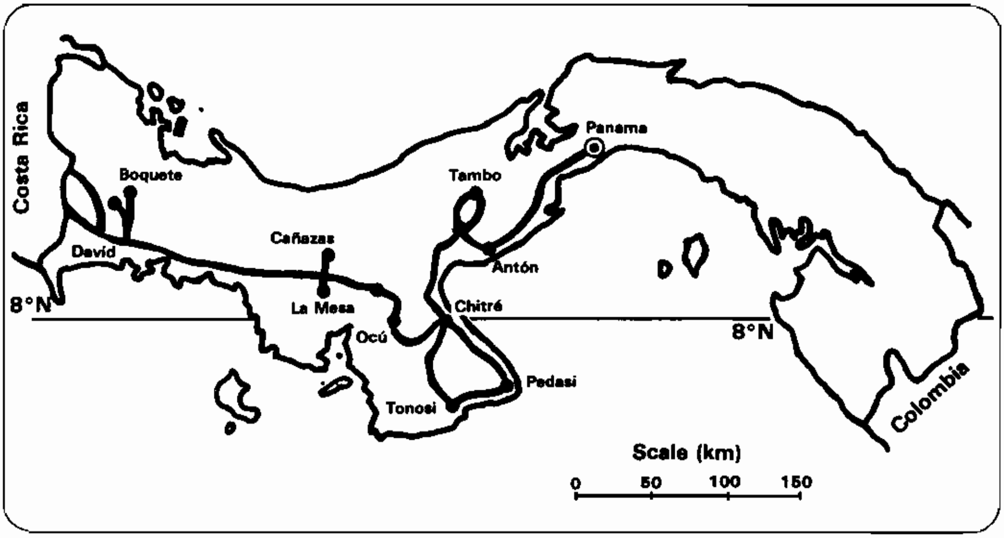


Figure 6. Routes of systematic forage germplasm collection in Panama (CIAT/IDIAP/Banco Nacional de Panama), January 1978.

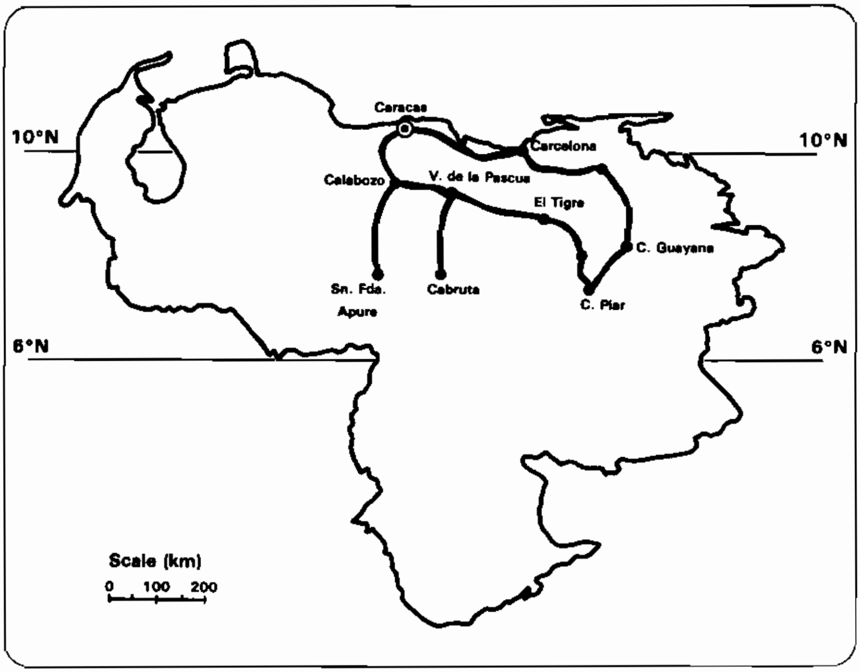


Figure 7. Routes of systematic forage germplasm collection in Venezuela (CIAT/FONIAP), February 1978.

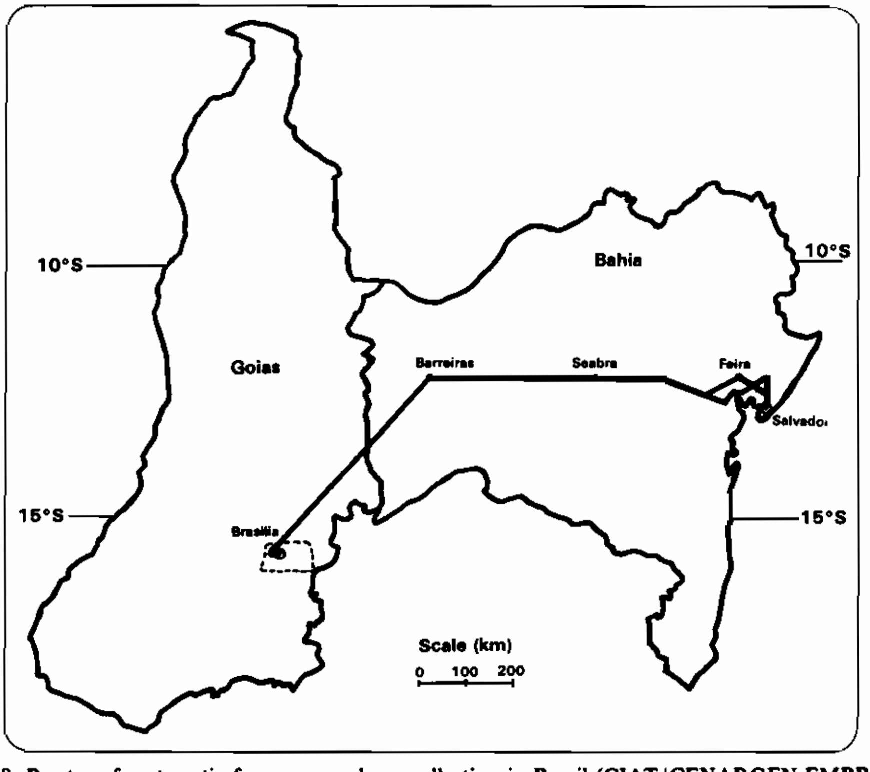


Figure 8. Routes of systematic forage germplasm collection in Brazil (CIAT/CENARGEN-EMBRAPA), September-October 1978.

Table 1.

Introduction of forage germplasm through direct collection and exchange with other institutions during 1978 and total accessions in the forage germplasm bank as of Nov. 1, 1978.

	Introductions during 1978						
	Direct collections						
Genera	Panama	Venezuela	Brazil	Occasional collections	Exchange	Total	Total accessions in bank
Stylosanthes	39	57	190	43	53	382	1204
Desmodium	56	42	33	68	32	231	670
Zornia	21	29	76	27	22	175	316
Aeschynomene	32	36	46	30	16	160	255
Macroptilium/Vigna	21	24	14	44	42	145	401
Centrosema	21	37	23	18	38	137	325
Galactia	12	25	18	26	7	88	168
Arachis			1		2	3	48
Miscellaneous legumes[1]	111	83	48	104	47	393	1110
Grasses				3	157	160	284
Total	313	333	449	363	416	1874	4781

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

Table 2.

Forage germplasm under initial seed increase for maintenance and working collection, during 1978.

Genera	No. of accessions
Stylosanthes	469
Desmodium	247
Zornia	178
Aeschynomene	107
Macroptilium/Vigna	176
Centrosema	125
Galactia	72
Arachis	47
Miscellaneous legumes[1]	289
Grasses[2]	248
Total	1958

1 *Calopogonium, Pueraria, Teramnus, Glycine, Rhynchosia, Cassia, Crotalaria, Tephrosia, Eriosema, Clitoria, Indigofera, Leucaena*, and others.
2 Also for preliminary evaluation.

material is classified in Category 2 by the Program's Germplasm Committee.

Of 13 *Centrosema* spp. accessions, three were selected as superior to the control (CIAT 438) (Table 4). While two of them are genetically improved materials introduced from Brazil (*Centrosema pubescens* CIAT 5122 and CIAT 5124, bred by Dr. Aryno Serpa, Unidade de Execução de Pesquisa de Ambito Estadual (UEPAE) at Itaguaí), the most outstanding ecotype was CIAT 5065, an accession from a 1977 collection expedition to the Colombian Llanos Orientales.

Within a group of 26 accessions of several *Aeschynomene* species, wide variation was observed with regard to plant type, longevity, growth habit, leafiness, drought resistance and adaptation to the Ultisol (pH 4.0 in the introduction plots) at CIAT-Quilichao. The species *Aeschynomene histrix, Aeschynomene*

Table 3.

Preliminary evaluation of 54 *Zornia* spp. accessions for vigor/productivity as rated during monthly evaluations in CIAT-Quilichao[1].

CIAT No.	Origin	Estab-lish-ment	Mean vigor during: 1st dry season	Re-growth	2nd dry season	Obser-vations
728	Meta, Col.	3.0	3.0	3.0	3.0	Control
9203	Meta, Col.	1.3	2.0	2.2	2.0	
9214	Meta, Col.	1.3	2.0	2.4	2.0	
9215	Meta, Col.	2.0	1.5	2.0	3.0	
9220	Meta, Col.	4.0	4.0	3.4	3.0	Selected
9225	Meta, Col.	2.7	2.0	3.0	3.0	
9245	Meta, Col.	3.0	3.0	4.0	3.0	Selected
9258	Meta, Col.	3.7	3.0	4.6	4.0	Selected
9260	Meta, Col.	3.7	4.0	4.4	4.0	Selected
9270	Meta, Col.	4.0	4.0	4.6	4.0	Selected
9286	Meta, Col.	3.0	3.0	4.0	4.0	Selected
9295	Meta, Col.	3.7	4.0	3.8	4.0	Selected
9164	Vichada,Col.	1.3	2.0	2.0	1.0	
9179	Vichada,Col.	3.0	4.0	3.0	4.0	
9278	Vichada, Col.	1.3	2.0	2.0	2.0	
9190	Valle, Col.	3.7	3.0	2.2	2.0	
9518	Valle, Col.	2.3	2.0	1.6	1.0	
9559	Cauca, Col.	3.0	3.0	2.4	2.0	
9576	Cauca, Col.	3.3	4.0	3.4	2.0	
9577	Nariño, Col.	3.0	3.0	2.0	2.0	
9304	Tolima, Col.	4.0	3.0	2.2	2.0	
9307	Amazonas, Braz.	2.0	2.0	1.8	2.0	
9208	Amazonas, Braz.	2.0	1.5	1.0	1.0	
9309	Dist. Federal, Braz.	2.3	2.0	1.4	1.0	
9646	Goiás, Braz.	1.3	2.0	2.0	2.0	
5 access.	Mato Grosso, Braz.	2.7-3.3[2]	0	0	0	Annual ecotypes
24 access.	Mato Grosso, Braz.	1.3-2.7	1.0-3.0	1.2-2.8	1.0-2.0	

1 Rating from 0 to 5 in comparison with control accession CIAT 728: 0 = dead plants; 1 = much less and 2 = less vigor than control; 3 = same vigor as control; 4 = more and 5 = much more vigor than control.

2 Range between lowest and highest individual ratings.

brasiliana and *Aeschynomene paniculata*, which so far have been unknown agronomically, were identified as potentially promising forage species for acid soil conditions. Four accessions (CIAT 9665, 9666, 9681 and 9690) were selected for further evaluation in Category 2.

Out of a group of 31 accessions of several *Macroptilium* and *Vigna* species, after one year of observations none of the materials tested could be considered well-adapted to the CIAT-Quilichao environment. Most of the accessions behaved as annuals, and those with a longer life cycle were severely

Table 4.

Preliminary evaluation of 14 *Centrosema* spp. accessions for vigor/productivity as rated during monthly evaluations in CIAT-Quilichao.[1]

CIAT No.	Origin	Estab-lish-ment	Mean vigor during: 1st dry season	Re-growth	2nd dry season	Obser-vations
438	Hybrid	3.0	3.0	3.0	3.0	Control
5122	Hybrid	5.0	4.0	4.0	4.0	Selected
5123	Hybrid	3.0	2.0	3.0	3.0	
5124	Hybrid	5.0	4.0	4.0	4.0	Selected
5052	Vichada, Col.	3.7	4.0	3.0	2.0	
5063	Meta, Col.	2.7	3.0	2.5	2.0	
5065	Meta, Col.	4.0	4.0	4.5	5.0	Selected
5105	Cauca, Col.	2.3	2.0	2.3	2.0	
5106	Cauca, Col.	2.7	3.0	3.0	2.0	
5130	Valle, Col.	2.7	2.0	2.0	2.0	
5125	Antioquia, Col.	3.3	3.0	2.8	2.0	
5109	Mato Grosso, Braz.	3.0	3.0	3.0	2.0	
5111	Mato Grosso, Braz.	1.7	1.0	0	0	
5114	Mato Grosso, Braz.	2.7	3.0	3.0	2.0	

1 Rating from 0 to 5 in comparison with control accession CIAT 728: 0 = dead plants; 1 = much less and 2 = less vigor than control; 3 = same vigor as control; 4 = more and 5 = much more vigor than control.

Table 5.

Forage legume germplasm under preliminary evaluation in CIAT-Quilichao during 1978.

Species	No. of accessions
Stylosanthes capitata	87
Stylosanthes bracteata	20
Zornia spp.	231
Desmodium spp. (erect browse types)	24
Desmodium barbatum	129
Aeschynomene spp.	36
Centrosema spp	43
Macroptilium/*Vigna* spp.	62
Calopogonium spp.	82
Galactia spp.	79
Pueraria phaseoloides	11
Total	804

Table 6.

Specimens of tropical forage plants, savanna vegetation and weeds in CIAT's reference herbarium, as of November 1, 1978.

	No. of specimens
CIAT forage germplasm	
Gramineae	51
Leguminosae	194
Savanna vegetation	
Gramineae and *Cyperaceae*	35
Leguminosae	55
Other families	60
Weeds	96
Total	491

affected by fungal and bacterial diseases. Furthermore, during 1978 new preliminary evaluation plots with a total of 804 accessions from 10 genera, were established (Table 5). In these experiments, special emphasis was given to genera and species which already have been identified as promising for the Beef Program's target area.

Reference Herbarium

Development of a reference herbarium continued with the specimen collection increasing to 491 exsiccates through October 1978 (Table 6). A major acquisition was the weeds collection previously held by CIAT's former Weed Control Section.

Plans for 1979 include decreased field collecting and concentration on characterizing and cataloguing existing accessions. The rate of collecting is expected to increase again in 1980, particularly in Africa and Southeast Asia.

FORAGE BREEDING

The objective of the Forage Breeding Section is to breed for specific combinations of desirable characteristics not likely to be obtained via plant exploration. Initial crossing was aimed at: (1) recombining certain desirable characteristics of *Stylosanthes capitata;* and, (2) introducing or strengthening acid soil tolerance in *Centrosema, Leucaena* and *Panicum maximum.*

Stylosanthes capitata

Twelve promising ecotypes of *S. capitata* were selected in conjunction with the legume agronomists for inclusion in the half-diallel crossing program. The ecotypes represent a range of vigor, maturity, seed production and adaptation. The aim is to combine high yield and seed production, ability to grow in the dry season, active nodulation, high anthracnose and stemborer resistance and adaptability to soils with pH values from 4.2 to 6.0. It is of interest that central Brazilian ecotypes appear intolerant of higher pH's, while the Venezuelan ecotypes used in the program are tolerant.

Only a few of the diallel combinations (about 6 of 78) have not been obtained by crossing as yet. The F_1 plants are being raised and some are already producing F_2 seed. By February 1979 it is hoped that quantities of F_2 seed of all diallel combinations will be available for planting out populations at CIAT-Quilichao. The plant populations will be oversown with *Andropogon gayanus* and selections will be made under periodic grazing.

Centrosema pubescens

Eight diverse ecotypes of *Centrosema* (one proved not to be *Centrosema pubescens)* were selected for vigor and high tolerance in a pot experiment with Carimagua Oxisol (pH 4.5, 90% Al saturation). These are now entered in a half-diallel crossing program to combine vigor and tolerance to grazing (in conjunction with a suitable grass), insects and diseases, with high tolerance to very acid soils, as well as adaptability to soils of higher pH. With the aim of overcoming the slow early growth of *Centrosema,* active early nodulation and efficient P uptake will be important selection criteria.

A number of the crosses have been achieved and F_2 seeds should be available in February 1979 for plant populations to be grown at CIAT-Quilichao and evaluated in conjunction with *A. gayanus* under periodic grazing.

Leucaena

Populations of fertile progenies from several backcrosses between *Leucaena leucocephala* (cv. Cunningham) with 104 chromosomes and *Leucaena pulverulenta* with 56 chromosomes were screened for vigor and tolerance in a pot experiment with Carimagua Oxisol. A number of intolerant plants were retained as control material, and a range of promising well-nodulated plants with vigorous root development selected. Six *L. leucocephala* varieties were also grown in the Carimagua Oxisol.

All the above *Leucaena* plants are now growing at CIAT-Palmira for studies of edible forage and seed production, mimosine levels and chromosome numbers. An important aim is to obtain sufficient quantities of seed for screening large populations for acid tolerance in a sand culture system. It is hoped that some of the vigorous plants from the preliminary screening in the Carimagua Oxisol will combine high edible forage production with low mimosine levels and high tolerance to acid soils. Selected lines from this material will be grown at CIAT-Quilichao, Carimagua and Brasilia.

Desmodium ovalifolium

Desmodium ovalifolium flowers need to "trip" to form seed, so it is possible its plant populations vary to a degree. A preliminary screening of a large *D. ovalifolium* population for acid tolerance is in progress in the sand culture system.

A number of *Desmodium heterocarpon* introductions have been obtained for crossing studies. It may be possible to incorporate greater drought resistance and better seed production in the current CIAT 350 accession of *D. ovalifolium* which associates so well with *Brachiaria decumbens*. Breeding could markedly increase the range of adaptability of this valuable legume and adaptation to the Brazilian Cerrado would be very important.

Panicum maximum

Sexual plants propagated from a selection made by Dr. Wayne Hanna, Coastal Plain Research Station, Tifton, Georgia, U.S.A., have been planted at CIAT-Palmira. In addition, several plant populations derived from crossed seed from the same station are available. Numbers of plants of each of CIAT's *P. maximum* introductions are also established in the block.

Several crosses are being made using the better apomictic *P. maximum* introductions (e.g., Makueni) as the pollen parents and the sexual material as the females. Good quantities of crossed seed are being produced and germination of some will be attempted soon. *P. maximum* seed has a dormancy period of several months but it may be possible to break this dormancy by germinating in Petri dishes with 0.2% KNO_3. Plant populations from the crosses will be grown out for: (1) selection for tolerance to acid conditions (low pH, high Al, low Ca, low P) in the sand culture system; (2) selection for drought tolerance and dry season growth; and (3) selection for disease resistance. Once a superior apomictic plant has been identified it is "fixed" because of the nature of apomixis. It can then be multiplied and evaluated without delay.

A number of selections made from the populations raised from the crossed seed from the Coastal Plain Station are already being evaluated for drought resistance, etc. at Carimagua, in collaboration with the Grass Agronomy Section. A cytological method for rapidly identifying sexual and apomictic plants in hybrid populations is being investigated. This will obviate the need for time-consuming progeny testing.

LEGUME AGRONOMY

During 1978, ecotype evaluation of promising legume germplasm continued at Carimagua and CIAT-Quilichao, and started in Brasilia, with the arrival of the Forage Agronomists at the Cerrado Center.

At Carimagua, as a result of systematic evaluation of 177 accessions in introduction plots during 1976-77, 32 lines were selected for observations under grazing (Table 7). Those accessions which had shown outstanding promise, were sown in larger areas. A total of 12 ha were established with the selected lines in associations with two grasses *(Brachiaria decumbens* and *Andropogon gayanus);* grazing started in December 1977, using a flexible grazing system with an average stocking rate of 3.5 animals/ha.

Data taken during nine months in this grazing area as well as in parallel cutting experiments confirm *Zornia latifolia* (CIAT 728), *Desmodium ovalifolium* (CIAT 350) and several *Stylosanthes capitata* accessions (CIAT 1019, 1078, 1097, 1315, 1405), as highly promising legumes for conditions of the Colombian Llanos Orientales and similar areas.

Zornia latifolia

Out of five *Zornia* spp. accessions, the late-flowering ecotype CIAT 728 *(Z. latifolia)* proved the most productive, in terms of both dry matter and protein production (Table 8). The superiority of this accession was not only evident during the establishment phase but also during and after grazing (Table 9). Active growth during the dry season with abundant production of nutritionally valuable leaves is one of its most important characteristics (Fig. 9). Occasionally, insect and disease attacks produced severe defoliation, but plants recuperated completely within a few days.

Desmodium ovalifolium

After a somewhat slow initial growth, *D. ovalifolium* 350 has a great potential of producing dry matter during the rainy and early dry seasons, outyielding other promising species such as *S. capitata*. Later in the dry season, however, production of *D. ovalifolium* drops sharply due to defoliation (Fig. 10). This lack of resistance to very severe drought limits its potential to areas with a dry season not longer than three to four months. However, regrowth and production of nutritious dry matter starts immediately after the onset of the rainy season, and regrowth is faster than in the case of *S. capitata* (Fig. 11).

Due to its stoloniferous growth habit, *D. ovalifolium* is aggressive enough for association with stoloniferous prostrate grasses such as *Brachiaria decumbens* which is known to be legume suppressing. Figure 12 shows that under cutting, it is possible to maintain stable grass/legume mixtures of *D. ovalifolium* and *B. decumbens*. In mixtures with a tufted grass such as *A. gayanus*, the persistence of *D. ovalifolium* indicates a good shade tolerance. Under grazing, however, due to an apparently higher palatability of *A.*

Table 7.

Evaluation of legume accessions in introduction plots at Carimagua.[1] (Summary of selected lines).

Species	CIAT No.	Origin	Adaptation to Soil Stress	Dry Season Performance	Self-Propagation	Disease Tolerance	Pest Tolerance	Seed Production	Productivity	Promising Status[2]
Stylosantes										
humilis	1222	Maranhão, Braz.	2	3	4	1	3	4	2	b
	1303	Maranhão, Braz.	2	1	4	1	3	4	2	b
humata	147	Guárico, Ven.	2	2	3	1	1	2	2	b
	1040	Magdalena, Col.	2	3	4	3	3	2	4	b
capitata	1007	CPI, Braz.	2	3	3	4	4	2	3	b
	1019	Minas Gerais, Braz.	4	3	4	4	4	4	2	a
	1078	Bahía, Braz.	4	4	2	2	3	2	2	a
	1097	Bahía, Braz.	2	4	2	2	3	2	2	a
	1315	Maranhão, Braz.	2	3	4	2	2	4	2	a
	1318	Maranhão, Braz.	2	3	4	2	2	4	2	a
	1323	Maranhão, Braz.	2	3	4	4	2	4	2	a
	1325	Maranhão, Braz.	2	3	2	2	3	2	2	b
	1328	Maranhão, Braz.	2	3	4	2	2	2	2	a
	1338	Piauí, Braz.	2	3	4	2	2	4	2	a
	1339	Piauí, Braz.	2	3	4	4	2	4	2	a
	1342	Piauí, Braz.	2	2	4	2	2	4	2	a
	1405	Mato Grosso, Braz.	2	3	2	2	2	2	3	b
bracteata	1281	Dist. Fed., Braz.	2	3	2	2	2	4	3	b
sp.	1093	Bahía, Braz.	2	4	3	2	2	3	1	b
Desmodium										
barbatum	3040	Maranhão, Braz.	4	2	1	2	2	2	2	b
	3063	Cauca, Col.	4	2	1	2	2	2	2	b
canum	367	Unknown	3	3	3	2	4	2	3	b
	388	Bahía, Braz.	3	2	3	2	4	2	3	b
	3005	Guiana Fr.	3	2	1	4	4	2	3	b
	3033	Maranhão, Braz.	2	2	3	2	2	2	3	b
	3042	Monagas, Ven.	3	2	4	2	4	3	1	b
ovalifolium	350	Malaysia	2	2	4	4	4	1	4	a
Zornia										
latifolia	728	Meta, Col.	4	4	4	3	3	2	2	a
sp.	802	Brazil	4	1	4	2	4	2	3	b
	883	Goiás, Braz.	4	3	4	2	2	2	2	b
	897	Mato Grosso, Braz.	4	3	4	2	2	2	2	b
Macroptilium sp.	535	Barinas, Ven.	3	4	3	3	2	4	4	b

1 Rating system: 4 = very positive to factor; 3 = positive; 2 = intermediate; 1 = negative.
2 Status: a = very promising; b = promising.

Table 8.

Dry matter yields, protein content (%N x 6.25) and protein yields of five *Zornia* accessions in Carimagua. (Six months after sowing.)

CIAT No.	DM (kg/ha)	Protein (%)	Protein (kg/ha)
728	4917	16.3	801.5
883	3564	10.9	388.5
897	3389	11.4	386.3
802[1]	1883	9.2	173.2
814[1]	617	9.8	60.5

1 Annual ecotypes.

gayanus during the rainy season, *D. ovalifolium* tends to dominate the grass. With *B. decumbens*, however, a stable grass/legume mixture was maintained under grazing (Table 10).

Of six *Desmodium* accessions tested in mixed swards with *B. decumbens*, *Brachiaria humidicola*, *A. gayanus* and *Panicum maximum* at CIAT-Quilichao, *D. ovalifolium* 350 was the most productive and most persistent legume, mainly in association with the prostrate *Brachiaria* spp. accessions (Figs. 13 and 14). In mixtures with tufted grasses *(Andropogon* and *Panicum)*, yield and persistence of CIAT accession 3063 of *D. barbatum* (a species native to the Quilichao area) were about equal to those of *D. ovalifolium*. In all cases the lowest yielding species was *D. scorpiurus* which disappeared completely.

Stylosanthes capitata

According to differences in flowering time, the two previously identified *S. capitata* types (an early-flowering ecotype from central Brazil and a late-flowering ecotype from the coastal region of Bahia) performed differently during the dry season (Fig. 10). Mid-season ecotypes were also identified.

Whereas the early flowering ecotype CIAT 1019 stops growing at the onset of the dry season and drops its seed heads (which at the end of the rainy season represent 60-70% of the total dry matter), the late-flowering CIAT 1078 continues growing actively and its leaves and seed heads represent a valuable source of protein during the dry season (Fig. 11).

Grazing experiments showed that the high seed production potential of the early and mid-season flowering *S. capitata* types (CIAT 1019 and CIAT 1315, respectively), through spontaneous generation of large

Table 9.

Available forage of five *Zornia* accessions under grazing in Carimagua.

CIAT No.	Dec. 1977 (before first grazing)	Sept. 1978 (after last grazing)	Oct. 1978 (after 4 weeks resting period)
	Dry matter (kg/ha)		
728	4917	848	1990
883	3564	203	516
897	3388	425	723
802[1]	1883	493	1493
814[1]	617	-	-

1 Annual ecotypes.

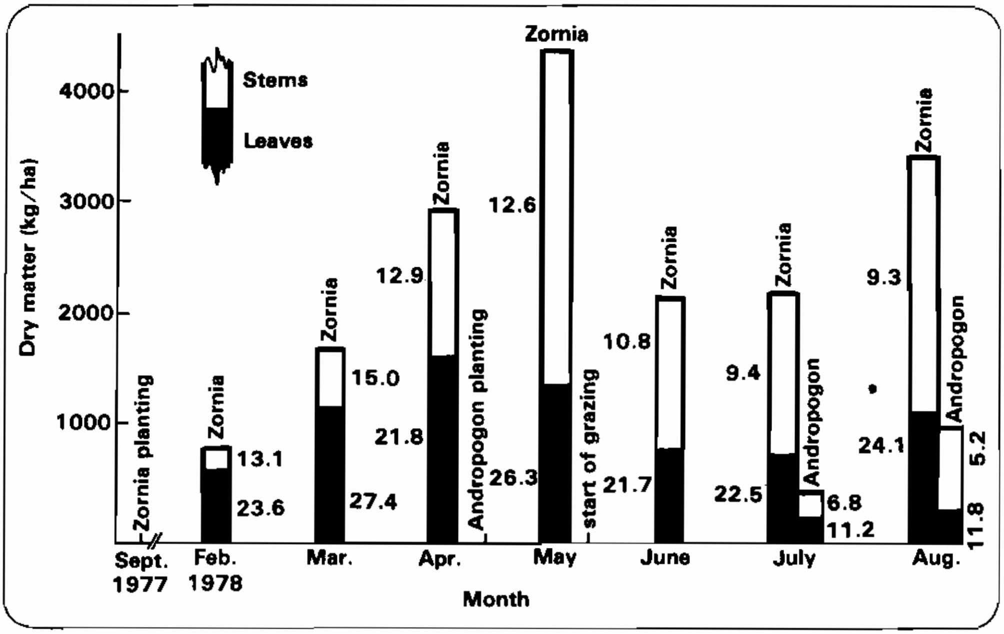


Figure 9. Dry matter yields of leaves and stems of *Zornia latifolia* CIAT 728 associated with *Andropogon gayanus* during establishment at Carimagua. (Figures along bars represent protein percentages.)

quantities of seedlings, represents an important self-propagation mechanism of these accessions (Table 11), thus contributing to a stable grass/legume mixture.

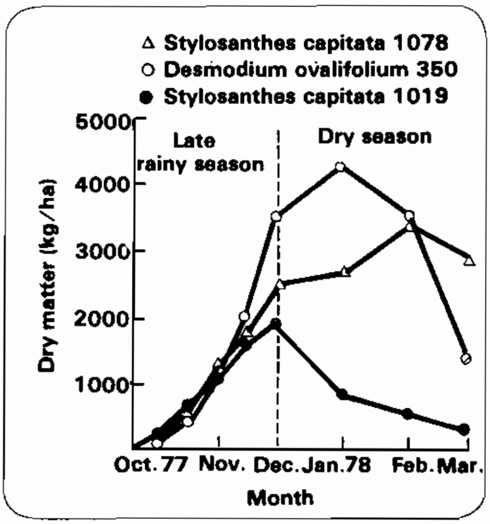


Figure 10. Dry matter production of three selected legume accessions in pure swards, during eight sequential growth periods after a standardization cut in the late rainy season at Carimagua.

Although this seems to be true also for an association with *B. decumbens* (Fig. 15),

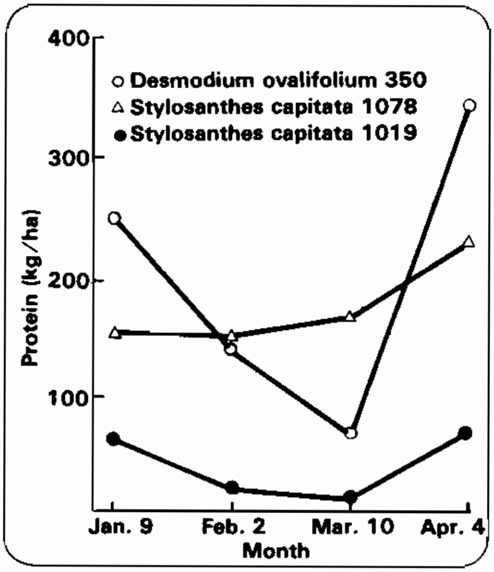


Figure 11. Changes in protein yield of inflorescences/seed heads and leaves of three selected legumes in a pure sward during the dry season (January-March) and at the beginning of the rainy season (April) at Carimagua.

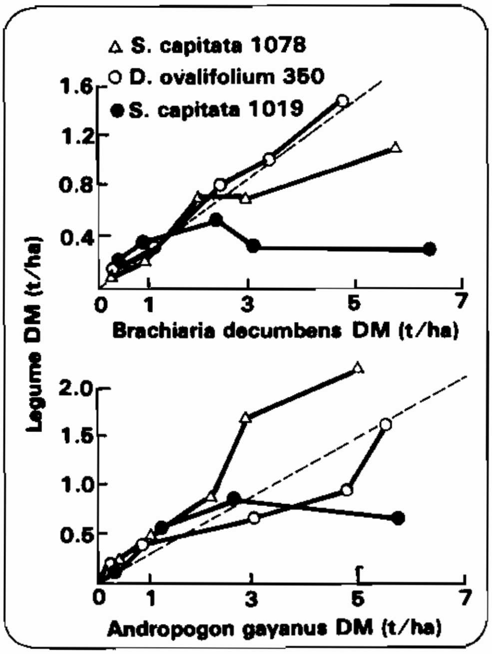


Figure 12. Relationship between three selected legume accessions and two grasses *(Brachiaria decumbens* and *Andropogon gayanus)* in mixed swards at Carimagua.

further conclusions can only be drawn after evaluating the persistence of the new plant generation. To date, observations indicate that maintaining a stable mixture with *A. gayanus* under grazing is feasible.

In connection with its high seed production potential, *S. capitata* has another characteristic. Due to hard seed coats, cattle apparently cannot digest all the seeds and these are dispersed through the feces (Fig. 16).

On the basis of these data, *Z. latifolia* CIAT 728, *D. ovalifolium* CIAT 350, and *S. capitata* CIAT 1019, 1315, 1405, 1078 and 1097 (the latter also a late-flowering type from Brazil) have been included in Category 4 (animal production experiments) of the Beef Program's list of promising legume germplasm (Table 12).

Evaluations of new germplasm (material collected or introduced in 1977) were initiated by establishing space-planted introduction plots with a total of 350 new accessions. After initial observations of their adaptation to the Carimagua environment, these accessions will be grazed.

Stylosanthes guianensis

Species evaluation in mixed swards under cutting and grazing continued in

Table 10.

Available forage of *Desmodium ovalifolium* 350 and two associated grasses *(Andropogon gayanus* and *Brachiaria decumbens)* under grazing in Carimagua.

Species	Dec. 1977 (before first grazing)	Jan. 1978 (after first grazing)	Mar. 1978 (end of dry season)	Sept. 1978 (after last grazing)
	Dry matter (kg/ha)			
D. ovalifolium	3639 (59)[1]	1854 (77)	680 (68)	2660 (74)
A. gayanus	2527	541	318	929
Total	6166	2395	998	3589
D. ovalifolium	2147 (28)	1107 (45)	853 (41)	2390 (56)
B. decumbens	5429	1332	1196	1845
Total	7576	2439	2049	4235

1 Numbers in parentheses are the percentage legume dry matter in the sward.

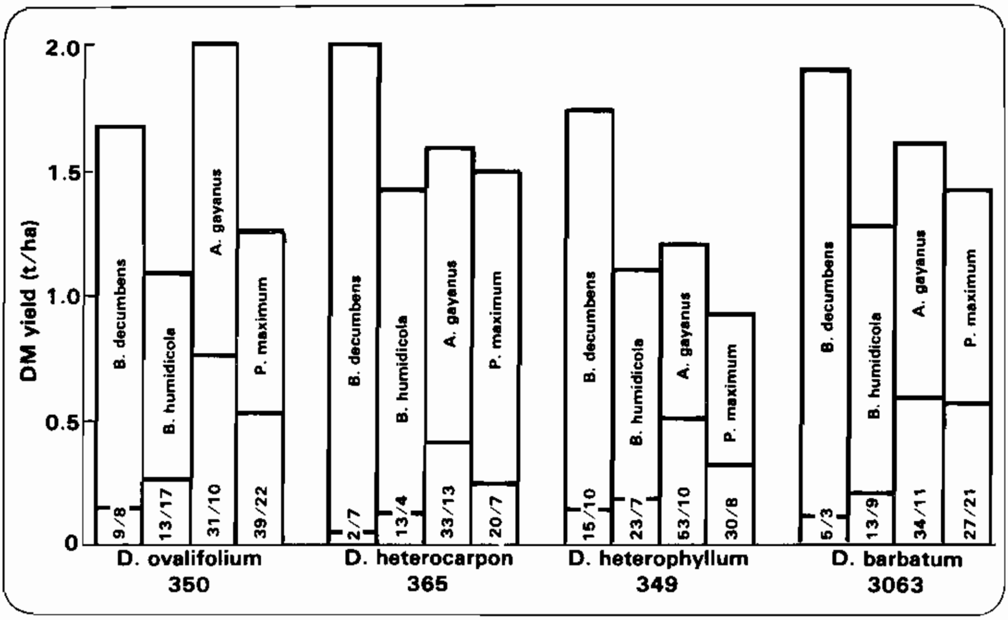


Figure 13. Dry matter yields (means of four cuts) of four *Desmodium* species in mixed swards with four grasses under a six-week cutting regime at CIAT-Quilichao. (Figures in bases of bars are the percentage legume at first and last cuts.)

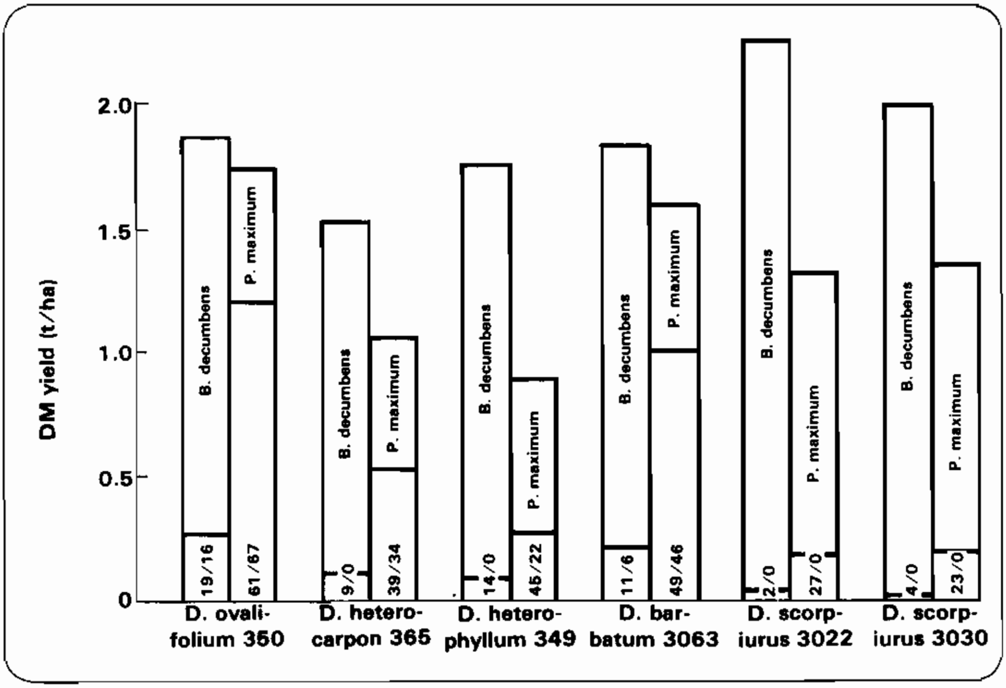


Figure 14. Dry matter yields (means of four cuts) of six *Desmodium* accessions in mixed swards with *Brachiaria decumbens* and *Panicum maximum* under a six-week cutting regime at CIAT-Quilichao. (Figures in bases of bars are the percentage legume at first and last cuts.)

Table 11.

Self-propagation of three *Stylosanthes capitata* ecotypes associated with two grasses under grazing in Carimagua.

S. capitata accession	Associated with	March 1978	June 1978	Sept. 1978
		(seedlings/m²)		
1019	*Brachiaria*	2341	165	135
(early)	*Andropogon*	1188	187	141
1315	*Brachiaria*	266	116	68
(midseason)	*Andropogon*	140	56	35
1078	*Brachiaria*	0	0	5
(late)	*Andropogon*	0	0	8

CIAT-Quilichao and El Limonar (near Quilichao) with germplasm that had previously been identified as potentially promising for the Quilichao environment.

The grazing trial with two *Stylosanthes guianensis* accessions (CIAT 136 and 184) in mixtures with *B. decumbens, A. gayanus, Hyparrhenia rufa* and *P. maximum* entered its third year (second year of grazing). Since the first two years were extremely dry, anthracnose had not been important. In 1978, however, there was a severe outbreak of anthracnose. Furthermore, as *S. guianensis* plants grew older, stemborer infestations increased considerably. Mainly due to these factors,

Figure 15. Self-propagation of *Stylosanthes capitata* through seedlings in a grazed mixture with *Brachiaria decumbens* at Carimagua.

Figure 16. Self-propagation of *Stylosanthes* through animal feces at Carimagua.

Table 12.

CIAT forage legume accessions classified as promising Categories 4 and 3 (materials for animal production and grazing pressure trials, respectively), as of November 1, 1978.

Category	Species	CIAT No.	Selection criteria (blanks represent unknown)												
			Adaptation to Carimagua	Adaptation to Quilichao	Auto-propagation	Disease tolerance	Insect tolerance	N fixation potential	Seed production potential	Water stress tolerance	Al and low P tolerance	Nutritional quality	Ease of management	Animal production	Persistence under grazing
4	*Zornia latifolia*	728	+	+	+	+	+	+	+	+	+	+			
	Desmodium ovalifolium	350	+	+	+	+	+	+	-	+	+				
	Stylosanthes capitata	1019	+	+	+	+	+	+	+	+	+				
	Stylosanthes capitata	1078	+	+	+	+	+	+	+	+	+				
	Stylosanthes capitata	1097	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1315	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1405	+	+	+	+	+		+	+	+				
	Pueraria phaseoloides	9900	(+)[1]	+	-	+	+	+		+	+				
3	*Centrosema* hybrid 17-33	438	-	+		+	+	+	+	+	+	+			
	Desmodium heterophyllum	349	(+)	+	+	+	+	+	+	-		+			
	D. (= Codarocalyx) gyroides	3001	(+)	+		+	+		+	+					
	Stylosanthes hamata	147	(+)	+	+	-	-		+	+	+				
	Stylosanthes capitata	1318	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1323	+	+	+	+	+		+	+					
	Stylosanthes capitata	1325	+	+	+	+	+		+	+					
	Stylosanthes capitata	1342	+	+	+	+	+		+	+					

1 (+) Adapted at a higher soil fertility level.

plants of both accessions tended to disappear. This tendency was somewhat stronger for CIAT 136 than for CIAT 184, and more accentuated in mixtures with *B. decumbens* and *A. gayanus* than with the other two less vigorous grasses (Fig. 17). Consequently, further evaluations of these accessions have been discontinued in areas where anthracnose and stemborer are important. It is also important to note that it took two grazing years to determine the persistence of these legumes.

This finding in effect downgraded *S. guianensis* from the Program's promising categories list but does not mean that the species is discarded as such. Future work with this species will concentrate on the late-flowering, fine-stemmed ecotypes which have shown good anthracnose and drought tolerance (CIAT Annual Report, 1977, p. A-22). According to preliminary evaluations, these latter *S. guianensis* types are also showing promise at the Cerrado Center.

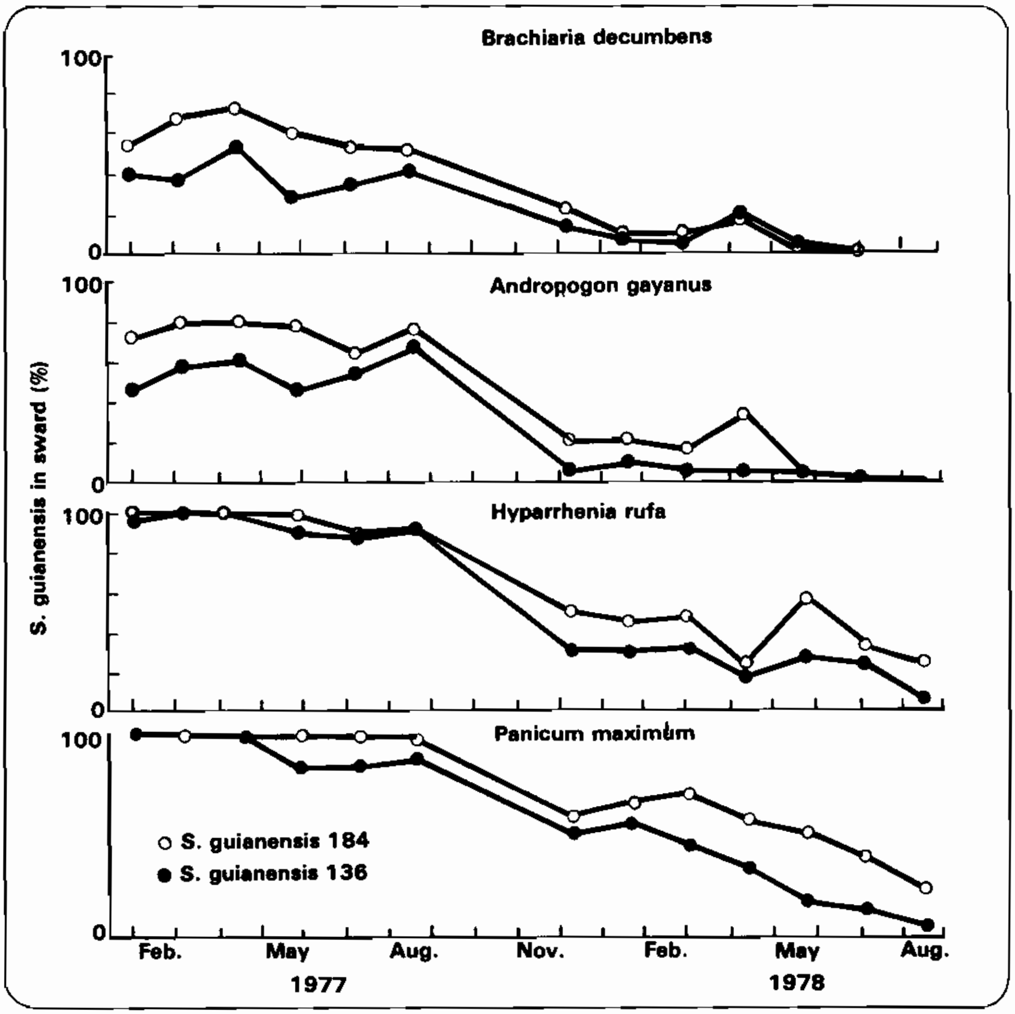


Figure 17. Botanical composition of two *Stylosanthes guianensis* spp. accessions in association with four grasses during the first two years under grazing at El Limonar (near CIAT-Quilichao).

Centrosema hybrid 438

The *Centrosema* grazing experiment, with five accessions, entered its second year under grazing in mixture with *A. gayanus* at El Limonar. With the exception of the low-yielding local accession CIAT 456, no differences were observed between the tested lines. Although the percentage of *Centrosema* diminished considerably during the second year of grazing, mixtures tended to stabilize at a low value of 10% botanical composition (Fig. 18).

An interesting finding was that *Andropogon gayanus,* when associated with *Centrosema* had higher protein contents than when associated with *S. guianensis* (Fig. 19). A similar tendency also was evident in a cutting experiment where *Centrosema* had considerably higher protein contents than *Z. latifolia* and *D. ovalifolium* (Table 13).

In another cutting experiment, in which productivities of three *Centrosema* lines in association with *A. gayanus* and *P. maximum* were compared, a mixture of the hybrids 438 and 442 outyielded the other two accessions in either association (Table 14).

Browse Legumes

Species with an erect growth habit, such as *Desmodium (= Codarocalyx) gyroides* 3001 and *Desmodium* sp. 3019 have significant potential as browse plants. In a

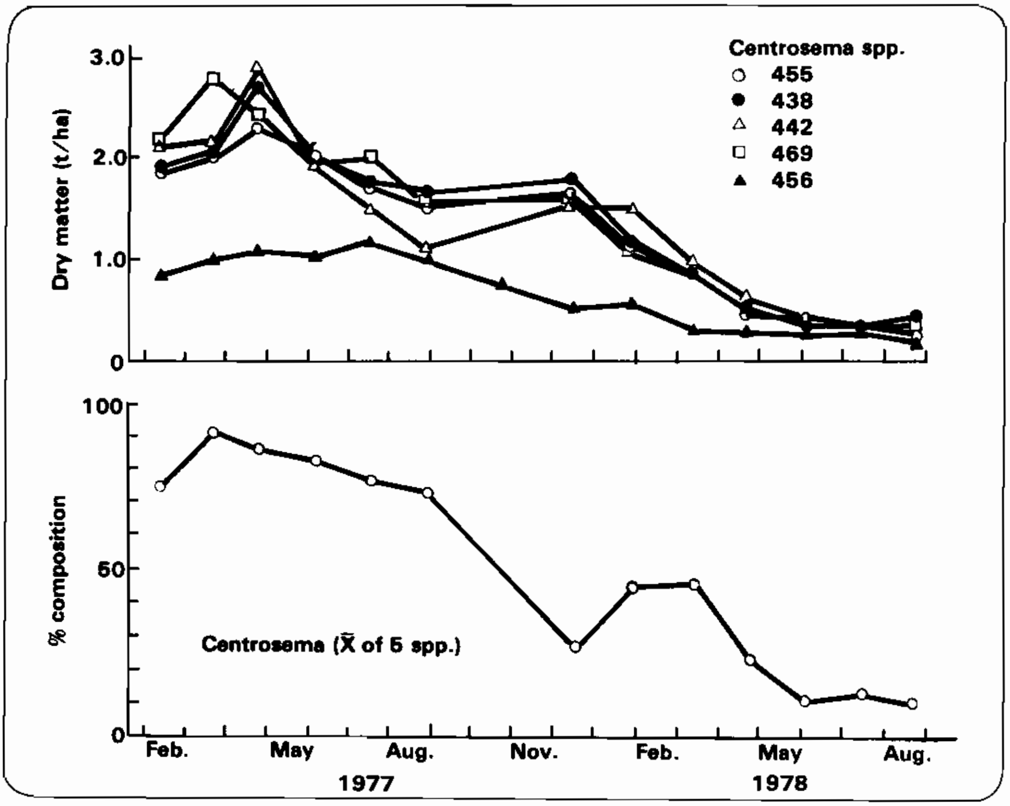


Figure 18. Presentation yields and botanical composition of five *Centrosema* spp. accessions grown with *Andropogon gayanus* during the first two years under grazing at El Limonar (near CIAT-Quilichao).

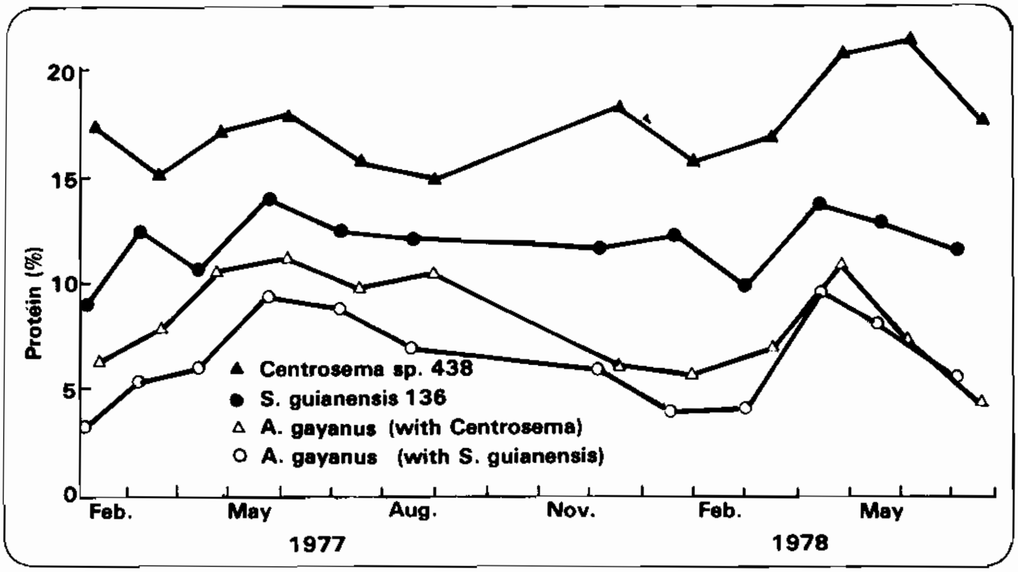


Figure 19. Protein content of *Centrosema* spp., *Stylosanthes guianensis* and *Andropogon gayanus* under grazing at El Limonar (near CIAT-Quilichao).

cutting experiment where no major effects of different cutting heights and intervals were observed at CIAT-Quilichao, *D. gyroides* 3001 yielded considerably more dry matter but only slightly more protein than 3019. Over a 40-week period, both species produced very high levels (1000-1500 kg) of protein/ha (Fig. 20).

The leguminous shrub *Leucaena* is potentially capable of producing high yields of dry matter and crude protein, far in excess of the best herbaceous species. However, previous experience with this plant has shown it to be of poor productivity on acid soils. Consequently, large quantities of lime are necessary for establishment and maintenance. As soon as seed of *Leucaena leucocephala* x *Leucaena pulverulenta* populations from

Table 13.

Protein content (%N x 6.25) of three legumes in association with *Andropogon gayanus* at CIAT-Quilichao. (Means of 6 cuts.)

Accession	% Protein of regrowth after		
	4 weeks	6 weeks	8 weeks
Desmodium ovalifolium 350	13.0	11.8	12.1
Zornia latifolia 728	13.0	15.5	18.8
Centrosema sp. 845	20.5	21.6	22.1
Andropogon gayanus 621			
growing with:			
D. ovalifolium	11.3	9.2	8.1
Z. latifolia	11.5	9.4	8.1
Centrosema sp.	12.5	9.6	10.5

Table 14.

Dry matter production of three *Centrosema* lines in mixture with *Andropogon gayanus* and *Panicum maximum* at CIAT-Quilichao. (Means of 5 cuts).

Mixture	Dry matter yield (kg/ha)			
	Grass	Legume	Total	% legume
A. gayanus + CIAT 438/442	1244	258	1502	17
A. gayanus + CIAT 845	1188	148	1336	11
A. gayanus + CIAT 413	1463	110	1573	7
P. maximum + CIAT 438/442	775	357	1132	31
P. maximum + CIAT 845	714	189	903	21
P. maximum + CIAT 413	813	212	1025	21

the Forage Breeding Section are available, the CIAT Forage Agronomist at the Cerrado Center will begin research to select acid-tolerant, vigorous, low-mimosine lines. Hopefully, this new material will be available for evaluation on the Cerrado during the 1979-80 rainy season. Meanwhile, an attempt will be

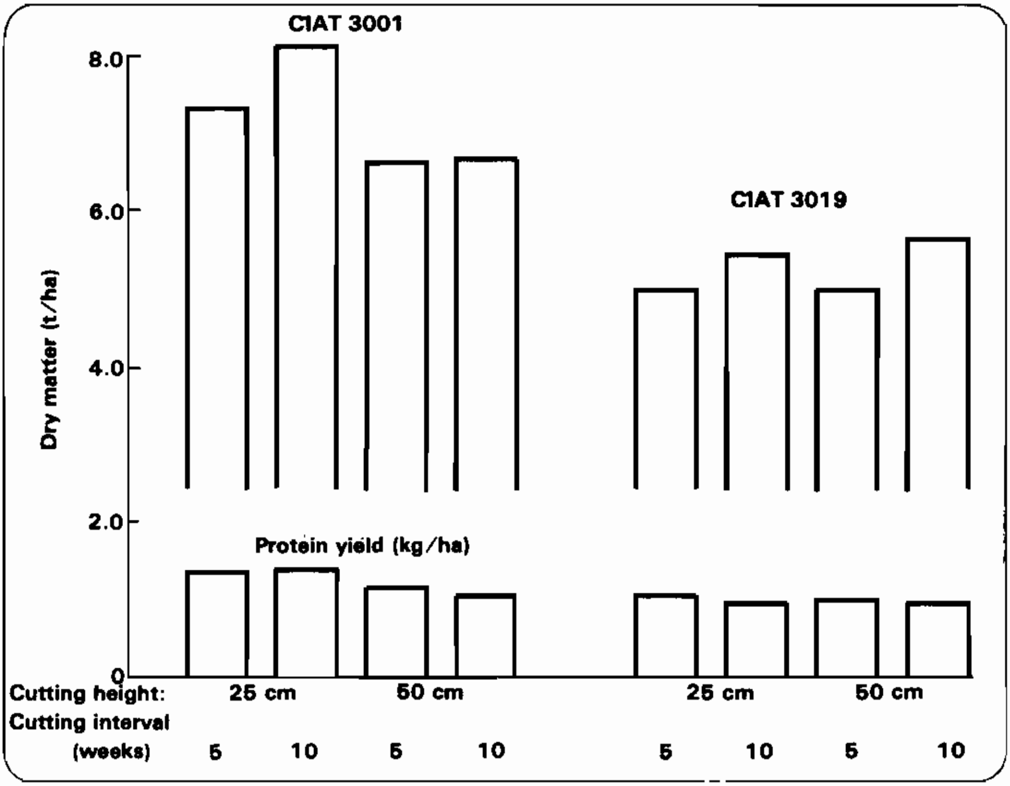


Figure 20. Total yields of dry matter and protein of two *Desmodium* browse-type species under different cutting regimes, over 40 weeks, at CIAT-Quilichao.

made to improve the productivity of existing cultivars utilizing a combination of inoculation/pelleting techniques. Three important *Leucaena* cultivars, Peru, Cunningham, and Giant Hawaii, will be inoculated with new *Rhizobium* strains collected on acid soils and pelleted with rock phosphate or lime. The present commercial *Rhizobium* strains NGR 8 and CB 81 will be used as controls. The most promising treatment or treatments will become the controls against which new lines of *Leucaena* will be screened.

In the future, legume bacteriology studies will be extended to include field testing of new *Rhizobium* strains for herbaceous legumes. However, first it will be necessary to identify the promising species before attempting to increase productivity still further by inoculation and pelleting techniques.

New Activities

Systematic evaluation of Category 2, 3 and 4 germplasm was initiated at the Cerrado Center in late 1978. A total of 352 accessions of Category 2 material of *Stylosanthes*, *Aeschynomene*, *Calopogonium*, *Macroptilium*, *Centrosema*, *Galactia*, *Zornia*, *Pueraria*, *Desmodium*, *Teramnus*, *Vigna*, *Soemmeringia*, and *Leucaena* were planted in triple replicates. Two replicates (one grazed) mixed with *A. gayanus* will be sited on a Dark Red Latosol (Oxisol), and one replicate, on a Red-Yellow Latosol (also an Oxisol). These two soil types represent 58% of all Cerrado soils. A similar program with grasses will begin during the 1979-80 rainy season when CIAT will have expanded its collection of *Panicum* and *Andropogon* ecotypes.

Fourteen highly promising legumes that have performed well will be evaluated under grazing as Category 3 materials. These include an anthracnose-resistant *S. guianensis*, four lines of *S. capitata*, *Stylosanthes bracteata*, two lines of *Centrosema*, *D. ovalifolium* and *Z. latifolia*. Where possible, Brazilian commercial varieties will be used as controls. These activities mark the initiation of the Beef Program's third major research site in germplasm evaluation, at the Cerrado Center.

New experiments established during 1978 in CIAT-Quilichao included a *Macroptilium atropurpureum* evaluation project, selected for acid soil tolerance in Australia and planted with *A. gayanus*.

Germplasm Classification

The germplasm classification scheme developed by the Beef Program's Germplasm Committee essentially followed the selection criteria established in 1977 (CIAT Annual Report, 1977, p. A-15), with two modifications. These include: (1) the elimination of the selection criteria "Adaptation to medium soil fertility" and "Adaptation to high soil fertility", and, (2) the addition of a new criterion "Autopropagation" (AP). Based on experiences with germplasm evaluation under grazing, this plant characteristic was considered an important part of a forage legume's ability to survive and/or to spread under grazing in mixtures with grasses. Autopropagation may be due to aggressive stoloniferous growth or free-seeding habit coupled with ready germination of fallen seeds or seeds passed through animals' digestive tracts.

With data expected from the Program's regional trials and work at Brasilia, major changes in the classification scheme will be necessary to account for environmental differences between the various sites. Plans for 1979 include the quantification and sub-division of several criteria.

Present status of promising germplasm included in the two most advanced categories (Category 3 — grazing pressure trials, and Category 4 — animal production trials) is shown in Table 12. Blanks in the selection criteria for Category 4 germplasm (in which *Pueraria phaseoloides* is included as a commercial control) refer mainly to "Nutritional quality" and "Nitrogen fixation potential", which need to be quantified. However, considerable liveweight gains obtained during the various grazing experiments, and in-field observations on nodulation, indicate that these factors are not limiting. If Category 4 germplasm continues to show good persistence during present grazing experiments described in the Pasture Utilization Section, pre-cultivar release (Category 5) will be considered in the near future.

At this point it is not possible to predict which accessions of the three most promising species — *Z. latifolia, D. ovalifolium* and *S. capitata* — will be the best under specific environmental conditions. Work planned for 1979 at the three main research sites, and throughout the target area via regional trials, are expected to provide much of the additional information needed before the technology transfer process begins.

GRASS AGRONOMY

The major research activities of the Grass Agronomy Section during 1978 were: (1) to determine the drought tolerance, response to defoliation, response to fertility, and nutritional quality of selected promising accessions; (2) to classify grass accessions according to their relative promise; and, (3) to develop techniques to facilitate future research activities. Criteria for classifying grass accessions are given in Table 17, page B-43. Table 18, page B-44 shows the current classifications based on 1978 results reported in this section.

Drought Tolerance

The drought tolerance of 17 accessions in Categories 3 and 4 were studied in CIAT-Quilichao. Figure 21 shows the dry matter poduction of the 12 most important ones averaged across eight fertility treatments at the end of the April-June rainy season and early and late in the June-September dry season. Erect species were generally more productive than prostrate species early in the dry season, probably because of their reduced water use due to lower mean leaf area indices (LAI). Mean LAI's were lower because more drastic clipping reduced the LAI's of erect species (see Fig. 27).

Figure 22 shows that although the soil was at field moisture capacity (FMC) on May 11 (following heavy rains), by the end of the first growth period (June 15), *Brachiaria decumbens* 606 had reduced the soil profile water content of the top 2 m by 62 mm, and *Andropogon gayanus* 621 had reduced it 44 mm. By the end of the second growing period (August 2), *B. decumbens* had reduced the profile water content a total of 141 mm, and *A. gayanus,* a total of 101 mm. By September 7, the difference in profile water content was calculated to be 33 mm, 187 mm below FMC for *B. decumbens* and 154 mm below FMC for *A. gayanus.*

Table 15 gives typical values of plant water potential and leaf diffusive resistance on the abaxial surface measured in *A. gayanus* 621, *B. decumbens* 606, *Panicum maximum* 604 and *Hyparrhenia rufa* 601 during the June-August dry season in

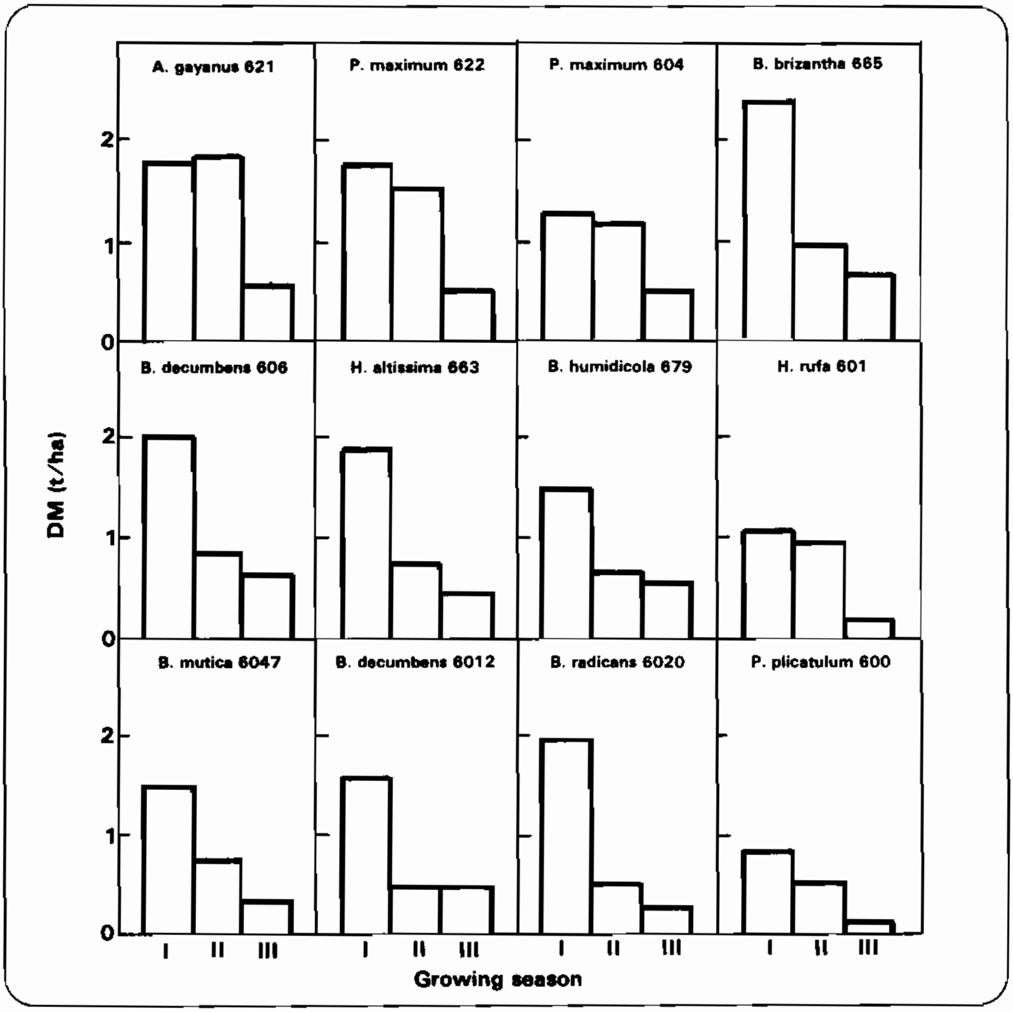


Figure 21. Dry matter (DM) yield of 12 grass accessions averaged across eight fertility treatments and cut at six-week intervals at the end of the April-June 1978 rainy season (I), and early (II) and late (III) in the June-September 1978 dry season, at CIAT-Quilichao.

CIAT-Quilichao. Although differences were not always significant, in both CIAT-Quilichao and Carimagua, *A. gayanus* and *P. maximum* normally maintained a higher plant water potential relative to *H. rufa* and *B. decumbens*. In contrast, *A. gayanus* and *B. decumbens* tended to maintain lower diffusive resistance values than the other two species.

These data suggest that the four species do not close their stomata at the same level of plant water potential. This is shown in more detail in Figure 23. The diffusive resistance of the abaxial leaf surface appears to be most sensitive to plant water potential in *P. maximum*, where stomata always closed before plant water potential reached -20 bars. The diffusive resistance of *B. decumbens* is apparently the least sensitive to low leaf water potential since relatively low abaxial leaf water potentials were observed even when plant water potential approached -30 bars. *A. gayanus*

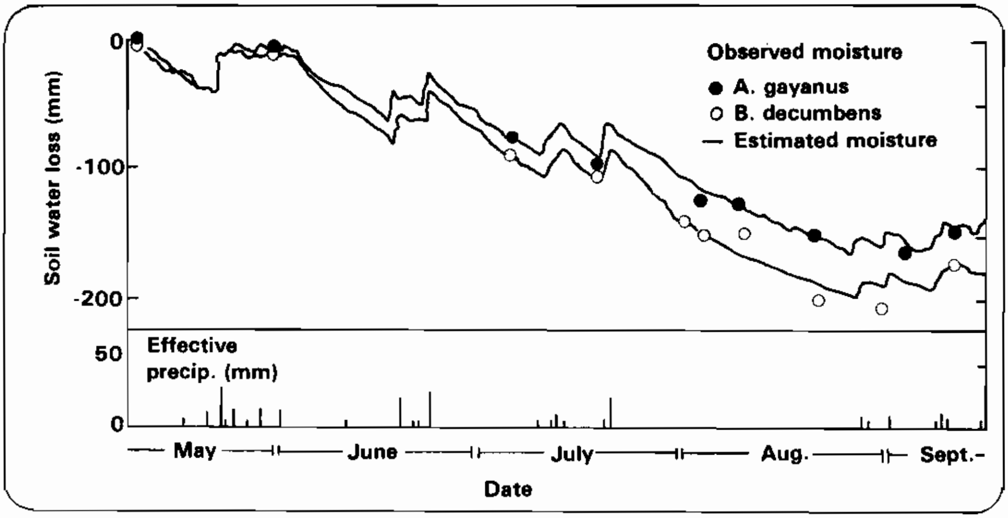


Figure 22. Observed and estimated soil profile moisture content at CIAT-Quilichao. (Soil profile water content was at field capacity on the first sampling date in May).

and *H. rufa* were intermediate in their sensitivities to plant water potential.

Table 16 shows the rooting density and rooting density per unit LAI in the same four species. Although no significant differences in rooting density were observed, the rooting density per unit LAI of *B. decumbens* was notably inferior to the other species.

In summary, the yield advantage of erect species over prostrate species during the early part of the dry season (Fig. 21) was probably due to their conservation of soil water because of lower mean LAI's (Fig. 22). By the late dry season this advantage appears to have disappeared, and *B. decumbens* 606 yielded slightly more than *A. gayanus* 621 and *P. maximum* 604, and much more than *H. rufa* 601. This was

Table 15.

Plant water potential and leaf diffusive resistance in four grass species on two dates during the June-September 1978 dry season at CIAT-Quilichao.

Ecotype		3 Aug. 1978[1] Water potential (bars)	3 Aug. 1978[1] Diffusive resistance (sec/cm)	10 Aug. 1978[2] Water potential (bars)	10 Aug. 1978[2] Diffusive resistance (sec/cm)
Panicum maximum	604	-13.42 a[3]	26.41 b	-10.38 ab	15.84 a
Andropogon gayanus	621	-15.50 a	13.45 a	- 9.51 a	12.36 a
Hyparrhenia rufa	601	-18.96 b	36.72 c	-13.13 b	37.45 b
Brachiaria decumbens	606	-19.08 b	16.34 a	-12.43 ab	14.06 a

1 Experiment 1, 6 weeks of regrowth, LAI > 1.5
2 Experiment 2, 3 weeks of regrowth, LAI < 1.0 except in *B. decumbens*, LAI > 3
3 Means within columns followed by the same letter are not significantly different at P = 0.05.

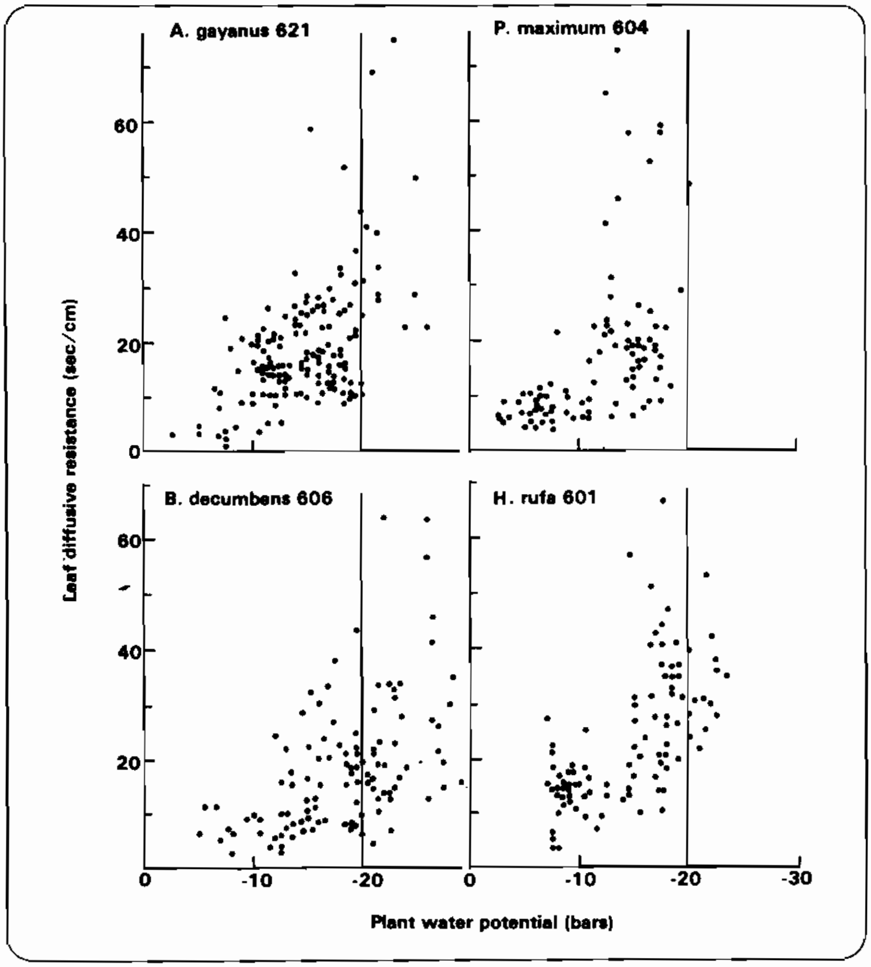


Figure 23. Relationships between plant water potential and leaf diffusive resistance of the abaxial leaf surface in four grass species at CIAT-Quilichao.

Table 16.

Leaf area index (LAI) and root density at 40-80 and 80-120 cm soil depths, for four grass species grown at CIAT-Quilichao.

Ecotype		LAI	Roots 40-80 (cm/cm³)	Roots 80-120 (cm/cm³)	Roots/LAI 40-80 (cm/cm³ / LAI)	Roots/LAI 80-120 (cm/cm³ / LAI)
Panicum maximum	604	1.2	1.5 a[1]	0.7 a	1.3 ab	0.61 a
Andropogon gayanus	621	1.3	2.2 a	0.3 a	2.5 a	0.36 ab
Hyparrhenia rufa	601	1.0	2.3 a	0.5 a	2.4 a	0.51 a
Brachiaria decumbens	606	2.0*	1.2 a	0.4 a	0.4 b	0.11 b

1 Values in the same column followed by the same letter are not significantly different at the 0.05 level.

probably due to its ability to maintain open stomata under drought stress (Fig. 23). Since *B. decumbens* 606 also had the lowest mean values of rooting density and rooting density per unit LAI, rooting density probably is not a major determinant of drought tolerance in these species.

Response to Defoliation

Twelve accessions were evaluated to determine the effect of clipping height on regrowth. Figure 24 shows their response to a single clipping to 0, 5, 10 and 15 cm. Of the prostrate species, *Brachiaria radicans*

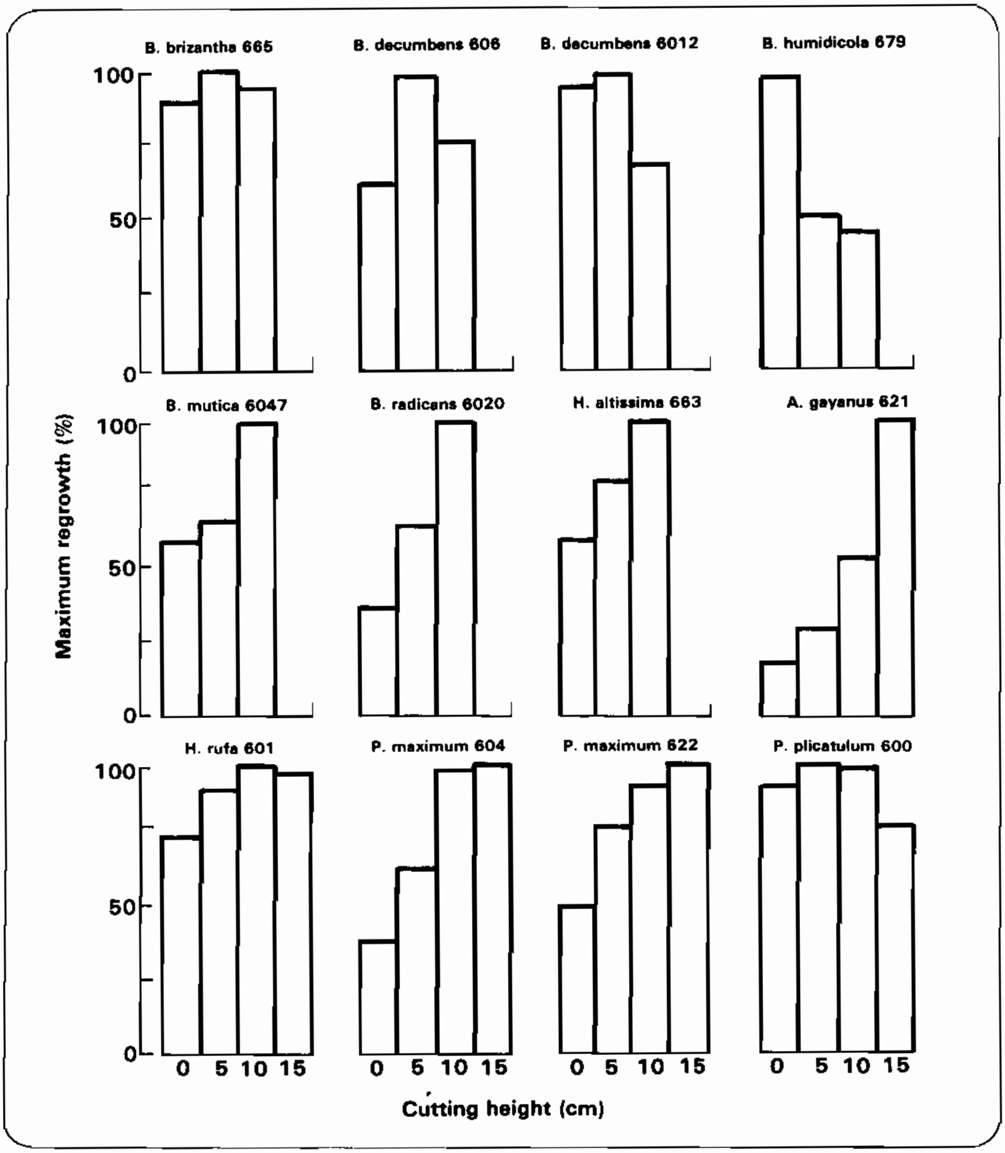


Figure 24. Response of 12 grass accessions to clipping height at CIAT-Quilichao.

6020, *Brachiaria mutica* 6047 and *Hemarthria altissima* 663 were most susceptible to clipping to ground level or 5 cm. Of the erect species, *A. gayanus* 621 and *P. maximum* 604 were the most susceptible.

Since defoliation by burning is common in tropical savannas it is important to know how promising accessions respond to this practice. Figure 25 shows that *A. gayanus* 621 and both accessions of *P. maximum* (604 and 622) were very resistant to burning. Although *Brachiaria* species recovered from burning, they did so more slowly than erect species, and burning could not be recommended as standard practice.

Considerable controversy has been centered on the relative importance of reserve carbohydrates and residual leaf area in determining the regrowth rate of tropical grasses. Regrowth in the dark (regrowth potential) has been shown to be positively correlated with the amount of reserve carbohydrates in the stubble. No correlation was found between regrowth potential and either total regrowth or the mean relative regrowth rate of 11 grass accessions. However, data in Figure 26 show that in the three most productive erect and three most productive prostrate accessions a positive correlation existed between either residual dry matter or residual LAI and regrowth. Regrowth in erect species was more sensitive to the amount of residual material than was regrowth of prostrate species. There were negative relationships between either residual dry matter or residual leaf area and the mean relative regrowth rate. These data illustrate the importance of maintaining sufficient residual dry matter and

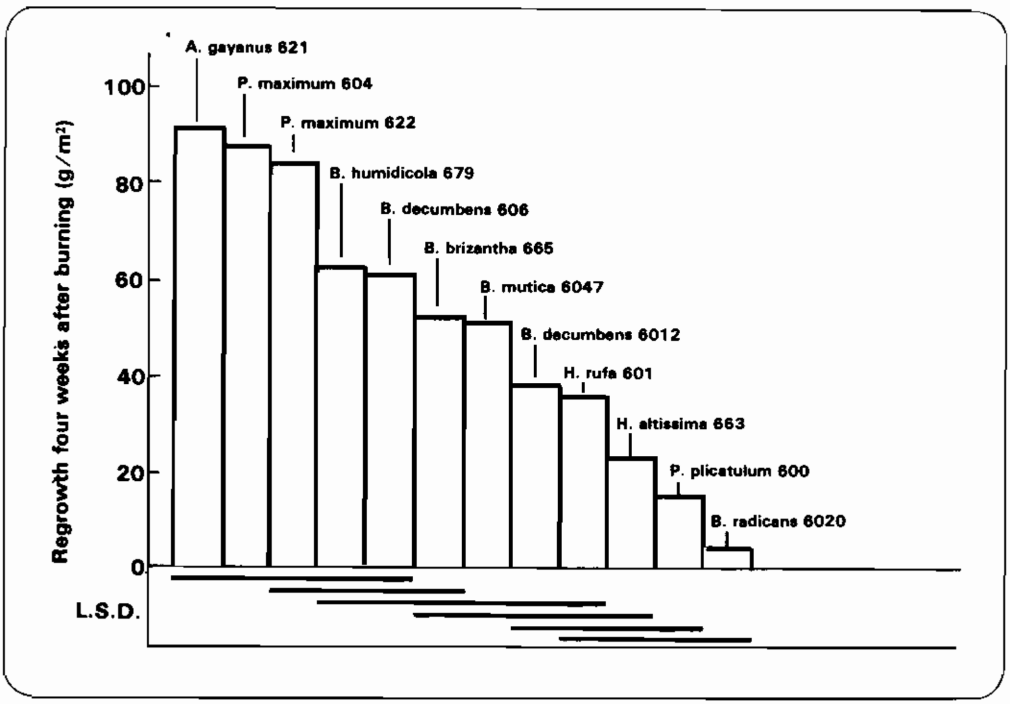


Figure 25. Response of 12 grass accessions to a standard burning treatment at the beginning of the dry season at CIAT-Quilichao.

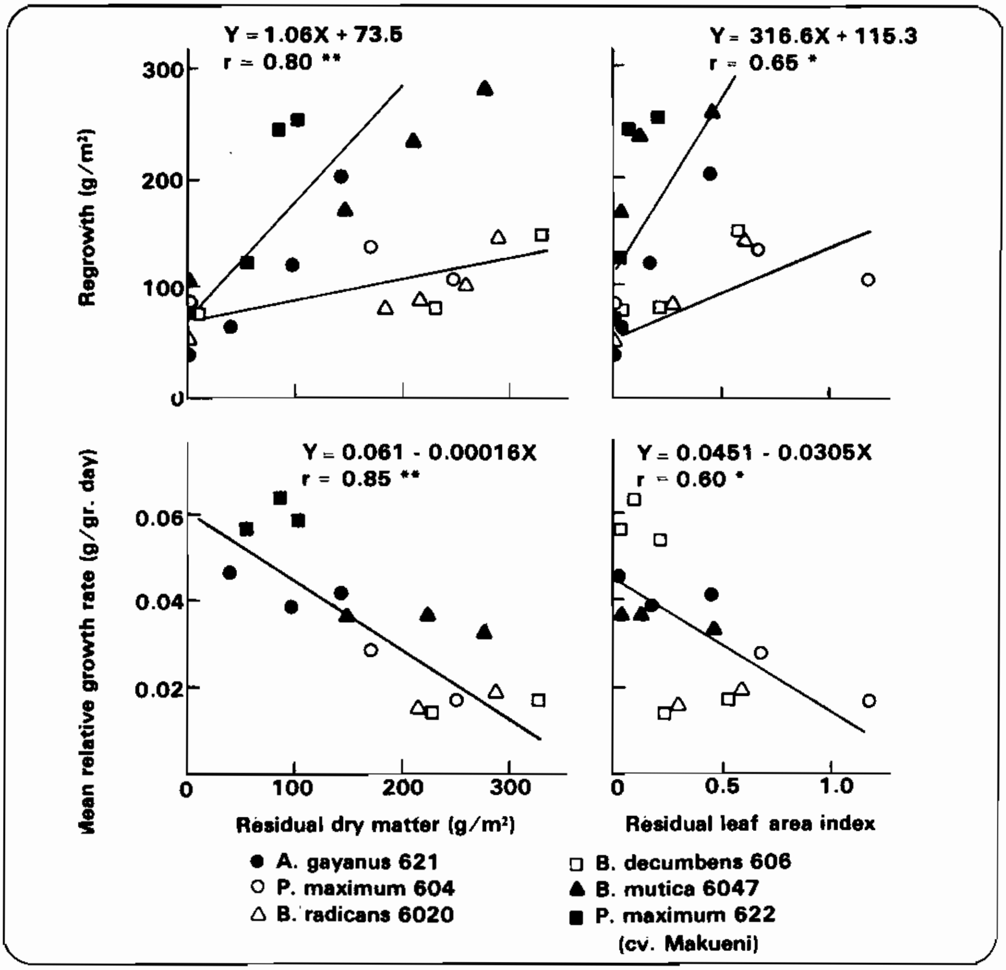


Figure 26. Effects of residual dry matter and residual leaf area index on regrowth and mean relative growth rate in six grass accessions.

leaf area after grazing, especially in erect grasses. Figure 27 shows that after severe defoliation (clipping to 10 cm) two erect and two prostrate accessions had similar relative growth rates, but because erect accessions were left with much less residual dry matter, their actual regrowth rates were lower for the first few weeks.

Fertility Response

Knowledge of the fertility response of grass accessions is important in determining the minimum fertility levels necessary to produce adequate growth. Figures 28 and 29 show first-year rainy season growth response curves of selected accessions to varying levels of N and P fertility in Carimagua. Accessions are arranged in decreasing order of fertilizer response. With high rates of N, *Brachiaria brizantha* 665, *B. decumbens* 606, *Brachiaria humicola* 679 and *A. gayanus* 621, produced over 2.5 t/ha dry matter (DM) basis during an 18-week period without application of fertilizer P, and

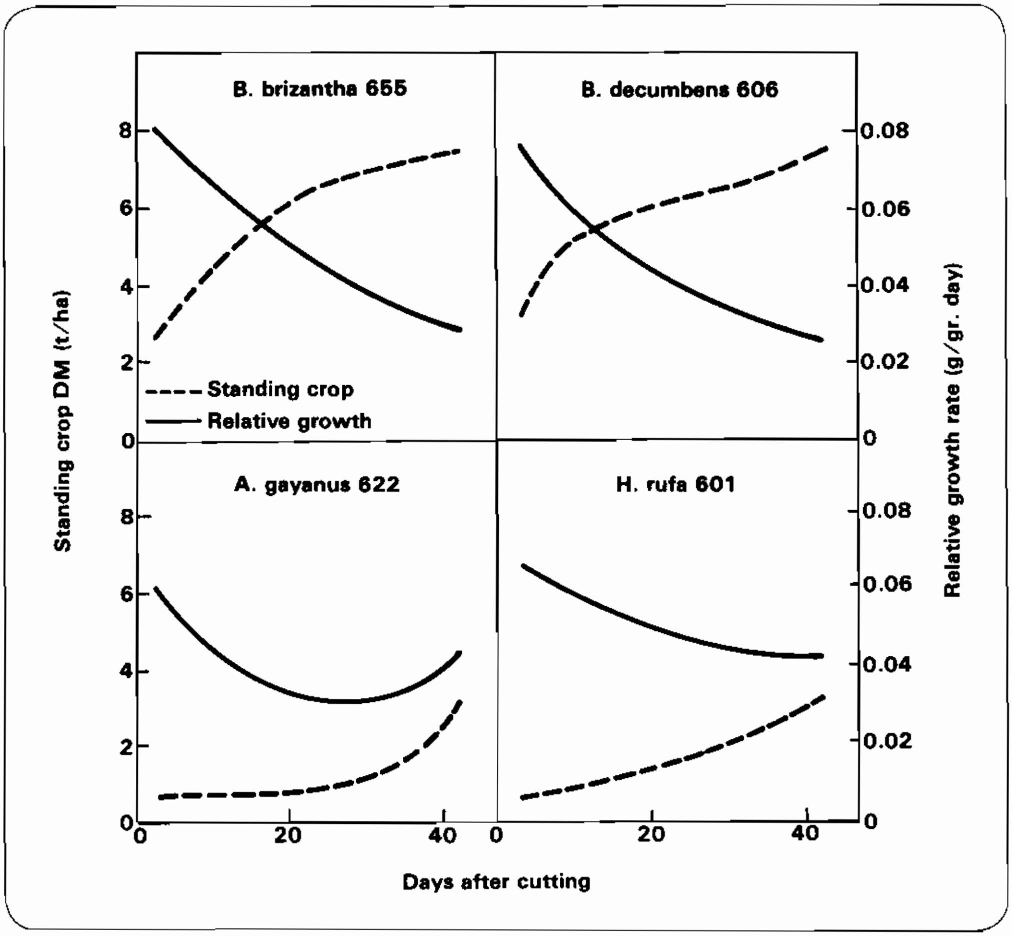


Figure 27. Standing crop and relative growth rate in four grass accessions after severe defoliation at CIAT-Quilichao.

produced over 5 t/ha DM with the application of 50 kg P_2O_5/ha.

In most regions of the Beef Program's target area the routine application of fertilizer N is not economically feasible. It therefore becomes important to identify accessions which have adequate growth rates with minimal inputs of N. Figure 28 shows that *B. brizantha* 665, *B. decumbens* 606, *A. gayanus* 621, *H. rufa* 601, and *P. maximum* 604 yielded at least 4 t/ha DM without fertilizer N, but with adequate P. *A. gayanus* 621, *B. decumbens* 606, and *B. brizantha* 665 performed best under conditions of both low N and low P fertility.

Nutritional Quality

The nutritional quality of tropical grasses is often limited by the DM digestibility or the crude protein (CP) content of material consumed. Figure 30 shows the mean rainy season DM digestibility of 12 accessions. It is notable that even when grab samples are taken to eliminate the error associated with whole-plant samples, *A. gayanus* 621 and *B.*

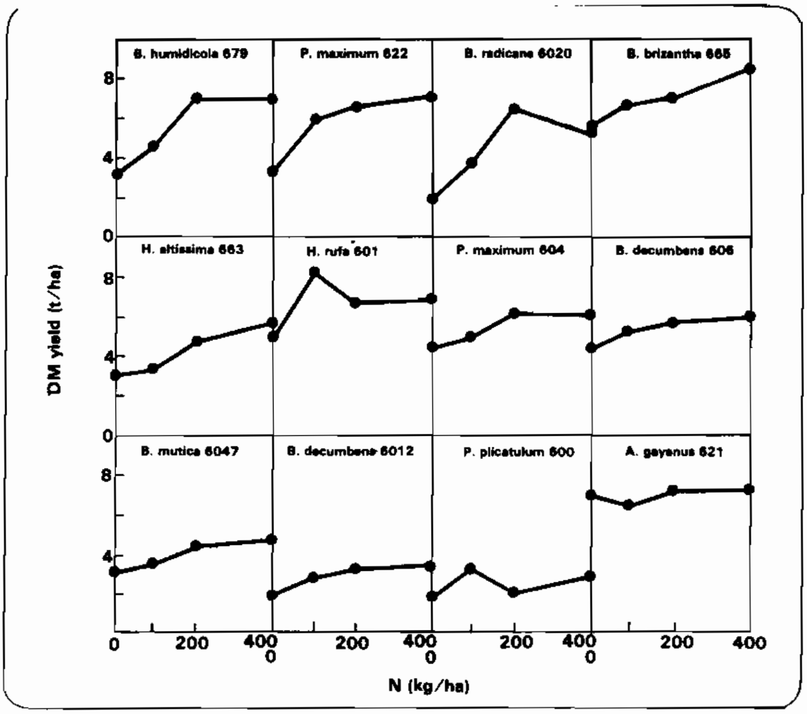


Figure 28. Response of 12 grass accessions to N fertilization at Carimagua. (Sums of three cuts in rainy season; all treatments received 200 kg P_2O_5/ha.)

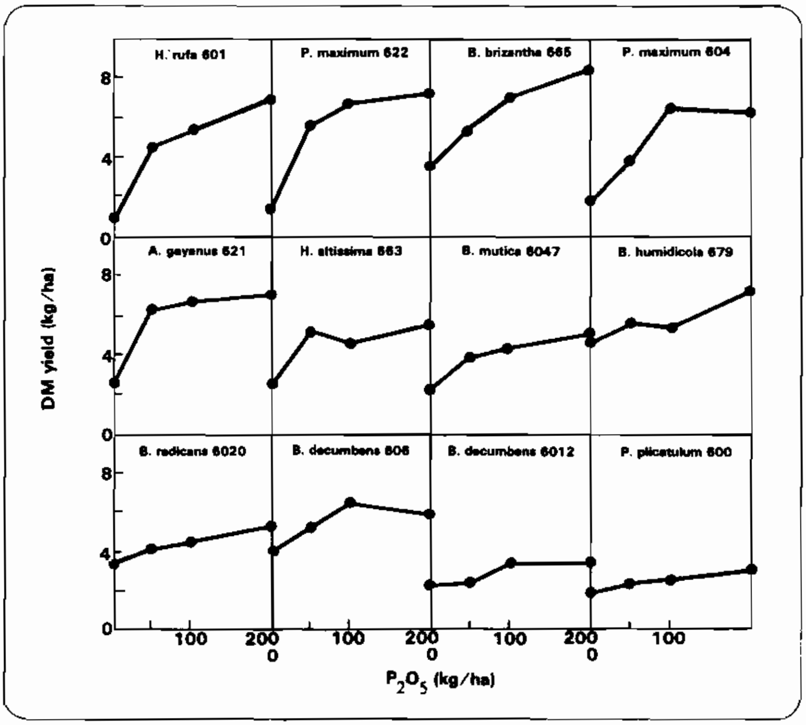


Figure 29. Response of 12 grass accessions to P fertilization at Carimagua. (Sums of three cuts in rainy season; all treatments received 400 kg N/ha/year).

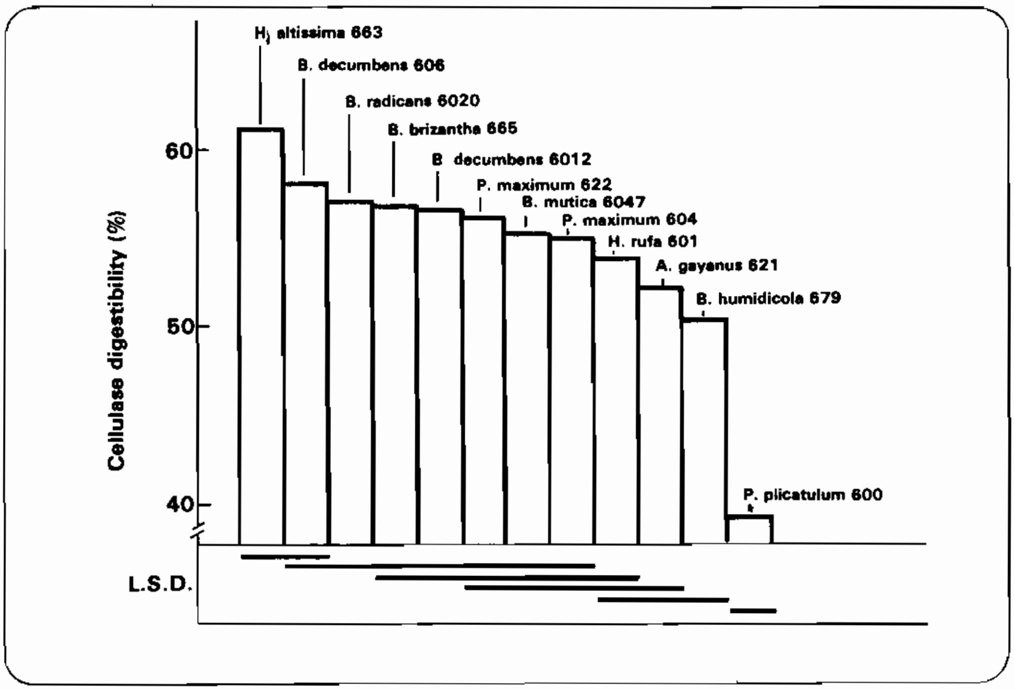


Figure 30. Mean dry matter digestibility by cellulase assay of grab samples of six-week-old regrowth in the rainy season and under eight fertility treatments at Carimagua.

humidicola 679, are among the lowest in DM digestibility.

The N or CP content of grasses growing on soils low in N often limits animal growth in the tropics. Figure 31 shows the mean N content of grab samples of the six-week regrowth of 12 accessions taken from low-N treatments. *A. gayanus* 621, although relatively low in DM digestibility, has relatively high levels of N. *H. altissima* 663, although the highest in DM digestibility, is low in N. *B. humidicola* is low in both DM digestibility and N.

Improvements in Methodology

Other activities during the year involved adapting the Campbell-Brewster hydraulic press (Fig. 32) to estimate leaf water potential in tropical grasses. This method is about twice as rapid as the Scholander pressure chamber and allows up to four treatments to be measured simultaneously. Its ease of construction and handling in the field are additional advantages. The correlation coefficient between measurements with the hydraulic press and the pressure chamber was 0.90.

Root length per unit volume of soil (rooting density) is a widely accepted measure of root system "activity". One of the most time-consuming steps in measuring rooting density is measuring the root length of the samples of roots. A technique was developed whereby root samples are passed by the sensing head of an automatic leaf area meter, and the root "area" of the sample is correlated with root length estimated by conventional means. The regression coefficient between the conventional technique and the root area technique was 0.85. The root area technique requires approximately one-tenth the time of conventional measuring techniques.

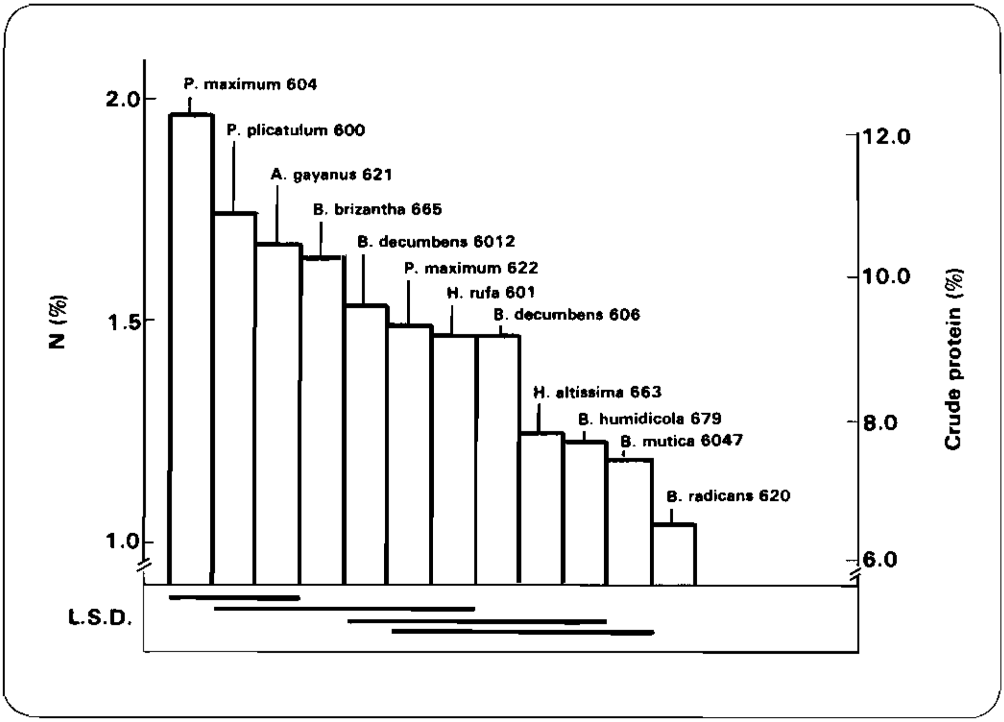


Figure 31. Mean N and crude protein contents of grab samples of six-week-old regrowth in the rainy season at Carimagua and CIAT-Quilichao in treatments having 0 or 50 kg N/ha/year.

In cooperation with the Climatology Unit, a computerized soil water balance model utilizing soil, plant, and climatic inputs and developed for use in a humid sub-tropical environment was adapted for use in the tropics. In CIAT-Quilichao the model predicted the water content of profiles under *B. decumbens* and *A. gayanus* with an error of less than ± 15 mm throughout the period from May to September 1978 (see Fig. 22).

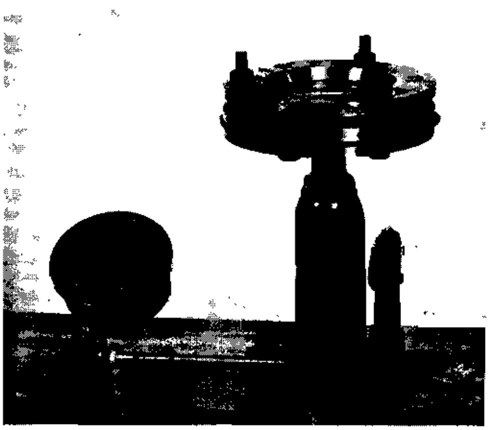


Figure 32. Adapted Cambell-Brewster hydraulic press.

The soil water balance model was used to estimate the transpiration from a clipping frequency experiment conducted by the Legume Agronomy Section. When transpiration calculated by the model was regressed on dry matter yield, a high correlation (0. 95) was observed. Although the relationship between transpiration and dry matter production must be determined at a given location, the technique could be very valuable for the simulation of seasonal growth or growth during years with different precipitation totals.

Table 18.

Summary of evaluations of promising grass accessions included in Categories 3, 4 and 5. (Blanks indicate unknown reactions to conditions.)

Species and CIAT No.	Acid soil tolerance	Vigor in CIAT-Quilichao	Vigor in Carimagua	Drought resistance	Disease resistance	Insect resistance	Nutritional quality	Tolerance to burning	Seed production	Ease of management	Compatibility with legumes	Animal productivity	Tolerance to flooding	Category in 1978	Recommendation for 1979
Andropogon gayanus 621	+	+	+	+	+	+	-	+	+	-	+	+	-	4	5
Brachiaria brizantha 665	+	+	+	+	+	-	+	+	+				-	3	3
Brachiaria decumbens 606	+	+	+	+	+	-	+	-	+	+	-	+	-	4	4
Brachiaria decumbens 664	+	-	-	-	+	-	+	-					-	3	S[1]
Brachiaria decumbens 6012	+	-	-	-	+	-	+	-					-	3	S
Brachiaria humidicola 679	+	+	+	+	+	+	-	-	-				+	3	4'
Brachiaria humidicola 6013	+	+	+	+	+	+	-	-	-					3	S
Brachiaria mutica -	+	+	-	-	+	+	+	-	-				+	3	3
Brachiaria radicans 6020	+	+	-	-	+	+	-	-					+	3	3
Brachiaria ruziziensis 6019	+	-	-	-	+	+	+	-	-					3	S
Eriochloa polystachya 6017	+								+				+	3	3
Hemarthria altissima 663	+	+	-	-	+	+	+	-	-				+	3	3
Hyparrhenia rufa 601	+	-	+	-	+	+	-	-	+		+		-	3	S
Melinis minutiflora 608	+		-	-				-	+	+			-	3	S
Panicum maximum 604	+	+	+	-	-	+	+	+	+	+	+	+	-	3	4
Panicum maximum 622	+	+	+	-	+	+	+	+	+		+		-	3	4
Paspalum plicatulum 600	+	-	-	-	-	-	-	+	+	+			+	3	S

1 S = suspended from further evaluation

Classification of Grass Accessions

All grass accessions were classified according to our knowledge of their agronomic behavior and their promise within the Program. Table 17 is a summary of the evaluations used for each category. Table 18 summarizes current evaluations of accessions in Categories 3, 4, and 5 according to the selection criteria established in 1977. Approximately 40 accessions are currently in Category 2 and are being evaluated under common grazing and in association with a common legume in Carimagua and CIAT-Quilichao.

Andropogon gayanus

In 1973 *Andropogon gayanus* 621 was introduced from Shika, Nigeria by Dr. Bert Grof of the CIAT Beef Program. It has been extensively evaluated at CIAT-Palmira, Carimagua, El Limonar and CIAT-Quilichao. It is included in the Beef Program's regional trials, and as a result of its promise for the acid, infertile soils of the target area it was promoted this year to Category 5 (Tables 17 and 18).

Table 17.

Categories of promise and their implications for grass germplasm evaluation.

Category	Type of evaluation
1	1. Botanical characterization 2. Adaptation to soil and climate in CIAT-Quilichao 3. Disease and insect resistance
2	1. Response to 2 fertility levels in Carimagua 2. Persistence and compatibility with legumes under common grazing 3. Drought resistance 4. Disease and insect resistance 5. Nutritive value
3	1. Regional trials 2. Fertility requirements
4	1. Systems of establishment 2. Seed production systems 3. Systems of utilization and management (animal production trials
5	1. Multiplication of basic seed 2. Completion of research prior to release

Preliminary rainy season animal gain data are also promising, but adequate dry season data are not yet available. Nevertheless, *A.gayanus* 621 is sufficiently promising that basic seed production will begin in 1979, and a final decision regarding a joint release with the Instituto Colombiano Agropecuario (ICA) will be made in late 1979.

SEED PRODUCTION

This Section continued to meet two basic objectives: (1) seed production for experimental purposes and production of foundation seed of new cultivars, and (2) development of relevant technology for commercial forage seed production.

Primary emphasis has been upon seed increase of experimental lines with seeds being used within the Beef Program. However, with increasing emphasis upon certain species, an expanded research effort was defined, collaborators identified and projects initiated both in Colombia and in locations at higher latitudes.

Seed Increase

Seed increase is confined to accessions nominated to the promising list by the Program's Germplasm Committee. Initial seed production targets are consistent with the five categories assigned. Seed was produced from 35 accessions at three locations in Colombia during the year.

A large part of this seed increase effort is plant propagation. Seed production plots are established either by vegetative propagation, single plant transplanting or direct field seeding. A total of 12 ha of new crop area was established and the average total area under seed increase was 15 ha during 1978. CIAT-Quilichao was the principal location with 10 ha of crops while 3 ha were maintained at Palmira and 5 ha of new plots were established at Carimagua. The transition from the rainy season to dry season at CIAT—Quilichao during December 1977 was prolonged, causing adverse effects upon flowering synchronization, especially in *Centrosema, Pueraria* and *Stylosanthes capitata*. With few exceptions, harvesting was done manually to avoid contamination and for greater efficiency of recovery when working with relatively small crop areas. Harvesting was during January-February and again during July-August at CIAT-Quilichao and Palmira, and during November at Carimagua. Total production amounted to 2468 kg of graded seed (Table 19), with emphases upon *Andropogon gayanus* and accessions of *S. capitata*.

The present production locations all share the restriction of little variation in dry season length due to their low latitude. Palmira and Quilichao have bi-modal rainfall patterns and the effective natural growing season is restricted to three months—insufficient for all species within the establishment year. The longer growing season available at Carimagua is therefore an advantage within the establishment year but is basically a disadvantage in the following years. Plans were made to initiate seed increase at Brasilia (17°S latitude), both to exploit the higher latitude and to help fulfill the expanding seed requirements for experimentation in the Cerrado.

Seed Production Technology

Crop Maturity Patterns and Harvest Methodology

Brachiaria decumbens. A crop was sampled over a one-month period extending from early seed maturity until complete seed shattering (Fig. 33). The objective was to record hand-harvested seed yield and quality and to identify the optimum harvest period.

This seedling crop of relatively low plant density flowered over an extended period commencing in early July. As a result, seed maturity showed a very broad peak in that more than 50 kg/ha of pure seed was harvestable for a two-week period and even 75% of maximum yield of pure seed was recoverable over seven days. After the total population of inflorescences reached a plateau by August 2, a maximum yield of 89 kg/ha of pure seed was recorded by August 9. This coincided with marked changes in the relative proportion of "immature", "mature" and "shattered" inflorescences. At maximum yield of pure seed, the percentage of mature inflorescences declined markedly from a peak of approximately 70% while percentage shattered inflorescences increased markedly above 10%. The unit weight of pure seed was approximately 400 mg/100 seeds at maximum yield of pure seed but continued to increase for another eight days to a maximum of 450 mg/100 seeds. Seed germination data are needed to

Table 19.

Summary of forage seed produced during the period October 1977-October 1978.

Species	No. of Accessions	Total seed production (kg)
Centrosema sp.	3	31
Desmodium spp.	8	83
Glycine wightii	2	117
Leucaena leucocephala	2	10
Macroptilium sp.	1	111
Pueraria phaseoloides	1	35
Stylosanthes capitata	5	404
Stylosanthes guianensis	3	20
Stylosanthes hamata	2	72
Stylosanthes sympodialis	2	62
Stylosanthes humilis	1	9
Stylosanthes scabra	1	32
Teramnus uncinatus	1	16
Zornia sp.	1	10
Total legumes[1]	33	1012
Andropogon gayanus	1	1400
Brachiaria decumbens	1	56
Total grasses[2]	2	1456

1 Legumes, graded seed or seed in pod, > 95% purity.
2 Grasses, graded seed, > 40% purity.

conclude this study, but the unit weight data indicate that despite the deceptive attraction of significant quantities of ripe seed on the plant and on the ground, it could be disadvantageous to harvest before the peak of maximum yield of pure seed. Thus, easily identifiable indices of this critical period are required. The utility of the proportions of mature and shattered inflorescences to serve this function will be tested further.

Pure seed yields were estimated in three commercial lots by both direct combine harvesting and by manual cutting, field sweating for three days and then manual threshing (Table 20). Relative recovery rates were quite consistent over the wide range of yields encountered, with the combine recovering an average of 59% of the pure seed recovered by the manual method. Unit weights of pure seed, however, differed markedly with the combine consistently recovering a heavier seed fraction, 457 versus 388 mg/100 seeds. This probably reflects the fact that after three days of sweating, manual threshing removes many more pure, but smaller and partially immature seed than does combine threshing immediately after cutting. Thus, the 41% difference in recovery of pure seed by the two methods does not indicate gross

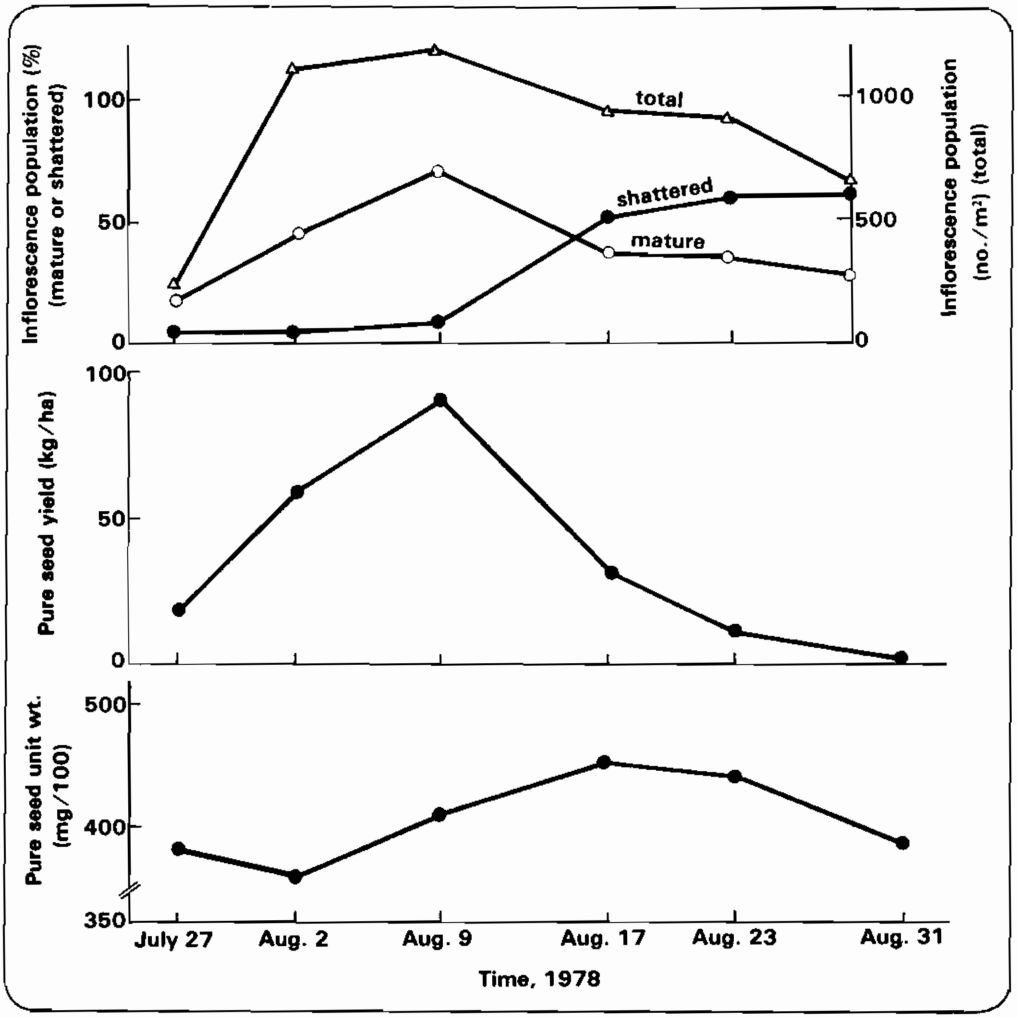


Figure 33. Developmental sequence of inflorescence and seed population in a seedling crop of *Brachiaria decumbens* at El Limonar (near CIAT-Quilichao).

inefficiency by the combine. The final comparison of relative harvest efficiency will be based upon relative yields of pure live seed.

Andropogon gayanus. During the harvest of seed increase areas in January and July, exploratory investigations were made of the relative efficiency of alternative harvest methods. The objectives were to determine: (1) if the traditional practice of manual cutting, field sweating and manual threshing was the most efficient; (2) other promising harvest strategies; and, (3) the role of mechanization. Five basic methodologies were compared in two unreplicated experiments in different fields and pure live seed estimates are presented for seed of different ages (Table 21); thus, comparisons are valid only within each experiment.

In January all methods were initiated at what was judged to be optimal plant

Table 20.

Comparison of manual and direct combine harvesting of three commercial lots of *Brachiaria decumbens.*

Comparison	Direct combine	Manual
Pure seed yield (kg/ha)	35	59
Percent recovery (on pure seed basis)	59	100
Unit weight of pure seed (mg/100)	457	388

harvest maturity. Therefore, the method of recovery from the ground was obviously not at its maximum potential. The traditional manual method provided highest yields of pure live seed, 34 kg/ha. A re-threshing step added to the manual method provided 10% more pure live seed, but this seed had a low germination capacity (25%), and probably a short storage life; thus, re-threshing is not recommended. Even at this time, the recollection from ground was the next most efficient method, recovering 24 kg/ha of pure live seed mainly because of the very high (74%) seed germination. Direct combining versus windrow pick-up by the combine four days after cutting recovered 13 and 17 kg/ha pure live seed, respectively, indicating the combine recovered at best 50% of yields obtainable by the traditional manual method. Comparison of the traditional method versus windrow pick-up indicates that 50% losses can be made by the combine during threshing alone, even after sweating.

Yields in the July crop were higher than the January crop. The manual method was initiated on July 7 but a mechanical problem delayed combine treatments until July 11. During this period there was a very significant increase of seed recovered from the ground (over 100 kg/ha), indicating a high degree of seed shattering. Thus, when compared to the manual method, two methods including the combine (3 and 4) confound methodology and time of harvest and reduce the interpretations which can be made. The potential of recovering seed from the ground becomes more apparent as sampling was continued for 12 days after the point of optimal plant harvest and a maximum of 100 kg/ha of pure live seed was collected on July 19. Again, very high seed germination was recorded, 43% compared to an average of 20% for other methods. It is not valid to compare the combine-involved methods 3 and 4 to the traditional hand-harvest method. Comparing methods 1 and 5 indicates 30% losses due to threshing by the combine after sweating as opposed to manual threshing. Again, there was a small advantage to windrow pick-up as opposed to direct combining.

Overall, it appears that the cheapest and most efficient harvest method for *A. gayanus* is the traditional manual method. In regions where crop maturity coincides with a dependable dry season that reduces the risk of damage from unseasonal rainfall, recovery of shattered seed from the ground appears very feasible and would be facilitated by row spacings of approximately 1.5 m. Obviously, with large crop areas, combining would become feasible even with lower efficiency of recovery. These investigations will be continued.

The traditional hand-harvest method used with many tropical grasses including *A. gayanus,* includes a field sweating phase where flowering stems are cut and stacked in heaps for three to four days. Concern is often expressed that conditions within the heap may adversely affect seed germination. Tests conducted upon hand-harvested seed with post-harvest

Table 21.

Results of evaluations of harvest methodology for *Andropogon gayanus*.

		Expt. 1, January			Expt. 2, July		
		Pure seed		Pure live seed	Pure seed		Pure live seed
Harvest method	Date 1978	Yield (kg/ha)	Germination 7 mo. (%)	Yield 7 mo. (kg/ha)	Yield (kg/ha)	Germination 3 mo. (%)	Yield 3 mo. (kg/ha)
1. Traditional manual cutting, field stacking,	Jan. 23	69	50	34	-	-	-
and threshing	July 7	-	-	-	262	18	47
1a. Same as 1, plus re-threshing	Jan. 23	11	25	3	-	-	-
2. Recovery from ground	Jan. 23	32	74	24	-	-	-
	July 7	-	-	-	104	27	28
	July 12	-	-	-	208	35	73
	July 19	-	-	-	232	43	100
3. Direct combining	Jan. 23	32	41	13	-	-	-
	July 11	-	-	-	47	25	12
4. Manual cutting, *in situ* wind-rowing and	Jan. 23	33	50	17	-	-	-
combine pick up	July 12	-	-	-	64	22	14
5. Manual cutting and field stacking with combine	Jan. 23	32	52	17	-	-	-
threshing	July 7	-	-	-	233	14	33

treatments of 0, 3, 6 and 9 days sweating, resulted in 83, 78, 63 and 44% germination, respectively, at 10 months. These results indicate that while sweating in properly constructed heaps for three days has no adverse effects, longer periods can reduce germination.

Regional Seed Production Potentials

Identifying appropriate geographic regions for seed production is of fundamental importance to the development and economics of commercial seed production and any research effort to support this enterprise. Geographic regions where seed (not forage) production is optimized provide favorable combinations of climatic, edaphic, agronomic and economic factors to consistently promote both high yield and quality of seed, plus consistent recovery at harvest. Generally, the legumes are more demanding in this regard than most grasses. CIAT, as an international institution, is well-suited to coordinate such a widespread project, one which will also assist the development of seed supplies required for the Beef Program's experimental activities.

A formal project proposal was developed and sent to potential collaborators at locations over a range of latitudes, total annual precipitation and seasonal temperature regimes but emphasizing regions with marked seasonal distribution of rainfall and low or zero incidence of frost. Plantings of a variety of legumes and grasses, nominated by the collaborators at CIAT, were made beginning in November 1978 to define phenology, seed yields, incidence of pests and diseases, and other parameters relating to commercial production potentials. Collaboration has been confirmed with the Centro de Pesquisa Agropecuaria de Cerrados (CPAC) at Brasilia, 17°S; the Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) at Sête Lagoas, 18°S, and Felixlandia, 17°S, in Brazil; at Santa Cruz, 17°S, with the Centro de Investigación Agrícola Tropical (CIAT), Santa Cruz, and at Valle de Sajta, 17°S, with the Cooperación Técnica del Gobierno Suizo (COTESU) in Bolivia; and with the Instituto Colombiano Agropecuario (ICA), at Valledupar, Colombia.

A preliminary experiment conducted in collaboration with the Beef Program Forage Agronomist at CPAC, Brasilia during 1978 indicated the potential severity of weed problems in legume establishment (especially *Pennisetum setosum, Cenchrus* sp. and *Acanthosperum australe)* and the presence of the budworm *Stegastra bosqueella* in all *Stylosanthes* species. High first-year, hand-harvested, pure seed yields were recorded in *A. gayanus*, 290 kg/ha; *B. decumbens*, 96 kg/ha; *Brachiaria ruziziensis*, 160 kg/ha; and *Calopogonium muconoides*, 900 kg/ha.

Andropogon gayanus. Nitrogen response: An established stand at El Limonar (near CIAT-Quilichao) provided an experimental area to investigate effects of N rates and application methods on yield of pure seed. The stand was burned on August 25, received adequate rainfall after September 14, commenced flowering in mid-October and matured in mid-December. Nitrogen applications are described in Table 22. Considerable difficulty was encountered in determining the optimal harvest date. One replication was harvested on December 19 and the remainder on December 27. There were no differences between treatment means based upon data from all four replications. However, there was a significant difference between repetitions related to date of harvest, clearly indicating that the December 27 harvest was too late and that any possible treatment differences could not be recorded at that time. Therefore, the unreplicated data from the December 19 harvest warrants independent comment. These data indicated a strong trend for pure seed yield to increase with levels of increasing N. A pure seed yield of more than 200 kg/ha was recorded with both 200 and 300 kg N/ha applied in two split applications. These investigations will be continued.

De-awning: With the *A. gayanus* spikelet being very hairy and having a long awn, seed masses naturally tend to clump and do not flow easily. A de-awner or debearder was developed to overcome this

Table 22.

Effect of N applications upon pure seed yield of *Andropogon gayanus* at El Limonar.

Nitrogen application (kg/ha)			Yield of pure seed (kg/ha)	
Sept. 20	Oct. 14	Total	Dec. 19	Dec. 27
0	0	0	111	68
100	0	100	134	66
200	0	200	163	60
50	150	200	206	80
50	250	300	225	80

difficulty which complicates seed processing.

Basically, this machine includes a metal cylinder 71 x 30 cm with protruding rubber fingers, an upper concave with a ribbed rubber surface, and a curved semi-cylindrical lower concave made up of screens with variable apertures. A range of cylinder speeds from 250 to 750 rpm are available from three pulleys and clearance between the drum fingers and the curved concave screen is adjustable from 1 to 5 cm. Seed is fed manually from a small hopper into the central revolving cylinder and are withdrawn by a basal auger. The machine has a capacity of approximately 50 kg/hr.

Purity analysis: Determinations of both yield in standard terms of pure seed and of germination of the pure seed fraction require a standardized method of purity analysis.

A "quick" or "Irish" purity test was developed using a 10-g sample and defining a pure seed as any basal spikelet plus appendage. The main value of this test is its speed and the fact that 100 minus Irish purity equals the minimum level of inert matter as would be defined by the International definition of purity. The Irish purity test, therefore, provides an easy check on the minimum quantity of inert matter present in a seed sample but does not define the real nature of the pure seed fraction.

An International purity test (where the pure seed fraction is only those spikelets which contain a confirmed caryopsis) was developed defining the pure seed fraction as the basal spikelet containing a caryopsis but excluding the awn, any free caryopsis or parts thereof and germinated spikelets excluding the awn. Inert material includes basal spikelets without caryopsis, all upper spikelets, all awns, as well as soil, sand and vegetative plant parts, etc. The separation of a 6-g sample into its three component fractions — pure seed, inert matter and weeds — is very laborious and requires approximately four hours.

An attempt was made to develop a more rapid indirect means of estimating International purity, exploiting the relationship between caryopsis content (expressed as a percent based on number) and International purity (expressed as a percent based on weight) of the Irish pure seed fraction of any sample. Using a wide range of samples a linear regression equation of $Y = 1.099 X$, ($R^2 = 0.993$), was defined where Y = International purity of the Irish pure seed fraction and X = caryopsis content of the Irish pure seed fraction. For a given seed sample the procedure to calculate International purity indirectly is: (1) determine Irish purity and caryopsis content; (b) from the equation determine the International purity of the Irish pure seed fraction; and (c) multiply this value by percentage Irish purity. While this method is providing data closely approximating values derived by direct determinations of International purity, its utility remains under investigation.

PLANT PATHOLOGY

The Plant Pathology Section commenced activities in July 1978. The major aims of this section are to detect, identify and assess diseases of germplasm under evaluation and to develop control measures for damaging diseases of promising forage species.

The primary activity this year was initiation of extensive microflora surveys of germplasm currently under field evaluation and of related indigenous species to determine the incidence and severity of pathogenic organisms.

Anthracnose

Anthracnose is the most damaging disease of tropical forage legumes in Central and South America, Australia and Florida. In Central and South America, this disease had been reported to be caused by one fungus, *Colletotrichum gloeosporioides,* and only *Stylosanthes* species have been reported to be affected.

Because of its importance, a specific survey to determine the occurrence and severity of anthracnose at Carimagua, El Limonar (near CIAT-Quilichao) and the Quilichao sub-station was initiated. Fifteen random isolations were made from accessions with suspected anthracnose lesions. To date, results have emphasized the widespread occurrence of anthracnose (Tables 23, 24 and 25). Most legume genera currently under evaluation, as well as members of the indigenous flora, were hosts to anthracnose at the three locations. In addition, two species of *Colletotrichum* were involved, *C. gloeosporioides* and *C. dematium,* and on any particular accession, symptoms caused by both fungi were identical.

Although anthracnose was widespread, its severity varied considerably among genera and accessions. At all locations, anthracnose, primarily caused by *C. gloeosporioides,* was severe on *Stylosanthes guianensis* accessions. Most *Stylosanthes capitata* plantings at Carimagua and Quilichao were only slightly infected or unaffected. At El Limonar, although stem lesions were numerous in 2.5-year-old plantings of *S. capitata* (CIAT 1019, 1078, 1097 and 1405), their effects appeared minor. Past screening of stylo accessions to *C. gloeosporioides* (CIAT Annual Report, 1976 and 1977), together with field observations, had shown *S. capitata* to be highly tolerant to anthracnose. A study of this tolerance is being initiated.

On *Zornia* accessions, slight to moderately severe leaf spotting was caused by *C. dematium* at Carimagua and by both *Colletotrichum* spp. at Quilichao. *C. gloeosporioides* caused die-back in several plantings of *Pueraria phaseoloides* at Carimagua. Anthracnose fungi caused minor leaf and stem lesions on other legumes. *Desmodium ovalifolium* was the

Table 23.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi (*Colletotrichum* spp.) at Carimagua. (Mean of 15 random isolations per accession).

	Accessions showing occurrence of	
Species	*C. gloeosporioides*	*C. dematium*
Stylosanthes capitata		
No occurrence	1342, 1497, 1504, 1520, 1533, 1535, 1642, 1728	1342, 1497, 1535, 1728
Slight occurrence	1019, 1315[1], 1499	1504, 1520, 1533, 1642
Moderate occurrence	1078	1019, 1078, 1499
Severe occurrence	-	1315
Stylosanthes guianensis		
No occurrence	1533, 1551, 1569	136, 1553, 1569, 1571
Slight occurrence	1486, 1578	1480, 1486, 1503, 1533, 1549, 1551, 1562, 1565, 1573, 1649
Moderate occurrence	1480, 1503, 1549, 1565, 1571, 1573	1578
Severe occurrence	136, 1553, 1562, 1649	
Stylosanthes hamata		
No occurrence	-	147
Severe occurrence	147	-
Stylosanthes humilis		
No occurrence	1303	-
Moderate occurrence	-	1303
Stylosanthes ingrata		
No occurrence	-	1604
Severe occurrence	1604	-

1 Sexual state production.

continued

Table 23. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes scabra		
No occurrence	1583	1583
Aeschynomene sp.		
No occurrence	9874	-
Slight occurrence	-	9874
Cassia sp.		
No occurrence	Native	-
Slight occurrence	-	Native
Centrosema spp.		
No occurrence	5061	5061
Moderate occurrence	438	-
Severe occurrence	-	438
Desmodium barbatum		
No occurrence	Native	-
Slight occurrence	-	Native
Desmodium heterophyllum		
No occurrence	349	-
Slight occurrence	-	349
Desmodium heterocarpon		
No occurrence	365	365
Desmodium ovalifolium		
No occurrence	350	350

continued

Table 23. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Galactia spp.		
No occurrence	964, 9152	9152
Moderate occurrence	-	964
Indigofera sp.		
No occurrence	Native	-
Severe occurrence	-	Native
Macroptilium spp.		
No occurrence	-	4049
Slight occurrence	4115	4115
Moderate occurrence	4049	-
Pueraria phaseoloides		
No occurrence	-	9900
Severe occurrence	9900	-
Soemmeringia spp.		
No occurrence	9471, 9844	-
Slight occurrence	Native	9471, 9844
Moderate occurrence	-	Native
Zornia spp.		
No occurrence	9166, 9199, 9203, 9225, 9226, 9245, 9258, 9284, 9292, 9602, 9644, 9915	9258
Slight occurrence	728	9166, 9203, 9225, 9226, 9245 9602, 9644, 9915
Moderate occurrence	-	728, 9199, 9284
Severe occurrence	-	9292

Table 24.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi *(Colletotrichum* spp.) at El Limonar, near CIAT-Quilichao. (Mean of 15 random isolations per accession).

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes capitata		
No occurrence	-	1078, 1097, 1342
Slight occurrence	1342	1405
Moderate occurrence	-	1019
Severe occurrence	1019[1], 1078[1], 1097[1], 1405[1]	
Stylosanthes guianensis		
No occurrence	1200	64-A, 151-A, 184, 191-B, 1135, 1152, 1175, 1200 1705
Slight occurrence	1152, 1175,	191-A
Moderate occurrence	151-A, 1135[1]	-
Severe occurrence	64-A, 184, 191-A, 191-B 1705[1]	-
Stylosanthes hamata		
No occurrence	-	118, 147
Moderate occurrence	118	-
Severe occurrence	147[1]	-
Stylosanthes humilis		
Slight occurrence	1304	-
Moderate occurrence	-	1304
Stylosanthes sympodialis		
No occurrence	-	1043, 1044
Moderate occurrence	1043, 1044	

1 Sexual state production.

continued

Table 24. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes viscosa		
No occurrence	-	1074-A, 1132
Slight occurrence	1132	-
Severe occurrence	1074-A	-
Calopogonium muconoides		
No occurrence	-	Sp.
Moderate occurrence	Sp.[1]	-
Desmodium ovalifolium		
No occurrence	350	350
Desmodium heterocarpon		
No occurrence	365	365
Desmodium canum		
No occurrence	367	367
Desmodium barbatum		
Slight occurrence	Native	Native

1 Sexual state production.

Table 25.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi (*Colletotrichum* spp.) at CIAT-Quilichao. (Mean of 15 random isolations per accession).

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes capitata		
No occurrence	1325, 1495, 1499, 1520, 1728	1315, 1325, 1342, 1405
Slight occurrence	1342[1], 1497, 1516, 1519, 1535	1019, 1078, 1097, 1497, 1535,
Moderate occurrence	1019. 1097, 1315[1],	1499, 1520
Severe occurrence	1078[1], 1405	1495, 1516, 1519, 1728
Stylosanthes guianensis		
No occurrence	1062, 1175, 1825, 1829, 1832, 1833, 1838, 1842, 1856, 1871, 1905	64-A, 184, 1062, 1135, 1175, 1698, 1735, 1749, 1755, 1763 1825, 1826, 1829, 1830, 1832 1833, 1838, 1842, 1846, 1856, 1863, 1867, 1871, 1902, 1905,
Slight occurrence	1135, 1698[1], 1830	136
Moderate occurrence	1826	-
Severe occurrence	64-A, 136, 184, 1735, 1749, 1755, 1763, 1846, 1863[1], 1867, 1902	-
Stylosanthes hamata		
No occurrence	-	118, 147
Slight occurrence	147	-
Severe occurrence	118	-
Centrosema spp.		
No occurrence	4042, 5175, 5177, 5196	438, 4042, 5062, 5107, 5108, 5175, 5177, 5196
Slight occurrence	5062, 5108	-
Severe occurrence	438, 5107	-

1 Sexual state production

continued

Table 25. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Desmodium ovalifolium		
No occurrence	350	350
Desmodium barbatum		
Slight occurrence	-	Native
Severe occurrence	Native[1]	-
Galactia striata		
Slight occurrence	-	964
Severe occurrence	964	-
Macroptilium spp.		
No occurrence	4014, 4015, 4050, 4133	535, 4009, 4014, 4015, 4050 4133
Slight occurrence	535	-
Moderate occurrence	4009	-
Vigna spp.		
No occurrence	4188, 9546	4120, 4139, 4188, 9546
Moderate occurrence	4120[1], 4139	-
Zornia spp.		
No occurrence	9472, 9651, 9925	9166, 9292, 9472, 9651, 9771, 9925
Slight occurrence	9166	-
Moderate occurrence	728, 9292, 9771	728

1 Sexual state production.

only promising forage legume not affected by anthracnose.

Colletotrichum isolates are being collected from most-affected accessions. Screening trials to evaluate resistance of promising legumes to anthracnose fungi and to determine host ranges are in progress. If legume mixtures are used, it is essential to determine whether *Colletotrichums* pathogenic to one legume could affect other legumes.

At Carimagua, newly established *S. guianensis* germplasm accessions from Colombia were more susceptible to anthracnose than germplasm from Venezuela and Brazil (Table 26). These observations suggest that further collections of *S. guianensis* should be made in Venezuela and Brazil where anthracnose pressures appear to be more selective than in Colombia.

The importance of evaluating germplasm under a variety of ecosystems is stressed.

Table 26.

Evaluation of anthracnose on *Stylosanthes guianensis* in introduction plots (for grazing) at Carimagua.

CIAT No.	Origin	Date planted 1978	Preliminary anthracnose evaluation[1] 11 October
136	Meta, Col.	April 29	3
1562	Meta, Col.	April 29	3
1578	Meta, Col.	April 29	2
1571	Meta, Col.	April 29	3
1563	Meta, Col.	June 3	3
1549	Meta, Col.	June 3	3
1577	Meta, Col.	June 3	2
1564	Meta, Col.	June 3	1
1551	Meta, Col.	June 3	1
1552	Meta, Col.	June 3	3
1572	Meta, Col.	June 3	3
1573	Meta, Col.	June 3	2
1566	Meta, Col.	June 3	3
1557	Meta, Col.	July 20	2
1568	Meta, Col.	July 20	4
1574	Meta, Col.	July 20	1
1553	Meta, Col.	July 20	4
1560	Meta, Col.	July 20	1
1561	Meta, Col.	July 20	1
1565	Meta, Col.	July 20	2
1559	Meta, Col.	July 20	1
1480	Vichada, Col.	June 3	2
1483	Vichada, Col.	June 3	3

1 Anthracnose rating: 0 = no anthracnose; 1 = minor leaf and/or stem spotting; 2 = moderate leaf and/or stem spotting; 3 = severe spotting; defoliation; 4 = severe defoliation; plant death.

(continued)

Table 26 (continued)

CIAT No.	Origin	Date planted 1978	Preliminary anthracnose evaluation[1] 11 October
1484	Vichada, Col.	June 3	0
1481	Vichada, Col.	June 3	3
1482	Vichada, Col.	June 16	0
1479	Vichada, Col.	July 8	3
1575	Vichada, Col.	August 8	4
1478	Vichada, Col.	August 8	4
1477	Cauca, Col.	June 3	0
1648	Cauca, Col.	July 20	1
1649	Cauca, Col.	August 8	4
1580	Tolima, Col.	July 20	3
1539	Venezuela	April 29	1
1523	Venezuela	June 3	1
1503	Venezuela	June 3	3
1491	Venezuela	June 16	0
1533	Venezuela	July 20	1
1521	Venezuela	July 20	0
1531	Venezuela	July 20	0
1508	Venezuela	July 20	0
1507	Venezuela	August 8	0
1500	Venezuela	August 8	0
1498	Venezuela	August 8	0
1335	Brazil	June 16	0
1678	Brazil	July 20	0
1633	Brazil	July 20	0
1741	Brazil	July 8	0
1604	Brazil	August 8	0
1640	Brazil	August 8	0
1681	Brazil	August 8	0
1486	Panama	April 29	1
1600	Belize	June 3	1
1602	Belize	July 20	0
1609	Belize	July 20	1
1599	Belize	July 8	0
1598	Belize	July 8	0
1611	Belize	July 8	0
1585	Belize	July 8	0
1622	Belize	August 8	0
1591	Belize	August 8	0
1589	Guatemala	July 20	3
1948	Ecuador	August 8	2

1 Anthracnose rating: 0 = no anthracnose; 1 = minor leaf and/or stem spotting; 2 = moderate leaf and/or stem spotting; 3 = severe spotting; defoliation; 4 = severe defoliation; plant death.

Blight

Blight, caused by *Sclerotium rolfsii,* was first detected in Carimagua in 1977 and was again observed from August to October 1978. The fungus attacks two- to three-month-old *S. capitata* plants near the soil surface, causing wilting and plant death. CIAT 1019 was the most susceptible while 1078, 1315 and 1328 were occassionally affected. Although, at present, disease incidence is low, blight is a potentially important disease due to the ability of fungal sclerotia to survive in the soil for many years. Experiments have been initiated to screen promising legume accessions against *S. rolfsii* and to study variation in susceptibility with age of accession 1019.

Root-knot Nematode

Several plantings of *D. ovalifolium* CIAT 350 at Carimagua, El Limonar and CIAT-Quilichao were affected by the root-knot nematode, *Meloidogyne javanica.* Large galls developed on roots of infected plants which were chlorotic and stunted. Severely infected plants died. Only vegetatively propagated plantings of *D. ovalifolium* at Carimagua and Quilichao were affected. Surveys of indigenous legumes, including *Desmodium* species, at Carimagua, El Limonar and Quilichao failed to detect root-knot nematodes, with one exception. At Carimagua, one indigenous *Desmodium,* growing near an infected *D. ovalifolium* planting, was infected. It appears that introduced infected *D. ovalifolium* material and / or soil, possibly from soil used in Jiffy pots from CIAT-Palmira where cassava and the composite *Bidens pilosa* are hosts to this nematode, are responsible for the presence of root-knot nematode at Carimagua and Quilichao. Screening of all promising legumes and many accessions of *Desmodium* species for resistance to *M. javanica* is in progress.

Camptomeris Leaf Spot

This disease, caused by *Camptomeris leucaenae,* is specific to *Leucaena* species. Previously, it has been recorded only from Caribbean islands, Venezuela and, in February 1978, from Mexico, where its incidence was sporadic but its effect often severe. Newly established plots of *Leucaena leucocephala* CIAT 734 were severely affected by *C. leucaenae* at CIAT-Quilichao in September 1978. Small brownish spots or chlorotic patches appeared on the upper surface of diseased leaflets while the fungus sporulated profusely as black pustules on the lower surface. Heavily infested leaflets turned yellow and there was considerable defoliation. Periods of dry weather favored the disease. This potentially damaging disease will require basic study if *Leucaena* is further considered as a tropical forage legume for this region.

Cercospora Leaf Spot

At CIAT-Quilichao and Carimagua, most plantings of *Panicum maximum* were affected by *Cercospora* leaf spot. Infestations were more severe in the wetter environment of Carimagua. The reddish brown spots enlarged and coalesced on leaves of all ages, producing extensive areas of necrotic tissue. Studies on the effect of *Cercospora* sp. on yield of *P. maximum* and field evaluations for resistance are being initiated.

Rust

Accessions of *Macroptilium* and *Vigna* species were moderately to severely affected by the rust, *Uromyces appendiculatus,* at CIAT-Quilichao. Large reddish brown sori containing uredospores developed profusely on both leaf surfaces. *Macroptilium* sp. CIAT 4050 was severely affected with many leaves turning yellow and falling. This disease will warrant investigation if *Macroptilium* and *Vigna* are further evaluated as forages.

Powdery Mildew

Powdery mildew, caused by *Oidium* sp., was observed on accessions of *Macroptilium* and *Vigna* species at CIAT-Quilichao. Several plants of *Macroptilium* sp. CIAT 4195 were killed. At present, however, disease incidence is low.

Other Potentially Important Fungi

Legumes

Moderately severe spotting of leaves and stems was caused by *Alternaria alternata* on *Zornia* sp. CIAT 9203; by *Cercospora* spp. on accessions of *Centrosema, Galactia, Macroptilium* and *Vigna;* by *Cercosporidium* sp. on several *Aeschynomene* accessions and by *Dreschslera* sp. on several *Zornia* accessions. Other fungi commonly isolated from leaf spots included *Curvularia* spp., *Drechslera* spp., *Leptosphaerulina* spp., *Pestalotia* spp., *Phoma* spp., *Phomopsis* sp., and *Stemphylium* spp.

Grasses

Potentially pathogenic fungi isolated from leaf spots on grasses included *Alternaria* spp., *Curvularia* spp., *Drechslera* spp., and *Colletotrichum graminicola*. Inflorescens of *P. maximum* were sporadically affected by *Fusarium* spp. and a smut *(Ustilago* sp.). No potential plant pathogens have been identified as attacking *Andropogon gayanus* 621.

ENTOMOLOGY

The objective of the Entomology Section is to develop pest management systems for tropical forages in the Beef Program's Target Area. These systems are designed to avoid or minimize chemical controls.

Studies this year concentrated on the biology, ecology and population dynamics of insect pests together with the development of a screening system for host plant genetic resistance to the stemborer. In addition, biological control agents and forage and animal management practices were identified and evaluated as components of integrated control systems.

Life Cycle Studies

Stemborer

The stemborer, tentatively identified as *Zaratha* sp. in last year's report, was now identified as *Caloptilia* sp. by D.R. Davis of the Beltsville Agricultural Research Center, U.S.A. *Caloptilia* sp. attacks *Stylosanthes* species at the three major field research sites of the Beef Program, in the Colombian Llanos and Cauca Valley of Colombia and in the Cerrado of Brazil. The female oviposits on the plant stem; eggs are red, elongated and about 0.42 mm long with a corrugated surface. The incubation period is approximately 11 days at 25°-30°C. Newly emerged larvae are about 0.6 mm long, of a creamy white color with a very well differentiated anal plate. Larvae then penetrate into the stem and continue their development attaining a length of about 7.5 mm. The larval stage averages about 58 days. Pupation occurs inside the stem and after 18 days the adult emerges. The adult stemborer is a microlepidoptera, brown-grey in color, 5 mm long with very long filiform antennae. The life cycle of this stemborer is shown in Figure 34.

Budworm

Information on the biology of the stylo budworm, *Stegasta bosqueella* Chambers, was obtained under field conditions from *Stylosanthes capitata* 1019. Females lay their eggs on the trichomes of the external bracts of the inflorescences. Eggs are elongated and creamy white in color with a corrugated surface. The incubation period is about five days; at the time of hatching larvae are creamy yellow with a dark reddish pro- and mesothorax and are 0.5 mm long. Last instar larvae grow to 6 mm, becoming pinkish in color. The larval period lasts about 18 days and the pupal stage, 9 days. Under field conditions the budworm is found feeding on terminal branches, before the plant starts flowering. The budworm's life cycle is shown in Figure 35.

Biological Control

Larval Parasitism

Stemborer larval populations are parasitized by wasps identified as a Hymenoptera, family Eupelmidae, *Anastatus* sp. and Hymenoptera, family Braconidae, *Bracon* sp. (both determined by Paul M. Marsh of the Beltsville Agricultural Research Center). Although

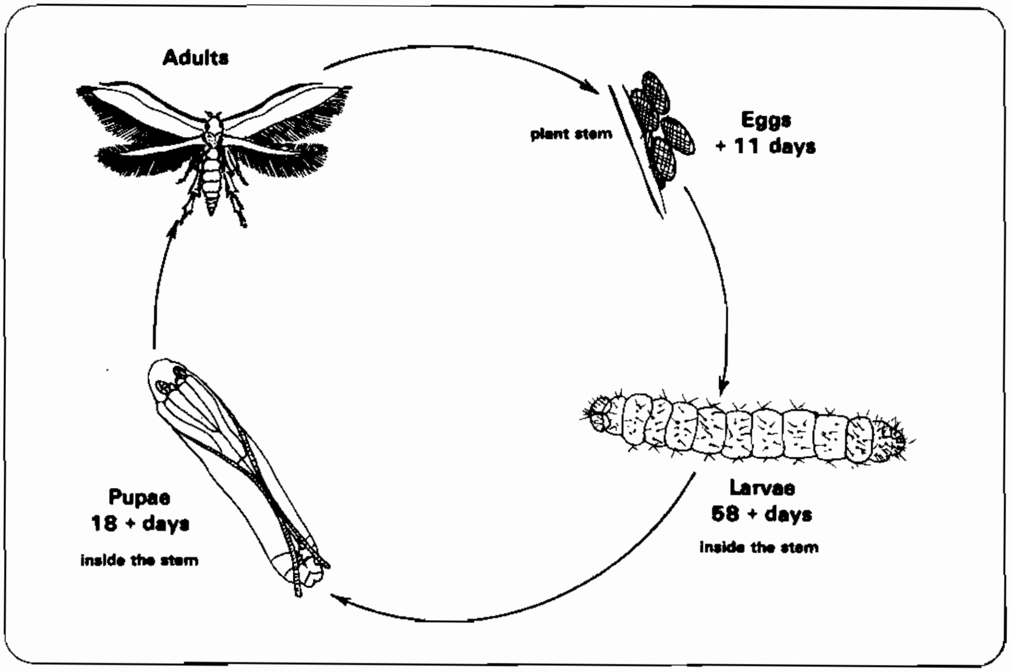


Figure 34. Life cycle of the stemborer *(Caloptilia* sp.) attacking *Stylosanthes.*

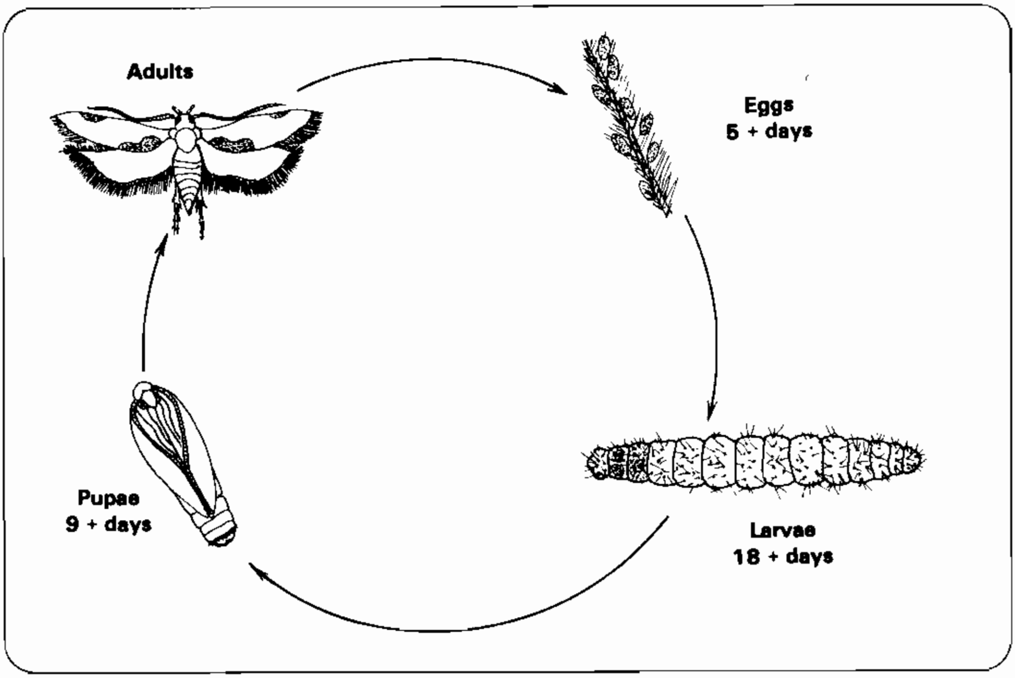


Figure 35. Life cycle of the budworm *(Stegasta bosqueella* (Chambers)) attacking *Stylosanthes.*

both species are found parasitizing the stemborer under natural conditions, apparently *Anastatus* sp. (Figure 36) is more specific than *Bracon* sp. (Figure 37). Both species oviposit in the stemborer larvae where the parasite larvae develop.

Further studies will be conducted to determine the efficiency and functional and numerical response of these parasites as potential components of an integrated control system. *Bracon* sp. is found in CIAT-Quilichao and Carimagua, but *Anastatus* has only been found at El Limonar, near CIAT-Quilichao, where populations are established. At Quilichao

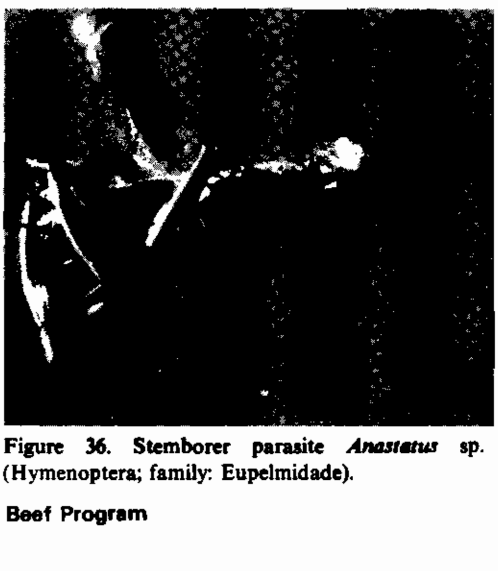


Figure 36. Stemborer parasite *Anastatus* sp. (Hymenoptera; family: Eupelmidade).

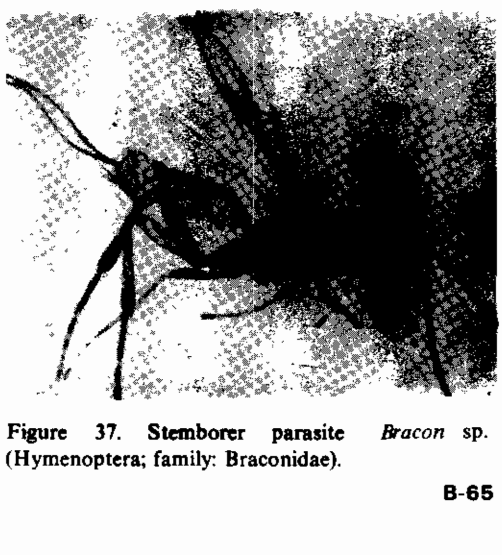


Figure 37. Stemborer parasite *Bracon* sp. (Hymenoptera; family: Braconidae).

the stemborer infestation is presently very low.

Stemborer Pathogen

A fungi affecting stemborer larvae was found in the field at CIAT-Quilichao. The fungi is probably *Spicaria* and studies of its influence on the stemborer will be continued.

Budworm Parasitism

Three different parasites have been found attacking budworm larvae: *Bracon* sp. (same as the stemborer parasite); a Hymenoptera, family Braconidae, *Chelonus* sp.; and a Hymenoptera, family Braconidae, *Orgilus* sp. (Figures 38 and 39).

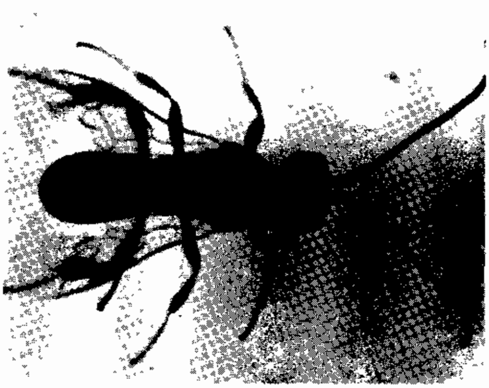


Figure 38. Budworm parasite *Chelonus* sp. (Hymenoptera; family: Braconidae).

Host Plant Resistance

Screening System

Since the stemborer is the most important pest affecting *Stylosanthes* accessions, emphasis has been given to developing a screening system to evaluate CIAT forage germplasm for tolerance or resistance as quickly as possible. The system consists of three steps.

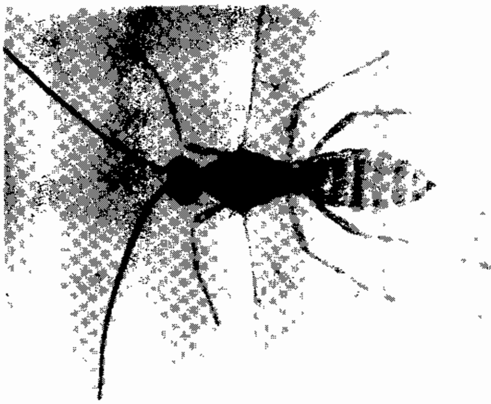


Figure 39. Budworm parasite *Orgilus* sp. (Hymenoptera; family: Braconidae).

(1) Field Screening. Using germplasm material planted at CIAT-Quilichao, Carimagua and elsewhere by other sections of the Beef Program, evaluations are made throughout the year. During natural outbreaks, data on tunnel length, larvae size and numbers, and plant phenology are recorded.

(2) Oviposition Preference Test. For this test cages were designed in which *Stylosanthes* plants are randomly placed. Plant material is infested with males and females of *Caloptilia* sp. The plants remain in the cages three to four days under stemborer stress; afterwards they are removed and replaced by another set which is infested with a new group of males and females. Oviposition evaluations are made by recording the numbers of eggs found per plant ecotype tested.

(3) Feeding Preference Test. Stems of several promising *Stylosanthes* accessions are placed on Petri dishes infested with stemborer larvae, providing the larvae with the opportunity to infest and penetrate the ecotype preferred.

Population Dynamics

A study was initiated to identify the

orders, families and species of insects found more frequently on the different ecotypes of legumes and grasses, and to understand insect population flows and preferences. An insect collection and a catalog of the main insects found on forages and legumes were developed. High populations were recorded during the first year of sampling; species of Homoptera appear to be potential pests at both CIAT-Quilichao (Figure 40) and Carimagua. Figure 40 shows insect orders to be more evenly distributed on *Andropogon gayanus* than on other species. Many of these insects are beneficial ones (Hymenoptera, Diptera including insect pollinators, some Hemiptera and Coleoptera).

Characterization of Effects of Anthracnose/Stemborer Attacks

In order to understand and to differentiate the effects of anthracnose and stemborer on *Stylosanthes guianensis* 136 pastures an experiment with either fungicide (benomyl), insecticide (carbofuran) or fungicide/insecticide treatments was designed. The experiment was located in an *S. guianensis* paddock at Carimagua. Data from one year of observations (Table 27) showed: (1) that reduced forage production was due to anthracnose attacks and not to stemborer infestations; (2) that defoliation was

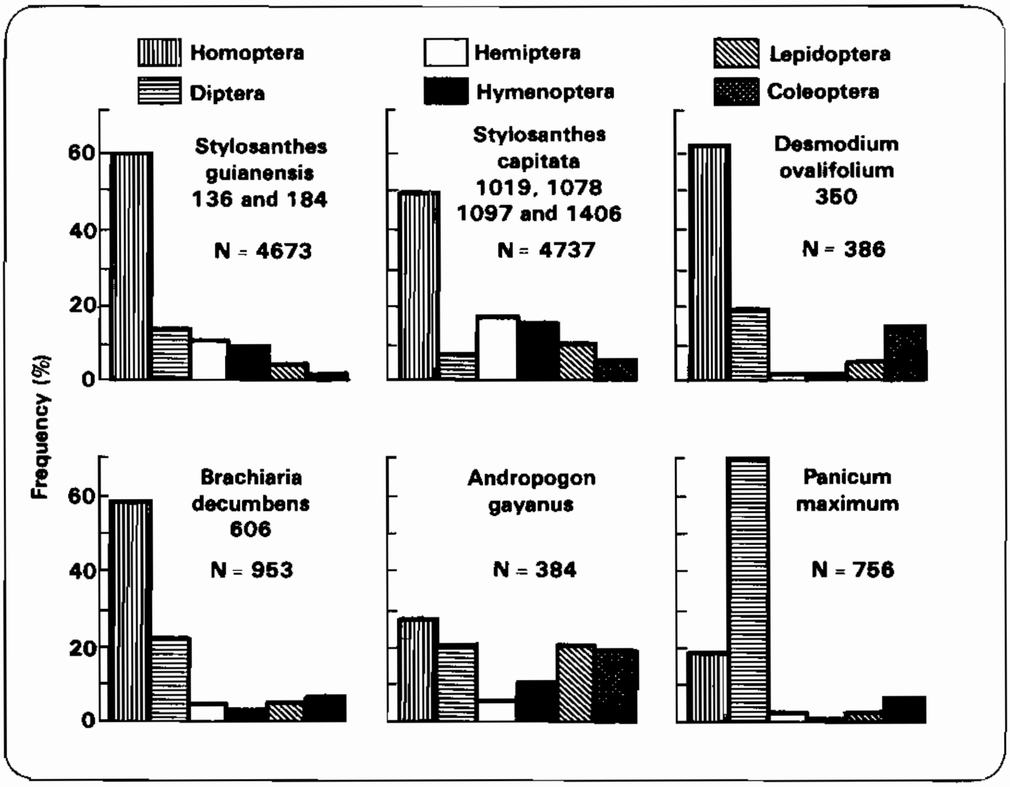


Figure 40. Frequency of appearance of different insect orders on some legumes and grasses in samplings at CIAT-Quilichao, 1978. (N = number of insects observed.)

Table 27.

Effects of fungicide, insecticide and fungicide/insecticide treatments on the incidence of anthracnose and stemborer infestations on *Stylosanthes guianensis* 136 pasture yields at Carimagua during 1978.

Parameter	Treatments[1]				
	Check	Insecticide	Fungicide	Insecticide/ fungicide	Grazed
Stemborer infestation (%)	8.0	5.3	7.8	4.5	3.3
Defoliation (%)	53.7	51.7	43.4	44.1	54.9
Fresh matter[2] (kg/ha)	2041	2100	3740	3780	-
Dry matter[2] (kg/ha)	660	667	1180	1172	-

1 Insecticide: carbofuran; fungicide: benomyl.
2 At first cutting, August 1978.

greater on treatments not receiving the fungicide; and (3) the treatments receiving the fungicide provided the highest forage production. The percentage of stemborer infestation throughout the year was low, and the infestation level was less than one larvae per plant. Based on these preliminary results stemborer cannot be considered a limiting factor in forage production, at least during the establishment year. This experiment will be maintained two more years.

Field Evaluations

Stemborer infestation was monitored at Carimagua throughout the year. Field plots of *Stylosanthes* accessions planted alone or associated with grasses, and with or without grazing were evaluated.

Comparing *S. capitata* 1019 against *S. capitata* 1078, in association with *Brachiaria decumbens* and *A. gayanus* and with and without grazing, accession 1019 showed less infestation than the latter under both situations (Figure 41). Also, 11 ecotypes in association with grasses and under grazing were evaluated during the year. Results showed some variability in infestation among the ecotypes. *S. capitata* 1019 had the lowest percentage of infestation, while *S. capitata* 1078 showed the highest (Figure 42). However, the infestation levels (number of larvae per plant) were low in all cases except for 1078 which showed more than one larvae per plant (Figure 43). When both the percentage and level of infestation were recorded for *Stylosanthes* plants in pure stands without grazing, *S. capitata* 1097 and *S. guianensis* 1200 showed the highest percentage and level of infestation (Figure 44).

Bases for Host Plant Resistance

As a result of field evaluations certain *S. capitata* ecotypes have been identified which consistently show low stemborer damage; these include accessions 1019, 1405, 1342, 1339, 1338 and 1325.

Most Lepidoptera, when reaching the adult stage, search for food sources of nectars and honeydew and insects are frequently found visiting plants that provide these foods. It is possible that female stemborers are being attracted by stylo accessions that have morphological characteristics of the stem with glandular trichomes having exudations on the tip of the hair. Usually, these exudations contain

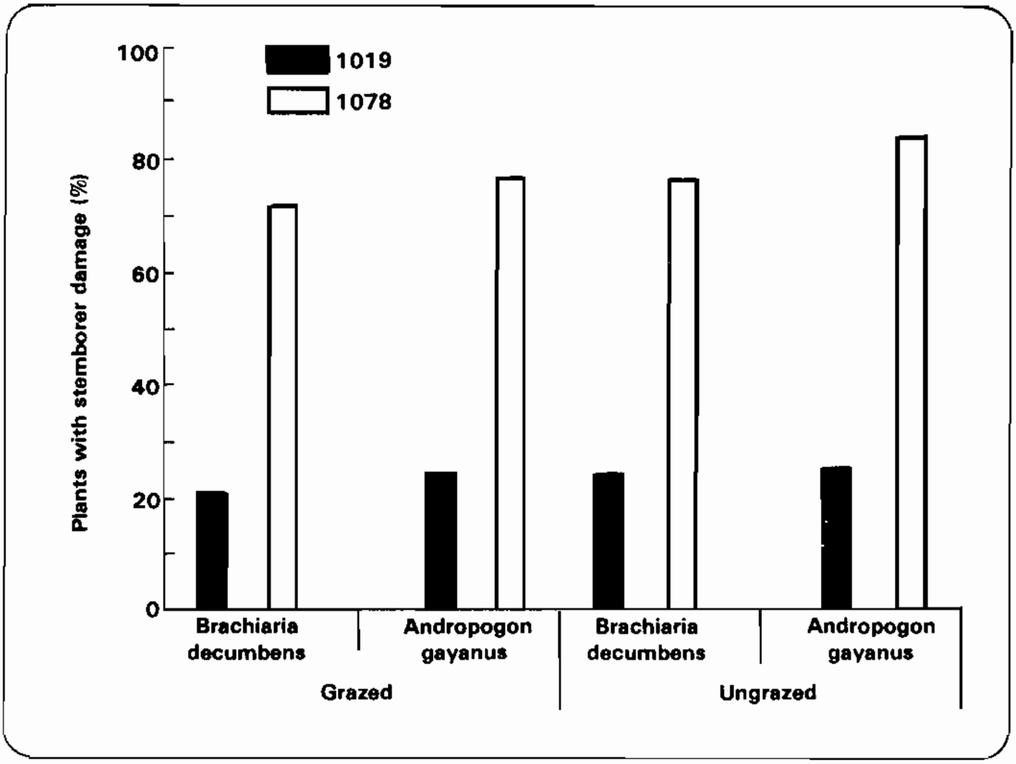


Figure 41. Infestation percentages of stemborer *(Caloptilia* sp.) on two ecotypes of *Stylosanthes capitata* in association with two grasses, with and without grazing, at Carimagua, 1978.

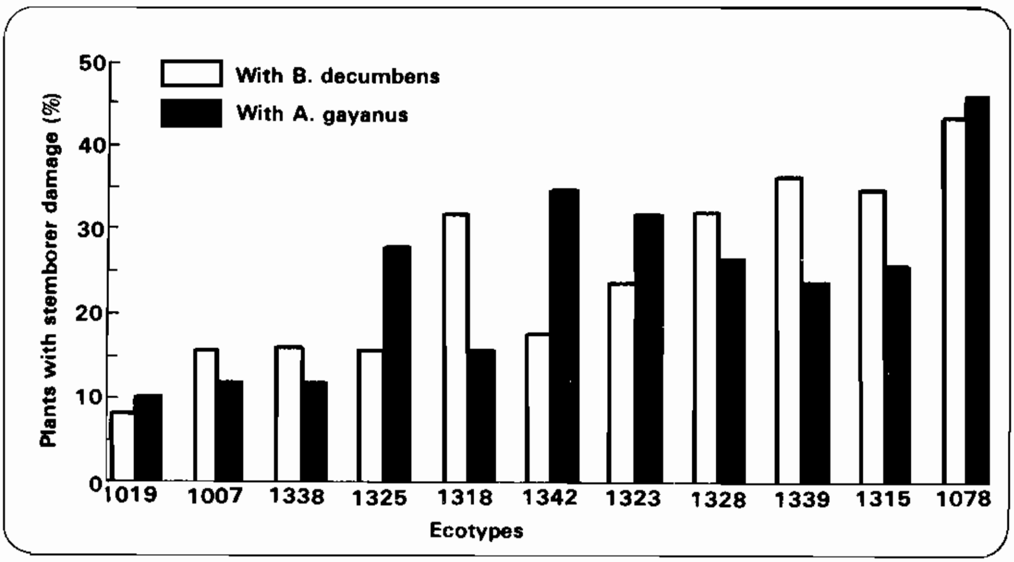


Figure 42. Infestation percentages from the stemborer *(Caloptilia* sp.) found on some ecotypes of *Stylosanthes capitata* in association with grasses under grazing at Carimagua, 1978.

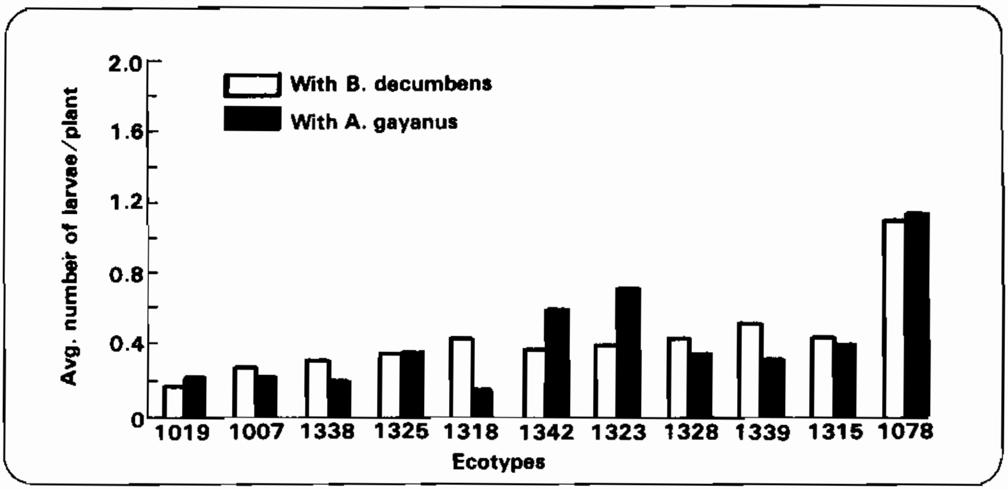


Figure 43. Numbers of stemborer *(Caloptilia* sp.) larvae found on some ecotypes of *Stylosanthes capitata* in association with grasses under grazing at Carimagua, 1978.

sugars that act as insect attractants and often serve as stimuli to oviposition. This morphological characteristic of the plant could be used as a tool in selecting accessions resistant or tolerant to stemborer attack.

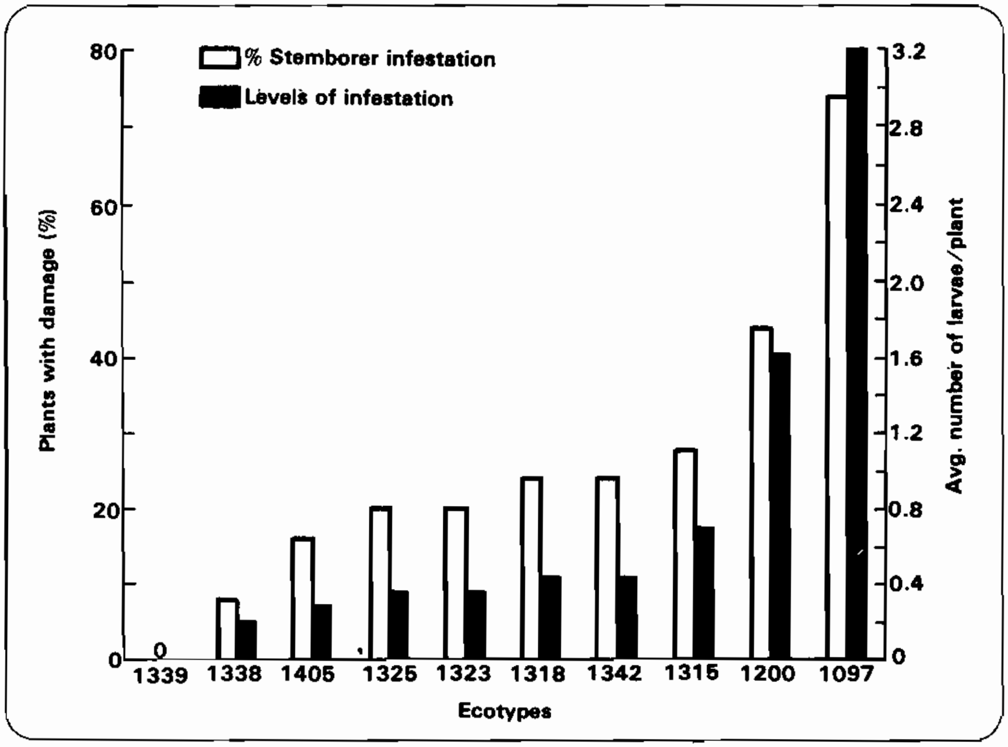


Figure 44. Percentages of plants with damage and numbers of stemborers recorded on ecotypes of *Stylosanthes* in pure stands, without grazing at Carimagua, 1978.

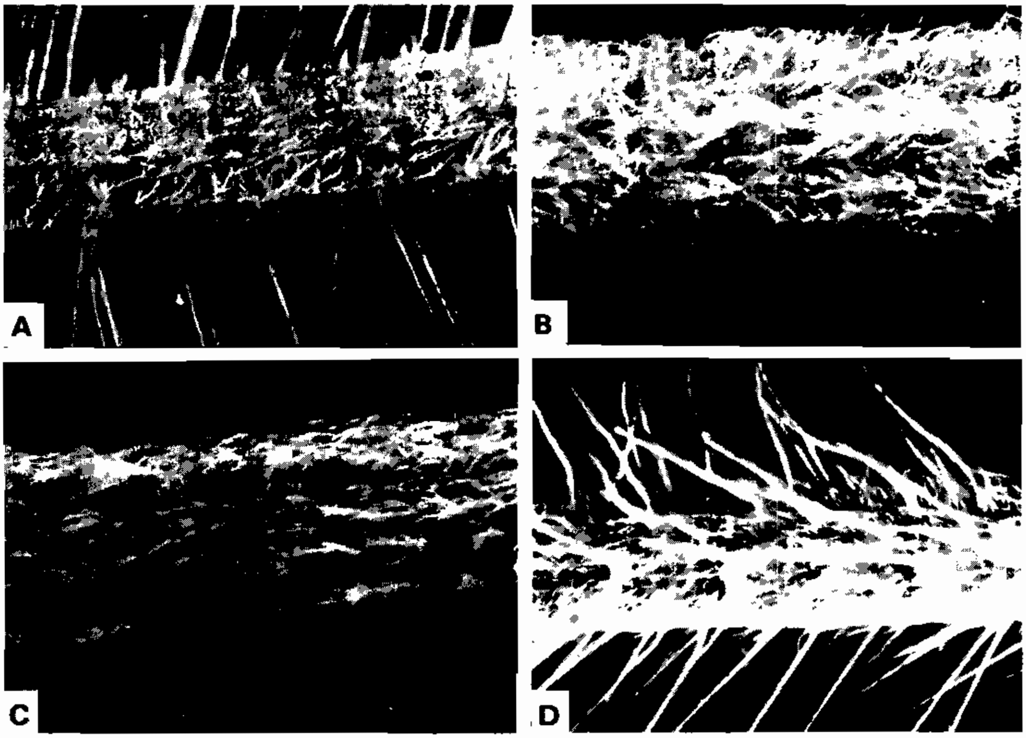


Figure 45. Four *Stylosanthes* ecotypes with varying trichome structures. (A) *S. guianensis* 136 with glandular trichomes; (B) *S. guianensis* 184 with glandless trichomes; (C) *S. capitata* 1019 with glandless trichomes; and, (D) *S. capitata* 1078 with glandular trichomes.

Also, by crossing hairy with glabrous types it might be possible to obtain plants with desirable forage production qualities that also feature this morphological factor for resistance to stemborer.

In preliminary research, the stemborer has been observed to prefer accessions with glandular trichomes (*S. guianensis* 136 and *S. capitata* 1097 and 1078) while *S. guianensis* 184 and *S. capitata* 1019 and 1405 which do not have glandular trichomes have shown less stemborer damage (Figure 45).

Based on these results chemical analyses of total carbohydrate and protein contents between the two types of plants have been initiated to better identify causes of resistance or tolerance to stemborer damage.

SOIL MICROBIOLOGY

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

Rhizobium Collection

The number of strains in the CIAT *Rhizobium* collection for tropical forages doubled during 1978 to 2043 through donations by collaborators (principally R. A. Date of the Commonwealth Scientific and Industrial Research Organization (CSIRO), Brisbane, Australia) and through collecting trips to eastern Venezuela (CSIRO/CIAT), Ecuador (CSIRO/CIAT), and northeastern Brazil (EMBRAPA/CSIRO/CIAT). The second edition of the catalog of strains of *Rhizobium* for forage legumes was published and is available.

Research on collection methodology revealed that although silica gel and $CaCl_2$ do not differ significantly in the rate at which they dessicate nodules in storage vessels, the viability of rhizobia in stored nodules is greater and the level of contaminating organisms on primary isolation plates is reduced when $CaCl_2$ is used.

It is now known that a key factor in past failures of isolating *Rhizobium* from nodules of plants (especially *Stylosanthes* spp.) growing in acid soils was because many such strains have an acid requirement for growth and cannot grow on the standard medium (pH 7) used for isolation. This implies that the search for acid-adapted *Rhizobium* in existing collections of strains which were originally isolated onto routine, non-acid media may not be the most valid nor fruitful approach. Collecting activities have been increased using acid media to isolate and maintain cultures.

Strain Selection

Strains of *Rhizobium* for forage legumes which are nominated as promising by the Beef Program's Germplasm Committee continue to be selected by the five-stage program outlined last year, (CIAT Annual Report, 1977). One change from previous methodology is that the soil used in pot trials at Stage III is not sterilized.

Stage I (Aseptic Tube Culture)

Stylosanthes capitata. Forty-three strains of *Rhizobium* isolated from root nodules of *Stylosanthes* species from various soil types were tested with two *S. capitata* genotypes (CIAT 1019 and 1078). Nodulation did not occur in any host genotype by strain combination. When the standard agar rooting medium was acidified to pH 4.9, however, 15 strains produced nodulation on *S. capitata* 1019. It is concluded that *S. capitata* has an acid requirement for nodulation. *S. capitata* exhibited greater specificity in its strain requirement than *S. guianensis* CIAT 136, *S. hamata* PI 40264A and *S. hamata* PI 38842, each of which nodulated with all 43 strains.

Zornia spp. Eight out of 15 strains of *Rhizobium* tested with *Zornia* sp. CIAT 728 formed nodules under the test conditions.

Macroptilium sp. CIAT 535. Only half of the *Rhizobium* strains tested with this host formed nodules, indicating a much higher degree of specificity of strain requirement than occurs with the very promiscuous *Macroptilium atropurpureum* cv. Siratro.

Stage II (Sand Culture with pH 7 Nutrient Solution)

Desmodium ovalifolium CIAT 350. The

ranking of 39 strains of *Rhizobium* in order of their nitrogen fixing potential with this host is given in Figure 46. The best non-CIAT isolate was 26th in effectiveness. Variation in strain effectiveness can be attributed mainly to differences in the mass of nodules formed (Fig. 47) rather than the rate at which the nodules function (specific nodule activity).

Stylosanthes capitata CIAT 1019. The result of this experiment (Fig. 48A) indicated that growth requirements of the plant have not been met satisfactorily by the medium used routinely in this stage. CIAT 71, a strain known to be effective with *S. capitata,* was ineffective. Work continues to develop a nutrient solution suitable for sand culture of *S. capitata.*

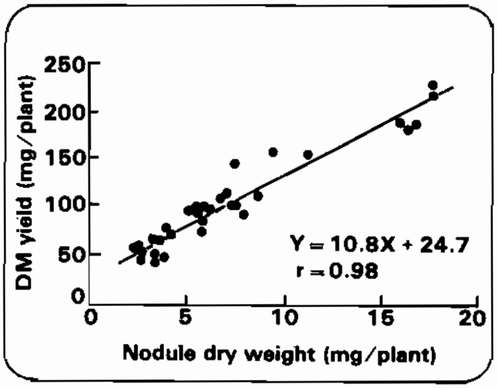


Figure 47. Correlation between nodule mass and dry matter production by *Desmodium ovalifolium* 350 in symbiotic associations with 35 strains of *Rhizobium.*

Macroptilium sp. CIAT 535. The wide spectrum strain CB 756 was moderately effective with this host (Fig. 48B). The

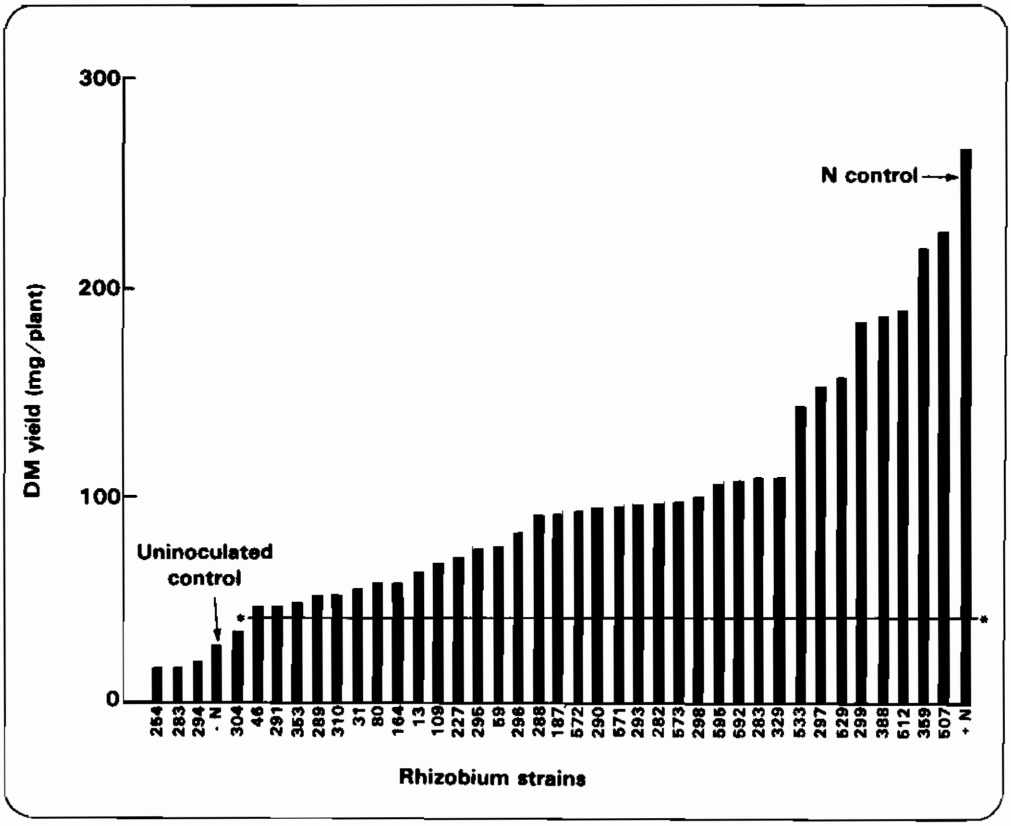


Figure 46. *Rhizobium* strain selection for *Desmodium ovalifolium* 350 (during Stage II). (* = upper confidence limit (95%) to mean of uninoculated control.)

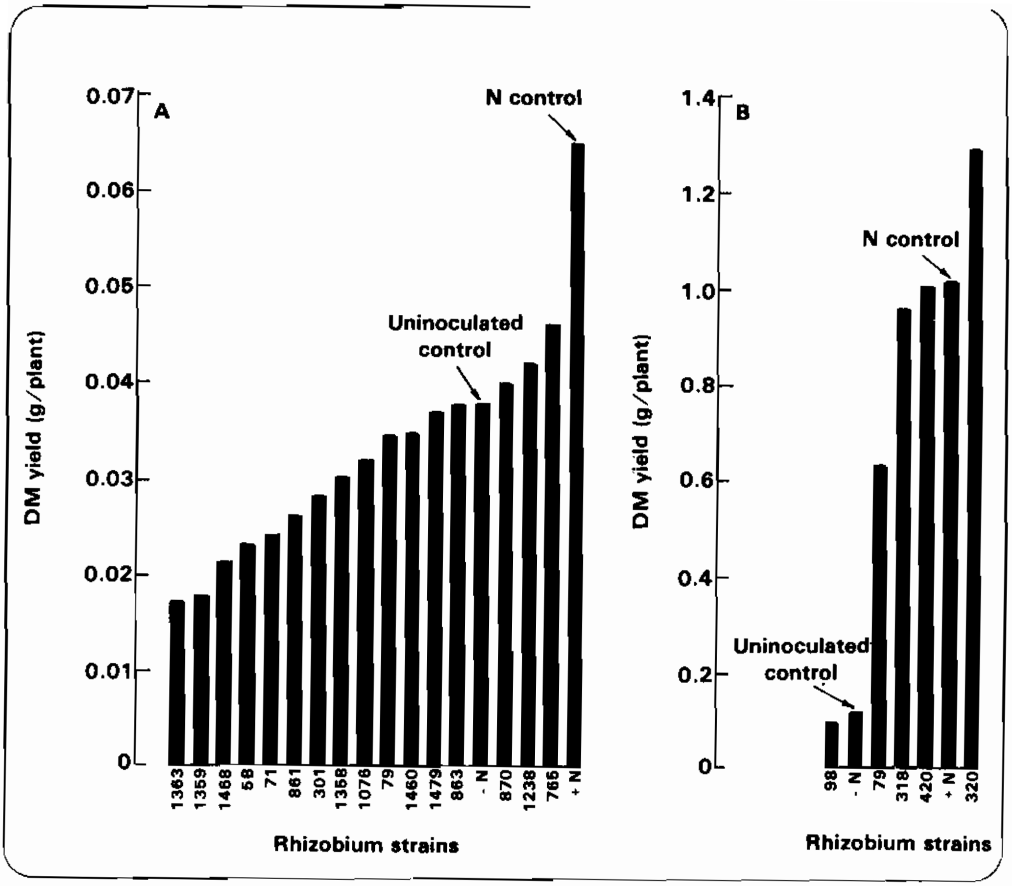


Figure 48. *Rhizobium* strain selection for (A) *Stylosanthes capitata* 1019, and (B) *Macroptilium* sp. 535, during Stage II.

strains CIAT 320, 420 and 318 were more effective.

Stage III (Pot Culture in Site Soil)

Stylosanthes capitata CIAT 1019. Plants inoculated with the best strain in this trial yielded double the dry matter of uninoculated control plants (Fig. 49A). The strain CIAT 71, which to now has been recommended for *S. capitata* only on the basis of high effectivity with *S. guianensis* and genetic compatability with *S. capitata,* was confirmed as a highly effective nitrogen fixing symbiont for this host and has increased attractiveness as a wide spectrum inoculant strain for acid soils. CB 756, a strain often used to inoculate *Stylosanthes,* was confirmed to be ineffective with this *S. capitata* accession.

Zornia sp. CIAT 728. Strain CIAT 71, originally isolated from *Stylosanthes* nodules, proved to be one of the most effective strains on this taxonomically closely related genus (Fig. 49B). Strain CIAT 103, which had been recommended previously for *Zornia* on the basis that it was a *Zornia* isolate, is only moderately effective with this accession.

Desmodium distortum CIAT 335. Only 3 of 12 strains of *Rhizobium* that were

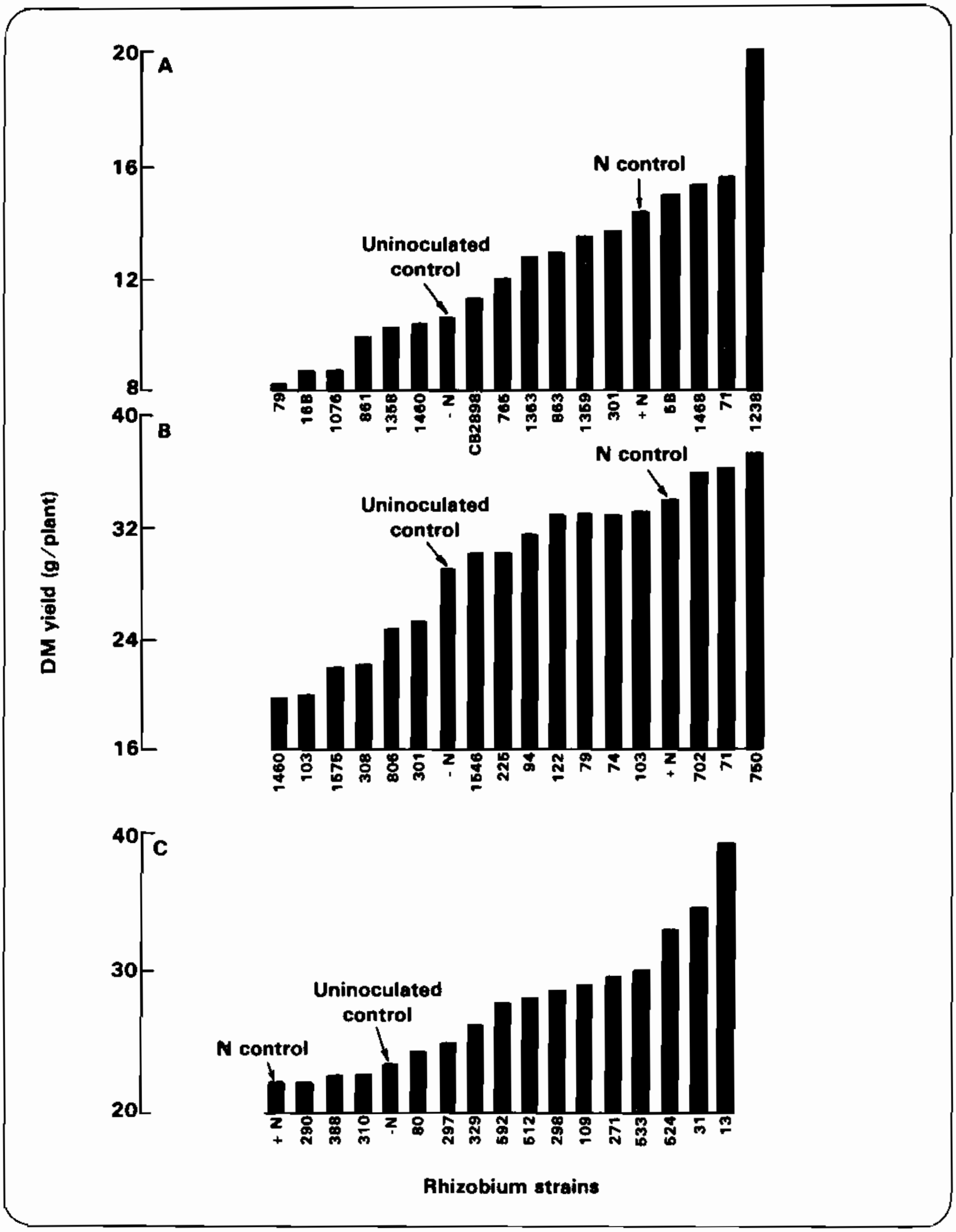


Figure 49. *Rhizobium* strain selection at Stage III for (A) *Stylosanthes capitata* 1019; (B) *Zornia* sp. 728; and, (C) *Desmodium distortum* 335.

highly effective in nitrogen fixation in sand jars were capable of nodulating and fixing nitrogen under acid soil stress (Fig. 49C).

Centrosema hybrid brasilianum x virginianum CIAT 438. The ranking of effectiveness in nitrogen fixation in acid soil in the presence of competing native strains of *Rhizobium* for the best 10 strains from Stage II (CIAT Annual Report, 1977) differs from the order of merit under optimal plant growth conditions (Fig. 50A). The best strain under stress in site soil was eighth in effectiveness in sand jars. Also, several strains that were very effective in sand jars fixed no nitrogen in acid soil. It was particularly surprising that strain CIAT 324 which was 49th among 50 strains in sand jars gave the second highest yield in the Stage III trial.

Desmodium heterophyllum CIAT 349. Only 1 out of 10 strains of *Rhizobium* that were fully effective in nitrogen fixation at Stage II was fully effective in nitrogen fixation under stress in acid soil (Fig. 50B)

Stage III results emphasize the important modifying role which the soil can play on the legume/*Rhizobium* symbiosis and urges caution in over-dependence on the standard sand jar test to select strains of *Rhizobium* for a stress condition.

Stage IV (Field Trials)

CIAT-Quilichao. Data from the field trials with *Desmodium ovalifolium* 350, *S. guianensis* 136, *Centrosema* hybrid *brasilianum* x *virginianum* 438, *Galactia striata* 964, *D. distortum* 335, *Macroptilium* sp. 535, *D. heterophyllum* 349, *S. capitata* 1019, *S. capitata* 1078 and *Pueraria phaseoloides* 9900 are summarized in Table 28.

Carimagua. Results of the field trials with *D. ovalifolium* 350, *S. capitata* 1019,

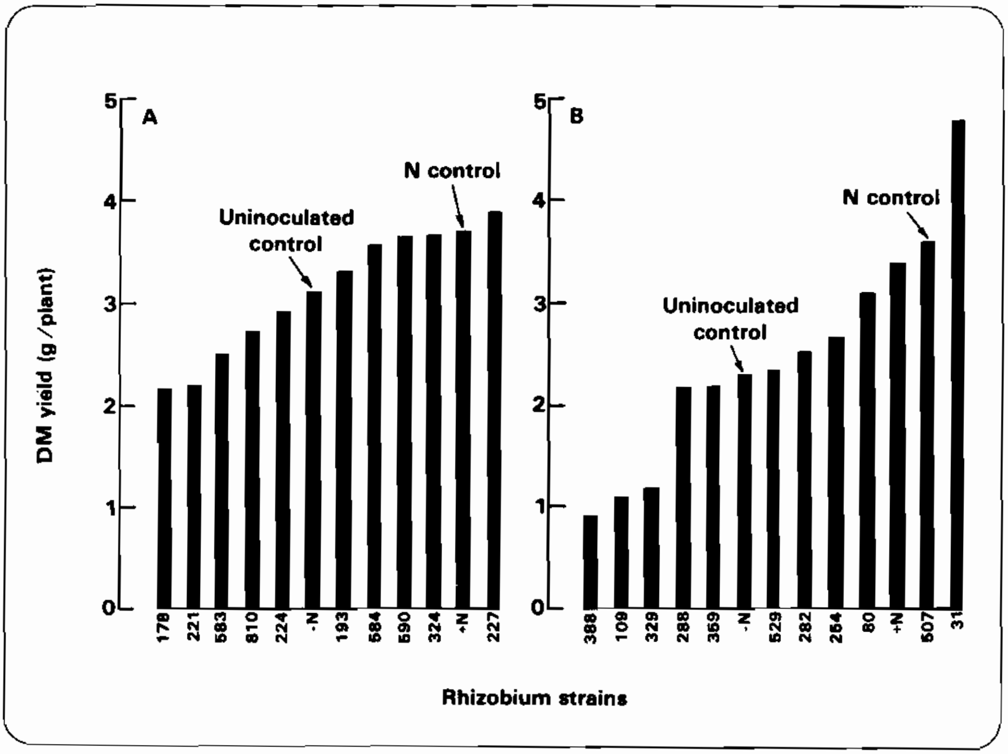


Figure 50. Rhizobium strain selection for Stage III for (A) *Centrosema* hybrid 438 and (B) *Desmodium heterophyllum* 349.

Table 28.

Summary of field trials of *Rhizobium* strains and inoculation technologies at CIAT-Quilichao.

Species and accession number		Best treatment[1]	Inoculation response (as % of uninoculated control) 1st cut[2]	2nd cut	3rd cut	4th cut
Stylosanthes guianensis	136	CIAT 79 lime pellet	52.5	28.3	43.3	14.8
Centrosema hybrid	438	CIAT 590 lime pellet	17.4	0	5.1	-[4]
Galactia striata	964	CIAT 378 RP[3] pellet	19.7	0	0	0
Desmodium ovalifolium	350	CIAT 299 lime pellet	101.0	35.6	-	-
Desmodium distortum	335	CIAT 299 no pellet	34.1	20.3	3.2	-
Macroptilium sp.	535	CIAT 319 lime pellet	70.9	-	-	-
Desmodium heterophyllum	349	CIAT 80 RP pellet	48.8	-	-	-
Pueraria phaseoloides	9900	CIAT 79 RP pellet	61.1	3.3	-	-
Stylosanthes capitata	1019	CIAT 71 RP pellet	0	-	-	-
Stylosanthes capitata	1078	CIAT 71 RP pellet	12.5	-	-	-

1 Standard field trial of three selected strains and three inoculation technologies.
2 Cutting interval depended on the production by each species, but was usually around 3 months.
3 Rock phosphate.
4 Blanks indicate data are not yet available.

S. capitata 1078 and *Macroptilium* sp. 535 are summarized in Table 29. The experiment with *Macroptilium* has been terminated due to lack of host plant adaptation to the soil, climatic, insect and disease stresses of the region. With *S. capitata* accessions neither 1019 nor 1078 survived into the second year under small plot, pure sward conditions. Adult plants of 1019 were virtually eliminated by spider mites

Table 29.

Summary of field trials of *Rhizobium* strains and inoculation technologies at Carimagua.

Species and accession number	Best treatment[1]	Inoculation response (as % of uninoculated control) 1st cut[2]	2nd cut	3rd cut
Desmodium ovalifolium 350	CIAT 46 RP pellet	22.3	0	-
Stylosanthes capitata 1019	CIAT 71 lime pellet	39.5	-	-
Stylosanthes capitata 1078	CIAT no pellet	15.1	0	4.1
Macroptilium sp. 535	CIAT 318 lime pellet	98.3	41.3	1.6

1 Standard field trial of three selected strains and three inoculation technologies.
2 Cutting interval depended on the production by each species, but was usually around 3 months.

and in 1078 stemborer reduced the population of mature plants to near zero. These results are inconsistent with the observed behavior of these accessions in mixed pasture with grasses. Some useful data may be obtained on the persistence of introduced strains in soil and their ability to nodulate new seedlings but it is not possible to study the inoculation response for more than one growing season with this experimental design. Future experiments with these accessions will be performed in larger plots with mixed swards.

Acid Tolerance by Rhizobium

Results for field and pot trials show that a response to inoculation with selected strains of *Rhizobium* is the rule rather than the exception although response tends to be reduced over time. It is likely that protecting the inoculant strain with pelleting at the time of sowing permits an early and high percentage infection by the effective introduced strain thus giving a marked initial response. A critical point is reached when the primary nodule population decomposes (after 2-3 months) and the rhizobia must survive in the acid soil as free-living soil saprophytes. Multiplication at low pH is extremely important for reinfection of the legume root, competition with native strains of *Rhizobium* for nodule sites and persistence in the soil microflora. Research was therefore directed at developing a medium to test for this character.

Alkali production by tropical rhizobia has been an obstacle to developing such a test causing the pH to rise from its initial value of around pH 4 to above pH 8, thereby confusing interpretation of the results. A stable acid medium which eliminates the ability of *Rhizobium* to produce alkali was developed (Table 30). The medium permits selection of strains genuinely capable of multiplication at low pH (Fig. 51) and will enable the effect of Al and other acidity stresses on *Rhizobium* to be determined.

Table 30.

Liquid medium for selecting acid-adapted strains of *Rhizobium*.[1]

Ingredient	Quantity
KH_2PO_4	68 mg
K_2HPO_4	87 mg
$CaCl_2.2H_2O$	39.4 mg
$MgSO_4.7H_2O$	74 mg
Fe+++Na EDTA	36.8 mg
$MnCl_2.4H_2O$	0.49 mg
$ZnSO_4.7H_2O$	0.29 mg
$CuCl_2.2H_2O$	43 μg
$Na_2MoO_4.2H_2O$	12 μg
$CoCl_2.6H_2O$	1.2 μg
Sodium glutamate	220 mg
Thiamine[2]	100 μg
Biotin[2]	250 μg
Arabinose	10 g
Distilled water	to one liter

1 Acidified with 0.1 *N* HCl (before autoclaving).
2 Filter sterilized and added after autoclaving the medium.

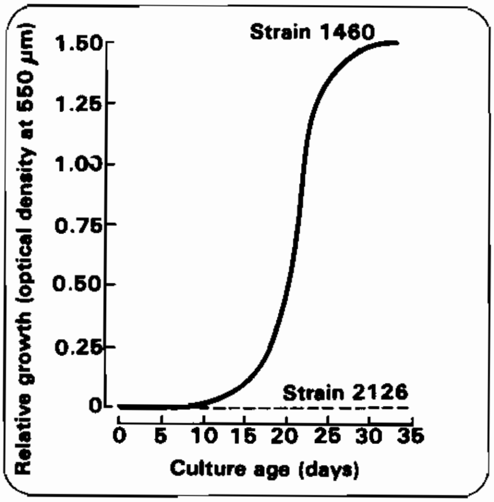


Figure 51. Relative growth of *Rhizobium* strains CIAT 1460, originating from an acid soil (pH 4.5), and CB 2126, from an alkali soil (pH 8.5), in a defined, acid medium (initial pH 4.2).

Demonstration that alkali production by the tropical rhizobia depends on the culture medium reopens the debate over whether these microorganisms actually produce alkali in the rhizosphere of their host and whether it was correct to attribute an evolutionary and ecological role to the process. It has been considered that lack of alkali production by the non-typical *Rhizobium* for *Leucaena leucocephala* is the prime reason for this species' lack of adaptation to acid soils. Parallel experiments at CIAT-Quilichao and Carimagua employing identical treatments and a recently assembled collection of strains of *Rhizobium* isolated from *Leucaena* has revealed that there is not, as was thought, a block of nodulation of *Leucaena* below pH 5.0. A wide array of strains from differing soil types were capable of forming effective symbioses in acid conditions (Fig. 52). A few strains were exceptionally effective and are being investigated further.

Inoculation Recommendations

The inoculation recommendations for promising legume accessions (as of Oct. 31, 1978) are given in Table 31. In some cases there is a change (improvement) from last year's list. During 1978, 86 kg of peat-

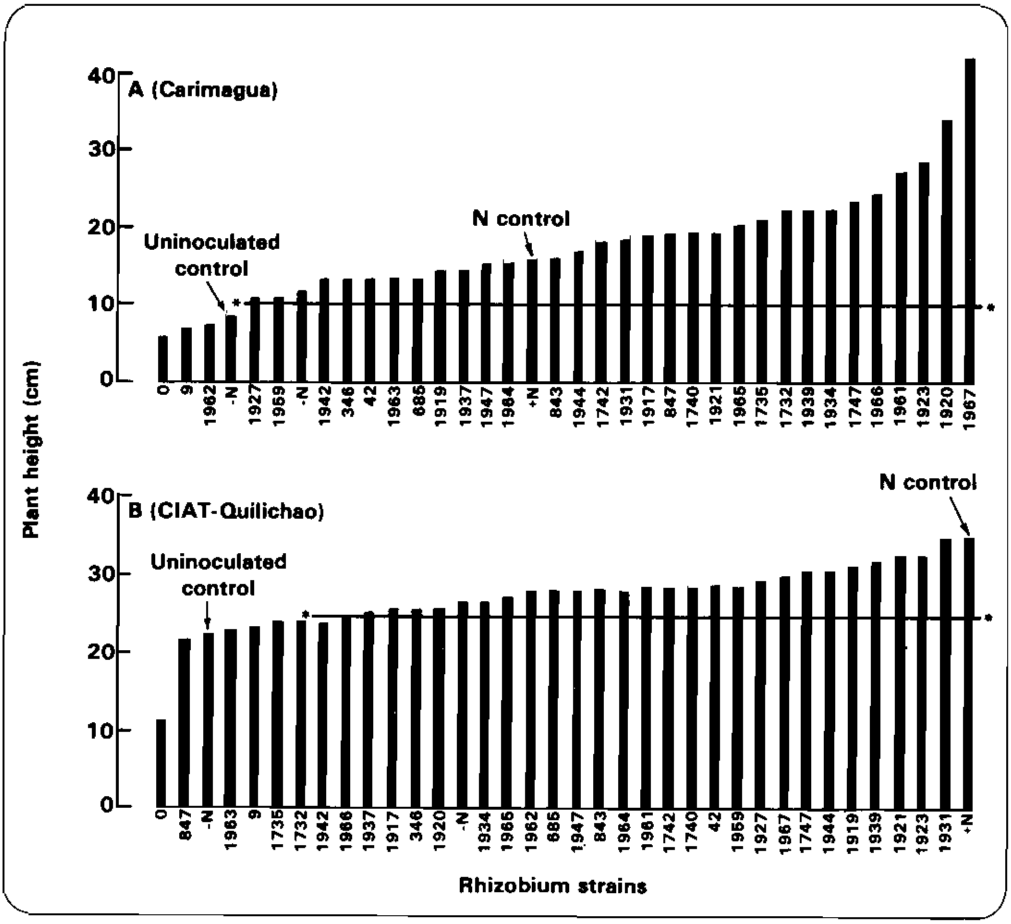


Figure 52. Response by *Leucaena leucocephala* to inoculation with strains of *Rhizobium* at two acid soil sites. (* = upper confidence limit (95%) to mean of uninoculated control.)

Table 31.

Current inoculation recommendations developed for certain promising forage legumes.

Species	CIAT No.	*Rhizobium* strain	Technology
Category 4			
Desmodium ovalifolium	350	CIAT 299	lime pellet
Pueraria phaseoloides	9900	CIAT 71	lime pellet
Stylosanthes capitata	1019/1078	CIAT 71	lime pellet
Zornia aff *latifolia*	728	CIAT 71	lime pellet
Category 3			
Centrosema hybrid	438	CIAT 590	lime pellet
Desmodium heterophyllum	349	CIAT 31	rock phosphate pellet
Category 2			
Stylosanthes guianensis	136/184	CIAT 71	lime pellet

based inoculum were produced; 45 kg were used for research in Colombia by CIAT and the Instituto Colombiano Agropecuario (ICA), and 10 kg and 6 kg were requested by national and international research institutes, respectively, while 25 kg were sent to private entities.

SOIL FERTILITY AND PLANT NUTRITION

Research on the nutritional requirements of promising grass and legume germplasm, and fertilization technology designed to efficiently meet such requirements was conducted CIAT-Palmira, CIAT-Quilichao, Carimagua and Brasilia. Emphasis this year was on: (1) N requirements of the main tropical grasses, and the N contribution of associated legumes; (2) P requirements of the main grasses; (3) more efficient use of cheap sources of P, primarily rock phosphates and its alteration products; and, (4) development of systematic techniques for estimating nutritional requirements of promising germplasm accessions. The properties of the main soils used, the Quilichao Ultisol and the Carimagua and Brasilia Oxisols,were described in the 1977 CIAT Annual Report (pages A44 and A45). Data from Brasilia are reported in the Pasture Development section.

Nitrogen Requirements of Forage Grasses

Although nitrogen fertilization of forage grasses is not considered feasible for the target area, basic information is needed to quantify their N needs and to ascertain the potential contribution of legumes in mixtures.

The N responses of *Andropogon gayanus* 621, *Brachiaria decumbens* 606 and *Panicum maximum* were determined in a small plot experiment at Quilichao, where the grasses received a basal application of 150 kg P_2O_5/ha and 60 kg K_2O/ha, followed by a maintenance application of 50 kg P_2O_5/ha, 50 kg K_2O/ha and 50 kg $MgSO_4$ six months later, thus satisfying the plant's nutritional requirements while maintaining an acid soil environment (pH 4.5, 67% Al saturation, with no lime applied).

Response to N is shown in Figure 53, where the contrasting behavior of the three grasses is evident. *B. decumbens* and *P. maximum* produced significantly less dry matter than *A. gayanus* without N (13.6 vs 21.3 t/ha/year). *B. decumbens* responded positively to the highest rate of 400 kg N/ha, while *P. maximum* required 200 kg N/ha for maximum growth. In sharp contrast, *A. gayanus* showed a significant response only to 50 kg N/ha. The dry matter yields of *A. gayanus* were significantly superior to those of *B. decumbens* at all N rates, suggesting that the former utilizes available soil N better than the latter.

Table 32 shows the N uptake values for the first five cuts. The high N-supplying power of this Ultisol is evident from the high uptake values without fertilization and is probably due to its high organic matter content (about 7%) and the fact that this trial was initiated in the first year after plowing. Uptake of native soil N, measured in check plots, was about 200 kg N/ha/year, with no significant differences

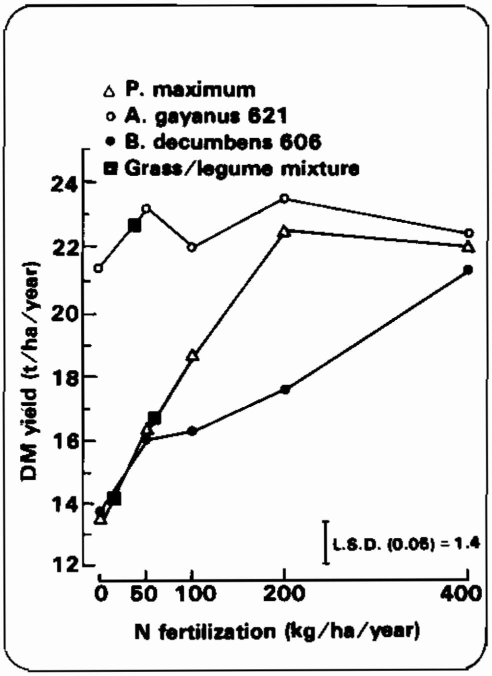


Figure 53. Nitrogen responses of three forage grasses grown alone and in association with *Stylosanthes guianensis* 184, in an Ultisol from CIAT-Quilichao. (Sum of 6 cuts per year.)

Table 32.

Nitrogen uptake of three grasses during the first 10 months of growth (5 cuts), at CIAT-Quilichao.

N applied (kg/ha/year)	*Andropogon gayanus* 621	*Panicum maximum* (kg/N/ha)	*Brachiaria decumbens* 606
0	225	184	192
50	268	234	243
100	315	291	249
200	323	355	264
400	294	336	374

between grass species. The superior behavior of *Andropogon,* therefore, does not appear to be due to its higher capacity to take up native soil N, but rather to a more efficient use of N in dry matter production. Table 33 shows the lower overall plant N content of *A. gayanus.*

The black squares of Figure 53 indicate the estimated N contributions of *Stylosanthes guianensis* 184. By placing the dry matter yield of the association of the N response curve and extrapolating to the X-axis, it is estimated the legume contributed the following amounts of N, expressed in equivalent amounts of inorganic fertilizer N applied: 40 kg N/ha with *A. gayanus,* 60 kg N/ha with *P. maximum* and only 15 kg N/ha with *B. decumbens,* (due to its aggressive growth habit).

Another N experiment was established on 0.25-ha enclosures in *B. decumbens* grazing trials of different ages in Carimagua. Several N rates were applied. All treatments received a basal application of 50 kg P_2O_5/ha, 60 kg K_2O/ha, 20 kg S/ha and 20 kg Mg/ha, except for an unfertilized "absolute or negative check" and a "positive" check which received 0.5 t lime, 700 kg N, 100 kg P_2O_5, 100 kg K_2O,

Table 33.

Plant nitrogen content and protein equivalent of three forage grasses under cutting regimes at Quilichao. (Mean of 5 N rates and 5 cuttings in 10 months.)

Species	N (%)	Protein (%)
Andropogon gayanus 621	1.58	9.9
Panicum maximum	1.75	10.7
Brachiaria decumbens 606	1.93	12.1

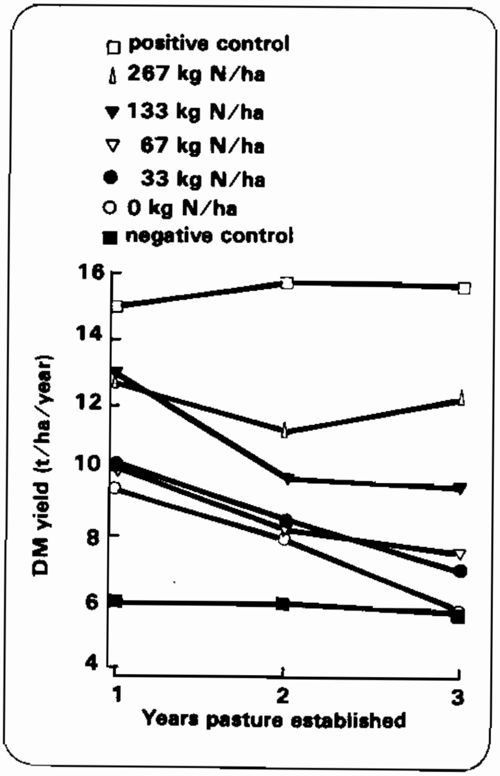


Figure 54. Effects of N fertilization and pasture age on dry matter production of *Brachiaria decumbens* in grazing paddocks at Carimagua. (Positive control: 700 kg N/ha, 0.5 t lime/ha + basal treatment + micronutrients; negative control: no fertilizers or lime.)

20 kg S, 20 kg Mg, 10 kg Zn, 5 kg Cu, 1 kg B, and 0.2 kg Mo/ha.

Figure 54 shows the first year's results (4 cuttings). Urea was the N source. Dry matter production in the negative check averaged 6 t/ha/year. Yields from plots receiving moderate levels of P, K, S and Mg, but no N, sharply decreased with increasing age of the pastures. This result correlates with the decrease in liveweight gains shown in Tables 43 and 44 and gains shown in Tables 43, 44 and 45 of the Pasture Utilization Section.

These differences in pasture age were gradually offset by N fertilization, there being no difference at 267 kg N/ha/year with a dry matter production of 12 t/ha, twice that of the negative control. This shows that N is limiting *B. decumbens* production in Carimagua grazing trials and that the N deficiency increases with increasing age of the pasture. The positive control with heavier fertilization plus lime and micronutrients increased dry matter production to about 15 t/ha/year, almost three times the negative control. Since 1 kg of liveweight gain pays for only 1 kg of N at Carimagua, N fertilization is not presently economical. These results point out the need for associating legumes with grasses as a cheap source of N.

Phosphorus Requirements of Forage Grasses

Two experiments were established in the Quilichao Ultisol and the Carimagua Oxisol to provide a sufficiently wide range of P rates to determine the external (soil test) and internal (% plant P) critical levels during the establishment year. Although both experiments include different rock phosphate sources only the triple superphosphate (TSP) data are presented here.

The Quilichao experiment consisted of two mixtures: *A. gayanus* 621 and *P. maximum*, each associated with *Centrosema* hybrid 438.

Figure 55 shows the growth rates of the two grasses for four cuts as a function of P rate. *P. maximum* showed a fast initial growth rate with maximum at 200-400 kg P_2O_5/ha with growth decreasing afterwards, particularly during the two dry

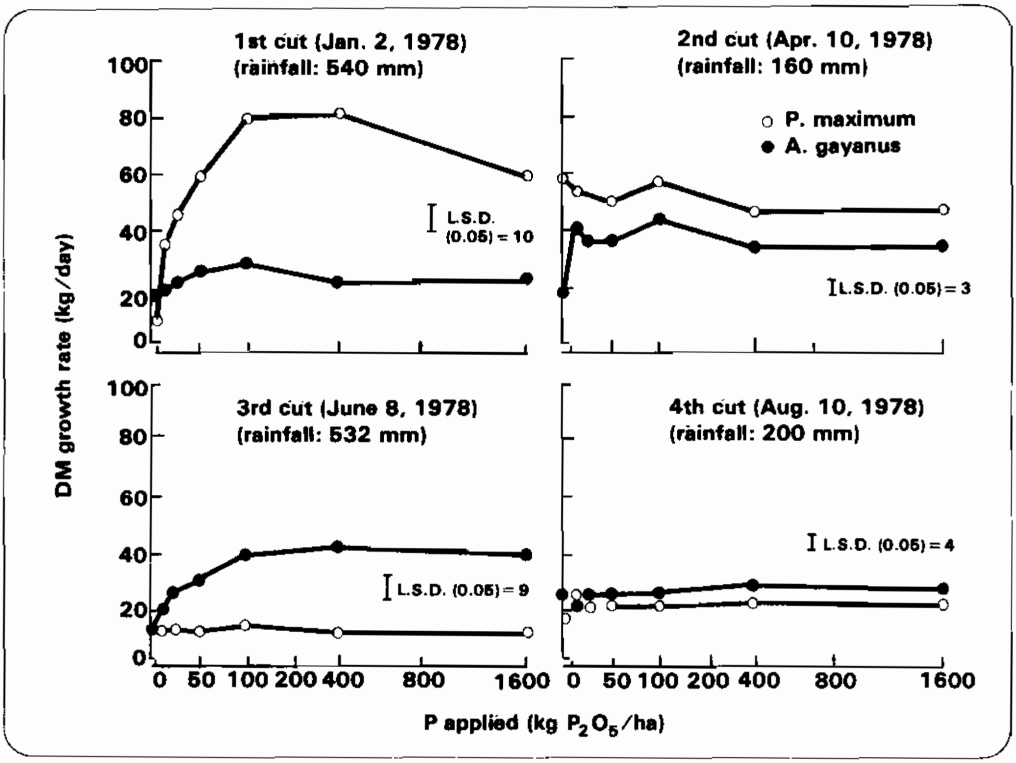


Figure 55. Effects of P on growth rates of two grasses associated with *Centrosema* hybrid 438 during the establishment year at CIAT-Quilichao.

season harvests (2 and 4). *A. gayanus* started very slowly, but gradually surpassed *P. maximum* in growth rates. Figure 56 shows the overall effect of the establishment year. *P. maximum* responded positively up to 70 kg P_2O_5/ha/year, while *A. gayanus* produced its maximum yield at 0 kg P_2O_5/ha.

Figure 56 also shows the effects on the associated legumes. *Centrosema* produced much more dry matter with *A. gayanus* than with *P. maximum*, showing a clear response up to 80 kg P_2O_5/ha. When mixed with *Panicum*, *Centrosema*'s response to P was negative, probably because of excessive competition by the

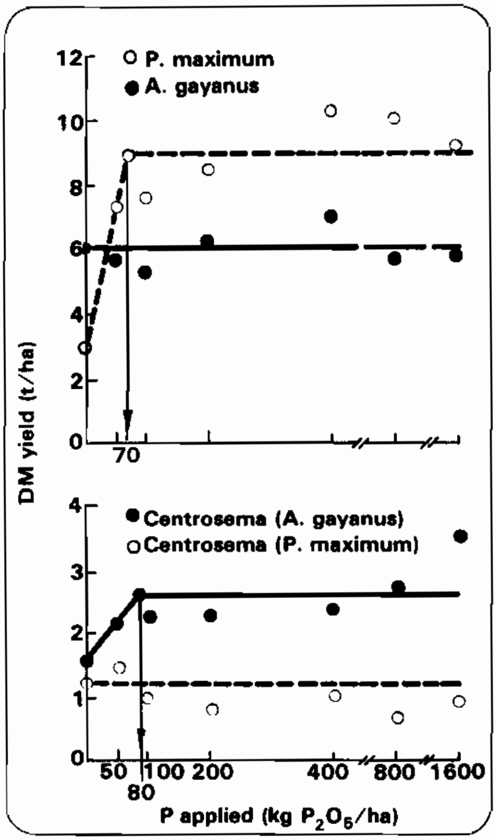


Figure 56. Phosphorus response of *Andropogon gayanus* and *Panicum maximum* in CIAT-Quilichao and its contrasting effect on the associated legume (*Centrosema*).

grass which increased sharply with increasing P level. These preliminary data show that *A. gayanus* has lower P requirements than *P. maximum*, and therefore may be more compatible with a legume like *Centrosema* hybrid 438.

In Carimagua, a similar experiment including *B. decumbens* was established with *Desmodium ovalifolium* 350 as the associated legume. The P rates were lower because P fixation in the Carimagua Oxisol is about half that of the Quilichao Ultisol. Figure 57 shows that *B. decumbens* responded much more to P than the other two species. *B. decumbens* and *A. gayanus* reached maximum yields at 50 kg P_2O_5/ha while *P. maximum* responded positively up to 100 kg P_2O_5/ha.

The internal and external critical levels of P calculated for three species on the Carimagua Oxisol are shown in Table 34. This confirms the similar critical levels of P for *A. gayanus* and *B. decumbens*, which

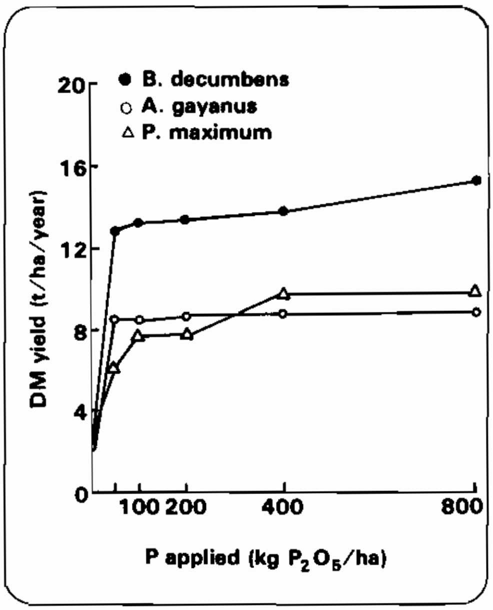


Figure 57. The effect of P on dry matter production of three tropical grasses grown in an Oxisol, at Carimagua.

Table 34.

External and internal critical levels of P for three grass species during the establishment year under a cutting regime on a Carimagua Oxisol.

Species	Critical levels: external avail.P (Bray II) (ppm)	internal P in tissue (%)
Andropogon gayanus 621	5	0.11
Brachiaria decumbens	7	0.12
Panicum maximum	6-10[1]	0.15

1 Not well-defined.

are lower than those of *P. maximum*. The Carimagua data indicate that *B. decumbens* may utilize P more efficiently than *A. gayanus*, although both species are well-adapted to low P availability.

The Phosphorus Project

The overall objective of this project is to develop a P management strategy for the principal cropping systems of acid soils of the Latin American tropics.

The high P fixing capacity and low total and available P in these soils in tropical Latin America are well-documented in the 1977 CIAT Annual Report. Although low P status predominates in vast areas of tropical Latin America, the region is blessed with known major phosphate rock deposits (Fig. 58). In order to characterize these rocks according to their relative agronomic effectiveness, samples from most of the major known deposits are being screened and compared in greenhouse trials with *P. maximum* as the test

Figure 58. Major known phosphate rock deposits in tropical South America.

crop. In addition, many of these phosphate rocks are being altered chemically and thermally to ascertain if the agronomic effectiveness of the materials can be significantly increased. Preliminary indications are that phosphate rocks which are partially acidulated (20%) with H_3PO_4 and those which are fused with magnesium silicates show very good potentials from both an initial and a residual standpoint. In addition, the physical mixtures of powdered phosphate rock and TSP also appear quite promising.

Soil Test Calibration

Although many of the acid, infertile soils of tropical Latin America are classified differently, their P status is relatively the same. As a result, it has generally been assumed that these soils would react about the same to similar applications of fertilizer P. To validate this, several soil samples were taken from selected field experiments with known amounts of added TSP, from both the CIAT-Quilichao Ultisol and Carimagua Oxisol, and Bray II P measured. Figure 59 illustrates the similar behavior of the two soils to all levels of applied P. In addition, it should be noted that even species requiring low P (2.5 to 6 ppm P, Bray II) will likely need P applications of from 50 to 100 kg P_2O_5/ha.

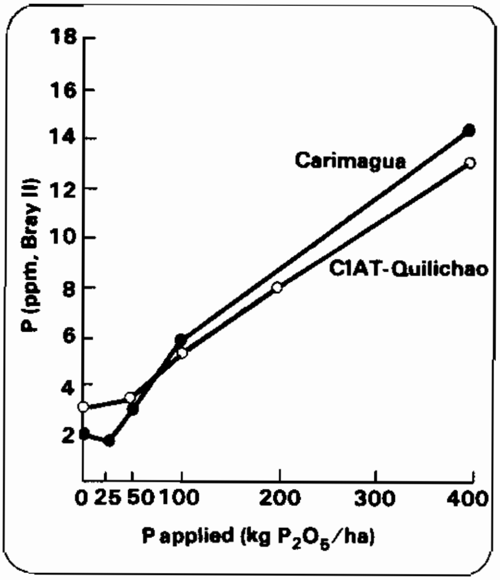


Figure 59. Effect of triple superphosphate additions on soil test P, for soils from two locations in Colombia.

Lime/Phosphorus Experiments

An incubation experiment was conducted with the Quilichao and Carimagua soils to determine the effect of varying levels of lime and P, as single superphosphate (SSP), on the availability of P as determined by Bray II. Generally, there was no apparent interaction except at the highest rate of applied P (400 kg P_2O_5/ha) and lower rates of lime where the P availability appeared to increase markedly on the Carimagua soil (Fig. 60). In all cases, however, the available soil P increased with each increment of applied P. It is also interesting to note how similarly the two soils reacted to the varying lime rates when soil pH and percentage Al saturation of the effective cation exchange capacity were considered (Fig. 61).

A greenhouse experiment was also conducted to determine the effect of rate and source of P on yield of *P. maximum* grown on two limed and unlimed Colombian soils. The amount of lime added was that calculated to neutralize 80% of the exchangeable Al. This amount was underestimated for the Quilichao soil because of the influence of the high organic matter content. Lime did not generally influence the yield of *P. maximum*, however, yields did increase with increasing increments of P up to a rate of about 300 ppm P for all carriers except TSP, which leveled off at about 150 ppm P (Fig. 62 and 63).

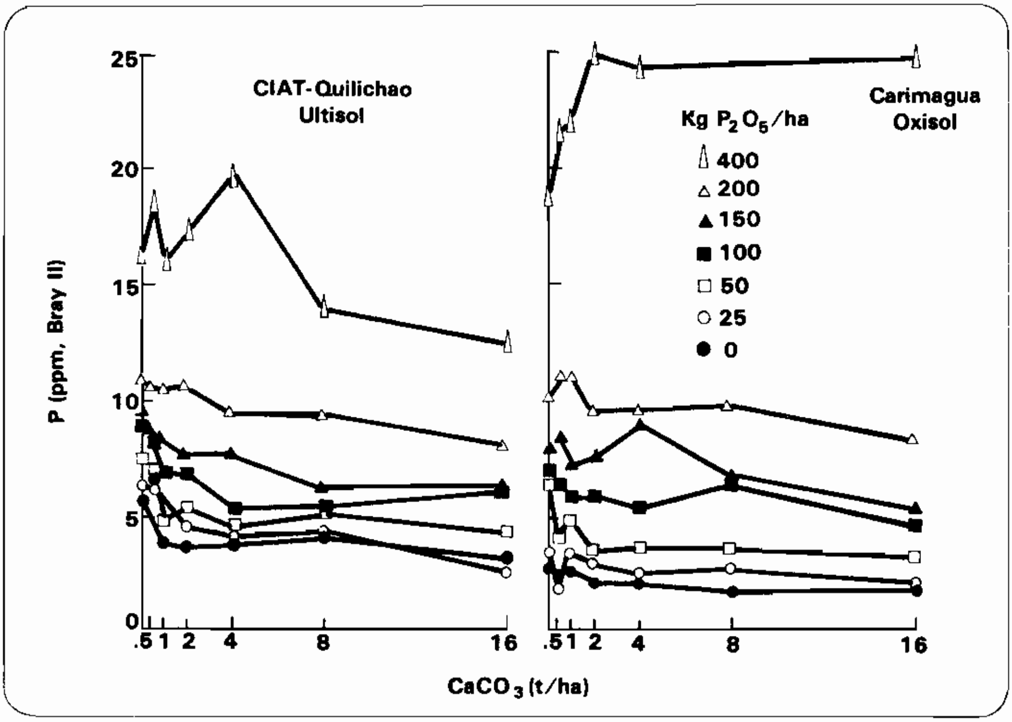


Figure 60. Effect of varying levels of applied single superphosphate and lime on availability of soil P on two soils from Colombia, after 30 days incubation.

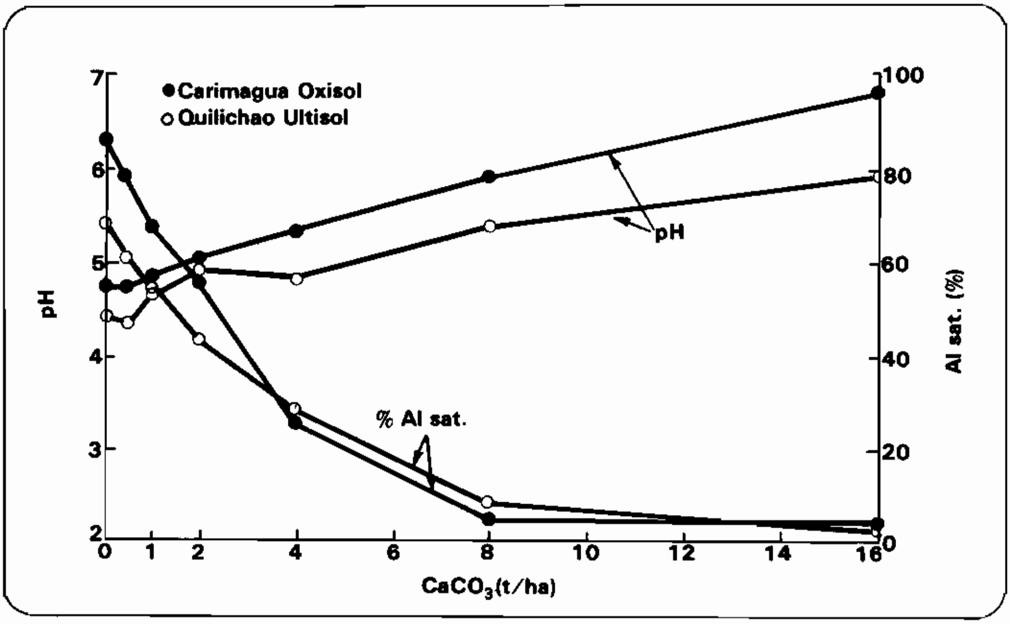


Figure 61. Effect of varying rates of lime on soil pH and percentage Al saturation on two soils from Colombia, after 30 days incubation.

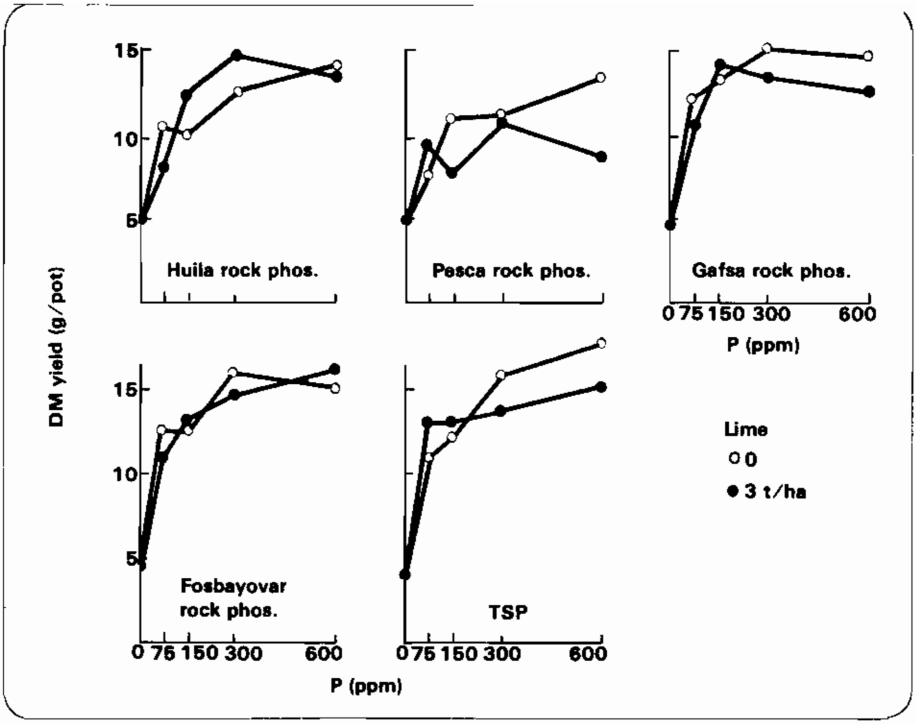


Figure 62. Effect of rate and source of P on yield of *Panicum maximum* grown in the greenhouse on a limed and unlimed Ultisol from CIAT-Quilichao. (Average of 5 cuts.)

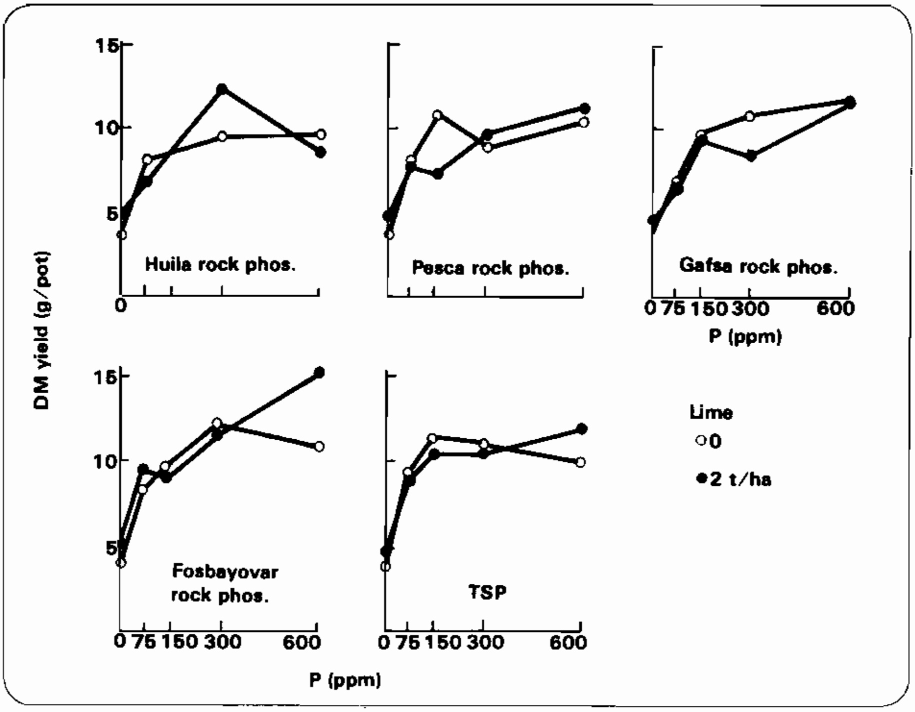


Figure 63. Effect of rate and source of P on yield of *Panicum maximum* grown in the greenhouse on a limed and unlimed Inceptisol from Popayan, Colombia. (Average of 5 cuts.)

Phosphorus Incubation Experiment

An incubation experiment was conducted with a Carimagua Oxisol to determine the changes in P availability (Bray I) due to rate and time of reaction of six different P carriers. Available P dropped markedly during the first incubation period (16 days) and remained relatively constant thereafter, regardless of the P carrier (Fig. 64). This was somewhat surprising as one would expect the more soluble TSP and basic slag to decrease in available P with time due to fixation. Apparently, a state of equilibrium is reached and the levels of available P remain constant, the level of which is determined by the rate of applied P and relative solubility of the P carrier.

Mixtures of Phosphate Rock and Triple Superphosphate

One possibility for improving P availability in phosphate rocks is to mix them with an acid-forming material such as TSP. By using a material such as TSP there is also the added advantage of supplying P in an immediately available form. Accordingly, a greenhouse experiment was established to study the effect of ratio of TSP to phosphate rock on yield of *P. maximum*, grown on a Carimagua Oxisol. Results would indicate that the ratio of P as TSP to phosphate rock varies markedly as far as availability of P to the *P. maximum* is concerned, especially at the lower rate of applied P (Fig. 65). For Pesca phosphate rock, a 75:25 ratio of TSP to rock is superior, whereas with Huila

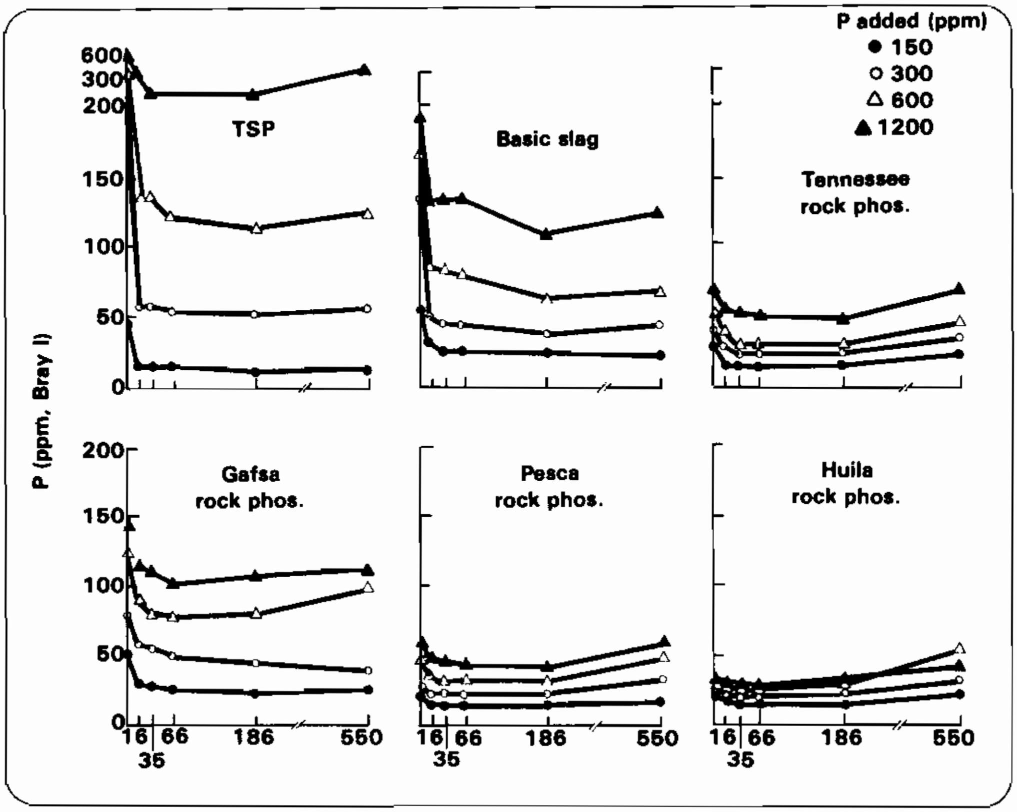


Figure 64. Changes in P availability (Bray I), due to time of reaction of six different P carriers with a Carimagua Oxisol.

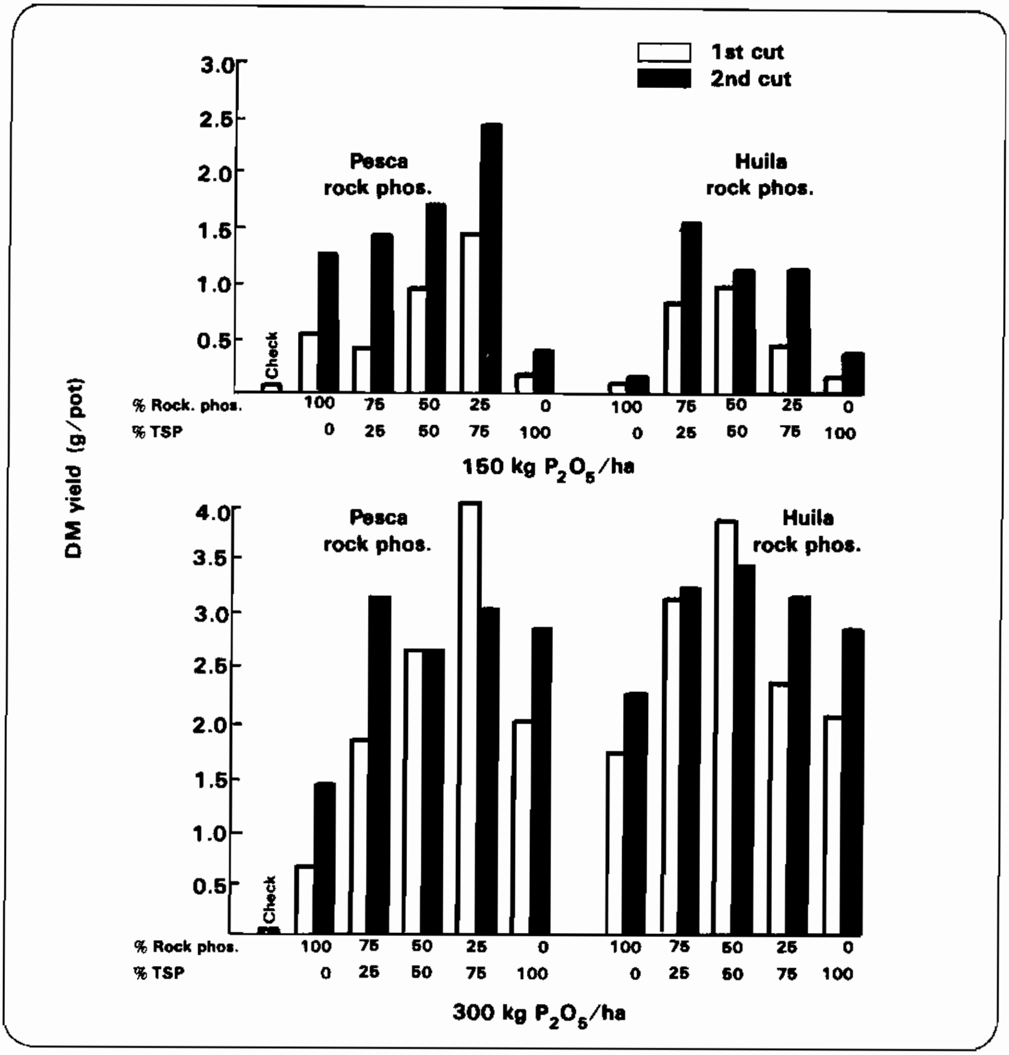


Figure 65. Effect of ration of TSP to rock phosphate and P rate on yield of *Panicum maximum* grown in the greenhouse on a Carimagua Oxisol.

phosphate rock a 25:75 ratio appears optimum. At the higher rate of applied P the ratio effect was not so clear, probably due to increased amounts of TSP.

It is difficult to explain why, at the lower rate of P, the 100% TSP did so poorly (Fig. 65). Since all sources were finely ground, perhaps the soluble TSP was fixed and therefore unavailable to the plant. Results of this experiment do suggest, however, that a similar trial should be conducted in which finely ground materials are granulated to determine the effect of aggregate size. Furthermore, granulation of these mixtures would insure intimate contact between the phosphate rock and the TSP so that acid from the TSP would be more likely to react with the rock and not be dissipated in the soil.

Long-term Effects of Different Phosphate Rocks

A long-term field experiment with *B. decumbens* was established in 1976 at

Carimagua to compare effects of six phosphate rocks with TSP. Application rates range from 0 to 400 kg P_2O_5/ha, all broadcast and incorporated into the topsoil. To date the grass has been cut seven times; results are given in Figure 66. Although yields differed markedly at first, due to the P carrier, after seven cuts total yields are remarkably similar for all carriers at any given rate of applied P. Figure 67 shows excellent performance of the phosphate rocks when compared with TSP. In any given time the phosphate rocks appear equal to and, in many instances, superior to the TSP, especially from a residual standpoint. The overall performance of the P carriers is given in Table 35.

It might be concluded that with time one

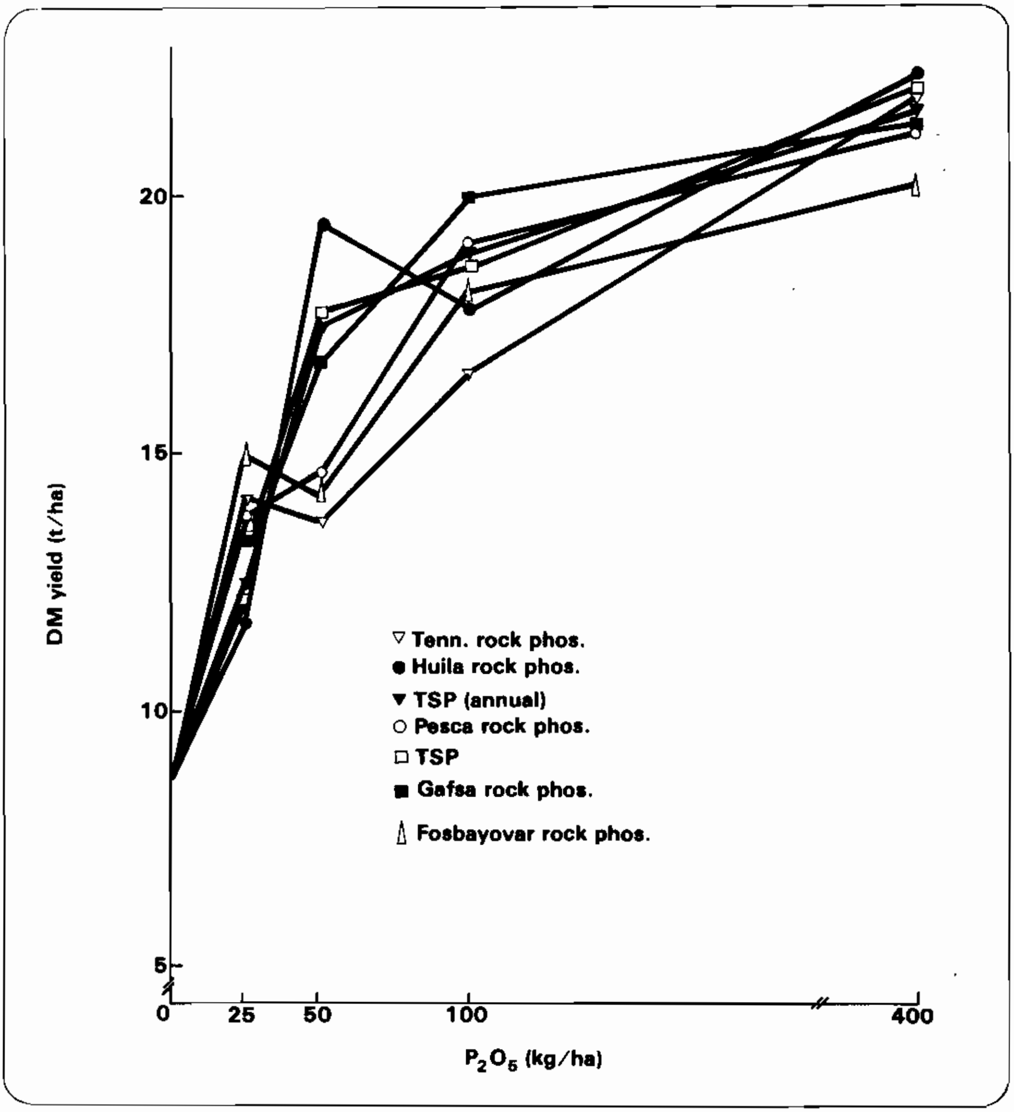


Figure 66. Effect of P carrier and rate of application on yield of *Brachiaria decumbens* grown on a Carimagua Oxisol. (Total of 7 cuttings.)

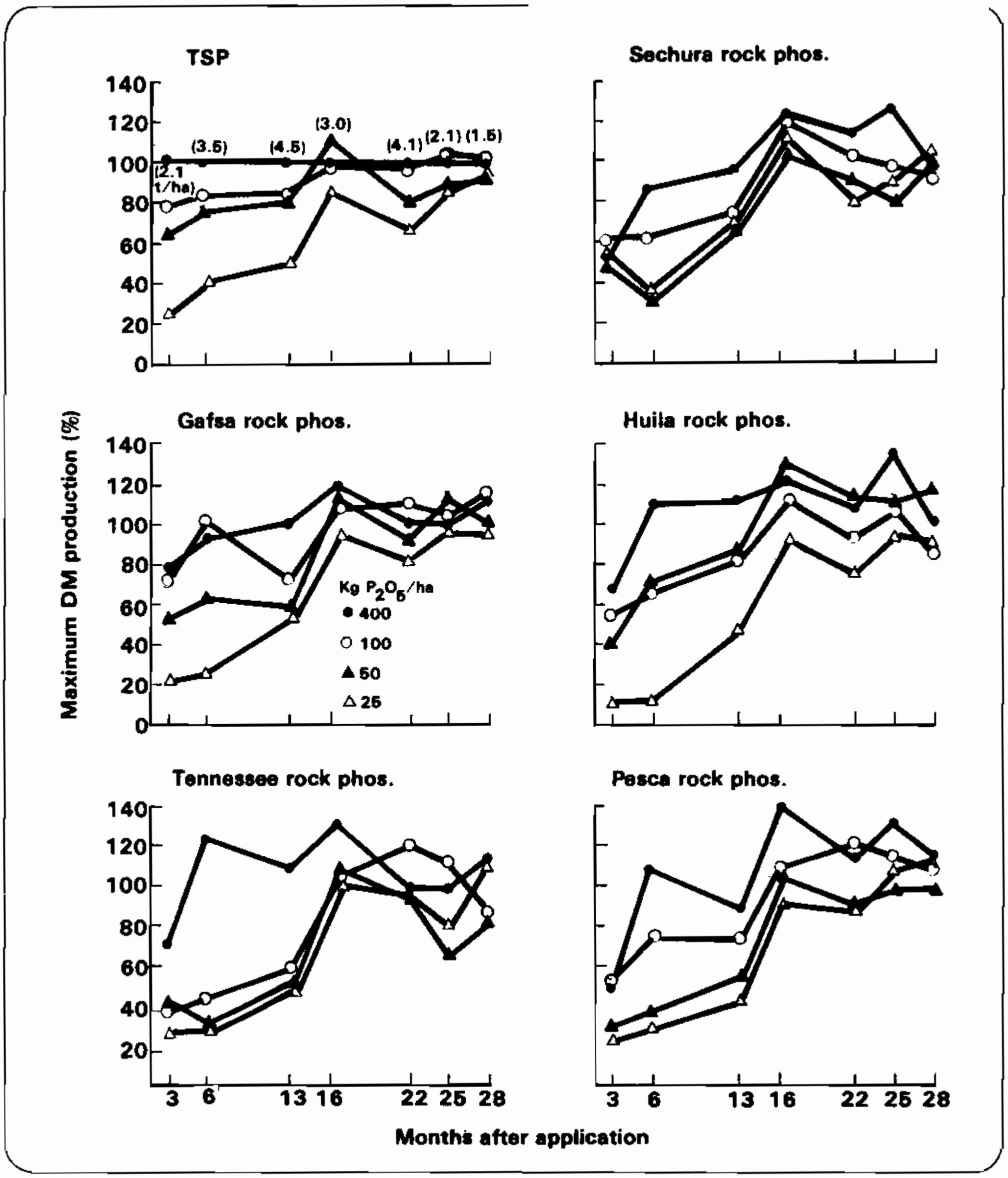


Figure 67. Initial and residual effects of five phosphate rocks relative to TSP applications on *Brachiaria decumbens* yields on a Carimagua Oxisol. (TSP considered as 100%, with actual yields given in parentheses.)

P source is just as effective as another in a long-term forage production scheme. However, this may not be true since other essential nutrients probably became more limiting than P, thus creating this leveling effect. Figure 68 illustrates quite vividly the extreme K deficiency which occurred between the second and fourth cuts. There are indications that Zn might also be reaching deficiency levels in the plant tissue (Fig. 68). To insure validity of experimental results, it would appear that a complete tissue analysis monitoring scheme must become an integral part of the on-going P research program.

Table 35.

Relative agronomic effectiveness of phosphate rocks from several sources as determined by yield of *Brachiaria decumbens* grown in the field at Carimagua.(Sum of 7 cuts taken over a 28-month period.)

P source	Relative effectiveness (%) P_2O_5 applied (kg/ha) 25	50	100	400
Triple superphosphate	100	100	100	100
Huila rock phosphate	96	110	96	109
Pesca rock phosphate	111	81	101	104
Gafsa rock phosphate	110	75	108	99
Tennessee rock phosphate	112	78	88	106
Sechura rock phosphate	125	90	87	98

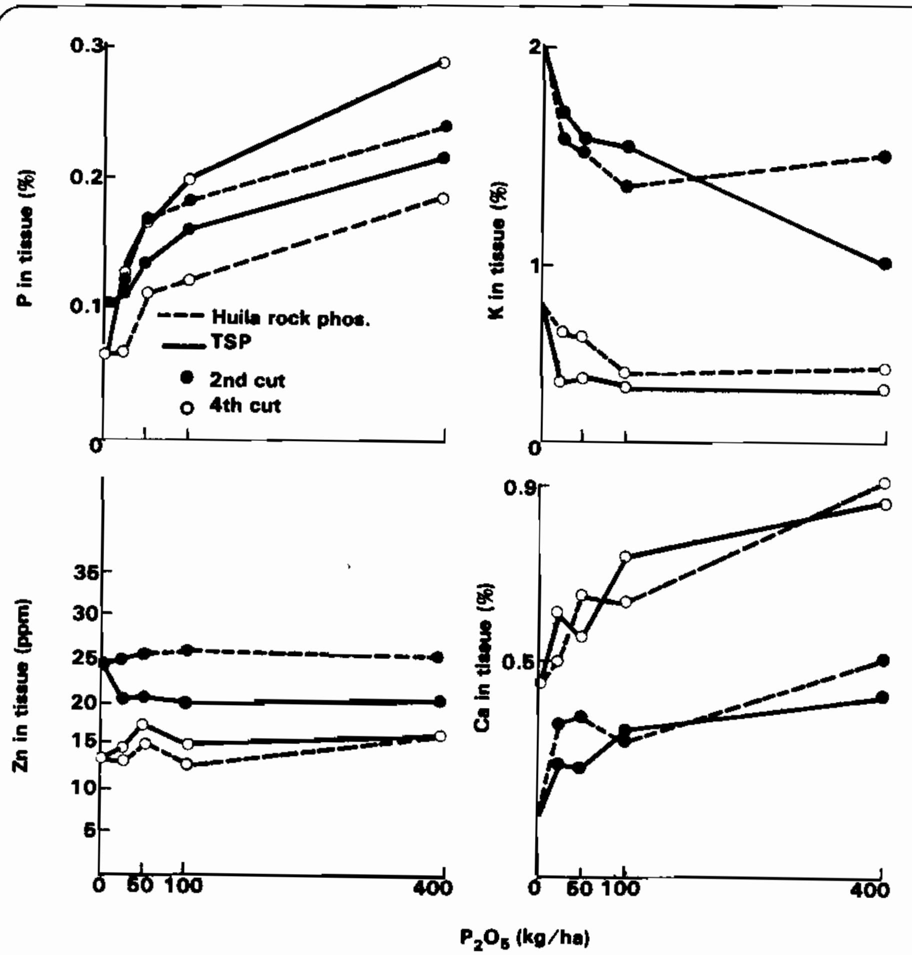


Figure 68. Effect of two P carriers and application rates on selected essential elements in *Brachiaria decumbens* grown on a Carimagua Oxisol.

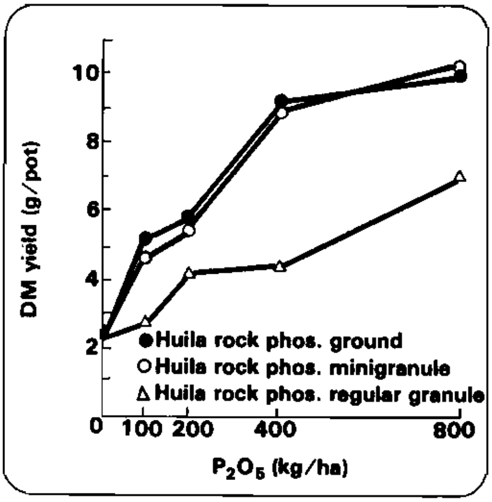


Figure 69. Effect of rate and granule size of Huila phosphate rock on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

Granule Size of Phosphate Rock

In general, phosphate rock must be finely ground to be most effective. This

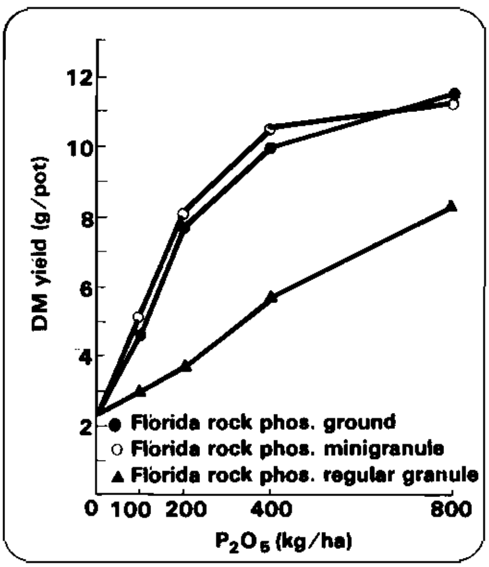


Figure 70. Effect of rate and granule size of Florida phosphate rock on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

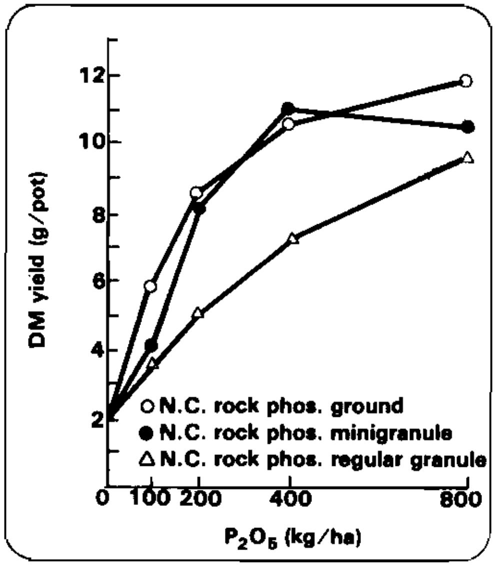


Figure 71. Effect of rate and granule size of North Carolina rock phosphate on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

creates certain problems since the product is usually quite dusty and hard to spread evenly on the field. A greenhouse experiment was established to determine the effect of granule size of phosphate rock on yield of *P. maximum* grown on a Carimagua Oxisol. The granules were made by granulating finely ground phosphate rock with a 3.3% KCl binder. Three particle sizes were used: powdered (< 200 mesh), minigranules (- 48 + 140 mesh) and regular fertilizer granules (-16 + 16 mesh). Figures 69-71 illustrate quite clearly that the minigranules are as effective as the powdered materials at all application rates. The use of minigranules would eliminate most of the physical problems of handling finely ground phosphate rocks.

Developing a Phosphorus Research Network

To date, 16 field experiments have been established with several crops on representative sites throughout Colombia, and at

Table 36.

List of established and proposed field experiments of the Phosphorus Project.

Location	Crops	Status[1]	No. of exper.	Cooperators
Colombia				
Popayán	Beans	E	1	
Carimagua	*B. decumbens*	E	1	
	Cassava	E	1	
	Peanuts/Rice	E	1	
	P. maximum	P	1	
Quilichao	Cassava	E	2	
	B. decumbens	E	2	
	Rice/Peanuts	E	1	
	Maize/ *D. ovalifolium*/ *P. maximum*	P	1	
Villavicencio	Lowland rice/Peanuts	E	1	ICA
	Upland rice/Peanuts	E	1	ICA
	B. decumbens	E	1	ICA
	P. maximum	P	1	ICA
Peru				
Pucallpa	*B. decumbens*	E	2	IVITA
	P. plicatulum/ *C. pubescens*	E	1	IVITA
Yurimaguas	Rice/Peanuts/Soybeans	E	1	CRIA I-NCSU
Brazil				
Cerrado Center	Cassava	P	1	EMBRAPA-CPAC
	Soybeans	P	1	EMBRAPA-CPAC
Venezuela				
Jusepin	Maize/Peanuts	P	1	U. ORIENTE

1 E = established, P = proposed.

Pucallpa, Perú. Early in 1979 several additional field experiments will be established in Brazil, Colombia, Perú, and Venezuela (Table 36). In addition, greenhouse and laboratory studies are underway to screen for promising phosphate materials which will then be field-tested.

Although the Phosphorus Project is an integral part of the Beef Program, it also has equal research responsibility to other crops, most of which are preceeded by or grown in rotation with tropical pastures in Oxisols and Ultisols.

Systematic Estimation of Nutrient Requirements

The Soil Fertility and Plant Nutrition Section was established in June 1978. Its fundamental objective is to understand, within an acceptable level of precision, nutrient requirements of forage species grown under acid, infertile soil conditions.

In most cases, nutritional requirements of the promising grasses and legumes accessions have not been determined and this lack of information presents an important gap. The specific objectives of this section are the following: (1) to characterize and define analytical methods for acid soils and plant tissue; (2) to evaluate the introduced germplasm by a rapid method which will determine preliminary selection criteria; (3) to determine the critical nutritional requirements of the promising germplasm.

Activities began with an evaluation of the CIAT soil and plant analyses laboratories, including the analytical methods used for soils and plant tissue.

For routine soil analysis from CIAT-Quilichao and Carimagua the extraction methods adopted are: 1*N* KCl for exchangeable Al, Ca and Mg, Bray II extractant for P and K, and finally the double acid extract for micronutrients. At the moment, the analytical laboratory is adapting to a system for analyzing a large volume of samples.

Keeping in mind that the grass and legume germplasm has been classified in categories based on previous evaluations, an evaluation system has been adopted which is compatible with the established categories. The preliminary selection which has been used in the Grass and Legume Agronomy sections (CIAT Annual Report 1977), represents the established selection criteria. Within this parameter, the Plant Nutrition section will use the following criteria for selecting new germplasm:

1. An evaluation based on visual symptoms of deficiencies or mineral toxicity. The objective is to characterize the factors contributing to general adaptation to conditions at CIAT-Quilichao and Carimagua.

2. Selection for tolerance to Al by simple and rapid techniques. The objective is to characterize the factors contributing to Al tolerance.

Existing material in introduction gardens at Quilichao and Carimagua and newly introduced material will be evaluated by assigning values for visual symptoms of deficiencies or toxicity; these will be confirmed with foliar analysis including controls. In addition to providing information for selecting tolerant species, this system will allow charting of symptoms of foliar deficiencies and mineral toxicities which will facilitate future evaluations.

Germplasm will be screened for tolerance to Al by using the differential correlation of the radicular system technique. This technique uses a hematoxilin solution having a high affinity for Al and permits the differentiation of the meristematic tissues which also have a direct affinity for Al.

The original hematoxilin method was modified slightly to adjust for the germination characteristics of forage seeds and the initial growth of the forage plants. This technique should permit evaluating a large proportion of the Category 1 material in a relatively short time.

For materials in categories 2, 3 and 4, a quantitative determination of nutritional requirements has been adopted using the critical concentration method. This method uses the Cate-Nelson interpretation technique, which is widely accepted for its simplicity and acceptable precision.

Since research in the area of fertilizer requirements is dynamic, it is convenient to use an easy model to manage where the results are easily calculated and can be interpreted rapidly. Once data are analyzed, it will then serve as a basis to revise and make necessary adjustments for succeeding experiments. Also, this method will be useful for readjusting previous results.

Studies on nutritional requirements will be initiated in 1979. To facilitate rapid interpretation these studies will be done in the glasshouse using soils from Carimagua, with most of the nutrients to be studied. To study Mn toxicity, soils from Quilichao will be used.

At each nutritional level it will be possible to study various species which will be subjected to the following evaluation: (1) production of dry matter (aerial part and roots); (2) rate of growth (GR, RGR); (3) foliar analysis; and (4) rate of nutrient translocation.

Once these parameters have been determined they will be subjected to two types of evaluation to determine the critical nutritional requirements: (a) dispersion diagrams, and (b) linear discontinuous models.

Finally, the results will be interpreted by multiple nutrients through the combination of linear discontinuous models by individual nutrients. For each species, these criteria will be used to formulate the fertilizer requirements which will be initially evaluated in CIAT-Quilichao and Carimagua and later in regional trials throughout the Program's target area.

PASTURE DEVELOPMENT

Research on pasture development was conducted at CIAT-Quilichao, Carimagua and Brasilia with the overall objective of developing low-cost methods of establishing and maintaining improved pastures. Advances were made in: (1) using crops as precursors to pasture establishment; (2) low density seedings; (3) determining components of conventional establishment methods; (4) strip plantings; and (5) introducing legumes into native Cerrado.

Crops as Precursors for Pasture Establishment

The possibilities of establishing pastures while growing crops were studied at Quilichao and Carimagua. The intercropping potentitals of key grass and legume pasture species were tested with crops having a wide range in growth habit, growth duration, plant architecture and fertility requirements. An experiment on the Quilichao Ultisol tested the establishment of pure *Stylosanthes guianensis* 184, and mixed swards of that legume with *Brachiaria decumbens* or *Panicum maximum* under stands of cassava, beans, rice, corn, sorghum and peanuts. The combinations were planted in October 1977 at two soil fertility levels: "low" 0.5 t/ha of dolomitic lime, and 100 kg P_2O_5/ha as triple superphosphate, and "high" with 4 t/ha of lime, 400 kg P_2O_5/ha and 100 kg K_2O/ha, all broadcast and incorporated into the top 15 cm of the soil. The crops were sprinkle-irrigated when required. The results with cassava, rice and beans at Quilichao are summarized below.

Cassava

The variety Chiroza planted at 1.2 x 0.8 m grew very well and yielded up to 53 t/ha of fresh roots in 12 months when grown in monoculture (Table 37). When the three pastures were planted at the same time as the cassava, *S. guianensis* decreased cassava yields about 20% but established itself well, reflecting a positive intercropping effect. Mixed grass/legume pastures proved too competitive for cassava. Root yields decreased drastically and the pasture had to be cut while cassava was growing, an unlikely practical situation. *P. maximum* depressed cassava yields more than *B. decumbens,* presumably because of its erect growth habit. There were no significant differences due to fertility. When pastures were planted 60 days after the cassava, growth of both grasses and legumes was poor, probably due to low light intensity and anthracnose attacks in *S. guianensis*. Likewise, when pastures were broadcast 210 and 300 days after cassava planting, stands were poor. The only practical alternative seems to be simultaneous planting of the pasture legume with cassava.

Rice

The variety CICA 8 was drilled in 30-cm

Table 37.

Effect of simultaneous intercropping of cassava (cv. Chiroza Gallinaza) and pasture production (3 cuts) on the Ultisol at CIAT-Quilichao.

Fertility level	Species[1]	Cassava (roots) Mono-culture (t/ha)	Cassava (roots) Inter cropped (t/ha)	Cassava RY[2] (%)	Pastures (dry matter) Mono-culture (t/ha)	Pastures (dry matter) Inter-cropped (t/ha)	Pastures RY (%)
Low	Cassava + Sg	45.6	38.2	84	2.1	1.0	48
	Cassava + Sg + Pm	50.8	8.9	17	6.0	6.2	103
	Cassava + Sg + Bd	42.4	17.0	40	7.0	6.4	92
High	Cassava + Sg	53.0	34.4	65	2.7	1.5	56
	Cassava + Sg + Pm	42.7	10.2	24	9.6	8.6	89
	Cassava + Sg + Bd	46.6	23.9	51	8.5	7.7	91

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum;* Bd = *Brachiaria decumbens.*

2 RY = Relative yield = $\frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

rows and managed as an upland crop but without serious water stress due to frequent sprinkle-irrigation. Rice growth was so vigorous that the pastures performed poorly (Table 38). When planted at the same time, forage grasses did establish themselves, but produced only about 32% of the dry matter of pastures without rice.

S. guianensis alone produced very little. It was affected by anthracnose when grown with rice, but much less severely when grown alone. When pastures were planted 45 and 60 days after rice, so few plants established themselves that measurable dry matter was not produced. Rice yields were high, particularly at high fertility. At the low fertility level, rice yields actually increased about 27% when pastures were interplanted; this effect practically disappeared at the high fertility level. The reasons for this unexpected observation are not understood.

A second experiment was established in July 1978 with the same rice variety planted at two row spacings (30 and 45 cm) to provide less competition for the pastures used. *Desmodium ovalifolium* 350 replaced *S. guianensis* because of its better anthracnose and shade tolerance. The legume was planted with *B. decumbens,* each between alternate rice rows at 14, 30, 45 and 120 days after rice planting. Rice was harvested 180 days after seeding. Rice yields were even higher than before, reaching a maximum of 7.7 t/ha. Figure 72 shows that rice yields were severely affected by interplanting pastures 15 days after rice seeding, but rice yields approached maximum when interplanting was delayed to 45 days and pasture growth was still reasonable. The optimum point for the intercropping system seems to be between 30 and 45 days. This figure also shows the highly competitive nature of this intercropping system. The wider row is better for pastures and *vice versa.* The results indicate that with vigorous, short-statured, high-yielding rice varieties, pasture establishment is feasible.

Beans

Beans were also tested, to evaluate the potential of an early maturing crop with high fertility requirements. The results of the first crop (Table 39) showed high yields at the high fertility level and no effect on bean yields of interplanting pastures roughly halfway in the bean life cycle. Pasture production was decreased by about half in the presence of beans. Nevertheless, the fact that the pastures had no detrimental effect on bean yields indicates that pasture establishment via intercropping is highly desirable in this short season crop.

Pasture Development in the Llanos

The Carimagua Pasture Development unit initiated a number of new trials during 1978 primarily emphasizing low input pasture establishment methods and pasture maintenance and management systems. This expanded effort was made possible by the addition of a plant nutrition specialist who has assumed responsibility for much of the liming and nutrient requirement research previously done by this group.

During establishment of a number of new trials, some important lessons have been learned relative to establishment methods. A number of new trials were planted where native savanna had been grazed rather intensively, resulting in changes in botanical composition and the presence of many more weeds than are normally encountered in virgin native savanna. Serious problems with weed competition occurred in several trials where P was applied broadcast prior to or

Table 38.

Intercropping effects of rice (var. CICA 8) and pastures (3 cuts) planted at different times on CIAT-Quilichao Ultisol. (First rice experiment planted 12 October 1977).

Days of pasture seeding after rice	Fertility level	Species[1]	Rice (grain) Mono-culture (t/ha)	Rice (grain) Inter-cropped (t/ha)	Rice RY[2] (%)	Pastures (dry matter) Mono-culture (t/ha)	Pastures (dry matter) Inter-cropped (t/ha)	Pastures RY (%)
0	Low	Rice + Sg	2.27	2.80	123	2.15	0.04	2
		Rice + Sg + Pm	2.65	3.38	128	5.97	2.31	39
		Rice + Sg + Bd	3.06	3.82	125	6.99	1.96	28
		Mean	2.66	3.33	125	5.04	1.44	29
	High	Rice + Sg	4.59	5.04	110	2.67	0.02	1
		Rice + Sg + Bd	4.54	4.18	92	9.60	3.98	41
		Rice + Sg + Bd	6.53	4.80	74	8.96	2.03	23
		Mean	5.22	4.67	90	6.98	2.01	28
45	Low	Rice + Sg	2.27	3.19	140	2.15	0.00	0
		Rice + Sg + Pm	2.65	3.82	144	5.97	0.00	0
		Rice + Sg + Bd	3.06	4.32	141	6.99	0.00	0
		Mean	2.66	3.78	142	5.04	0.00	0
	High	Rice + Sg	4.59	5.14	112	2.67	0.00	0
		Rice + Sg + Pm	4.54	6.37	140	9.60	0.00	0
		Rice + Sg + Bd	6.53	6.20	95	8.96	0.00	0
		Mean	5.22	5.90	113	6.98	0.00	0
60	Low	Rice + Sg	2.27	3.61	159	2.15	0.00	0
		Rice + Sg + Pm	2.65	2.40	91	5.97	0.00	0
		Rice + Sg + Bd	3.06	3.10	101	6.99	0.00	0
		Mean	2.66	3.04	114	5.04	0.00	0
	High	Rice + Sg	4.59	5.23	114	2.67	0.00	0
		Rice + Sg + Pm	4.54	4.90	108	9.60	0.00	0
		Rice + Sg + Bd	6.53	6.20	105	8.96	0.00	0
		Mean	5.22	5.44	104	6.90	0.00	0

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum;* Bd = *Brachiaria decumbens.*

2 RY = Relative Yield $= \frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

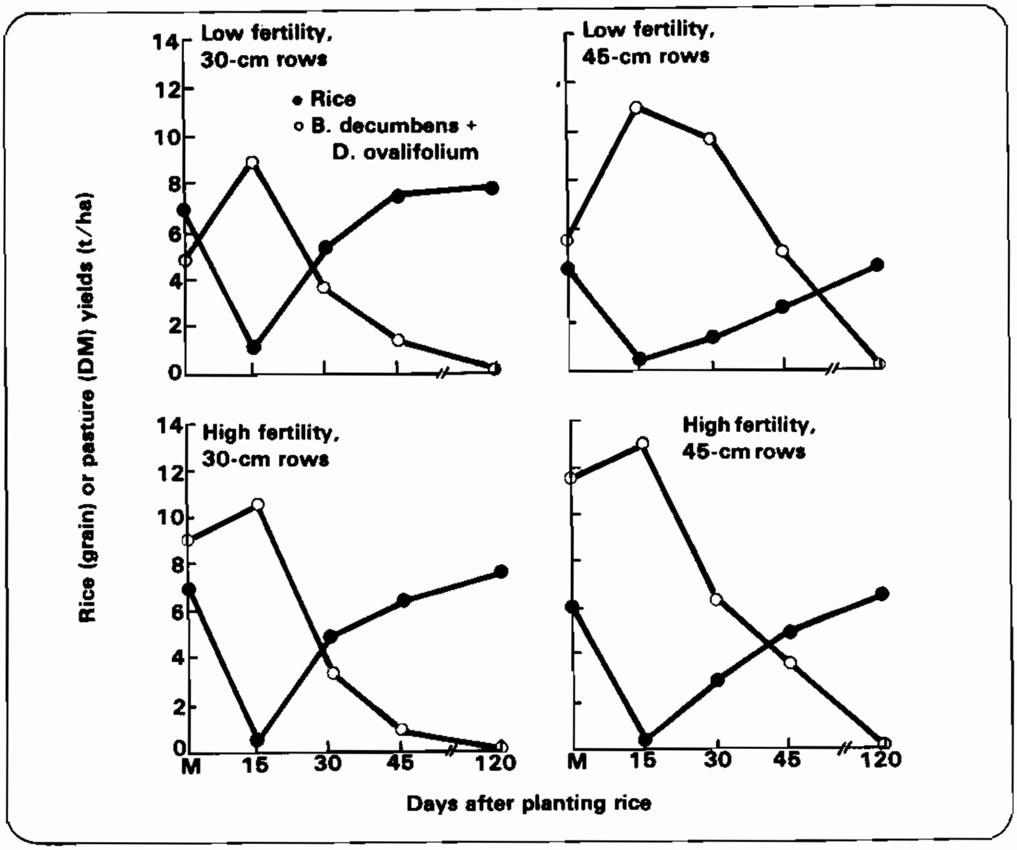


Figure 72. Effects of time of intercropping rice (var. CICA 8) with *Desmodium ovalifolium* and *Brachiaria decumbens* as affected by fertility level and rice row spacing, at CIAT-Quilichao. (July 1978 planting. M = monocultures for rice or pasture species.)

at planting time, thus necessitating either chemical or manual post-planting weed control. In contrast, trials that were row-seeded with band-applied fertilizer had no serious weed problems during the establishment phase. The most severe weed problems were encountered when both seed and fertilizer were broadcast. This experience emphasizes the importance of band or localized placement of fertilizer applied at seed time. After the pasture is established, broadcast fertilizer applications are appropriate.

Several observations during the season underscore the importance of competition of grass and legume seedlings with established grasses and legumes. For example, new seedlings of *A. gayanus* rarely survived or grew appreciably in the presence of a rather thinly established stand (about 20,000 plants/ha) of *A. gayanus*. In a low-density seeding trial (1000 plants/ha) with *A. gayanus*, a radius of approximately 1 m around mother plants (originally seeded plants) was essentially free of any new seedlings. Beyond that point the stand of new seedlings was excellent. Another example is that of *Stylosanthes capitata* seedlings. In the presence of established plants of *S. capitata*, seedlings developed in a moderately vigorous manner, but in the presence of established grasses, the

Table 39.

Effects of intercropping beans (var. ICA-Tui) with pastures (1 harvest) planted 45 days after beans at CIAT-Quilichao. (Oct. 17, 1977 planting.)

Fertility level	Species[1]	Bean grain yields: Monoculture (t/ha)	Bean grain yields: Intercropped (t/ha)	Bean grain yields: RY[2] (%)	Pasture DM yields: Monoculture (t/ha)	Pasture DM yields: Intercropped (t/ha)	Pasture DM yields: RY (%)
Low	Beans + Sg	1.08	1.08	100	0.80	0.37	46
	Beans + Sg + Pm	1.06	0.91	86	2.03	1.27	62
	Beans + Sg + Bd	1.22	1.24	102	1.70	0.93	55
	Mean	1.12	1.08	96	1.51	0.86	57
High	Bean + Sg	1.57	1.58	100	1.40	0.85	61
	Bean + Sg + Pm	1.63	1.47	90	6.06	2.19	36
	Bean + Sg + Bd	1.67	1.84	110	2.29	2.11	92
	Mean	1.62	1.63	100	3.25	1.72	53

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum*, Bd = *Brachiaria decumbens*.

2 RY = Relative yield $= \frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

seedlings were dwarfed and exhibited severe K and Mg deficiency symptoms. It is well-known that pasture plants generally have higher nutrient requirements (nutrient concentration in soil solution) in the seedling phase than after establishment. It seems logical that competition from established plants would aggravate this situation, thus requiring special maintenance when seedling survival is required to thicken stands.

Pasture Establishment

Work continued in low-density seeding experiments which were previewed last year (CIAT Annual Report, 1977, pp. A 61-63). Ten species were planted at 1000 hills/ha with initial fertilizer applied only in the hill. After establishment was assured, fertilizer was broadcast between hills. Preliminary establishment data were presented last year. Percentage coverage of the plot area, used as a measure of establishment, is shown in Figure 73. Complete coverage had been achieved by May with *Brachiaria humidicola*,

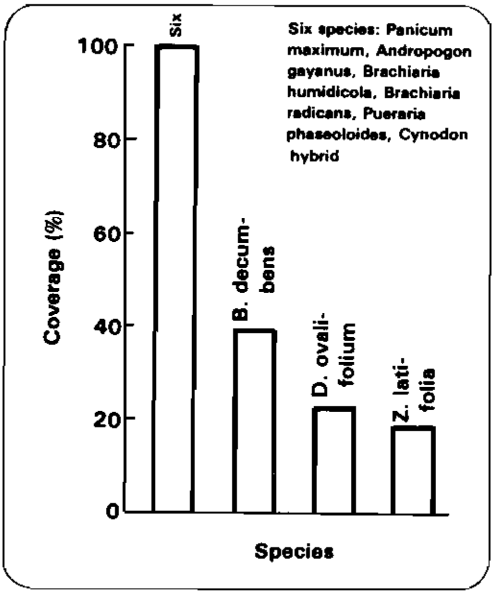


Figure 73. Percentage coverage provided by stolons and/or seedlings in May 1978 from a low-density planting (1000 hills/ha) made in September 1977.

Brachiaria radicans, a *Cynodon* hybrid, *A. gayanus*, *P. maximum* and *Pueraria phaseoloides*. The extremely low fertility of the soil was an effective weed control mechanism and almost none were present. Initial stands of *S. capitata* 1078 were very poor and reseeding was not successful, therefore reliable data are unavailable for that species.

By June, nine months after seeding, *B. humidicola*, *B. radicans*, *P. maximum*, *A. gayanus* and *P. phaseoloides* (kudzu) were ready for grazing. At that time, the kudzu mat was not well-rooted but after grazing, it was thoroughly anchored to the soil. The *Cynodon* hybrid provided cover but is too poorly adapted to be considered for this ecosystem.

By September 1978, i.e., one year after establishment, all species excepting *S. capitata* had provided essentially complete cover. Figure 74 shows the condition of *A. gayanus* in May, shortly after the beginning of the rainy season. Stand counts, shown in Table 40, averaged over 150 plants/m^2 for *A. gayanus* developed from the 1000 plants/ha in the original seeding. Stand counts for *P. maximum* were much lower, ranging from 5 to 15 plants/m^2, but entirely adequate for pasture establishment.

The low density planting system of pasture establishment shows considerable promise for reducing initial investment in fertilizer, labor, and seed which are all often critically limiting resources in developing areas. From this early experience a number of new trials have been established. In one, the interaction of

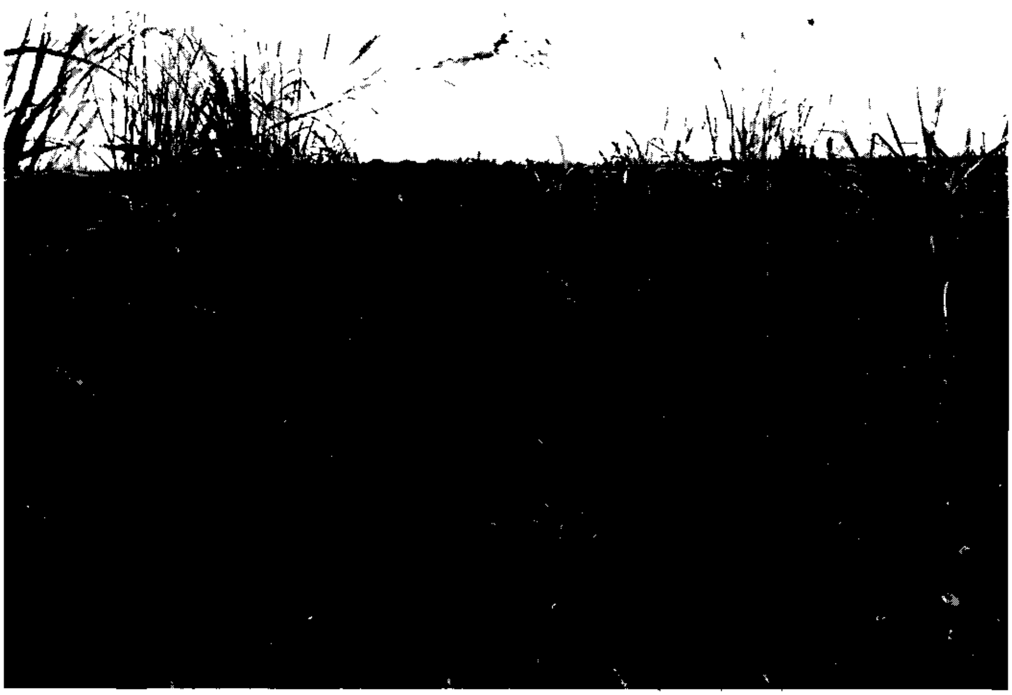


Figure 74. *Andropogon gayanus* established via low-density seeding method at Carimagua. The large "mother" plants were planted in September 1977, spaced 3.16 m apart (1000 hills/ha). They began seeding in November at the end of the rainy season and germination occurred after first rains of the next rainy season in March 1978. Seed settled to bottom of furrows left by field cultivator and appear to have been seeded in rows. Stand counts in April 1978 averaged 150 plants/m^2.

Table 40.

Effects of P and K on stand counts from low density seeding of *Andropogon gayanus* and *Panicum maximum* at Carimagua, 1978.

	P_2O_5 kg/ha			
	0.5	1	3	9
	(plants/m²)			
A. gayanus	97	170	144	176
P. maximum	4.8	6.3	6.6	13.2

	K_2O kg/ha		
	0	0.5	1.5
A. gayanus	136	160	146
P. maximum	6.4	7.3	9.5

tillage methods with planting density of *A. gayanus* is studied. In another, the effect of the stage of development of native savanna (burned and unburned) on establishment of three legumes *(D. ovalifolium, S. capitata* and *P. phaseoloides)* associated with *A. gayanus* will be evaluated. Another trial tests the interaction of tillage methods and grass species.

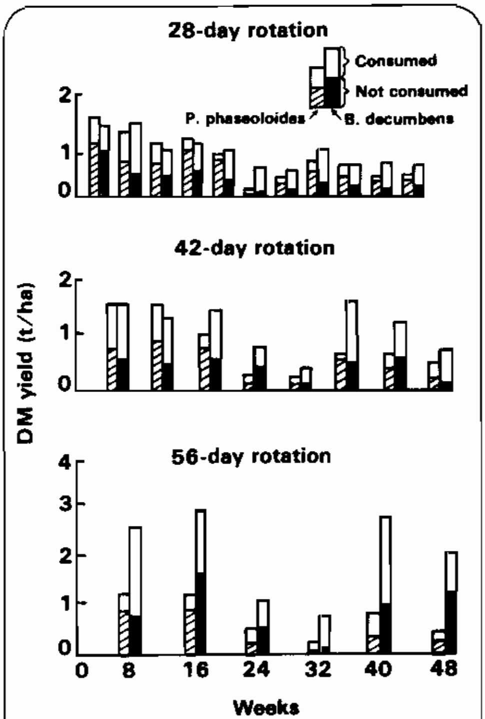


Figure 75. Effect of grazing frequency on dry matter production and forage consumption of *Pueraria phaseoloides* and *Brachiaria decumbens* seeded in alternate 2.5-m strips, at Carimagua.

Conventional establishment methods are also being studied in trials planted during the year. The interaction of tillage x species x date of seeding includes conventional seed bed preparation and the stubble mulch sweep method of controlling native savanna and preparing the seed bed. Another trial is designed to test the interaction of methods of seeding and time of seeding of legumes relative to time of seeding of grasses. Four associations composed of *S. capitata, P. phaseoloides. A gayanus* and *P. maximum* are included. Early evaluation indicates that seeding in alternate rows or alternate pairs of rows provides the best balance. Broadcast seeding and fertilizer application has resulted in excessive weeds and poor species balance.

Pasture Maintenance and Management

The kudzu/grass strip seeding experiment initiated in 1975-76 and described in the 1977 Annual Report continued in 1978 with some modifications. *B. decumbens* remains strongly competitive in 56- and 42-day rotations and maintains good stands even in the 28-day rotation (Fig. 75 and 76). It has invaded the kudzu strips, especially in the 56-day rotation. This is sufficient time for *B. decumbens* to produce seed and most of the invasion appears to be via new seedlings. There is much less invasion in the 42- and 28-day rotations.

On the other hand, *Melinis minutiflora* and *Hyparrhenia rufa* began to decline in the very early grazing cycles under all three

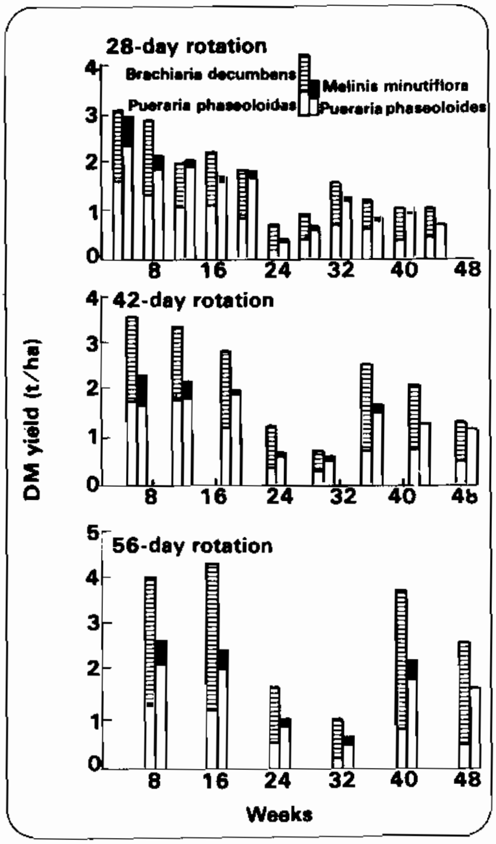


Figure 76. Effect of grazing frequency on total dry matter production of two pasture associations, at Carimagua.

rotations, and had essentially disappeared by mid-1978 from the 2.5-m strips where they were initially seeded. They were displaced by kudzu from the alternate 2.5-m strips. The failure of these two grasses was due to a number of factors. Initial stands of all species were good with the exception of *H. rufa,* which was handicapped from the outset. Both species have relatively slow growth rates under Carimagua conditions, compared to *B. decumbens* which recovers rapidly after grazing and produces much more dry matter in a given rest period than the others. The design of the experiment did not permit separate grazing of the three associations and as a consequence, preferential grazing of *M. minutiflora* and *H. rufa* also contributed to their failure. Both are relatively palatable in the rainy season. The rapid decline of *M. minutiflora* is shown in Figure 76. The data for *H. rufa* are almost identical.

The two grasses which were displaced by kudzu were replaced late in the year by *B. humidicola* and *P. maximum* after disking the grass strip to control the invading kudzu. Both species are expected to be sufficiently aggressive to maintain stands with kudzu. They appear to be much more like *B. decumbens* in vigor and rate of dry matter production, based on observations in a number of other trials at Carimagua.

Figure 75 shows that legume production is negatively correlated with grass production. Total legume production to date has been greatest in the 28-day rotation and least in the 56-day rotation. Total grass production has tended in the opposite direction with greatest production in the 56-day rotation. Total combined production was greatest for the 28-day rotation and least for the 56-day rotation. It appears that the 42-day rotation would result in the best compromise for production and persistence of both *B. decumbens* and kudzu.

During the 1978 grazing season, it was observed that *B. decumbens* within the kudzu strip benefited greatly from the improved fertility environment whereas *B. decumbens* only 2.5 m away in the middle of the grass strip is grossly N-deficient. The grass appears to be improving at the expense of the legume in the legume strip and declining rapidly for lack of N in the grass strip. It is possible that the legume will now rapidly improve in the grass strips as grass competition decreases. There may be (in space) an example of ascending grass/declining legume and subsequently, declining grass/ascending legume cycles that are observed in time under field conditions. It may be possible to design a paddock with spatial distribution which would encourage this cyclic change in balance but with the cycles out of phase from one strip to the other, providing for a more continued availability of forage and more constant pasture quality within the paddock.

The kudzu in this experiment was established in 1975 and the grasses were established in early 1976. Although the legume is declining in the *B. decumbens* association (Figure 75) it has persisted through three dry seasons and appears to be a productive, rather long-lived pasture species for savanna ecosystems similar to that of Carimagua. It does require higher fertilizer input than *S. capitata* and *Zornia latifolia.*

The validity of this type of rotational grazing experiment is subject to question and it is difficult to extrapolate from the research experience to farm conditions. Based on the promising results with *B. decumbens* and kudzu and the apparent longevity of kudzu, we have initiated a new trial on spatial distribution of the two species in which the strip width of each species is varied from 0 to 8 m while maintaining the strip width of the associated species constant at 4 m. The new trial will be grazed continuously with grazing pressure adjusted to forage availability. Data will be taken on persistence of species, invasion of strips, weed incidence and efficiency of N transfer to the grass.

An additional trial related to maintenance and pasture management was initiated in 1978 to study the interaction of

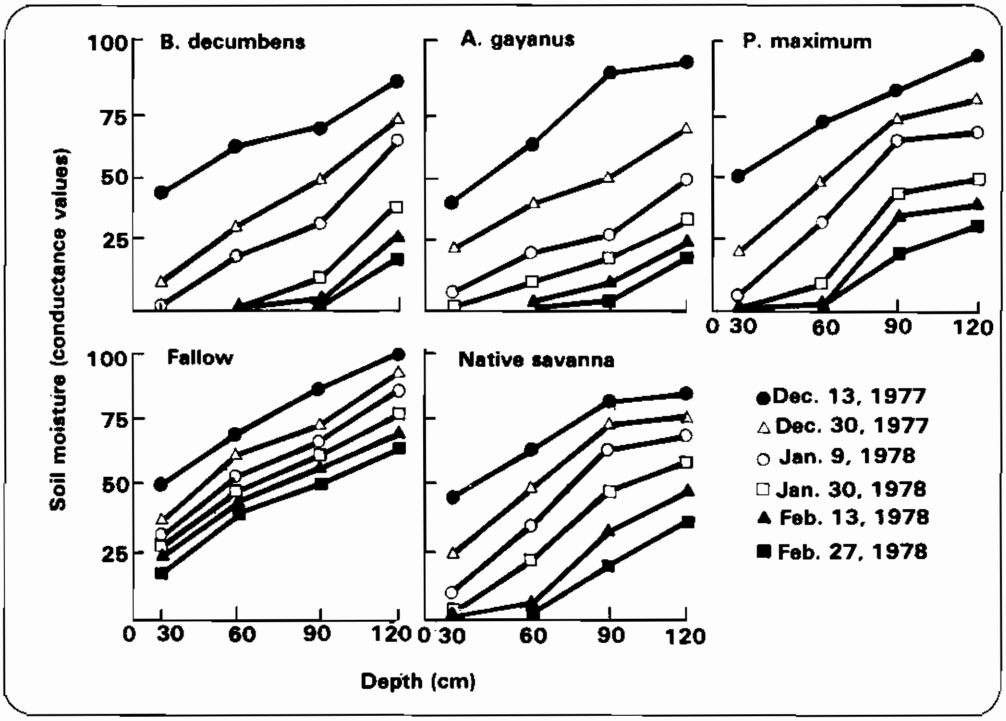


Figure 77. Moisture extraction profiles under fallow, ground, native savanna, *Brachiaria decumbens, Andropogon gayanus* and *Panicum maximum* during the 1977-78 dry season at Carimagua.

P levels and pasture associations. Two grasses and two legumes *(P. maximum, A. gayanus, S. capitata, P. phaseoloides)* are combined in four associations which are each fertilized at three different P levels. The grasses and legumes included differ markedly in their P requirement, thus P level should have a strong effect on relative competitiveness and productivity of the components of the associations.

Subsoil Moisture Availability to Pasture Species

At the beginning of the 1977-78 dry season sets of Bouyoucos blocks were installed in a number of different profiles to a depth of 1.20 m to follow the extraction of subsoil moisture by several grasses. The results are preliminary and additional work will be undertaken in the coming dry season. In Figure 77 it can be seen that *P. maximum* and the native savanna displayed almost identical moisture extraction capabilities. Both pastures were relatively inefficient at extracting moisture at the 90- and 120-cm depths compared with *A. gayanus* and *B. decumbens*, both of which dried the profile completely to the 90-cm depth and apparently dried it somewhat greater at 120 cm than did the other two pastures. Under fallow, although some moisture was lost from the subsoil it remained quite moist throughout the dry season, even at the 30- cm depth. It should be noted that the values obtained are not soil moisture content but are conductance values and therefore, should not be taken as precise moisture measurements.

These observations correlate well with apparent drought resistance of the species observed. *A. gayanus* and *B. decumbens* are both noted for their good performance during the dry season. This may be largely due to their ability to root deeply, taking advantage of stored moisture in the subsoil. *P. maximum* is a relatively poor summer performer and is apparently unable to utilize subsoil moisture as effectively as the other two grasses.

It is speculated that for legume/grass associations for savanna ecosystems where the dry season is severe and long, the most drought-tolerant grasses may not be the most desirable since they would obviously compete more strongly with the legume for limited moisture. A less competitive grass that tolerates the dry season well and recovers quickly in the following rainy season may in fact be a more desirable companion grass for legumes.

Fertilizer Maintenance Requirements under Grazing

Small enclosures in grazing paddocks are used for testing for nutrient responses in *B. decumbens* grazed at three stocking rates. A large N response has been observed, but we are still unable to show responses to P and K treatments using two replicates of a complete 3 x 3 factorial.

Pasture Development in the Cerrado

A review of available edaphic and nutrient response data for crops and forages shows that little information is available for predicting the most important soil limiting factors for forage grasses and legumes of interest for this area. Phosphorus fertilization requirements for establishment is well-known for some crops and possibly *B. decumbens* but little is known regarding establishment and maintenance requirements for forage legumes or grass/legume associations. Most of the work in 1978 related to establishment methods has been done with cultivated pastures. There is little information on native pasture improvement, including legume introduction in native savannas. Traditionally, improved pastures in the Cerrado of Brazil have been developed by expensive mechanized clearing, plowing, liming and complete seed bed preparation for pure stands of grasses or grass/legume associations. Legume persistence has always been a problem and at present most farmers and research workers are pessimistic about the potential of grass/legume associations. Maintenance fertilization and better grazing management would probably overcome some of the problems of persistence.

Limiting Fertility Factors

To identify these factors a series of exploratory pot experiments was initiated. All major, secondary and micronutrients except N, P, Cl and Fe were included in a 2^8 factorial with one-quarter of a replication. Phosphorus and Fe were considered in satellite experiments, P being applied as a constant in the factorial experiments. Two test plants representing high and low fertility requirements were used in two experiments with two Oxisols, the Latosol Vermelho Escuro (LVE) and a Latosol Vermelho Amarelo (LVA). A striking visual plant response to S was observed in both soils with both test plants. Plant response data in terms of dry matter are available only for the LVA. They confirm the S deficiency observations and show other deficiencies as well.

The dry matter production of the *Centrosema* hybrid 448 was doubled when 30 kg S/ha was applied. *Calopogonium mucunoides* also responded significantly to S. Both legumes responded to Ca when 500 kg/ha was added as $CaCO_3$. This has been interpreted as a nutrient response more than a liming effect of $CaCO_3$. Plant and soil analyses are being performed to check this hypothesis.

Potassium has also been identified as limiting for both legumes in the LVA soil. A significant response to Mo was observed with *Centrosema*. Other deficiencies will probably show up as nutrients are extracted by additional harvests.

Based on these findings, experiments with S, Ca, K and Mo have been initiated. Spray application of other nutrients will be tested if they are identified in the pot experiment as potentially limiting.

Establishment Requirements

Cerrado soils are typically P-deficient but the amount of P required for pasture legume establishment and maintenance is not well-defined. As a basis for selecting P levels to be used in field experiments, a preliminary pot trial was performed with the same legumes and soils previously described. An additional objective was to check the validity of the P and Ca levels chosen for the previous experiment.

Four levels of P equivalent to 50, 100, 200 and 400 kg P/ha as calcium monophosphate and 0, 100, 500 and 1000 kg $CaCO_3$/ha were used. Plant responses are shown in Figures 78 and 79 for the LVA soil. Plant response to $CaCO_3$ was

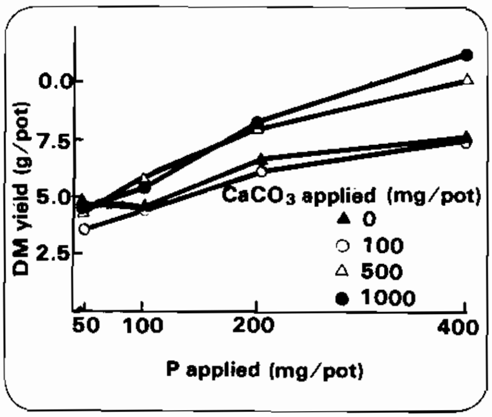


Figure 78. *Calopogonium muconoides* response to lime and P on a Red-yellow Latosol at Brasilia, Brazil.

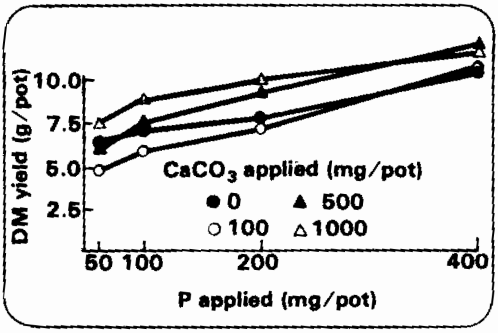


Figure 79. *Centrosema* hybrid 438 response to lime and P on a Red-yellow Latosol at Brasilia, Brazil.

detected for both species at levels equivalent to 500 kg $CaCO_3$/ha but not above this level. Response to P was high even at levels as high as 200 and 400 kg P/ha. This indicates that large amounts of P are necessary for maximum seedling growth in the field.

Based on previous results a field experiment was initiated this year to evaluate three sources and several rates of P. Sulphur, Ca, K, Zn, and Mo were included at uniform levels, based on results of the 2^8 factorial experiment and information available for other crops. The objective is to determine P fertilization requirements for establishment of an *A. gayanus*/ *capitata* association using trip superphosphate, Araxá rock phospha and Yoorin, a thermal rock phosphat Main plots will be divided next year determine residual effects and optimu maintenance rates.

Establishment Methods

A field experiment was established January 1978 to test several methods legume introduction into native savann with various degrees of tillage. Thre legume species — *S. capitata,* *mucunoides* and *Glactia striata* — we selected, based on previous informatio available at CPAC. Burning was include as a treatment to eliminate excessi mature vegetation accumulated previous years and improve seed/so contact.

A 20-day drought followed planting a growth was reduced by the short rai season but establishment was successf with some species and methods. Sta counts are shown in Table 41 for April a August observations.

Table 41.

Effects of establishment methods on stand counts of three legumes introduced in native savanna (Brazilian Cerrado, LV soil). (Means of 20 observations in April and 40 observations in August.)

	Stylosanthes capitata 1405		*Calopogonium mucunoides*		*Galactia striata*	
	April 78	August 78	April 78	August 78	April 78	August 78
Method	(plants/m²)					
Oversowing	<1	<1	<1	<1	3	1
Burning & oversowing	2	1	8	3	2	<1
Disking & oversowing	2	2	31	12	13	4
Burning, disking & oversowing	4	2	29	16	10	5
Sod-seeding	2	1	32	17	12	4
Burning & sod-seeding	3	<1	40	16	8	4

sture Renovation

'here are vast areas of pure grass tures as well as grass/legume ociations in which the legume compot has disappeared in the Cerrado of zil. The dominant species are *B. umbens, H. rufa* and *M. minutiflora.* ese pastures decline in productivity after w years, probably due primarily to low N availability as a result of a low rate of anic matter mineralization under graz-. In addition, forage quality declines, ecially during the dry season in pure nds of these species. Legume introduc- in grass swards is known to increase al production, improve forage quality l incorporate N into the system as well.

3. decumbens dominates almost all er species in association. There is a clear d to identify adequate species and thods of establishing legumes in old *chiaria* swards.

\ field experiment was started this year test several methods and species for ovating a three-year-old *Brachiaria* ture. The renovation methods tested in 12 m plots in a randomized complete ck design are the following: (1) overving *Brachiaria;* (2) oversowing *chiaria* after disking; (3) sod-seeding n wide furrows 50 cm apart); (4) planting in strips (1.50-m wide rotovated band); and (5) N fertilizer application after disking, with no legume introduction.

Three species were planted for each establishment method. *C. mucunoides,* a well-known legume adapted to Cerrado conditions; *Centrosema* hybrid CIAT 438, more productive at relatively higher soil fertility levels and *D. ovalifolium* CIAT 350, probably the legume best-equipped to compete with *Brachiaria.*

The experiment will provide information on adaptation of species for association with existing *Brachiaria* and on methods most suitable for legume introduction. The grass/legume associations which succeed will be compared to N fertilized *Brachiaria.*

Other Experiments

Additional field and pot experiments designed to help interpret the experiments outlined above have been initiated. Two pot experiments are in progress to study Fe, Ca and Mn and sources of S in two major soils using two test plants. Two field experiments have been established on old experimental sites with contrasting levels of available P and pH, to study the effect of these factors on grass/legume associations.

PASTURE UTILIZATION

'he Units of the Pasture Utilization tion of the Beef Program conducted ivities at Carimagua, CIAT-Quilichao l Brasilia. All activities are related to luating Category 4 material from the ndpoint of the use that animals can ke of this promising germplasm.

Nutritive Value of Andropogon gayanus

Intake and digestibility trials were conducted with several promising forages at Quilichao, employing crated wethers offered forage in increasing quantities.

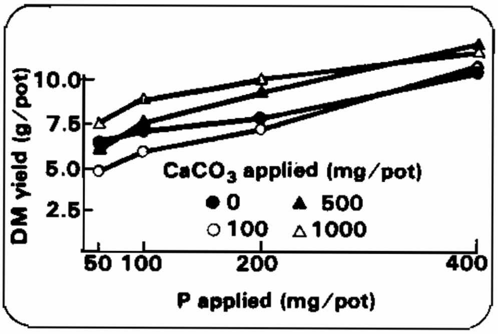


Figure 79. *Centrosema* hybrid 438 response to lime and P on a Red-yellow Latosol at Brasilia, Brazil.

detected for both species at levels equivalent to 500 kg $CaCO_3$/ha but not above this level. Response to P was high even at levels as high as 200 and 400 kg P/ha. This indicates that large amounts of P are necessary for maximum seedling growth in the field.

Based on previous results a field experiment was initiated this year to evaluate three sources and several rates of P. Sulphur, Ca, K, Zn, and Mo were included at uniform levels, based on results of the 2^8 factorial experiment and information available for other crops. The objective is to determine P fertilization requirements for establishment of an *A. gayanus/S. capitata* association using triple superphosphate, Araxá rock phosphate and Yoorin, a thermal rock phosphate. Main plots will be divided next year to determine residual effects and optimum maintenance rates.

Establishment Methods

A field experiment was established in January 1978 to test several methods of legume introduction into native savanna with various degrees of tillage. Three legume species — *S. capitata, C. mucunoides* and *Glactia striata* — were selected, based on previous information available at CPAC. Burning was included as a treatment to eliminate excessive mature vegetation accumulated in previous years and improve seed/soil contact.

A 20-day drought followed planting and growth was reduced by the short rainy season but establishment was successful with some species and methods. Stand counts are shown in Table 41 for April and August observations.

Table 41.

Effects of establishment methods on stand counts of three legumes introduced in native savanna (Brazilian Cerrado, LV soil). (Means of 20 observations in April and 40 observations in August.)

	Stylosanthes capitata 1405		*Calopogonium mucunoides*		*Galactia striata*	
	April 78	August 78	April 78	August 78	April 78	August 78
Method	(plants/m²)					
Oversowing	<1	<1	<1	<1	3	1
Burning & oversowing	2	1	8	3	2	<1
Disking & oversowing	2	2	31	12	13	4
Burning, disking & oversowing	4	2	29	16	10	5
Sod-seeding	2	1	32	17	12	4
Burning & sod-seeding	3	<1	40	16	8	4

Pasture Renovation

There are vast areas of pure grass pastures as well as grass/legume associations in which the legume component has disappeared in the Cerrado of Brazil. The dominant species are *B. decumbens, H. rufa* and *M. minutiflora*. These pastures decline in productivity after a few years, probably due primarily to low soil N availability as a result of a low rate of organic matter mineralization under grazing. In addition, forage quality declines, especially during the dry season in pure stands of these species. Legume introduction in grass swards is known to increase total production, improve forage quality and incorporate N into the system as well.

B. decumbens dominates almost all other species in association. There is a clear need to identify adequate species and methods of establishing legumes in old *Brachiaria* swards.

A field experiment was started this year to test several methods and species for renovating a three-year-old *Brachiaria* pasture. The renovation methods tested in 8 x 12 m plots in a randomized complete block design are the following: (1) oversowing *Brachiaria;* (2) oversowing *Brachiaria* after disking; (3) sod-seeding (1-in wide furrows 50 cm apart); (4) planting in strips (1.50-m wide rotovated band); and (5) N fertilizer application after disking, with no legume introduction.

Three species were planted for each establishment method. *C. mucunoides,* a well-known legume adapted to Cerrado conditions; *Centrosema* hybrid CIAT 438, more productive at relatively higher soil fertility levels and *D. ovalifolium* CIAT 350, probably the legume best-equipped to compete with *Brachiaria*.

The experiment will provide information on adaptation of species for association with existing *Brachiaria* and on methods most suitable for legume introduction. The grass/legume associations which succeed will be compared to N fertilized *Brachiaria*.

Other Experiments

Additional field and pot experiments designed to help interpret the experiments outlined above have been initiated. Two pot experiments are in progress to study Fe, Ca and Mn and sources of S in two major soils using two test plants. Two field experiments have been established on old experimental sites with contrasting levels of available P and pH, to study the effect of these factors on grass/legume associations.

PASTURE UTILIZATION

The Units of the Pasture Utilization Section of the Beef Program conducted activities at Carimagua, CIAT-Quilichao and Brasilia. All activities are related to evaluating Category 4 material from the standpoint of the use that animals can make of this promising germplasm.

Nutritive Value of Andropogon gayanus

Intake and digestibility trials were conducted with several promising forages at Quilichao, employing crated wethers offered forage in increasing quantities.

The digestibility of *Andropogon gayanus* CIAT 621 was determined using hay cut during the dry season after 44 days of regrowth. The hay was offered at four levels between 50 and 200 g of DM/W$^{.75}$/-day. Figure 80 shows a quadratic relationship between forage consumption and digestibility. Maximum digestibility of 60% was attained at a level of consumption of 60 g. Moreover, Figure 81 shows that the consumption of digestible DM was above maintenance at forage levels of 50 g and over, indicating a good degree of utilization.

Nutritive Value of Desmodium Species

Desmodium ovalifolium 350 was fed fresh, unchopped at levels between 30 and 240 g of DM/W$^{.75}$/day, and at five plant ages averaging 50, 80, 100, 125 and 145 days of regrowth. The last trial coincided with the beginning of the dry season at Quilichao.

Figure 82 shows the relationship between the amount of *D. ovalifolium* offered and its consumption. The relationship is clearly asymptotic and very similar for all forage ages. Maximum DM intake was reached between 80 and 90 g of DM/W$^{.75}$ offered, including the forage cut during the dry season. Digestibility increased as the level of consumption increased, reaching levels of around 60% in all cuts, which can be considered adequate for tropical forage legumes (Fig. 83). The increase in digestibility with increasing forage consumption can be explained by the increase in leaf consumption as shown in Figure 84. It is important to observe that the intake of digestible dry matter was above the approximate maintenance level of 25 g/W$^{.75}$/day (Fig. 85).

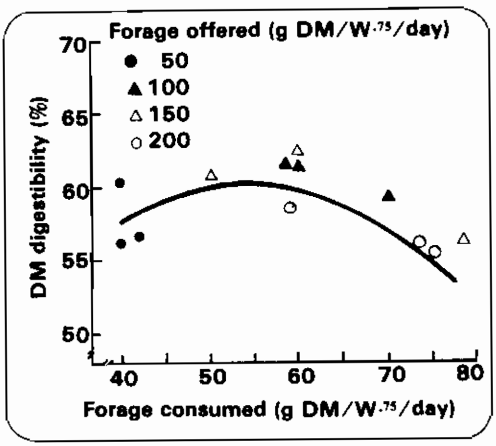


Figure 80. Relationship between forage offered, forage consumed and digestibility of *Andropogon gayanus* 621 hay made from 44-day regrowth during the dry season.

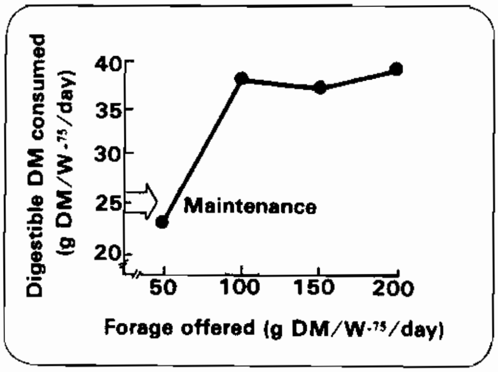


Figure 81. Effect of amount of forage offered on consumption of digestible DM of *Andropogon gayanus* 621 hay made from a 44-day regrowth cut during the dry season and fed to crated wethers.

Figure 86 shows the average crude protein (CP) and P contents of leaf and stem at each age. Protein is not particularly high, but its level in the leaves is quite adequate for animal growth and reproduction. Leaf P is insufficient for growth or reproduction in spite of the application of 200 kg P_2O_5/ha at establishment. The critical levels of protein and P are generally considered to be 7-10% and 0.2%, respectively.

The digestibility and intake of three *Desmodium* species were compared when

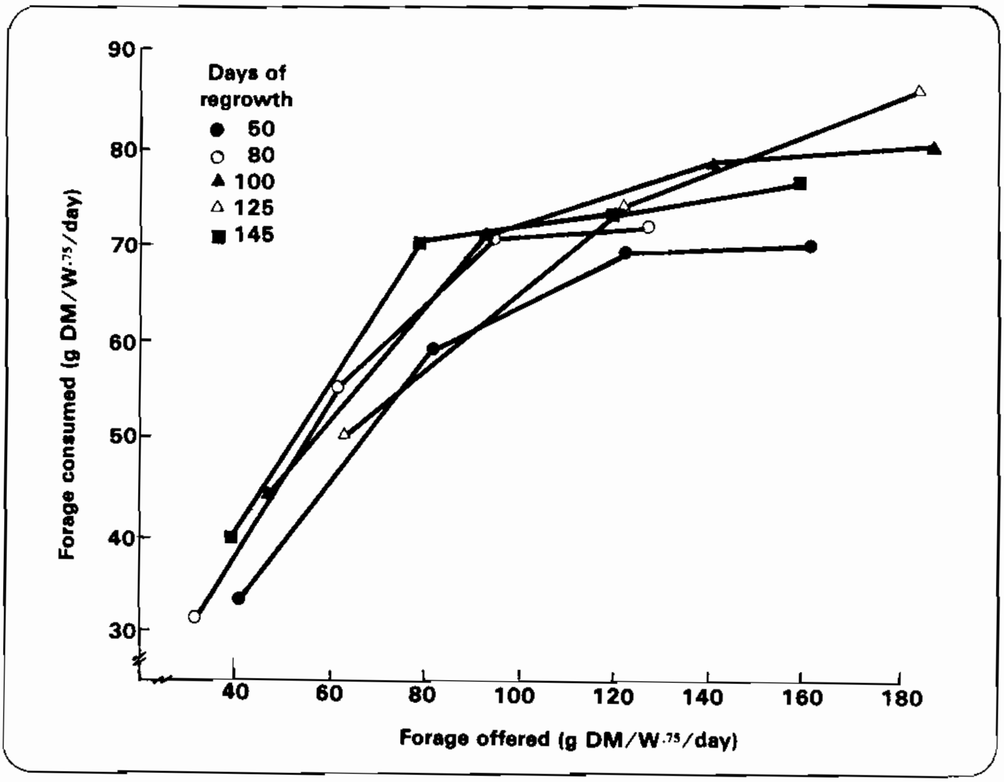


Figure 82. Relationship between stage of regrowth, forage on offer and consumption of green *Desmodium ovalifolium* 350 fed to crated wethers.

cut for hay, during the dry season. *D. ovalifolium* 350 and *Desmodium heterophyllum* 349 are species of interest for Oxisol and Ultisol areas. *Desmodium distortum* 335 was included as a positive control since it has been previously found to be of high nutritive value although not adapted to acid soils. Figures 87 and 88 show the intake and digestibility values of the three legumes with increasing levels of forage offered. The high nutritive value of *D. distortum* is again demonstrated by its linear increase in intake and digestibility up to the highest level offered. *D. heterophyllum* had higher consumption than *D. ovalifolium* but both reached near maximum intake at 80 g of offer. Digestibility of the latter two legumes did not change with increased forage offer or consumption, in marked contrast with *D. distortum*. The difference reflects the much more drastic selection for leaves occurring as forage availability increased; at 40 g of DM offered the low digestibility of *D. distortum* was associated with near total consumption of the woody main stems of the legume. *D. heterophyllum* and *D. ovalifolium* appear to be very palatable species of high intake potential in spite of decreased possibility of selection for leaves.

Grazing Management of Legume/Grass Associations

The effect of the rotation interval on the survival and productivity of *Centrosema* hybrid 438, was studied in two experiments at Quilichao. In one experiment, *Centrosema* was mixed with *Panicum max-*

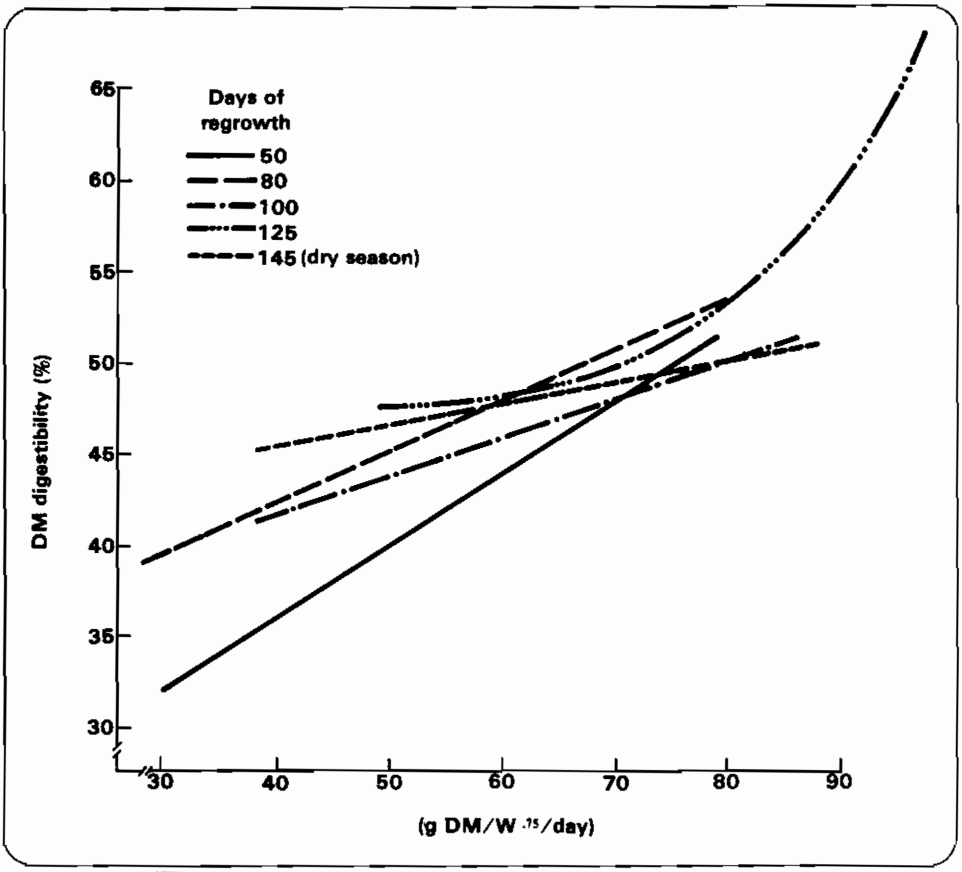


Figure 83. Relationship between stage of regrowth, forage consumption and digestibility of green *Desmodium ovalifolium* 350 fed to crated wethers.

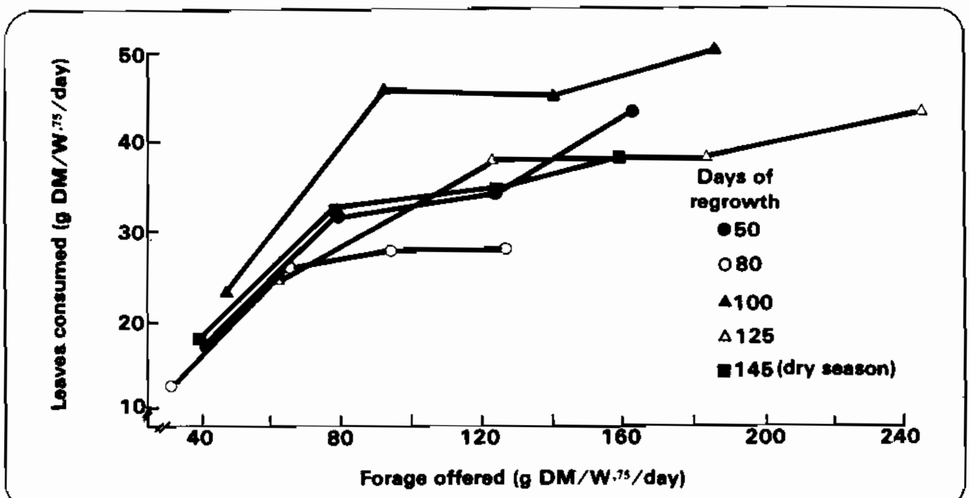


Figure 84. Relationship between stage of regrowth, forage on offer and leaf consumption by crated wethers fed green *Desmodium ovalifolium* 350.

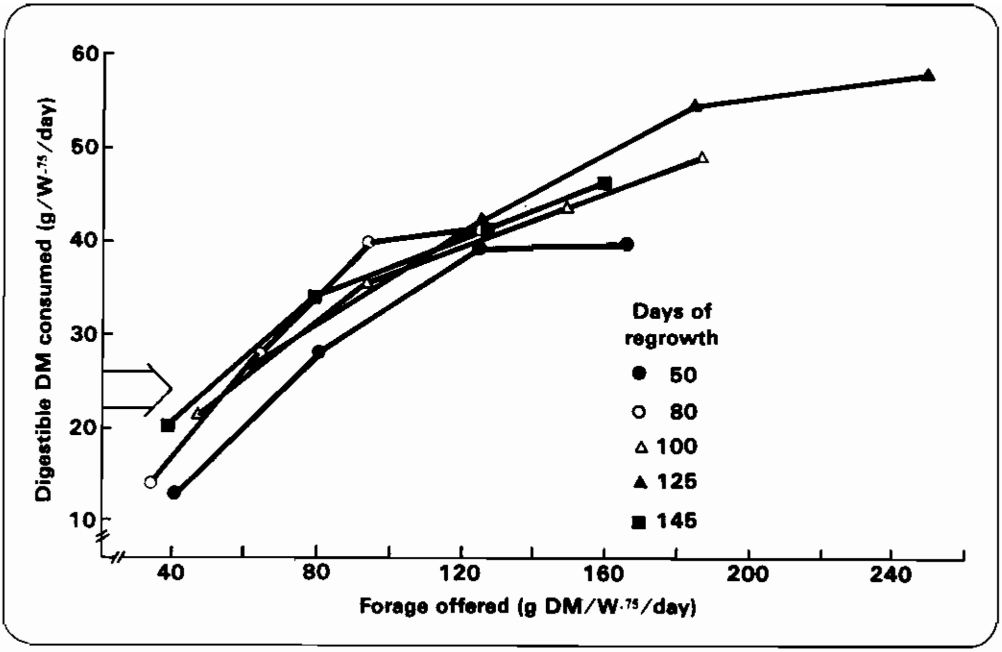


Figure 85. Effect of amount of forage on offer and stage of regrowth on consumption of digestible dry matter by crated wethers.

imum var. Common, *Brachiaria decumbens* and *A. gayanus* 621 and grazed at three intervals — 4, 6 and 8 weeks — at low and high grazing intensities. In all mixtures, forage yield tended to increase as the rest periods increased, the increase

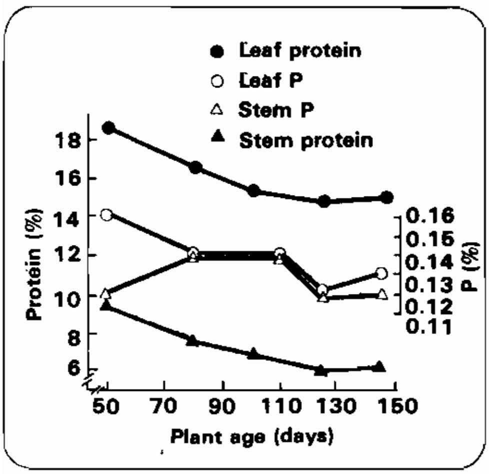


Figure 86. Effect of plant age on protein and P content of leaves and stems of *Desmodium ovalifolium* 350.

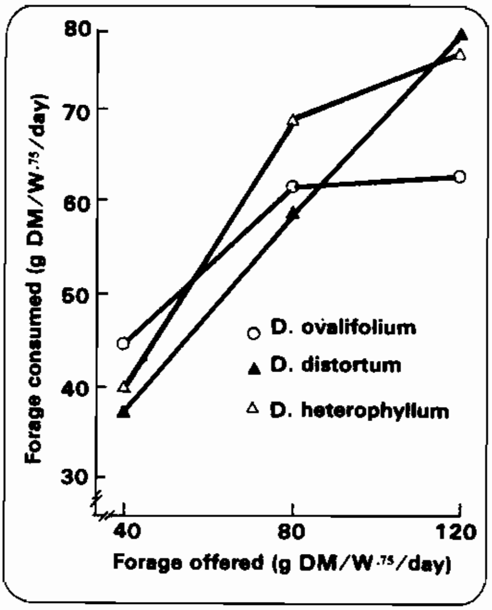


Figure 87. Effect of amount of forage offered on consumption of *Desmodium ovalifolium, Desmodium distortum* and *Desmodium heterophyllum* hay cut in the dry season and fed to crated wethers.

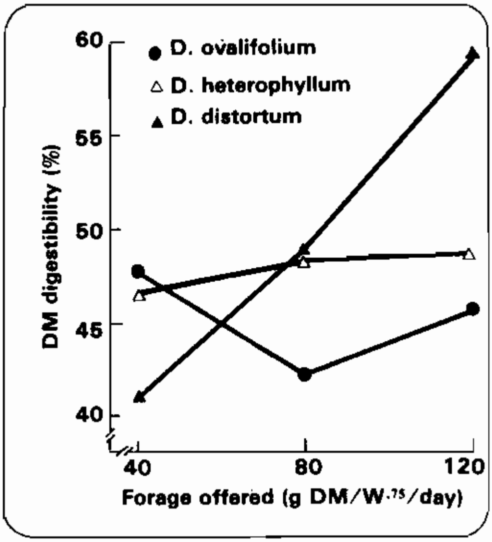


Figure 88. Effect of amount of forage offered on DM digestibility of *Desmodium ovalifolium, Desmodium distortum* and *Desmodium heterophyllum* hay cut in the dry season and fed to crated wethers.

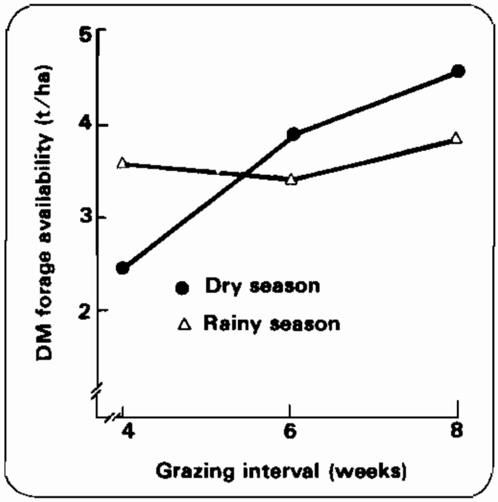


Figure 90. Effect of grazing interval on dry matter availability of mixtures of Centrosema hybrid 438 and the grasses *Panicum maximum* var. Common, *Brachiaria decumbens* and *Andropogon gayanus* 621 during the rainy and dry seasons, at Carimagua.

being more pronounced in the *Centrosema/Andropogon* mixture and less in *B. decumbens* (Fig. 89). This increment was not observed in in the first rainy season but was large in the following dry season (Fig. 90).

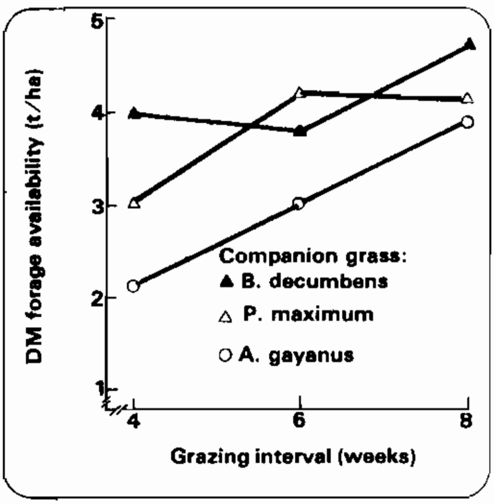


Figure 89. Effect of grazing interval on mixtures of *Centrosema* hybrid 438 and each of three grasses, *Panicum maximum* var. Common, *Brachiaria decumbens* and *Andropogon gayanus* 621.

The effect of the companion grass on legume content of the mixtures is presented in Figures 91 and 92 for the rainy and dry seasons, respectively. The legume content was low in the mixture with *B. decumbens* and *P. maximum* in the first rainy season and decreased to nearly nil in the following dry season. *A. gayanus,* on the other hand, allowed good legume persistence while still maintaining a reasonable DM yield, particularly with the longer rest periods (Fig. 89). The data from the first two grazing seasons indicate that only *A. gayanus* will allow this legume to persist under the conditions of the experiment.

In the second experiment, legume/grass associations are being continuously grazed at a stocking rate of 2 animals/ha. All mixtures contain *Centrosema,* one of the two *Stylosanthes guianensis,* 136 and 184, and one of the grasses *P. maximum* var. Common, *B. decumbens* and *A. gayanus*

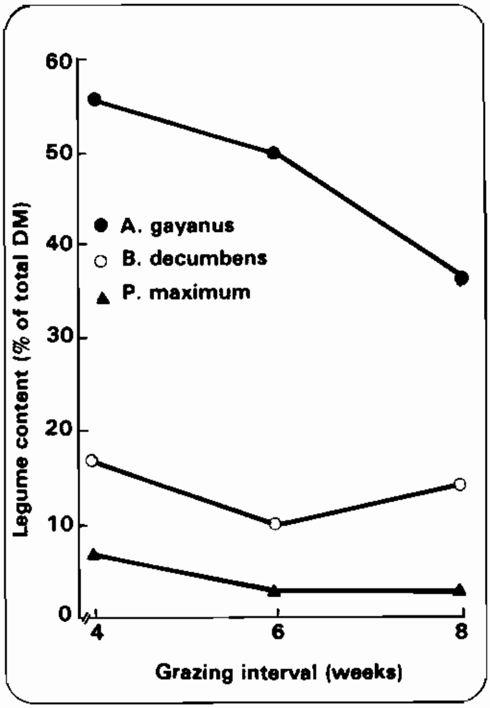


Figure 91. Effect of grazing interval on legume content of pastures containing mixtures of *Centrosema* hybrid 438 and one of the grasses *Panicum maximum, Brachiaria decumbens* or *Andropogon gayanus* 621, during the rainy season at CIAT-Quilichao.

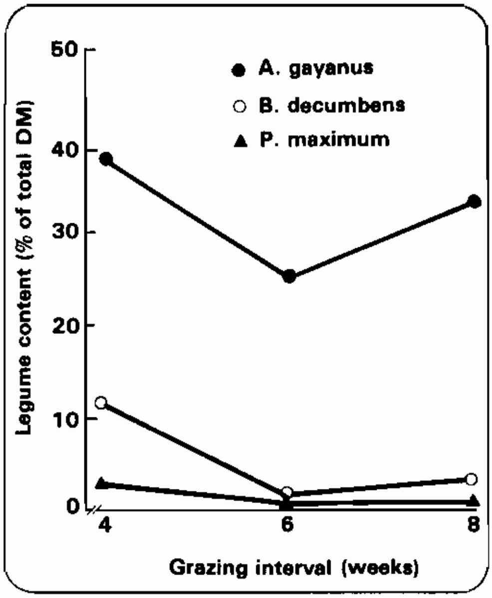


Figure 92. Effect of grazing interval on legume content of pastures containing mixtures of *Centrosema* hybrid 438 and one of the grasses *Panicum maximum, Brachiaria decumbens* or *Andropogon gayanus* 621, during the dry season at CIAT-Quilichao.

621. Table 42 shows the available DM for each of the mixtures during the first rainy season and the following dry season. In all cases DM availability decreased, but the quantities are large, indicating a problem of understocking. This will be corrected by increasing to 3 animals/ha in subsequent years. Under continuous grazing, yield of *A. gayanus* has been severely reduced. This can be partly explained by insufficient initial stand resulting from vegetative

Table 42.

Forage availability of mixtures of *Centrosema* CIAT hybrid 438, *Stylosanthes guianensis* 136 and 184 and one of the grasses *Panicum maximum, Brachiaria decumbens* and *Andropogon gayanus* 621 in continuously grazed plots at CIAT-Quilichao.

	DM yield in rainy season (t/ha)			DM yield in dry season (t/ha)		
Component	*P. maximum*	*B. decumbens*	*A. gayanus*	*P. maximum*	*B. decumbens*	*A. gayanus*
Centrosema	2.5	3.8	3.4	0.9	0.5	2.4
S. guianensis	1.5	2.8	2.9	0.2	0.2	0.8
Grass	3.9	3.2	1.2	3.3	2.6	0.2
Total	9.3	11.6	9.0	5.2	3.7	3.6

propagation, and by a strong preference of the steers for this species. By the end of the dry season the contribution of *A. gayanus* had decreased to less than 5% (Fig. 93). The other two grasses have become dominant and the legume has decreased to 10 to 20% of the stand. Both introductions of *S. guianensis* are rapidly disappearing.

From results obtained thus far, it appears that *A. gayanus* should not be grazed when initial plant populations are low because it can be grazed out rather rapidly.

Two animals continuously grazing a 1-ha paddock have gained 164 kg each during 233 days of grazing for an average daily weight gain of 704 g/steer.

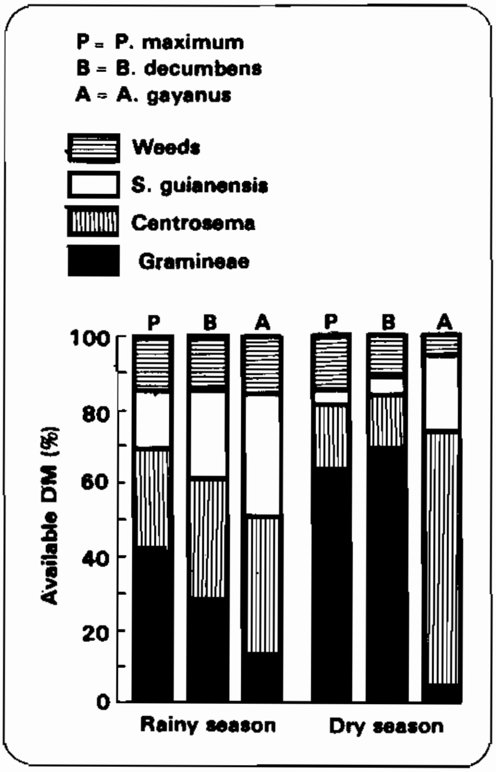


Figure 93. Botanical composition of plots comprised of mixtures of *Centrosema* hybrid 438, *Stylosanthes guianensis* 136 and 184 and one of the grasses *Panicum maximum*, *Brachiaria decumbens* and *Andropogon gayanus* 621 under continuous common grazing, at CIAT-Quilichao.

Two new experiments, similar to those above, have been established at Quilichao to determine the most adequate grazing management for mixtures of *D. ovalifolium* 350 and two of the grasses. Under continuous grazing, *B. decumbens* will not be included and *A. gayanus* will occupy most of the area in the mixture to avoid its elimination by preferential grazing.

Animal Production Potential of Pure Grass Pastures

Brachiaria decumbens

The *B. decumbens* trials at Carimagua continued into their fourth year in order to determine the most appropriate year-round management. This year's results are presented in Tables 43 to 45. Liveweight gains are similar to previous years with the exception of certain treatments with variable dry season/rainy season stocking rates. It is important to note that *B. decumbens* is capable of producing as much as 260 to 280 kg of liveweight gain/ha/yr. Forage availability ranged from 1 to 2 t/ha of green DM during the rainy season and 0.2 to 0.5 t/ha during the dry season. Recovery at the beginning of the rainy season (April) is rapid, but as shown in Figure 94, it is slower at the higher stocking rate. Rainy season forage availability had been restored by May, in every case. Figure 95 shows a similar situation when stocking rates are higher in the rainy season, clearly demonstrating the need to wait at least one month after rains start to establish rainy season stocking rates.

Pasture productivity in Carimagua is fairly stable over time in spite of large seasonal variations. Differences tend to

Table 43.

The effect of stocking rate on liveweight changes of steers grazing *Brachiaria decumbens* at constant stocking rates throughout the year at Carimagua. (Fourth year of grazing).

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
Dry season[1]	Rainy season[2]	Dry season	Rainy season	Total	Dry season	Rainy season	Total
0.9	0.9	-8	86	76	-7	77	70
1.3	1.3	2	71	73	3	92	95
1.7	1.7	3	73	77	5	124	129

1 83 days of grazing, December to March.
2 251 days of grazing, March to November.

cancel out in consecutive seasons due to compensatory gains as shown in Figure 96 for continuously grazed and set-stocked *B. decumbens*.

Panicum maximum

Panicum maximum var. Common was sown July 1977, with the application of 140 P_2O_5/ha as basic slag, and has been continuously grazed at 0.9, 1.3 and 1.7 steers/ha since February 1978. At that time, the pasture was already tall with an excess of dry, old material. It was necessary to increase stocking rates in May and June 1978 to reduce the forage available. Nevertheless, weight gains during the dry and rainy seasons were excellent, reaching a maximum of 314 kg/ha and gains per animal of 114 kg at 1.7 animals/ha stocking rate (Table 46). These are only first year results and as such are of limited value because it is well-known that *P. maximum* is a fast-growing, nutritious grass with high nutrient requirements, particularly for N, which is usually depleted rapidly in tropical soils.

Andropogon gayanus

An experiment was seeded with *A. gayanus* 621 in August 1976. Vegetative

Table 44.

The effect of rainy season stocking rates on liveweight change of steers grazing *Brachiaria decumbens* at low stocking rates during the dry season.(Third year of grazing.)

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
			Rainy season				
Dry season[1]	Rainy season[2]	Dry season	Early	Late	Dry season	Rainy season	Total
0.7	1.62	15	36	63	11	127	138
0.7	2.34	10	25	55	7	146	153
0.7	3.06	37	45	66	26	233	259

1 83 days, from December to March.
2 Rainy season stocking rates were not re-established until May 5, 1978 to allow recovery of the pastures. Early rainy season from March to May, 57 days and late rainy season from May to November, 194 days.

Table 45.

The effect of dry season stocking rate on liveweight change of steers grazing *Brachiaria decumbens* at medium stocking rate during the rainy season. (Second year of grazing.)

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
			Rainy season				
Dry season[1]	Rainy season[2]	Dry season	Early	Late	Dry season	Rainy season	Year
0.72	2.16	20	29	49	14	127	141
1.03	2.08	27	38	104	28	255	283
1.36	204	13	24	87	18	210	228

1 83 days, from December to March.
2 167 days. Rainy season stocking rates were not re-established until May 5, 1978 to allow recovery of the pastures. Early rainy season from March to May, 57 days and late rainy season from May to November, 194 days.

material was taken from this planting and used in May-August 1977 to plant two more similar experiments. The first experiment was stocked in December 1977, at 0.9, 1.3, and 1.7 steers/ha, and the other two in June 1978, at 0.9, 1.3, 1.7 and 1.63, 2.34 and 3.06 steers/ha. Grazing management of these experiments was not easy because the plants were slow to establish, particularly when vegetative material was used. Almost a year was required to accumulate sufficient growth for safe grazing. Once established however, *A. gayanus* grows very rapidly, requiring high stocking rates to maintain reasonable pasture height.

Table 47 summarizes the comparison of the forage availability of the three main grass species presently being used in Carimagua. Care must be used in interpreting those data, since the ages of the pastures are different, but they serve to point out the large biomass production in

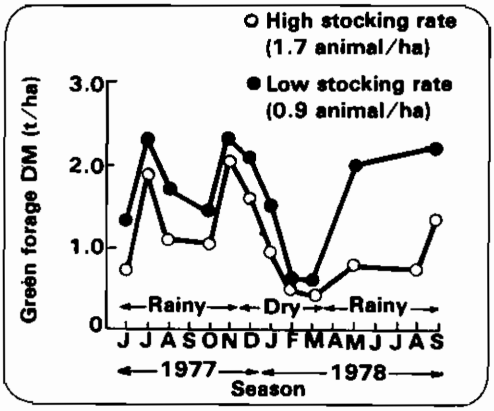


Figure 94. Effect of stocking rate and season on amount of forage on offer in *Brachiaria decumbens* pastures grazed continuously at constant year-round stocking rates (medium stocking rate not shown).

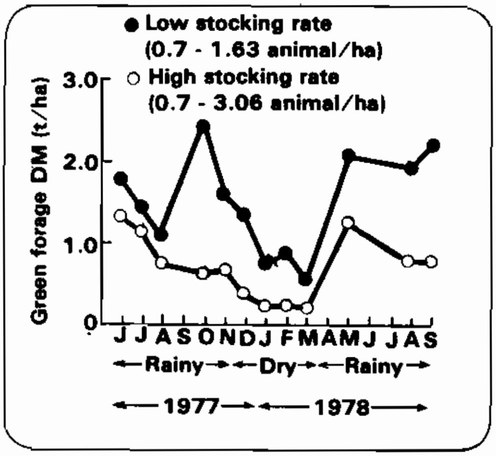


Figure 95. Effect of rainy season stocking rates and season on amount of forage on offer in *Brachiaria decumbens* pastures grazed continuously at low (0.7 animal/ha) stocking rates during the dry season.

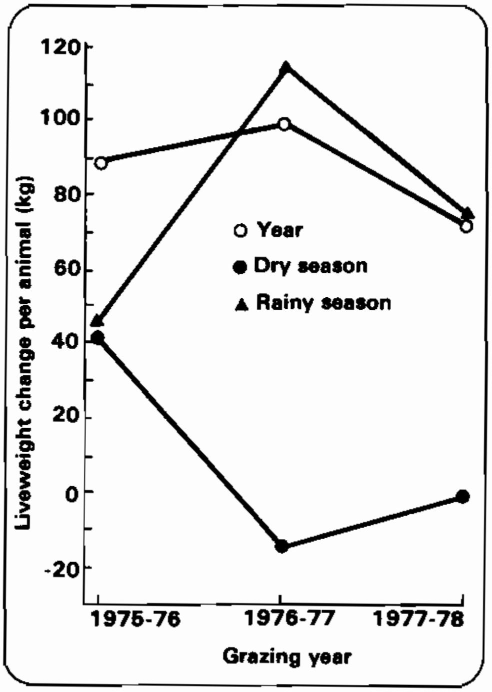


Figure 96. Effect of year on liveweight changes of steers grazing *Brachiaria decumbens*. Data are averages of three set stocking rates, 0.9, 1.3 and 1.7 steers/ha.

A. gayanus and the difficulties in grazing it properly.

Tables 48 and 49 show the protein and P content of *B. decumbens* and *A. gayanus* to be fairly similar during the rainy season. During the dry season, however, *B. decumbens* has 1% more protein and P at equivalent stocking rates (1.7 animals/ha). Protein content of the green forage of *B. decumbens* during the dry season was much higher when it was grazed during the previous rainy season at 3.06 animals/ha than at lower stocking rates. This explains the higher dry season weight gains observed for animals grazing at the highest stocking rate.

Brachiaria humidicola

Brachiaria humidicola, a grass well-known in Brazil and other areas of the world, has been incorporated in the list of promising species for Carimagua. *B. humidicola* is a strongly stoloniferous plant, which by virtue of its ability to root at stolon nodes, covers the ground rapidly and competes particularly well with weeds. *B. humidicola* was planted at Carimagua in May-June 1978 and will be grazed beginning in 1979.

Table 46.

The effect of stocking rate and season on liveweight gains of steers grazing *Panicum maximum* in first grazing year at Carimagua.

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
Dry season[1]	Rainy season[2]	Dry season	Rainy season	Total	Dry season	Rainy season	Total
0.9	0.9	9	127	135	8	172	180
1.3	1.3	11	111	121	15	232	247
1.7	1.7	13	96	114	23	291	314

1 27 days, February to March.

2 251 days. Stocking rate was increased from May 4 to June 21, 1978 to 2.7, 3.9 and 5.1 steers/ha, respectively, to reduce the excessive accumulation of forage.

Table 47.

The effect of season forage availability and stocking rate on three grasses continuously grazed in Carimagua[1].

Stocking rate (steers/ha)	Dry season *A. gayanus*	Dry season *B. decumbens*	Rainy season *A. gayanus*	Rainy season *B. decumbens*	Rainy season *P. maximum*[2]
	(t dry green forage/ha)				
0.9	3.7	2.1	7.7	1.6	2.4
1.3	3.3	1.4	4.2	1.1	1.6
1.7	5.5	1.6	4.7	0.8	1.7

1 Number of years under grazing: *A. gayanus* and *P. maximum*, one year; *B. decumbens*, four years.
2 Not sampled in the dry season. Grazing started in February 1978.

Animal Production Potential of Grass/Legume Pastures

Seven legumes have reached Category 4 of the Program's germplasm classification system: *Pueraria phaseoloides* (kudzu), *D. ovalifolium* CIAT 350, *S. capitata* (CIAT 1019, 1315, 1405, 1078) and *Zornia latifolia* CIAT 728. Replicated 2-ha plots of each species were sown at Carimagua in combination with *A. gayanus* to measure animal production potential. Grazing started in November 1978.

For areas of extensive or semi-intensive grazing where native savanna is plentiful, the concept of establishing a limited area of legume/grass pasture seems the most logical and feasible technique for increased reproductive performance and calf growth (see the Animal Management Section report). Another alternative is to establish

Table 48.

The effect of stocking rate and season on the chemical composition of *Brachiaria decumbens* at Carimagua, 1978.

Stocking rate (steers/ha) Dry season	Stocking rate (steers/ha) Rainy season	Season	Plant part	Protein (%)	P (%)
1.7	1.7	Rainy	Green	7.00	0.15
			Dead	[1]	-
		Dry	Green	3.50	0.13
			Dead	0.82	0.10
0.7	3.06	Rainy	Green	6.70	0.16
			Dead	-	-
		Dry	Green	6.61	0.20
			Dead	2.03	0.08

1 Samples not available for analysis.

Table 49.

Chemical composition of *Andropogon gayanus* 621 in two seasons of the year. (Stocking rate 1.7 animals/ha all year.)

Season	Plant part	Protein (%)	P (%)
Rainy	Green	7.04	0.16
	Dead	2.94	0.05
Dry	Green	2.43	0.09
	Dead	1.82	0.02

small areas of pure legume as protein banks to be used during times of protein stress, particularly in the dry season. *P. phaseoloides* is a legume which normally does not thrive under continuous grazing but which covers the ground rapidly and effectively competes with weeds. It was planted at Carimagua as a protein bank in combination with native savanna and *B. decumbens*. Grazing started in November 1978.

Animal Production Trials at Brasilia

One grazing trial was started at the beginning of the rainy season, utilizing a legume-based pasture (*Brachiaria ruziziensis* x *Stylosanthes guianensis* cv. Endeavour) which had been established the previous year as part of a larger experiment designed to study methods of managing the Cerrado for agriculture. The effect of two levels of P_2O_5 (120 and 240 kg/ha applied during establishment) and stocking rate on animal performance are being studied. The experiment was grazed from one month after the rains began until the animals began losing weight in the following dry season.

Animal gains were inversely related to stocking rate with the lowest stocking rate (1.5 animals/ha) resulting in gains of 582 g/day as compared to gains of 343 g/day at the highest stocking rate (2.7 animals/ha) (Fig. 97).

Neither stocking rate nor P_2O_5 level resulted in differences in average daily gains at the two intermediate stocking rates (1.9 or 2.3 animals/ha). The gains of both these groups were superior to those from the highest stocking rate (Table 50) and nearly equal to gains of the lowest stocking rate. Thus, their gain/ha/day was greater than that of the low stocking rate, especially at the 2.3 animals/ha stocking rate. The relationship of individual and per hectare gains are shown in Figure 98.

At the beginning of the experiment, the pasture was estimated to contain 40% legume and 60% grass. As the rains began to diminish, the availability of *B. ruziziensis* decreased with increased stocking rate and paddocks with 2.7 animals/ha appeared to be almost pure *S. guianensis,* indicating a preference for *Brachiaria* over *Stylosanthes* during the rainy season.

The number of grazing days (Table 50) was directly related to the stocking rate, i.e., as the stocking rate increased the number of grazing days increased even though the higher stocking rates were removed from the experiment first. When the number of grazing days is multiplied by average daily gain, there is no difference in total weight gain between the highest and lowest stocking rates and the two intermediate stocking rates are superior to both high and low stocking rates in total weight gain.

As in Colombia, anthracnose has destroyed about 90% of the *S. guianensis* plants during this trial, confirming the need to eliminate susceptible cultivars from the germplasm evaluation flow.

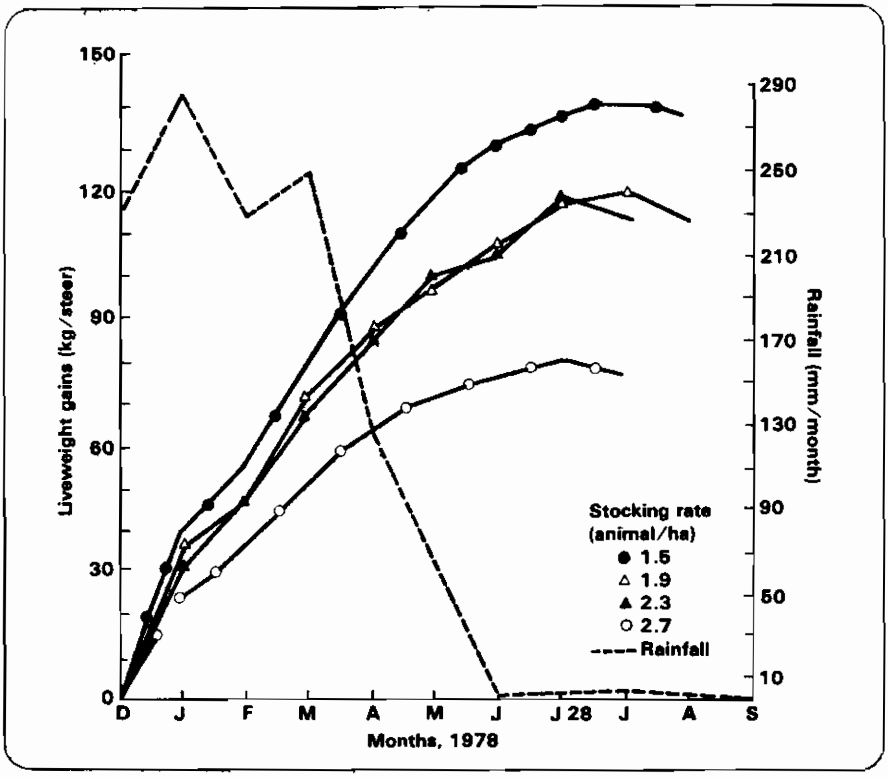


Figure 97. Effect of stocking rate and season on distribution of steer gains on a *Brachiaria ruziziensis*/*Stylosanthes guianensis* pasture in the Cerrado.

Table 50.

The effect of stocking rate and P fertilization on growth of Zebu steers in *Brachiaria ruziziensis*/*Stylosanthes guianensis* pastures at the Cerrado Center, Brazil. (December 1977 to August 1978).

	Stocking rate (steers/ha)					
	1.5	1.9		2.3		2.7
	(kg P_2O_5/ha)					
Parameters	120	120	240	120	240	240
Days on experiment	238	238	238	224	224	224
Daily gains per animal (g)	582	492	481	514	519	343
Daily gains per hectare (g)	878	934	913	1177	1188	929
Total weight gain/ha during experiment (kg)	209	222	217	264	266	208

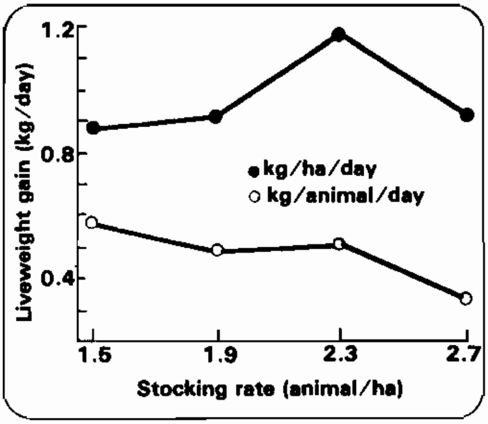


Figure 98. Effect of stocking rate on steer gains on *Brachiaria decumbens/Stylosanthes guianensis* mixed pasture in the Cerrado.

Unlike Colombia, however, there is vigorous new seedling growth at the start of the 1978-79 rainy season, which should extend the life of the legume component.

Three new experiments were initiated during the year. One is designed to compare the effect of grass alone plus N versus grass/legume associations for growing weaned beef calves. Grasses and legumes to be used are *B. decumbens, A. gayanus, S. capitata* and *Calopogonium mucunoides*. *Brachiaria* and *Calopogonium* are the most commonly found improved pasture species in the Cerrado. They are being compared with two relatively new species.

A second experiment is designed to study the effect of different levels of pasture nutrition and weaning age on reproductive performance of lactating cows.

A long-term experiment which began in the last quarter of the year is designed to study the effects of: (1) the length of the breeding season; (2) strategic use of improved pasture during the breeding season; and, (3) weaning ages on the reproductive performance of beef cattle in the Cerrado.

ANIMAL MANAGEMENT

The two units of the Animal Management Section of the Beef Program, at CIAT and Brasilia, are developing improved beef production systems utilizing the improved pasture technology being developed by other sections. Activities during 1978 concentrated on: (1) evaluation of existing beef production systems in Colombia, Brazil and Venezuela; (2) the strategic use of improved pastures in Colombia; and (3) management of test herds. Herd management experiments in Brasilia were started during the year but no results are yet available.

Evaluation of Beef Production Systems

The Beef Production Systems Evaluation project (ETES) is being conducted jointly by the Animal Management and Economics sections, with support of Animal Health and in collaboration with EMBRAPA's Cerrado Center (CPAC) in Brazil, and FONAIAP's Centro de Investigaciones Agropecuarias del Nororiente (CIARNO) in Venezuela. The prevailing beef production systems of the Colombian and Venezuelan Llanos and the Cerrado of Brazil are being evaluated in technological and economic terms.

Within each region, farms representing different technology levels have been selected and monitored in relation to natural resources, applied management, physical inputs, production, animal health and economic conditions. Three regional teams visit the selected farms three or four times a year to collect data.

Llanos of Colombia

In this region, on-farm data collection started in October 1977. Up to October 1978, four periodic studies at 17 farms (out of 20 initially), have been done. Two studies, corresponding to late rainy and early rainy seasons, provided a full set of data on animal performance. The other two served as follow-ups, mainly for updating of records.

Another major activity in cooperation with the CIAT Data Services Unit, was the development of a computerized data processing system to store and analyze a data bank of: (1) non-varying farm descriptors; (2) variable farm descriptors; (3) pasture utilization (animal inventory by paddock); (4) individual performance of female stock; (5) individual performance of male stock; and (6) expenditures and income. Final analyses will be made after two years of observation. Preliminary analyses have been run for files 3, 4 and 5.

Table 51 shows pasture availability on the selected farms. Average farm size is about 2900 ha, of which 5% is sown pastures and the rest, native savanna. A high variation of total sown pasture area and of the three species have been found. *Brachiaria decumbens* is the predominant grass, while *Melinis minutiflora* and, particularly, *Hyparrhenia rufa* are decreasing in importance. This confirms experimental results from Carimagua, which show low productivity during the dry season of both *Melinis* and *Hyparrhenia* and poor adaptation to acid soil conditions of the latter. In almost all cases, *H. rufa* is found on land which was originally forest. The area under *B. decumbens* is increasing rapidly, since it has shown good adaptability, high production and relative superiority during the dry season. High interest for this latter species is rather disturbing, because establishment costs are high and its productivity over time (productive persistence) is unknown. Also, the spittlebug risk and related management problems are often overlooked.

In general, there is a lack of knowledge of how to manage this pasture. Data in Table 51 summarize pasture utilization in terms of stocking rate. Farms show highly variable stocking patterns. Stocking rates vary from 2.9 to 12.5 ha/A.U./ha (0.08-0.34 A.U./ha).

The mean figure observed, 5.9 ha/A.U., is considered adequate and is contrary to the general opinion that Llanos farms are understocked. The optimum stocking rate on native savanna for maximum animal performance is not precisely known, but at Carimagua breeding herds are managed under similar stocking rates, 6 to 7 ha/A.U.

The mean availability of sown pastures per animal unit is 0.36 ha/A.U. In general, farmers give breeding stock little access to sown pastures, but prefer to utilize them with male stock or cows culled for sale. In most cases, sown pastures are also used for recovery of cows in extremely poor condition, such as those lactating during the dry season. This "strategic" use to avoid cow losses during the dry season is a common management practice.

Table 52 shows the herd structure, i.e.,

Table 51.

Pasture inventories and animal stocking in relation to amounts of sown pastures on 16 farms in the Colombian Llanos.

Farm No.	Total area[1] (ha)	Sown pastures: Total sown area (ha)	Sown pastures: % of total area	Sown pastures: Species (%) *Brachiaria decumbens*	Sown pastures: Species (%) *Melinis minutiflora*	Sown pastures: Species (%) *Hyparrhenia rufa*	Cattle stock (A.U.)	Overall stocking rate (ha/A.U.)	Sown pasture availability (ha/A.U.)	Sown pastures per breeding cow (ha)[2]
2	1060	272	26	62	20	18	292	3.7	0.93	0.1
4	3050	22	1	27	73	0	610	5.0	0.04	0.0
5	810	143	18	50	0	50	238	3.4	0.60	0.5
6	1590	231	15	47	5	48	398	4.0	0.58	0.3
7	4950	457	9	27	25	48	969	5.3	0.47	0.0
8	380	162	43	100	0	0	130	2.9	1.25	3.0
9	470	0	0	0	0	0	131	3.6	0.00	0.0
11	5250	52	1	0	0	100	436	12.5	0.12	0.0
12	4430	161	4	94	6	0	558	8.3	0.29	0.0
13	1410	0	0	0	0	0	258	5.6	0.00	0.0
14	1700	30	2	17	83	0	325	5.3	0.09	0.0
15	3580	164	5	21	79	0	930	3.8	0.18	0.0
17	2240	321	14	1	99	0	329	6.7	0.98	0.0
18	8890	144	2	38	33	29	1101	8.3	0.13	0.0
19	3950	20	1	0	0	100	377	11.1	0.05	0.0
20	2860	65	2	77	23	0	559	5.3	0.12	0.0
Mean	2910	140	5	35	28	25	488	5.9	0.36	0.06

1 Includes native savanna, gallery forests and sown pastures.
2 Dependent on degree of utilization by breeding cows.

Table 52.

Herd structure of 16 farms in the Colombian Llanos.

Farms	Animal categories (%)				Total
	Breeding cows	Bulls	Heifers[1]	Steers[1]	No.
2	36	2	24	38	315
4	49	3	33	15	674
5	50	3	31	17	265
6	46	4	34	15	460
7	40	3	35	23	1038
8	37	3	36	24	145
9	43	4	31	22	145
11	36	5	33	27	517
12	24	2	26	48	603
13	44	2	35	19	282
14	44	3	34	19	369
15	34	2	37	25	1046
17	33	3	34	22	369
18	40	4	30	26	1219
19	40	2	30	27	412
20	33	2	32	33	627
Overall mean	39	3	33	25	530
Total	3324	258	2833	2779	9194

1 Heifers and steers include suckling calves and steers include cull cows for fattening.

the proportion of animals in each major category. Approximately 39% of the total stock are breeding cows (females which have calved). This figure is typical for a cow-calf and stocker operation, with low reproductive rates, advanced age of heifers at first calving, and advanced marketing age of steers.

Farms 4, 5 and 6 have a well-above-average percentage of breeding cows (and a low proportion of steers) indicating operations tending towards the cow-calf type and selling steers at a rather young age.

The farm sample includes one case (farm 10) of management oriented towards fattening (on *Brachiaria)* and is thus not representative of the Llanos. Seven farms (e.g., farm 12) are also engaged with fattening, but as a rather marginal or tentative operation.

A high proportion of heifers, which are kept for replacement, are common in the herds. This explains the age structure of the breeding stock given in Table 53.

The average age of cows is 76 months, indicating a relatively short productive life. Only 8% of total breeding stock has been classified as old cows (over 9 years of age).

In the total sample of 196 palpated heifers, between 2 and 4 years of age, only

Table 53.

Relative age structure of breeding cows in 16 farms of the Colombian Llanos.

Farm No.	No. of observations	Age classes: Young <60 months (%)	Medium 60-108 months (%)	Old > 108 months (%)	Mean age (months)
2	55	44	42	14	74
4	0	–[1]	–	–	–
5	73	37	62	1	71
6	46	46	46	8	68
7	79	4	96	0	73
8	49	18	79	3	71
9	44	25	68	7	71
11	73	45	55	0	59
12	65	25	69	6	75
13	72	26	74	0	70
14	56	22	71	7	78
15	0	–	–	–	–
17	47	9	55	36	106
18	73	14	74	12	84
19	43	25	70	5	80
20	50	26	52	22	84
Overall mean	825[2]	26	66	8	76

1 Information not available.
2 Total number of observations.

37% were pregnant. These 72 pregnant heifers were 38 months old, with average weights of 305 kg. These figures generally indicate that replacement heifers produce their first calf at more than 4 years of age. Therefore, the average productive lifetime of a cow, including first gestation, can be estimated to be 4 to 5 years, not much longer than the raising period. If these results are confirmed next year, together with the calculated average calving rate of 50%, one can expect a cow to produce 2 to 2.5 calves during her lifetime. It has to be considered that young cows, particularly first calvers, are less efficient than old cows. Therefore, the age structure shown in Table 53 may explain the low reproductive indices.

The low proportion of old cows is probably not related to longevity of the female population as such, although continuous nutritional stress may have an effect. The main reason for short lifetimes of cows is their high beef value, i.e., if cash is needed, farmers prefer to sell old cows (rather than young steers, which next year might have a higher value). This culling of heavy (often pregnant) cows, has an adverse effect on the herd's reproductive level.

Table 54 summarizes the adoption of herd management technology by the farms. Application of techniques 1 to 4 has a direct (active) effect on herd output, while the others may have an indirect

Table 54.

Frequency and degree of adoption[1] of herd management techniques on 16 farms of the Colombian Llanos.

Technology component	Farm																Relative adoption (%)
	2	4	5	6	7	8	9	11	12	13	14	15	17	18	19	20	
1. Mineral supplementation	4	8	10	4	8	10	8	8	6	4	8	4	10	10	8	4	70
2. Animal health program	6	8	8	6	8	10	6	10	4	4	6	8	10	6	-	8	70
3. Culling	-	10	10	2	2	2	2	2	-	-	2	2	5	2	-	2	30
4. Weaning	4	10	4	8	4	10	8	10	4	4	4	4	10	4	-	10	60
5. Herd subdivision	4	10	4	10	4	10	-	10	4	-	-	4	8	4	-	4	50
6. Production records	-	5	5	-	-	5	-	2	2	-	2	2	-	-	-	-	20
7. Seasonal mating	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8. Technical assistance	-	5	3	-	1	-	3	-	-	-	3	1	3	-	-	-	20
9. Dehorning	-	-	5	-	-	-	-	-	-	-	5	-	5	-	-	-	20
10. Animal identification	-	5	5	-	5	5	-	5	5	-	5	5	5	5	-	5	60
Relative management level (%)	24	81	72	40	43	70	36	63	33	16	47	40	75	41	10	44	46

1 Techniques 1 to 5 had a maximum rating of 10 points; techniques 6 to 10 a maximum of 5 points. Therefore, a total maximum of 75 points can be achieved.

(passive) effect. A maximum of 10 points (according to degree of adoption) was computed for techniques 1 to 5, and a maximum of 5 points to techniques 6 to 10. This quantification does not imply application of *appropriate* technology.

Contrary to general opinion, mineral supplementation is quite common on the farms, i.e., all farms supplement animals with minerals, although mostly in a more or less restricted manner. An overall average estimated daily intake of 48.6 g/A.U./day (17.7 kg/A.U./year) was recorded, with a mineral mixture of about 5% P, equivalent to 2.8 g P/A.U./day. It is interesting to note that most owners and even cowboys are well aware of mineral deficiency and its relation to abortions and low fertility. The degree of adoption of mineral supplementation is mainly limited by cash availability.

Animal health practices (vaccination, parasite control, navel disinfection of newborne calves) also show a relatively high adoption level, although most of the technology has not been developed for the Llanos and therefore may be inappropriate.

The culling of unproductive cows is seldom practiced because it requires some basic techniques such as individual animal identification and production (abortion, calving, calf mortality) records that imply a high overall management level. The potential of adopting this management practice is considered high, because it could be done relatively cheaply and would assure a strong, immediate impact on reproductive efficiency of breeding herds.

Little systematic weaning is practiced on the farms; in many cases weaning occurs naturally (cows stop producing milk). This is related to the continuous mating used on all farms, with calves being born throughout the year. Most ranchers are aware of a natural concentration of calving during late dry season, consistent with Carimagua findings. Since ranchers commonly gather their herd only once or twice a year, during early and late rainy season, ages of nursing calves vary widely, complicating weaning at a given age. In this case, farmers prefer to wean calves at a rather old age, approximately 10 months.

Restricted or seasonal mating is not practiced on the sampled farms, nor has it been heard of outside the sample. Ranchers believe that "it doesn't work", because "cows will fail to conceive". This is consistent with the fact that successful adoption of seasonal mating requires good managerial skill. This knowledge gap emphasizes the importance of the Carimagua experiment, described later in this section.

While individual animal identification and branding is quite common, individual performance records are seldom kept except for controlling the cattle inventory.

Data in Table 54 show an enormous potential to increase herd productivity by transferring known management technology such as culling and seasonal mating, which can be adopted at a low cost. On most farms, the existing infrastructure (e.g., corrals and fences) would need only minor improvement for these practices.

Table 55 gives an estimate of the reproductive performance of the breeding herds, in relation to the body weight of cows according to lactation status. Since farmers do little to improve pastures, the nutritional condition of the cows, and the resulting reproductive indices, are expressions of the forage production potential of the savanna. According to results obtained at Carimagua, the mature body weight of a dry cow commonly found in the

Table 55.

Reproductive performance[1] of breeding stock in 16 farms of the Colombian Llanos.

Farm No.	Cow age (months) X̄	Body weight of cows (kg) Dry cows No.	X̄	Lactating cows No.	X̄	Estimated calving rate[2] (%)	Reproductive index[3] (%)
2	74	29	317	26	302	45	0.78
4	-[4]	107	320	-	-	34	0.85
5	71	39	297	33	284	57	0.74
6	68	25	348	22	299	77	0.94
7	73	58	303	25	290	42	0.67
8	71	15	410	31	356	67	1.09
9	71	21	344	20	313	54	0.85
11	59	44	326	29	298	51	0.96
12	75	50	308	16	283	38	0.59
13	70	45	344	27	285	59	0.79
14	78	42	306	14	272	48	0.73
15	–	32	303	26	289	56	0.85
17	106	23	337	23	310	52	0.91
18	84	31	298	41	261	44	0.83
19	80	28	279	16	264	30	0.56
20	84	23	312	26	276	45	0.92
Overall mean	76	622	318	375	293	49	0.81

1 Based on data obtained in May - June, 1978.
2 Calculated from lactation and pregnancy status (see text).
3 Sum of proportion of lactating and pregnant cows.
4 Information not available.

Llanos under adequate pasture-based feeding conditions for satisfactory reproductive performance is about 400 kg. On the farms, average weight of dry cows was 318 kg (in the early rainy season), approximately 20% below the estimated optimum. On some farms, the nutritional stress appeared to be extremely high. For example, in farms 18 and 19 lactating cows averaged only 262 kg. On only four farms did lactating cows weigh more than 300 kg. These inadequate feeding conditions are the main cause of poor reproductive performance in the Colombian Llanos.

The estimated calving rates in Table 55 correspond to the period from November 1977 until October 1978. The following formula was used: Number of lactating (1-6 months) cows plus number of pregnant (3-9 months) cows divided by total number of cows in the sample.

Because of the known natural within herd variation of calving rates between years, these figures have to be complemented with one more year of observation. However, the average rate of 49% appears reliable and agrees well with the 52% reported from a former survey (CIAT Annual Report, 1974). According to the initial hypothesis, variation between farms is high, ranging between 30 and 77%. The close relationship between nutritional condition (body weight) and reproduction is evident.

Table 55 also shows values for the reproductive index, obtained by adding together all lactating and pregnant cows (lactating pregnant cows are rated twice) and dividing by the total number of cows in the sample. This index quantifies the proportion of actively reproducing cows over a period of approximately 18 months, and is therefore a better parameter to compare the reproductive status of a herd than the estimated calving rate based on single observations.

The best and worst reproductive indices (farms 8 and 19, respectively) coincide with the highest and lowest cow weights. Based on this index, it is estimated that approximately 10 to 15% of the cow population should be culled, because of extremely poor reproduction or infertility.

The relative distribution of breeding cows, according to pregnancy and lactational status, of a total sample of 988 observations is shown in Table 56. Only 2% of lactating cows were found to be pregnant. The survey reported in 1974 indicated 9%. This finding again confirms that the vast majority of lactating cows are not able to reconceive, primarily due to nutritional stress. The average cow has to recover for several months from lactation after weaning, resulting in an average calving interval of approximately 24 months and corresponding to 50% calving rates.

Table 57 gives the average body weight of young stock, within age categories. Fattening operations are excluded so results refer to cattle grazing savanna only. Also, the results of the two weighing seasons are shown. No significant differences were found in age within

Table 56.

Distribution of breeding cows in relation to pregnancy and lactation status, based on 988 observations in the Colombian Llanos.

Pregnancy	Dry	Lactating ≤6 months	Lactating >6 months	Mean
	(%)			
Open	21	23	13	57
Pregnant ≤3 months	16	-	1	17
Pregnant >3 months	25	-	1	26
Mean (lactation)	62	23	15	100

Table 57.

Body weights of animal stock, by age categories, on sampled farms of the Colombian Llanos.

Age categories	Overall mean			Early dry season		Early rainy season	
	No.	Age (months)	Weight (kg)	No.	Weight (kg)	No.	Weight (kg)
Female stock							
Weaners	195	8	138	87	129	180	145
1 - 2 years	267	16	185	89	191	178	182
2 - 3 years	226	27	250	105	245	121	254
3 - 4 years	193	38	267	118	259	75	279
>4 years[1]	100	52	280	62	272	38	294
Cows (dry)	1245	76	309	632	300	613	318
Male stock[2]							
Weaners	187	8	136	111	138	76	132
1 - 2 years	273	16	184	125	178	148	189
2 - 3 years	90	26	232	38	240	52	227
>3 years	23	49	259	19	259	4	258

1 Have not yet calved.
2 Castrated and uncastrated.

categories during these seasons. While the data have not been fully analyzed, sex and seasonal effects appear not to be important. Females in category over 4 years of age are heifers which have not calved yet.

Cerradò of Central Brazil

Four major ecologically homogeneous sub-regions of the Brazilian Cerrado were identified by the Target Area Survey Section and are: (1) Central-west Minas Gerais; (2) Southern Goiás; (3) Northern Goiás; and (4) Central Mato Grosso.

Activities started in January 1978, as the CIAT special-funded Animal Scientist joined the CIAT-CPAC team. Due to physical limitations to cover these four vast sub-regions, an initial screening was necessary. For this purpose, extensive recognition trips were made. Based on the findings that in sub-regions 1 and 2 dairy ranching prevails (60 to 80% of the farms use beef cows for milk production), it was decided to concentrate efforts and resources on sub-regions 3 and 4, where beef production systems definitely predominate. Nevertheless, the increasing importance and trend toward dual-purpose ranching may have implications with the Program's orientation.

From May onward, farms were pre-selected, and by September, eight farms in Central Mato Grosso area and seven farms in Northern Goiás were identified and initial data collections to characterize the farms were concluded. For records of individual animal performance a sample of

1900 head of cattle was identified and numbered. The selected farms are shown in Table 58.

Table 58 shows a relatively high variation in farm size, herd size, and actual stocking rates, ranging from 2 to 5 ha/head of cattle. Nevertheless, it is interesting to note that the mean figures for both regions are very similar. Also, the herd structure is comparable, with breeding stock representing 45-47% of the total stock.

The main difference between the two sub-regions appears to be the proportion of planted pastures on the farms, being higher in Mato Grosso (24% of total pastures) than in Goiás (14%). Nevertheless, in both regions the only two important species, *Hyparrhenia rufa* and

Table 58.

Characteristics of selected farms in the Cerrado of Brazil.

Farm No.	Technology level[1]	Type of operation[2]	Area (ha) Total[3]	Area (ha) Sown past.	Cattle Cows	Cattle Total	Stocking rate[4] (ha/animal)
Sub-region: Central Mato Grosso							
1	M	C/R	2000	400	-	-	-
2	M	C	1700	310	88	300	5.6
3	M	C	2000	550	300	503	3.9
4	H	C/R	5450	1200	520	1200	4.1
5	L	C/R	990	250	305	442	1.9
6	L	C/R	4400	800	460	1135	3.4
7	M	C	1126	215	210	419	2.4
8	M	C/R	1467	220	120	307	4.2
Mean: Mato Grosso			2400	500	290	615	3.6
Sub-region: Northern Goias							
9	H	C/R	1630	288	200	593	2.0
10	L	C	700	250	120	255	2.2
11	L	C	870	50	90	244	3.6
12	M	C/R	3100	500	348	661	4.6
13	M	C/R	3560	100	308	791	4.4
14	H	C	3370	300	300	540	4.0
15	M	C	2100	275	420	816	1.9
Mean: Northern Goias			2200	250	255	560	3.2

1 H: High, M: Medium, L: Low
2 C: Cow-calf, R: Raising
3 Includes crops and forest
4 Overall stocking rate: Savanna + Sown pasture/Total No. of cattle.

Brachiaria decumbens, have been found in the same two-thirds: one-third proportion, respectively.

Comparing these findings with results from the Colombian Llanos, there appear to be no major differences in farm area and herd size. Cerrado farmers appear to have a higher stocking rate (3-4 ha/head in Brazil), than in the Llanos of Colombia (5-6 ha/head). A significant difference can also be observed in the proportion of sown pastures on the farms (Cerrado 14-24%, Llanos 5%). While in Brazil the most important sown pasture species is *H. rufa*, *B. decumbens* and *M. minutiflora* predominate in the Llanos. In both Cerrado regions, almost all farms do some cropping (rice mainly), although at a relatively small scale. On the Llanos farms, commercial crops were not found.

Also some differences can be observed in herd structure. While on the Cerrado farms over 45% of the total stock are breeding cows, on the Llanos farms only 36% are cows. This indicates that Brazilian ranchers sell their stock at a younger age than their Colombian counterparts.

Eastern Llanos of Venezuela

During 1978 an agreement with FONAIAP was signed. Among other collaborative research activities, the ETES Project will be carried out as a joint venture. In October, a CIAT Animal Scientist joined the multidisciplinary team assigned to the project at the CIARNO regional center in Maturín. Initially, the northeastern Llanos region has been selected, with possibilities to expand into the central Llanos later. Pre-selection of farms has been concluded, providing a basis for final selection. Data collection concerning animal performance will start early in 1979.

Breeding Herds Management Systems

The main objective of this large experiment is to evaluate the strategic use of improved pastures on cow-calf type production systems in tropical savanna regions.

Strategic use is defined as a temporary access of the breeding stock to improved pastures, during critical periods of the reproductive cycle (calving, early lactation, reconception). For a rational strategic use of improved pastures, a seasonal restricted mating appears to be essential.

The experimental objectives were described in the 1977 Annual Report. The final design is shown in Table 59.

Approximately 10% of the total area utilized by Herds 2, 4 and 6 is improved pastures, i.e., 120 ha of grasses (mainly *B. decumbens*, but associated with *M. minutiflora* and partially with *A. gayanus)* and 30 ha of *Stylosanthes guianensis* 136 planted in August-September 1977, with low fertilizer inputs (47 kg P_2O_5/ha, to all plus 10 kg S/ha on legumes).

Strategic use with 20 high-priority (early lactating) cows per Herds 2, 4 and 6 started in the late dry season (February 15 till April 30, 1978). During this period, stocking rate of the legume paddock was 1.6 A.U./ha, and in the grass paddocks (during establishment), 0.36 A.U./ha.

From May until September, grass and legume paddocks were grazed intermittently, at an average stocking rate of 1.6 A.U./ha. The periods during which Herds 2, 4 and 6 had access to the improved pastures are shown in Table 59.

The native savanna pastures had an average stocking rate of 0.15 A.U./ha.

Table 59.

Treatments in breeding herds management systems experiment, during 1978 at Carimagua.[1]

Herds	No. of Cows	Pastures: Type	Pastures: Time on improved pastures (days)	Mating periods: Months	Mating periods: Duration (days)
1	54	Savanna only	0	Jan.-Dec.	365
3	54	"	0	June-Sept.	120
5	54	"	0	May-July[2]	90
2	54	Savanna + Improved pastures	114	Jan.-Dec.	365
4	54		155	June-Sept.	120
6	54		91	May-July[2]	90

1 Within herds, 50% of calves will be weaned at 6 months and 50% at 9 months.
2 A second mating period of 90 days, during December 1978-January 1979 is planned.

These pastures are burned in sequence (within paddocks) 2 or 3 times per year. Some of them include a high proportion of good, productive low areas (up to 50%). In an attempt to eliminate paddock effects, all herds on savanna are rotated monthly throughout all paddocks.

The experimental herds were formed in December 1977. Cows were selected with the only criterion being proven fertility—at least two calves for old (born in 1969) cows and one calf or pregnant for young cows. Replacement heifers must weigh 280 kg by 3 years of age. Culling of infertile cows is routine. All herds are comparable in age and physiological (lactation and pregnancy) status. In August 1978, another 16 heifers were included so that each herd now has 56 breeding females.

The routine management program for the six herds includes: (1) Year-round *ad libitum* mineral supplementation. Phosphorus content in the mixture varies from 7 to 8%. Average consumption has been 58 g/A.U./day (21 kg/A.U./year); (2) A complete animal health program, including control of infectious diseases (foot-and-mouth, brucellosis, malignant edema, pasteurellosis and black leg), external (every two months) and internal parasites (calves twice a year, adults once a year), and care of newborne calves (particularly navel disinfection). (3) All bulls are supplemented with 0.6 kg of cottonseed meal during the dry season and are kept on improved pastures during rest periods. (4) Individual animal checks every two months, during data collection.

Therefore, general herd and pasture management is near feasible optimum, in relation to the environment and present state of knowledge.

From September 1977 to August 1978, the experimental breeding herds had the following average performance: calving rate, 72.5%; preweaning calf mortality, 9.9%; adult mortality, 1.5%; and, abortions, 0.6%.

In the same period, these traits were not yet influenced by experimental treatments. But the high calving rate, due to selection and culling in December 1977, resulted in a high proportion of lactating cows during mating periods, thus permitting the study of reconception during lactation.

A significant effect of the pasture treatment on weaning weight of calves was observed from June onwards. All calves that conceived during 1977 (with continuous mating in all herds) were weaned at 9 months of age. In Table 60 the results of June and August are shown. Although cows from Herds 2, 4 and 6 had access to improved pastures during late lactation for only an average of 160 days, they weaned 11% (18 kg) heavier calves than cows grazing only native savanna.

The effect of pastures on body weight of cows, according to their lactation status is shown in Figure 99. While dry cows with access to improved pastures showed an almost constant, positive difference compared to the cows with access to native savanna only, there are continuously increasing differences between lactating cows.

In October, lactating cows of Herds 2, 4 and 6 were 31 kg heavier than comparable cows of the savanna herds.

In analyzing the effect of pastures on body weight of cows by lactation periods, it becomes evident that improved pasture supplementation is particularly effective during early lactation, when nutritional requirements are highest. Figure 100 shows the weights taken in June and August. Although all differences are significant, differences due to improved pastures during the first half of lactation is about 30 kg, and only 10 kg during the second half.

Table 61 provides results of the weighing in October. The difference between early lactating cows has increased to 43 kg, to 23 kg for late lactating and only 18 kg for dry cows.

A pregnancy diagnosis was done at the end of October (Table 62). Conception rates were calculated over total cows, and over "able" cows, defined as cows which calved 90 days or less before the end of the mating season, and therefore have recovered from normal lactation anestrus. The conception rate for able cows is approximately equivalent to overall conception rate, once the reproductive cycles of the breeding herds are adjusted to the respective mating seasons.

Table 60.

Pasture effect on weaning weight of calves during the rainy season.

Weaning month	Calf weight (kg)						
	Overall mean		Savanna only		Savanna + 10% sown pasture		
	No. of observ.	Mean	No. of observ.	Mean	No. of observ.	Mean	Difference
June	56	176	26	166	30	185	19
August	28	179	15	171	13	189	18
Total	84	177	41	168	43	186	18

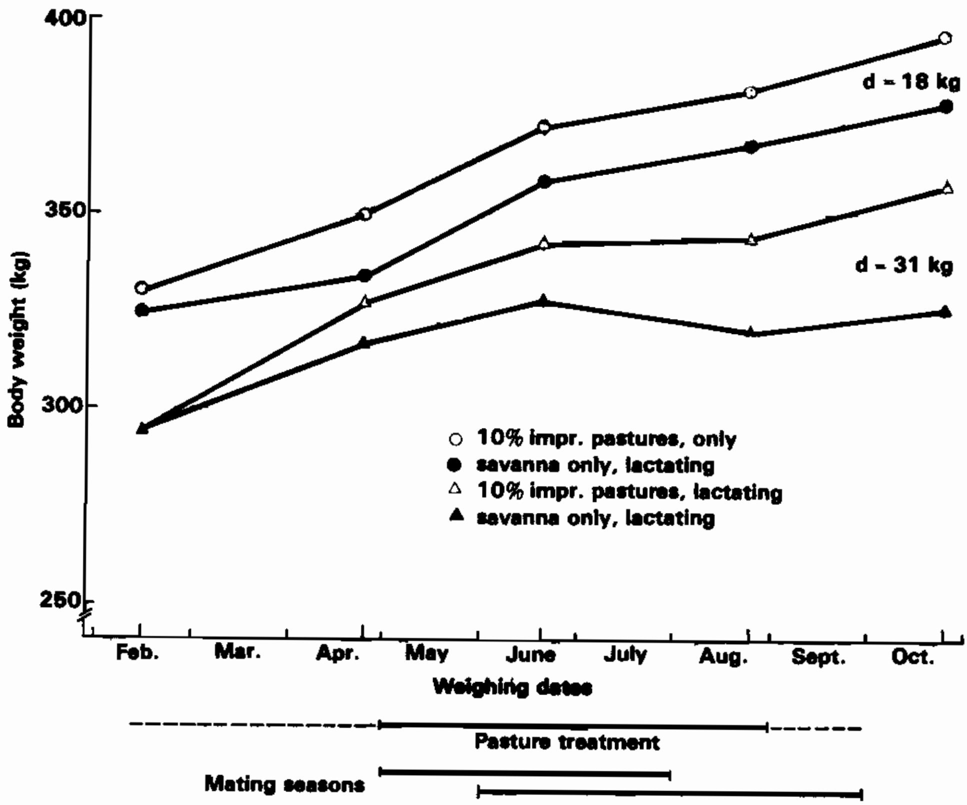


Figure 99. Efect of pasture systems on body weight of cows, according to lactation status, in the Breeding Herds Management Systems, Carimagua.

Of particular interest is the reconception rate of lactating cows, since low reproduction rates generally found under tropical savanna conditions are closely related to the fact that most cows will not conceive until after weaning.

The pasture effect on conception rates is shown in Table 63. The savanna herds also show relatively high indices as a result of high management level. Nevertheless, a 25% increase in herds supplemented with improved pastures can be observed. This is explained through the high (68%) reconception rate of lactating cows, due to better nutritional condition.

In Table 64, conception rates in relation to mating periods are given. Possibly pregnancies in Herds 1 to 4 are slightly underestimated. Although results are not quite conclusive, it appears that a 3-month mating period (Herds 5 and 6), during the early rainy season (May - July), particularly in combination with improved pastures (see Herd 6 in Table 62) assures a high conception ability, possibly due to the "flushing" effect. Adoption of restricted mating periods appears feasible, and does not necessarily have a negative effect on reproductive rates during the first year of adoption. The adoption of short mating periods makes possible the practical

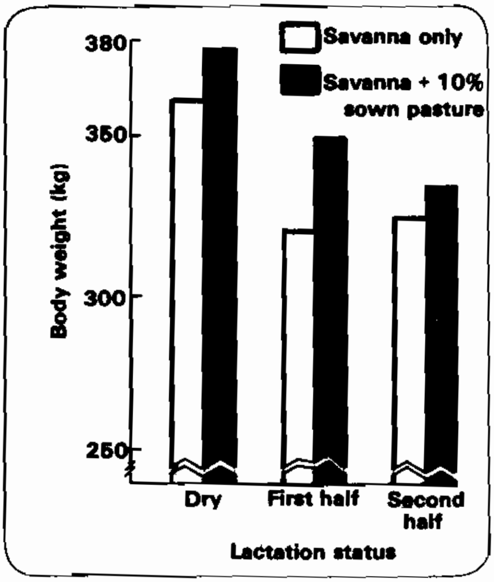


Figure 100. Effect of strategic use of sown pastures on body weight of cows in relation to lactation status, during the rainy season at Carimagua (means for June-August).

strategic management of improved pastures.

The results obtained during this first experimental year were used for an overall evaluation of the two basic systems: "A" on savanna only with the best possible management, and "B", savanna plus 10% of improved grass plus legume pasture. Analysis of the 1978 data showed that 10% improved pastures increased the annual liveweight output to 23 kg/ha, that is 2.5 times that from system A (9 kg/ha).

There are indications, however, that the stocking rates of the improved pasture can be increased from 1.6 to 2.0 A.U./ha, that the age of heifers at first calving can decrease to 3 years and pre-weaning calf mortality can decrease to 5%. In this case, system B could produce an output of 30 kg/ha/year, or 3.5 times more than system A.

Corresponding economic analyses presented in the Economics Section suggest that the limited strategic use of improved pastures with breeding herds is an attractive alternative for beef producers, once legume-based pastures become available and persist for at least six years under Colombian Llanos conditions.

Test Herd

At Carimagua, the Section manages the ICA-CIAT Test Herd, with the major objective of producing suitable cattle for grazing experiments. At the same time, new management techniques, adapted to the environment, can be validated under practical, extensive, commercial production conditions.

The Test Herd uses about 5900 ha, of which 160 ha (3%) are planted with *B. decumbens*. Average stocking rate of the savanna pastures varies between 6 to 7 ha/head. The present cattle stock includes 267 breeding females (158 cows and 109 mated heifers), and 11 bulls (3 San Martinero and 8 Zebu). The project also receives weaners from Carimagua experiments and raises them until they are used again in grazing experiments or are sold.

Cows are mated from April 1 until November 30. All animals are supplemented *ad libitum* with minerals. Bulls are supplemented daily with 500 g cottonseed meal during the dry season. Soft culling based on reproductive performance is practiced. The herds are gathered three times a year. At this time animals are vaccinated, dipped, weighed, identified, males are castrated, calves near 9 months of age are weaned and, once a year, cows are palpated for culling.

Overall mortality was 1.8% and of calves before weaning, 5.4%. Due to extensive management, the latter figure might be

Table 61.

Body weight of cows according to lactation status and herds (October 1978).

Herd	Dry		Lactation status: First half		Lactation status: Second half	
	(No.)	(kg)	(No.)	(kg)	(No.)	(kg)
Savanna only						
1	29	391	9	330	18	326
3	38	373	7	335	11	325
5	32	370	11	301	13	336
Savanna + improved pastures						
2	27	407	10	365	19	345
4	37	395	9	367	9	358
6	39	387	7	351	10	360
Means						
Savanna only	99	377	27	320	42	329
Savanna + improved pastures	103	395	26	362	38	352

Table 62.

Conceptions in breeding herds management systems experiment according to palpation done at end of October 1978.

Parameters	Herds: Savanna only 1	3	5	Savanna + 10% improved pasture 2	4	6
Total cows	54	54	53	52	52	52
Able cows[1]	50	47	38	49	43	44
Pregnant cows	30	28	26	39	31	37
Overall conception (%)	56	52	49	75	60	71
Conception of able cows (%)	60	60	68	80	74	84
Conception over total lactating cows (%)	22	6	21	62	28	53
Conception over lactating able cows (%)	25	9	38	69	56	78

1 Able to conceive, with more than 90 days between calving and end of mating season.

Table 63.

Pasture effect on conception rates.

Pasture treatment	Overall conception (%)	Conception, able cows[1] (%)	Conception lactating able cows[1] (%)
Savanna only	52	63	24
Savanna + 10% improved pastures[2]	69	79	68

1 Able to conceive (over 90 days between calving and end of mating period).
2 Average of 120 days on improved pastures.

underestimated. The average weaning weight of 67 calves (weaning in November not included) was 143 kg (males 144 kg, females 139 kg) at an average of 9 months of age. Eight abortions (5%) were recorded.

For the period between October 1977 and September 1978, the calvings registered are shown in Table 65. For Herds 1 to 3, average calving rate was 58%, similar to that reported last year. The 109 heifers of Herds 4 and 5 were tentatively mated for 45 days only during October-November 1977, resulting in 34% calving and indicating that, although body weight was satisfactory, the mating period and particularly the season of the year were not adequate.

The following numbers of animals were provided to other research projects at Carimagua during the year: Legume Agronomy Section, 20 female weaners; Animal Management Section, 55 female weaners; Pasture Utilization Section, 160 steers and male weaners; Mineral Supplement Studies (ICA), 335 heifers; and Beef Production Studies (ICA), 114 steers. In addition, the Test Herd handles calves

Table 64.

Effect of mating periods on conception rates.

Mating periods	Overall conception (%)	Conception, able cows (%)	Conception, able lactating cows (%)
Continuous (Herds 1 + 2)[1]	65	70	47
4 Months (Herds 3 + 4)[2]	56	66	32
3 Months (Herds 5 + 6)[3]	60	77	58

1 Since May 1978.
2 During June, July, August, September 1978.
3 During May, June, July 1978.

Table 65.

Calvings recorded in Carimagua Test Herds.

Herds	Mated cows/ heifers	Parturitions	Calving rate (%)
1	61	35	57.4
2	47	30	63.8
3	50	27	54.0
4[1]	52	(20)[2]	(38.5)[2]
5[1]	57	(17)	(29.8)
Total	267	129	(48.3)

1 Heifers mated only during Oct.-Nov. 1977.
2 Values in parentheses are low reflecting the short mating period for heifers in Herds 4 and 5.

from other projects. A main calf producer was the Breeding Herd Management Systems experiment. Another 68 non-suitable animals were sold, and 56 animals were consumed at the Center.

ANIMAL HEALTH

This section continued the monitoring and surveillance of animal health problems at three levels of intensity. The macro-level consists of an animal disease inventory of the target area and is an integral part of the Target Area Survey. Macro-level studies will provide general background information for any condition that could affect cattle productivity in the area.

Intermediate level work comprises the surveillance at Carimagua, the ETES Project, miscellaneous surveillance from the Cerrado Center in Brazil and an area in Paraguay, and a description of problems arising from pasture toxicity (toxic plants.).

At the micro-level, studies were conducted on a parasite profile at Carimagua, the epidemiological study of a natural leptospirosis infection in the Colombian Llanos and a report on the artificial leptospira infection in well-nourished cows. The micro-level studies are directed to obtaining information for devising a practical preventive medicine approach for control of specific conditions already defined as important.

Macro-monitoring

Animal Disease Inventory

Data has been obtained from regions of the target area, especially in Brazil, Colombia and Paraguay.

Brazil has considerably more information on disease aspects than any other country in the target area. The information, however, is in the hands of local institutions, individuals and private practitioners and will require considerable effort to collect and assemble.

Table 66 describes conditions found in the states of Mato Grosso and Goiás with priorities as they appear now, with limited data. As more quantitative data are collected, the information will be more dependable.

Four conditions merit attention. First, considerable numbers of tuberculosis lesions are found at slaughterhouses in beef cattle from this area of Brazil. In Mato Grosso only, 1166 carcasses were condemned in 1977 because of TB. This infection is important not only from the standpoint of meat loss, but also because of dangers of human infections.

Second, brucellosis infections appear very high (15-18% prevalence) in some regions, however, the high figures come from specific farms and the disease is not randomly distributed. The official prevalence figures for the Mato Grosso show 9.43% reactors and for Goiás, 11.60% reactors, the latter figure being the highest for the country.

A third important condition is bursitis, an infection of the bursa underneath the hump in *Bos indicus* cattle. Its nature has not yet been determined. Bursitis has increased considerably in the last two

Table 66.

Some conditions affecting beef cattle health in the states of Mato Grosso and Goiás, Brazil. (Preliminary information for the Animal Disease Inventory of the Target Area Survey.)

Conditions	Observations	Tentative priority
Tuberculosis	1116 carcasses condemned in Mato Grosso in 1977.	1
Brucellosis	Some regions with 15-18% prevalence.	1
Bursitis	91 cases at slaughterhouse in Mato Grosso in 1977.	1
Internal parasites	Mainly *Cooperia* and *Haemonchus* species (treated during dry season).	1
Botulism	Produced as a consequence to mineral deficiencies.	2
Toxic plants	Six outstanding: Anilão, Dama da noite, Erva Café, Faveira, Barbatinão, Piriquiteira.	2
"Espichamento"	Due to *Solanum malacoxica* (toxic plant).	2
"Peste Secar"	Blamed mostly on Co deficiency.	2
Anaplasmosis	Primarily in calves.	3
"Peste Rachar"	Probably nutritional (25% deaths in Northern Goiás in 1-4 months old calves).	3
Rabies	From vampire bats, in outbreaks (15 cases in Goiás in one month)	3

years, causing some meat losses. The last condition is internal parasites, which are seriously impairing calf growth in the area. Problems are being produced by parasites of the *Cooperia* and *Haemonchus* species. Two treatments during the dry season are being advanced as efficacious.

The information from Colombia will come primarily from previous studies reported in CIAT Annual Reports, data that is being obtained from the ETES and other projects described below, and information that is being collected from Colombian institutions.

Data from Paraguay to be used for this disease inventory is described below under miscellaneous surveillance; these are results from direct laboratory examination of serum samples sent to CIAT laboratories.

Table 67.

Causes of cattle mortality in the Carimagua Research Station in 1978.

Condition	No. of cases
Malnutrition (clinical)	27
Unknown	26
Sinking in mud or watering holes	17
Bone fractures	15
Snake bite	6
Polyarthritis	4
Photosensitization	1
Total reported deaths	96[1]
Total animals in station	2600
Mortality rate	3.7%

1 Only from animals that had been ear tagged. Some calves that died before they were branded are not included.

Intermediate Monitoring

Carimagua Surveillance

The main health problems occurring in Carimagua are calf mortality and malnutrition.

Calf mortality is most common in the first few days of life; many calves just disappear and are not even seen in closely observed and managed herds. It appears that some animals are born prematurely, some at full term but weak and others are lost inside bushy areas. Data from two herds (64 calvings) showed 9.6% mortality in calves under one month of age. The breeding experiment herd showed 23 deaths from 233 calvings, a 9.9% mortality rate. Most of this calf mortality is registered as unknown (Table 67) for the reasons given. A stronger effort should be made to analyze these cases better.

Malnutrition causes deaths in cattle of all ages but is most common in cows over 8 years and in weaners from 12 to 18 months.

Two other factors affecting mortality are cattle becoming mired in mud and quicksand at water holes, which accounted for 17 cases during 1978, and bone fractures, which caused 15 deaths in the same period (Table 67).

The conditions responsible for treatment procedures are mainly uterine infections, polyarthritis and malnutrition.

ETES Project

The second visit to the 17 farms of the ETES Project (see sections of Animal Management and Economics) was useful for gathering the first set of information on internal and external parasites. There are observations for assessment of infestations due to *Dermatobia hominis*, ticks, Stephanofilaria, internal parasites, and lice (Table 68).

Table 68.

Summary data of internal and external parasites identified from animals in farms of ETES Project in the Colombian Llanos, examined at beginning of the rainy season.

Infection level	Internal parasites[1] (No. of animals)	(%)	Interpretation (egg/g feces)	*Dermatobia hominis* (No. of animals)	(%)	Stephanofilaria (No. of animals)	(%)
Clean	85	61.1	0	1.430	96.3	487	38.7
Low	38	27.3	1-500	44	2.9	589	46.8
Medium	10	7.1	501-5500	4	0.2	103	6.3
High	6	4.3	> 5500	7	0.4	80	6.3
Total animals examined	139			1485		1259	

1 Includes nematodes and protozoa.

The criteria for the evaluations has come from previous work at Carimagua and in some Llanos farms. It is continuously tested for improvement.

In tests for internal parasites, 10% of the adult animals and 20% of the calves going through the chute are sampled. Levels of infestation are classified as clean, low, moderate and high. From 139 animals examined, only 4.3% had high infections (over 5500 eggs per gram of feces), 61.1% were clean, and 10 farms had animals classified only in the low infection level (50 to 500 eggs per gram of feces). It appears that internal parasites, at the beginning of the rainy season, produced mainly low infection levels on these farms and do not constitute a herd problem. However, there are individual animals that would have benefited from treatment at this time. The results of this preliminary sampling will be evaluated against the data obtained from further samplings and with data from the parasites profile being constructed at Carimagua and reported below.

External parasites showed low levels of infestation. In 8 of the 15 farms sampled, no ticks were found and in the rest only 10% of the animals had low infestation levels. This will have to be further evaluated against the level of hemoparasites. For the fly, *D. hominis*, at this sampling 96% of the 1430 animals were clean and only 0.7% had medium to high infestations requiring treatment. Stephanofilaria is a cutaneous microfilaria that produces a verminous dermatitis. Forty-eight percent of 1259 animals examined had at least one focus of infection on the underside of the abdomen and 6.3% had more than three foci. The significance of this infection in relation to productivity has not been evaluated, and it might be worthwile to look into its relation with other external parasites.

One farm which had continuous reports of calf and weaner losses was followed in-depth to monitor the problem. Fifty animals were examined for ecto- and endoporasites, urinalysis, hematology, blood chemistry and antibodies for infectious diseases. In general, the exams revealed animals at a low nutritional level and severe management deficiencies, since salt offered did not contain minor mineral elements, calves' navels were not disinfected and dead animals were not buried.

There was a complex mixture of disease problems with inadequate handling. Six calves had high counts for Coccidia, a protozoan that accounts for a bloody diarrhea. Two calves had high counts for round-worm of the family Trichostrongylidae and one calf had a high count for Ascaris round-worm.

In relation to hemoparasites, *Anaplasma* is not a problem on this farm, however *Babesia argentina* is highly endemic. Twenty animals had strong antibody reactions, and this could account for clinical cases of babesiosis. Tick counts at the end of the dry season were high for two animals. Together with the low nutritional levels, all of these parasite burdens are contributing to the low productivity.

The overall health status revealed 25 of the 50 animals examined to be in bad clinical condition. Twelve animals (24%) had low hemoglobin and hematocrit levels, and 6 had low total protein blood plasma levels; these were animals with anemia and hypoproteinemia. SGOT enzyme was high in 9 animals and indicates critical energy supply or a hepatic lesion. Two animals showed an obvious infectious disease at the moment of examination as indicated by the high neutrophil blood cell count. Mean blood parameters in this herd were low in comparison to means from cows of the experimental herd in Carimagua, reported last year.

For this farm, the procedure described to evaluate nutritional and health status, using as standards previously obtained mean values, is working satisfactorily, for blood parameters. Better standards are required for evaluating internal and external parasite burdens, including their antibody reactions.

Miscellaneous Surveillance

Cooperative work with the Veterinary Diagnostic Laboratory of the Ministry of Agriculture in Paraguay and Cerrado Center of EMBRAPA in Brazil, was initiated last year. Work was started to gather some information on animal health problems of beef cattle. Serum samples for detection of infections associated with reproductive and nutritional problems were received from those laboratories this year. As was decided previously, samples were used for the following serologic tests: plaque micro-agglutination for *Leptospira* spp., passive hemo-agglutination for infectious bovine rhinotracheitis (IBR) virus, complement fixation antibodies for *Anaplasma marginale*, and indirect immunofluorescent test for *B. argentina* and *Babesia bigemina*.

Paraguay

A total of 274 serum samples from four different areas of Paraguay were tested for any evidence of infection in beef cattle with the agents mentioned above. Table 69 shows the results of the serologic survey of the bovine serum samples tested against different reference antigens. The prevalence of IBR antibodies in beef cattle from those areas of Paraguay was very low (2.5%) which could indicate that IBR virus activity is also of low importance there. However, the disease has been found in beef cattle of tropical America (Target Area), so this information should be considered for further studies.

With the exception of *Leptospira*

Table 69.

Antibody prevalence for different infectious agents in beef cattle from Paraguay and Brazil.

Antigen	Paraguay[1] (P/T)[3]	Paraguay[1] (%)	Brazil[2] (P/T)	Brazil[2] (%)
IBR virus	4/274	1.5	6/165	3.6
Leptospira spp.				
L. hebdomadis	86/274	31.4	40/167	23.9
L. hardjo	112/274	40.9	58/166	34.9
L. pomona	0/274	0.0	3/167	1.8
L. wolffi	82/274	29.9	22/167	13.2
L. sejroe	106/274	38.7	64/167	28.3
Anaplasma marginale	4/274	1.5	0/166	0.0
Babesia argentina	12/274	4.8	14/166	8.4
Babesia bigemina	9/274	3.3	9/166	5.4

1 Paraguay: Diagnostic Laboratory of the Ministry of Agriculture.
2 Brazil: Cerrado Center (EMBRAPA).
3 P/T: Positives/Total tested.

pomona (0% prevalence) antibody prevalences for the other leptospiras tested were rather high. *Leptospira hardjo* should be of some consideration because it had the highest antibody prevalence (46.9%) of the leptospiral agents and 27 animals showed titers ≥ 1:800 for it which means that disease prevalence for chronic cases was 9.8%. Titers higher than 1:800 were also detected for the other leptospiras tested.

The antibody prevalence for *A. marginale*, *B. argentina* and *B. bigemina* was relatively low, however, results indicate that diseases caused by these agents are present in those areas of Paraguay and probably in an enzootic form.

Future studies over time should be developed in beef cattle in Paraguay in order to get more information about the epidemiological implications of these and other infectious agents in that area.

Brazil

Sera from 167 cattle from the Cerrado Center were tested against the aforementioned antigens to evaluate antibody prevalences. Results are summarized in Table 69. IBR antibody prevalence was 3.6%, a very low figure possibly reflecting a low activity of IBR virus in the specific area or herd where the samples originated. A wider survey may be indicated to get more dependable figures. Considering the different species of leptospiras tested, all demonstrated infectious activity among beef cattle of this specific area. *Leptospira sejroe* and *L. hardjo* were notoriously more prevalent than the others while *L. pomona* had a very low prevalence rate. Twelve animals had titers ≥1:800 for *L. hardjo* but only two animals showed titers ≥1:800 for *L. sejroe*.

There was no indication of infection for *A. marginale* but *B. argentina* and *B. bigemina* showed antibody prevalences of 8.4% and 5.4%, respectively, suggesting that babesiosis is present in the area and may be enzootic.

Further studies should also be considered for this area in Brazil.

Brachiaria decumbens Toxicity

There were two reports of *Brachiaria decumbens* photosensitization during the year; one occurred at Carimagua where two heifers (18-24 months old) of a group of 20 in the pasture showed marked lesions in the skin. They were pasturing *B. decumbens* and the lesions started to recede after the animals were removed from the pasture. One heifer died and the lesions found at necropsy were of a liver tissue damage and skin necrosis. The cultures from pasture material revealed mostly saprophytic species but also one possible animal pathogen, *Fusarium,* described below.

The second documented report of *B. decumbens* toxicity was on a farm 50 km west of Carimagua, where 123 sheep were introduced into a *B. decumbens* pasture. Sixteen animals died within three weeks with swollen faces, edema, weakness and anemia. When the animals were taken from the pasture no more deaths occurred. The lesions in one animal necropsied were liver necrosis and facial edema.

Five farms in the Colombian Llanos with previous reports of photosensitivity were followed to study possible relationship with pasture. All had *B. decumbens* pastures. Vegetative material (stems and leaves) with lesions (dead material) was collected and transferred with adequate humidity to the laboratory where direct observations and cultures for fungi were conducted.

Principal fungi obtained were *Fusarium, Helminthosporium, Curvularia* and *Nigrospora*. It appears that *Fusarium* (detected in three farms) could be a possible agent of toxicity in cattle, however, extracts of this fungus were injected intradermally in rabbits and no toxin was detected. It is interesting to note that *Phytomices chartarum,* the fungus reported in some areas of Brazil, was not detected although sampling may not have been repeated long enough.

Data obtained from the National Beef Center of EMBRAPA, in Campo Grande, shows that 252 sick animals and 57 deaths were found in a population of 1950 animals pasturing *B. decumbens* from seven municipalities in the State of Mato Grosso do Sul, in 1977.

Despite these and other reports, and considering that large numbers of cattle are pasturing *B. decumbens,* it appears that the intoxication produced by this forage affects only a very small proportion of animals exposed (1 to 5%). It occurs primarily in cattle under 14 months of age and if affected animals are moved to other pastures soon after showing signs of intoxication they will gradually recover. There is a neglibible figure of animals that die, primarily from liver tissue damage. The symptoms and lesions indicate a photosensitization, and the ultimate cause is not known.

Micro-monitoring

Internal Parasite Profile

Work began on the study of the natural evolution of internal parasites in the savannas of the Colombian Llanos. The result of this work will be preventive medicine control procedures specifically adapted to the prevailing ecological conditions. Control procedures should consequently be less costly. Two herds of 50 pregnant cows each (6-9 months of pregnancy) were chosen for monitoring. The animals were placed in a native savanna pasture at a stocking rate of 6.5 to 7 ha/A.U.

Proportionate areas of savanna have

Table 70

Average fecal egg counts for internal parasites in calves from Carimagua, 1978.

Date	No. animals examined	Fecal content (eggs/g)					
		Total all species	Trichostron-gylidae	*Ascaris*	Strongy-loides	*Eimeria*	*Moniezia*
March 6	8	373.4	0	42.4	331.0	0	0
April 5	18	141.2	35.1	76.1	30.0	0	0
May 9	15	612.7	540.3	12.3	42.6	30.8	0
June 6	29	338.4	197.6	0.9	77.6	54.6	0
July 5	31	912.2	198.7	78.7	120.8	513.8	0
Aug. 2	36	2 457.4	459.9	74.1	32.3	1 862.3	28.6
Sept. 1	34	556.7	302.3	24.0	27.0	173.7	29.1
Oct. 2	37	416.2	238.9	0	12.1	149.4	15.7

been burned sequentially and the management is generally similar to that used by farmers in the area. Animals receive a complete mineral supplement. No treatment is applied to control internal parasites. The animals are subjected to the standard vaccination scheme for the farm. In group I, the calves were born from March through July and have been sampled monthly by complete fecal examinations and blood parameters. The cows are also being studied through fecal examinations. Fecal samples are being analyzed for total egg counts (Sloss test) and lung-worm larvae counts (Baerman test).

The results of the first eight months of sampling showed that calves are affected rapidly in the first few days of life with parasites of the genus *Strongyloides*. Larvae of this parasite penetrate readily through the skin. The infestation however appears to be under control at this time (Table 70 and Fig. 101). This parasite is responsible for nearly all of the compounded average egg counts for several parasites from April through June. The second parasite affecting calves in early life in this region is of the family Trichostrongylidae (several genera). They reach a peak in May at the beginning of the rainy season, but seem to be well-controlled by the calves until the October sampling.

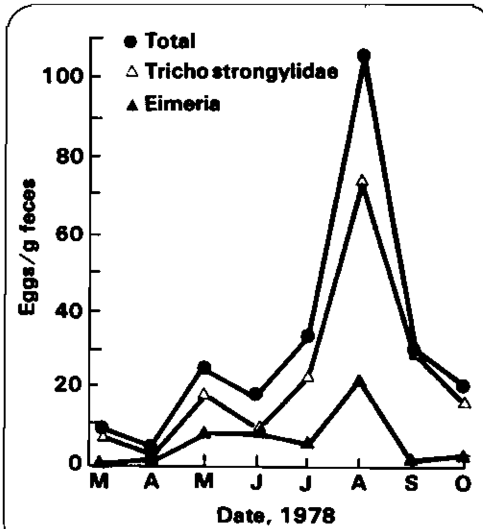


Figure 101. Averages of total fecal egg counts for internal parasites in cows from Carimagua.

The *Eimeria* protozoa (at least four species identified so far) are beginning to emerge as the most pathogenic internal parasite for calves in this area. The calves are gradually being invaded by this protozoan which reached the highest level in August, two months after the peak of the rainy season. The infection level, however, has decreased considerably in the last two samplings. The Coccidias are responsible for most of the compounded average egg counts for several parasites from June through September (Fig. 101). The levels of infection reached by *Eimeria* (Coccidias) in this period goes well beyond the levels considered in other regions as producing clinically sick animals (>500 egg/g feces). However, none of the affected calves had died yet from this infection, even though they have not been treated. On the other hand, figures given in Table 70 are averages, and there are individual calves that are beginning to show marked anemia as a consequence of high Coccidial infections. It will be interesting to see the pattern of this infection as the calves get older and other parameters are analyzed. They will be monitored after weaning up to 18 months of age. The analysis and evaluation of blood parameters in these animals is underway. The second group of calves is being formed with animals calved at the end of the rainy season and these examinations are in progress.

The results of the cow exams revealed, in general, low parasite burdens for most of the sampling period. In March and April, the first examinations, parasite counts were very low. They increased gradually reaching their highest level in August (Table 71) at the same time that the compounded egg counts from the calves reached their peak. In fact the shape of the curve (Fig. 102) is very similar to the one for the calves, although the scale is much smaller for the cows. Parasites of the Trichostrongylidae family are mostly responsible for the compounded average of internal parasites for the cows.

In one of the samplings, a 9-year-old cow showed several eggs with characteristics of a Trematode. Later an 11-year-old cow also showed some eggs with identical conformation. With this lead a search was made in animals slaughtered for meat at

Table 71.

Average fecal egg counts for internal parasites in cows from Carimagua.

Date	No. animals examined	Fecal content (eggs/g) Total all species	Trichostrongylidae	*Eimeria*	*Moniezia*	*Capillaria*
March 6	5	9.8	8.6	0	0	1.2
April 5	47	4.3	3.2	0	1.1	0
May 9	47	25.8	19.7	4.8	0.9	0.25
June 6	47	18.6	9.4	8.6	0.3	0.17
July 5	48	35.7	22.6	7.7	5.3	0.06
Aug. 2	45	103.1	74.3	23.3	5.2	0.1
Sept. 1	45	29.9	28.1	0.5	1.3	0.02
Oct. 2	51	20.5	17.1	2.9	0.3	0.07

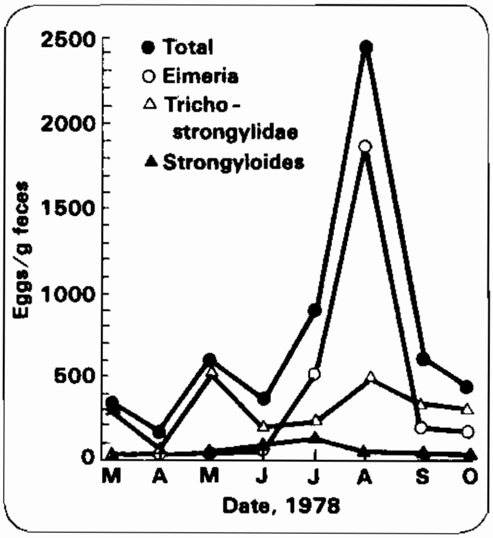


Figure 102. Averages of total fecal egg counts for internal parasites in calves from Carimagua.

the Carimagua Experimental Station. From 35 apparently healthy animals observed from May through August, 14 (40%) had in the rumens several adult forms of a Trematode classified as *Paramphistomum* spp. The parasite was also found in the rumen of a 14-month-old steer at the same time that a *B. bigemina* infection was diagnosed. This is the first time this parasite has been described in cattle grazing tropical savannas in Colombia, and probably in similar savannas of South America. The significance of the infection in relation to productivity will be further evaluated.

Natural Leptospira Infection under High Nutritional Stress

The purpose of this study was to understand better the pathogenesis, epidemiological diagnosis and effect on productivity of leptospira infections while at the same time observing the effects of antibiotic treatment.

Observations were started in July 1976 and completed in July 1978 on the commercial herd used for this study. The observation period started with 100 cows and 7 bulls and ended with 83 cows and 6 bulls. The herd grazed continuously on 400 ha of native savanna in a farm 65 km east of Puerto López in the Meta region of Colombia.

Four isolations of *L. hardjo* were obtained from urine cultures performed under field conditions. Serum antibodies to *L. hardjo* were used to evaluate evolution of the infection and one-third of the animals were given two injections of Streptomycin (October and December 1976), a second third of the cows received Streptomycin once (April 1977) and the remainder did not receive any antibiotic.

The infection was reported last year to have diminished considerably as a whole in the herd from July 1976 through July 1977. However, comparing the number of animals that previously had low infections with the new chronic infections occurring in both the untreated and treated groups (Fig. 103), one can see an overall increase in the latter. Although the infection generally decreased in the herd in the first year, this appears to be not only a reflection of the treatment, but also a result of the natural evolution of the disease. Curves of the untreated group and the two treated groups have the same shapes and do not differ markedly, except for group II that had new chronic infections from July 1976 through February 1977. A reduction of chances of acquiring the infection could have occurred in the untreated groups as a result of fewer *Leptospira* being eliminated by the treated groups, since all animals were in the same pasture.

In relation to abortions, 11 occurred from September 1977 through July 1978, 3 in Treatment I, 3 in Treatment II and 5 in the untreated group. Some abortions

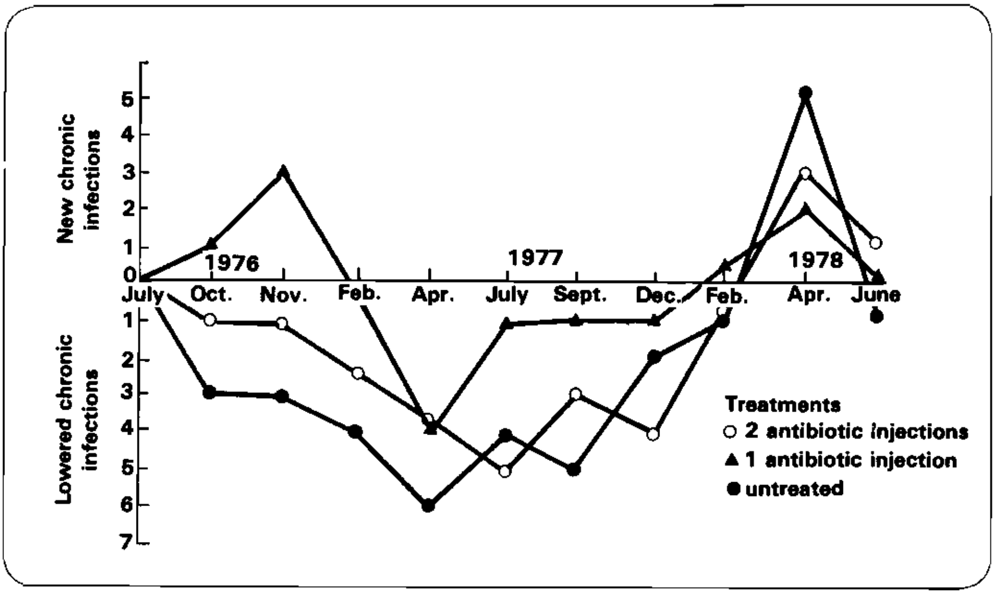


Figure 103. Cows naturally infected with *Leptospira hardjo* that had high levels of reaction over two years (July 1976-June 1978), on a commercial farm in the Colombian Llanos.

occurred in animals not showing evidence of *Leptospira* infection. It might be that management factors accounted for some of these losses. Moreover, animals whose infections, detected by serology, had high titers initially ended the two-year observation period with very similar high reactions. It appears then, that treatment with antibiotics as used in the trial does not eliminate the infection from chronically affected animals (ones with high titers). There is evidence that more frequent antibiotic treatments will reduce the infection, however, this is not practical in the field.

At the beginning of the observation period it was thought that some blood parameters were useful to detect affected animals. However, variations tend to be cyclical and in the final analysis, there are no differences between infected animals and cattle with no detectable infection (Table 72). In fact, all values for the herd as a total, and values from infected animals are within the mean values reported last year for breeding cows in the Colombian Llanos. Consequently, it appears that animals with chronic *Leptospira* infections do not have blood changes resembling those of malnutrition. The disease is masked by deficient nutrition due to its effects but with appropriate tests could be readily differentiated.

Studies on Pathogenicity of Leptospira hardjo

To test the ability of *L. hardjo* as a pathogen, an intensive study was started in 1977 to evaluate its infectivity and its pathogenicity by experimental inoculation into carefully selected pregnant cows. A strain of *L. hardjo* isolated from naturally infected cows from the Colombian Llanos was adapted to laboratory conditions and used for these experiments. Levels of 6 x 10^8 cells of *L. hardjo* were inoculated intravenously into each of 10 animals. Two more pregnant cows were used as non-inoculated controls. Urine samples for

Table 72.

Mean values of five blood parameters of beef cattle from the Colombian Llanos in a herd naturally infected with *Leptospira hardjo*.

Animals	Parameters				
	Packed cell volume (%)	Hemoglobin (g %)	Total protein (g %)	Creatinin (mg %)	Phosphorus (mg/100 ml)
Herd total	38.6	13.2	7.3	2.3	4.7
Infected cows[1]	41.2	14.0	8.1	2.5	4.0

1 Chronic infections with serological titers <1:800.

isolation of *Leptospira* were taken periodically from all animals and inoculated into hamsters and tubes containing artificial media. Serum samples were also taken during the experimental period to determine the antibody levels that animals developed after the challenge with *L. hardjo*. Clinical and pathological observations were described for each cow during the experiment. Blood samples were used to determine packed cell volume (PCV), hemoglobin, total protein, albumin, urea, ureic nitrogen (BUN) and creatinin.

L. hardjo was detected in 9 of the 10 cows inoculated. The leptospira were mainly detected by urine cultivation but also, by direct examination of urine under dark ground illumination. Shedding of leptospiras in urine was detected from four days to 10 months post-inoculation. Six of the cows shed leptospiras in the urine for less than five months after the challenge. Two cows stopped shedding leptospiras for two months, after which leptospiras were detected for several days and disappeared again. One cow shed the bacteria in urine from 23 days to 10 months post-inoculation with only a short period of time (seven months into the experiment) when leptospiras were not found. The results suggest that cows get re-infected within a short period of time with *L. hardjo* and may be chronically infected, or that a latent infection may be established in cattle.

All inoculated cows reacted against the *L. hardjo* antigen and developed a serologic response with variable levels during the time post-inoculation. Figure 104 shows the mean antibody levels (reciprocal logarithm) throughout 302 days post-inoculation for the group of animals challenged. Antibody response was detected at the first sampling (four days) after challenge. The antibody level peaked sharply at 13 days (mean titer 1:700), then decreased to the lowest level at 73 days. After that time the mean antibody titers oscillated within a narrow range, varying between 1:40 to 1:115 for two months. The antibody response after 142 days slowly increased to intermediate antibody levels (1:200) which continued until the end of the experiment. The second rise of the curve indicates that re-infection of the animals occurred and this is explained by the shedders (in the urine)

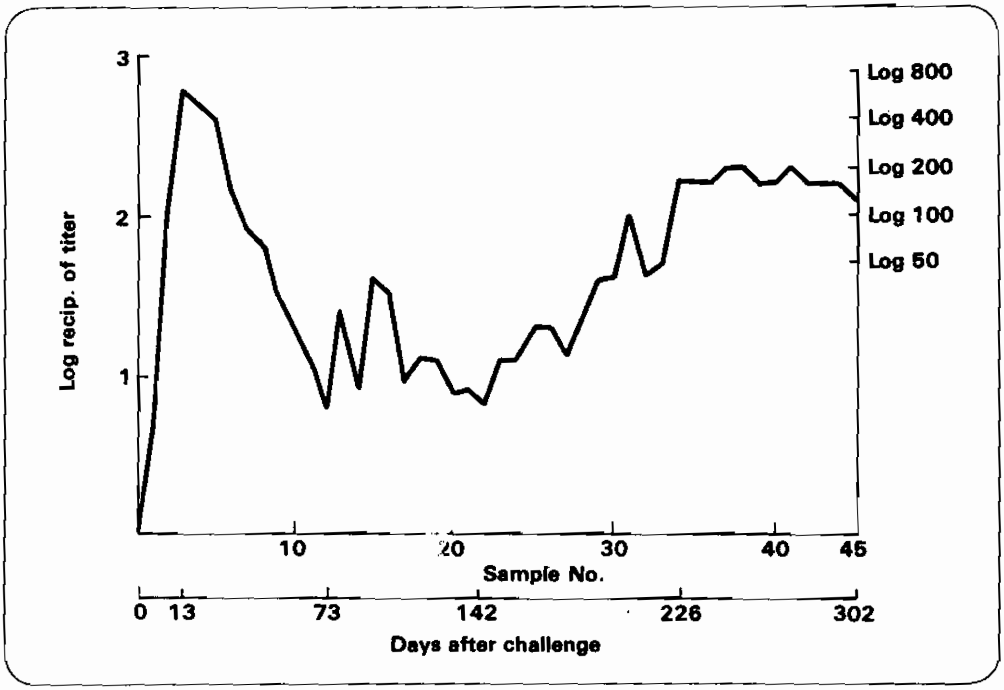


Figure 104. Mean serologic titer for 10 pregnant cows inoculated with *Leptospira hardjo*, at Carimagua.

described above. A latent infection established in these animals could also show a similar serologic response. If animals remain infected as has been seen in the last period of the experiment, a chronic form of the disease caused by *L. hardjo* should be possible.

Table 73 shows the alterations observed in cows inoculated with *L. hardjo*. The most significant lesions from the standpoint of productivity are the retained placentas and metritis which occurred in half of the exposed cows. However, the effect on the neonate is also highly significant. Eight calves were born weak and three had edema and icterus in the internal surfaces.

Mean values of some blood parameters were established for control and experimental animals. Hemoglobin, PCV, total protein, albumin, and urea mean values for both experimental and control animals were within the range determined last year for Zebu breeding cows on the experimental station at Carimagua with an adequate nutritional level. Mean values for BUN and creatinin were 4.6 mg/100 and 2.3 mg/100, respectively. These results suggest that the nutritional level has little influence on the level of *Leptospira* infection. However, they could be additive as explained before.

Immunoglobulin G (IgG) and immunoglobulin M (IgM) concentrations were determined in sera from the group of cows experimentally inoculated with *L. hardjo*. A chromatographic column with DEAE-Cellulose for extraction of immunoglobulins, the method described by Lowry, *et al.* for protein quantification and the method of electrophoresis for protein identification, were used for determinations of immunoglobulin in the serum

Table 73.

Clinico-pathological alterations observed in pregnant cows after challenge with *Leptospira hardjo*.

	Gross lesions			Histopathology		
Cow No.	Retained placenta	Metritis	Kidney	Nefritis	Perimetritis, Parametritis	Calf condition
1 (Control)	-	-	-	-	-	Normal
3 (Control)	-	-	+	+	-	Normal
24	+	+	+	+	+	Weak
10	+	+	+	+	-	Weak
20	-	-	-	+	-	Weak
6	+	+	+	+	-	Weak
33	-	-	+	+	-	Weak
64	-	-	-	+	-	Weak
5	-	-	+	+	-	Normal
36	-	-	+	+	-	Weak
42	+	+	+	+	-	Weak
71	+	+	+	+	-	Not determined

samples. Concentrations of IgG and IgM among inoculated animals tended to be higher than concentrations of Ig's in the control group. There is some relationship between the antibody level for *L. hardjo* detected by the microscopic agglutination test and the concentrations in the serum of IgG and IgM.

A test vaccine is currently being tried to evaluate its effect in controlling some of the clinical signs of the disease.

ECONOMICS

In 1978 the Economics Section was engaged in: (1) evaluation of improved beef production technology components: (2) anticipation of the expected profitability of legume-based pastures on cow-calf farms in the Colombian Llanos through simulation; and, (3) anticipation of the expected distribution of benefits of increased beef production among consumers of different income levels in urban areas of Latin America.

Costs of Pasture Establishment

Costs of different pasture establishment methods in the Carimagua region were estimated using 1978 prices. The methods considered were: (1) plowing plus two diskings; (2) three diskings; (3) two diskings; (4) stubble mulch sweeps used once; (5) low density seeding with stubble mulch sweeps; and (6) low density (or spaced planting) with two diskings.

Methods 1 through 3 are conventional. For a description of methods 4 through 6 see Pasture Establishment Section of the CIAT Annual Reports for 1976, 1977 and 1978.

The following criteria were used in estimating the costs for each method:

- A tractor of 75-78 HP with no alternative use on the farm except for pasture establishment and maintenance.
- Direct labor costs were charged according to *time* worked in each method, plus equipment preparation and transportation time required.
- Depreciation of equipment was charged according to *use*.
- Depreciation of facilities (shelter) and tools according to *time*.
- Interest (10%) on equipment was charged according to *time*.
- Maintenance of equipment according to *use*.
- Repairs of equipment according to *use*.
- Coefficients of time/ha and fuel consumption/hr or each activity were direct estimates obtained from the CIAT-Quilichao and Carimagua stations.

Costs presented in this report correspond to Methods 1, 3, 4, and 6. The cost of Method 2 falls consistently between those of Methods 1 and 3. The cost of Method 5 consistently falls slightly below that of Method 6.

The pasture establishment cost is divided into: land preparation cost, fertilizer cost and seed cost. Due to the influence of fixed costs, land preparation cost per hectare varies according to the area worked per year. These are depicted in Figure 105 for every method.

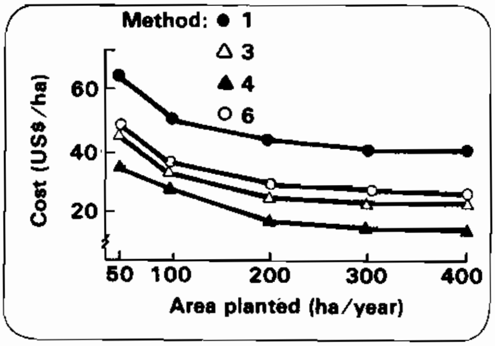


Figure 105. Land preparation costs using alternative pasture establishment methods, as a function of the area planted per year.

Since each system has a different establishment period, in order to make the systems comparable, all cost items in each system are capitalized up to the moment the pasture is at its full carrying capacity. Capitalized establishment costs for 100 ha/year and two alternative fertilizer and seed costs are reported in Table 74. Note that for the currently recommended levels of fertilizer for legume/grass mixtures (medium: 50 kg of P_2O_5 + 25 kg of K_2O + 20 kg of S + 20 kg of Mg/ha), the fertilizer cost accounts for 42 to 60% of total cost, depending on the establishment method.

In Figures 106 and 107, the total capitalized cost of each method is depicted for medium and low fertilizer and seed costs, respectively. These figures clearly show that establishment cost varies greatly among the methods considered. Second, economies of scale exist for each establishment method. However, alternative methods could compensate this bias, resulting in an overall "scale-neutral" technology. The lower seed costs of the low density or spaced planting system (Method 6), have this effect.

Since in its present stage of development this method appears to be more feasible for planting small areas, it partially compen-

Table 74.

Pasture establishment costs[1] using alternative methods, for 100 ha/year.

Method	Establishment costs (US$/ha)			
	Land preparation	Fertilizer	Seed	Capitalized total
1- Medium	48	64	34	153
Low	48	45	17	116
3- Medium	30	64	34	133
Low	30	45	17	96
4- Medium	20	64	34	122
Low	20	45	17	86
6- Medium	32	64	3	106
Low	32	45	2	84

1 Prices of 1978.

sates the economies of scale present in the other systems. This is especially so when seed costs are high. It should be kept in mind that smaller and less expensive equipment would also reduce unit costs, although not necessarily proportionately i.e., the cost of a 35-HP tractor is more than half that of a 70-HP tractor. Hence, the development of establishment methods appropriate for small farms is a reasonable objective. In this way alternatives which compensate the within-method economies of scale are developed.

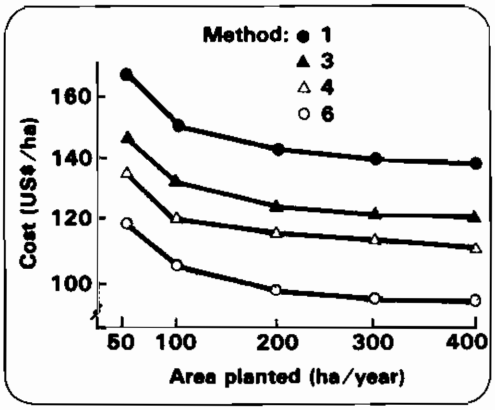


Figure 106. Total establishment costs using alternative pasture establishment methods, assuming medium fertilizer (US$64/ha) and seed (US$34/ha) costs.

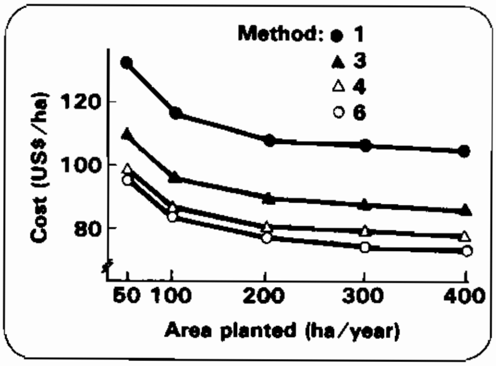


Figure 107. Total establishment costs using alternative pasture establishment methods, assuming low fertilizer (US$45/ha) and seed (US$16/ha) costs.

Selected Parameters of Herd Systems

In Table 75, selected parameters of several herd systems for the Llanos are presented for comparative purposes. They correspond to the Herd System Experiment (HSE) reported in CIAT's 1977 Annual Report, to the Breeding Herd Management System (BHMS), the ETES project, and the Carimagua Test Herd described in the Animal Management Section of this report, and to the systems which were simulated in 1977. In Systems 1 through 6, cows graze native savanna, and in Systems 3 and 4, some animals also occasionally graze introduced grasses.

System 1 results in a decreasing herd over time. System 2 simulated in 1977, was considered more representative of production systems in the Llanos. Results obtained during 1978 in the ETES project (averages of 16 farms monitored in the area) yielded similar calving and adult mortality rates to those in System 2, but greater calf mortality. Results obtained this year in the BHMS (System 8) with strategic grazing of *Brachiaria decumbens* and *Stylosanthes guianensis* (10% of total area) are similar to those of System 9, a simulated breeding herd strategically grazing a legume-based pasture.

Body weights of cows and calves for all systems are presented in Table 76. The low body weights of lactating cows in Systems 1 through 3 explain the low calving rates

Table 75.

Selected parameters of actual and simulated herd systems in the Colombian Llanos.

System	Observation period (years)	Calving rate (%)	Mortality rates (%)	
			Calves	Adults
Savanna only				
1. HSE[1] (Herds 2-3)	4	46	26	5
2. Simulated[2] (native)	-	50	8	5
3. ETES[3] (farms)	1	49	13-14	4-5[4]
4. Test herd	2	58	6	2
5. HSE (Herds 4-5)	4	65	12	5
6. BHMS[5] (Herds 1-3-5)	1	63	10	1.5
Introduced Pastures				
7. HSE (Herds 6-7) *Melinis minutiflora* + savanna	4	64	10	5
8. BHMS (Herds 2-4-6) 10% *Brachiaria decumbens* + *Stylosanthes guianensis* + savanna	1	79	10	1.5
9. Simulated[2] legume-based pasture	-	77	7	3

1 Herd Systems Experiment.
2 In 1977.
3 ETES: Technic-Economic Study of Systems.
4 Preliminary estimates.
5 BHMS: Breeding Herd Management Systems.

Table 76.

Body weight of cows and calves in selected systems in the Colombian Llanos.

System[1]	Cows (kg)		Calves (kg) Age in months	
	Dry	Lactating	9	18
Savanna only				
1. HSE (Herds 2-3)	302	272	117	150
2. Simulated (native)	302	272	117	150
3. ETES (farm)	318	293	136	184
4. Test herd	n.a.	n.a.	143	n.a.
5. HSE (Herds 4-5)	334	305	147	175
6. BHMS (Herds 1-3-5)	377	320	168	n.a.
Introduced pastures				
7. HSE (Herds 6-7) *Melinis minutiflora* + savanna	325	297	132	165
8. BHMS (Herds 2-4-6) 10% *Brachiaria decumbens* + *Stylosanthes guianensis* + savanna	395	363	186	n.a.
9. Simulated legume-based pasture	370	330	170	210

1 For explanation of systems, see footnotes to Table 75. Source: CIAT Annual Reports, 1977 and 1978.

observed. The *average* body weight for 375 lactating cows in the ETES project is 293 kg. Many of the animals in this sample have a low probability of reconception during lactation since their weight is substantially below the sample average.

Calving frequencies as a function of cow weights at mating, for 2-month intervals in HSE, are presented in Table 77. The adjusted frequency figures could be interpreted as the percentage probability that an open cow within a given weight interval could calve if exposed to the bull for a period of two months. In this sense, probabilities increase rather markedly up to weights of 280-299 kg. Reduced probabilities beyond the 360-379 kg weight interval are due to the fact that no culling based on reproductive performance was made in the HSE. Infertile but otherwise healthy cows did not suffer lactational stress and therefore tended to be in the heavier weight intervals.

These probabilities help explain the observed calving rates obtained in the different systems and give support to the practice of strategically grazing improved pastures to increase body weights of individuals cows beyond the critical conception weight of 300 kg. For heifers, the equivalent critical conception weight is approximately 270 kg.

Simulation of Strategically Used Legume-based Pastures

Even though there is as yet no proven persistent legume-based pasture available for the Llanos, there are some issues that could be addressed in anticipation of such

Table 77.

Calving frequency as a function of cow weight at mating, at two-month weighing intervals, Herd Systems Experiment.

Weight interval (kg)	No. of observations	No. of births	Adjusted frequency (%)	Relative frequency (%)
<220	300	1	0.1	0.1
220-239	137	9	6.6	2.8
240-259	229	34	14.8	6.3
260-279	414	105	25.4	10.7
280-299	402	125	31.1	13.1
300-319	358	105	29.3	12.4
320-339	282	97	34.4	14.5
340-359	124	37	29.8	12.6
360-379	106	31	29.2	12.4
380-399	59	9	15.3	6.4
400-419	32	1	3.1	1.3
420-440	23	4	17.4	7.3
Totals	2466	558	236.8	100.0

a package. Would the target legume-based pasture be profitable at the farm level? How many years should it persist in order to be profitable? How is its profitability affected by establishment and maintenance costs?

Obviously, the exact answer to these questions will depend on the particular circumstances of each farm, farmers' access to resources, the opportunity cost of capital and management, and the attitude of farmers toward risk. However, a tentative answer could still be obtained in terms of expected profitability of moving from the "typical native system" to the "target system". For this purpose, both systems were simulated over a 22-year period, starting with the same initital herd of 190 cows for a commercial ranch of 2500 ha. Once the herd is stabilized, the target system produces nearly 300% more output per hectare than the native system.

The parameters of the native system are those of System 2 described in Tables 75 and 76. The parameters of the target system are roughly those of System 8, in the same tables, except for slightly lower body weights of weaners and culled cows. Such parameters correspond to a system in which a legume-based pasture (10% of the farm's area) is grazed strategically by lactating cows and replacement heifers. Although based on experimental results of only one year, these parameters are considered feasible as a target at the farm level. In addition, the following were assumed for this system: (a) heifers reach mating weight (270 kg) at 2.5 years of age; (b) stocking rates of 1.0 and 2.0/A.U./ha are feasible for improved pasture in the dry and rainy season, respectively; (c) intake of mineral mixtures of 21 kg/A.U./year; (d) bull:cow ratio of 1:20; (e) hard culling during the first 2 years; (f) 20% annual culling rate of cows and bulls for the

Table 78.

Establishment cost[1] estimates used in simulation of strategic legume-based pastures.

	Fertilizer (kg/ha)				Costs (US$/ha)			
Levels	P_2O_5	K_2O	S	Mg	Fertilizer	Tillage	Seed	Total
High	100	25	20	20	94	42	34	170
Medium	50	25	20	20	64	42	34	140
Low	30	15	10	10	41	42	17	100

1 1976 prices.

remaining years; (g) the farm could not buy replacement heifers or cows; and, (h) 1976 prices.

In order to perform a sensitivity analysis, three levels of pasture establishment and maintenance costs were considered (Tables 78 and 79). The "medium" levels correspond to current costs, and to current (tentative) fertilizer recommendations.

The results of the sensitivity analysis, expressed in terms of rates of return to incremental capital and management of alternative pastures with different fertilizer requirements, but yielding the same animal output per hectare, are presented in Table 80. Such rates of return are to be compared with that obtained with the native system (System 2), which was estimated at 8.1% per year (CIAT Annual Report, 1977, pp. A-102).

These results are encouraging. Strategically grazing a legume-based pasture which persists for at leat six years, with medium establishment and maintenance costs, appears to be economically attractive for cow-calf operations. As anticipated in the 1977 Annual Report, pasture persistence beyond six years is of less economic importance when grazed strategically, compared to continuous grazing by a large number of animals.

Figure 108 through 111 illustrate the

Table 79.

Maintenance cost[1] estimates used in simulation of strategic legume-based pastures.

	Fertilizer (kg/ha)				Total cost[2]
Levels	P_2O_5	K_2O	S	Mg	(US$/ha)
High	40	20	10	10	50/year
Medium	20	10	5	5	28/year
Low (every 2 years)	20	10	5	5	14/year

1 1976 prices

2 Including application costs.

Table 80.

Returns to incremental capital and management of improved pastures having identical animal performance with the same stocking rate, but requiring different fertility levels, and of varying persistence.

Cost (US$/ha)		Pasture persistence (years)			
		6	8	10	12
Establishment	Maintenance	Return (%)			
	50/year	10.1	11.1	11.8	12.6
170	28/year	15.3	16.0	17.2	17.8
	14/year	17.9	19.1	20.5	21.3
	50/year	12.7	13.0	13.5	14.2
140	28/year	17.3[1]	18.1	19.0	19.5
	14/year	20.5	21.8	22.9	23.7
	50/year	15.1	15.3	15.9	16.1
100	28/year	20.9	21.7	22.1	22.2
	14/year	25.0	26.0	26.8	27.2

1 Decreases to 10.9 if pastures persist only 3 years.

cash flows for selected situations. It can be seen that reducing establishment costs, and especially maintenance cost, would substantially affect profitability. Farm cash flow is improved, and due to probable difficulties of farmers in obtaining supplies of the appropriate fertilizer mix, adoption becomes more likely.

A word of warning is in order. The above simulated results have ignored production and market risks, and hence may overestimate the expected returns. Also the technology has yet to be validated at the farm level. Hence, it is reasonable to conclude that for cow-calf operations, the current strategy of the Program of screen-

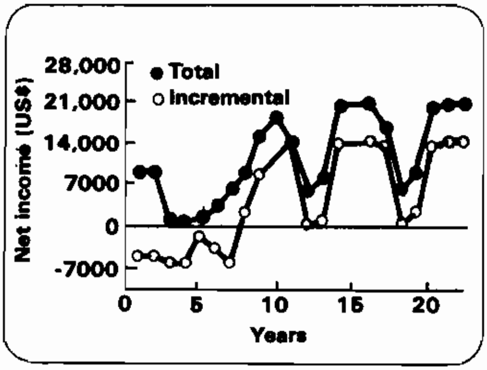


Figure 108. Total and incremental annual net income for high establishment and maintenance costs, for pasture persistence of six years.

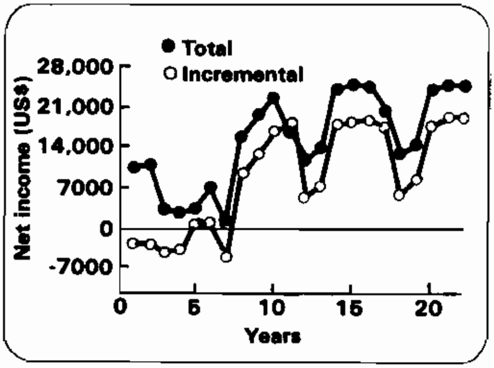


Figure 109. Total and incremental annual net income for medium establishment and maintenance costs, for pasture persistence of six years.

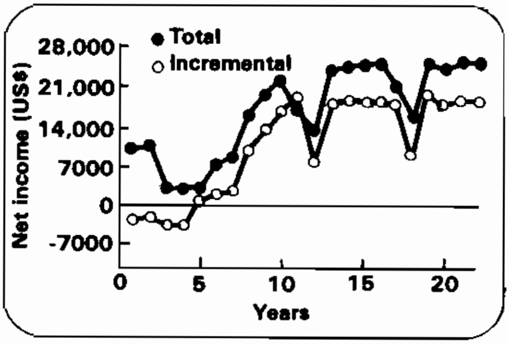


Figure 110. Total and incremental annual net income for medium establishment and maintenance costs, for pasture persistence of 12 years.

ing selected species for the Llanos which require low inputs is appropriate. For other regions with less fertility stress, selection of species of low fertility requirements will be less critical, provided that: (a) on-farm input: output price ratios are equal to or more favorable than in the Llanos; and, (b) that there are no serious problems in the supply of inputs.

Distribution of Benefits among Consumers from Increased Beef Production

A feature common to most Latin American countries during the last 15 years is the fact that demand for beef (at constant real prices) has been growing at a faster rate than production. As shown in Table 81, demand for beef in tropical Latin America during 1960-1975 grew at an average annual rate of 5.6%. Except for Central America, production increases during that same period lagged significantly behind, averaging 3.6% per year in the tropics. Future trends, based on the observed growth rates of population, per capita real income and beef production project a very large "potential" increase in beef consumption for the next decade and a half[1]. While Central America and the temperate region are expected to continue as net exporters, Mexico and the rest of tropical Latin America will likely become net importers by 1990. This projected gap between the supply and the demand for beef in the tropics would imply an increasing trend in the real price of beef. Due to the importance of this commodity in the budget of low-income families in these countries, price increases would have a considerable effect on income distribution and in total protein intake of these groups.

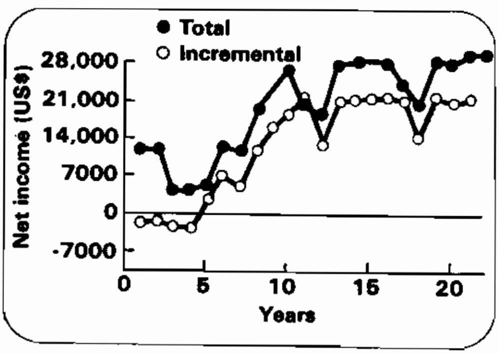


Figure 111. Total and incremental annual net income for low establishment and maintenance costs, for pasture persistence of 12 years.

Objectives of the Study

In view of the above analysis, it was considered important to study the potential *(ex ante)* economic benefits to be expected from increased beef production due to research in pastures and forages for the acid infertile soils of tropical Latin America, their distribution between producers and consumers, and among consumers of different income strata. The study dealing with the latter aspect of distribution of benefits among urban consumers was inititated in 1978. A previous CIAT study had dealt with this question for the case of Cali, Colombia; a summary of the results pertinent to beef is shown in Table 82.

1 See Valdés, A. and G. Nores, "Growth Potential of the Beef Sector in the Economic Context of Latin America," *In* Proceedings of the IV World Conference on Animal Production, Buenos Aires, Argentina, August 1978. In press.

Table 81.

Growth of demand at constant real prices and production of beef in Latin America, 1960-1975.

Region and Country	Growth rate of Demand[1] (%)	Growth rate of Production[2] (%)
Tropical Latin America	5.6[3]	3.6
Mexico	5.3	5.2
Venezuela	6.9	5.1
Ecuador	7.5	4.2
Brazil	6.9	3.9
Dominican Republic	5.8	3.7
Colombia	5.2	2.0
Peru	4.7	1.4
Bolivia	4.0	0.0
Surinam	6.2	0.0
Paraguay	3.1	-1.1
Central America	5.2[3]	5.8
Honduras	4.6	8.3
Costa Rica	5.2	7.1
Nicaragua	5.2	6.7
Panama	5.9	5.3
Guatemala	5.6	4.6
El Salvador	4.8	1.8
Caribbean	3.7	1.0
Guyana	4.1	2.6
Haiti	3.3	1.2
Jamaica	4.4	0.4
Temperate Latin America	2.0[3]	0.3
Argentina	1.7	0.5
Chile	3.0	0.2
Uruguay	1.3	-1.2
Latin America	5.1[3]	2.2

1 $\dot{d} = \dot{P} + \dot{Y}\,\varepsilon_y + \dot{P}\,\dot{Y}\,\varepsilon_y$
where:
$\dot{d}$ = growth rate of demand
$\dot{P}$ = growth rate of population
$\dot{Y}$ = growth rate of real income per capita
ε_y income elasticity of demand
2 Slaugther only
3 Average weighted by population

Table 82.

Budget allocation and elasticities of demand for beef by income strata, Cali, Colombia.

Income strata	Per capita income (US$/ month)	Family size (persons)	Income spent on beef (%)	Income elasticity (%)	Price elasticity (%)
I	5	5.9	10.5	1.52	1.46
II	9	6.3	10.1	1.35	1.31
III	13	6.8	12.1	0.99	0.99
IV	26	6.3	9.5	0.67	0.69
V	59	6.7	10.3	0.47	0.50

Sources: P. Pinstrup-Andersen, "Decision-making on Food and Agricultural Research Policy: The Distribution of Benefits from New Agricultural Technology Among Consumer Income Strata", *Agricultural Adm.* (4), 1977.

P. Pinstrup-Andersen and Elizabeth Caicedo, "The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition", *A.J.A.E.*, August 1978.

A question arises as to whether the proportion of total income spent in beef could indeed be expected to remain constant across income groups, as was observed in that study, and yet income elasticity decreases as a function of income. Also, the fact that average family size varied without a consistent pattern among income strata, could have been due to the grouping criteria, to sample design, or was simply a peculiar characteristic of the population of Cali. Therefore, there was a need to verify whether the results for beef consumption previously obtained for Cali were equally valid for other urban areas of tropical Latin America, and if not, what implications this would have on the results and conclusions which had been derived earlier.

Preliminary Results

The data used are from consumer expenditure surveys which were undertaken in several Latin American urban centers between late 1966 and late 1969 by Estudios Conjuntos sobre Integración Económica Latinoamericana (ECIEL), and coordinated by the Brookings Institution. The data refer to a large number of families interviewed in the following cities and countries: Bogotá, Cali, Medellín, and Barranquilla, Colombia; Rio de Janeiro, Recife, and Porto Alegre, Brazil; Caracas and Maracaibo, Venezuela; Quito and Guayaquil, Ecuador; Lima, Peru; Asunción, Paraguay; and Santiago, Chile. In addition, data became available from a similar family budget survey for São Paulo, Brazil, which was carried out in 1971-72 by the Fundação do Instituto de Pesquisas Economicas (FIPE) of the University of São Paulo, and which included 2380 families. All of these surveys contain information on family income and expenditures, plus several socio-demographic characteristics of the households.

Preliminary results were obtained for the four Colombian cities as well as for São Paulo. Table 83 contains a selection of descriptive characteristics of the sample of

Table 83.

Selected descriptive characteristics of the sample of families in a survey on distribution of benefits from increased beef production among urban consumers.

Country, city and income quartile[1]	Per capita expenditure range	Average per capita Total expen-diture	Average per capita Total monetary income	Average per capita Food expen-diture	Average family size	Number of persons in families interviewed
	(US$/month)				(persons)	
Colombia[2]						
Bogotá:						
I	3.9 - 16.6	12.0	11.0	6.3	7.5	1427
II	16.7 - 27.9	22.0	21.4	10.9	5.8	1103
III	28.0 - 62.0	40.8	39.8	16.1	4.7	894
IV	62.3 - 514.0	137.1	143.2	37.0	4.0	761
Barranquilla:						
I	4.2 - 17.8	12.6	10.1	7.9	7.4	1262
II	17.9 - 28.0	22.0	19.0	13.3	5.7	972
III	28.3 - 56.5	40.5	42.0	19.0	4.9	835
IV	56.7 - 399.5	105.5	113.1	32.5	4.0	682
Cali:						
I	3.3 - 15.6	10.5	9.7	6.5	6.9	1019
II	16.0 - 29.6	22.2	20.6	12.5	5.5	813
III	29.7 - 61.2	41.9	38.8	19.0	4.4	650
IV	61.4 - 541.7	129.6	136.5	37.0	3.5	517
Medellín:						
I	2.0 - 13.0	8.9	9.1	5.1	8.1	1492
II	13.1 - 26.2	18.5	18.4	6.6	5.9	1087
III	26.3 - 56.7	38.8	41.0	16.8	4.4	811
IV	56.8 - 721.2	124.7	151.2	31.9	3.9	718
Brazil[3]						
Sao Paulo:						
I	5.1 - 28.0	21.2	25.4	11.1	5.5	3273
II	28.1 - 44.8	37.6	45.2	17.1	4.4	2618
III	44.9 - 75.6	60.9	76.1	23.3	4.1	2440
IV	75.8 - 642.0	147.2	179.5	39.5	3.7	2202

1 Families are classified into income quartiles according to average per capita expenditure; each quartile represents 25 percent of the families.

2 At prices of 1967; 1 dollar=Col.$15.82. Source: CIAT, estimated from Family Budget Survey (CEDE-Brookings Institution 1966 - 1967).

3 At prices of 1971; 1 dollar= Cr.$5.72. Source: CIAT, estimated from Family Budget Survey (FIPE-University of Sao Paulo 1971-1972).

Table 84.

Allocation of family income and expenditures to beef consumption and income elasticity of demand for beef, by city and income strata.

Country, city and income quartile[1]		Food/ total expen- diture (%)	Expenditure in beef as percentage of: Food expen- diture	Total expen- diture	Total income	Income elas- ticity (%)
Colombia[2]						
Bogotá:	I	54.1	18.6	10.0	10.6	1.09
	II	49.9	18.4	9.2	9.4	0.83
	III	40.2	18.5	7.5	7.5	0.52
	IV	28.0	14.3	4.0	3.7	0.20
	Total	36.3	16.5	6.0	5.8	-
Barranquilla:	I	64.0	23.1	14.8	18.0	1.01
	II	60.6	24.8	15.2	17.3	0.62
	III	47.3	23.3	11.0	10.6	0.58
	IV	33.7	21.2	7.1	6.1	0.52
	Total	45.7	22.7	10.4	9.9	-
Cali:	I	64.6	24.2	15.6	16.4	1.28
	II	56.5	24.3	13.7	14.7	0.77
	III	45.2	23.3	10.5	11.4	0.42
	IV	31.2	18.6	5.8	5.5	0.41
	Total	42.4	21.6	9.1	9.0	-
Medellín:	I	57.9	23.1	13.3	12.9	0.79
	II	50.8	23.0	11.7	11.3	0.88
	III	43.9	23.1	10.2	9.5	0.64
	IV	27.8	15.8	4.4	3.3	0.38
	Total	37.6	19.8	7.4	6.3	-
Brazil[3]						
Sao Paulo	I	52.5	9.5	9.0	6.7	0.86
	II	45.5	12.5	8.8	7.0	1.18
	III	38.3	12.8	6.5	4.8	0.47
	IV	26.8	13.4	4.6	3.6	0.43
	Total	40.8	12.0	6.0	4.6	-

1 Families are classified into income quartiles according to average per capita expenditure; each quartile represents 25% of the families.
2 CIAT: estimated from Family Budget Survey (CEDE-Brookings Institution, 1966-1967)
3 CIAT: estimated from Family Budget Survey (FIPE-University of Sao Paulo, 1971-1972).

families included in each of the surveys. Families are classified into income quartiles, each one containing 25% of the households in the sample. In Table 84 the main preliminary estimates obtained from the survey data are presented. These consist of a set of descriptive statistics along with econometric estimates obtained by fitting Engel curves or expenditure functions. The figures shown for income elasticity were estimated by fitting double-log regressions between *per capita* beef expenditure and total *per capita* expenditure. In all cases elasticity estimates were significant at P = 0.05.

As may be noted, beef expenditure comprises approximately 20% of the food budget in the Colombian cities and 12% in São Paulo, with slightly higher figures for lower than for higher income strata. The proportion of total family income devoted to beef consumption is also high, indicating the importance of this commodity for consumers of all income groups. This is particularly so for the low income stratum, which spends no less than 7% (São Paulo) and as much as 18% (Barranquilla) of its total income on beef. With respect to income elasticities of demand for beef, it may be seen that in general these figures are high, especially in the case of the low income quartiles which reflect a high preference for beef consumption. The elasticity decreases towards the higher socio-economic strata, as is expected for a food item.

The results for Cali may be compared to the previous estimates shown in Table 81. Earlier, families were classified according to their total income, and emphasis was placed on separating low income consumers, in such a way that strata I, II, and III show relatively small differences in total per capita income. Instead, the new results are obtained from classifying families into income groups according to average *per capita* expenditure of each family, resulting in sharp differences between strata, and a clear pattern in family size, which diminishes as income increases. With respect to beef consumption by income strata, the new results show a larger share of the budget devoted to beef in Cali, Medellín, and Barranquilla compared with the previous estimate of 10 to 12%. More important is the fact that the proportion of the total budget spent in beef clearly decreases as income increases, and thus is consistent with a decreasing income elasticity of demand.

Preliminary Conclusions

Although the two CIAT studies on the distribution of benefits among consumer income strata from increased beef production present certain differences, the following conclusions based on the earlier estimates for Cali still stand and, on the basis of these preliminary estimates, seem to be applicable to other urban areas in the region:

1. If the supply of any one of the 17 food commodities (considered in the previous CIAT study) is increased by 10%, the largest absolute consumer benefit is obtained from beef. It should be pointed out, however, that this conclusion ignores the costs involved in increasing supply;
2. A 10% increase in beef supply provides a larger net impact on protein intake among protein deficient groups than a similar increase in the supply of any other single food. This conclusion now seems even more strongly supported.
3. Consumer benefits from an expanding beef supply are expected to be distributed less regressively than current income distribution. This conclusion is also reinforced by the study underway.

TRAINING AND REGIONAL TRIALS

Activities of the Training and Regional Trials Section concentrated on efforts of developing and strengthening a network of scientists and technicians working on the production and utilization of forages on acid soils with low native fertility in the tropics. This network will validate, adopt and assist in the transfer of technology developed by CIAT and national research institutions. At the same time, contacts were established with national research and development institutions for all collaborative activities of the Program, especially those related to regional trials.

Training

During 1978, 39 professionals received training in the various disciplines of the Program. By selecting technicians from national institutions that work in Latin American countries comprising the Target Area of the Beef Program, strengthening of the research capacity for validation of technology at the regional level is being accomplished.

From among these professionals, eight visiting research associates are participating in research projects in several disciplines of the Program in collaboration with universities in Canada, France, Mexico, the United States and Western Germany. This work fulfills some of the requirements for obtaining the MS, PhD or equivalent degrees. In this manner the Beef Program is contributing to preparing research leaders who will strengthen collaborative links with national institutions and the universities in countries having the most advanced technology.

The First Course on Research for the Management of Tropical Pastures was held during the second semester of 1978. Twenty technicians from eight countries in the Target Area participated, representing research and development institutions as shown in Table 85. Principal objectives of the course were to offer specific training in: (1) the identification, interpretation and validation of new forage production technologies; and, (2) the development of strategies for the introduction of adequate management practices for improved pastures to assist beef producers. Course participants spent 25% of the time at CIAT-Palmira, on the theoretical phase, and another 60% on practical training at CIAT-Quilichao and selected farms in the surrounding area. The remainder of the time, including course evaluations, was spent on study trips to the Colombian North Coast and the Llanos, especially at the Carimagua station.

Regional Trials

Table 86 shows the locations and edaphic and climatic characteristics for sites where regional trials for the adaptation of forage species selected by CIAT were established or projected for planting in 1978. Twenty-five localities, throughout the Target Area and with varying levels of fertility and soil moisture, offer the Program an excellent opportunity to verify the production potential of promising forage legume and grass species, in comparison with check species considered most productive in each locality (Tables 87 and 88). Evaluations will be for periods of at least two years under conditions of cutting and grazing that are common for each site, in order to select the most productive species to be evaluated for their

Table 85.

Distribution by countries and institutions of research and development of participants in the First Course on Research in the Management of Tropical Pastures.

Country	National institution for: Research	Development	Total
Bolivia	1	0	1
Brazil	3	4	7
Colombia	1	3	4
Cuba	1	0	1
Nicaragua	1	1	2
Panama	0	1	1
Peru	2	1	3
Venezuela	1	0	1
Total	10	10	20

animal production potential when associated with grasses and legumes. Preliminary results indicate that the promising grass *Andropogon gayanus* 621 is performing well at all sites where it is being evaluated.

Conferences

The Beef Program assisted in sponsoring two important conferences in April 1978, with a total attendance of 257 scientists and other professionals.

The first conference was a Workshop on the Collection, Preservation, Distribution and Characterization of Forage Plant Genetic Resources, organized in collaboration with the University of Florida (U.S.A.) and sponsored by the U.S. Agency for International Development. Sixty-eight persons representing 40 institutions in 20 countries attended this workshop.

Its principal objective was to produce a manual that would serve as a guide for establishing a coordinated system of collecting, classifying, preserving, distributing and evaluating native tropical forage species. The manual will be published in Spanish, Portuguese and English, during 1979.

The second conference, a Seminar on the Production and Utilization of Forages in Acid, Infertile Soils of the Tropics, had

Table 87.

Accessions of grasses under evaluation in regional trials for adaptation of forage species selected by CIAT.

Species	CIAT No.	No. of locations
Andropogon gayanus	621	25
Brachiaria decumbens	606	25
Panicum maximum (Common)	604	25
Hyparrhenia rufa	Check	12
Melinis minutiflora	Check	1
Paspalum plicatulum	Check	1
Digitaria decumbens	Check	1
Digitaria unfolozi	Check	1
Cenchrus ciliaris	Check	1

Table 86.

Locations, collaborators and characteristics of the zones where regional trials for adaptation of forage germplasm are established.

Location	Institution	Principal collaborator	Date of planting	Annual precip. (mm)	Climate[1] (mm)	Soil	Soil characteristics[2] pH	Avail. P (ppm)	Al satur. (%)
Bolivia									
San Ignacio	CIAT	G. Sauma	Jan. 18	1142	II	Ultisol	5.5	5	19
Ecuador									
Santo Domingo	INIAP	R. Santillán	Feb. 15	3230	III	Alfisol	5.7	5	0
Peru									
Pucallpa	IVITA	V. Morales	Feb. 28	1708	III	Ultisol	(4.2)	2	61
Yurimaguas	CRIA-III	D.E. Bandy	May 9	2002	IV	Ultisol	4.0	2	85
Tarapoto	CRIA-III	H. Schiere	May 9	1150	(III)	Ultisol	4.5	4	88
Venezuela									
Jusepín	Univ. Oriente	C. Alcalá	June 1	1052	I	Ultisol	5.8	(7)	(20)
El Tigre	CIARNO	O. Parra	June 8	1234	II	Oxisol	5.1	(3)	(70)
Atapirire	IUTET	O. Parra	June 9	1023	II	Oxisol	5.1	(6)	(25)
Calabozo	CIARLLACEN	D. Escobar	June 12	1326	II	Inceptisol	(6.0)	(8)	(0)
Uracoa	FUSAGRI	N. Tafur	June 13	1325	II	Ultisol	-	-	-
Guachi	Univ. Zulia	I. Urdaneta	June 15	2740	I	Ultisol	4.0	3	52

1 Based on potentital evapotranspiration during the rainy season: I <910; II = 910-1060; III = 1060-1300; IV > 1300.
2 Numbers in parentheses are estimated. Data for P are variable extractants.

Table 86.(continued)

Location	Institution	Principal collaborator	Date of planting	Annual precip. (mm)	Climate[1] (mm)	Soil	Soil characteristics[2] pH	Avail. P (ppm)	Al satur. (%)
Colombia									
Santander de Quilichao	CIAT	-	Mar. 20	1845	-	Ultisol	3.8	4	70
La Libertad	ICA	R. Pérez	July 13	2639	IV	Oxisol	4.7	11	78
El Nus (Medellin)	ICA	S. Monsalve	Sept. 21	2200	-	Oxisol	4.9	4	15
Nicaragua									
Nueva Guinea	INTA	D. Padgett	July 26	2894	IV	Ultisol	-	-	-
Brazil[3]									
Sête Lagoas	EPAMIG	N. Costa	December	1209	III	Oxisol	(4.8)	(2)	(75)
Goiania	EMGOPA	M. Sobrinho	"	1487	II	Oxisol	(5.0)	(5)	(70)
Belém	CPATU	A. Serrão	"	2762	IV	Oxisol	(4.8)	(2)	(75)
Paragominas	CPATU	A. Serrão	"	1068	III	Oxisol	6.4	6	2
Marabá	CPATU	A. Serrão	"	1988	III	Oxisol	5.4	5	14
S. do Araguia	CPATU	A. Serrão	"	1727	III	Ultisol	5.2	5	0
Marajó	CPATU	A. Serrão	"	(2000)	III	Ultisol	5.1	5	83
Macapa	CPATU	A. Serrão	"	1309	II	Oxisol	5.1	5	75
Itacoatiara	CPATU	A. Canto	"	2101	III	Oxisol	4.6	5	27
Boa Vista	CPATU	A. Canto	"	1941	II	Oxisol	(5.3)	(5)	(20)
Porto Velho	CPATU	A. Serrão	"	2232	III	Ultisol	(5.1)	(3)	(75)
Guiomar Santos	CPATU	A. Serrão	"	(2200)	III	Ultisol	6.5	3	0

1 Based on potential evapotranspiration during the rainy season: I < 910; II = 910-1060; III = 1060-1300; IV > 1300
2 Numbers in parentheses are estimated. Data for P are variable extracts.
3 Projected

Table 88.

Species and ecotypes of forage legumes and recommended *Rhizobium* strains under evaluation in regional trials of adaptation for forage species selected by CIAT.

Species	CIAT No.	*Rhizobium* strain (CIAT No.)	No. of locations
Stylosanthes guianensis	184	71	4
Stylosanthes guianensis	136	71	25
Stylosanthes capitata	1019	71	25
Stylosanthes capitata	1405	71	25
Stylosanthes capitata	1078	71	17
Stylosanthes capitata	1097	71	17
Stylosanthes hamata	147	71	25
Desmodium heterophyllum	349	80	6
Desmodium ovalifolium	350	46	25
Macroptilium sp.	535	313	25
Centrosema sp.	438	590	25
Zornia latifolia	728	103	15
Pueraria phaseoloides	Check	79	25
Centrosema pubescens	Check	590	7
Macroptilium atropurpureum	Check	79	5
Macroptyloma axilare	Check	79	1
Zornia sp. (native)	Check	103	1
Stylosanthes guianensis cv. Schofield	Check	71	2

189 participants from 69 institutions in 23 countries.

Principal objectives of this seminar were to review the state of knowledge on production, management and utilization of forages under conditions of acid, infertile soils (Oxisols and Ultisols) of the Latin American tropics and similar areas. Thirty papers were presented in seven groups, including a series on experiences in transfer of technology to beef producers. Proceedings of the seminar are being produced in Spanish, Portuguese and English, for distribution in the first part of 1979.

Both conferences included meetings to discuss mechanisms of collaboration between national, regional and international institutions and the CIAT Beef Program in order to enhance the development and transfer of technology on pasture production to beef producers. Participants also visited the experimental stations at Quilichao and Carimagua.

PUBLICATIONS

Aycardi, E. 1978. La Leptospirosis una enfermedad poco conocida en los bovinos de carne. Veterinario Práctico. March 1978 (3): 1

Aycardi, E., V. Sanclemente y **J.M. Cortés.** 1978. Prevalencia de anticuerpos para el virus de rinotraqueitis infecciosa en ganado de carne en Colombia y aislamiento del virus de casos clínicos. Veterinaria y Zootécnica. 30(85-86): 14-19.

Buol, S.W. and **P.A. Sánchez.** 1978. Rainy tropical climates: physical potential, present and improved farming systems. Trans. XI Congr. Int. Soc. Soil Sci. (Edmonton, Canada) 2:292-312.

Corrier, D.E., J.M. Cortés, E.R. Aycardi, E.A. Wells, M. Bohorquez and **J.J. Salazar.** 1978. A survey of cattle health problems in the eastern plains of Colombia. British Veterinary Journal 134: 101-107.

Couto, W. 1978. Algumas alternativas para o desenvolvemento das pastagens no Cerrado. *In:* Gartner, A. (ed):Ecología das Pastagens Nativas. Centro Nacional de Pesquisa de Gado de Corte, EMBRAPA, Campo Grande, MS.

Date, R.A. and **Halliday, J.** 1979. Selecting *Rhizobium* for acid infertile soils of the tropics. Nature 277:5691 pp. 62-64.

Halliday, J., Gutierrez, F. and **Sánchez, G.** 1977. *Rhizobium* strain selection for tropical forages adapted to acid, infertile soils. Proceedings VI American *Rhizobium* conference. University of Florida, Gainesville.

Halliday, J. 1978. Comparative physiology of nitrogen-fixing symbioses. *In,* Proceedings 2nd Latin American Botanical Congress. Brasilia, Brazil (In English and Spanish). (In press).

Halliday, J. 1978. Maximizing N fixation in tropical forages. *In,* Limitations and potentials for biological nitrogen fixation in the tropics. pp. 344-345. Ed. J. Dobereiner, R.H. Burris, A. Hollaender. Plenum, New York.

Halliday, J., and **Graham, P.H.** 1978. Coal compared to peat as a carrier for *Rhizobium.* Turrialba (In press).

Howeler, R.H. y **J.M. Spain.** 1978. Fertilización potásica en algunos suelos de clima cálido. Suelos Ecuatoriales. 9(2): 59-67.

Jones, C.A. 1979. The potential of *Andropogon gayanus* Kunth for the Oxisol and Ultisol savannas of tropical America. Herb. Abs. 49: 1-8.

León, L.A., A. Riaño, E. Owen, M. Rodríguez y **L.F. Sánchez.** 1978. Investigaciones realizadas en Colombia sobre el uso de diversas fuentes de fósforo como fertilizante. ICA-ABOCOL, Bogotá, 32 pp.

Paladines, Osvaldo. 1978. Sistemas de producción ganadera en el trópico de América. *In* Proc. IV Congreso Mundial de Producción Animal. Buenos Aires, Argentina. August 1978. (In press).

Sánchez, P.A. 1977. Manejo de solos da Amazonia para producao agropecuaria intensiva. Bol. Inf. Soc. Bras. Ciencia Solo 2(3): 60-63.

Bean Program

Previous reports of this Program have documented the search for outstanding germplasm, and the gradual strengthening of bean hybridization activities at CIAT. The year 1978 marked new gains for the Program with the movement of large quantitites of hybrid material toward advanced generation testing. A total of 1464 materials of which 937 were selections from the breeding program were screened in the Bean Team Nursery (VEF) and 700 materials, including 200 breeding selections, were evaluated in the Preliminary Yield Trial (EP). The screening of these lines for factors as diverse as yield, tolerance or resistance to rust, anthracnose, common bacterial blight (BCMV), and *Empoasca,* as well as sensitivity to photoperiod demanded excellent coordination and cooperation, and demonstrated again the integrated multidisciplinary approach adopted by the bean team. Results from the EP in particular were spectacular, demonstrating major gains in yield among colored materials and a very high proportion of breeding lines resistant to BCMV. Many lines demonstrated multiple disease resistance with gains in this area generally greater than had been anticipated.

The program continued to emphasize international yield and disease resistance testing. In 1978, 150 International Bean Yield and Adaptation (IBYAN) nurseries were distributed (88 color, 62 black) to 34 countries. Ninety-five different varieties have been included so far in these trials, with the 1978 IBYAN being notable for a marked increase in the number of CIAT-bred materials included. Rust, bean golden mosaic virus (BGMV) and common bacterial blight nurseries were also distributed.

Other major advances included: (1) initiation of a breeding program for climbing cultivars to be grown in association with maize; (2) establishment of temperature conditions likely to limit nitrogen fixation by bean root nodules; (3) identification of bean cultivars tolerant to low soil P; (4) micro-regions of bean production in Latin America were identified and an agro-climatology survey initiated; (5) on-farm trials demonstrated that low cost agronomy practices could increase farm yields 50%, and were profitable in the main production zones of beans in Colombia; and (6) intensification of the breeding work for anthracnose, angular leaf spot, and other conditions common to cooler climates.

As in previous years much emphasis was given to postgraduate training and to documentation. Two bean courses were held, with participation by 59 scientists from 14 countries.

BEAN PROGRAM ACTIVITIES IN 1978

The principal objective of the bean program is to increase yields of *Phaseolus vulgaris* in Latin America. Given the comparative advantage of international centers in germplasm evaluation and manipulation, and the need for additional trained scientists and research support in national bean programs, it is hoped to achieve this goal through four strategies:

(1) The production of improved germplasm having high yield and with resistance to the important pathogens and pests of the region. Initial focus has been toward bean rust *(Uromyces phaseolis)*, anthracnose *(Colletotrichum lindemuthianum)*, bean common mosaic virus (BCMV), common bacterial blight *(Xanthomonas phaseoli)* and the leafhopper, *Empoasca kraemeri*. The improved materials must additionally be acceptable to the consumer in grain type and cooking quality.

(2) The development of a complementary package of agronomic practices, suited to the improved germplasm but based on simple agronomic practices and using the minimum technical inputs to obtain good yields.

(3) The training of scientists from national institutes to facilitate their work in bean research and extension.

(4) Close collaboration with national bean programs and with other institutions working with the crop.

To fulfill these strategies the Bean Program in 1978 was active in seven major areas: (1) screening of cultivars for desired traits; (2) hybridization of promising materials and evaluation of their progeny; (3) evaluation and improvement of current agronomic practices; (4) in-depth studies of specific problem areas; (5) validation of technology in on-farm trials; (6) postgraduate training; and (7) collaboration with national programs and other institutions.

Since many of the areas of research undertaken depended upon the multidisciplinary cooperation of bean team members this report is not presented by discipline areas, but by research topic.

SCREENING OF CULTIVARS FOR DESIRED TRAITS

In 1976 the International Board for Plant Genetic Resources (IBPGR) designated that CIAT would be responsible for the collection, management, evaluation, and distribution of *Phaseolus* germplasm. The germplasm bank facility at CIAT now contains approximately 21,000 entries, more than 11,000 of which have been extensively characterized. While the urgency for germplasm evaluation abated somewhat in 1978, it still remained a major component of the research program, with inputs from virtually all disciplines. Major activities are detailed in the following sections.

Screening for Resistance to Pathogens and Pests

Resistance to Pathogens

Initial studies in this area sought materials with resistance to bean common mosaic virus (BCMV), rust, anthracnose, common bacterial blight and angular leaf spot (CIAT Annual Reports, 1974-1977). As reliable resistance sources have been identified for these pathogens, emphasis has also been placed on screening for resistance to bean golden mosaic virus (BGMV), *Ascochyta, Cercospora* and web blight *(Thanatephorus cucumeris)*. Distinction between available resistance sources has been sought using genetic studies and international disease nurseries. Finally, there has been a continued improvement in screening methods, and a consideration of strain frequency in the continent.

Improved Methods for BCMV and Anthracnose Evaluations. The contamination of BCMV-inoculated plants with bean rugose mosaic virus, and the low inoculation efficiency obtained on BCMV-susceptible materials has complicated the evaluation of germplasm accessions and breeding lines in past years. The method detailed below limits these problems.

To avoid contamination with other viruses, the inoculum was obtained from 12-day-old Diacol Calima seedlings grown from BCMV-infected seed and was serologically assayed for the presence of bean rugose and bean southern mosaic viruses. For the inoculation, the virus was then extracted (1:10, w/v) in 0.01 *M* potassium phosphate buffer, pH 7.6, and inoculated (wearing disposable gloves) with the aid of a sterile cheesecloth pad (Fig. 1). In the field, the inoculum was poured into 150-ml plastic bottles, and dispensed using a sterile cheesecloth pad attached to the mouth of the bottle (Fig. 2).

Figure 1. Inoculation of bean plants in the screenhouse using sterile cheesecloth pads.

Following this methodology 1158 materials (approximately 16,000 plants) were manually inoculated and evaluated

Figure 2. Field inoculation of bean plants using plastic bottles stoppered with sterile cheesecloth pads.

under glasshouse conditions without a single case of contamination, and with an inoculation efficiency of 95-100% in susceptible materials. In order to expand present glasshouse capacity (limited to 10,500 plants/20-day cycle) a study to determine the reliability of screening under semi-controlled conditions was undertaken; 21,500 plants being manually inoculated under screenhouse conditions. Efficiency was equal to that obtained in the glasshouse.

For field screening the use of bottles to dispense the inoculum facilitated the inoculation and evaluation of 4684 bush and climbing bean materials in 1978B, and resulted in infection rates of between 80 and 90%. The use of containers and disposable sterile cheesecloth pads kept contamination in field screenings to 0.1% of the inoculated materials. The contaminant virus was serologically identified as southern bean mosaic virus, a seed-borne pathogen.

To further facilitate the screening of germplasm and breeding materials the practicality of multiple inoculation (BCMV and anthracnose) under controlled conditions was studied.

Nearly 300 entries (10 seeds each) were planted in flats in the glasshouse, inoculated seven days later with BCMV and 24 hours later with a mixture of anthracnose races, incubated for 12 days in a moist chamber at moderate temperatures, and evaluated for resistance to the composite inoculation.

Materials which were resistant to BCMV and anthracnose were efficiently detected within 20 days after planting. Selections could then be successfully transplanted for seed production or subsequent field trials. It was impossible to deteremine the reaction of every entry to both pathogens since some entries were killed by the anthracnose fungus before BCMV symptoms could be expressed. However, this method is very useful in a practical program designed to efficiently identify resistance to multiple pathogens.

Sources of Resistance to the Florida Strain (USA 5) of BCMV. Recent studies have shown the Florida strain (USA 5) in natural infections of beans grown at CIAT. Since this strain can overcome the resistance of two groups of cultivars not attacked by the type strain of BCMV used in initial screenings, a search for resistance to BCMV USA 5 has been undertaken among CIAT germplasm materials. In 1978B, 290 promising lines, 104 other germplasm accessions, and 35 other materials were screened. Of these, 120, 54 and 15 respectively, proved resistant (or symptomless) to strain USA 5 of BCMV.

Methodology for Evaluation of Resistance to Angular Leaf Spot. For evaluation of resistance to angular leaf spot, a spore preparation is obtained from plates of V-8 agar grown 10-15 days in the dark at 19°C. Conidia are harvested in water by rubbing the sporulating colonies with a soft wire brush. A spore concentration of 10^4/ml is used in the inoculations with Triton or gum arabic added to obtain uniform infection. A disease evaluation scale based on the percentage leaflet area affected is utilized to measure resistance. On a 1-5 scale, immune materials (1) show no infection; (2) resistant materials have less than 2% of the actual leaflet area infected; (3) intermediate, 3-10% actual leaflet area infected; (4) susceptible, 11-25% actual leaflet area infected, and sometimes limited chlorosis; and (5) very susceptible, more than 26% actual leaflet area infected, and often accompanied by chlorosis and/or defoliation.

Sources of Resistance to Powdery

Mildew. A natural and severe epiphytotic of powdery mildew *(Erysiphe polygoni)* occurred in a nursery of over 1400 germplasm accessions planted in Popayan (Fig. 3). Subsequent disease evaluations identified the following 18 accessions which were highly resistant: G-1841, 2092, 2325, 2351, 2546, 3038, 3716, 3777, 3783, 3791, 3988, 4721, 5508, 6636, 6638, 6640, 6641 and 7464.

Root Rots. CIAT has been developing methodology to evaluate germplasm and progenies for resistance to infection by *Rhizoctonia solani, Sclerotium rolfsii, Fusarium* sp. and *Pythium* sp. Field and glasshouse inoculations and natural infestation trials were utilized to select evaluation scales which would be most efficient and practical for the Bean Program to utilize during progeny development.

Evaluation of resistance to infection by *R. solani, S. rolfsii,* and *Pythium* spp. (primarily *Pythium aphanidermatum* and *Pythium debaryanum)* was most efficiently accomplished by measuring the percentage germination and survival of plants when subjected to natural or artificial inoculum pressure in the glasshouse or field. No correlation was found between lesion depth and/or frequency and yield loss magnitude because of the increased growth compensation and reduced plant competition between surviving plants in inoculated trials.

Evaluation of resistance to infection by *Fusarium solani* f. sp. *phaseoli* was most efficiently accomplished by determining the depth of lesion development in seedling hypocotyls according to the following scale: (1) Resistant, no lesion development; (2) Intermediate, shallow lesions confined

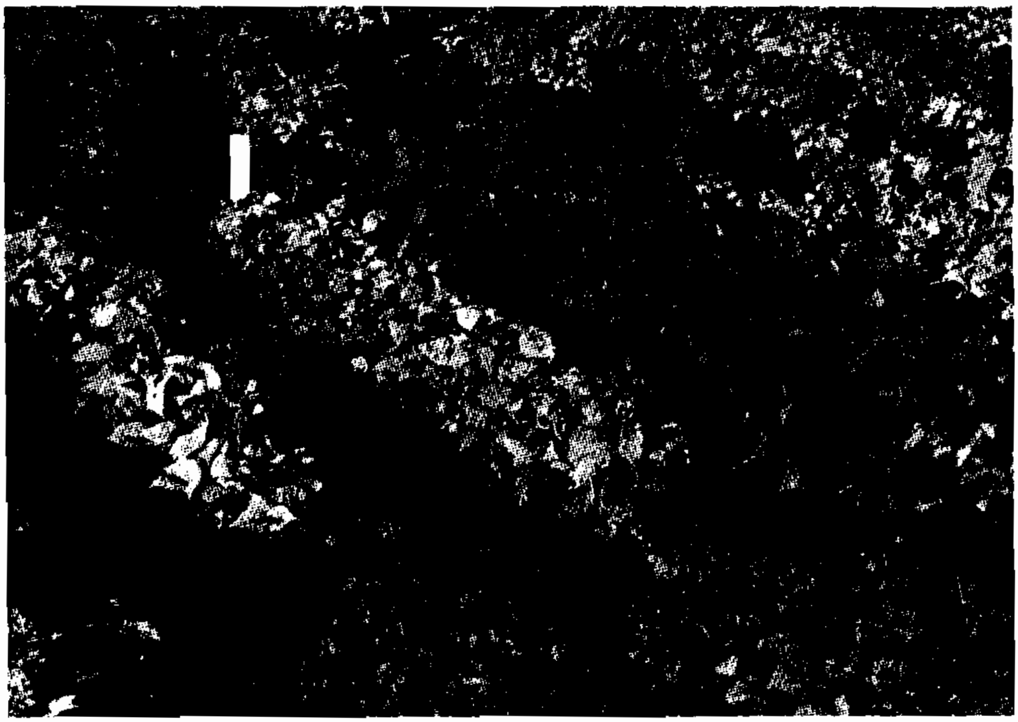


Figure 3. Susceptible and resistant reactions to a natural epidemic of powdery mildew in a germplasm nursery planting at Popayan.

to the outer 50% of the cortical tissue; (3) Susceptible, lesion development extended to the midpoint of the cortex or beyond, but not into the vascular system; and (4) Very susceptible, lesion development extended into the vascular system and/or pith region. Resistant parental materials are being utilized by the breeding program, and seedlings will be evaluated in advanced generations with replicated family testing at a planting density of 20-30 plants/m^2 under the high natural field infestation present in CIAT-Palmira fields. Indirect selection pressure against progeny susceptible or highly susceptible to *Fusarium solani* and/or other root rot pathogens is being exercised in earlier generations.

Other evaluation methods utilized during flowering or post-flowering stages were discarded because of confounding effects caused by physiological root senescence, planting depth, root wounds and secondary infection internally, adaptation, and environmental factors. Additional studies are required to determine the correlation between seedling and adult plant resistance, especially with regard to *S. rolfsii*.

Resistance to Insect Pests

Empoasca kraemeri. Evaluations for resistance to the leafhopper *(Empoasca kraemeri)* were conducted on approximately 4000 materials derived from screening work in the various disciplines of the Bean Program.

The following groups of materials were evaluated: International Bean Yield and Adaptation Nursery (IBYAN); International Bean Golden Mosaic Nursery (IBGMN); the Preliminary Yield Trial-F_3 (Climbing Beans); the 1978 Preliminary Yield Trial (EP) and the 1978 Bean Team Nursery (VEF); as well as introductions of *Phaseolus acutifolius* and *Phaseolus filiformis* and other cultivars in various stages of selection for resistance to *Empoasca*. The best materials selected from the different nurseries and selection stages are being used to form part of the International Nursery for *Empoasca*.

Of all the materials studied, about 400 (10%) showed high levels of resistance to leafhopper damage. Table 1 lists the cultivars classified as being most resistant to *E. kraemeri* in 1978. Among the 27 best materials, 63% are black-seeded. As in previous years not many sources of resistance were found among red beans. It should be emphasized that there were some non-black beans which had visual damage classifications less than 2. Climbing materials studied showed low resistance levels; the majority of them changed their growth habit from Type IV to II in the presence of *E. kraemeri* attacks.

Tetranychus desertorum. In 1977, screenhouse evaluations were initiated on bean varieties and cultivars for resistance to the red mite *(Tetranychus desertorum)*. The optimum period of infestation of these materials was found to be 15 days after seeding and a visual scale was developed to evaluate mite damage. A total of 561 varieties were studied of which 124 were very susceptible and 139 were selected for more detailed studies.

This year for the first time, varietal resistance to the red mite was studied in the field, beginning with a group of 64 varieties. The materials P- 83, 84, 85, 179 and 301 showed resistance while P- 52, 172, 217, 277 and 363 were classified most susceptible. This experiment included the varieties Oregon 58 and 58R and CRIA-1, which had been evaluated as resistant in Peru. In the screenhouse, they exhibited more resistance than other lines but in the field Oregon 58 and 58R were susceptible, suggesting that it is necessary to do studies

Table 1.

Cultivars and varieties of *Phaseolus* showing the highest grades of resistance to *Empoasca kraemeri*, during 1978 evaluations.

Nursery or other source	Identification	Primary color	Average classification[1]	Total materials: Evaluated	Resistant[2]
Rust Nursery (IBRN)	G124	White	1.4	135	27
(1976-77 plantings)	G4463	Black	0.9		
	G5773	Black	1.2		
	G5942	Black	1.1		
Selection Stages	G8058	White	1.2	296	92
	G8059	White	1.0		
	G8062	White	1.2		
	G8475	Black	1.0		
International Golden	Sucre 7	Black	1.8	235	21
Mosaic Nursery	G1257	Black	1.8		
(IBGMN)	G1157	Mottled Cream	1.0		
1978 Bean Team	78 VEF 89	Black	1.2	2221	204
Nursery (VEF)	78 VEF 92	Black	1.2		
	78 VEF 276	Cream	1.1		
	78 VEF 460	Black	1.2		
	78 VEF 846	Black	1.4		
	78 VEF 1006	Variable	2.0		
1978 Preliminary	P14	Black	1.7	780	36
Yield Trial-Bush Beans	P785	Black	1.8		
(78 EP)					
Preliminary Yield	FF0016-23-3-				
Trial-F_3, Climbing	CM-CM-CM	Brown	2.0	300	4
Beans	FF0594-7	Black	2.0		
	FF0611-1	Black	2.0		
	FF0623-29	Black	2.0		
Other *Phaseolus* spp.					
Phaseolus acutifolius	G3568	Black	1.2	93	23
	G4401	Black	1.2		
	G5917	White	1.3		
Phaseolus filiformis	NI-31	Cream	1.6		

1 Average of two replications and three observations, on a scale of 0-5: 0 = high grade of resistance; 5 = no resistance.
2 Resistant: average classification ≤ 2.

correlating evaluations from the screenhouse, field and laboratory and determining which selection methods should be followed.

Also this year, the species *P. acutifolius* var. *acutifolius* and *P. acutifolius* var. *latifolius* were evaluated in the field for mite resistance. Generally, these materials showed a higher grade of resistance than *P. vulgaris*. Some *P. acutifolius* accessions had little damage up to the end of the vegetative period.

Germplasm Evaluation for Architecture and Yield

Bush Bean Cultivars

During 1978 more than 6000 germplasm accessions were evaluated for lodging resistance, foliage type, maturity, and pod and seed characteristics.

Type II and III lines with medium to large seeds, small foliage, outrigger (multipodded) inflorescence, and one line (G8063) with male sterility were identified from germplasm bank growouts (Table 2) but minimal variation for lodging resistance and delayed maturity was found. Some selections from breeding nurseries were identified for the latter two characters and a lanceolate leaf type was also identified and appears promising. However, these are associated with exceptionally low productivity. Purification and determination of their genetic worth is underway.

Climbing Bean Cultivars

Though the available collection of climbing beans in CIAT (1950 accessions) had been adequately screened at Palmira in previous years, little was known of its performance at other altitudes. To study this all cultivars were planted at three highland locations, Popayán, La Selva, and Obonuco, using monoculture, relay cropping and direct association with maize, respectively.

A preliminary screening in the first semester with 30 materials demonstrated that in selected materials any imagineable response of growth habit to temperature and other climatic factors could be found (Figure 4). For example, G2540 (white) climbed more than average at all three locations; G413 (yellow) was better adapted in climbing response to cool

Table 2.

Phaseolus vulgaris **selections made for interesting architecture and yield characters.**

Character	Growth habit	No. of entries	Sources
Lodging resistance	II	7	Breeding nurseries
Small foliage	II, III	9	Germplasm bank
Lanceolate leaf	II	2	Breeding nurseries
Delayed maturity	I, II, III	7	Breeding nurseries
Early maturity	I, II	6	Germplasm bank
Outrigger inflorescence	I	2	Germplasm bank
Medium to large seed	II, III	22	Germplasm bank
Male sterility	III	1	Germplasm bank

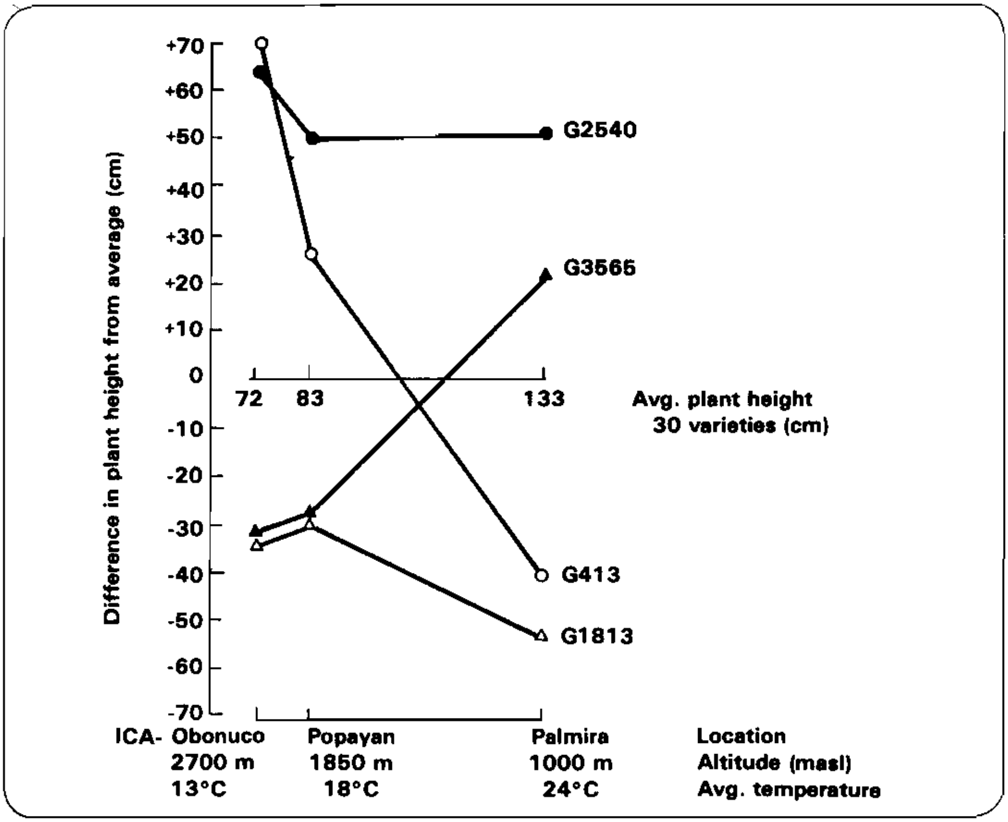


Figure 4. Change in height of growth for four climbing bean varieties caused by differences in locational altitides.

temperatures whereas G3565 (white) was better adapted to warm temperatures. G1813 (yellow) showed a stable response to temperature, but climbed less than average at all locations. Flowering response was also highly variable: only two materials (G3371 and G2545) demonstrated satisfactory pod set and growth habit stability at all locations.

The complete screening of all materials was planted in the second semester in unreplicated hill-plots, using three bean plants plus, where associated, three maize plants in the same hill This has proved to be a very cheap and effective means of evaluating large quantities of material in a small land area. The nurseries were not protected against diseases except that any plants showing BCMV were rogued out. Evaluations were made for climbing adaptations, earliness, pod set and disease incidence. The first results from ICA-La Selva in relay cropping have shown that 24% of the collection climbed well (true type IV). Those demonstrating exceptional highland adaptation originated mostly from Mexico, Turkey and South Africa. There are, however, relatively few accessions available to date from Andean zone countries.

Screening for Tolerance in Moderately Acid Soils

While beans are not normally grown under highly acid soil conditions they are often planted in circumstances of low phosphorus and moderate soil acidity.

Preliminary screening of the promising bean varieties (P-lines) for tolerance to low levels of soil phosphorus was carried out at the Popayan site. From this screening it appears that dry beans *(P. vulgaris)* can be divided into four categories of P requirement: (1) inefficient at low P level and non-responsive to applied fertilizer; (2) inefficient at low P level but responsive to fertilizer; (3) efficient at low P level but non-responsive to fertilizer; and (4) efficient at low P level and also responsive to fertilizer.

Plants in category 1 may be rejected as worthless for breeding and/or agronomy. Category 3 plants would be of value only when they have other advantageous characteristics.

Screening for low soil P and acid soil tolerance in 1978 was carried out at the CIAT-Quilichao substation. The experiment included both lime and P treatments and was designed to permit evaluation of both tolerance to low P and to soil acidity and Al toxicity.

The results from the screening of 188 CIAT promising lines for tolerance to low soil P at Quilichao are plotted in Figures 5, 6 and 7, according to the seed color. The efficiency factor plotted on the ordinate axis is specific for the semester of testing, and P source, and is derived from the formula:

$$\frac{\text{Yield at high P level - Yield at low P level}}{\text{Difference in units of } P_2O_5 \text{ applied}}$$

Since bean yields are subject to soil and climatic variation, yields will vary every planting season. Only beans that remain in the upper right-hand quadrant are chosen as tolerant to low soil P. These correspond

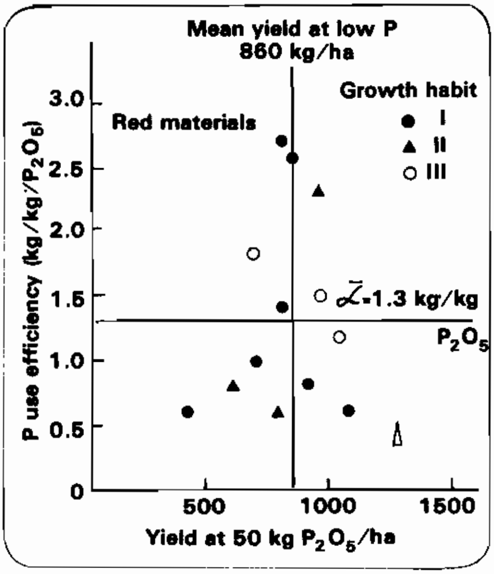


Figure 5. Evaluation of promising lines at low and high P applications, at CIAT-Quilichao, 1978A.

to the category 4 plants previously mentioned.

The two ICA materials, P692 (Diacol Calima) and P637 (Linea 17) both with red seed and of growth habit I have a high efficiency factor in using applied P and their yields at low P were also reasonable. Other good materials from the 1978A screening are listed in Table 3.

Only 11 of 188 materials tested survived and yielded more than 100 kg/ha in unlimed plots (pH 4.1, 4.1 meq. Al/100 g) (Table 4). To determine more realistic lime levels for screening, 60 bean varieties (30 blacks and 30 colored) were planted in plots limed with 0, 0.5, 2 and 6 t lime/ha as calcitic lime. Initial Al content in this test was lower than in the other experiment (3.5 meq./100 g). Figure 8 shows the average response and the response of the variously colored beans to liming. As in previous experiments (CIAT Annual Report, 1973) black-seeded cultivars proved more tolerant to acid soils than cultivars of other

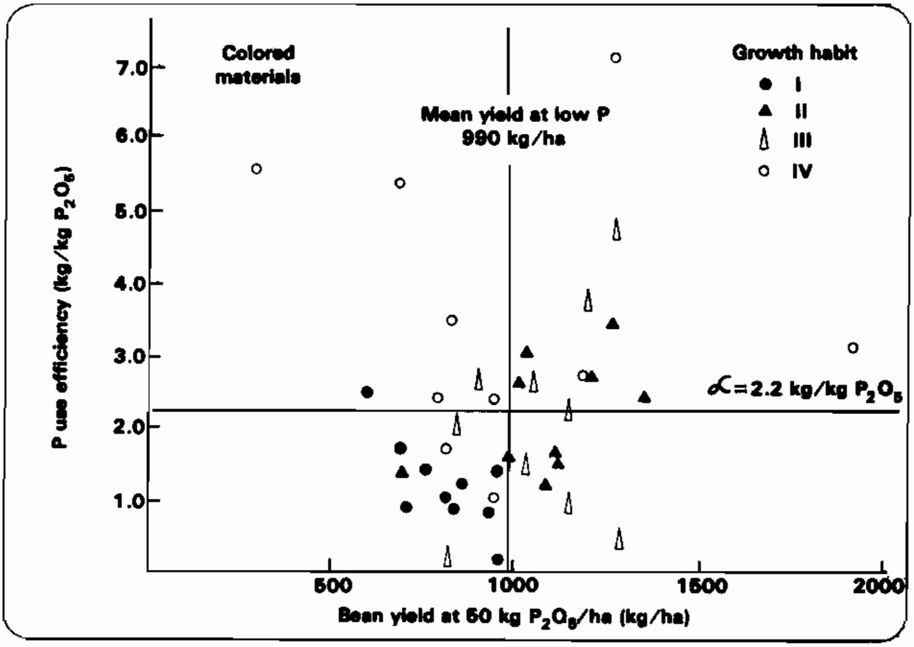


Figure 6. Evaluation of promising bean lines at low and high levels of P application, at CIAT-Quilichao, 1978A.

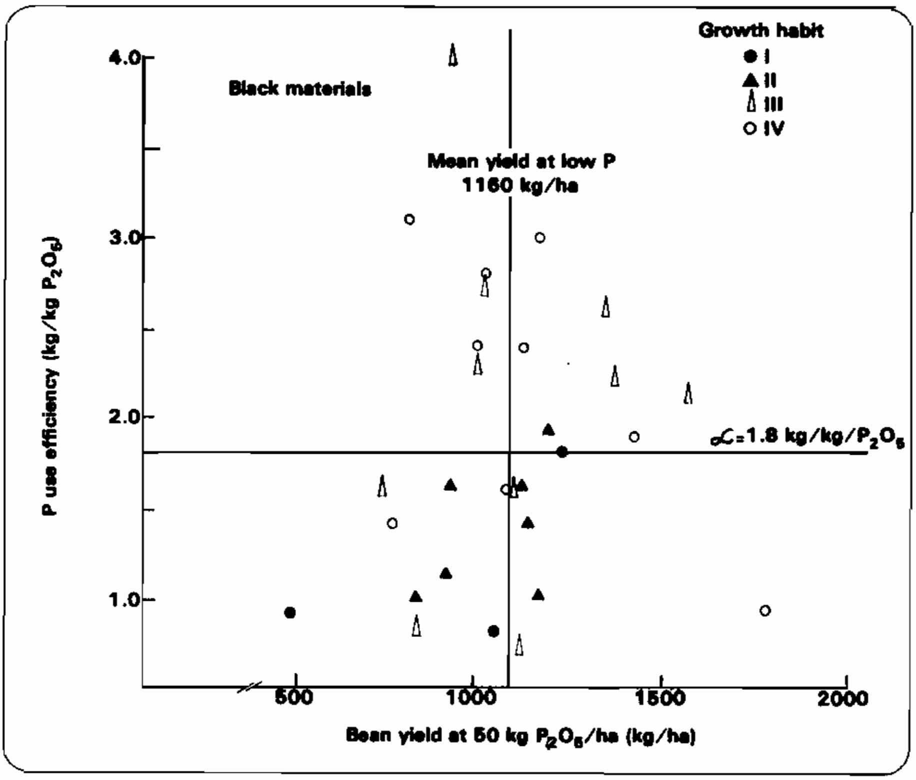


Figure 7. Evaluation of promising bean lines at low and high levels of P application, at CIAT-Quilichao, 1978A.

Table 3.

***Phaseolus vulgaris* materials tolerant to low levels of soil P selected from 188 cultivars tested at CIAT-Quilichao, during the first semester 1978.**

Seed color	CIAT Promising No.	Growth habit	Country of origin	Yield (kg/ha) 50 kg P_2O_5/ha	Yield (kg/ha) 330 kg P_2O_5/ha	Eff. factor[1]
Red	P4	IV	U.S.A.	1050	1360	1.2
	P543	II	Venezuela	960	1540	2.3
	P637	I	Colombia	860	1500	2.6
	P692[2]	I	Colombia	820	1490	2.7
Black	P6	III	U.S.A.	1390	1930	2.2
	P9	III	Guatemala	1590	2110	2.1
	P337[2]	II	U.S.A.	1310	1760	1.8
	P382	II	Venezuela	1490	1940	1.8
	P420	III	Venezuela	1370	2020	2.6
	P423	II	Venezuela	1470	2030	2.2
	P499	III	Mexico	1300	1830	2.1
	P527	IV	Venezuela	1450	1920	1.9
	P566	III	Honduras	1190	1500	1.2
	P700[2]	II	Guatemala	1230	1880	2.6
	P717	IV	Guatemala	1450	2270	3.3
	P752	II	Chile	1300	1840	2.2
Colored	P46	III	U.S.A.	1220	2140	3.7
	P260	IV	U.S.A.	1940	2720	3.1
	P402	I	Venezuela	1360	1970	2.4
	P476[2]	II	Costa Rica	1280	2120	3.4
	P482[2]	III	Costa Rica	1290	2460	4.7
	P589	IV	U.S.A.	1290	3070	7.1
	P654	II	Costa Rica	1220	1900	2.7
	P749	IV	U.S.A.	1200	1880	2.7

1 Efficiency factor: Efficiency of use of P fertilizer expressed as ratio of

$$\frac{\text{Yield at high P level - Yield at low P level}}{\text{Difference of fertilizer units between high and low levels}}$$

2 Also tolerant to extreme acid soil conditions.

colors. Average bean yields increased from 0.5 t/ha at pH 4.0 to 1.6 t/ha at pH 5.0 (6.0 t/ha $CaCO_3$ applied). There was marked variation in yields at lower lime levels and it was not possible to establish a critical level at which effective screening for acid soil tolerance could be undertaken.

Screening for Tolerance to Drought

Research has continued on the development of a screening method for the identification of water stress-tolerant

Table 4.

Phaseolus vulgaris materials that survived the extreme acid soil stresses (86% Al saturation and pH 4.1) at CIAT-Quilichao, during screening in the first semester 1978.

Seed color	CIAT Promising No.	Growth habit	Country of origin	Yield (kg/ha) without lime	Yield (kg/ha) with 5 t/ha of lime
Red	P623	I	Costa Rica	130	970
	P692	I	Colombia	190	1490
Black	P337	II	U.S.A.	120	1760
	P699	IV	El Salvador	170	1930
	P700	II	Guatemala	140	1880
	P709	II	Guatemala	150	1810
Colored	P166	I	U.S.A.	280	940
	P476	II	Costa Rica	350	2120
	P482	III	Costa Rica	170	2460
	P473	III	Brazil	170	1220
	P786	III	Brazil	200	1610

germplasm. Results are available for two large screenings (100 and 168 materials) during the two dry seasons at CIAT-Palmira. The method used was a field screening in which the entries were sown so that all commenced flowering over the same three-day period. Irrigation was suspended in the stress treatment just prior to flowering (50% of plants with one or more flowers per plant) and control plots were irrigated to avoid stress. The number of stress days applied differed in the two experiments due to the incidence of 10 mm of rainfall in three light falls in experiment 7818 during the stress period. A total of 14 stress days were applied in experiment 7728 and 29 in 7818. The yield reductions were more severe in 7728 compared to 7818. A series of problems including, principally, lateral soil water movement in 7818, chlorotic mottle in susceptible entries in 7728 and variable plant density with some varieties, caused variability between replications in the stress treatment. Comparative yield reduction percentages due to stress for 19 cultivars included in the two experiments, as controls, are shown in Figure 9. Data were excluded for three varieties which suffered from the problem of lateral movement of water from the non-stressed to the stressed plots, in 7818. The consistency of these data suggests that the

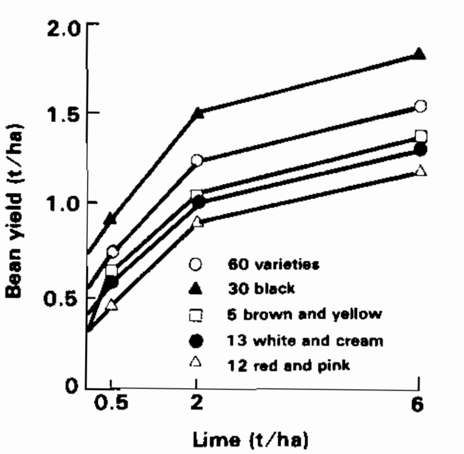


Figure 8. Average response of beans of various colors and of various colors and of total number of varieties to lime applications at CIAT-Quilichao.

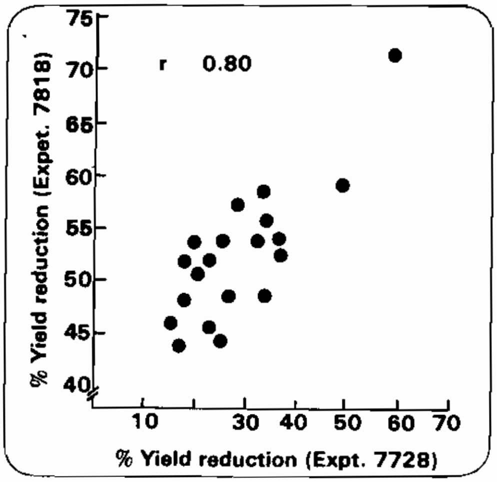


Figure 9. Comparison of yield reduction (control yield - stress yield)/(control yield) due to water stress for 19 control varieties in two screenings at CIAT-Palmira. (Three entries excluded from the data set due to explainable variability between replications in one trial.)

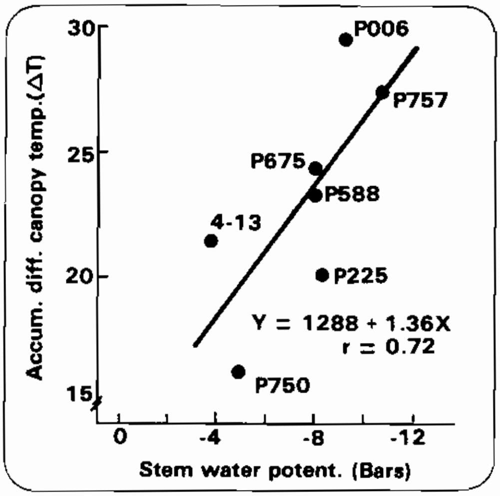


Figure 10. Relationship between accumulated differential conopy temperature (ΔT) for six days during the drying cycle for seven cultivars versus the mean (n=8) stem water potential measured during four hours around noon, for one day during the cycle, Experiment 7728.

screening method may be reliable and that relative water stress tolerance does exist in *Phaseolus* germplasm

On most of the stress days during the drying cycle, canopy temperatures for the wet and dry plots (on either side of a 1-m path) were determined using infrared thermometry between 1100 and 1400 hours each day. The daily difference in canopy temperature (ΔT°C) was summed for the whole stress period (ΣΔT) and is used here as an index of the stress received by each stressed plot during the drying cycle. The relationship of ΔT to stomatal resistance and plant water potential is shown in Figures 10 and 11. These data suggest that ΔT can be used as an index of internal water stress levels. The scatter diagram of percentage yield reduction versus ΣΔT for 127 cultivars in experiment 7818 is shown in Figure 12. The number of entries in each quadrant is shown in the body of the figure. The materials with low yield reduction and low stress are in the bottom left quadrant of the diagram. While soil variability could account for some of the low stress experienced in these latter materials these data do suggest that large differences in yield reduction due to stress was present among these entries. P730 has been

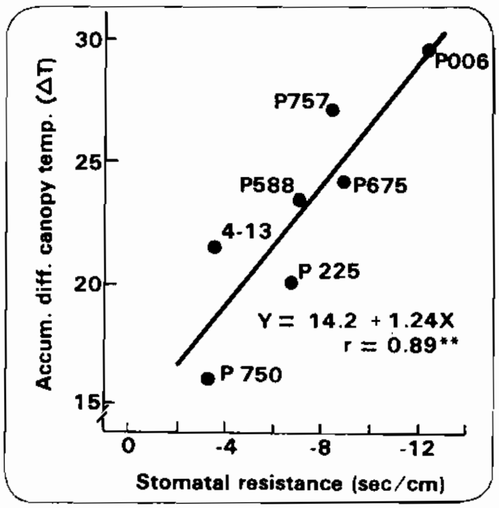


Figure 11. Relationship between differential canopy temperature (ΔT) for six days during the drying cycle for seven cultivars versus mean stomatal resistance (n=16) of exposed canopy leaves measured four hours around noon, for one day in the cycle, Experiment 7728.

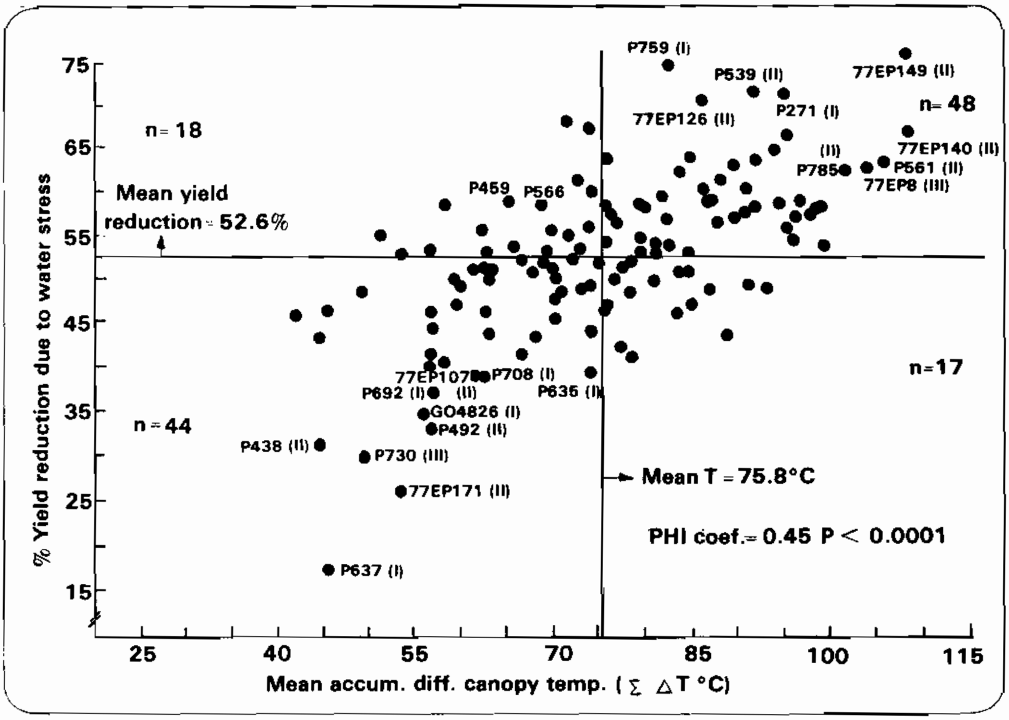


Figure 12. Yield reduction due to water stress in 127 entries versus mean accumulated differential canopy temperature, Experiment 7816. Data for 41 entries were excluded due to problems of soil variability and/or due to recuperation after stress was relieved. (Mean of three replications for each entry.)

previously identified as stress tolerant. P637 has not been identified in previous experiments. Confirmation of the relative stress tolerance of these materials will be necessary with further experimentation. The direct use of $\Sigma \Delta T$ methodology as a primary screening technique for stress tolerance in advanced materials appears to have promise.

Data in Table 5 from experiment 7818 show materials which had a high degree of stress tolerance and a generally low stress index. Contrasting materials with a low degree of tolerance are also shown for comparison. Certain cultivars not shown in Figure 12 or Table 5, mainly from Type III, proved to have a high degree of flower abscission under stress but showed a strong yield recuperation through pod set on secondary flowers once the stress was relieved. The final maturity date was considerably delayed in the stress plots in these latter materials.

Continued methodological research is required before conclusive data on water stress tolerance in *P. vulgaris* can be obtained. Precautions to avoid the sources of variability mentioned here are planned for future screening experiments. Soil textural changes, particularly in relation to variable occurrence of sand layers in the subsoil, may be an added source of variability which will need to be considered in siting future screenings.

Screening for Temperature Adaptation

A series of replicated experiments were conducted at six sites at various altitudes in Colombia (Table 6) during 1978, with 250 selected promising germplasm accessions

Table 5.

Mean control yield, stress yield, percentage yield reduction and accumulated differential canopy temperature (Σ ΔT) for 23 days during a 29-day post-flowering drying cycle for 10 entries showing low yield reductions due to stress compared to four entries with high yield reductions. (Experiment 7818, CIAT-Palmira, 1978).

Indentification	Yield (kg/ha)		Yield reduction (%)	Σ ΔT (°C)
	Control	Stress		
Stress tolerant group				
77 EP 107	378	230	39	62
P438	372	255	31	45
G4826	369	240	35	56
77 EP 171	360	265	26	54
P692	355	224	37	57
P637	345	286	17	46
P708	340	208	39	63
P730	335	234	30	50
P635	266	161	40	75
P492	254	170	33	57
Stress susceptible group				
P539	441	127	72	92
P271	273	78	71	96
77 EP 149	410	99	76	109
77 EP 140	431	143	67	109
Mean of 127			53	76

and advanced breeding materials from CIAT. All four growth habits were represented. The objective of this work was to define the overall temperature adaptation to a wide range of temperature conditions (mean temperatures 12° to 27°C) in a large, representative group of *P. vulgaris* germplasm. The experimental

Table 6.

Locations in Colombia selected for temperature adaptation studies of bean germplasm.

Location	Departamento	Collaborator	Altitude (masl)	Mean temperature (°C)
Santa Fé	Antioquia	Univ. Nal. de Medellin	350	27.0
El Estrecho	Cauca	Private farmer	520	26.0
CIAT-Palmira	Valle	-	1001	23.9
Popayán	Cauca	Sec. de Agricultura	1880	17.6
Manizales	Caldas	Univ. de Caldas	2350	16.0
Pasto	Nariño	ICA - Obonuco	2710	12.7

conditions were designed to minimize disease, insect and differential soil effects and to optimize the water environment, through irrigation, where necessary. The physiological effects of temperature *per se* could then be evaluated without the confounding influence of other environmental effects. Data for 1978A for three locations where these conditions were largely met are available and are shown in Table 7. The complete data set for all six locations will be analyzed when available.

At the low temperature site only 67 of the 250 entries actually set seed with reproductive failure occurring at all stages up to failure to fill apparently fertilized embryos in some lines. The higher yielding cold tolerant group included material from Colombia (P637, P590 and G5772) and from Kenya (G8042). The Kenyan and Colombian highlands are homoclimatic, and further evaluation of the Kenyan collection at high altitude is planned.

Table 7.

Yield data for the highest yielding *Phaseolus vulgaris* materials from among 250 entries at each of three locations having different temperature regimes,[1] in Colombia.

Identification	Growth habit	Yield (t/ha, 14%) at:		
		Santa Fé	Popayán	Pasto
Group 1: Highest yielders at high temperatures (Santa Fé)				
P589	IV	2.23	3.10	0.00
P518	II	2.22	2.72	0.00
P723	II	2.14	2.63	0.00
P757	II	2.14	2.66	0.00
FF00036-3	II	2.12	2.87	0.00
Group 2: Highest yielders at moderate temperatures (Popayán)				
P449	IV	1.22	3.32	0.00
P693	IV	0.96	3.28	0.53
G3144	IV	1.53	3.27	0.19
P738	II	2.10	3.22	0.00
G2227	IV	0.96	3.21	0.14
Group 3: Highest yielders at low temperatures (Pasto)				
P637	I	1.63	2.02	1.41
G5752	I	0.02	1.88	1.32
G8042	I	0.64	1.32	1.04
P590	IV	0.02	1.83	0.94
P706	IV	1.26	2.72	0.92
Site mean yield		1.26	2.38	
L.S.D.		0.47	0.69	
C.V. (%)		23.5	17.9	

1 Temperatures (°C): Santa Fé— Mean, 26.7, Max., 31.3, Min., 22.1; Popayán—Mean, 17.9, Max., 23.9, Min., 11.0; Pasto—Mean, 12.7, Max., 16.4, Min., 9.7.

A very large break in adaptation exists between 17.9° and 12.7°C, exemplified by the highest yielding group out of the 250 entries at Popayan which yielded very poorly or failed to set seed at Obonuco. By contrast, materials such as P589 (IV) and P518 (II) performed quite well at both Santa Fe and Popayan.

The complete data for the temperature adaptation study at the six locations will be used to further define the most appropriate strategy with respect to future screenings for "wide" adaptation to temperature in advanced materials. Preliminary target area study data (see page 49) suggest that the majority of beans are in fact grown over a relatively narrow range of mean temperature conditions compared to the range in this study.

HYBRIDIZATION OF PROMISING MATERIALS AND EVALUATION OF THEIR PROGENY

Mainstream Breeding Activities

In 1977 the Bean Program developed a system for the sequential evaluation of hybrid materials. This is outlined again in Figure 13. Virtually all phases of this program were in operation for the first time in 1978 with advanced generation testing at the Bean Team Nursery (VEF) the Preliminary Yield Trials (EP) and International Bean Yield and Adaptation Nursery (IBYAN) levels. This activity required major inputs from virtually all team members, and other Center Staff including the Data Services Unit, and called for a major logistic and coordination effort and the development of several new testing methodologies. These challenges not withstanding, results were excellent.

Mainstream Crossing Program

In 1978, the number of hybridizations effected at CIAT was somewhat lower than anticipated due to difficulty in obtaining screenhouse space. During the year 558 F_2 populations were evaluated at CIAT. Emphasis in early generation testing remained on resistance (I gene) to bean common mosaic virus (BCMV), rust and anthracnose (screened at Popayan) and tolerance to *Empoasca*. Materials also had to demonstrate good plant architecture and yield potential. As a result of these evaluations 185 families have been selected for inclusion in the 1979 EP.

Bean Team Nursery

The 1978 Bean Team Nursery (VEF) included 1464 materials of which 510 were promising new accessions from the germplasm bank, 937 were selected advanced generation breeding materials and 67 materials had been suggested by national bean programs. Within the trial, accessions were evaluated simultaneously for resistance to BCMV, rust, anthracnose, common bacterial blight and *Empoasca* and for adaptation at CIAT-Palmira and Popayan. Table 8 summarizes results from these evaluations and Table 9 characterizes some of the most promising materials.

Major points observed from results included: (1) virtually all materials showed

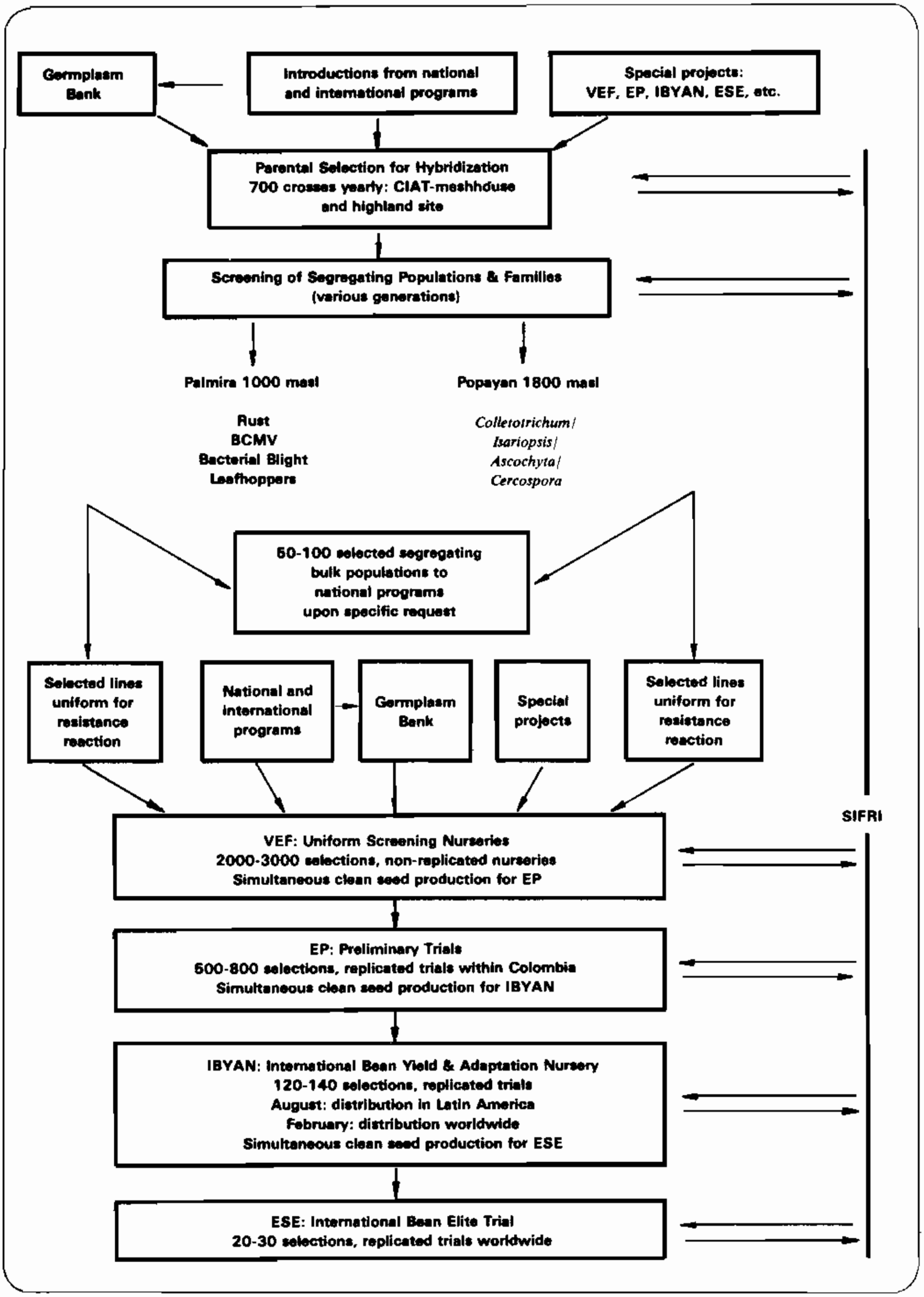


Figure 13. Program for simultaneous and sequential development and evaluation of bean germplasm proposed by the CIAT bean program in 1977.

Table 8.

Summary of evaluations for 1464 entries in the 1978 Bean Team Nursery (VEF).

Category	Insect and Disease Evaluations				
	Leafhoppers	Bean common mosaic virus	Common bacterial blight	Rust	Anthracnose[1]
Resistant	15	1211	5	206	188
Intermediate	165	0	35	67	59
Susceptible	1282	180	1373	782	1173
Variable	0	65	0	407	17
Not evaluated	2	8	51	2	27
	Adaptation Evaluations				
	CIAT-Palmira				Popayan
Excellent	0				0
Good	12				9
Average	539				305
Poor	805				446
Very poor	91				687
Not evaluated	17				17
	Agronomic Evaluations				
	Seed size/Color				
Large/Variable colors	12				
Medium/Variable colors	187				
Small/Black	622				
Small/Red	100				
Small/Other colors	543				

1 Reaction to mixed inoculation to two isolates each of the beta and gamma races.

resistance to BCMV; (2) resistance or immunity to the rust races present at CIAT occurs in 24.3% of the materials; (3) high levels of resistance to bacterial blight have been obtained, but the number of materials possessing this resistance is limited; and, (4) good materials exist in a range of seed coat colors.

One hundred eighty-five of the materials evaluated will pass to the 1979 Preliminary Yield Trial (EP). All selected materials have resistance to BCMV, while 73.5, 38.9 and 17.8% are resistant to rust, anthracnose and *Empoasca*, respectively. Sixteen of the selected lines are well-adapted at both CIAT and Popayan and resistant to BCMV, rust and anthracnose; five of these lines also show resistance to angular leaf spot.

Table 9.

Characteristics of the best entries for major grain types recorded in the 1978 Bean Team Nursery (VEF).

	1978 VEF No.					
Character	1681	1064	1740	2068	1787	1176
Origin	Hybrid	Hybrid	Hybrid	Germ. Bank	Hybrid	Hybrid
Seed color	Red	White	Cream	Pink mottl.	Brown	Black
Seed size	Small	Small	Small	Medium	Small	Small
Days to flower	38	41	39	35	38	42
Growth habit	3	3	2	2	3	2
BCMV	R	R	R	R	R	R
Bacterial blight[1]	4	3	2	4	2	3
Rust	R	R	R	Ip[3]	S	IP
Leafhopper[1]	2.3	2.7	3.7	3.7	3.2	3.5
Adaptation:[2]						
CIAT-Palmira	4	3	4	3	3	3
Popayan	3	3	3	4	4	3
Anthracnose	R	S	R	R	R	R
Angular leaf spot[1]	3	3	1	-	-	-

1 Scored from 1-5; 1 = resistant, 5 = fully susceptible.
2 Scored from 1-5; 1 = highly adapted, 5 = poorly adapted.
3 Intermediate with small pustules.

Preliminary Yield Trial, 1978

While the first Preliminary Yield Trial (EP) contained more than 700 materials, within the range suggested in Figure 13, approximately 500 of these were promising germplasm selections and only 200 advanced hybrid lines from the breeding program. Materials were evaluated for yield (at CIAT-Palmira and Candelaria) and for photoperiod sensitivity, resistance or tolerance to BCMV, rust, angular leafspot, bacterial blight and *Empoasca*, and adaptation (at CIAT-Palmira and Popayan). Results for the trial are summarized in Table 10.

The results show significant gains in several areas: including the following. (1) Virtually all hybrid selections included in the trial showed resistance to BCMV. Almost 99% of the selections made for further study have this property. This has made it possible for the program to implement the decision that all CIAT materials to be included in international trials must have this trait. This will eliminate the possibility of accidental seed transmission of the pathogen. (2) There was a major shift in the proportion of red and colored lines yielding in excess of 2.0 t/ha. While approximately 7% of the germplasm accessions from these color groups yielded over 2.0 t/ha, 46-48% of the breeding selections did. The best yielding materials in each color group are shown in Tables 11 and 12.

At both locations CIAT advanced breeding materials, in all seed colors, outyielded promising lines and germplasm bank materials. Some of these promising lines are the progenitors of the CIAT advanced materials. Furthermore, of the

Table 10.

Percentage frequency of selected traits in germplasm and hybrid selections evaluated by Bean Program disciplines in the 1978 Preliminary Trial (EP).

Character	Selected germplasm				Hybrid selections			
	Seed color			No. of	Seed color			No. of
	Black	Red	Other	entries	Black	Red	Other	entries
1. Yield >200 g/m² [1]	37.0	7.0	7.2	455	61.5	46.4	48.5	277
2. Adaptation >2.5 [2]	44.4	2.2	10.5	498	29.1	7.1	13.9	277
3. Bacterial blight <3.5 [3]	11.5	49.4	31.3	472	44.3	71.4	47.5	278
4 Intermed. or Resist., Rust	6.4	28.4	14.1	401	57.1	35.7	34.7	278
5. Resist. or Segreg. Resist., BCMV	72.6	5.6	40.3	208	99.3	88.9	96.0	274
6. Angular leaf spot ≤3.0 [3]	67.8	28.2	41.5	464	29.3	68.4	48.5	267
7. Leafhopper ≤3.0 [3]	64.1	14.3	21.1	493	65.8	32.1	29.7	278
8. Photoperiod insensitive or slightly sensitive	95.8	54.6	86.8	150	81.8	56.3	62.3	206
9. 1 + 2 + 3 + 5 + 7	0	0	0	500	19.5	10.7	5.9	278
10. 1 + 2 + 5 + 6	0	0	0	500	4.0	1.0	3.5	278

1 Combined average of replicated trials in two locations.
2 Rating scale: 5 = excellent; 1 = poor.
3 Rating scale: 5 = highly susceptible; 4 = susceptible; 3 = resistant; 2 = highly resistant; 1 = immune.

10 best materials in each color group at least 50% have good resistances to at least two major disease pathogens or insect pests. This suggests that substantial progress has been achieved in incorporating good resistance with high yield ability. This is especially true in the red and colored materials whereas the improvement in yield of the black seed color lines was not as dramatic. Growth habit II dominated in the best CIAT breeding materials, however, there were a few outstanding type III lines in the top 10. Many of the promising lines are inferior to the CIAT advanced lines and the germplasm accessions, suggesting that the addition of new parental material to the breeding program would be advantageous.

The best yielders at CIAT-Palmira were not necessarily best at Candelaria. This suggests that factors besides temperature or altitude may need to be taken into account in evaluating the materials for wide adaptation. (3) Table 12 gives the breakdown of the results for photoperiod sensitivity in 353 advanced breeding lines, 206 of which were from the EP trial. While photoperiod response is not being used as a strict selection criterion at this stage, it is interesting to note a marked increase in the proportion of insensitive lines in the advanced breeding material compared to the combined data for previous screenings of germplasm collections. There is, however, some indication of a decline in the proportion of photoperiod insensitive material from the select germplasm to the advanced breeding lines (Table 10). Although not part of the EP system a total of 541 other promising lines and breeding selections were evaluated in yield trials during 1977-78. Outstanding entries are listed in Table 14.

Table 11.

Average yields, compared to the means of the group, of outstanding materials included in 1978 Preliminary Trials (EP), at CIAT-Palmira.

	Yield (t/ha) of:			
	CIAT breeding materials	Promising lines	Germplasm materials	ICA breeding materials
Red materials				
Best material	2.94	1.87	2.24	2.34
Mean of 10 best materials	2.05	1.48	1.44	1.60
Mean of all materials tested	1.72	1.19	0.97	1.25
	(22)[1]	(12)	(12)	(30)
L.S.D. (0.05)	0.60	0.48	0.45	0.66
C.V. (%)	21	24	28	32
Black materials				
Best material	2.62	2.24	2.05	2.11
Mean of 10 best materials	2.33	2.02	1.82	1.75
Mean of all materials tested	1.84	1.51	1.41	1.45
	(122)	(110)	(47)	(32)
L.S.D. (0.05)	0.68	0.53	0.73	0.60
C.V. (%)	23	22	31	24
Colored materials				
Best material	2.55	2.00	1.78	2.24
Mean of 10 best materials	2.20	1.73	1.48	1.87
Mean of all materials tested	1.79	1.23	1.09	1.33
	(64)	(51)	(36)	(35)
L.S.D. (0.05)	0.54	0.56	0.49	0.51
C.V. (%)	19	28	27	23

1 Values in parentheses are the numbers of materials tested in the group.

International Bean Yield and Adaptation Nursery

The network of international yield trials of beans was initiated in 1976 when the International Bean Yield and Adaptati⋅n Nursery (IBYAN) program was put into action. During the three years that this research network has operated, 48 countries have participated and a total of 348 experiments have been distributed throughout the world. Eighty percent of the trials have been sent to countries in Latin America (Table 15).

During the first two years of operation of the network, the principal source of experimental materials was the CIAT *Phaseolus* germplasm bank. In 1976, 20 varieties were tested, all of them having been furnished by national programs; in 1977, 39 new entries were tested with only two of them being lines developed by CIAT. In 1978, however, 36 new materials

Table 12.

Average yields, compared to the means of the group, of outstanding materials included in 1978 Preliminary Trials (EP), at Candelaria.

	Yield (t/ha) of:			
	CIAT breeding materials	Promising lines	Germplasm materials	ICA breeding materials
Red materials				
Best material	2.91	2.20	2.03	1.84
Mean of 10 best materials	2.50	1.91	1.82	1.62
Mean of all materials tested	2.34	1.54	1.51	1.35
	(13)[1]	(30)	(20)	(23)
L.S.D. (0.05)	0.82	0.82	0.66	0.33
C.V. (%)	21	37	27	15
Black materials				
Best material	3.55	2.75	3.01	2.44
Mean of 10 best materials	2.88	2.66	2.79	2.29
Mean of all materials tested	2.02	2.12	2.24	2.06
	(117)	(92)	(43)	(31)
L.S.D. (0.05)	0.71	0.45	1.05	0.29
C.V. (%)	23	13	29	9
Colored materials				
Best material	2.92	2.83	2.48	2.20
Mean of 10 best materials	2.69	2.20	2.20	2.04
Mean of all materials tested	2.08	1.61	1.58	1.63
	(64)	(18)	(35)	(32)
L.S.D. (0.05)	0.67	0.97	1.04	0.28
C.V. (%)	20	36	40	10

1 Values in parentheses are the numbers of materials tested in the group.

were evaluated and 30 of them were CIAT breeding lines. In summary, up to now this testing network has evaluated 95 materials, including 32 lines from CIAT, under a wide range of agroclimatic conditions (Fig. 14).

Table 16 shows the results for the 3rd IBYAN (1978) of colored grain, locally planted in the first semester at CIAT-Palmira and Popayan. Yields of the CIAT lines were excellent, with levels attained that previously were only reached by black-seeded beans. The five best colored lines from CIAT in these two trials exhibited yields as high as ICA-Pijao, the best black variety now commercially available in Colombia. The varieties for temperate zones— Pinto Dorado and Tórtola Diana—are not suitable for the environmental conditions at either CIAT-Palmira or Popayan, although both materials are excellent yielders in Chile, their zone of origin.

The 1978 IBYAN for black-seeded materials showed a group of very promis-

Table 13.

Summary of photoperiod screening results for advanced breeding lines (EP stage) at CIAT-Palmira, 1978A, compared to the distribution of photoperiod sensitivity in all germplasm collections previously screened.

Growth habit	Classification of photoperiod response[1] <4 1	4-10 2	11-20 3	21-30 4	>30 5	Total
I	25[2] (100)	-	-	-	-	25 (100)
II	194 (71)	28 (10)	46 (17)	3 (1)	4 (1)	275 (100)
III	29 (55)	6 11	13 (25)	4 (7)	1 (2)	53 (100)
Total	248 (70)	34 (10)	59 (17)	7 (2)	5 (1)	(353) (100)
% Distribution[3] in germplasm collection	41	12	23	12	12	(100)

1 Range of days of flowering delay in 18 h days compared to natural daylength (12 h 20 m).
2 Data in body of table is number of entries in each classification by growth habit and the percent for each growth habit in brackets.
3 See Table 34, page B-37, Annual Report 1977.

ing breeding lines including FF2-6-3-M-M, FF24-1-M-CB-M, FF26-6-1-M-M-M and FF28-6-1-M-M-M. The first yielded particularly well at both CIAT-Palmira and Popayan and the last one yielded the highest of all materials at Popayan (Table 17).

Table 14.

Best promising materials and breeding selections in yield tests during 1977-78.

Identification	Growth habit	Seed color	Yield (t/ha)	Site	Trial mean (t/ha)
FF 28-6-1	II	Black	3.4	Popayan	2.8
P300	II	Black	3.3	Popayan	2.8
FF 26-6-1	II	Black	3.3	Popayan	2.8
ICA Linea 39	II	Black	3.1	Popayan	2.4
FF 1964-1-CM (8-C)	II	Cream	3.1	Popayan	2.3
FF 2-6-3	II	Black	2.9	CIAT	2.5
FF 16-20-1-M.M.	II	Red	2.8	Popayan	2.3
FF 28-6	II	Black	2.8	Popayan	2.4

Table 15.

Number of trials of the International Bean Yield and Adaptation Nursery (IBYAN) dispatched during 1976-1978.

			Trials dispatched			
	1976 IBYAN		1977 IBYAN		1978 IBYAN[1]	
Region and country	Trials dispatched	Data received	Colored seed	Black seed	Colored seed	Black seed
South America						
Argentina	-	-	-	1	2	2
Bolivia	3	-	-	-	1	1
Brazil	15	9	3	11	16	16
Chile	4	3	2	3	3	2
Colombia	7	6	8	4	4	4
Ecuador	5	2	1	2	1	-
Guyana	-	-	-	1	1	-
Peru	6	5	1	2	5	3
Uruguay	-	-	-	1	-	1
Venezuela	4	1	-	3	-	3
Total	44	26	15	28	33	32
Central America and Mexico						
Belize	1	-	1	1	3	1
Costa Rica	1	-	2	4	4	5
El Salvador	5	5	-	4	5	4
Guatemala	2	-	-	5	-	5
Honduras	4	3	5	2	11	3
Mexico	3	3	1	1	3	5
Nicaragua	3	2	1	-	2	-
Panama	1	-	-	-	2	-
Total	20	13	10	17	30	23
Caribbean						
Cuba	-	-	-	1	3	3
Dom. Republic	3	2	3	-	3	-
Haiti	1	-	1	-	2	-
Jamaica	-	-	2	-	2	-
Puerto Rico	-	-	-	1	1	1
Trinidad & Tobago	1	-	2	-	1	-
Total	5	2	8	2	12	4

1 Through Nov. 30, 1978.

continued

Table 15. (continued)

Region and country	Trials dispatched					
	1976 IBYAN		1977 IBYAN		1978 IBYAN[1]	
	Trials dispatched	Data received	Colored seed	Black seed	Colored seed	Black seed
North America, Europe and Oceania						
Australia	1	1	-	-	-	-
Bulgaria	-	-	1	-	-	-
Canada	1	1	1	-	2	1
Great Britain	2	2	-	1	-	-
Portugal	-	-	1	1	-	-
Russia	1	-	-	-	-	-
Spain	-	-	1	-	-	-
United States	2	2	2	1	1	1
Yugoslavia	1	-	-	-	-	-
Total	8	6	6	3	3	2
Asia						
India	-	-	-	1	-	-
Iran	1	1	-	-	1	-
Israel	1	1	1	-	-	-
Japan	2	1	-	-	-	-
The Philippines	1	1	6	6	-	-
Syria	-	-	-	-	1	-
Thailand	4	1	-	-	-	-
Total	9	5	7	7	2	-
Africa						
Cameroons	-	-	-	-	1	-
Egypt	-	-	1	-	1	-
Gabon	-	-	-	-	3	-
Lesotho	-	-	-	-	1	1
Malawi	1	1	1	-	-	-
South Africa	-	-	1	1	1	-
Swaziland	-	-	1	-	1	-
Tanzania	3	1	-	-	-	-
Total	4	2	4	1	8	1
Grand Total	90	54	50	58	88	62

1 Through Nov. 30, 1978.

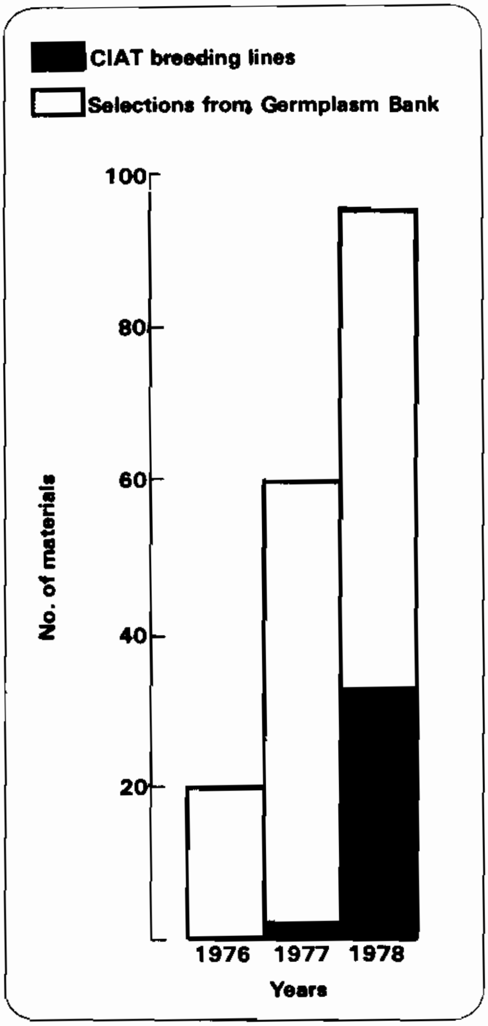


Figure 14. Cumulative numbers of new materials tested in International Bean Yield and Adaptation Nurseries (IBYAN), over three years.

Physiological and Methodological Implications of the 1976 IBYAN. Studies have begun on physiological implications of results obtained in the 1976 IBYAN. As a first step in this evaluation, the flowering phenologies of the 20 international entries were grouped for similarity of performance across world locations (latitude range 0° to 53°). The cluster groups defined by the cluster analysis on days to flowering are shown in Figure 15. The growth habit observed for each line at CIAT and the photoperiod classification are shown to the left of the cluster groups. The clustering had been very efficient at discriminating both growth habits and the photoperiod classification groupings within a growth habit. This means that cultivars within each cluster group behaved similarily in terms of phenology at world locations and that the clustering was in agreement with the independent photoperiod screenings at CIAT. The position of some outlying cultivars, e.g., P643 and P539, can be explained in terms of days to flowering differences measured at CIAT or as a result of photoperiod/temperature interactions. These data open the way for the development of phenological models which will be used as an integral part of the target area study and possibly, at a later stage, in defining adaptation zones for advanced material following photoperiod screening at CIAT.

Similarly, the data in Figure 16 shows the mean yield for the 20 international entries in the 1976 IBYAN at each of 41 locations versus the mean growing season temperature at those locations. The mean temperature conditions at the two principal CIAT bean research locations in Colombia (Palmira and Popayan) are shown as vertical lines. The hand-drawn curve represents the approximate limits of the data with the exception of one tropical Mexican location (sub-humid, irrigated). The highest yielding locations,Chile (CHI) and Israel (ISR),both have Mediterranean climates with warm days, cool nights, high radiation and relatively disease-free conditions. The three lowest yielding locations— coastal El Salvador (ELS) and the Philippines (PHI)—had high temperatures, high humidity and high disease pressure. The high-temperature Colombian location (Santa Fe) was sub-humid and disease free but irrigation was not adequate to prevent severe stress.

Table 16.

Yield for non-black varieties and advanced lines in the Third International Bean Yield and Adaptation Nursery (IBYAN), grown at CIAT-Palmira and Popayan in 1978A.

Entry	Pedigree or name	Seed color	Growth habit	Palmira Yield (t/ha)	Palmira Rank order	Popayan Yield (t/ha)	Popayan Rank order
Best 5 CIAT breeding lines[1]							
FF 16-3-M	P459 x P4	Yellow		3.4	1		
FF 16-3-1-M	P459 x P4	Yellow		3.3	2		
FF 16-26-2-M	P459 x P4	Red		2.8	7		
FF 12-13-1-M	P459 x P567	White		2.8	8	2.8	7
FF 16-10-2- CM-M	P459 x P4	Red-Brown- Yellow		2.8	9		
FF 16-10-1- CM-M	P459 x P4	Red				2.9	1
FF 16-20-1-M	P459 x P4	Brown-Yellow				2.9	2
FF 16-20-2-M	P459 x P4	Brown-Red				2.9	3
FF 16-20-3-M	P459 x P4	Pink-Yellow				2.8	5
Mean				3.0		2.9	
Standard P-line entries[1]							
P402	Brasil 2	Brown	I	3.2	3	2.7	9
P756	-	White	II	2.7	10	2.7	13
P692	Diacol Calima	Red (mottled)	I	2.6	19	2.6	14
Mean				2.8		2.6	

1 Common entries for every trial.

continued

Table 16. (continued)

Entry	Pedigree or name	Seed color	Growth habit	Palmira Yield (t/ha)	Palmira Rank order	Popayan Yield (t/ha)	Popayan Rank order
Entries from national programs[1]							
INIA-Chile	Pinto Dorado	Cream (mottled)	I	2.4	24	2.6	16
INIA-Chile	Tortola Diana	Grey	III	1.9	25	1.9	25
Mean				2.2		2.2	
Local checks							
	ICA-Pijao	Black	II	3.1	4	2.7	12
	C-63 S-630-B	Cream	II	3.1	5	2.6	17
	Puebla 152	Brown	III	3.0	6	2.8	4
	Flor 76	Red	I	2.7	15	-	
	Porr. Sintetico	Black	II	2.6	18	2.4	23
	Neo-2	White	I			2.7	10
Mean				2.9		2.6	
Mean of 25 materials				2.7		2.6	
L.S.D. (0.05)				0.5		0.4	
C.V. (%)				11.28		8.71	

1 Common entries for every trial.

Table 17.

Yield for black varieties and advanced lines in the Third International Bean Yield and Adaptation Nursery (IBYAN), grown at CIAT-Palmira and Popayan in 1978A.

Entry		Pedigree or name	Growth habit	Palmira Yield (t/ha)	Palmira Rank order	Popayan Yield (t/ha)	Popayan Rank order
Best 5 CIAT breeding lines[1]							
FF 2-6-3-CM-M	F_7	P459 x P6	III	2.9	3	2.8	3
FF 49-1-1-M-M	F_5	(P459 x P8) (P8 x P568)	III	2.8	4		
FF 24-9-1-M-CB-M	F_6	(P459 x P488) (P459 x P568)	II	2.8	5		
FF 831-CB-CM-CM	F_5	P346 x P720	II	2.7	7		
FF 1282-CB-CM-M	F_5	(P538 x P337) (P556 X P685)	II	2.6	9		
FF 28-6-1-M-M-M	F_6	(P459 x P568) (P488 x P568)	II			3.0	1
FF 26-6-1-M-M-M	F_6	(P566 x P568) (P459 x P568)	II			2.8	2
FF 551-CB-CM-M	F_5	P511 x P5	II			2.6	6
FF 45-2-M-M-M-M	F_5	(P459 x P568) (P8 x P568)	III			2.6	8
Mean				2.8		2.8	
Standard P-line entries[1]							
P675		ICA-Pijao	II	2.9	2	2.3	18
P737		Jamapa	II	2.6	10	2.4	15
P566		Porrillo Sintetico	II	2.3	18	2.1	24
Mean				2.6		2.3	
Entries from national programs[1]							
INIA-Chile		Negro Argel	II	2.8	6	-	
ICA 77A 10103		Venezuela 44 x Jamapa	II	2.7	8	2.4	13
Mean				2.8		2.4	
Local checks							
		Ex Rico	II	3.0	1	2.8	4
		ICA-Tui	II	2.5	12	2.6	7
		S-166-A N-555	II	2.5	13	2.4	14
		PI 309 804	II	2.5	14	2.7	5
		Venezuela 2	II	2.1	23	1.4	25
Mean				2.5		2.4	
Mean of 25 materials				2.5		2.4	
L.S.D. (0.05)				0.5		0.4	
C.V. (%)				12.46		9.37	

1 Common entries for every trial

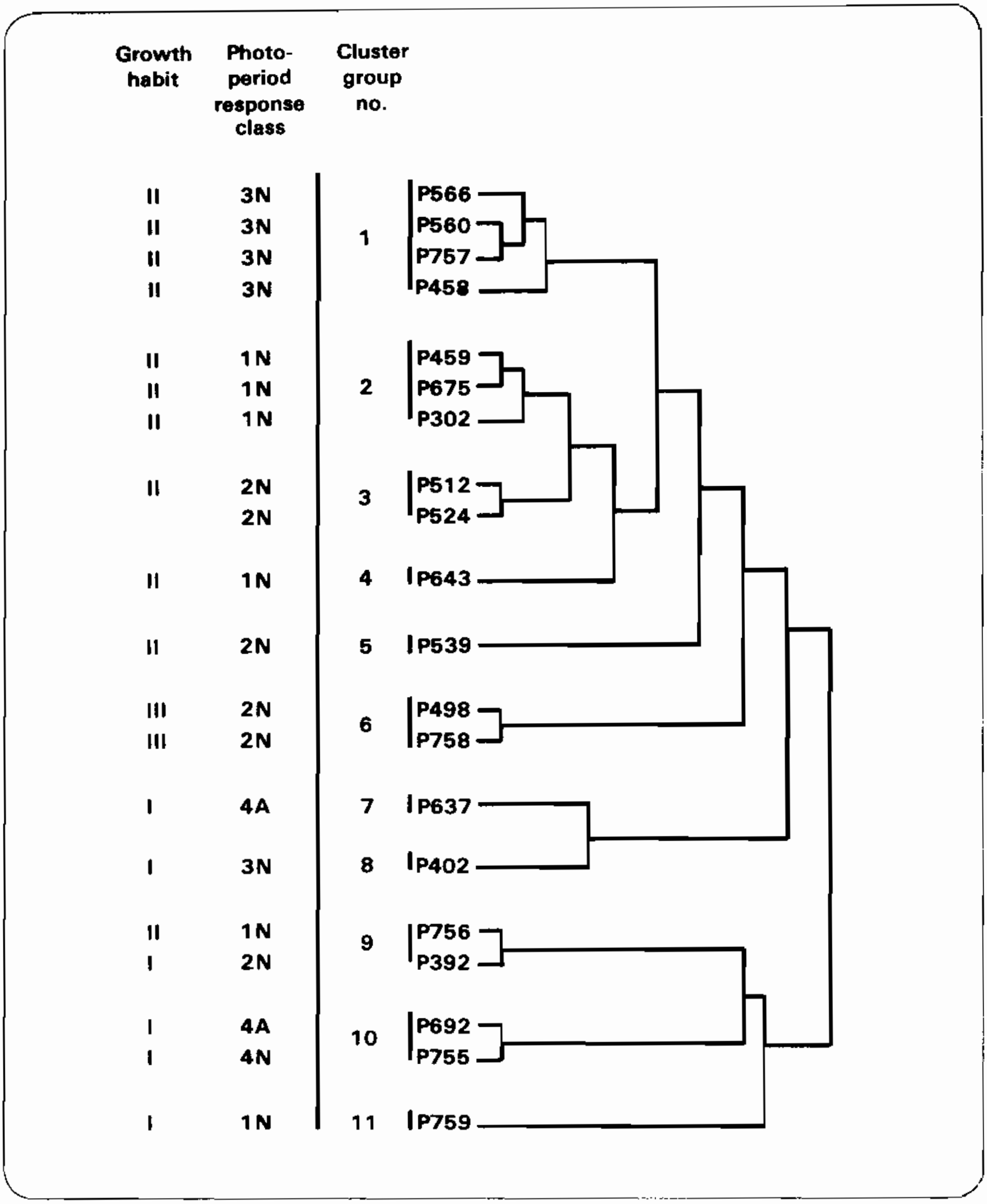


Figure 15. Cluster analysis diagram of similarity of flowering phenology at 27 world locations of the 1977 IBYAN (right of vertical line) compared to independent evaluation of photoperiod sensitivity at CIAT (left of line). Photoperiod classes: 1 = <4 days flowering delay in 18 hours (h) compared to 12 h 20 min; 2 = 4-10 days; 3 = 11-20 days; 4 = 21-30 days; 5 > 30 days. N = normal flowering (in 18 h) when flowering commences; A = abnormal flowering with abscission.

The position of most of the Brazilian and Peruvian locations at "optimum" temperatures but with very low yields suggests that other factors were operating such as disease and soil problems in Brazil and possibly low radiation at the Peruvian irrigated sites. The position of many of the other data points can be explained on the

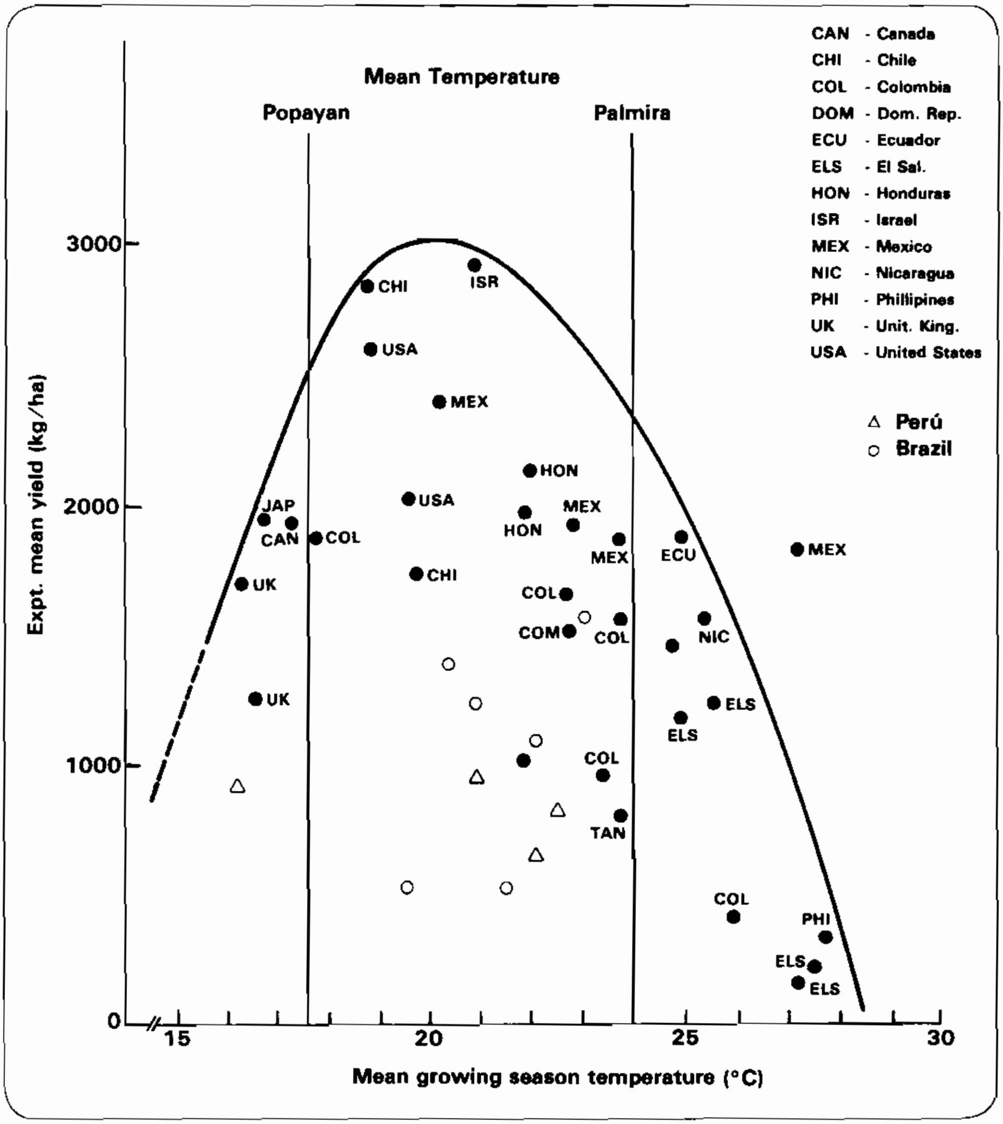


Figure 16. Mean yield across 20 common entries in the 1976 IBYAN versus growing season mean temperature for each of 41 locations where temperature data were provided. Data points for Brazil (BRA), Peru (PER) are separately identified. Chile (CHI) and Israel (ISR) have the two highest yield levels. Other countries identified by first three letters.

basis of agronomic problems encountered at each location. The cooler high latitude locations in the United Kingdom (UK), Japan (JAP) and Canada (CAN) are grouped closely together. The predominance of the locations between the mean temperature limits set by CIAT-Palmira and Popayan suggest that these two sites are probably ideal for the evaluation of adaptation to temperature in advanced materials, at least for bush beans. The analysis of individual cultivar responses to temperature within the IBYAN data set will assist in defining the relationship between yield evaluations in Colombia and world performance.

Bush Bean Breeding — Specific Problem Activities

Separate projects have been developed for several traits where evaluation of the germplasm available has failed to reveal adequate diversity. It is planned that these projects will enhance levels of disease or insect tolerance, and build architecturally better plants having enhanced yield potential.

Common Bacterial Blight

Crosses are being evaluated from the intermating of selections from P698 and P684 progenies and several mainstream families that demonstrated blight resistance. Breeding activities are being intensified to increase genetic resistance to *Xanthomonas phaseoli,* which appears to be one of the most widespread and yield-limiting factors for bean production in Latin America. Results from screening an array of germplasm from the bank and hybrid progenies, suggest that black materials do not enjoy the same advantage as in other diseases.

Bean Golden Mosaic Virus

The national program in Guatemala has conducted replicated yield trials, under BGMV pressure, of F_4 and F_5 families from selections of the first group of crosses evaluated in Central America (CIAT Annual Report, 1977). Results of those black-seeded progenies, tested by the Instituto de Ciencia y Tecnología Agrícola (ICTA) in monoculture and in association with maize, appear very promising.

A total of 766 F_2 and F_3 populations were distributed among four collaborating countries during 1977. Greater priority has been given to increasing BGMV resistance in non-black materials. Additional crosses have been made to recombine the resistance of ICTA-CIAT selections with resistance reported by Brazilian workers.

An integrated breeding, selection, and progeny testing scheme for BGMV improvement was developed during 1978 with the collaboration of national program scientists (Figure 17), with the objective of obtaining a complete cycle of recurrent selection and intermating each year.

Empoasca kraemeri

Breeding for resistance to *Empoasca kraemeri* has progressed through three generations of intermating and recurrent selection since the initial single and double crosses were made (Table 18). F_1 progenies are divided into screenhouse (female) and field (male) groups, utilizing F_2 seed from the previous cycle to progeny test under *Empoasca* pressure in the field. Parents are selected and intermatings made on the basis of the progeny test.

A field comparison was made of materials produced by different amounts and methods of selection (Table 19). Each material was evaluated visually for *Empoasca damage* (0 = no damage, 5 = highly susceptible) and dry seed yield per plant. The superiority of more highly selected materials is apparent. The mean squares variances are sufficiently similar between groups to be regarded as coming from a single population for the two characters evaluated. Comparisons between groups indicated that pedigree selections from the base population, and selections used as females for the third crossing cycle, were superior to the base population.

The relatively poor performance of selections used as males for the third crossing cycle is perhaps explained by confounding effects from a heavy attack of chlorotic mottle in the nursery where these selections were made. Results from *Em-*

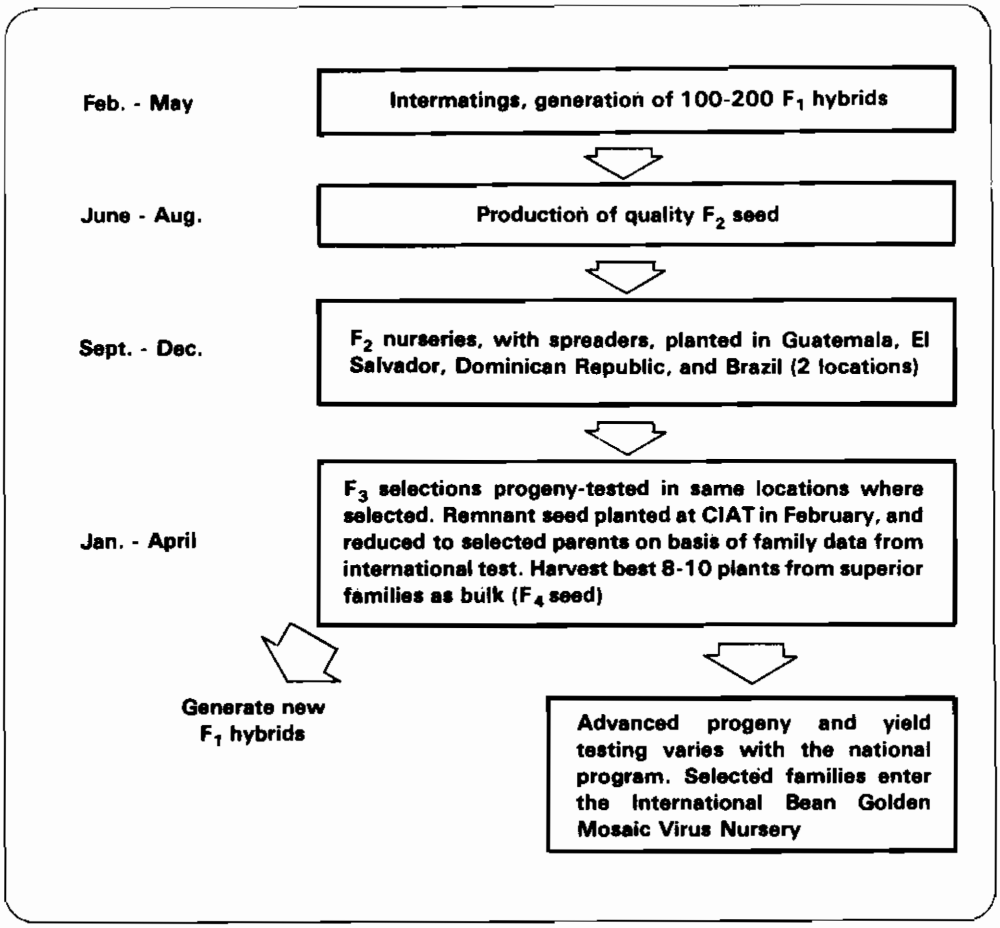


Figure 17. Genetic improvement for resistance of beans to bean golden mosaic virus.

poasca breeding are most encouraging when one considers that selection pressure is being exerted in favor of non-black offspring, while most of the *Empoasca*-resistant parents are black-seeded or mulatinho (beige).

Plant Architecture

Based on available germplasm, improvement projects were initiated in the 1978B season for: lodging resistance, small foliage, early maturity, and delayed flowering and foliage senescence. Numbers of parents used and crosses made are shown in Table 20. About 400 F_3 families and 128 F_2 populations, primarily interesting for architectural characters, were screened at Popayan during the 1978B season. Approximately 45 F_3 families and 483 single plant selections from 48 F_2 populations with anthracnose resistance and good adaptation were selected for further evaluations.

Drought Tolerance

Materials with moderate levels of drought tolerance were identified by the team physiologist. Based on those results

Table 18.

Stages in development of intermating and recurrent selection for resistance to *Empoasca* spp.

1976-77	- 224 single and double crosses among original *Empoasca* parents. - 1000 selections evaluated 1977. - 54 families to 1978 VEF.
1977	- 175 intermatings and three way crosses. - 15 new parents added from germplasm. - Initiated intermating and progeny testing. - Best 30 families to 1979 VEF. - Inheritance studies inititated.
1978	- 135 intermatings. - Progeny tested in field 1978B. - 28 best families to 1979 VEF.
1979	- Intermating, progeny testing, and selection. - Emphasis to larger, non-black grain types. - Examine related *Phaseolus* species.

and additional observations, 12 sources of drought tolerance and 4 leading cultivars grown in the target areas were selected to initiate the breeding project. Six crosses were made for improvement of drought tolerance, however, the current screening technique appears inadequate to evaluate segregating populations and early generation families.

Climbing Bean Breeding

During the year the climbing bean breeding program has developed rapidly. It is aimed mainly at breeding bean varieties suitable for associated cropping systems with maize. Within the range of temperatures most important for bean production in Latin America (see p. 49), production from climbing beans tends towards the cooler end of the scale. That is, they are mostly found at present in the highland regions of Central and South America, planted in direct association or relay cropping with maize. The most important temperature range for South America is thought to be covered by two locations in Colombia, Popayan (1850 m) and ICA- La Selva (2200 m), and for Central America by CIAT-Palmira (1000 m) and Popayan. A fourth location, ICA-Obonuco (2700 m) is being used to test materials for extreme highland adaptation, thus covering almost completely the whole temperature range of probable production.

Crossing Program and Early Generation Selection

During the year a total of 231 climbing bean crosses were made, all of them simple crosses involving two parents only and divided into projects according to preferred colors for which later selection is directed (Table 21). A backcrossing program in collaboration with ICA (Colombia) was also begun for highland adapted climbing beans of favored commercial grain type for the Andean countries and the highlands of Mexico and some Central American countries. The recurrent parents selected were: Cargamanto (large grain cream/red mottled); Ecuador 51 (large grain yellow); and ICA L.32980 M (4) (large grain red). These varieties have useful agronomic characteristics for relay cropping and association with maize at mean temperatures below about 20°C. The backcrossing program aims to introduce resistance to anthracnose and BCMV to the varieties mentioned.

Table 19.

Mean *Empoasca* scores and yields of eight groups of materials representing different stages of selection, evaluated under *Empoasca* pressure at CIAT-Palmira.

Germplasm group	*Empoasca* score[1] No.	Avg.	Mean squares	Yield (g/plant) Avg.	Mean squares
Parents and single crosses	59	2.39	.812	15.4	46.63
Initial parents[2]	19	2.34	1.008	16.3	58.42
Double crosses	40	2.44	.884	16.8	41.57
Mass selection from double crosses	40	2.16	.870	17.6	68.07
Pedigree selections from single crosses	40	2.08	.851	17.9	60.51
New germplasm[3]	15	2.33	1.062	14.9	82.39
Males for fourth crossing cycle	67	2.26	.861	18.6	49.15
Females for fourth crossing cycle	37	1.91	.909	19.7	58.00

1 Rating scale of 1-5: 1 = highly resistant; 5 = highly susceptible.
2 Considered as the base population.
3 New bank accessions introduced to crossing block.

A total of 129 F_2 hybrid populations were also planted and evaluated for BCMV, rust and anthracnose resistance. Plants showing resistance or tolerance were selected individually for plant type, pod type and seed color.

Table 20.

Summary of parents used in field crossing work by the Bean Program, 1978.

Project	No. of parents used	No. of crosses
1. Anthracnose resistance	22	107
2. Lodging resistance	4	14
3. Small foliage	5	8
4. Drought tolerance	4	6
5. Heterosis	15	14
6. Miscellaneous	29	142
Total	79	291

Progeny Testing and Preliminary Yield Trials

A total of 300 progenies from single plant selections made in CIAT-Palmira were tested in the first semester of 1978 in parallel evaluations: in the screenhouse for

Table 21.

Hybrids made according to project color in the climbing bean crossing activities, CIAT Bean Program, 1978.

Project color	No. of hybridizations	Percentage of total
Black	111	48
Red	57	25
Yellow	23	10
Cream	18	8
Coffee	15	6
White	7	3

Table 22.

Some selections of climbing beans made from progeny testing and preliminary yield trials, in 1978.

Identification		No. of F_2 single plant selections	Reaction to:			Yield (kg/ha)		Growth habit	Color[6]
Climbing bean code	Cross		Leaf-hopper[1]	BCMV[2]	Anthrac-nose[3]	Palmira[4]	Popayan[5]		
16	P459 x G2115	4	2.5	R	U	503	1801	III b	Red
248	G3762 x G3738	9	2.5	R	R	2004	1342	IV b	Black
259	G5710 x G3736	6	5.0	R	R	1452	1042	IV a	Cream mottl.
615	G1813 x G3738	5	3.8	R	R	1574	1111	IV a	Yellow
623	G3130 x G3738	15	2.2	R	R	1573	1123	IV a	Black
623	G3130 x G3738	20	3.2	R	S	1590	2257	IV a	Black
623	G3130 x G3738	29	2.0	R	S	1262	1991	IV a	Black
3632	G881 x G2540	16	2.8	R	S	1385	1478	IV b	White

1 Mean of three ratings; values up to 3 indicate acceptable tolerance.
2 Glasshouse seedling test; R = uniform resistance.
3 Under field inoculation; R = resistant, U = uncertain, S = susceptible.
4 Sown at 40,000 plants/ha with maize at same density, with two insecticide applications only.
5 Sown at 40,000 plants/ha below mature maize stalks at same density, with two insecticide applications only.
6 Uniform color, bulk selected at harvest.

BCMV; in the field (Popayan) for anthracnose; in the field (Palmira-dry season) for *Empoasca;* and in preliminary yield trials two replications) in Palmira and Popayan. This methodology is only possible given the large quantity of seed produced by climbing bean single plant selections.

Of these materials 74% proved fully resistant to BCMV and 22% had acceptable levels of tolerance to *Empoasca.* Data for some outstanding selections are shown in Table 22.

International Bean Climbing Trials

The first International Bean Yield and Adaptation Trial for climbing beans (IBYAN-climbers) was organized during 1978. While based on the methodology already developed for bush beans, the collaborator may either plant simultaneously with local maize, or in relay cropping depending on the common practice or most appropriate system for the area. It is believed to be the first ever international trial of varieties selected for associated cropping.

Its objectives are to make available to national programs the best materials selected by CIAT from the germplasm bank or from breeding, and to evaluate progress from year to year of CIAT-selected materials relative to local control varieties in a wide range of environments.

Because of strong local consumer preferences the trial is divided according to color : Black, with nine varieties and one control; Red, with nine varieties and one control; and other colors, 24 varieties and one control.

The trials are being distributed in September of every year. In September 1978, 19 trials were sent to 13 countries, mainly in Latin America.

EVALUATION AND IMPROVEMENT OF AGRONOMIC PRACTICES

Response to Plant Density

To evaluate how plants of different growth habit respond to plant density 55 cultivars of growth habits I, II and III were grown at 8 established plants/m² (a density common in farmers' fields) and 24 plants/m² (a value commonly found to be optimum in CIAT bean trials). Yields for the 55 varieties at each plant density are shown in Figure 18. In general, type I cultivars responded strongly to higher densities while type II cultivars showed a moderate density response, although again the two highest yielders at low density (P498 and P758) were of this growth habit.

In further studies on this topic the spatial relationships of plants at any given density was shown to be important. Thus for a type I plant with limited branching the yield at 20 plants/m² varied from 1300 kg/ha when rows were 1. 0 m apart and seeds packed within the row, to almost 1900 kg/ha when rows were 0.4 m apart (Fig. 19). A similar result occurred with the type II Porrillo Sintetico (P566) but was much less noticeable in the case of P498.

Maize/Bean Association

Growth and Development of Maize and Beans

Analysis of growth and development for a type IV bean variety grown in direct

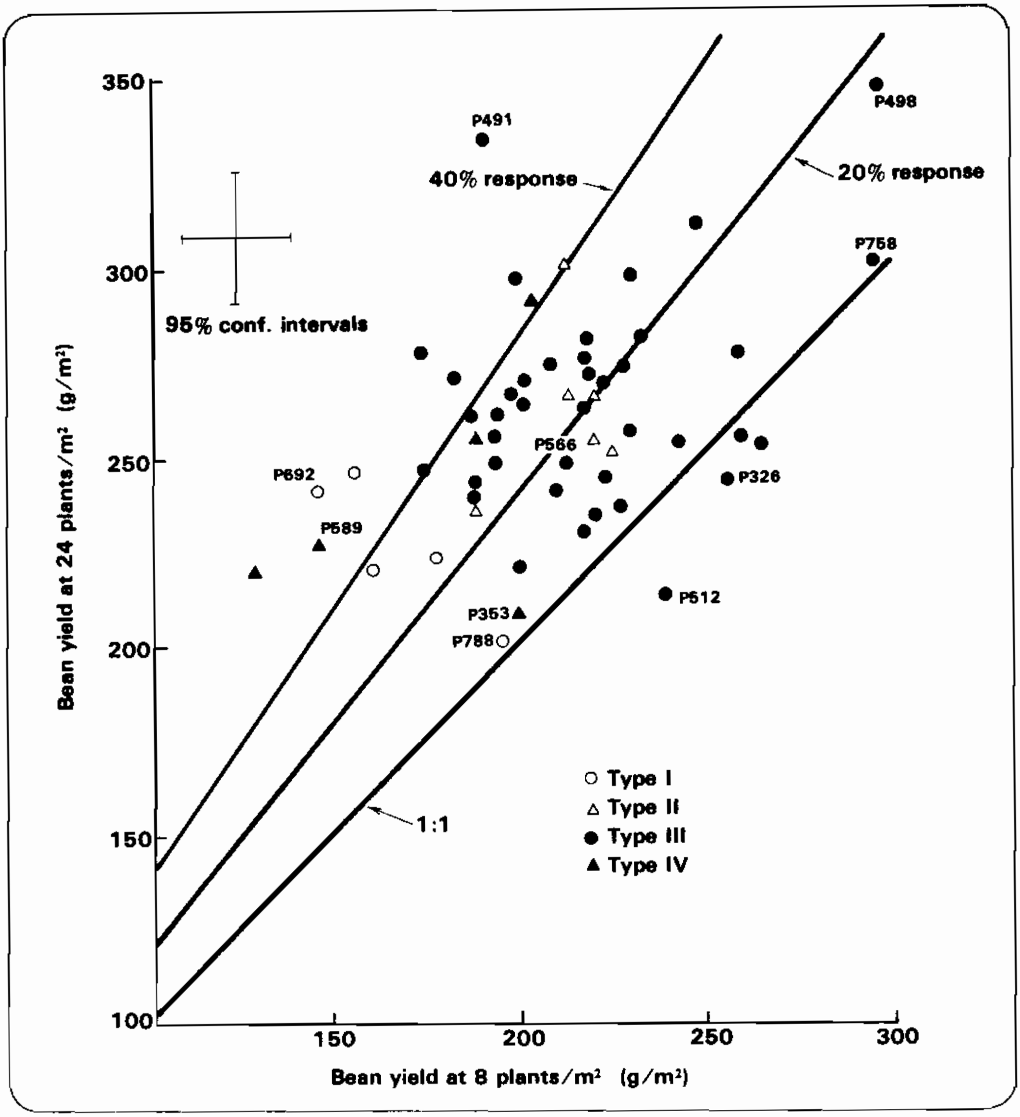


Figure 18. Yield of selected cultivars from growth habits I-IV in monoculture without support when grown at 8 plants/m² compared to yield measured at 24 plants/m², at CIAT-Palmira, Experiment 7807, 1978A.

association with maize (an ICA brachytic hybrid was used to ensure lodging resistance) was studied in 1977-78. Yields of both crops decreased heavily when grown in association (Table 23). The bean variety climbed vigorously on the relatively short-statured maize with a resulting 45% decrease in yield of maize. In recent experiments at CIAT-Palmira with normal height maize, maize yield reductions of 20-30% have been recorded. On the other hand, the 51% yield reduction in beans is a common figure in most direct associations. Leaf area curves for the two species are shown in Figures 20 and 21. The early competition from the maize was associated with a slower rate of leaf area development in beans and lower maximum leaf area compared to monoculture. Leaf area duration (LAD) was reduced in beans by

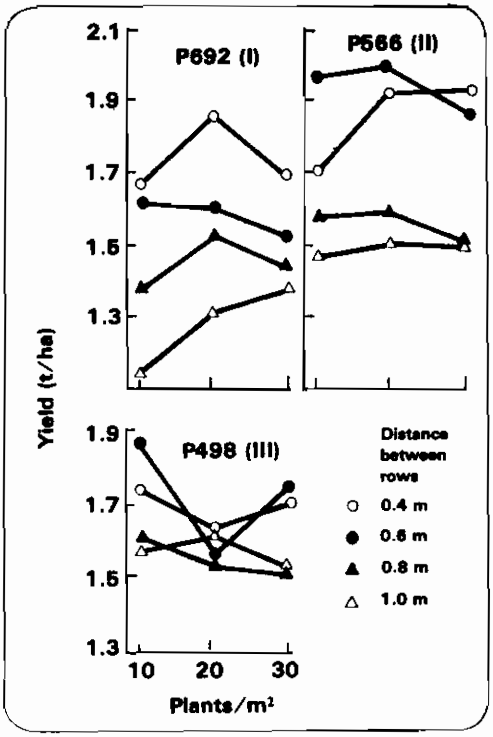


Figure 19. Response of three bean cultivars of different growth habits to various planting densities and between-row distances.

the maize competition while maize had a lower LAD after flowering, presumably due to more rapid leaf senescence arising from the bean competition. A comparison of the reduction in LAD and yield/LAD values for the two species suggests that the beans suffered a greater reduction in the LAD but less relative reduction in efficiency of the LAD. The vertical profile of the bean leaf area, placed above the majority of the maize leaf area in the later phase of growth, probably contributed to shading and more rapid senescence of the maize leaves with a resulting greater reduction in maize leaf efficiency.

In a second trial three maize genotypes (ICA H-210, the brachytic maize used in the previous experiment; Suwan I, a CIMMYT selection of intermediate height; and La Posta, a tall maize from CIMMYT) were grown in association with 10 bean genotypes. In associated culture with 40,000 maize plants/ha, La Posta consistently out-yielded Suwan 1, with the

Table 23.

Yield and other key parameters for the direct association of maize (var. ICA H-210) and a climbing bean (P589) compared to monoculture of both species, CIAT-Palmira, 1977B.

Parameter	Monoculture maize	Association		Monoculture beans
		Maize	Beans	
Yield, (kg/ha)[1]	5734	3185 (55)[2]	1943 (49)[2]	3925
Cobs or pods/m²	4.1	2.8 (68)	163 (63)	258
Grains/cob or pod	453	280 (62)	5.6 (81)	6.9
Bean size (mg/bean)	-	-	183 (97)	189
Harvest index (%)	32.6	29.6 (91)	57.4 (94)	60.9
Days to silking/flowering	59	62 (105)	49 (102)	48
Days to physiological maturity	117	129 (110)	102 (109)	94
Yield per day (kg/ha/day)	49.0	24.7 (50)	19.0 (46)	41.7
Leaf area duration[3] (LAD)	176	141 (80)	119 (64)	185
Yield/LAD[4]	3.25	2.26 (70)	1.63 (77)	2.12

1 Grain moisture content; 15% maize, 14% beans.
2 Percent of values in monoculture of each species.
3 LAD emergence to physiological maturity (m² days/m²).
3 Leaf area efficiency (g/m² days/m²) (yield on 14 or 15% basis).

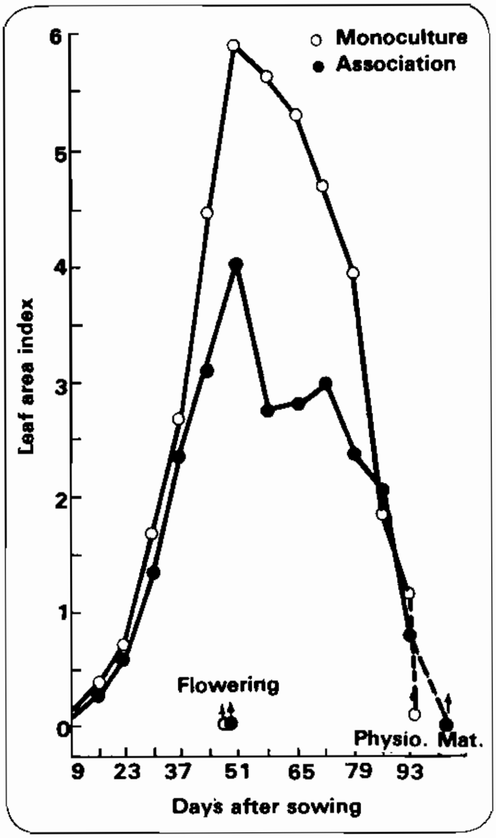


Figure 20. Leaf area growth curve for bean cultivar P589 (IV) when grown in monoculture and in association with maize (ICA H-210), at CIAT-Palmira, 1978A.

ICA hybrid generally lowest yielding (Fig. 22). In contrast bean yields were generally greatest when planted in association with Suwan 1. Two extremely vigorous bean cultivars, G2258 and P503 (Type IVb) performed extremely well in association (Table 24).

The price differential of beans:maize in Colombia is more than 3: 1. At above 2.5:1 it was more economical to use Suwan 1 in association than the higher yielding La Posta (Fig. 23). When a price ratio of 3:1 was assumed, there was no difference in net income between the type IV and IVb bean cultivars. However the type IVb showed increasing advantage as the bean:maize price differential increased (Fig. 24). Type

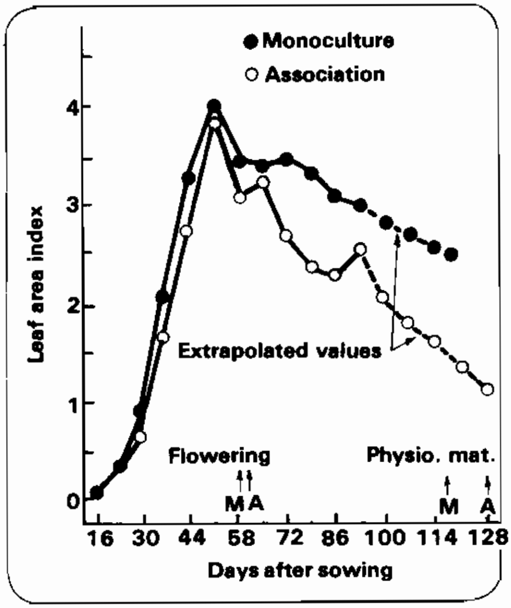


Figure 21. Leaf area growth curve for ICA-H210 brachytic maize hybrid when grown with bean cultivar P589 (IV) in association and in monoculture, at CIAT-Palmira.

IVa plants were more productive in monoculture and may therefore be preferred for relay cropping with maize.

Effect of Maize Genotype

A trial was carried out with several

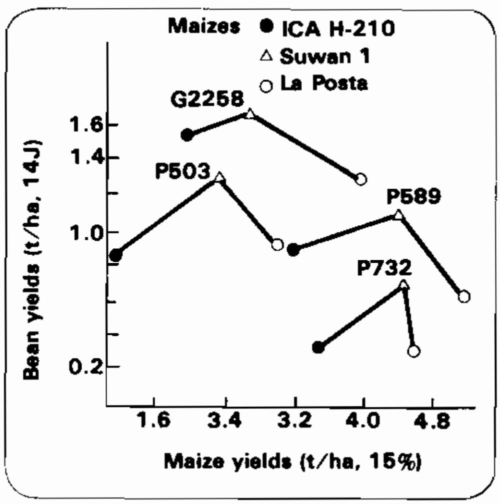


Figure 22. Yields of four climbing bean varieties and three maizes, at CIAT-Palmira.

Table 24.

Yields of 10 climbing bean cultivars in monoculture (on trellises) and in association with three maize varieties, at CIAT-Palmira, 1978.

Identification	Growth habit	Yield in monoculture (kg/ha)	Yields (kg/ha) in association with: H-210	Suwan-1	La Posta	Mean yield in association (kg/ha)	Association/monoculture yield (%)
G2258	IV b	3499	1563	1669	1298	1510	43
P503	IV b	2062	856	1320	924	1033	50
P589	IV a	3610	902	1108	636	882	24
P105	IV a	3214	1205	526	668	799	25
P326	III a	3513	893	762	656	770	22
G2801	IV a	3872	821	825	640	762	20
P526	IV a	3263	851	737	603	730	22
P758	III b	3310	597	509	476	527	16
P732	IV a	1762	343	704	321	456	26
P472	III b	1757	371	313	268	317	18
Mean		2986	840	847	649	779	
L.S.D. (0.05)		519	364	364	364	210	
F test		21.15***	7.99***	10.14***	5.25***	20.03***	

maize genotypes in direct association with the climbing bean, P589, to determine an ideal maize type for association. While maize yields were reduced in every case as

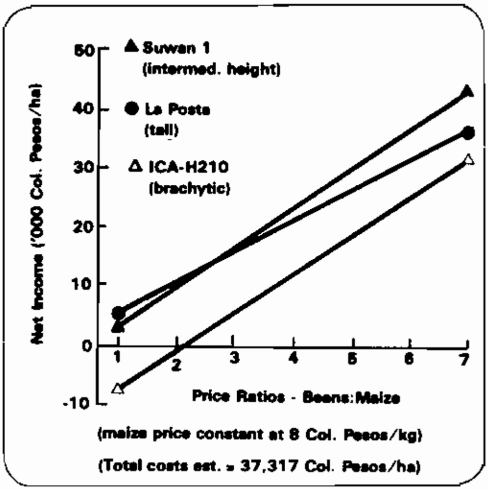


Figure 23. Net income at various bean: maize price ratios for three maize genotypes in association with 10 climbing bean varieties, (Mean yield data).

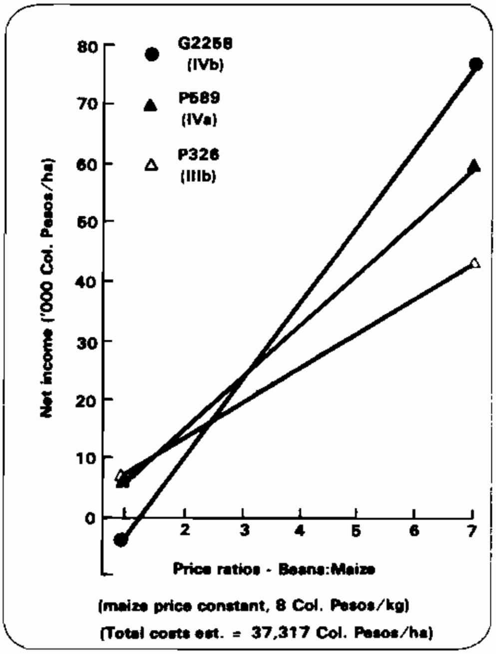


Figure 24. Net income at various bean:maize price ratios for the highest yielding bean varieties of each plant type in association with the maize Suwan 1.

shown above, taller maizes did not suffer as much as the shorter or brachytic maizes and maizes with a high percentage of root lodging tended to do relatively better in association (Table 25). Root lodging was greatly reduced by association in almost every case, due to a physical anchoring effect of climbing beans planted on either side of the maize. Stem lodging, on the other hand, increased in association in almost every case. Maize genotypes for association should, therefore, be reasonably tall and as resistant as possible to lodging.

Evaluation of Herbicides

Previous studies have shown that for local conditions at CIAT-Palmira, the combination of linuron and fluorodifen, in pre-emergent applications, adequately controls the majority of weeds that develop in bean fields.

In order to find the most economical formula for controlling weeds, an experiment was conducted during the first semester of 1978. Five compounds were evaluated in various combinations and compared with manual weeding at different ages of the crop. The bean variety Diacol Calima was seeded in beds with 0.5 m between the ridges. All the chemical treatments were in pre-emergent applications.

Practically all the combinations of herbicides were equally effective in controlling weeds. Bean yields with the chemical treatments were statistically similar to hand weeding up to time of flowering (Table 26).

Phosphorus Fertilization of Beans

Studies at Popayan (CIAT Annual Report, 1977), using rates of fertilization from 0-2060 kg P_2O_5/ha as triple superphosphate, showed beans to have a high P requirement. When these plots were planted a third time to assess residual effects, yields were maximum at 1280 kg P_2O_5/ha.

The external P requirement, calculated as 95% of maximum yield, was determined to be 0.06 ppm P in soil solution, the same as for maize and not very different from the 0.056 and 0.08 ppm determined in 1977

Table 25.

Relationship of yields of seven contrasting maize genotypes in association with the climbing bean variety P589 to maize yields in monoculture, at CIAT-Palmira, 1978.

Maize variety	Yield association/ monoculture (%)	Mono-culture height (cm)	Stalk lodging (%)		Root lodging (%)	
			mono.	assoc.	mono.	assoc.
ICA H-209	139	262	1	4	77	17
La Posta	76	256	1	6	43	25
Antigua x Rep. Dominicana	89	246	2	9	81	51
Amarillo subtropical	81	232	1	26	87	41
ICA H-210	65	191	1	0	2	2
Mezcla Tropical Blanco	78	240	3	1	22	8
ICA-7431 Br. 2	79	228	1	0	6	2

Table 26.

Effects of combinations of several herbicides applied pre-emergence on grain yields of Diacol Calima beans, at CIAT-Palmira, 1978A.

Treatment	Application rate (kg/ha, a.i.)	Percentage control of: grassy weeds 14	grassy weeds 21	grassy weeds 28	broadleaf weeds 14	broadleaf weeds 21	broadleaf weeds 28	Toxicity index[1]	Yield[2] (t/ha)
		days after application							
fluorodifen + linuron	2.1 + 0.5	99.3	99.3	98.3	100	98.3	95.0	0	2.0 a[3]
penoxalina + linuron	0.66 + 0.5	99.3	100	93.3	97.6	99.3	94.0	0	2.0 a
penoxalina + nitrofen + DNPB	0.66 + 1.44	97.6	99.3	95.6	95.0	92.3	76.6	0	2.0 a
metolachlor + linuron	0.66 + 0.5	98.3	97.6	98.3	99.0	98.3	92.6	0	1.9 a
fluorodifen + nitrofen + DNPB	2.1 + 1.44	100	100	95.0	99.3	97.3	91.6	1.6	1.8 ab
metolachlor + nitrofen + DNPB	0.66 + 1.44	100	100	100	96.0	90.0	85.0	0.3	1.8 ab
Hand-weeded at 7, 14 and 21 days									2.0 a
Hand-weeded at 21 days									1.8 ab
Hand-weeded at 28 days									1.8 ab
Hand-weeded at 14 days									1.7 abc
Unweeded control									1.3 c

1 Toxicity scale: 0 = no toxicity, 10 = complete kill.
2 Average of four replications.
3 Means followed by the same letter are not significantly different at the 0.05 level.
Major grass and broadleaf weeds included: *Echinochloa colonum, Leptochloa filiformis, Portulaca olearacea* and *Amaranthus dubius.*

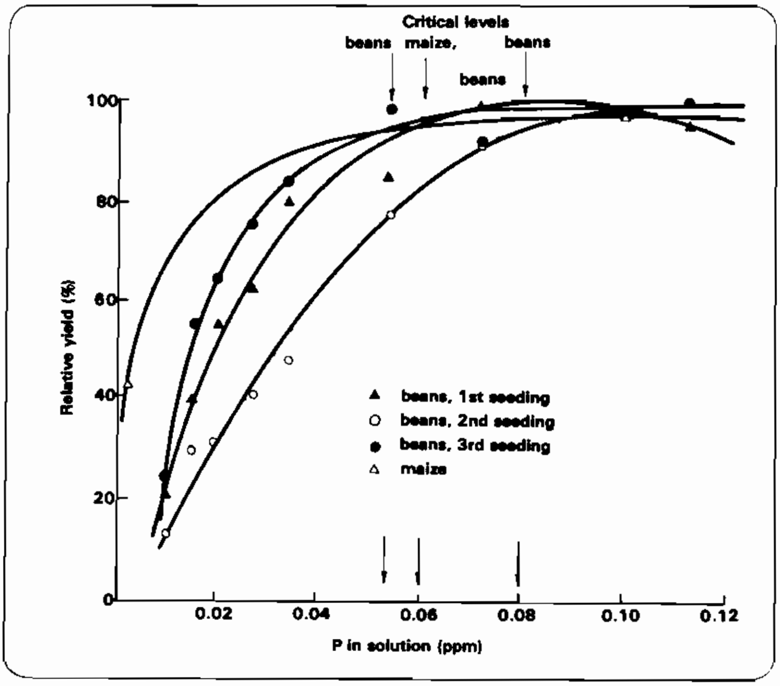


Figure 25. Relative yield of maize (data from Hawaii) and three consecutive seedings of beans (at Popayan), as affected by concentration of P in solution determined by sorption isotherms.

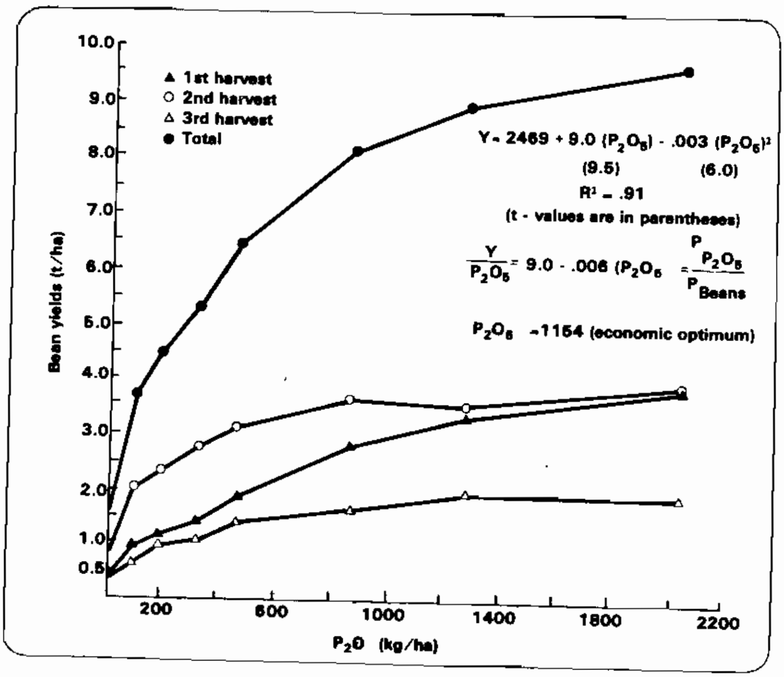


Figure 26. Response of beans (var Huasano) over three harvest to applications of P_2O_5, at Popayan. (Data from R.H. Howeler and A. Leon).

(Fig. 25). Although maize and beans seem to have a similar external P requirement, beans are more seriously affected by sub-optimal P levels than is maize.

A similar trial at CIAT-Quilichao obtained maximum yields of 1.93 t/ha with the application of 1680 kg P_2O_5/ha, but 80% of the maximum yield was obtained when only 76 kg P_2O_5/ha was supplied. The critical P content of leaves was estimated to be 0.39% P, a value very similar to those reported earlier for Popayan.

Results from the Popayan trial were subjected to economic analysis. From this analysis, and taking into account residual effects, an economic optimum of 1/1154 kg P_2O_5/ha was obtained (Fig. 26). While banding of fertilizer to improve efficiency could probably reduce this requirement to perhaps 300 kg P_2O_5/ha, near optimum yields could only be obtained at a production cost of 60,000 Col. Pesos/ha. While this would return a net income of 15,000 Pesos/ha, it is doubtful that risk-avoiding farmers would consider this type of investment. Thus, while this type of experiment provides useful data on critical concentrations of P it is unlikely to have much application in bean program target areas.

Interaction of Nitrogen and Phosphorus in CIAT-Quilichao

A systematic design trial was planted with variety Diacol Calima to determine the interaction of N and P in CIAT-Quilichao. Twenty levels of N, from 0 to 400 kg/ha, were combined with 20 levels of P from 0 to 400 kg P_2O_5/ha by systematically increasing the two elements in perpendicular directions. Plots were 1 m^2 each with two bean rows 1 m long.

Highest yields were obtained with 380 kg N and 390 kg P_2O_5/ha. However, near maximum yields were obtained with 160 kg N and 200 kg P_2O_5.

Figure 27 indicates the average response to P and N. It is clear that the P response was much more marked (from 0.3 to 1.7 t/ha) than the N response (from 1.0 to 1.7 t/ha). Although yields increased about one t/ha by P application in the absence of N (but not by N application in the absence of P), it is clear that maximum yields are obtained only with the balanced application of both elements at this site.

Target Area Agro-climatology Study

The purpose of this study is to provide a data management and analysis capability to answer questions on various aspects of bean production areas in Latin America. It is envisaged that enquiries will be made at two distinct levels. First, the goal orientation level— to decide on research and breeding priorities or tactics; and second the product dispersal level— to determine the probable impact and region of adapta-

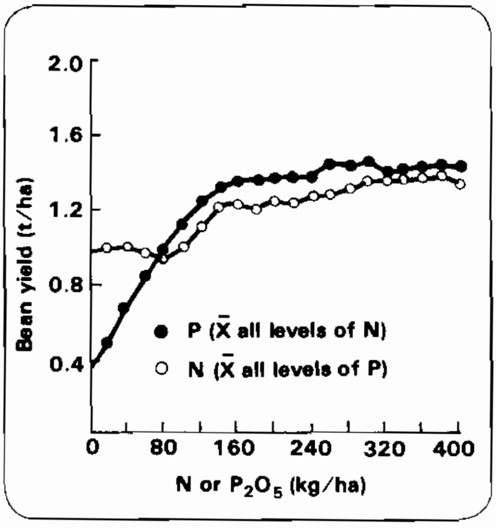


Figure 27. Average response of Diacol Calima to applications of P and N at CIAT-Quilichao.

tion of new CIAT products, either germplasm, technology or a combination of both.

The method chosen was to define more or less uniform, bean growing, micro-regions as a basic unit for data collection and analysis. Each micro-region can then be categorized by climatic, edaphic, agronomic and economic parameters. Using this information on a micro-region basis it will be possible to estimate both the extent of current practices and problems and the possible agronomic consequences of changes to the system. The data fall into two basic types described in the next sections.

Meteorological Data

The long-term mean meterological data have a readily specified numeric form, but may be used in many different ways. Therefore, a task-specific data retrieval system has been developed to store these data in minimum space and to deliver them to an applications programmer with minimum difficulty. A series of direct access files hold information on the station, institute and country of origin of the data, and the data themselves, linked by keys within and between files for fast access. The data are stored as coefficients of a 12-point Fourier transform and can be very quickly reconstituted to form an array of means for periods of any length required by the applications programmer. Long-term monthly mean data from a wide variety of sources have been processed into a system of sequential work files and are at present being edited and transferred to the retrieval system, where they will undergo further rigorous check for consistency and accuracy.

In later developments of the study it is intended to collect representative daily meteorological records where available for each micro-region for use in more exact studies of seasonal variation and crop hazards.

Agronomic and Edaphic Micro-region Data

In this section two main tasks present themselves. The first is the implementation of a retrieval system for the data. This needs to be a system capable of accepting data with relatively diverse structures and that can make efficient use of empty data space. To this end the CDC data language INFOL is being translated to run on the IBM 370 system available to CIAT. The second main task is the geographical definition of the bean growing micro-regions. These units, defined by geographical coordinates, will constitute the basic element for the data files. This task is now in progress as a cooperative team effort.

Data Interpretation

The ability to derive quantitative results from the data depends, in many cases, on being able to calculate the effects of climatic and agronomic practices in each micro-region considered. The first priority is to be able to define the growing season length in terms of crop phenology. This depends on photoperiod and temperature and the relationship changes from cultivar to cultivar. Predictive equations for these relationships are being developed, using data from the IBYAN trials.

Preliminary Results

Although the data are not yet in efficient machine retrievable form, some tentative results have been compiled. Figure 28 shows a breakdown of bean production of Central and South America by mean daily temperature during the growing season. As these results were compiled from

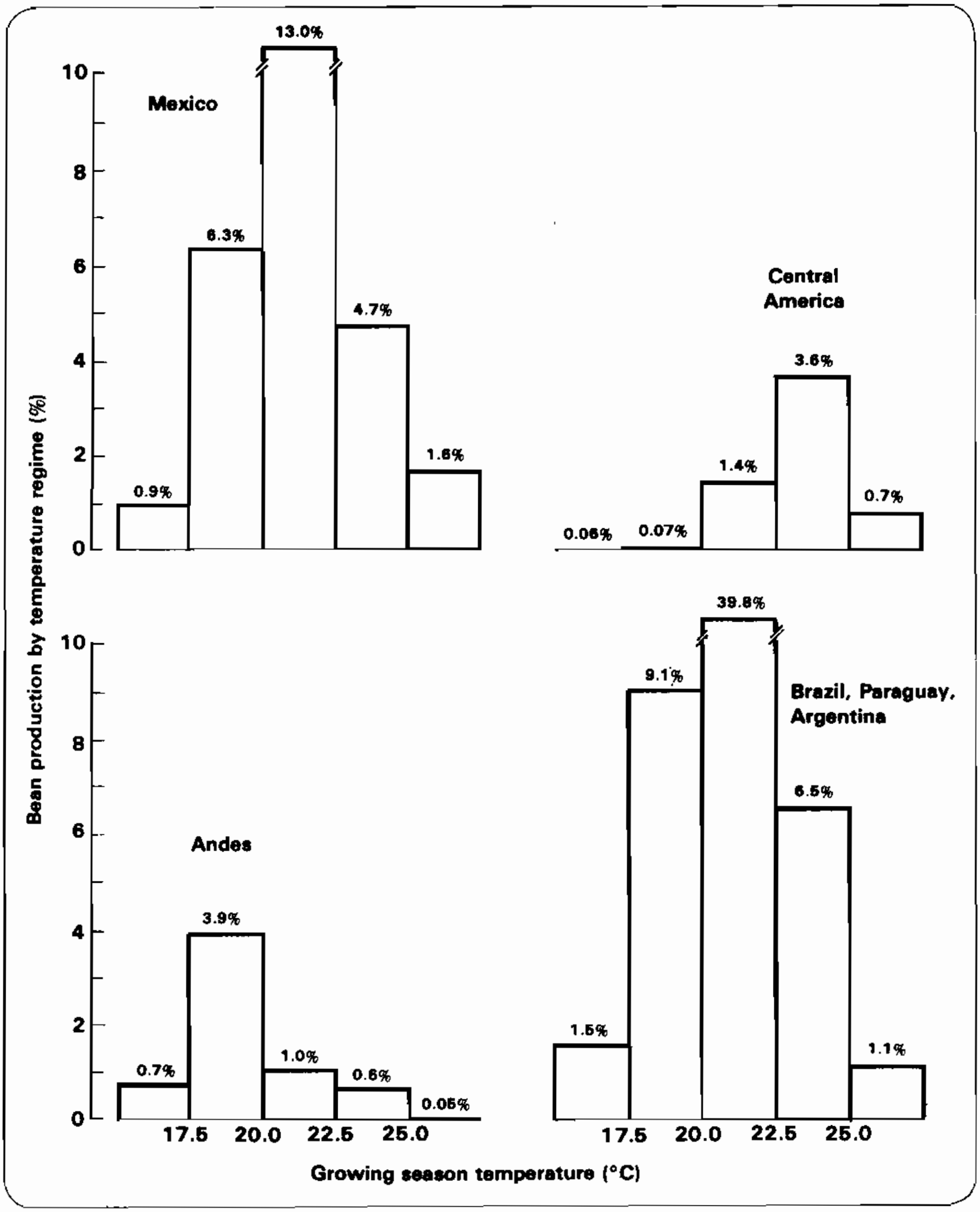


Figure 28. Proportion of total bean production in Central and South America, by regions and temperature regimes within regions.

preliminary estimates of the bean growing micro-region boundaries they should be regarded as preliminary. However, it is felt that the overall form of the distributions shown should be quite reliable. The total distribution for the area (Fig. 29) shows the magnitude of the bean production which was not allocated to specific growing regions. This residual is grown in small areas that could not be accurately estimated or included in the analysis and may well be distributed about the margins of the temperature distribution, although even in this worst case the overall relationships will change little from that shown.

Not unexpectedly, the distribution for Central America shows a tendency towards a slightly higher modal temperature regime, whereas that for the Andean countries tends to a cooler regime. The majority of the production, particularly from Mexico and Brazil falls within the range 20°-22.5°C. The overall temperature range proved to be much narrower than expected, and suggests that undue emphasis on screening for extreme temperature adaptation may be unwarranted for all but the marginal situations.

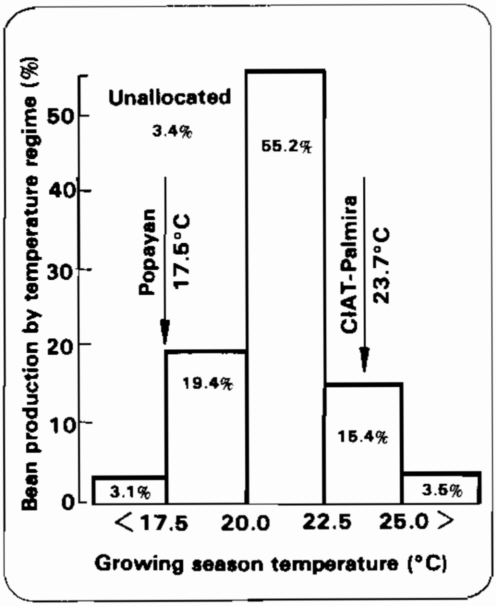


Figure 29. Proportion of total bean production in the target area which falls within five growing temperature regimes.

IN-DEPTH STUDIES OF SPECIFIC PROBLEM AREAS

Physiology of Yield

Comparative Studies with Other Legumes

Research elsewhere has suggested that *Phaseolus vulgaris* is an inefficient species with respect to grain production.

A comparative growth analysis study of five grain legume species was conducted under irrigation' at CIAT-Palmira to evaluate this hypothesis. Adapted representative genotypes (Table 27) for each species were chosen on the basis of varietal evaluations previously conducted by the CIAT Special Studies Unit and others. Yield and associated parameters are shown in Table 27. The two most efficient entries on a yield/day basis were the cowpea and the common bean while the dwarf pigeonpea had the highest absolute yield. Leaf area duration (LAD) from emergence to physiological maturity was highly correlated with yield (r = 0.90), implying that the efficiency of the available leaf area (yield/LAD) was relatively similar for the five species. Leaf area growth curves of the five species are shown in Figure 30. The rapid growth of leaf area in *Phaseolus* is notable and contrasts with the very slow growth of leaf area in the small-seeded pigeonpea. The common bean variety had the highest harvest index and the lowest dry matter production (minus leaves and petioles at maturity). Based on these limited data it would appear that, among these grain legumes, the representative of *P. vulgaris* was an extremely efficient producer of economic yield. Experimental conditions were not ideal due to periods of poor

Table 27.

Yield and other selected parameters measured on five grain legumes species for comparative growth analyses, CIAT-Palmira, 1978A.

Species[1]	Total yield 14% (kg/ha)	Daily yield[2] (kg/ha/day)	Days to: flowering	Days to: physio. maturity	Total dry matter[3] (kg/ha)	Harvest index[4] (%)	Maximum node no.[5] ($1/m^2$)	LAD[6] (m^2 day/m^2)	Yield/LAD (g/m^2 day/
Cajanus cajan									
(pigeonpea)	2693	22.6	73	119	5776	39.6	1684	192	1.40
Phaseolus vulgaris									
(common bean)	2560	29.8	40	86	3250	66.9	801	154	1.66
Vigna ungiculata									
(cowpea)	2423	30.7	49	79	4397	46.8	691	175	1.38
Glycine max									
(soybean)	2297	21.9	35	105	3706	52.7	610	176	1.30
Vigna radiata									
(mungbean)	1653	24.0	41	69	3271	42.9	213	95	1.74
L.S.D. (0.05)	551	6.2	-	-	800	13.1	-	52.3	-
C.V. (%)	12.6	13.0	-	-	10.4	14.2	-	17.5	-
r (versus yield)	-	0.46	0.40	0.58	0.61	0.26	0.81	0.90	0.54

1 Cultivars and sources: Pigeonpea—3D8111, from IITA; Common bean—Puebla 152 (P498), from Mexico; Cowpea—Tvn 201-1D, from IITA; Soybean—ICA-Tunia, from ICA-Colombia; and Mungbean—2010M-314, from AVRDC.

2 Days from sowing to final physiological maturity.

3 Minus leaves and petioles at maturity.

4 Yield/total dry matter.

5 Vegetative node number from growth analysis samples.

6 Integrated area under fitted leaf area curve from emergence to physiological maturity.

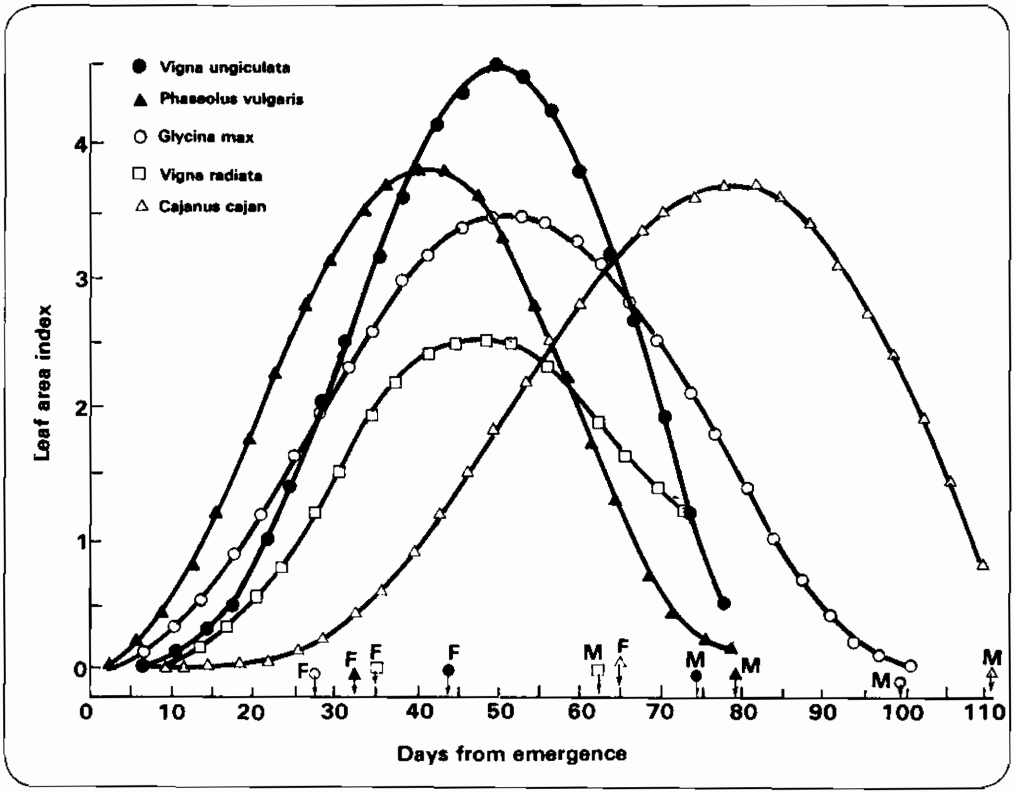


Figure 30. Leaf area growth curve for five grain legume species versus days from emergence; curves derived from predicted value of equations of the form LAI = at + b sin t + c sin 2t + d cos t + e cos 2t, where t = time and a-e are coefficients. R^2 values for all species ranged from 0.95 to 0.96 with replication (n = 3) effects removed. Data points are predicted values at each sampling date.

drainage. The experiment will be repeated in 1979, particularly in view of the rather poor performance of the soybean entry.

Growth Analysis Experiments on Phaseolus vulgaris Germplasm

Ten selected cultivars from growth habits I and II were evaluated to check earlier preliminary conclusions about the importance of physiological characters in yield determination in beans. The overall yield level in the experiment was not as high as normal, due to periods of poor drainage and a moderate attack of common blight. A summary of key parameters is presented in Table 28. As a group the type II varieties out-yielded the type I lines. Yield per day, total dry matter and total green leaf area duration were all highly correlated with yield. Harvest index was only slightly higher, on average, in the type II lines. Differences in maturity were not sufficient to explain the yield differences. The higher leaf area duration of the higher yielding lines was associated with higher dry matter production (r = 0.87). Thus, where maturity differences were not very great, there were large differences in leaf area duration (LAD) leading to high yield per unit area and per unit time in material with high LAD. The marked inferiority of type I materials is again clear in these data. IBYAN data for 1976 (CIAT Annual Report, 1977) support this conclusion for a number of locations.

The maintenance of a high leaf area index for as long as possible, i.e., within the environmental limits, is one of the key

Table 28.

Physiological parameters for 10 *Phaseolus vulgaris* cultivars from a comparative growth analysis experiment, CIAT-Palmira, 1978A.

Cultivar	Growth habit	Yield 14% (g/m^2)	Daily yield[1] ($g/m^2/day$)	Total dry matter[2] (g/m^2)	Harvest index (%)	Days to: flowering	Days to: physio. maturity	LAD[3] (m^2 days/m^2)	Yield/LAD (g/m^2 days/m^2)
P548	II	186	2.41	277	58	39.2	76.8	156	1.19
P566	II	172	2.24	264	56	38.7	76.7	159	1.08
P756	II	158	2.10	242	56	34.0	75.0	108	1.46
P643	II	156	1.95	263	51	38.7	80.0	128	1.22
P524	II	148	1.96	210	62	39.7	75.2	129	1.15
P759	I	127	1.80	215	52	31.5	71.0	101	1.26
P788	I	127	1.77	213	51	31.0	71.5	88	1.44
P402	I	113	1.61	202	48	37.7	70.0	91	1.24
P635	I	103	1.36	214	43	31.2	75.5	109	0.94
P392	I	75	1.10	116	56	34.2	68.5	60	1.25
Mean, habit	II	164	2.13	251	57	38.0	76.7	136	1.22
Mean, habit	I	109	1.53	202	52	33.1	71.3	90	1.23
L.S.D. (0.05)		27	0.35	57	10	1.0	1.3	27	0.28
C.V. (%)		13.7	13.3	17.6	11.8	1.9	1.2	16.5	15.8
r (versus yield)			0.99	0.85	0.47	0.58	0.74	0.87	0.05

1 Days from sowing to final physiological maturity.
2 At harvest; minus leaves and petioles.
3 Area under fitted leaf area curve from planting to physiological maturity.

factors necessary to increase yield, at least in bush beans. This can be achieved either by increasing the leaf area within the same time frame or by increasing the length of the growth cycle (see previous CIAT Annual Reports for a fuller discussion of these conclusions).

Temperature Effects on Symbiotic Nitrogen Fixation

Studies in previous years have suggested that high soil temperature could be a major limiting factor to N_2 fixation in beans. To evaluate this possibility, controlled environment studies were undertaken at the Biotron facility, University of Wisconsin (U.S.A.).

Preliminary studies evaluated growth and N_2 (C_2H_2) fixation in five bean cultivars inoculated with different strains of *Rhizobium*. Thirty days after planting, N_2 (C_2H_2) fixation at 30° - 20°C day-night temperature was considerably above that at 35°-25°C, but little difference in plant weight was observed. There was a strong strain-temperature interaction (Table 29).

The growth, N_2 (C_2H_2) fixation and N accumulation of the cultivars P498, P566 and P635 were further studied using weekly sampling to establish profiles of development and N_2 fixation under three different growth temperature regimes. Temperature influenced both the onset, intensity and duration of N_2 (C_2H_2) fixation. Thus while maximum fixation increased from 33.8 μmol C_2H_4 produced/plant/hour at 35°-25°C day-night temperature to 73.0 μmol C_2H_4 produced/plant/hour at 25° - 15°C, this peak in fixation was increasingly delayed as growth temperature was reduced (Fig. 31). In the 25° - 15°C treatment, this delay in the onset of fixation led to falling leaf N concentrations and visible N-deficiency symptoms at the 28-day harvest (Fig. 32).

In this study the influence of temperature on N fixation by beans was less than anticipated, and given the average growth season temperatures for beans discussed on page C-48 is not likely to be a major limiting factor for bean production under field conditions. It is possible, however, that delaying the onset of fixation at lower temperatures might necessitate the use of starter N dressings. This possibility is being investigated.

Table 29.

Variation in *Rhizobium* strain response to temperatures. (Means of five *Phaseolus vulgaris* cultivars.)

Temperature (day/night)	*Rhizobium* strain				Not inoculated
	CIAT 57	CIAT 161	CIAT 137	CIAT 632	
Measured by acetylene reduction (μmol/plant/hour)					
35°/25°C	19.62	13.91	11.10	0.92	0
30°/20°C	28.14	23.19	16.77	17.88	0
Measured by plant weight (g/plant)					
35°/25°C	3.73	5.23	4.99	2.06	3.03
30°/20°C	3.75	4.73	4.27	4.58	2.48

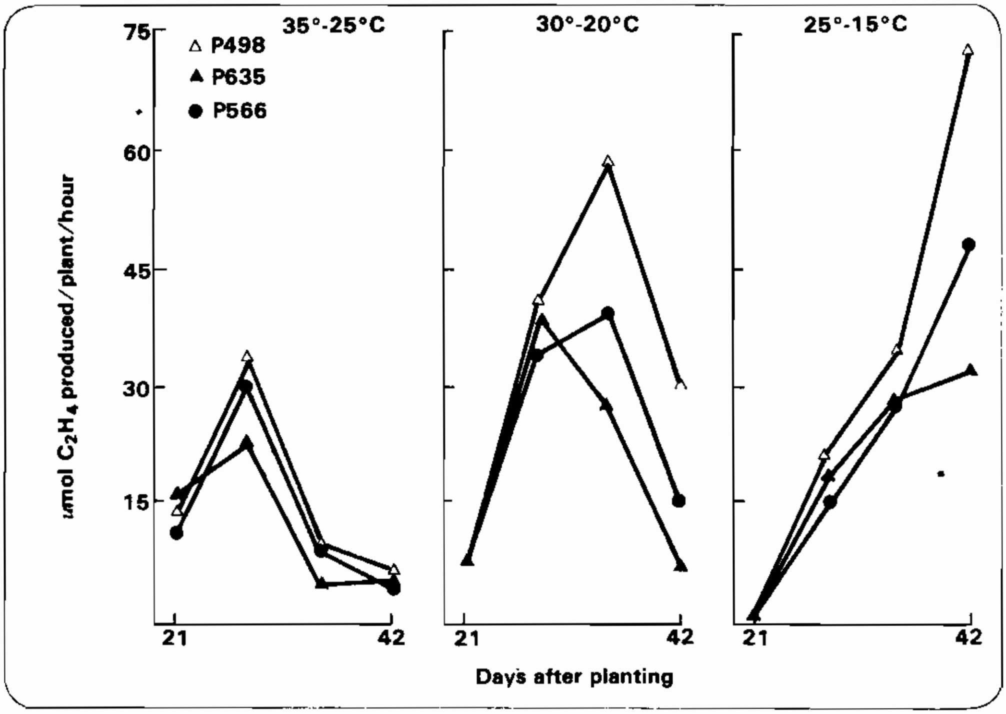


Figure 31. Nitrogen (C_2H_2) fixation in three bean cultivars as influenced by day/night temperatures.

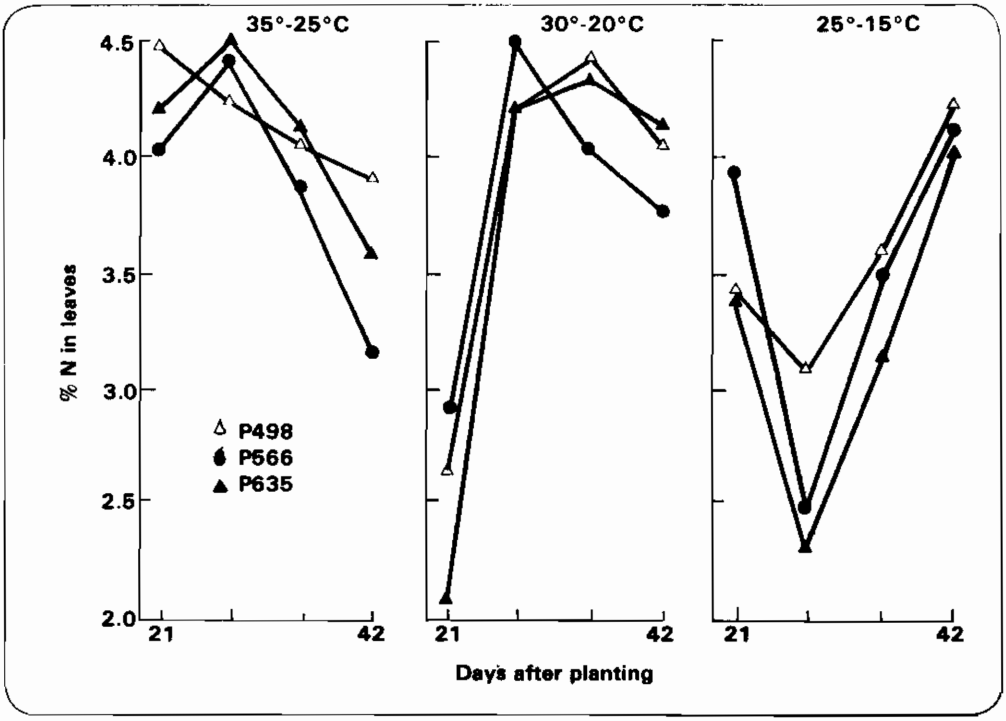


Figure 32. Nitrogen content of leaves of three bean cultivars as influenced by different day/night temperatures.

Importance of Nematodes in Bean-Producing Regions of Colombia

To evaluate the importance of nematodes in bean-producing regions of Colombia, a total of 112 soil and 66 root samples were taken from eight bean production areas. These included research plots on CIAT stations at Palmira, Popayan and Santander de Quilichao; ICA stations at La Selva and Pasto; and on-farm trials in the Huila, Restrepo, (Valle) and Rio Negro (Antioquia) regions. Nematodes were extracted from soil by centrifugal-flotation in sugar solution. Washed roots were incubated 24 hours at 24°C in shaken water to extract endoparasites. Collections of *Pratylenchus* and *Meloidogyne* were identified to species. *Aphelenchus, Aphelenchoides, Ditylenchus, Tylenchus,* and *Psilenchus* were not included in the survey.

Eighteen genera of plant parasites were collected from bean soil (Table 30) and three genera from bean roots. Three genera occurred generally in soil and root samples. *Helicotylenchus, Pratylenchus* and *Meloidogyne* occurred in 66% and 18%, 37% and 62%, and 36% and 41% of soil and root samples, respectively. Since *Helicotylenchus* is primarily ectoparasitic, relatively low recovery from roots would be expected. Populations of *Meloidogyne* spp. from root samples represent egg hatch during 24 hours incubation. These populations are not necessarily indicative of relative degrees of root infestation.

Helicotylenchus spp., while quite generally occurring in bean soils, were usually present at frequencies less than 1000/500 ml soil. There is no literature concerning the pathogenicity of *Helicotylenchus* to beans. However, unusual population development at CIAT -Palmira (3000/500 ml), Restrepo (3800/500 ml) and Rio Negro (4800/500 ml) may indicate some damage to beans at these sites. Damage to beans in Huila could be expected because of the very large population of spiral nematode (9700/500 ml).

Meloidogyne spp. occurred on 9 of 10 farms sampled at Rio Negro with *Meloidogyne arenaria* the predominant species. Soil samples frequently contained large numbers of larvae (5100/500 ml). In this limited sample, cultivars P706 showed larger galls than P590. Occurrence of *Meloidogyne* spp. was favored by the coarse soil textures and long history of monocultured beans at Rio Negro.

Five of six farms visited at Restrepo were infested with root-knot nematodes, probably *Meloidogyne incognita.* Cropping practices at Restrepo favor maintenance of *Meloidogyne* spp. in bean soils. *Aracacia xanthorhiza,* an excellent host of *Meloidogyne* spp. (10,100/500 ml), is frequently interplanted with beans and tomato, another good host, may be rotated with beans. *Bidens pilosa* (Compositae), a common weed in bean fields is another good host of *Meloidogyne.*

Meloidogyne hapla occurred in all soil samples from Popayan. *M. hapla* is generally not as destructive as southern species. However, at Popayan, seedlings are subjected to high populations (4800/500 ml) which would increase the effect of nematodes on beans. Root rot was common at Popayan. Since *M. hapla* can increase root rot incidence, this species could be causing losses in this way in addition to direct pathogenicity. *B. pilosa* is important at Popayan in maintaining high populations throughout the plot area. Lack of crop rotation also contributes to population increase.

Table 30.

Genera of plant parasitic nematodes extracted from 200 ml soil by centrifugal-flotation.

	Genera in bean soil							
Genus	La Selva	CIAT-Palmira	Pasto	Popayán	Potosí	CIAT-Quilichao	Restrepo	Río Negro
Cacopaurus		4/44[1](3200)[2]						
Criconema	1/6 (100)							12/19 (2800)
Diptherophora	4/6 (200)		1/7 (500)				2/10 (200)	
Gracilacus		2/44 (1200)						
Helicotylenchus	6/6 (100)	24/44 (3000)	1/7 (100)	14/23 (1200)	2/2 (9700)	1/1 (400)	7/10 (3800)	19/19 (4800)
Heterodera			2/7 (700)	1/23 (100)				
Hoplolaimus							2/10 (300)	
Longidorus	2/6 (200)							
Macroposthonia			1/7 (100)	7/23 (400)			1/10 (600)	3/19 (200)
Meloidogyne	6/6 (800)		3/7 (600)	19/23 (4800)			6/10 (800)	16/19 (5100)
Paratrichodorus				5/23 (300)				
Paratylenchus		1/44 (100)						
Pratylenchus	5/6 (900)	17/44 (500)	4/7 (1000)	2/23 (200)			1/10 (200)	12/19 (800)
Telotylenchoides		2/44 (2200)						
Tetylenchus		1/44 (200)						
Trichodorus	3/6 (100)			8/23 (400)			6/10 (700)	14/19 (700)
Tylenchorhynchus		4/44 (700)	5/7 (2500)					
Xiphinema	6/6 (600)			2/23 (200)				1/19 (100)

1 Numerator = number of samples in which genus occurred; denominator = total number of samples collected at site.
2 Numbers in parentheses are maximum populations/500 ml soil.

Soil from La Selva was infested with *Meloidogyne* spp. Since root samples with females were not included in these samples identification cannot be certain, yet larval measurements indicate *M. incognita* is the predominant species. *M. incognita* commonly occurs on vegetables and weeds at La Selva.

Meloidogyne spp. occurred in soil samples from Pasto but galled bean roots were not collected. Nematodes could have been reproducing on weeds. The species has not been identified but the cool soil environment at Pasto would favor *M. hapla*.

Meloidogyne spp. levels found in this survey would undoubtedly cause yield reductions in beans.

Pratylenchus penetrans and *Pratylenchus crenatus* were present in high numbers in both the La Selva and Rio Negro samples. Since *P. penetrans*, in growth chamber work, can stunt bush beans at populations of 1/plant, the field levels reported must have been injurious to bean growth. Associative cropping of maize and beans would favor *P. penetrans*.

Cultural and Biological Control of Insect Pests

Studies with Empoasca kraemeri

Studies continued on the influence of aluminum and other mulches on *Empoasca kraemeri* populations and bean yields. Covering the soil with aluminum and with rice straw reduced nymphal and adult populations of the leafhopper, compared to the control treatment without chemical protection or mulching, both for the susceptible variety Diacol Calima (Fig. 33 and 34) and for the resistant line P14 (Fig. 35).

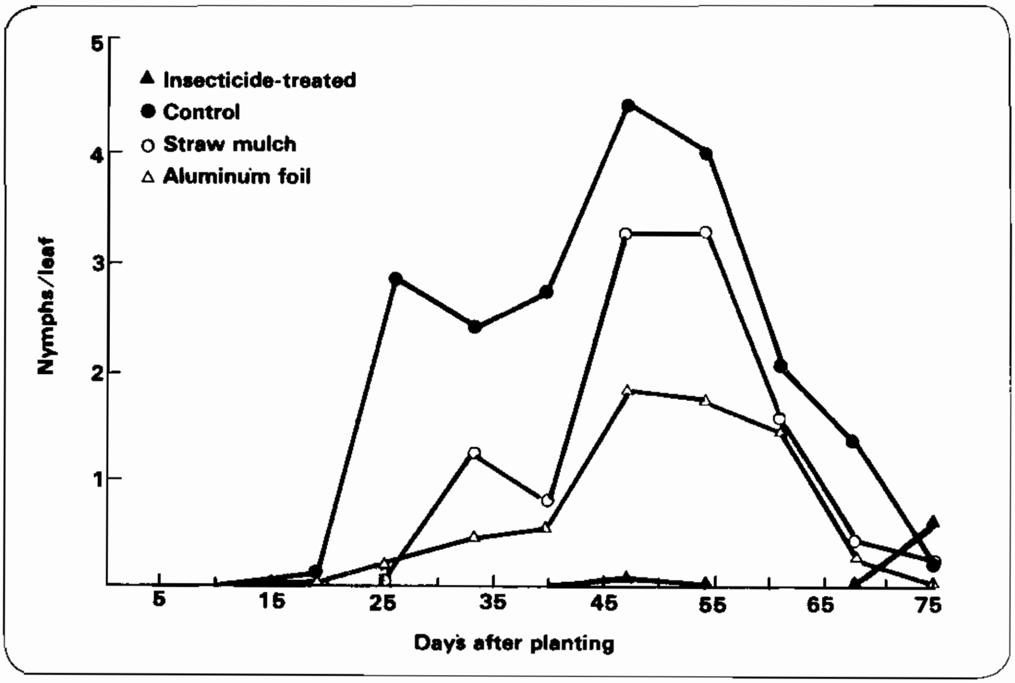


Figure 33. Effect of various soil covers on nymphal populations of *Empoasca kraemeri*, with bean variety Diacol Calima.

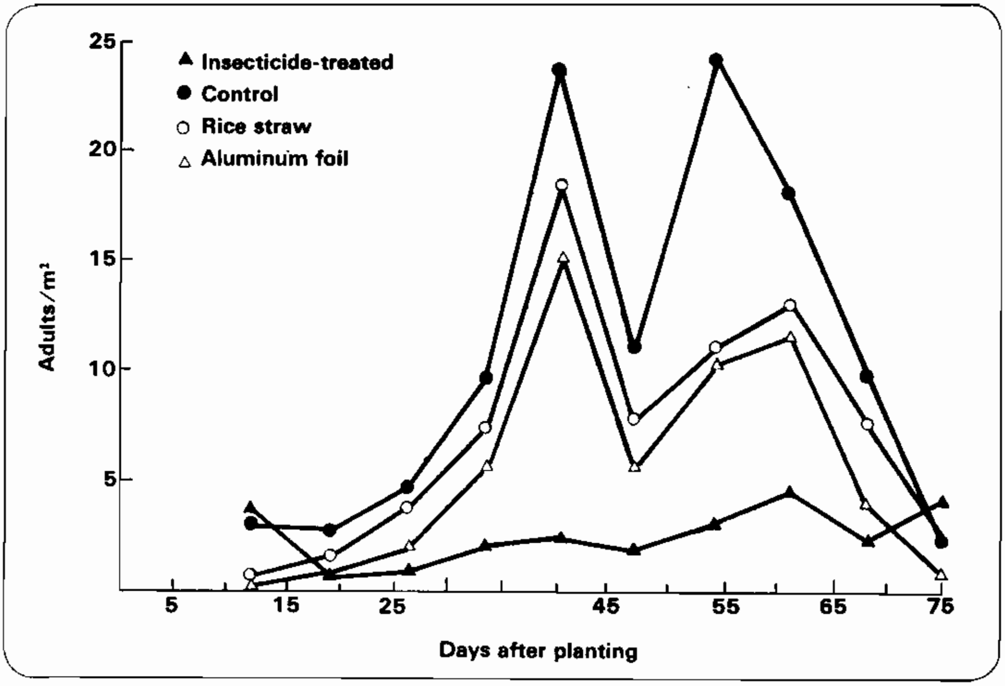


Figure 34. Effect of various soil covers on adult populations of *Empoasca kraemeri*, with bean variety Diacol Calima.

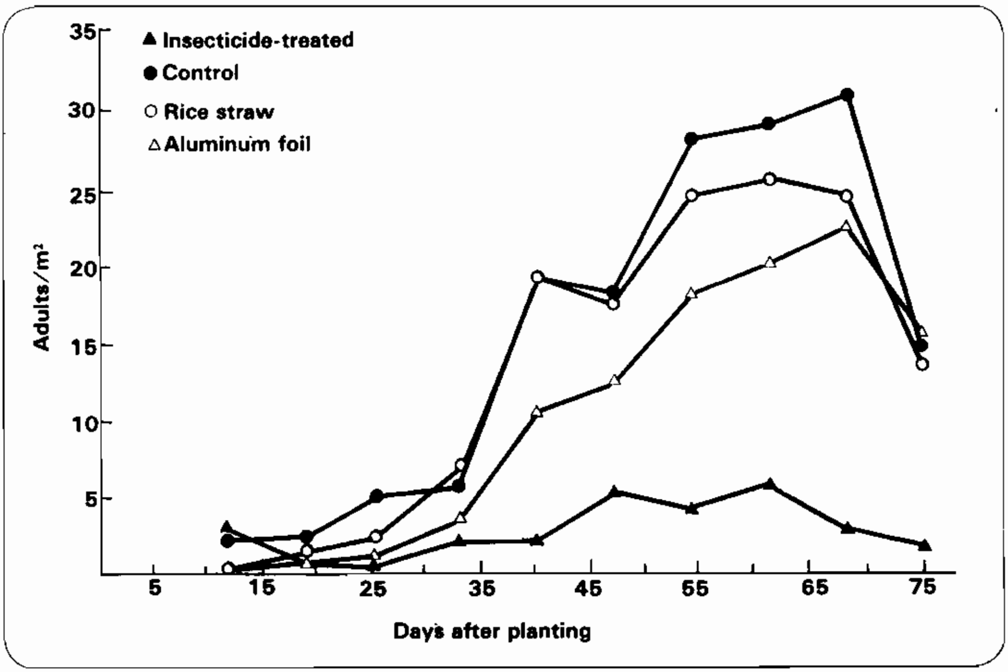


Figure 35. Effect of various soil covers on adult populations of *Empoasca kraemeri*, with bean variety P14.

Table 31.

Yields of a susceptible variety (Diacol Calima) and a resistant variety (P14) of *Phaseolus vulgaris* under different treatments for the control of *Empoasca kraemeri*.

Treatment	Yield (kg/ha) Diacol Calima	P14
Treated with insecticide	1574 a[1]	1549 a
Aluminum foil mulch	1450 a	1385 ab
Rice straw mulch	1007 b	1445 ab
Control	673 c	1101 b

1 Values followed by the same letter are not significantly different at the 0.05 level.

With Calima, yields were significantly different between the aluminum and rice straw mulches and the control. Being resistant, P14 did not respond significantly, although it produced 400 kg/ha more with the aluminum mulch than did the unprotected control (Table 31). Differences between the controls of the varieties were significant, showing again the importance of varietal resistance on yields.

To complement the cultural practice studies and as basic essential information on the design of traps for population dynamics studies, the behavior of leafhoppers and chrysomelids was investigated with respect to the surface color surrounding the bean plant. Colors green and especially yellow, attracted the most *Empoasca* adults; black and straw colors gave a mixed or intermediate response. Aluminum and white were definitely repellent colors. Response of the chrysomelids to colors was not so marked as for leafhoppers (Table 32).

Table 32.

Response of *Empoasca kraemeri* and chrysomelid adults to surface colors surrounding the bean plant.

Treatment color	Expt. 1	Expt. 2	Expt. 3	Expt. 4
No. of *Empoasca* adults per plant				
Green	6.2 a[1]	4.2 a	3.6 b	11.8 bc
Control	3.5 b	1.7 bc	2.2 bc	14.4 b
Yellow	3.5 b	3.6 a	5.6 a	18.9 a
Straw	2.6 bc	0.8 c	1.5 cd	2.1 d
Black	1.7 cd	2.8 ab	2.1 bc	14.6 b
Aluminum	0.9 cd	0.4 c	0.9 cd	0.9 c
White	0.2 d	0.1 c	0.3 d	4.2 d
No. of chrysomelid adults per plant				
Straw	1.6 a	1.6 ab	1.6 ab	1.4 ab
Yellow	1.2 ab	1.8 ab	1.8 a	1.7 ab
Control	0.9 ab	1.4 ab	1.0 abcd	0.7 b
Green	0.8 ab	1.2 ab	1.3 abc	1.5 ab
White	0.8 b	0.9 ab	0.1 d	2.2 a
Aluminum	0.7 ab	0.3 b	0.3 cd	1.4 ab
Black	0.5 ab	0.5 ab	0.6 bcd	0.6 b

1 Values within columns and for each species that are followed by the same letter are not significantly different at the 0.05 level.

Studies with Grain Storage Pests

In collaboration with ICA and CARE, and at the farm level, a study was done on controlling insect pests of stored beans. Treatments included soybean oil (3 ml/kg of beans), harvest residues (25% by weight), pyrethrins (1.7 ppm) and the unshelled pods with beans. The experiment was done at four locations, three in the Cauca Valley of Colombia (1000 masl) where conditions were adequate for *Zabrotes subfasciatus* attacks. The fourth experiment was at Popayan (1900 masl) where conditions were favorable for *Acanthoscelides obtectus*.

After four months of storage, the unshelled beans at Popayan had 34% damage from *Acanthoscelides* and 39% of the pods were perforated. Untreated beans and the treatment with harvest residues both had 2% damage. No damage was observed on seed treated either with oil or pyrethrins throughout the nine-month experimental period.

Table 33.

Comparative survival of larvae of *Diabrotica balteata* and *Cerotoma facialis* fed with the maize hybrid ICA H-207 or the bean variety Diacol Calima.

Age of larvae (days)	Live *D. balteata*		Live *C. facialis*	
	on maize[1]	on beans[1]	on maize[1]	on beans[1]
1	20	20	20	20
4	20	10	0	19
8	19	4	-	13
12	18	2	-	12
% survival	90	10	0	60

1 Four days after germination; average of 20 replications.

Table 34.

Number of chrysomelid larvae found in the soil of associated bean and maize crops three to six weeks after planting beans.

Days after bean planting	Maize planting with respect to beans	Total larvae in		Total larvae in	
		beans	maize	beans	maize
21	14 days before	0	7	0	0.3
	simultaneously	0	0	0	0
	14 days after	0	0	0	0
28	14 days before	0	11	0	0.6
	simultaneously	3	4	0.3	0.3
	14 days after	1	0	0.1	0
35	14 days before	2	25	0.2	1.2
	simultaneously	11	23	0.9	1.2
	14 days after	4	0	0.4	0
42	14 days before	1	12	0.1	0.6
	simultaneously	1	47	0.1	2.9
	14 days after	2	7	0.2	0.5

Table 35.

Foliar area, in terms of percentage foliar area of the control, after bean plants were infested with 10 larvae of *Diabrotica balteata* per plant, under greenhouse conditions.

Instar	Days after planting when infested: 0	1	4	7	14	21	Average
First	99.0	73.0	105.7	102.7	98.2	102.2	96.1
Second	11.0	12.5	75.7	73.5	96.0	89.3	67.7
Third	12.6	8.5	7.6	0	98.3	104.7	33.8

In beans stored in the Cauca Valley, the first attack by *Zabrotes* occurred at nine months into storage. All treatments greatly reduced insect attack compared with the control. On only one farm was a light attack of bruchids noted in beans treated with oil.

Biology of Cerotoma facialis

To complement information reported last year (CIAT Annual Report, 1977), more studies were done on the biology of *Cerotoma facialis*, another important chrysomelid pest of beans. In the laboratory, eggs hatched within 4 to 5 days and the three larval instars lasted 4 to 5, 3 to 4 and 3 to 5 days, respectively. The prepupal stage was 3 to 4 days and the pupal period, eight days. The period from egg to appearance of the adult is thus 26 to 32 days.

Also in the laboratory, *Diabrotica balteata* survived better on maize than on beans, while *C. facialis* did not develop on maize (Table 33). In the field, in associated cropping systems, the highest incidence of chrysomelid larvae on bean roots occurred 35 days after planting and when planting was at the same time as the maize. The lightest attack occurred when maize was planted two weeks earlier than beans (Table 34).

Table 36.

Average yields per bean plant (var. Diacol Calima) under different periods of attack at various levels of infestation by *Diabrotica balteata* adults.

Days after seeding when attack occurred	No. of adults per plant: 0	2	4	6	Average
	Yield (g/plant)				
8-15	3.08	2.50	2.10	0.95	2.16 b[1]
15-22	2.59	3.57	3.03	3.18	3.09 a
22-29	2.67	2.98	2.47	2.25	2.59 ab
29-36	2.53	2.46	2.48	2.28	2.44 ab
Average	2.72 c[1]	2.88 c	2.52 cd	2.17 d	

1 Average values followed by the same letter are not significantly different at the 0.05 level.

In expanding the work on larval damage of *D. balteata* on bean plants (CIAT Annual Report, 1977), it was found that plants less than 14 days after seeding had the most severe damage from third instar larvae. Severe damage was not observed on older plants, possibly because of their tougher stems (Table 35).

In the field, high infestation levels by adults (4 to 6 per plant) did not severely reduce bean production, except when damage occurred in the first two weeks after planting, and to a lesser extent, during the flowering stage (Table 36).

VALIDATION OF TECHNOLOGY IN ON-FARM TRIALS

Farm level activities are essential in all phases of international agricultural programs. In the initial stages farm interviews identify constraints to yield increases using current varieties and practices, and serve as an input into general research design. Combining this constraint identification with the breeder's judgements on the feasibility of obtaining desired plant characteristics permits definition of a strategy for germplasm evaluation and crossing programs. In the Bean Program this stage was essentially finished in 1978, and primary emphasis moved toward the testing of promising new varieties and agronomic practices, and of the technical barriers which could limit their success at the farm level. In 1978 the Bean Program undertook on-farm studies in Huila (Colombia) and Antioquia (Colombia).

Huila

Current Situation in Huila

Beans are generally planted following more valuable crops such as tomatoes, either in monoculture or intercropped with maize. In the region the average altitude is 900 to 1250 masl with an average temperature of 20°C and an annual rainfall of 1200 mm. The primary growing season for beans in this region is from March to July with a second season from September until December. Most farmers do not utilize fertilizer because the residual effect of the previous crop is still available and beans are mostly grown on soil with good fertility. Planting is still conducted principally by hand although there is some mechanized planting. In the predominant manual planting system, each hill receives two or three seeds and the distance between the holes is variable. This planting technique results in low plant population and no distinct planting pattern. Weeding, when done, is carried out three weeks after germination. Unfortunately, the planting and weeding times of bean in both semesters coincide with the coffee picking season, when very high daily wages can be earned. Hence, weeding is done irregularly or not at all.

Effects of Different Factors in Huila On-farm Trials

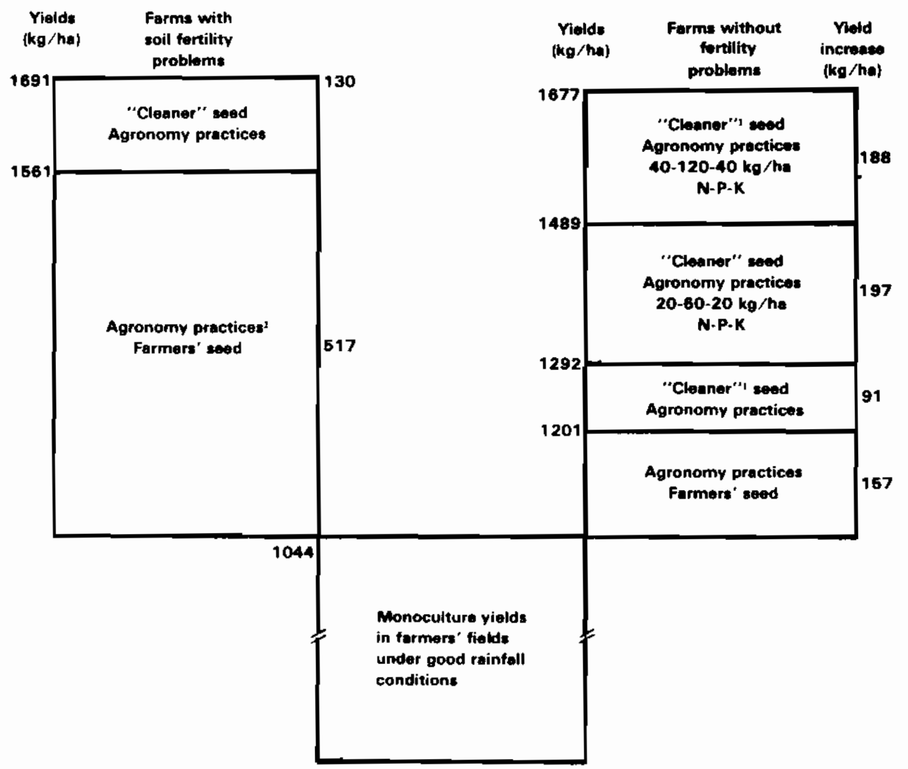
Based on experimental results and previous farm level testing (CIAT Annual Report, 1977) the technologies evaluated in 1978 were; (1) Increased density in monoculture: Population density was increased fron 9 to 18 plants/m^2; (2) Curative spraying; Fields were sprayed once to control anthracnose and *Empoasca;* (3) Use of Certified or "cleaner" seed (disease-free or nearly so) of the Colombian variety, Calima. Cleaner seed was produced under rainfed conditions but with intensive chemical protection. (4) Different levels (0, 200 and 400 kg/ha) of the complete fertilizer 10:30:10 were applied.

Monoculture yields under normal farmers' conditions were favored by excellent rainfall distribution and reached 1044 kg/ha (Fig. 36) when there was no soil fertility problem, the utilization of better agronomy practices with the farmer's seed increased yields to 1561 kg/ha, or 50%. These agronomy practices are low-cost ones involving curative spraying after the pest problem (anthracnose or *Empoasca)* was identified in the field and weeding at the apparent optimum time before flowering. The use of cleaner seed slightly improved yields by 130 kg/ha.

On those farms with a fertility problem (defined as below the critical level of one of the principal nutrients)[1] the combined effect of all four technologies was necessary to raise the yields to equivalent levels of the other group (Fig. 36). On these soils fertilizer use did increase yields. The simple agronomy changes with farmers' seed only increased yields 15%.

Yield increase is not a sufficient validation of new technology. Profitability and risk must also be considered. On farms

1 See Sánchez, P.A., *Properties and Management of Soils in the Tropics,* John Wiley and Sons, New York, N.Y., 1976.



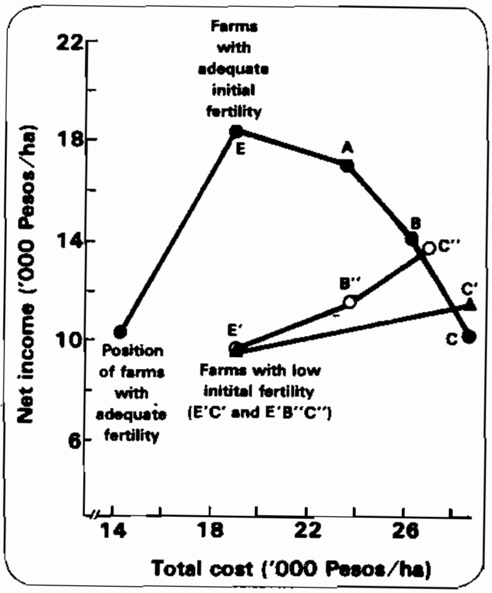
1 "Cleaner" seed refers to heavy chemical protection in Popayan. True disease-free seed will soon be available from an irrigated site. Variety is Diacol Calima.

2 Includes curative spraying and weeding at the optimal period before flowering.

Figure 36. Effects of different factors on yields in farm trials, Huila, Colombia, 1978A.

without a fertility problem the choice is simple. All other technologies besides optimum weeding with curative spraying *decrease* income. On farms with a fertility problem the high fertilizer/improved seed combination was more profitable, but also involved higher production costs than the weeding/curative spraying treatment with the farmer's seed. The farmer could choose from the low cost technology of good agronomy with his own seed (E') or the more profitable but higher cost use of fertilizer and cleaner seed (B" and C") (Fig. 37).

It was possible to determine the payoff to fertilization with soil tests and the definition of minimum initial nutrient levels. In most cases, in these alluvial soils and often following the highly fertilized tomatoes, fertilization was not profitable. Neither was seed quality very important. Certified seed from the Cauca Valley actually gave lower yields, although not significantly lower, than farmers' seed. It is important not to underestimate the farmer, who correctly preferred his own seed to certified seed. Finally, curative spraying, along with weeding at the optimum time gave a reasonable yield increment and was profitable with farmer's seed. Moreover, these yields of almost 1.7 t/ha help define the breeding requirement. A new variety with different seed type characteristics (the same color) would probably need to yield at least 2 t/ha on farmers fields in Huila to improve upon farmers' seed with good agronomy practices, and therefore be accepted by farmers.



E'B''C'' (-.-.-.) indicates seed production costs of protected seed of 50 Pesos/kg.

E'C' represents seed production cost of 70 Pesos/kg.

A: Protected seed, no fertilizer, good agronomic practices.

B: Protected seed, 20-60-20 kg/ha N-P-K, good agronomic practices.

C: Protected seed, 40-120-40 kg/ha N-P-K, good agronomic practices.

E: Farmers' seed, good agronomic practices including curative spraying and 2 weedings.

Figure 37. Net income and total costs per hectare ot alternative technologies for two initial soil fertility situations, in southern Huila, Colombia, 1978A.

Antioquia

On-farm trials in Antioquia were initiated in July 1978, and so only preliminary results are available. The technologies evaluated were: (1) Improved density and better support systems; (2) Improved anthracnose control with chemicals; and (3) Inoculation with rhizobia at several P levels.

While results of this study will be available in detail in 1979, the problems identified in the inoculation technology, evident soon after planting, have prompted detailed studies at the farm level.

Inoculant Studies in Antioquia

Initial studies indicated two major problems in the inoculation methodology: (1) competititon for nodule sites by native soil rhizobia, and, (2) need for fungicide application to overcome root rot problems and the possible deleterious effect of this on applied inoculants.

Fifteen farms were surveyed for incidence of native soil *Rhizobium*. Most probable number counts of soil at planting showed populations of *Rhizobium* from 102 to 58,880 cells/g soil (mean 6344 rhizobia/g soil). For most soils competition between native soil rhizobia could be expected, and must be studied. A complicating factor is that more than 30% of the isolates tested reacted serologically with antiserum against CIAT 57, the normal inoculant strain. Furthermore, many of the rhizobia isolated from nodules of test plants were ineffective in N_2 fixation, with fixation (C_2H_4) levels in 10 farms surveyed at flowering varying from 0 - 31.7 µmol C_2H_4 produced/plant/hour (Fig. 38). More detailed studies of inoculation problems in this region are underway, as are studies on achieving compatability between inoculant and fungicide on seeds.

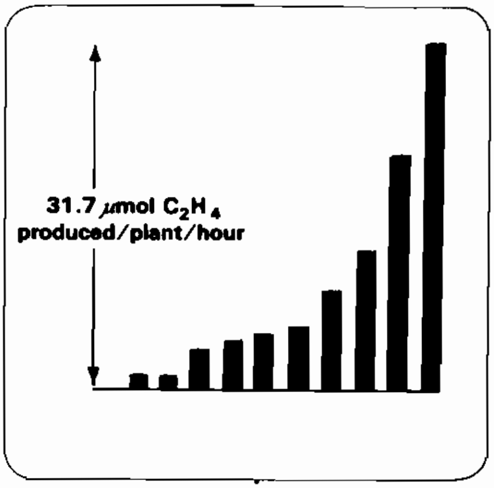


Figure 38. Variation in N_2 (C_2H_2) fixation rates in farmers' fields, in Antioquia.

COLLABORATIVE ACTIVITIES UNDERTAKEN IN 1978 WITH NATIONAL PROGRAMS AND SPECIFIC INSTITUTIONS

Numerous collaborative activities including distribution of IBYAN experiments, rust resistance nurseries and germplasm and hybrid materials have been discussed in the previous sections.

Collaborative Activities in Central America and the Caribbean

In late 1977, and following requests from several governments, CIAT relocated one of its bean scientists in Costa Rica, charging him with coordination within the region of the following activities:

— Supply of CIAT germplasm to national programs.
— Supply of advanced hybrid material to national programs.
— Supervision of international trials (IBYAN, IBRN et.) in the region.
— Cooperation in technical reunions, including the PCCMCA meetings.
— Selection of trainees for bean courses at CIAT and advanced degrees.

Major advances in 1978 have been in the identification of collaborators to receive IBYAN and other nurseries, and an increased efficiency in the prompt delivery, planting and supervision of CIAT trials. Numerous trainees for short courses have been identified, and four candidates suggested for MS degrees.

Collaborative Activities with Other Institutes

Cornell University

A collaborative study at Cornell University (U.S.A.) has studied phytochrome controlled photomorphogenic effects on stem elongation in indeterminate beans. This effect, controlled by a single gene, could be responsible for growth habit instability in particular lines and environments. The screening of CIAT germplasm material for this trait is underway.

Oregon State University

Studies at Oregon State University (U.S.A.) and CIAT compared mulching effects on symbiotic N_2 fixation, and the distribution of C^{14} labeled photosynthate to nodules at different stages of plant development.

Mulching lowered maximum soil temperatures, reduced temperature fluctuations, and slowed soil moisture loss. Nitrogen fixation rates were tripled, and nodule weight increased 50%. Differences in the carbohydrate content of leaves and roots were also noted.

Distribution of C^{14} labeled carbohydrate in the cultivar P498 differed with leaf node treated. Leaves at node 4, treated 35 days after planting, translocated 86% of the C^{14} label to roots, nodules and lower stem. At flowering 19% of the label was recovered in nodules. Photosynthate from leaves at node 8 did not pass to nodules.

Rothamsted Experimental Station

At Rothamsted (U.K.) the photoperiodic sensitivity of the cultivar P566 (CIAT Annual Report, 1975) was used to evaluate the effect of delayed flowering on N_2 fixation. As in the previous study a six-day delay in flowering markedly increased yield. Nitrogen fixation was similarly increased, the yield of more than 3 t/ha in the later flowering treatment being obtained without added fertilizer N.

Plant Breeding Institute, Wageningen

Collaborative studies at Wageningen, the Netherlands, funded through the Dutch government, emphasize breeding for resistance to necrotic strains of BCMV and to races of anthracnose not currently identified in Colombia. This permits breeding activities dangerous to undertake in Colombia.

University of Gembloux, Belgium

Studies at Gembloux, financed through the Belgian government emphasize wide crossing between *P. vulgaris* and other *Phaseolus* spp. and the collection and characterization of additional germplasm. Two Belgian technical experts are currently at CIAT and coordinate this research.

TRAINING

Some details of CIAT training activities are provided in the previous section on international collaboration. The Bean Program in 1978 received two Postdoctoral Fellows, two Visiting Research Associates, four Research Scholars, 28 Postgraduate Interns, two Special Trainees and 59 participants in short courses. Twenty-one countries were represented, the greatest number of trainees being from Brazil (20), Colombia (12), Honduras (9) and Costa Rica and Peru (6). Principal discipline specialities were agronomy (11), plant pathology (9) and plant breeding (7).

PUBLICATIONS

Coyne, D.P., J.R. Steadman and **H.F. Schwartz.** 1978. Effect of genetic blends of dry beans (*Phaseolus vulgaris*) of different plant architecture on apothecia production of *Sclerotinia sclerotiorum* and white mold infection. Euphytica 27: 225-231.

Davis, J.H.C. 1978. Mejoramiento de fríjoles volubles para sistemas de siembra en asociación de maíz. *In* Proc. XXIV Reunión del PCCMA, San Salvador, 10-14 de Julio de 1978. (in press).

Eskafi, F.M. and **Schoonhoven, A. van.** 1978. Comparison of greenhouse and field resistance of bean resistance to *Empoasca kraemeri* (Homoptera: Cicadellidae). Can. Entomol. 110, 853, 858.

Francis, C.A., Prager, M., Laing, D.R. and **Flor, C.** 1978. Genotype X environment interaction in bush bean cultivars in monoculture and associated with maize. Crop Science 18, 237.

Francis, C.A., Prager, M. and **Laing, D.R.** 1978. Genotype X environment interaction in climbing bean cultivars in monoculture and associated with maize. Crop Science 18, 242.

Francis, C.A., Flor, C.A., Prager, M. and **Sanders, J.H.** 1978. Density response in two cropping systems. Field Crops Research 1, 255.

Francis, C.A. and **Sanders, J.H.** 1978. Economic analysis of bean and maize systems: Monoculture versus associated cropping. Field Crops Research 1, 319.

Graham, P.H. 1978. Some problems and potentials of field beans (*Phaseolus vulgaris* L.) in Latin America. Field Crops Research 1, 295.

Graham, P.H. and **Rosas, J.C.** 1978a. Nodule development and nitrogen fixation in cultivars of *Phaseolus vulgaris* L. as influenced by planting density. Journal of Agricultural Science (Cambridge) 90, 19.

Graham, P.H. and **Rosas, J.C.** 1978b. Plant and nodule development in climbing cultivars of *Phaseolus vulgaris* L., grown in monoculture or associated with *Zea mays* L. Journal of Agricultural Science (Cambridge) 90, 311-317.

Halliday, J. and **Graham, P.H.** 1978. Comparative studies of peat and coal as inoculant carriers for *Rhizobium*. Turrialba (in press).

Kretchmer, P.J., Ozbun, J.L., Kaplan, S.L., Laing, D.R. and **Wallace, D.W.** 1977. Red and car-red effects on climbing in *Phaseolus vulgaris* L. Crop Science 17, 797.

Kretchmer, P.J., Wallace, D.H. and **Laing, D.R.** 1978. Inheritance and morphological traits of a phytochrome controlled single gene in beans *Phaseolus vulgaris* L. Crop Science (in press).

Laing, D.R. 1978. Competencia en los sistemas de cultivos asociados de maíz-fríjol. *In* Proc. VIII Reunión de Maiceros de la Zona Andina y I Reunión Latinoamericana de Maíz. Lima, Perú. May 1978. (in press).

Laing, D.R., Rachie, K.O. and **Giraldo, G.** 1977. Preliminary evaluation of mugbean material at CIAT. *In* Proc. of 1st. International Mung Bean Symposium. Los Baños, August. (in press).

Munévar, F. and **Graham, P.H.** 1977. Supervivencia de *Rhizobium trifolii* en tres portadores. Revista ICA (Colombia) 12, 225.

Schoonhoven, A. van. 1978. Use of vegetable oils to protect stored beans from bruchid attack. J. Econ. Entomol. 71, 254-256.

Schoonhoven, A. van., Piedrahita, J., Valderrama, R., and **Gálvez, G.** 1978. Biología, daño y control del ácaro tropical *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) en fríjol. Turrialba 28, 77-80.

Schoonhoven, A. van, Gómez, L.A. and **Avalos, F.** 1978. The influence of leafhopper *(Empoasca kraemeri)* attack during various plant growth stages on seed yield. Entomologia Experimentalis et Aplicata 23, 115-120.

Schwartz, H.F. and **Steadman, J.R.** 1978. Factors affecting sclerotium populations of an apothecium production by *Sclerotinia sclerotiorum*. Phytopathology 68: 383-388.

Schwartz, H.F., Steadman, J.R. and **Doyne, D.P.** 1978. Influence of *Phaseolus vulgaris* blossoming characteristics and canopy structure upon reaction to *Sclerotinia sclerotiorum*. Phytopathology 68: 465-470.

Schwartz, H.F. and **Sanders, J.H.** 1978. Plant diseases of dry beans (*Phaseolus vulgaris* L.) in Latin America and strategies for their control. *In* Proc. Int. Symposium on Diseases of Tropical Food Crops, Louvain-la-Neuve, Belgium, 25 p.

Schwartz, H.F. and **Temple, S.R.** 1978. Bean rust resistance strategy at CIAT. Ann. Rept. Bean Improv. Coop. 21: 48-49.

Temple, S.R. and **Song, L.** 1978. Crop improvement and genetic resources in *Phaseolus vulgaris* L. for the tropics. *In* Proc. Intern. Grain Legume Conf. Kew, England, 1978.

APPENDIX A

Description of growth habits of *Phaseolus vulgaris* L. used in this Annual Report

TYPE I: Determinate growth habit; reproductive terminals on main stem; with no further node production on the main stem after flowering commences.

TYPE II: Indeterminate growth habit; vegetative terminals on main stem with node production on the main stem after flowering commences; erect branches borne on the lower nodes of the main stem; erect plant with relatively compact canopy; guide development variable depending on environmental conditions and genotype.

TYPE IIIa: Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of prostrate branches borne on the lower nodes; guide development variable but generally showing no climbing ability.

TYPE IIIb: Indeterminate growth habit; vegetative terminals on the main stem with node production on the main stem after flowering; relatively heavily branched with variable number of facultatively climbing branches borne on the lower nodes; main stem guide development variable but generally showing climbing ability.

TYPE IVa: Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to main stem development; moderate climbing ability on supports and pod load carried evenly along the length of the plant.

TYPE IVb: Indeterminate growth habit; vegetative terminals on the main stem with heavy node production after flowering commences; branches not well-developed compared to mainstem development; strong climbing tendency with pod load mostly borne on the upper nodes of the plant.

NOTES: The growth habit classification has been expanded for the climbing types since the 1977 Annual Report. Type III materials with some tendency to climb are now recognized as Type IIIb and Type IV has been divided on the basis of vigor and pod distribution.

The most important distinguishing features of the growth habits are as follows: terminal raceme on main stem for Type I; indeterminate with erect branches for Type II; indeterminate with prostrate branches for Type IIIa; indeterminate with semi-climbing mainstem and branches for type IIIb; indeterminate with moderate climbing ability and pods distributed evenly up the plant for Type IVa; indeterminate with aggressive climbing ability and pods carried mainly on the upper nodes of the plant for Type IVb.

Growth habit is not necessarily a stable characteristic since changes in growth habit may occur from one location to another. The classification of growth habit for a particular genotype is only useful in a defined environment, particularly with regard to climbing ability.

APPENDIX B

List of Promising Lines of *Phaseolus* referred to in the 1978 Bean Program Annual Report.

Program Promising No.	CIAT Accession No.	Identification or Registration	Source
P004	G2115	PI 310 878	USA
P006	2005	PI 310 739	USA
P009	2959	Pecho Amarillo	GUA
P014	2146	PI 310 909	USA
P046	0101	PI 151-380	USA
P083	0239	PI 169 775	USA
P084	0241	PI 169 779	USA
P085	0244	PI 169 784	USA
P105	0380	PI 171 790	USA
P166	0677	PI 181 892	USA
P172	0706	PI 183 705	USA
P179	0684	PI 181 996	USA
P217	1280	PI 205 208	USA
P225			USA
P260	1098	PI 282 074 (Ocanero)	USA
P271	1659	PI 300 680	USA
P277	1675	PI 304 120	USA
P300	1757	PI 308 913	USA
P302	1820	PI 309 804	USA
P326	2006	PI 310 740	USA
P337	2045	PI 310 797	USA
P353	2327	PI 311 992	USA
P363	2541	PI 313 654	USA
P382	3647	Actopan	VEZ
P392	G4498	Sanilac	USA
P402	3807	Brasil 2 (Bico de Ouro)	VEZ
P420	3607	C.C.G.B. -44 (I-462)	VEZ
P423	3842	Colombia I-1156	VEZ
P438	3131	F. negro (GUA-0325)	GUA
P449	3451	Guanajuato 116A	MEX
P458	14454	ICA Tui	CLB
P459	3645	Jamapa (I-810)	VEZ
P472	3465	Michoacan 12	MEX
P476	4000	Nep Bayo 22 (C-286)	CRI
P482	3994	Olive Brown (C-236)	CRI
P492	3341	Puebla 87	MEX
P498	3353	Puebla 152	MEX
P499	3359	Puebla 172	MEX
P503	3371	Puebla 298	MEX
P512	4122	S-166-A-N (N-555)	CRI
P518	3689	S-315-N (I-957)	VEZ
P524	4421	S-630-B (C-63)	CRI
P526	3872	Trujillo 3	VEZ

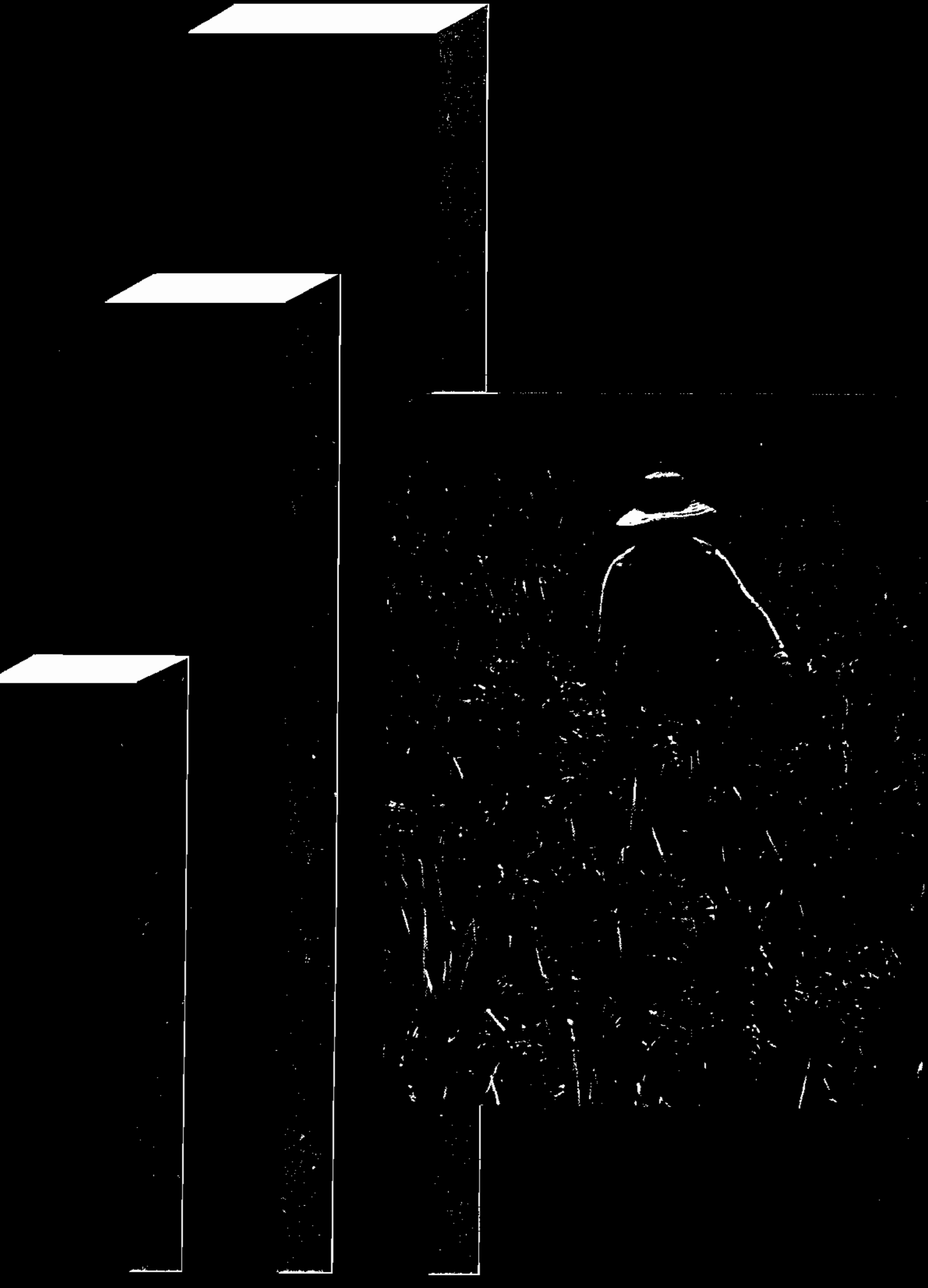
Program Promising No.	CIAT Accession No.	Identification or Registration	Source
P527	3874	Trujillo 7	VEZ
P538	G3709	Veranic 2 (I-980)	VEZ
P539	3776	Venezuela 2 (I-1062)	VEZ
P543	3800	Venezuela 72 (I-1075)	VEZ
P548	3792	Venezuela 48 (I-1079)	VEZ
P560	3834	51051 (I-1138)	VEZ
P561	4152	50609 (N-283)	CRI
P566	4495	Porrillo Sintético	HON
P567	5478	Tara	PRI
P568	5479	PR-70-15R87 (PR-5)	PRI
P588	4455	ICA Huasaño	CLB
P589	2525	PI 313 624	USA
P590	5702	Cargamanto	CLB
P623	4458	27R	CRI
P635	4452	ICA Guali	CLB
P637	4523	Línea 17	CLB
P643	4459	NEP - 2	CRI
P654	4035	S-490 B	CRI
P675	4525	Línea 32 (ICA Pijao)	CLB
P684	1320	PI 207 262 (Tlalnepantla 64)	USA
P692	4494	Diacol Calima	CLB
P693	5653	Ecuador 299	ELS
P698	5476	Jules	USA
P699	G5652	Mexico 309	ELS
P700	5706	Jalpatagua 72	GUA
P706	5701	Rojo 70	ELS
P708	4473	Titan	CHL
P709	4485	Turrialba 1	GUA
P717	5711	Comp Chimaltenango 2	GUA
P720	0832	PI 200 974	USA
P723	5213	Brasil 1096 (I-113)	BRZ
P730	2206	PI 311 818	USA
P732	2545	PI 313 658	USA
P738	4524	Línea 29	CLR
P749	2303	PI 311 359	USA
P750	4128	Santo Tomás 8N N-595	CRI
P752	3758	Negro Argel	CHL
P755	4460	Pompadour 2	CRI
P756	4445	Ex-rico 23	CLB
P757	4461	Porrillo 1	CRI
P758	4446	Ex-puebla 152 (Brown seeded)	MEX
P759	0076	Red kloud	USA
P785	5141	BRZ 805 Michoacan 75	BRZ
P788	1540	PI 284 703	USA

APPENDIX C

List of CIAT accessions (not classified as Promising Lines) of *Phaseolus* referred to in the 1978 Bean Program Annual Report.

CIAT Accession No.	Identification or Registration	Source
P. vulgaris		
G0124	PI 163 372	USA
0413	PI 173 017 (Barbunya)	USA
0881	PI 203 958 (N-203)	USA
1257	PI 201 300	USA
1813	PI 309 796	USA
1841	PI 309 866	USA
1873	PI 310 531	USA
2092	PI 310 854	USA
2227	PI 311 861	USA
2258	PI 311 904	USA
2325	PI 311 990	USA
2351	PI 312 030	USA
2540	PI 313 653	USA
2545	PI 313 658	USA
2546	PI 313 659	USA
2801	PI 319 597 (F. Almendrilla)	USA
3038	IAS (107)	Guatemala
3130	F. Negro (324)	Guatemala
3134	F. Negro (329)	Guatemala
3371	Puebla 298	Mexico
G3565	Oaxaca 39	Mexico
3716	Snandresi	El Salvador
3736	Alabama 1	USA
3738	Beurred' Paul Inat	France
3762	Negro de Guatemala	Venezuela
3777	Venezuela 4	Venezuela
3783	Venezuela 24	Venezuela
3791	Venezuela 47	Venezuela
3988	51054	Costa Rica
4463	Turrialba IN	Costa Rica
4721	San Martin 8	Peru
4826	Pintado	Brazil
5508	Rezayeh	Iran
5710	G.N UI. 31	USA
5752	Bountiful 181	USA
5772	Diacol Andino	Colombia
5773	ICA Pijao	Colombia
5942	PR-70-15R-55 (PR3)	Puerto Rico
6636	Cultivar de Haiti 226	Haiti
6638	47	Haiti
6640	157-A	Haiti
6641	Cultivar de Haiti 157-B	Haiti
7464	Far-lan-tou (NI-275)	China

CIAT Accession No.	Identification or Registration	Source
8058	59/3 (Pop. x Nep 2)	Uganda
G8059	59/4 (Pop. x Nep 2)	Uganda
8062	59/7 (Pop. x Nep 2)	Uganda
8063	60/1 (Pop. x Nep 2)	Uganda
P. acutifolius		
3568	Oaxaca 43	Mexico
4401	Oaxaca 88	Mexico
5917	PI 319 443	USA
P. lunatus		
1157	PI 299 388	USA



Rice Program

The principal objective of the CIAT Rice Program continues to be raising yields in order to increase and improve rice production in Latin America and meet demands for both quality and quantity.

Strategies for solving problems that limit these yields are the formation of varieties that meet the needs of production, quality and adaptation and which also incorporate resistance to diseases and insects common in the region so that production costs and input use may be decreased.

Agronomy designs and tests cultural techniques to make improved varieties as productive as possible in the different environments, with the view to increasing yields, lowering costs and reducing the use of chemical products to favor rice growers on small areas who may have available labor but may not be able to afford purchased inputs and mechanized practices.

The International Rice Testing Program (IRTP) furnishes the primary contact points with countries of Latin America, making available to them the new techniques and improved or segregating plant materials.

In the future, the Rice Program will continue to form a strong network of technical personnel in the different countries of the region. These technicians, many of whom will have received training at CIAT, can provide valuable support and contacts in the programs of the countries, receiving materials from breeders and new agronomic techniques through the Regional Testing Program. Personnel in the network will test, validate and disseminate these new materials and practices, bringing about the transfer of technology.

The continuous rice production system adapted for Latin America by CIAT has been well-accepted by medium- and large-scale farmers, but not by the small farmers, who are the main objectives. In order to let these farmers know about the method, demonstration plots will be made available where the advantages of the system for small farmers may be observed.

BREEDING

Development of high-yielding varieties for yield and production stability and reduction of cost inputs continued to highlight activities of the CIAT-ICA rice breeding program during 1978. The major method of attaining these goals is breeding for resistance to the major production constraints such as rice blast *(Pyricularia oryzae)*, Hoja blanca virus, the leaf hopper *(Sogatodes oryzicola)* and sheath blight *(Corticium sasakii)*.

Rice Blast

Rice blast is the major biological constraint and breeding for stable resistance to the pathogen *Pyricularia oryzae* continues to be the dominant objective of the Breeding Section. Exploition of major and minor genes for the achievement of stable blast resistance is being pursued, through pyramiding of major genes, multilines, pyramided multilines and concentration of minor genes.

Pyramiding Major Genes

A total of 26,000 F_2 plants were selected from 587 multiple crosses among 10 improved parent lines carrying resistant factors from the varieties Tetep, Colombia 1, Dissi Hatiff, C 46-15 and Carreon. The lines were observed and evaluated through the F_4 generation for plant type, resistance to blast and plant hopper *(Sogatodes)* and grain quality. A total of 560 promising F_4 progenies were observed in large unreplicated plots at ICA-Palmira Station, and 90 of these F_4 progenies were selected for replicated yield trials. The selected lines are expected to combine resistance factors from three or four different sources. Of the 90 selected lines, 55 have already been evaluated in replicated yield trials at ICA-Palmira. Stabilization of blast resistance through pyramiding has been the basic objective of the project rather than a yield increase *per se*. The three top yielders of the 55 lines already yield tested are shown in Table 1.

Multiline Varieties

The F_2 and the F_3 generations of the third and final backcross (B_3) for a five-component multiline with five different sources of resistance (Tetep, Colombia 1, Carreon, Dissi Hatiff and C46-15) with two recurrent parents were planted at ICA-Palmira and La Libertad. The recurrent parent phenotype has been reconstituted with the third backcross and acceptable phenotypic uniformity was observed among different isogenic lines in the B_3F_3 generation. Evaluation of the B_3F_3 lines for neck blast and grain quality under field exposure at La Libertad is being continued.

The second backcross for an expanded multiline project with seven different geographically diverse sources of resistance with seven different genetically diverse recurrent parents (CIAT Annual Report, 1977) were completed and the final

Table 1.

Performances of three pyramided rice lines.

Line	(kg/ha)	Percentage of control
5732	7830	125
5722	6712	107
5719	6667	107
CICA 8	6237	100

backcross is being attempted. Raminad Strain 3, the source of resistance from Thailand, has already succumbed to blast and is being withdrawn leaving only six sources of resistance.

Pyramided Multilines

Development of a six-component pyramided multiline with each isogenic line carrying resistant factors from three different sources of resistance (CIAT Annual Report, 1977) was attempted through intercrosses among B_3F_1 populations of the first multiline. The crosses were completed and the F_1 populations have been planted.

Concentration and Utilization of Minor Genes

Twelve varieties from four different countries (Table 2) said and reported to exhibit the rate reducing (horizontal) type of resistance to rice blast were obtained and observed in the blast beds and under field infection.

Under blast bed conditions, almost all the varieties exhibited a resistant reaction with a few restricted susceptible type or moderately resistant types of lesions. As varieties from the same continent are likely to be characterized by the same group of genes, to avoid duplication and for the combination of resistant factors from different continents, crosses were effected among varieties among countries. The F_1 populations are being topcrossed to high-yielding, widely-adapted varieties that have proven to be susceptible.

Crossing of Susceptible Varieties

Building up the rate reducing type of resistance (horizontal) from a completely susceptible base has been strongly advocated as a means of achieving stable resistance to diseases. Exposure of F_2 populations originating from susceptible varieties to heavy disease pressure, selection and subsequent intercrossing of resistant individuals (a system of recurrent selection) for the gradual accumulation and build up of minor gene resistance is

Table 2.

Characteristics of the rice varieties reported to demonstrate the rate reducing type of resistance to rice blast.

Variety	Plant type	Grain quality	Reaction to *Sogata*	Country/region of origin
Moroberekan	Tall	Poor	Susceptible	W. Africa
Suakoko	Tall	Poor	Susceptible	W. Africa
O.S. 6	Tall	Poor	Susceptible	W. Africa
68-83	Tall	Poor	Susceptible	W. Africa
IRAT 8	Dwarf	Poor	Susceptible	W. Africa
IRAT 10	Dwarf	Poor	Susceptible	W. Africa
IRAT 13	Intermediate	Poor	Susceptible	W. Africa
Tapuripa	Intermediate	Good	Resistant	Surinam
Camponi	Dwarf	Good	Resistant	Surinam
Ceysvoni	Dwarf	Good	Resistant	Surinam
Sensho	Dwarf	Good	Susceptible	Japan
IR 11-452	Dwarf	Good	Resistant	Philippines

being attempted. Twelve high-yielding, susceptible varieties (Table 3) were selected and 66 possible intercrosses among them are being made. Their segregating populations will be planted in La Libertad for observation and selection of any resistant individuals for a second cycle of crossing.

Tolerance to Sheath Blight

Varietal resistance to sheath blight *(Corticium sasakii)* has not been detected up to now; what is available is mere tolerance. Intercrosses were made among Tapoo-cho-z, K 8 and Bahagia, three varieties reported to be tolerant in international sheath blight nurseries and each single cross was topcrossed to CICA 4, CICA 7, CICA 9 and Line 4440. Nine F_2 populations from the nine different topcrosses were planted in Montería and Panamá. Additionally, F_2 populations of the backcrosses (Table 4) were also planted in the same locations.

Poor field infection of sheath blight in Montería precluded the evaluation of the populations for sheath blight tolerance. Hence, the F_2 populations were mass-selected to be planted and evaluated during the coming season. The F_2 populations planted in Panamá were also mass-selected under moderate disease pressure to be advanced to the F_3 generation.

Table 3.

List of varieties susceptible to rice blast being intercrossed for the accumulation of minor gene resistance.

Line or variety	Parents		
1170	Bg 90-2	x	[IR 1541 x ob 678]
2485	IR2035-290	x	[Bg90-2 x Pelita 1/1]
3674	73-797	x	[BKN6809 x IR1529]
2123	Bg 90-2	x	[IR 1541 x ob 678]
3838	IR 262	x	[BKN6809 x IR1529]
5568	P 1223	x	P 1248
IR 262	TN 1[4]	x	Peta
CICA 4	IR 8	x	IR 12
Inti	IR 8	x	[Fortuna x Minagra]
Line 8	IR930-53	x	IR579-160
Bg 90-2	IR 262	x	Remadja
Bg 374-1	Bg 66-1	x	IR 20

Table 4.

Backcrosses accomplished to develop tolerance to sheath blight.

CICA 9/2	x	Bahagia
CICA 7/2	x	Bahagia
4440/2	x	Tapoo-cho-z
CICA 9/2	x	Tapoo-cho-z
CICA 7/2	x	Tapoo-cho-z
4440/2	x	K 8
CICA 9/2	x	K 8

Two F_2 populations (Bahagia x 73-805 and Bahagia x IR 262) brought from Sri-Lanka were selected and observed at Palmira through F_2. Twenty-one F_5 lines derived from the said two crosses were yield-tested at CIAT and Panamá. Additionally, the 21 lines were also evaluated for tolerance to sheath blight under field infection in Panamá. Three of the 21 lines were observed to be tolerant to sheath blight (Table 5) in Panamá where the evaluation has been only under moderate field infection. A final conclusion should await the confirmation of the observation under severe disease pressure. Of the three lines observed to be tolerant, two are also found to be resistant to blast, even though the parents involved are susceptible.

Resistance to Bacterial Leaf Blight

Upgrading of Line 4440, CICA 9 and CICA 4 for resistance to bacterial leaf blight *(Xanthomonas oryzae)* is being attempted through backcrossing to three resistant donors, Remadja, Pelita 1/1 and

Table 5.

Evaluation of F_5 rice lines for tolerance to sheath blight and yield potential.

Line	Parents	Reaction to:[2] Sheath blight	Blast	Yield[1] (kg/ha)	% of control
5062	Bahagia x 73-805	T	R (3-4)	8784	109
5063	Bahagia x 73-805	T	R (3-4)	8853	110
5209	Bahagia x IR 262	T	S	10,064	126
CICA 8	(Control)	S	R	7985	100

1 Yield evaluation in CIAT fields.
2 Resistance scale: T = tolerant; S = susceptible; R(3-4) = resistant with few grade 3, 4 lesions.

Bg 66-1. The third and final backcross is being made to each of the recurrent parents. With progressive backcrossing, a dilution of resistance is being observed. As resistance to bacterial leaf blight is reported to be simply inherited (under major genes) the observed dilution of resistance with progressive backcrossing is contrary to expectation.

Genes for Resistance to Plant Hopper

Availability of different genes for resistance to the plant hopper *(Sogatodes oryzicola)* is highly desirable in view of the possibilities of physiologic specialization of the insect. Ten different resistant varieties were crossed and backcrossed to Bluebonnet 50 a susceptible tester. The B_1F_1 and the F_2 populations were evaluated in the greenhouse. High sterility in crosses involving Mudgo and RD 3 precluded a meaningful classification. Data from the F_2 generation from five crosses did not lend themselves for meaningful classification and interpretation even though seedlings from the same populations had been screened a second time. Disagreement prevails between the first and the second screenings. From the available data, the resistance of IR 8 is under the control of a monogenic recessive. A single dominant gene controls resistance in H-5.

Other Breeding Projects

Earliness

Varieties with maturities of 100-110 days are preferred by farmers in the Colombian rice zones of Tolima and the North Coast. Populations (F_2) of 17 three-way and double crosses involving the four early maturing varieties, IR 36, 74-5461, CICA 7 and IR 22, with three different sources of blast resistance, Tetep, Colombia 1 and C 46-15, were planted and observed. Segregates maturing 15 to 20 days earlier than CICA 9 and combining good grain type and plant type were identified in several populations. Eleven promising populations of the 17 were mass-selected for plant type, grain type and earliness, to be advanced to the F_3 generation.

Improvement of Bg 90-2

Bg 90-2 continues to exhibit wide adaptability and high yield potential over locations and seasons. Its commercial acceptability depends on the rectification of its blast susceptibility and grain quality improvement. Sixty-four F_2 populations involving Bg 90-2 crossed to diverse sources of blast resistance were planted. Twenty-seven of the populations matured during the year, and 16 of them were identified as promising and mass-selected to be advanced to the F_I generation.

Additionally, 26 different F_2 progenies of the third backcross of Bg 90-2 to Tetep (Bg 90-2 x Tetep) were planted and observed. Segregants combining blast resistance with improved grain quality and Bg 90-2 phenotype were identified.

Also, 74 F_2 progenies derived from the first backcross of Bg 90-2 to CICA 7 were planted with the dual objective of transferring CICA 7 grain quality and blast resistance of Colombia 1 to Bg 90-2.

Three backcross lines of IR 8 said and believed to combine genes for blast resistance from Tetep and Carreon were obtained from the International Rice Research Institute (IRRI) and were top-crossed to 27 single crosses involving CICA 4, CICA 7, CICA 8, CICA 9, 4414 and Bg 90-2. Five thousand F_2 plants from each top-cross were planted for combining IR 8 plant type, early vigor, acceptable grain quality, diverse sources of blast resistance and high yield.

Rectification of the Defect of CICA 8

High yield, an improved plant type, good grain quality, blast resistance and wide adaptability characterize CICA 8. However, particularly under rainfed or upland conditions, a noteworthy defect of moderate to severe lodging has been observed in this new variety. Ninety-seven different F_2 progenies of the first backcross of CICA 8 to Bg 90-2 and Bg 90-2 to CICA 8 were planted for observation of the incorporation of improved lodging resistance in CICA 8.

Evaluation of Selections Derived from Segregating Populations Obtained from Sri-Lanka

A total of 768 single plant selections were made from eight different F_2 populations of multiple crosses brought from Sri-Lanka (CIAT Annual Report, 1977). Of these, 90 promising lines were observed in unreplicated 5-m long, 6-row plots. A final 51 selections were retained and included in two different replicated yield trials. One of the trials containing 23 lines matured during the year and the performances of the top four yielders of the 23 lines are presented in Table 6.

Evaluation of Introductions

Eighty-five different advanced breeding lines and varieties obtained from IRRI, Ecuador, Perú, Africa, Japan and Surinam were observed in single row plots. Among

Table 6.

Performances of four rice lines derived from segregating populations brought from Sri-Lanka.

Line	Cross					Yield (kg/ha)	% of control
2135	Bg 90-2	x	[IR 1541	x	ob 678]	10,093	109
2196	Pelita 1/1	x	[ob 678	x	IR1529]	10,041	109
2123	Bg 90-2	x	[IR 1541	x	ob 678]	10,041	109
2485	IR2035-290	x	[Bg 90-2	x	Pelita 1/1]	10,024	108
CICA 8	(Control)					9252	100
Bg 90-2						12,015	129

them, suitable donor parents for early vigor, salinity tolerance, field resistance to blast and tolerance to *Rhyncosporium* were identified.

Chemical Induction of Male Sterility

Successful chemical induction of male sterility in whe_t *(Triticum aestivum)* with Ethrel (2 chloroetylphosphonic acid) has been reported.

A recurrent selection breeding procedure may be appropiate for the successful implementation of a breeding program for horizontal resistance to rice blast. Chemically induced male sterility eliminates laborious hand pollinations in recurrent selection breeding. Additionally, chemically induced male sterility also eliminates the complications and drawbacks of cytoplasmic male sterility.

Five different concentrations of Ethrel (1000, 1500, 2000, 3000, 4000 and 5000 ppm) were used on CICA 8 to investigate the possibilites of inducing male sterility in rice. The three highest rates produced male sterility ranging from 42 to 51%. More recent investigations suggest an earlier application to coincide with the initiation of meiosis with a second application to follow three days after the first. The investigation will be repeated.

AGRONOMY

Planting Systems

Maximum Production at Least Cost per Unit of Time and Area

In order to identify the planting system for irrigated rice that provides highest yields in the least time and at the least cost, three seeding systems were compared on puddled soils at CIAT-Palmira. The variety CICA 8 was planted by either: (1) broadcasting dry seed onto dry ground and then irrigating it; (2) broadcasting pregerminated seed onto soil that had been prepared under water; and, (3) transplanting an average of four plants at spacings of 30 x 30 cm in a soil prepared under water and covered with water at time of transplanting.

Transplanting has been demonstrated to be appropriate for preventing weed competition and at the same time is a good system for eliminating red rice.

In each one of the three planting systems, ratooning was practiced after the first rice harvest, to compare yields from this practice with destroying the stubble during repreparation of the field and reseeding.

The transplanting system provided the best yields at least cost, for the first harvest, and resulted in the best returns (Table 7).

Planting Distances and Densities for Transplanted Rice

The variety CICA 8 was transplanted at distances of 20 x 20, 30 x 30 and 40 x 40 cm between plants and between furrows; at each distance, two, four or six plants were set in each hill. The experiment was planted at CIAT-Palmira on soil that had been prepared under water and which was completely free of weeds at the time of

Table 7.

Calculated yield of dry paddy rice of variety CICA 8 and estimated costs of production for three planting systems.

Planting system	Planting density (kg/ha)	Production of dry paddy rice (kg/ha)	Average production costs per hectare[1]			
			Machinery	Labor	Inputs/water	Total
			(kg)			
Broadcasting dry seed on dry soil, with later irrigation	150	6662	285	2019	1594	3898
Broadcasting pre-germinated seed on saturated soil	80	7562	285	1906	1477	3668
Transplanting to 30 x 30 cm with 4 25-day-old seedlings on flooded soil	20	7871	285	2604	928	3817

1 Average 1978 Colombian costs in pesos transformed to the average price of one kg of dry paddy rice. Does not include value of land, management, technical assistance, capital and interest, transportation, drying and other processing.

transplanting. Development of the crop was similar for all treatments although the closer distances favored the most rapid covering of the ground with rice foliage.

Yields were better when rice was transplanted at the closer distances, regardless of the number of plants per hill. This indicates that the variety CICA 8 can be planted at a spacing of 20 x 20 cm at densities from two to six plants per hill. Placing an average of four plants per hill decreases the risk of empty spaces that cause seedling death when rice is transplanted at only one plant per hill.

The number of effective tillers for best productivity —those that form and mature properly— was better per unit area at the smaller distances because there were more hills. This effect diminished as the planting space increased and was not influenced by the number of plants per hill (Tables 8 and 9).

Table 8.

Calculated yield of dry paddy rice of variety CICA 8 under conditions of different transplanting distances and densities.

Transplanting distance (cm)	Yield (kg/ha)		
	Seedlings per hill		$\bar{X}$ of densities
20 x 20	2	8506	
	4	8724	
	6	8654	
			8628
30 x 30	2	8507	
	4	8533	
	6	8333	
			8458
40 x 40	2	7760	
	4	7925	
	6	7839	
			7841

Table 9.

Populations of effective tillers per area and per hill for CICA 8 at different transplanting distances and densities.

Transplanting distance (cm)	Seedlings per hill	No. of effective tillers per m²	X of densities	per transplanted hill
20 x 20	2	372		
	4	408		
	6	411		
			397	16
30 x 30	2	402		
	4	307		
	6	294		
			334	37
40 x 40	2	326		
	4	333		
	6	213		
			290	48

The number of effective tillers that each plant produces at each hill is less at a distance of 20 x 20 cm than at the wider spacing distances, but the total yield was higher and the total number of tillers per unit area was increased, indicating a better utilization of the space and energy that the plant needs during the reproductive phase.

At the 20 x 20 cm spacing, more seed and more man-hours are required for transplanting, however, the higher production makes up for these factors.

Rice Yields in the First Harvest and from Ratooning

The behavior of nine improved rice varieties transplanted at distances of 30 x 30 cm with one seedling per hill showed that yields in the first harvest are not a good indication of the production from ratooning because of varietal differences in performance under ratooning.

The highest yields in the first harvest and the lowest in the ratoon harvest were both with the variety CICA 8. The poor performance of this variety in ratoon permitted the variety Juma 57 to produce more total rice than did CICA 8.

Table 10 shows the yields of the nine varieties in the experiment and confirms results presented earlier (CIAT Annual Report, 1972) of the high regrowth capacity of CICA 4, which produced 30% as much rice in ratoon as it did in the first harvest.

As the number of tillers is only one of the factors affecting yield, there was no correlation between the number of effective tillers and yields (Table 10).

Weed Control

Weed Competition with Rice

When weeds are not properly surpressed they can affect the development and later yields of the rice crop. At certain stages of development, the rice plant is most susceptible to weed competition.

Table 10.

Yield of dry paddy rice and tillering effectiveness of nine rice varieties in the first harvest and in a ratoon harvest.

Variety	Yield (kg/ha)				Average number tillers/plant			
					1st Harvest		Ratoon	
	1st harvest	Ratoon	% - Ratoon/ 1st harvest	Total	Effective	Ineffective	Effective	Inefecctive
CICA 8	6046	119	1.96	6165	25.6	2.6	22.3	17.0
CICA 9	5793	478	8.25	6271	21.3	2.3	20.6	10.0
Juma 57	5543	1566	28.25	7109	28.0	2.3	26.3	23.0
Tikal 2	5236	421	8.04	5657	27.0	2.0	17.6	9.6
Inti	4926	415	8.42	5341	28.3	1.0	22.3	13.0
CICA 4	4343	1456	33.52	5799	33.0	2.3	28.6	23.6
CICA 6	4256	700	16.44	4956	29.3	3.3	34.6	22.6
CICA 7	4233	991	23.41	5224	27.6	4.3	36.3	27.3
IR 8	2463	590	23.95	3053	25.3	3.0	37.3	26.6

In experiments to find the most effective time of controlling weeds, the smallest amount of weeds (dry weight basis) and the highest rice yields were obtained when the weeds were removed manually or controlled chemically during the first 30 days after planting. When weed control occurred between 30 and 50 days, production was affected, but the most drastic decrease in rice yield and the largest growth of weeds occurred when they were allowed to grow freely during the first 70 days. Weedings after 70 days did not have any influence on increasing rice yields (Table 11).

Table 11.

Calculated rice yields and dry weight of weeds according to the different times when weeds competed with the rice variety CICA 8.

Age of rice after which it was free of weeds (days)	Yield of dry paddy rice (kg/ha)	Weed dry weight (g/m²)
0	7708	3
10	7463	3
15 (propanil)	7200	-
20	7150	48
30	6689	196
30-60-90	6031	305
40	5631	398
50	4476	513
70	912	806
90	260	1075
No weeding	157	1195

Weeds adversely affect plant height, tillering and size of the rice panicles that develop, in a manner similar to effects of the time of competition on eventual yields. The stage of development of the rice plant in which it is most susceptible to weed competition occurs at 30 days of age, therefore weed control should be early and effective.

Effectiveness of Pre-emergent Herbicides in Soil Prepared under Water and Planted with Pre-germinated Seed

The planting system in which pre-germinated seed is distributed over soils previously prepared under water increases yields and lowers costs, compared to the traditional planting system of broadcasting dry seed over dry soil, and then irrigating it. However, not all pre-emergent herbicides can be used with pre-germinated rice because some of the rice remains uncovered and the herbicide comes into direct contact with seed during the early germinating stage.

The herbicides RH 8817 and oxyfluorfen 2 CE, did not decrease populations of rice seedlings and provided good initial weed control when used in pre-emergence applications.

In preliminary observations, oxadiazon, at 1 kg a.i./ha, and dimethametrine, at 1.8 kg a.i./ha, both decreased rice populations when applied over pre-germinated seed. No decreases were noted when both were applied over seed that had been distributed dry, irrigated and then sprayed with the herbicides.

Mixtures of Post-emergent Herbicides

The herbicide propanil, in post-emergent applications is selective and does not have residual effects. For this reason, mixtures of propanil with other products are being sought to provide a residual effect without decreasing its selectivity.

The experimental product RH 5205 decreased rice plant populations and phytotoxicity problems from which rice did not recover. The compounds RH 2512 and RH 2915 gave good control of weeds and only showed slight toxicity to rice; they are being considered as promising materials.

Hormonal Herbicides Using Urea as the Carrier

With the objective of decreasing costs of spraying and preventing problems of volatility, commercial hormonal herbicides were distributed mixed with urea being applied as fertilizer. Observations were made on their weed control effectiveness, the response of the plant to the fertilizer and any possible phytotoxicity.

Treatments compared were the following: spraying the herbicides mixed in water as opposed to impregnating the urea with the hormonal herbicides 2,4,5-T, 2,4-D, picloran and MCPA, all at rates of 0.24 and 0.36 kg a.i./ha, when rice plants of the CICA 9 variety were 14 days old. The fertilizer with the herbicides was spread over the plots.

No treatment differences for the conditions studied were observed with respect to broadleaf weed control and phytotoxicity; plant response to the fertilizer was normal.

Effects of Planting System on Weed Control

Transplanting has been shown to be effective for preventing weed competition in rice because of the advantage that the seedlings have over weeds so long as transplanting is done on soil free of growing weeds and is covered with water. To integrate weed control methods one can complement transplanting with applications of herbicides although on soils that are not highly infested with weed seeds, chemical control is at times not necessary.

In a treatment in which dry seeds were broadcasted on dry, weed-free soil, both the rice and the weed seeds that were in the ground received the water necessary to germinate at the same time, initiating competition from the first stages of development.

Pre-germinated seed on soil prepared under water and still saturated with water has a small advantage over planting dry seed on dry soil, but it is not enough to provide complete protection until harvest, not even with herbicides and irrigation.

For cleaning fields of red rice and for producing harvests that are most pure and freest of weed seeds, transplanting has advantages over direct seeding.

Influence of Transplanting Distance on Populations and Weed Development

When transplanting seedlings of 25 to 30 days of age at a distance of 20 x 20 cm, the seedlings have an advantage over the weeds from their development and the foliage of the growing crop covers the area and prevents sunlight from reaching weed plants. These effects are, of course, most pronounced at close spacing of 20 x 20 cm, decreasing as the planting distance widens to 40 x 40 cm where the effects of weed competition are most pronounced (Table 12).

According to the results in Table 12, for CIAT conditions, the aquatic weeds are most abundant in fields prepared under water with the grasses being next in importance. The predominant species in each of the four groups were: aquatic weeds— *Limnocharis flava, Heteranthera reniformis, Jussiaea leptocarpa,* and *Sphenoclea zeylanica;* Grasses— *Echinochloa colonum, Chloris polydactyla* and *Leptochloa filiformis;* Cyperacea weeds— *Cyperus ferax, Cyperus flavus, Cyperus diffusus, Cyperus brevifolius* and *Eleocharis* spp.; and Broadleaf weeds— *Euphorbia hypericifolia, Eclipta alba* and *Boerhaavia decumbens.*

Weed Control in Transplanted Rice

In order to evaluate the chemical control of weeds in transplanted rice, manual weeding was compared with several commercial herbicides.

Treatments providing the highest yields were: hand-weeding followed by treatments receiving the granular herbicide

Table 12.

Weed dry weight in rice according to transplanting distances and densities.

Transplanting distance (cm)	and plants/hill	Weed dry weight (g/m^2) Aquatic	Broadleaf	Cyperaceas	Gramineas	Total
20 x 20	2	186.5	41.5	28.0	29.5	285
	4	80.3	26.3	40.5	21.0	168
	6	66.0	14.0	35.0	35.5	140
30 x 30	2	256.3	23.3	56.0	40.3	377
	4	110.0	20.3	41.0	59.0	230
	6	99.5	40.3	30.3	38.3	208
40 x 40	2	269.5	138.0	97.0	315.5	820
	4	141.3	72.0	73.6	199.0	485
	6	190.6	50.0	77.3	144.0	461
Total		1402.0	425.7	478.7	872.1	

oxyfluorfen (at 0.25 kg a.i. / ha, applied five days after transplanting); oxyfluorfen applied twice (at 5 and 15 days); oxyfluorfen (at 0.5 kg a.i./ha, applied five days after seeding); and propanil applied twice (2.0 kg a.i. / ha each application, at 15 and 25 days after transplanting). All provided yields above 8 t/ha (Table 13).

Propanil (at 4 kg a.i./ha) controlled weeds well but rice yields were less than in those treatments with the same amount divided. Although treatments with oxyfluorfen had larger populations of weeds than those plots receiving propanil, the yields were higher in the former case.

Machinery

Soil Preparation

Preparing soils by cultivating under water is a tillage system for rice that has the advantages of: good weed control, preparing the soil for efficient irrigation, and saving on irrigation water and fertilizer. However, when heavy machinery is employed for preparing land under water, for example tractors of 70 or more HP with rotatory cultivators having large blades, the hardpan of the soil is lowered. As work continues with machinery, during combine harvesting or subsequent land preparation, equipment frequently becomes buried, causing lost time and a danger of damage to the machines. To decrease the depth of the hardpan base it was decided to prepare rice agronomy lots at CIAT first in dry soil without any flooding but having a moisture content suitable for this type of preparation, and afterwards introducing water to flood the soil. Then, the ground was leveled using smaller two-wheeled tractors that are too light to get stuck. The rice grows well in well-prepared soil and the machinery suffers less wear and is more efficient.

Mechanized Transplanting

Transplanting rice with machinery is more demanding than manual transplanting because of the soil preparation and moisture involved. Mechanized work is

Table 13.

Effects of various weed control methods on rice yields and weeds present at harvest.

Treatment	Amount applied (kg a.i./ha)	When applied (days after transplanting)	Yield of dry rice (kg/ha)	Weed dry weight at harvest (g/m²)
Hand weeding	-	-	8486	4.0
oxyfluorfen	0.25	5	8257	70.0
oxyfluorfen	0.25 + 0.25	5, 15	8229	85.2
oxyfluorfen	0.50	5	8167	112.7
propanil	2.0 + 2.0	15, 25	8144	38.7
propanil + 2, 4, 5-T	2.0 + 0.2	15	7837	68.0
propanil	4.0	15	7828	22.0
propanil	2.0	15	7482	70.5
2, 4, 5-T	0.2	15	7227	155.0
2, 4, 5-T	0.4	15	7163	78.5
Check	-	-	4101	567.0

made more difficult by: (1) soils that were previously prepared under water with tractors heavier than 70 HP because a very deep soil layer has been removed; (2) soils prepared when dry and then flooded without any other cultivation or leveling because the seedlings do not have good anchorage; and, (3) soils prepared under water and having good support, but with a layer of water less than 5 cm deep, because the equipment did not plant. This is most serious in fields that were not well-leveled.

Transplanters were efficient in fields prepared under water when used with two-wheeled tractors that did not sink into the soil and on soils saturated with moisture but without a layer of water.

Fertilization

Influence of Planting Distance and Levels of Nitrogen on Plant Height and Tillering

The varieties CICA 8 and IR 22 were compared in plantings made at two spacings and under three levels of N. Planting either variety at a spacing of 20 x 20 cm with one plant per hill did not influence the number of tillers per plant at 95 days of age when N was applied at 0, 80 and 160 kg/ha. However, increasing fertilizer levels did cause increased tillering when plants were spaced at 30 x 30 cm.

Entomology

The *Hydrellia* is a miner insect that breeds primarily in rice fields that are prepared under water and that are irrigated by flooding permanently or frequently. Because the *Hydrellia* is an insect whose natural habitat is a high moisture one, for initial control it is necessary to drain the fields, removing favorable conditions for the pest. When, however, drainage is impossible because of drought damage to plants, chemical control is preferable using granular insecticides spread over the damp soil or even on the water surface when water is not moving.

The granular insecticides carbofuran

Table 14.

Effects of two transplanting distances and three N levels on plant height and number of tillers in two rice varieties, at 95 days.

Variety	Transplanting distance (cm)	N applied (kg/ha)	Plant height (cm)	Tillers per plant
CICA 8	20 x 20	0	94.5	20.0
		80	97.5	19.0
		160	106.0	17.5
	30 x 30	0	99.5	26.5
		80	98.5	33.5
		160	108.5	36.5
IR 22	20 x 20	0	84.5	19.0
		80	87.5	18.5
		160	97.0	22.0
	30 x 30	0	86.5	25.0
		80	92.5	33.5
		160	90.0	35.5

and diazinon were applied at rates of 0.6 kg a.i./ha, to control the insect. Diazinon proved to be a more rapid and effective control than did carbofuran, confirming earlier published reports (CIAT Annual Report, 1976).

Hoja Blanca and Sogatodes

Information was received on the presence of the insect *Sogatodes* and of symptoms of the disease Hoja Blanca in rice fields in Ecuador. To study the problem, identify the species of insect involved and the symptoms of the disease, visits were made to the rice-growing zones of Guayas and Arenillo where the insect infestation had lowered and evidence of the virus was not serious.

In agreement with technicians from that country, it was suggested to INIAP that is should acquire installations and train technicians at CIAT, so that studies could be initiated to serve the varietal improvement programs and provide a solution to the problem.

Seed

Basic Seed Multiplication

During 1978, through agreements between CIAT and ICA, basic seed was multiplied in the CIAT fields through the efforts of Station Operations. ICA delivers the seed obtained under pure methods and CIAT transplants this seed to insure the highest multiplication factor. The seed is harvested, dried, sorted and delivered to ICA as basic seed.

The complete production process is under the supervision of the Rice Program and the Seed Services Section of ICA, which guarantees the purity and quality of the final product. Varieties and quantities multiplied during 1978 were: CICA 8 (23,350 kg, in March), CICA 4 (18,000 kg, in April), IR 22 (37,850, in November), CICA 8 (43,000 kg, in December) and CICA 7 (18,000 kg, in December).

TRAINING

During the first semester of 1978, 10 trainees from various countries of Latin America attended a four-month rice production course at CIAT. When this ended, two of the professionals from Peru and one from Mexico remained at the Center for an additional month of training in plant breeding while one trainee from Ecuador received an additional month of training in agronomy.

Trainees were responsible for production plots in the field and also participated in the design, seeding and management of two experiments: one on Maximum Production at Least Cost per Unit of Time and Area; and the other on Planting Densities using Pre-germinated Seed on Soils Prepared under Flooding. These experiments were established so that other trainees could harvest them during the second semester.

In the second semester, two courses were organized—one a production course and the other, on present knowledge in rice production.

The production course had 10 participants from eight countries of Latin America. It lasted for three months, during which time the trainees received training in different aspects of rice production and designed and participated in the planting and management of an experiment on the Behavior of CICA 8 with Respect to N, Weeds and Planting Density. An important part of this training was the study trips made to the different rice-growing zones of Colombia, including the Valle del Cauca, Cauca, Tolima, Meta, Santander and Cesar. In these locations, they observed the different production stages on commercial farms as well as work in the transfer and adoption of technology.

Conferences on different types of cultural practices, alternating with practices in the field, laboratory and greenhouses, complemented this training. Seminars given by the trainees about their own countries and the individual work of reviewing the literature and speaking about technical work before their peers helped fulfill the objectives of training and facilitated group communication.

Three of the 10 trainees in the production course in the second semester remainded for an additional month to continue working in agronomy and transfer of technology.

The course on present knowledge in rice production was attended by 25 agronomists from ICA and the Federación Nacional de Arroceros (FEDERROZ). It lasted for two weeks during which emphasis was on preparing fields by the system of flooding, planting of pre-germinated seed and transplanting.

In order to train Latin American agronomists in field work using cultural techniques that can increase yields at lower costs, participants in the rice production course during the first semester planted plots with pre-germinated seed, broadcasting it at four seeding densities over soils prepared under flooding.

Seeding densities and their respective yields were: 80 kg/ha of seed, 8349 kg/ha of rice: 50 kg, 7600 kg; 110 kg, 6054 kg; and, 140 kg, 5445 kg.

INTERNATIONAL RICE TESTING PROGRAM FOR LATIN AMERICA

In order to help national rice programs to achieve their main objective of increasing rice production and productivity, the activities of the International Rice Testing Program (IRTP) for Latin America in 1978 were directed to accomplishing the following strategies: (1) evaluating multiplying elite basic germplasm from IRRI, CIAT and national programs; (2) selecting entries suitable and appropriate for testing through specific nurseries requested by national programs; (3) identifying problems and needs of rice production in Latin America (4) identifying personnel for training at CIAT and IRRI; (5) assembling and organizing data of nurseries distributed in 1977.

Results of IRTP Nurseries for Latin America Distributed in 1977

In mid-1977, 96 sets of six specific nurseries for Latin America were sent to 19 Latin American countries (CIAT, Annual Report, 1977). Most countries received the nurseries on time, planted them during the main growing season and returned the data. Table 15 shows the percentage of

Table 15.

Data sets returned from International Rice Testing Program Nurseries for Latin America, for 1977 plantings.

1977 Nurseries[1]	Number of sets Dispatched	Data returned	% of data received
VIRAL-P	28	18	64
VIRAL-T	28	17	61
VIRAL-S	22	13	59
VIRAL-F	5	-	-
VIAVAL	9	6	66
VIOSAL	4	-	-
Total	96	54	56

1 VIRAL-P = International Rice Yield Nursery—Early Maturing; VIRAL-T = International Rice Yield Nursery—Medium Maturing; VIRAL-S = International Rice Yield Nursery—Upland; VIRAL-F = International Rice Yield Nursery—Deep Water; VIAVAL = International Rice Sheath Blight Nursery; and VIOSAL = International Rice Salinity and Alkalinity Observational Nursery.

data received of each nursery. These percentages are rather high and give a good indication that this international cooperation is well accepted. It is expected that this cooperation would greatly increase as national programs become more conscious of its benefits.

The data received of various nurseries was analyzed and results were summarized. The final reports are under publication.

Yield data of the best five entries of VIRAL-T, VIRAL-P and VIRAL-S are presented in Table 16. Yields of the VIRAL-T best entries are high when one considers that they represent an average of 13 locations, and four of them were grown under upland conditions for which these entries were not recommended. Under irrigated conditions these entries yield over 6.0 t/ha.

The best five entries of the yield upland nursery (VIRAL-S) yielded better than local checks in locations with good rain distribution. But they were inferior to the local check (IAC 47) under unfavorable upland culture like Uberaba, Minas Gerais and CNPAF, Goiania in Brazil.

Yields of the best five entries of the VIRAL-P were as high as those medium entries of the VIRAL-T. In the average yields of 15 locations, yields of four locations where VIRAL-P was planted under upland conditions with good rain distribution, were included. Under these upland conditions the average yield for these entries ranged from 4.0 to 5.5 t/ha.

From the yield nurseries of early and medium maturing varieties, several promising lines have been advanced for yield trials and regional tests by national programs. Thirteen lines were selected in Nicaragua, 4 in Bolivia and Honduras, 5 in Peru and 2 in Panama. Colombia selected 12 lines for further yield trials and 10 as donor parents.

Table 16.

Average yield and growth duration of the best five entries in each of three International Rice Yield Nurseries from CIAT-IRRI, planted in 1977.

Designation	Origin	Yield (t/ha) Average	Yield (t/ha) Range	Rank	Days to maturity
VIRAL-T, 1977, planted at 13 locations[1]					
IR 2588-19	IRRI	5.9	0.5 - 9.3	1	139
IET 1785	India	5.8	0.5 - 8.9	2	135
Bg 375-1	Sri-Lanka	5.7	0.5 - 8.7	3	137
B 542b-Pn-68	Indonesia	5.6	0.1 - 10.4	4	137
CICA 9	CIAT-ICA	5.5	0.5 - 7.8	5	135
VIRAL-S, 1977, planted at 10 locations[2]					
CICA 8	CIAT-ICA	3.4	0.1 - 6.6	1	128
IR1529-430-3	IRRI	3.3	0.2 - 5.8	2	129
IR1750-F5-B-5	IRRI	3.1	1.6 - 5.0	3	122
IR2061-522-6-9	IRRI	3.1	0.4 - 5.0	3	120
IR 36	IRRI	3.0	0.1 - 5.2	5	121
VIRAL-P, 1977, planted at 15 locations[3]					
IET2881(RP319-34-8-1-3)	India	5.8	0.9 - 8.7	1	123
B541b-Pn-58-5-3-1	Indonesia	5.7	2.9 - 9.2	2	125
CICA 7	CIAT-ICA	5.3	2.5 - 9.6	3	128
BR51-46-1-C1	Bangladesh	5.3	2.5 - 9.0	3	128
IR1561-228-3-3	IRRI	5.3	2.7 - 7.6	3	119

1 Low yields correspond to Cárdenas, México, under unfavorable upland conditions.
2 Low yield corresponds to unfavorable upland conditions (Brazil) and high yield to favorable upland in Bolivia.
3 Low range yields correspond to upland conditions.

Evaluation of IRTP Nurseries from IRRI

1977 Nurseries

In the second semester of 1977 (August-December) seven nurseries (Table 17) from IRRI were planted at CIAT for evaluation and seed multiplication. The germplasm was evaluated under field conditions, for plant type, maturity, lodging resistance and yield, and under laboratory conditions, for *Sogatodes* resistance, grain type and quality. All entries having poor plant type (tall, leafy and susceptible to lodging), susceptibility to *Sogatodes*, late maturity, short grain and poor milling and cooking qualities were discarded. Therefore, only those entries combining good plant type (semi-dwarf or intermediate in height and resistance to lodging), resistance to *Sogatodes*, early and medium duration, long and medium size grain with good milling and cooking qualities, and good yield were selected to form seven specific nurseries for Latin America which were requested in the Second Conference of the IRTP, held at CIAT in November, 1977 (Table 18). These nurseries were distributed in March 1978

Table 17.

IRTP 1977 Nurseries from IRRI evaluated at CIAT, in the second semester, 1977.

Nursery[1]	No. of entries	No. of entries selected
IRYN-M	28	11
IURYN	25	7
IURON	153	23
IRON	391	37
IRBN	476	98
IRSHBN	154	18
IRSATON	77	25

1 IRYN-M = International Rice Yield Nursery—Medium
IURYN = International Upland Rice Yield Nursery
IURON = International Upland Rice Observational Nursery
IRON = International Rice Observational Nursery
IRBN = International Rice Blast Nursery
IRSHBN = International Rice Sheath Blight Nursery
IRSATON = International Rice Salinity and Alkalinity Tolerance Observational Nursery.

for those countries with planting dates between May-June, and in August for those countries that plant in October-November.

Tables 19 and 20 show the principal characteristics and yield of germplasm included in the yield nurseries of medium duration (VIRAL-T) and upland varieties (VIRAL-S). The VIRAL-T included three lines from India; four from Indonesia; two from IRRI, Philippines; and one each from Sri Lanka, Taiwan, Colombia and Surinam. Yields fluctuated from 5.3 to 8.4 t/ha.

Among the germplasm included in the yield upland nursery (VIRAL-S) seven lines (from India, Indonesia and IRRI) showed good yield potential (above 8.0 t/ha), were highly resistant to *Sogatodes* and had good grain quality (Table 20).

The germplasm of the Observational Nursery (VIOAL) was combined with upland and lowland entries and most of them with intermediate stature. This material will perform better than the dwarf types under upland conditions, especially in countries with problems of weeds and irregular rainfall distribution.

Entries of the blast nursery (VIPAL) originated from the 7th IRBN-77 of IRRI and were evaluated for blast reaction under bed conditions at the Palmira and La Libertad stations of ICA. Lines showing resistance in both locations at seedling stage and having desirable agronomic traits at CIAT-Palmira were selected to form the blast nursery for Latin America. This nursery was complemented with 67 entries from the CIAT-ICA rice breeding program.

1978 IRRI Nurseries

In June 1978, 14 nurseries were received from IRRI. Table 21 shows the type of nursery and number of entries. These nurseries were planted at CIAT-Palmira in August for evaluation, seed multiplication and selection. The germplasm of various nurseries was harvested and will be evaluated under laboratory conditions for *Sogatodes* resistance and grain quality in early 1979. The selected entries would be the basic material for distribution through specific nurseries for Latin American countries in 1979.

Monitoring Tours

One of the activities of the IRTP relates to monitoring tours that are organized with participation of rice scientists of the national programs. In 1977 and 1978 two monitoring tours were organized, one for Central America and Mexico, and a

Table 18.

IRTP Nurseries for Latin America distributed in 1978.

Nursery[1]	No. of entries	No. of sets	Yield range[2] (t/ha)
VIRAL-T	14	26	5.3 - 8.4
VIRAL-S	19	31	3.3 - 9.4
VIOAL	60	37	4.0 - 10.5
VIPAL	185	31	-
VIAVAL	20	11	4.0 - 8.6
VIOSAL	25	7	4.7 - 12.0
VIRAL-F	8	5	4.5 - 8.9
Total	331	148	

1 VIRAL-T International Rice Yield Nursery - Medium
VIRAL-S International Rice Yield Nursery - Upland
VIOAL International Observational Nursery
VIPAL International Rice Blast Nursery
VIAVAL International Rice Sheath Blight Nursery
VIOSAL International Rice Salinity and Alkalinity Observational Nursery
VIRAL-F International Rice Yield Nursery - Deep Water

2 Yields obtained at CIAT under irrigated-transplanted conditions.

second one for the Southern Region of South America.

The objectives of these monitoring tours were the following: (1) to observe the performance of the germplasm from the international nurseries and material from national programs; (2) to get acquainted with the cultural system in the region and the research activities being conducted by the national programs; (3) to determine specific problems limiting rice production which can be overcome with improved varieties; and (4) to identify personnel of national programs for training at CIAT or IRRI.

Monitoring Tour to Central America and Mexico

This monitoring tour was made between Nov. 7-13, 1977 to observe the rice culture and research activities in Panamá, Costa Rica, Guatemala and Mexico (states of Campeche and Morelos).

National program leaders of each visited country, the coordinator of the CIAT Rice Project in Central America and four scientists from IRRI, including the coordinator for Latin America, participated in this monitoring tour.

A detailed report covering the different activities and recommendations of the group was published in early 1978 and distributed to technicians and decision-makers in rice research of the region.

This monitoring tour was very interesting and the group had the opportunity to observe production-limiting problems such as sheath blight, leaf scald

Table 19.

Principal characteristics of the germplasm in the 1978 International Rice Yield Nursery— Medium Maturing varieties for Latin America (VIRAL-T).

			Agronomy		Insects	Quality		
Line No.	Identification	Country of origin	Height (cm)	Maturity (days)	*Sogatodes*[1]	Grain length[2]	Gelat. temp.[3]	Yield (t/ha)
1	IET 2080 (J3-756)							
	Cross 4/TN1	India	80	146	1	5	L	6.6
2	IET 2815 (RP6-516-34-1)							
	TKM 6/IR8	India	84	130	2	3	I	7.4
3	IET 4094 (CR156-5021-207)							
	BU 1/CR 115	India	78	130	2	3	I	6.2
4	B54lb-Kn-58-5-3							
	Pelita I-1/IR1108-2	Indonesia	107	139	3	5	AI	7.1
5	B5416-Kn 22-7-2							
	Pelita I-1/IR1108-2	Indonesia	111	147	1	5	I	8.0
6	B541b- Kn-91-34							
	Pelita I-1/IR1108-2	Indonesia	108	145	3	5	I	7.2
7	B541b-Kn-7-1-2-3							
	Pelita I-1/IR1108-2	Indonesia	105	148	1	3	I	7.2
8	IR2863-38-1-2							
	IR1529-680-3/CR94-13//IR480-5-9-3	IRRI	86	149	1	3	L	5.3
9	IR4422-98-3-6-1							
	IR2049-134-2/IR2061-125-37	IRRI	110	139	3	3	L	8.3
10	BG 375-1 (75-404)							
	BG 66-1/IR20	Sri-Lanka	96	150	1	5	I	8.4
11	Taichung sen yu 195							
	Bin-Tang-Chien/IR661	Taiwan	92	149	1	3	I	6.5
12	CICA 8	Colombia	96	147	1	3	I	7.8
13	Diwani	Surinam	93	130	-	-	-	7.2
14	CICA 4 (Check)	Colombia	87	130	2	3	I	7.7

1 International resistance scale of 1-9: 1-2.9 = resistant; 3.0-3.9 = moderately resistant; 4.5-5.9 = moderately susceptible; 6.0-9.0 susceptible
2 Scale for length of grain: 3 = long grain (6.61-7.50 mm); 5 = medium length grain (5.51-6.60mm)
3 Gelatinization temperature: L = Low; I = Intermediate.

Table 20.

Principal characteristics of germplasm in the 1978 International Rice Yield Nursery — Upland varieties for Latin America (VIRAL-S).

Line No.	Identification	Country of origin	Agronomy: Height (cm)	Agronomy: Maturity (days)	Insects: *Sogatodes*[1]	Quality: Grain length[2]	Quality: Gelat. Temp.[3]	Yield (t/ha)
1	KN361-1-8-6							
	JERAK/IR 8	Indonesia	133	132	2	5	I	8.6
2	IR 36							
	IR1561//IR24[4]/O.n.///CR94-13 (check)	IRRI	82	132	2	3	I	7.7
3	IR442-2-58							
	IR 95/Leb Mue Nahng	IRRI	98	147	1	3	I	6.3
4	IR1529-430-3							
	IR305/IR661-1-140	IRRI	81	147	1	3	L	8.4
5	IR2035-242-1							
	IR1416/IR1364//IR1824	IRRI	90	150	5	3	I	7.4
6	C 22	Philippines	109	146	1	5	I	6.0
7	C46-15/IR24[2]	Philippines	95	141	2	3	B/AI	7.7
8	IR3260-91-100							
	IR8/Dewan /IR8/Kataktara	IRRI	110	158	5	3	I	8.8
9	Salumpikit (check)	Philippines	110	120	2	5	I	3.3
10	C46-15/IR22[2]	IRRI	100	150	1	3	L	7.0
11	B1293b-Pn-24-2-1							
	IR747/Genjah Lampung	Indonesia	108	142	1	3	I	8.1
12	CR261-7039-236							
	Jayanti/IET 3144	India	85	136	2	3	L	8.3
13	IET 6047 (RNR 52162)	India	85	145	1	3	L	9.4
14	IR2058-78-1-3-2-3							
	IR1416-131/IR1364-37//IR1366-120/IR1539-111	IRRI	105	150	1	3	I/L	8.8
15	IR2070-199-3-6-6							
	IR20[2]/O.n.//CR94-13	IRRI	99	140	1	5	I	6.4
16	IR4422-164-3-6							
	IR2049-134-2/IR2061-125-37	IRRI	98	156	2	3	L	9.4
17	IR5106-80-3-1							
	IR841-85-1-1-2/IR2061-464-2	IRRI	78	145	1	3	L	6.1
18	CICA 8	Colombia	96	147	1	3	I	7.8
19	CR 1113	Costa Rica	87	140	-	3	L	4.1

1 International resistance scale of 1-9: 1-2.9 = resistant; 3.0-3.9 = moderately resistant; 4.0-5.9 = moderately susceptible; 6.0-9.0 = susceptible.
2 Scale for length of grain: 3 = long grain (6.61-7.50 mm); 5 = medium length grain (5.51-6.60 mm).
3 Gelatinization temperature: L = low; I = intermediate.

Table 21.

1978 IRRI Nurseries received in mid-1978 for evaluation at CIAT.

Nursery type	No. of entries
Yield	
IRYN-E	28
IRYN-M	28
IRYN-L	26
IURYN	28
Observational	
IURON	191
IRON	389
IRDWON	510
IRLRON	261
IRARON	137
IRCTN	237
IRSATON	72
Diseases and Insects	
IRBN	74
IRSHBN	20
IRSBN	20
Total	1.807

and blast diseases in Panamá, Costa Rica, Guatemala and México. Soil problems such as Fe deficiency were also affecting yields in Guatemala.

The group learned that semi-dwarf improved varieties perform well under upland conditions with good rainfall distribution and good management. However, good seedling vigor is essential in the semi-dwarf types for upland culture.

Monitoring Tour to the Southern Region of South America

This monitoring tour was held March 6-20, 1978. Among the participants were three Brazilian rice scientists, one each from Argentina and Perú; three scientists from IRRI and the rice breeder from CIAT. The group visited, in Brazil, the rice research activities of EMBRAPA, IAC and IRGA, in the States of Goias, Sao Paulo and Río Grande do Sul, respectively; the National Rice Program of INTA in Corrientes, Argentina; the Rice Program of the Ministry of Agriculture in Caacupé, Paraguay; the Rice Program of the Centro de Investigaciones Agrícolas del Trópico (CIAT) in Santa Cruz, Bolivia; and the National Rice Project of Perú in Chiclayo.

In each country the group had the opportunity to meet administrators and rice researchers and observe the problems affecting yields on the commercial scale.

A report covering the rice area production, observations and recommendations of the group was prepared and edited in October 1978. This report was distributed to rice technicians and all personnel met by the group in this monitoring tour.

Some highlights of this monitoring tour and the report follow.

Brazil. In Brazil 80% of the total area planted in the 1977-78 season (5.9 million ha) was upland, 12% irrigated and 8% was a combination of both systems. These systems contributed 67%, 28% and 5%, respectively, to the national production. Most upland rice is considered as the unfavorable upland type, that is, upland rice with drought and soil fertility problems. The upland area is concentrated in the area of "Cerrados" with soils of low fertility and high Al content, and irregular rainfall distribution. Two to three dry periods are very common during the rice growing season. In 1977-78, 45% of the upland rice area of Sao Paulo State (365,000 ha) was lost to drought.

Other problems affecting upland rice production are blast, brown spot and leaf scald diseases and insect damage of *Elasmopalpus lignosellus*, ants and weeds.

Field observations of IRTP nurseries from IRRI and CIAT planted under upland conditions in the Experimental Stations of EMBRAPA in Goiania, and IAC in Campinas, indicated that semi-dwarf types are not appropriate for the upland culture in Brazil. Provision of intermediate or tall stature varieties with resistance mainly to both drought and blast is a necessity which cannot be ignored for Brazil during the next 10-15 years.

Argentina. The monitoring tour group visited the Experimental Station of the Instituto Nacional de Tecnología Agropecuaria (INTA) in Corrientes where rice research activities are being conducted. Also some commercial rice crops of the region were observed. At this station the group observed the following problems affecting yield.

The rice water weevil and stink bug insects, straight head, and brown spot were all problems and were present on Fortuna and Bluebonnet 50, the main commercial varieties, and on some genetic material of the program as well as in IRTP nurseries from CIAT-IRRI. It was interesting to learn and know the damage of stink bug, *(Tibraca limbativentris)*, similar to that caused by stemborer (Fig. 1). On susceptible varieties like Fortuna and Bluebonnet 50 damage up to 20% was estimated.

Among the IRTP nurseries observed were the VIAVAL, VIRAL-P and VIRAL-T sent from CIAT in late 1977. The germplasm of these nurseries was at booting stage and showed severe damage caused by the rice water weevil insect, stunting, foliar yellowing and leaf miner damage. However, varietal resistance to the latter insect was noticed. In VIRAL-T, line IR 2823-399-5-6 was highly resistant and line IR 2071-586-5-6-3, planted in an adjacent plot, was the most susceptible.

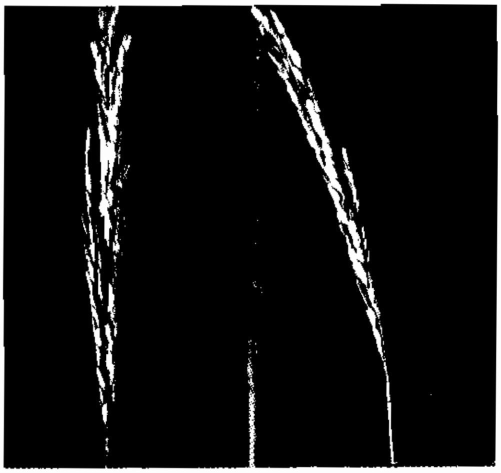


Figure 1. White heads caused by the stink bug *(Tibraca limbativentris)*. Arrow shows the initial damage on the stem.

Paraguay. In Paraguay the group visited a rice farm in Arroyos y Esteros, 50 kg northeast of Asunción, where the rice program of the Ministry of Agriculture was conducting a regional trial with introduced material from CIAT, Brazil and Argentina. In general, the material introduced from CIAT had very good adaptation in this area. The growth of CICA 6, CICA 7, CICA 9 and CICA 8 was normal. Excellent commercial crops of CICA 6 and CICA 7 were observed on this farm under irrigated conditions, at harvesting time. Yields of 5.5 t/ha had been obtained. It is important to mention that when tall varieties like Bluebonnet 50 and Fortuna were cultivated on this farm, yields averaged 2.8 to 3.5 t/ha, and now, with semi-dwarf varieties, yields have been doubled.

Bolivia. Rice production in Bolivia is totally under upland conditions. Some 60-70,000 ha are planted annually and 70% of this area is concentrated in the State of Santa Cruz, especially in the northern region were the average rainfall ranges from 1200 to 1800 mm. The Rice Program of the Centro de Investigaciones Agrícolas del Trópico (CIAT) of Santa Cruz has its headquarters at the Agricultural Experimental Station of Saavedra (EEAS), 65 km northeast of Santa Cruz. Rice research under upland conditions was inititated in 1950 by the introduction of varieties and up to now has recommended Dourado, Bluebonnet, Bluebelle, Pico Negro and Dawn. In 1974 the program began to evaluate semi-dwarf material from IRRI and CIAT and has selected three lines from IRRI (IR 2042-178-1, IR 1529-430-3 and IR 1840-3-2) and three from CIAT (CICA 6, line 4440 and CICA 9) which were in seed multiplications.

The monitoring group observed the regional trials being conducted in Saavedra, Portachuelo and San Pedro rice areas. The problems limiting yield in these trials were blast, brown spot, stem borers and drought, especially in Saavedra. But good material was identified in the IRBN and VIRAL-S nurseries which was recommended for seed increase.

Peru. The group visited the Experimental Station of Vista Florida in Chiclayo, where the National Rice Project has its headquarters. There the team observed the breeding material of the program which in general, showed superiority to breeding lines introduced from IRRI and CIAT. Among the introduced material Bg 90-2 and Juma 58 were the best entries. Line PNA 46-25 of the program was outstanding.

In a research farm of the University Pedro Ruiz Gallo, the group observed the Salinity and Alkalinity Observational Nursery (VIOSAL) from CIAT, which was planted in a highly saline area. Several lines, including the susceptible check were killed. However, lines IR 2145, IR 2153-26, DA 29, Patnai 23, SR26B, B57-c-Md-10-1, IR 2055-481-2-1-2 showed tolerance.

Several commercial rice crops were observed in the Chancay Valley; these were severely affected by a drought prevalent in the country during January and February. The water level of the Tinajones reservoir had decreased to its minimum level and sufficient water for irrigation was not being supplied. The monitoring team learned that about 50% of the rice area in the Chancay valley was lost to drought. However, excellent rice fields not affected by drought were observed with Naylamp and Inti varieties. Yields of 7-8 t/ha were estimated.

Individual Visits

Individual visits to Cuba, the Dominican Republic, Ecuador, Mexico and Panama were accomplished to evaluate IRTP nurseries, observe the breeding material of national programs and detect some constraints limiting rice production.

Among the germplasm of the IRTP nurseries, several promising lines were detected as resistant to Hoja blanca in Ecuador; to leaf scald and sheath blight in Panama; to salinity in the Dominican Republic and to alkalinity and Zn deficiency in Ciudad Altamirano, State of Guerrero, in México.

It was interesting to learn that rice culture in the Guayas region of Ecuador is a typical rainfed rice area (Fig. 2), mostly transplanted and belongs, in general, to small farmers who transplant rice as water from flooded areas comes down. This area is appropriate for growing deep water rice varieties; the potential area is estimated at 50,000 ha.

Figure 2. Typical rainfed rice crop in the Guayas region of Ecuador.

In commercial rice crops, some specific and localized problems were detected affecting yield. These were the root nematode in Chiriquí, Panamá; Zn deficiency in Camaguey, Cuba and Guerrero, México; and salinity in the northern rice area of the Dominican Republic.

Deficiencies in land preparation and leveling were noticed in commercial rice fields of Cuba and the Dominican Republic. A red rice infestation was another problem observed in various commercial crops, especially in the Dominican Republic, Panamá and Mexico. These problems apparently were accentuated as a result of a change from tall rice varieties to semi-dwarf types.

Despite the above factors, excellent rice crops were observed in these countries with high-yielding varieties recommended by national programs indicating that problems will be disminished and yields should increase rapidly in the near future.

Seed Distribution of Varieties and Promising Lines

Another activity of the IRTP Project is concerned with the seed distribution of varieties and promising lines requested by institutions of several countries. Table 22 shows the quantity of seed dispatched in 1978.

Release of CICA 8, a High-yielding Variety

In the second semester of 1977, basic seed multiplication of Line 4440, selections

Table 22.

Rice seed dispatched from CIAT to Latin American countries during 1978.

Country	Varieties and lines distributed (kg)						
	CICA 4	CICA 6	CICA 7	CICA 8	CICA 9	Bluebonnet 50	Line 4440
Brazil			50.0	50.0	50.0		
Bolivia				100.0			
Costa Rica				50.0			
Colombia				50.0			
Ecuador						0.01	6.01
Panamá				50.0			
Paraguay				100.0			
Puerto Rica	1.0	1.0			1.0		
Dominican Republic				55.0			
Surinam				0.05			
Uruguay		0.05	0.05		0.05		
Venezuela				50.0			
Total	1.0	1.05	50.05	505.05	51.05	0.01	6.01

Figure 3. Dr. M.J. Rosero, IRRI Liaison Scientist for Latin America, explains the characteristics of CICA 8 during its presentation to farmers in a field day at CIAT, in February 1978.

Table 23.

Yield and milling quality of CICA 8, compared with six commercial varieties.

Variety	Paddy yields (t/ha)[1]		Milling rice yields (%)[2]		Grain length (mm)	White center[3]
	Irrigated	Upland	Total	Head		
CICA 8	6.9	5.4	68.0	59.9	7.0	0.6
CICA 9	6.7	3.9	72.5	69.1	7.0	0.6
CICA 7	5.5	-	67.8	59.5	7.2	0.4
CICA 6	5.5	4.1	71.8	69.0	6.8	0.6
CICA 4	6.1	3.7	70.5	66.7	6.8	0.6
IR 22	5.3	-	73.0	66.4	6.8	0.2
Bluebonnet 50	4.0	3.3	69.2	58.5	6.8	0.4

1 Average of 41 irrigated and 6 upland regional tests in main rice areas of Colombia made by ICA from 1975-1977.
2 Based on 5 kg of paddy rice; head rice are whole and three-quarter size of grain.
3 Appearance of milled rice on a 0-5 scale: (0) absence of white center; (5) white center throughout the grain.

1 and 10, was continued on 4.5 ha each (CIAT Annual Report, 1977). In common agreement with the leader of the National Rice Program of ICA, it was decided to release selection 1 as a commercial variety. ICA named this line as CICA 8 and its presentation to farmers was made in a field day held in February, 1978 (Fig. 3).

This variety originated from a cross between CICA 4 and F_1 (IR665-23-3-1 x Tetep) made by the cooperative CIAT-ICA Project, in 1972. Tables 23 and 24 summarize the main characteristics of CICA 8 in comparison with other commercial varieties.

Table 24.

Incidence of diseases on CICA 8 and five commercial varieties under irrigated regional tests in Colombia from 1975-1977[1].

Variety	Sheath blight (%)[2]		Leaf scald (%)[3]		Blast (%)[4]	Neck	
	Range	Average	Range	Average	Leaf[5]	Range	Average
CICA 8	4-21	13	0-15	9	2-3	3-10	5
CICA 9	8-20	12	0-20	12	3-5	5-30	15
CICA 7	5-16	10	0-20	13	2-3	5-70	13
CICA 6	11-18	14	4-06	4	3-5	10-60	25
CICA 4	13-24	18	0-10	7	4-5	5-80	31
IR 22	6-18	11	0-10	8	4-5	10-70	26

1 Data observed on 41 regional tests conducted by National Rice Program of ICA.
2 *Thanatephorus cucumeris (Corticium sasakii).*
3 *Rhynchosporium oryzae.*
4 *Pyricularia oryzae.*
5 Based on 0-7 scale: 0-2 resistant; 2-3 moderately resistant; 3-4 moderately susceptible; greater than 4: susceptible.

Seed of CICA 8 was distributed to Latin American countries (Table 22) for semi-commercial tests. Some countries, like Panamá, México and Venezuela are recommending the variety for commercial production conserving its original name, but in Paraguay the variety is being promoted as Adelaida 1.

Swine Unit

International cooperation activites, particularly training, are a major part of the Swine Unit's program to increase the efficiency of production of this species in Latin America. Twenty professionals from national institutions in 10 countries of the region participated in the four-month Third Postgraduate Course in Swine Production. The Unit's cooperative programs with national institutions in Bolivia, Costa Rica, Ecuador and Peru have also intensified their training activities at local and regional levels.

Validation of technology oriented to solving problems limiting swine production has also expanded in the cooperative programs of the respective countries. Technology transfer to swine producers is being emphasized through extension activities and technical consulting by swine specialists in the national programs.

Research activities in the Unit during 1978 were primarily directed to evaluating feeding programs based on cassava roots and products processed from roots. By adding sugar cane molasses to diets based on cassava meal, pigs utilized these diets more efficiently. A series of experiments was done on ensiling chopped cassava roots; using this process, roots were conserved for a minimum of six months. Experimental results of the nutritive evaluations of ensiled cassava roots suggest a good potential for this conservation process for humid tropical regions and for small- and medium-scale farms, where the final product could be used for feeding swine. The utilization of diets containing 20 and 40% levels of cassava leaf meal for growing and finishing pigs was also evaluated. Acceptable results were obtained when this meal was fed at the lower experimental level to partially replace conventional protein sources.

Thirty-five fermentations were done during the year with the 3000-liter fermentor in the pilot plant for producing single-cell protein utilizing grated cassava roots as the energy substrate. Concentrations of 34 to 35% crude protein were obtained from the sun-dried biomass after average fermentation periods of 21 hours. The principal difficulty at this level of production was encountered during harvesting and drying of the final biomass.

The total quantity of biomass material produced enabled nutritional studies to be conducted with pigs. The single-cell protein (fermented with the fungus *Aspergillus fumigatus* I-21A) was the only protein source in diets which were compared to diets with soybean meal as the protein source. Nutritional quality of the single-cell protein was good for feeding swine, if it is adequately supplemented with methionine. Results of blood parameter analyses suggest that the single-cell protein is not toxic to pigs. Samples of organs and tissues have been taken for histopathological analyses.

Results from measuring the cyanogenic glucoside contents in cassava roots and root products suggest it is necessary to study in more detail the effect of methods of storage and processing on changes in content of this toxic component, especially for products that are to be used for feeding animals. These feed materials normally contain the root peels, which show higher cyanide levels than the parenchymatous tissue.

TRAINING

Third Postgraduate Course In Swine Production

The Third Postgraduate Training Course in Swine Production was held between July 17 and November 17, 1978. Twenty professionals participated from institutions involved in training, research and swine promotion activities in 10 Latin American countries. The objective of the course was to train these professionals in integrated systems of swine production to provide effective support to the Latin American swine industry.

The course was conducted by a group of specialists from various areas of swine production, in governmental and private institutions and firms, and scientific personnel of CIAT's Swine Unit, Data Services Unit and Training Office. Training activities during the course were distributed among production theory (36% of total time), practical activities in CIAT (21%), study tours (14%) and work on commercial farms (28%).

Production Theory

The initial part of the course was dedicated to conferences and seminars on selection, genetic improvement, nutrition and feeding, management, health, marketing and analyzing costs of production. Workshops, examinations and documentation exercises were utilized in this phase to insure that participants became familiar with library information sources and research results from CIAT investigations.

Practical Activities in CIAT

Two aspects of swine production were emphasized during this phase of the course: (1) planning and practical work in management, health, selection, reproduction and feeding; and, (2) conducting experiments planned jointly by trainees and instructors. These experiments involved early weaning, heat synchronization, artificial insemination, and restricted feeding of pigs during finishing. All activities took place in the CIAT Swine Unit.

Study Trips

For two weeks course participants traveled in the most important swine producing zones of Colombia. Twenty-five swine farms under various systems of production and 16 agro-industrial companies involved in the production, processing and marketing of swine supplies and products were visited.

Among some of the important management systems and other activities observed were the following: integrated swine/dairy systems where manure from the swine unit was utilized for pasture fertilization; utilization of whey from milk processing plants for swine feeding; operations of plants producing balanced rations for pigs; use of kitchen wastes and similar garbage in swine feeding; the process of marketing through organized sales, and slaughtering and processing of pork; and, the swine development programs and activities of the animal science and veterinary medicine sections of the Instituto Colombiano Agropecuario (ICA), especially the preventive measures that have been taken in relation to African swine fever.

Work on Swine Farms

Groups of two trainees each were assigned to work on swine farms in the Cauca Valley, near CIAT. Farms utilized were commercial ones dedicated to breeding, raising and fattening pigs; swine populations ranged from 500 to 2000 head per farm. In cooperation with the owners, farms had been selected previously with the objective of analyzing each operation and developing a simulated production program, based on resources available on each enterprise.

Among the principal activities the trainees accomplished on farms were: establishment of production registry systems; programs for selecting reproduction animals; management instruction for personnel of the farms; rearranging installations and programming their rational utilization according to production flow; formulation of rations and establishment of feeding programs; treatment, removal and utilization of swine wastes; and, sanitation programs.

INTERNATIONAL COOPERATION

Bolivia

The CIAT Swine Unit has continued to provide consulting to cooperative projects at the Universidad Boliviana Gabriel René Moreno (UBGRM) and to the Rural Development Commission/Inter-American Development Bank activities, in Monteagudo, Chuquisaca.

During 1978, the breeding herd at the UBGRM was increased to 200 sows to satisfy the growing demand for improved animals in the project's area of influence. Presently, about 100 pigs a month are being distributed to the promotional programs. Fifty purebred pigs were also delivered to the Heifer Project for distribution to small farms of the region, through agricultural extension programs.

The Swine Unit at the UBGRM is being utilized fully and up to this report, 166 farrowings have been obtained with satisfactory experimental results (Table 1). Training activities for producers and students recently graduated from the university have been developed during 1978. Five short courses, each lasting one month, were offered for swine producers of the region.

Research projects done during 1978 as a part of the CIAT/UBGRM cooperation included the following experiments: utilization of rice by-products, evaluation of dry yeast *(Saccharomyces cereviciae)* as a protein and energy source for swine feeding, and the evaluation of commercial additives in rations for nursing pigs. Most of these experiments are thesis projects of

Table 1.

Summary of the reproductive performance obtained in the Universidad Boliviana Gabriel René Moreno-Heifer/CIAT Cooperative Project.

Parameter	Value
Total farrowings	166
Fertility (%)	85
Farrowings/sow/year	1.6
Pigs/litter at farrowing	8.5
Pigs/litter at weaning, 56 days	7.6
Birth weight (kg)	1.25
Weaning weight, 56 days (kg)	13

students of the Faculty of Veterinary Medicine and Animal Science.

The Swine Development Project in Chuquisaca expanded its programs of credit and promotion for swine production during 1978. Credit is restricted to mandatory joint financing for maize growing and swine production; three sizes of enterprises have been established — 15, 30 and 45 breeding sows.

In the demonstration herds, management and production systems are being tested that can be implemented at the user level. Installations utilized are of simple construction and, as much as possible, pastures are on marginal areas or other sites not suitable for crop production on the farms. Areas required for pasturing have been calculated to be 1.5, 3.0 and 4.5 ha, for 15-, 30- and 45-sow units, respectively. The feeding system is based on maize on the cob that is produced on the farm, plus a protein supplement produced at the Project site. The first results from the demonstration herds and one of the commercial herds are presented in Table 2. The productive performances were satisfactory.

In addition, a work-study program has been initiated in connection with the demonstration herds whereby the participants receive training supervised by the professionals in charge of the project, as an **indispensable** requirement to obtaining credit for Project activities.

CIAT collaborated in conducting a swine production seminar, organized by the Rural Development Commission of Chuquisaca. The one-week seminar brought together 30 professionals from the Swine Project and regional credit agencies. In addition, three Bolivians attended the swine production course at CIAT this year;

Table 2.

Summary of the reproductive performance obtained in the swine herds of the Rural Development Committee/Inter-American Development Bank Project.

Parameter	Demonstration Unit (15 sows)	Demonstration Unit (30 sows)	Committee's commercial herd
Total farrowings	33	26	243
Pigs/litter at farrowing	8.0	6.5	7.8
Pigs/litter at weaning, 56 days	6.1	5.3	6.2
Birth weight (kg)	1.4	1.3	1.5
Weaning weight, 56 days (kg)	15.6	16.6	12.5
Mortality, birth-weaning (%)	19.4	18.9	19.9

one professional was from the UBGRM and two represented the Chuquisaca Swine Development Project.

Costa Rica

International cooperation work in Costa Rica has had a major impact during 1978, through the activities developed by the Swine Program of the Ministery of Agriculture and Livestock in the banana growing zone of the Atlantic Coast. In mid-year the Center for Research and Swine Promotion at the Los Diamantes Experiment Station, in Guápiles, was inaugurated as part of an agreement between the Ministry, the National Association of Banana Growers and the Central Bank of Costa Rica. This center has facilities to produce improved foundation breeding herds and for conducting applied research in swine feeding and management. Activities at the center were initiated with purebred pigs imported from the United States; pigs produced in the foundation herd will be distributed principally to banana producers in the Atlantic coastal region.

Research activities are oriented to evaluating practical feeding systems utilizing waste bananas as the principal energy source. CIAT's Swine Unit has collaborated in development of this new center, especially through planning the research work, technical consulting and postgraduate training.

Little progress was made in the Cooperative Swine Project at the University of Costa Rica, principally because construction of the swine unit has not begun. However, by utilizing rented installations, some experimental work was done and purebred pigs have been produced in the foundation herd to furnish breeding stock to farmers of the region.

Ecuador

The Swine Programs of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) continued to develop research and swine promotion activities in their areas of influence.

The Swine Program of the Santa Catalina Experiment Station has enlarged its extension activities to more than 10 agricultural cooperatives in the Andean region near Quito. Similar activities are being initiated in the region (Provinces of El Oro and Guayas) under the Swine Program of the Boliche Experiment Station. Based on results of a partial survey of the farmers of the region, it was found that the majority of the small- and medium-scale farms raise a few pigs under traditional systems of subsistence production. Extension work from these stations consists of technical consulting for the producers, especially regarding simple building installations for housing pigs, in furnishing boars of improved breeds and in calculating simple diets utilizing as much as possible by-products of the crops of the region (barley, wheat and potatoes, in the Andean region, and bananas, rice and sugar cane, in the southwestern region). Normally, practical training in the Swine Program Units of INIAP is provided to personnel of the cooperatives before initiating technical collaboration at the production level. With this objective and for demonstration purposes, thatched huts or sheds made with local materials have been constructed in which a limited number of pigs can be housed in semi-confined, controlled conditions.

Activities in the Swine Program at the Santo Domingo Experiment Station have been restructured and are now oriented to validating technology especially for management and feeding. Experimental results will serve for implementing trials or practical applications at the regional or local levels, principally for the western region.

The CIAT Swine Unit has provided collaboration through periodic visits and technical consulting according to the new focus of activities of the Swine Programs of INIAP. Two professionals from these programs participated in the swine production course at CIAT in 1978.

Peru

Activities of the Swine Program of the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), in Pucallpa, has been oriented to the continuation of gaining records of swine production on the Program's farm and to conducting research work, especially in some aspects of feeding. Distribution of foundation stock to swine producers of the region has continued, but for economic reasons extension activities and consulting outside of the Program have been limited.

Data of reproductive performance and litter production for three consecutive years (1976-1978) confirm partial results reported earlier (CIAT Annual Report, 1977) in which Yorkshire pigs adapted themselves and performed satisfactorily in the tropical conditions at Pucallpa. Studies of the effect of the seasons on litter size and weight of piglets at birth, and at 21 and 56 (weaning) days show that these parameters were not affected, at least over the two-year observation period (1977-1978).

During 1978 experimental work was completed on the utilization of locally available inputs, especially rice polishings and cassava roots, in feeding programs. The principal trials done were: utilization of fresh cassava roots with protein supplements based on fish meal containing 20, 30 and 40% protein, during the growing period; levels of 50 and 90% rice polishings supplemented with fish meal in swine growing diets; and, the effect of the number of daily feedings of a diet based on rice polishings, during the growing and finishing periods. In addition, trials are still being done on utilizing swine manure in fish production in ponds (jointly with the section of fish production) and for fertilizing cassava crops.

Three Peruvians participated in the swine production course in 1978. The three professionals represented IVITA, the Ministry of Agriculture and Food, and the Technical University of Piura, respectively.

RESEARCH

During 1978 research activities in the Swine Unit focused on utilizing cassava in swine feeding. Studies included the effect of adding sugar cane molasses to swine diets based on cassava meal, the process of ensiling and utilizing silage of cassava roots, feeding of cassava leaf meal, and the production and evaluation of single-cell protein utilizing fresh cassava roots as the energy substrate. In addition, the cyanide content was determined for roots of some cassava varieties as well as for products derived from cassava. A new methodology was used which permits the root content of this toxic compound to be measured more precisely.

Cassava Meal

Previously reported experimental results (CIAT Annual Report, 1976) demonstrated that cassava meal can furnish the largest part of the caloric requirement of pigs, substituting partially or completely conventional energy sources, especially the cereals. The principal limitation in the practical utilization of cassava meal in swine feeding programs is its relatively high cost, compared to other energy sources. Moreover, inclusion of high levels of cassava meal results in rations with a very powdery texture or appearance.

One possible solution to these problems is the addition of sugar cane molasses to reduce the quantity of cassava meal in the diets and to improve their physical consistency. The feasibility of employing increasing levels of molasses with a diet based on cassava meal has been demonstrated (CIAT Annual Report, 1976); however, management of this type of feeding requires much labor to readjust periodically the levels of molasses to be used. To simplify the management of this system, two molasses levels were tested: 10% during the growing phase and 20% during the finishing period. The composition of the experimental diets for the growing and finishing periods are shown in Table 3; the diets provided 16 and 13% protein for growing and finishing periods, respectively.

Results of the experiment are presented in Table 4. Pigs fed the cassava meal ration had a growth rate (average daily gain) slightly less than those fed the control diets. The addition of molasses improved performances both in diets based on sorghum and in diets of cassava meal. Improvement was more marked with the cassava meal which provided a feed conversion (feed/gain) better than that of the other three experimental groups. Results of this experiment, like those of the previous one, suggest that adding molasses to diets based on cassava meal helps to improve swine performance in the growing phase, by increasing diet consumption when increasing levels of molasses are used or by improving the efficiency or feed conversion when levels on the order of 10 and 20% are utilized in growing and finishing periods, respectively.

Root Ensilage

In tropical regions with high precipitation and high relative humidity it is difficult to dry chopped cassava roots to

Table 3.

Percentage composition of experimental rations based on cassava meal and containing two levels of molasses.

	Experimental variable			
	Sorghum + soybean meal (control)		Cassava meal + soybean meal	
Ingredient	without molasses	with molasses	without molasses	with molasses
Sorghum	77 (85)[1]	65 (60)	-	-
Cassava meal	-	-	65 (72)	55 (51)
Soybean meal	19 (11)	21 (16)	31 (24)	31 (25)
Molasses	-	10 (20)	-	10 (20)
Premix [2]	4	4	4	4

1 Percentages in parentheses are levels of ingredients in finishing rations.
2 Premix composition: bonemeal, 87.5%; iodized salt, 7.5%; premixed minerals and vitamins, 5%.

Table 4.

Results of feeding rations based on sorghum or cassava meal and containing two levels of molasses to pigs during the growing and finishing periods.

Parameter	Experimental variable: Sorghum + soybean meal (control)		Cassava meal + soybean meal	
	without molasses	with molasses	without molasses	with molasses
No. experimental days	112	112	119	112
Pigs/group	9	10	9	10
Average liveweight (kg)				
Initial	16.5	16.1	16.0	16.2
Final	95.9	99.0	93.3	93.7
Avg. daily gain (kg)	0.71	0.74	0.65	0.69
Avg. daily consumption (kg)	2.35	2.52	2.22	2.22
Feed:Gain ratio	3.3	3.4	3.4	3.2

produce meal. One practical method for conserving chopped roots under these conditions is to ensile them. The Swine Unit this year conducted several studies of ensiling cassava roots and evaluating the final product for nutritional quality.

Cassava roots were washed to remove excess dirt and then were cut in small chips with a mechanical chipper. These chips can be packed in silos (Fig. 1) when it is necessary to preserve considerable quantities of the product, or in polyethylene bags (Fig. 2), for small quantities.

Silos are made with wooden walls lined with sheet metal (2.3 m long, 1.5 m wide and 1.2 m high, giving a total capacity of 4.1 m^3). In such a portable silo set over a concrete floor five tons of cassava were conserved for six months. The surface of the ensilage was covered with plastic over which was placed wood shavings and tiles to prevent the entry of air; the silo was kept covered with a canvas to protect against rains.

Chemical Changes in Ensiled Roots

Figure 3 shows results from measuring

Figure 1. Silo made of wooden sides covered with sheet metal for conserving cassava roots.

Figure 2. Cassava root ensilage stored in polyethylene bags.

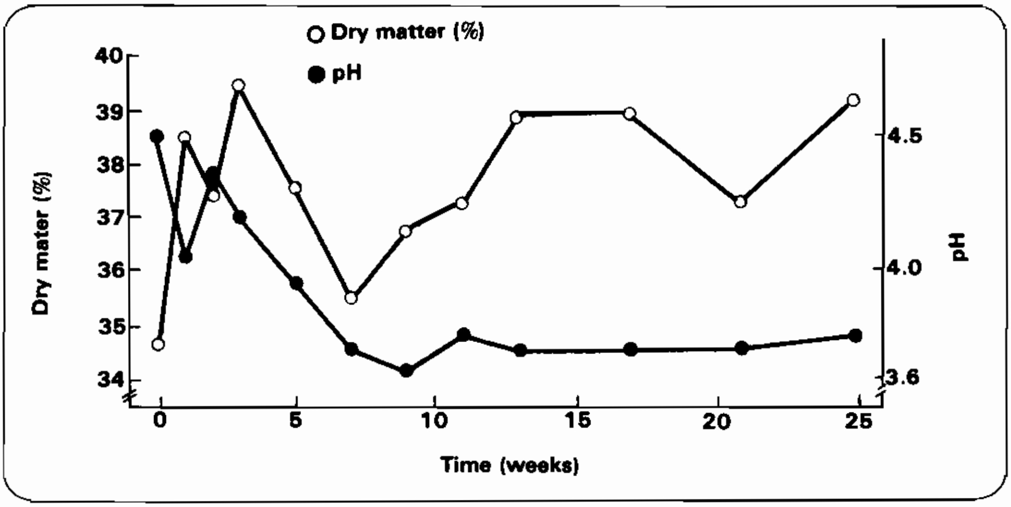


Figure 3. Changes in dry matter content and pH of ensiled cassava roots, over time at CIAT.

the dry matter content and the pH of ensilage samples during the six months of storage. Ensiled roots included a mixture of the varieties M Ven 270, M Mex 53 and M Col 655A. Marked variations, possibly due to the sampling technique, were observed in the dry matter contents and total carbohydrates. Tendencies observed were an increase in dry matter and a reduction in the total carbohydrate through the ensiling period. Initial and final contents of dry matter and carbohydrates were 34.5 and 39.1% and 90 and 80%, respectively. The concentration of dry matter and the reduction in total carbohydrates was due to the loss of water and utilization of the carbohydrates in anaerobic fermentation during the ensiling process. A rapid decrease in pH, from 4.5 to 3.7, was observed during the first seven weeks after the ensiling process was initiated. Although the concentration of volatile fatty acids was not measured, the decrease in pH should have been partly due to production of these acids, especially lactic acid, as products of the anaerobic fermentation that utilizes the root starch as the energy substrate.

Results of the chemical analyses of the initial and final samples of ensiled cassava are presented in Table 5. Non-nitrogen extract (soluble carbohydrates) was estimated in this case by differences and the content was above that reported for samples analyzed specifically for carbohydrates (Fig. 3). The most important changes observed were the reductions in moisture content and nitrogen-free extract and increases in fat (ether extract) and in crude fiber. Chemical analyses of samples taken from the silo throughout the storage period varied widely; part of this variation seemed to be due to the sampling system

Table 5.

Percentage dry matter chemical composition of fresh and ensiled (6 months) cassava roots.

Component	Fresh roots	Ensiled roots
Dry matter	34.6	39.1
Crude protein (N X 6.25)	2.8	3.2
Fat or ether extract	1.2	2.0
Crude fiber	2.4	5.5
Ash	2.3	2.9
Nitrogen-free extract[1]	91.2	86.5

1 Estimated indirectly by difference.

(done at different depths with a soil sampler) and to the fact that the mixed samples represented three cassava varieties.

Effects of Adding Salt, and Duration of Ensiling

To study the effects of the length of the ensiling period and of adding salt to the roots to be ensiled, a nutritional evaluation was conducted with swine during growing and finishing periods. Cassava ensiled in polyethylene bags for a minimum of six months was compared with roots ensiled for less time. In addition, common salt was mixed with one-half of each lot at a rate of 2% of the fresh weight of the chopped cassava at the time ensiling began.

Results of the chemical analysis of the ensiled roots in polyethylene bags were similar to those from cassava conserved in a silo, but the crude fiber content (about 2%) of roots stored in the bags was slightly less; ash content (about 5.4-5.8%) was almost double for the roots ensiled with salt.

The protein supplement employed to balance the cassava ensilage furnished 42% crude protein and contained the following percentages of ingredients: soybean meal, 44; cottonseed meal, 44; bone meal, 9; vitamins and minerals, 1; and salt, 2 (replaced by 2% cassava meal in supplements used with silage to which salt had been added). The supplement was mixed with the cassava silage at the time of feeding pigs on one day and on the following day, only the silage portion was offered.

Performances of pigs fed with rations based on ensiled roots are shown in Table 6. No differences in weight increase of pigs were observed. Average consumption per pig of roots ensiled for six months was slightly less than that of animals fed with roots for less time. In both cases, added salt decreased silage consumption but because the same weight gain was obtained, this diet produced a better feed conversion.

Additional experimental results have demonstrated that similar performance can be obtained by mixing the protein-

Table 6.

Swine performance during the growing and finishing periods when fed rations based on cassava root silage.[1]

	Cassava roots ensiled -			
	for more than 6 months		for less than 6 months	
Parameter	without salt	with salt	without salt	with salt
Avg. liveweight (kg)				
Initial	21.7	22.0	21.9	21.8
Final	96.7	95.7	96.6	97.0
Avg. daily gain (kg)	0.63	0.62	0.63	0.63
Avg. daily consumption (kg)				
Ensilage	3.30	2.87	3.45	3.20
Supplement[2]	0.78	0.78	0.78	0.78
Feed:Gain ratio[3]	3.71	3.45	3.84	3.63

1 Averages for six pigs/treatment, fed individually during 119-day experiment.
2 Supplement of protein, minerals and vitamins that furnished 42% protein.
3 Based on 90% dry matter.

mineral-vitamin supplement with cassava silage each day or every two days. Other results also suggest that adding 10% sugar cane molasses to the ensilage and the supplement mixture every two days provides an improved efficiency of feed conversion during the periods studied.

Evaluation of Different Protein Supplements

In order to evaluate various sources of protein that could be utilized to supplement rations based on ensiled cassava roots, an experiment was done with pigs during growing and finishing, utilizing the protein supplements with compositions shown in Table 7. These supplements furnished protein levels between 41 and 52%, and according to the protein source furnished, quantities mixed with the ensiled roots varied.

Because of the limited availability of ensiled roots, the trial was ended after 18 weeks. Groups of pigs fed with ensiled roots and supplements with soybean meal or the mixture of soybean and cottonseed meal reached the normal expected weight (90 kg) by the end of the experiment, while the other groups showed lower weights (Table 8). Average weight gains of the groups fed with cassava root ensilage were similar to the control group, except that the group fed with the supplement based on fish meal performed poorer than the other groups. Pigs fed a mixture of ensiled cassava roots and the protein supplement based on fish meal consumed a smaller total quantity of the mixture compared with the other groups, suggesting that lower palatability of the mixture limited its consumption. The supplement containing fish meal with cottonseed meal improved animal performances although they were not equal to those obtained with supplements based on soybean meal. Generally, each animal consumed about 3 kg of silage daily, a quantity similar to those reported in feeding programs that used fresh chopped roots (CIAT Annual Report, 1975).

Studies on the process of ensiling cassava roots and subsequent nutritional evaluations suggest this system of conserving roots is promising, especially at the small- and medium- scale farm levels and in regions with humid tropical climates where the drying process for producing cassava meal would be very risky. Additional investigations are being done to

Table 7.

Percentage compositions of supplements prepared with different protein sources for utilization with ensiled cassava roots.

	Protein source			
Ingredient	Cottonseed meal + soybean meal	Soybean meal	Cottonseed meal + fishmeal	Fish-meal
Cottonseed meal	44	-	48.5	-
Soybean meal	44	88	-	-
Fishmeal	-	-	48.5	97
Bonemeal	9	9	-	-
Salt	2	2	2	2
Minerals and vitamins	1	1	1	1
Calculated protein (%)	41	44	47	52

Table 8.

Performance of swine fed with rations based on silage of cassava roots combined with various sources of supplemental protein.[1]

Parameter	Control ration	Ensiled cassava roots + Cottonseed meal + soybean meal	Soybean meal	Cottonseed meal + fishmeal	Fishmeal
Avg. liveweight (kg)					
Initial	16.3	16.1	16.3	16.2	16.2
Final	87.0	90.9	90.4	85.0	79.2
Avg. daily gain (kg)	0.56	0.59	0.59	0.55	0.50
Avg. daily feed consumption (kg)					
Ensilage	-	2.85	3.10	3.01	2.98
Supplement	(2.06)[2]	0.86	0.73	0.67	0.60
Feed:Gain ratio[3]	3.68	3.61	3.58	3.65	3.84

1 Avg. of 10 pigs/group; 126-day experiment. Ensiled roots contained approximately 40% dry matter.
2 Avg. daily consumption of the control ration.
3 Based on 90% dry matter.

try and improve the ensiling process and to develop an adequate management system for feeding ensiled cassava roots to pigs.

Cassava Leaf Meal

Preliminary studies done by the Cassava Program suggest that aerial parts of the cassava plant (leaves and younger stems) can yield good levels of dry matter and crude protein per surface unit (CIAT Annual Report, 1973). The green or fresh foliage has good feeding value for ruminants (CIAT Annual Report, 1976); for monogastric animals it could be utilized in dry form as a protein source.

The cassava variety M Col 12 was used to produce vegetative matter. Entire plants were cut 20 cm above the soil and then passed through a forage chopper. Chopped forage was sun-dried in trays or on concrete floors; dried material was milled to obtain a whole meal. The chemical composition (in percentages) of this meal used for feeding pigs during the growing stage was: moisture, 8.5; crude protein, 17.2; total fat or ether extract, 5.8; crude fiber 17.5; ash, 9.6; calcium, 1.8 and phosphorus, 0.3. Percentages are expressed in the dry sample that contained 8.5% moisture; the moisture content of the fresh forage after chopping averaged 70%.

Nutritive Evaluation

In order to increase experimental information on the utilization of foliar protein and, especially meal of cassava leaves and young stems, an experiment was conducted with pigs during the growing and finishing periods utilizing two levels of leaf meal (20 and 40% of the diets) and adding sugar cane molasses to improve palatability of the experimental rations. Diet compositions are presened in Table 9.

Although the experiment had two replications per treatment, results in the second replication differed significantly

Table 9.

Percentage composition of the experimental diets for swine utilizing cassava leaf meal during growing and finishing periods.

Ingredient	Soybean meal control	Cassava leaf meal	
		20%	40%
Cassava meal	53.7 (49.8)[1]	40.5 (36.6)	27.0 (23.3)
Molasses	10.0 (20.0)	10.0 (20.0)	10.0 (20.0)
Soybean meal	31.6 (25.5)	24.8 (18.7)	18.3 (12.0)
Cassava leaf meal	-	20.0	40.0
Bonemeal	4.0	4.0	4.0
Salt	0.5	0.5	0.5
Minerals and vitamins	0.2	0.2	0.2

1 Numbers in parentheses are percentages of the finishing diets.

from those of the first, over all treatments. Data in Table 10 are the results from the first replication. These suggest that the utilization of increasing levels of cassava leaf meal tended to reduce pigs' performances during growing and finishing periods. However, results obtained with 20% cassava leaf meal, and even with 40%, are acceptable, taking into account the initial weights of the experimental animals. Total consumption of the diets per pig over the experimental period was 276, 358 and 381 kg for the control diet and the diets with 20 and 40% cassava leaf meal, respectively.

Experimental information suggests a potential for incorporating relatively low levels (about 20%) of cassava leaf meal in swine diets. As these trials were done on a limited scale, the actual cost of this protein source is not known. The pigs ought to be able to utilize high levels of this class of protein during the gestation period, but due to lack of raw materials, these experiments were not able to be done.

Production and Evaluation of Single-Cell Protein

Activities with the CIAT pilot plant for

Table 10.

Effects of utilizing two levels of cassava leaf meal in swine rations during growing and finishing periods.[1]

Parameter	Soybean meal control	Cassava leaf meal	
		20%	40%
Avg. liveweight (kg)			
Initial	15.1	15.1	15.3
Final	101.1	98.3	96.8
Days on experiment	119	147	147
Avg. daily gain (k)	0.72	0.57	0.55
Avg. daily feed consumption (kg)	2.32	2.44	2.59
Feed:Gain ratio	3.2	4.3	4.7

1 Avg. of five pigs/group.

producing single-cell protein by fermentation of cassava roots progressed well during 1978. Successful operation of the 3000-liter fermentor permitted sufficient quantities of biomass to be produced for nutritional studies with pigs during growing and finishing periods.

Production

Thirty-five fermentations were done with the 3000-liter fermentor (Table 11). The substrate employed was grated fresh cassava roots from different varieties with the total quantities utilized varying between 420 and 430 kg of cassava per fermentation. The initial concentration of soluble carbohydrates obtained was about 4% or 40 g/liter. The fungus *Aspergillus fumigatus* I-21A was used in all the fermentations following the procedure previously described (CIAT Annual Report, 1976). Results with the 3000-liter fermentor have been superior to those obtained with the 200-liter fermentor last year, especially with reference to the crude protein in the final dried biomass that has resulted from more efficient utilization of the cassava carbohydrate by the fungus.

The principal difficulty had been harvesting the biomass produced in the large fermentor and, especially, the extraction of water to sufficiently low levels to permit rapid drying of the biomass. To extract the water a special harvesting machine (filter-press) has been used which was designed and constructed at the University of Guelph, Canada (Fig. 4). In addition, another press operated by a hydraulic jack has been used. This device, constructed in CIAT's shops, permits better extraction of the water from the biomass and forms a meal cake which is easily milled in the cassava chopping machine. The meal from the ground biomass (with 65% water) can be sun-dried in 6-8 hours or dried in a forced air oven.

Table 11.

Production of single-cell protein from fresh cassava roots using *Aspergillus fumigatus* I-21A in a 3000-liter fermentor.

Parameter	Value
Fresh cassava/fermentation (kg)	423
Concentration of soluble carbohydrates (g/liter)	
Initial	41.1
Final	15.1
Avg. pH of fermentation medium	
Initial	3.5
Final	5.2
Crude protein in dry biomass (%)	34.2
Avg. duration of fermentation (hrs)	21
Avg. quantity of dry biomass produced/fermentation (kg)	55.5

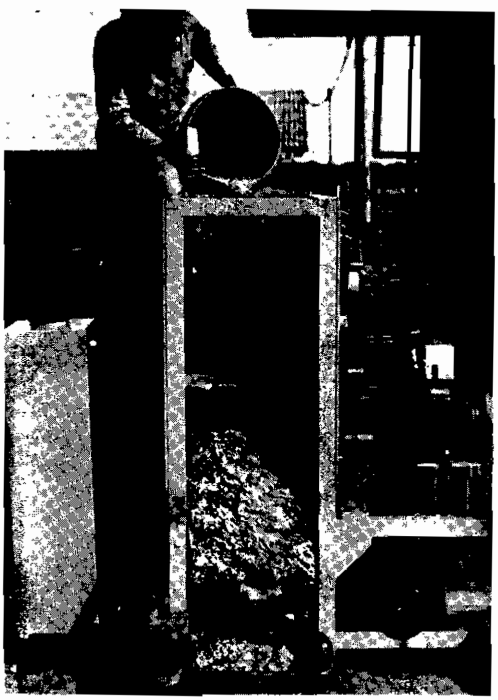


Figure 4. Partial extraction of water from single-cell protein biomass, utilizing a filter-press constructed at the University of Guelph, Canada.

Nutritive Evaluation

Table 12 shows the percentage composition of the experimental diets used for the nutritional evaluation of the protein biomass for feeding pigs in the growing and finishing periods. Previous results obtained in Guelph and in CIAT showed that the single-cell protein had a marked deficiency in the sulfur amino acids — particularly methionine. These experiments had also shown the beneficial effects of supplementing this amino acid during biological evaluations with rats. In the swine feeding experiments this year, single-cell protein was utilized as the only protein source in diets, with (0.3%) or without adding DL-methionine. The sun-dried protein biomass had the following chemical composition (in percentages): moisture, 11.6; crude protein (NX6.25), 35.0; ether extract or total fat, 3.0; crude fiber, 19.3; non-nitrogen extract, 30.0; ash, 4.1; calcium, 0.2 and phosphorus, 0.8. The total energy of the single-cell biomass was **4260 cal/g**, as measured in a calorimeter **bomb**.

Experimental results of the nutritional evaluation of the single-cell protein are presented in Table 13. The nutritive quality of the protein was good, and compared well with soybean meal if supplemented with methionine. The protein biomass without methionine produced inferior results; pigs needed three additional weeks to reach a final average weight similar to those of the group fed methionine-supplemented, single-cell protein. These two experimental groups had similar average daily consumption rates per pig for the diets, but methionine supplementation significantly improved weight gain and feed efficiency conversion performances. This latter parameter for the single-cell protein supplemented with methionine appears slightly better than that obtained with the diet based on soybean meal and cassava meal, but the final weight of the pigs in the two groups is different and no definite conclusions can be drawn. The results of the performances of pigs fed with the diet based on single-cell protein without methionine supplementation varied the most compared with the other three experimental groups.

Table 12.

Percentage composition of experimental growing and finishing diets for swine utilized for nutritional evaluations of single-cell protein (SCP).

Ingredient	Sorghum + soybean meal	Cassava meal + soybean meal	Cassava meal + SCP without methionine	Cassava meal + SCP with methionine
Sorghum	77.8 (85.4)[1]	-	-	-
Cassava meal	-	66.1 (72.4)	52.8 (61.0)	52.5 (60.7)
Soybean meal	18.0 (10.4)	29.4 (23.1	-	-
A. fumigatus I-21A biomass	-	-	43.0 (34.8)	43.0 (34.8)
Bonemeal	3.5	3.5	3.5	3.5
Salt	0.5	0.5	0.5	0.5
Minerals and vitamins	0.2	0.2	0.2	0.2
DL-methionine	-	0.3	-	0.3

1 Numbers in parentheses are percentages of the finishing diets.

Table 13.

Results of the nutritional evaluation of single-cell protein (SCP) in growing and finishing diets for swine.[1]

Parameter	Sorghum + soybean meal	Cassava meal + soybean meal	Cassava meal + SCP without methionine	Cassava meal + SCP with methionine
Days on experiment	112	119	140	119
No. of pigs	7	6	6	6
Avg. liveweight (kg)				
Initial	15.8	15.8	15.8	15.8
Final	94.4	95.7	90.0	90.7
Avg. daily gain (kg)	0.70	0.67	0.53	0.63
Total consumption/pig (kg)	288.2	282.4	292.1	252.8
Avg. daily gain (kg)	2.57	2.37	2.09	2.12
Feed:Gain ratio	3.67	3.53	3.94	3.37

1 Averages for pigs fed individually throughout the experiment.

Eleven pigs (two from the group fed cassava meal plus soybean meal and three from each of the other three groups) were slaughtered to assess carcass qualities and to take tissue and organ samples for histopathological studies. No significant differences were observed in qualities of the dressed carcasses, judged by measurements of dorsal fat and proportions of the different cuts made. Samples of a total of 18 tissues or organs were taken from each pig, and these are being analyzed. No gross changes were observed in any of the organ samples. Personnel of the CIAT Beef Program's Animal Health Section are collaborating in these studies.

During the course of the experiment, blood samples were taken from all pigs for hemotological analyses and other determinations of biochemical parameters of the blood. Results indicated that the single-cell protein fed to the pigs did not significantly alter any of the parameters studied, confirming results from previous experiments with laboratory animals at the University of Guelph.

Experience acquired over two years of operating the pilot plant demonstrates the technical feasibility of producing single-cell protein using grated cassava roots as the energy substrate to obtain a biomass having a good crude protein content. The nutritional quality of this protein is good for animal feeding if it is adequately supplemented with methionine, the most limiting amino acid. The protein biomass apparently does not adversely affect the health of the animals that consume it.

Security precautions normally observed in operating a pilot plant can be considered adequate protection for the management of the microorganism employed for fermentations. The transfer of this technology requires, however, careful consideration of aspects such as economic feasibility and other factors that could affect production performance on a practical, commercial scale.

Cyanide Contents in Cassava Roots and Products

Investigations reported in relation to the nutritional value of the roots or products derived from cassava and used especially for animal feeds show a lack of consistency in the repeatibility of results. Some of these discrepencies are due to variations in the chemical compositions of the products, which can be caused by various factors. Often the cassava variety used is not identified and information related to the cyanide content in products used is not included. Until a short time ago, the majority of the analytical methods for determinations were not fully reliable due to inexact and nonreproducible techniques. Recently, the Tropical Products Institute (TPI), in the United Kingdom, developed an enzymatic method to determine the cyanide content in cassava. The method surpasses the sensitivity, reproducibility and speed of the quantitative methods used previously. In collaboration with Dr. Rodney Cooke, who developed the new methodology at the TPI, the technique has been established in the CIAT laboratories.

Five roots from three cassava plants of each of the varieties Llanera, M Ven 218, M Col 1684 and M Col 22 were analyzed. Plants had been grown in experimental lots of CIAT's Cassava Program, Varietal Improvement Section. Total and free cyanide contents were determined in the root peel and the parenchymatous tissue of a central disk cut from each root. Average results of these analyses in relation to free cyanide/total cyanide and of total cyanide in the parenchyma/total cyanide in the peel are presented in Table 14.

Variations between roots of the same variety were considerable and have been reported in similar studies done at the International Institute for Tropical Agriculture. The relation of free cyanide/total cyanide varied around the 10% level, especially in the peel. Total cyanide contents in the peels are rather high, even in varieties like M Col 22 which is considered to be low in cyanide. Taking into account that, for animal feeding, the entire root including the peel is utilized, one can observe that the relationship of total cyanide in peels is about 15-25 times greater than the content in the parenchymatous tissue. In "bitter" cassava varieties like M Col 1684, the cyanide content in the parenchyma is very high, about one-half the concentration of the peel.

The analysis for cyanide done in other products derived from cassava, such as meal, root silage, leaf meal, fresh leaves and single-cell protein biomass were done with too few samples to permit valid conclusions. In general, cyanide concentrations of these products were much less than those observed in samples from fresh roots. For example, two samples of root

Table 14.

Total and free cyanide contents in the peel and parenchyma of roots of four cassava varieties.

Variety	Cyanide in peel			Cyanide in parenchyma			Cyanide ratio
	total (ppm)	free (ppm)	free:total (%)	total (ppm)	free (ppm)	free:total (%)	parenchyma: peel
Llanera	777	58.3	7.5	29.9	0.98	3.3	1:26
M Ven 218	1221	160.3	13.1	55.3	6.50	11.8	1:22
M Col 1684	796	87.2	11.0	401.8	7.18	1.8	1:2
M Col 22	2251	92.7	4.1	153.9	7.84	5.1	1:15

1 Averages of five measurements; contents expressed on fresh basis; plants were 9 months old.

silage analyzed after six months of conservation showed contents of 30 and 38 ppm total cyanide, all of which was in the form of free cyanide.

The new analytical method will allow more precise studies to be conducted to measure changes in cyanide content following different methods of storage or processing of cassava roots and products.

PUBLICATIONS

Buitrago, J., J. Chamorro, E. Taborda y **G. Gómez.** 1977. Melaza, pulidaras de arroz y torta de algodón para cerdos en crecimiento y acabado. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:143. (Abstr.)

Buitrago, J., M. Musmanni. J.H. Maner y **V. Carrizo.** 1977. Maíz y sorgo enteros para cerdos en crecimiento. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:144. (Abstr.)

Cabeza M., J. Buitrago y **A. Owen.** 1977. Rendimiento y comportamiento de cerdos criollos Zungo vs. Duroc-Jersey. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:145. (Abstr.)

Gómez, G., J. Santos, P. Zamora y **A. Monsalve.** 1977. Harina de yuca y metionina en dietas para cerdas gestantes y lactantes. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:140.(Abstr.)

Gómez, G., J. Santos y **J. Chamorro.** 1977. Suplementación de dietas a base de harina de yuca para cerdos en crecimiento y acabado. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:142.(Abstr.)

Gómez, G., J. Santos y **J. Chamorro.** 1977. Niveles crecientes de melaza en dietas a base de pulidaras de arroz o de harina de yuca para cerdos en crecimiento y acabado. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:151.(Abstr.)

Santos, J., y **G. Gómez.** 1977. Producción de proteína microbiana usando las raíces de yuca como substrato energético. *In* Proc. VI Reunión ALPA (Havana, Cuba, Dec. 4-9 1977). 2:150.(Abstr.)

Trujillo, C., J. Santos, L.E. Beltrán, J. Buitrago y **G. Gómez.** 1977. Características y perspectivas de la production porcina en Colombia. *In* Memorias Primer Encuentro Nacional de Zootecnistas (Medellín, Colombia, Dec. 8-10 1977). 155 pp.

Genetic Resources Unit

During 1978 the Genetic Resources Unit has become established in its remodeled building, so that at the end of the year the three cold rooms, the five laboratories, the herbarium and the two threshing areas were all fully utilized by staff of the Unit. A year ago no germplasm was actually housed in the Unit; by the end of 1978 over 26,000 accessions of *Phaseolus* bean (four species), tropical forage legumes and grasses (some 23 genera), and cassava were being stored in the Unit.

During the year the Genetic Resources Unit changed from being a collector of other *Phaseolus* collections to become an active collector of unique *Phaseolus* germplasm in central Mexico, one of its centers of diversity. A one-month study of herbarium specimens in Mexico was followed by a three-month field collection trip done in cooperation with the Instituto Nacional de Investigaciones Agrícolas (INIA). To mid-November, 120 seed samples covering 14 *Phaseolus* species, plus 165 plant samples, mostly weedy (silvestris) types were collected in eight Mexican states (from Durango south to Michoacan). Materials were also collected under contract in Peru, Spain and Portugal.

The CIAT *Phaseolus* bean germplasm has increased from some 13,000 accessions in 1977 to over 21,000 at present. More importantly, this germplasm is now actively being evaluated for genetic and agronomic characters and those materials contaminated with bacterial and/or viral diseases are being multiplied under careful control, and in close cooperation with the Bean Program, to produce seeds free of such contamination. Computerized data file systems have been developed to facilitate the entry, updating and retrieval of information gained in field and laboratory evaluations of germplasm.

Responsibility for the tropical forages germplasm held at CIAT (some 4500 accessions) has recently been transferred to the Genetic Resources Unit, where certain stages of evaluation and multiplication and all storage will take place. Some activities will be shared with the Beef Program, especially field evaluation at CIAT-Quilichao and Carimagua. A flexible data management system able to accommodate all evaluation inputs is being developed cooperatively with the Beef Program.

Since April the plant physiologist has been able to test and set up methods that permit the rapid development of cassava plantlets from meristem tissue cultures. The time required between the taking of the small tissue sample and its development into a small plant ready for transfer into the field is only eight weeks. In contrast, other techniques are being tested that will permit storing the cassava meristem plantlets in test tubes for at least a year free of disease and other field problems. Towards the end of 1978 action was taken to organize selected national centers into a small network that will allow distribution of cassava germplasm as tissue cultures through national quarantine inspection.

Phaseolus Germplasm

Acquisition and Seed Increase

Nearly 7500 *Phaseolus* accessions were acquired from other sources since January 1978 so that the size of the present CIAT collection is more than 21,000 entries (Table 1). Most of these new materials are *Phaseolus vulgaris* sent here from the USDA Regional Plant Introduction Station at Pullma, Washington to complete our collection of all 8554 *Phaseolus* materials with P. I. numbers. Also included in the new materials are the Norvel collection from Mexico, the collection from the Institute of Horticultural Plant Breeding at Wageningen, the Netherlands, and that of the Instituto de Ciencias y Tecnología Agrícola (ICTA) in Guatemala.

In addition to obtaining materials from various germplasm banks, CIAT has been involved with collecting *Phaseolus* material in Peru (233 samples of *P. vulgaris* and 39 of *Phaseolus lunatus)* as well as in Spain and Portugal (411 samples of *P. vulgaris* and 13 *Phaseolus coccineus).* Collection for more *Phaseolus* germplasm in Mexico has also been initiated this year in conjunction with the Instituto Nacional de Investigaciones Agrícolas (INIA), utilizing an FAO associate expert and partial funding by the International Board for Plant Genetic Resources (IBPGR). In this field collection, attention is being given to wild *Phaseolus* species, since these may be useful in the interspecific crossing program done in cooperation with the Faculté des Sciences Agronomiques, Gembloux, Belgium.

Of the 21,000 *Phaseolus* samples received, more than 13,000 have been seed increased. This represents a major effort which started in 1970, as each accession has to be checked for disease and genetic

Table 1.

***Phaseolus* samples on hand, accessions increased and accessions evaluated in the Genetic Resources Unit, as of November 1978.**

Species	No. of accessions	No. seed increased	No. evaluated
P. vulgaris	19,910	12,600	9500
P. lunatus	1010	310	-
P. coccineus	430	150	-
P. acutifolius	70	60	60
Other *Phaseolus*[1]	100	50	-

1 Includes samples of 8 wild species.

uniformity. Efforts in 1978 were concentrated on cleaning up a major part of the collection for major seed-borne diseases, such as bacterial blight, common bean mosaic virus and anthracnose. This aspect has been so important that materials harvested in the field have been stored as distinct seed lots labelled as to presence or absence of disease. More than 3500 accessions have been grown at CIAT-Palmira, Popayán and CIAT-Quilichao in April and May 1978. Another 5300 were planted in October and November at CIAT-Palmira and at Popayán.

Agronomic Evaluation of Collection

Since 1970 more than 9500 accessions of *P. vulgaris* have been evaluated at CIAT for some of the 32 taxonometric and agronomic characters considered most important for this genus (Table 2). However, since not all of these accessions have been evaluated for all 32 characters, efforts were made in 1978 to collect more information. As in previous years, this was done by growing an accession in a 6-m row at CIAT-Palmira at the onset of the rainy season. More than 500 accessions were evaluated between April and June and another 230 are being evaluated at the end of the year. An important development in 1978 was the identification of 200 lines of *P. lunatus* which are uniform for seed characters. These materials are now being evaluated at CIAT-Palmira.

From the 9500 accessions of *P. vulgaris*

Table 2.

Characters evaluated at CIAT-Palmira for the *Phaseolus vulgaris* germplasm collection.

Character	No. of accessions evaluated	Character	No. of accessions evaluated
Days to emergence	4406	Pod per plant	7238
Hypocotyl length	4386	Branches with pods	4331
Hypocotyl color*[1]	8960	Branch angle	4362
Leaflet length	4401	Seeds per pod	4337
Leaflet width	4401	Seed shape	7229
Canopy height	6521	Major seed color*	7827
Nodes at flowering*	4373	Secondary seed color*	1889
Nodes at maturity*	3457	Seed brilliance*	7230
Days to flowering*	4401	Seed weight*	8457
Duration of flowering	4386	Yield per plant	4292
Flower color	8978	Total dry matter	4311
Photoperiod sensitivity	691	Rust	2172
Growth habit*	8997	Anthracnose	456
Plant height*	6968	Common bean mosaic virus	823
Stem thickness	4399	Bacterial blight	2762
Racemes per plant	7913	*Empoasca*	5038

1 Characters with asterisks are those recommended by the *Phaseolus* Germplasm Advisory Committee of the International Board for Plant Genetic Resources, in July 1978.

evaluated, some 600 sets of duplicates (involving 1400 accessions) have been identified based on name and origin. This figure is expected to increase as more information on the materials gradually becomes available.

Seed Storage

During early 1978, standard methods recommended by the International Seed Testing Association (ISTA) were set up for the Unit. Seed germination and vigor as measures of seed viability are now determined routinely for *Phaseolus* bean accessions using rolled papers maintained at 100% relative humidity for seven days at 20°-30°C. Over 1750 accessions now have been tested for germinability; of 1113 general accessions tested, 69.0% had 90% or higher germination rate. In contrast, when 461 lots of clean seed were tested 90.5% showed a germinability level that high. While percent germination and percent vigor (estimated as number of significantly larger seedlings in each germination test) are only weakly correlated in the general accessions, this positive correlation was increased for the clean seeds to $r = 0.597$. This implies that when environmental factors, especially diseases, are removed, plant vigor may indeed be shown to be a genetic character.

A simple method for seed drying based on desiccation at room temperature was developed. Numerous small lots of seed (typically less than 1 kg for *Phaseolus* bean) are placed in desiccator cabinets over silica gel for seven days. During this period seed moisture content drops to below 7%. Such dried seeds, when packed into moisture-proof laminated packs, maintain this low moisture content regardless of ambient relative humidity. It is estimated that *Phaseolus* bean germplasm kept at -10°C and 7% content will retain 90% of its initial viability for a period of 300 years.

Germplasm Distribution

A total of 14,800 samples of *Phaseolus* germplasm (mostly *P. vulgaris)* were distributed in 1978. The distribution of materials outside CIAT was as follows: South America (391 samples), North America (190), Central America (6000), Asia (200), Africa (856), Europe (376) and Far East (346). Within CIAT nearly 6500 accessions have been distributed to the Bean Program, especially to the breeders.

Data Management and Cataloging

Management of germplasm data is an integral function of the Genetic Resources Unit. Sources of germplasm data include those from collection or introduction, maintenance, evaluation and distribution. For *Phaseolus* germplasm, a number of computer files to manage such data have been developed in conjunction with the Biometrics Section. Similar work has been initiated for the tropical forages germplasm with the collaboration of the Beef Program.

Some of the germplasm information generated should be made available to users at large by publishing a catalog. A revised version of the "promising" materials (803 selections of *P. vulgaris*) catalog has been completed, with revisions on seed characters and growth habit and updating of all field evaluation data. Similar work on the tropical forages germplasm in CIAT has been completed, to make available a catalog with computerized information on accession numbers, genus, species, source, and origin or collection site.

Multivariate Analysis

Multivariate analysis has been explored as an objective method to study genetic diversity in *Phaseolus* germplasm and also to investigate the interrelationships of variables currently under evaluation. To test this method, a new set of data has been generated to provide reliable information having wider genetic and environmental bases. Replicated evaluation trials were done at CIAT-Palmira, CIAT-Quilichao, and Popayan using both wide spacing (30 cm) and narrow spacing (8 cm) between plants. Ten accessions were randomly selected from *P. vulgaris, P. lunatus* and *Phaseolus acutifolius*, with some selection made for habit groups within each species. The characters recorded include the first 27 agronomic traits listed in Table 2. Means for the relatively more stable characters were calculated across locations, spacings and replications, and these were used for multivariate analysis.

Cluster analysis showed that genetic diversity could be easily demonstrated by the groupings of similar materials (e.g., species and growth habits) based on the above variables. Some overlapping of habit groups within each species occurred, but this was overcome by normalizing all variables, i.e. putting them on a scale of 0-9. The results of this study could be extended into two areas where some indication of genetic diversity is now needed. The first involves identifying the genetic diversity of the advanced progenies coming from the bean breeders and the second is in the study of similarities and differences in the germplasm bank accessions of *P. vulgaris*.

Using *P. vulgaris* germplasm data from the Promising Materials Catalog, last year 75% of the total genetic variability could be accounted for by four principal components. Using the new data, only three components or factors are needed to represent 83% of the total variability. Factor 1 carried 40% of the total variability; it included the characters growth habit, plant height, nodes at flowering, racemes per plant, nodes at maturity, seeds per pod and 100-seed weight. Factor 2 accounted for 29% of total variability and included leaflet length, leaflet width, stem thickness, dry matter yield and grain yield. Factor 3, describing only 14% of total variability, involved characters like length of hypocotyl, days to flower, pods per plant, racemes with pods and duration of flowering. Such results imply that selection of a few key characters, with one or more from each factor, would provide a basis for future evaluation over a wide range of environments. At present, growth habit, yield, and days to flower have been selected as the minimum characters for evaluating more than 6000 accessions of *P. vulgaris* grown out between the La Selva, Obonuco and Popayan locations.

Cassava Tissue Culture

Potential of the Method

The exchange of cassava germplasm with other countries is basic to CIAT's role in the improvement of this tropical crop. However, many countries have created strict quarantine barriers that prevent the distribution of vegetative materials because of the hazards of disseminating pests and diseases. Similarly, conventional vegetative field cultivation often exposes these valuable materials to pests and diseases. Tissue culture methods can be used for the vegetative propagation of cassava and such risks significantly reduced or eliminated. The potentially high propagation rates that can be achieved with tissue cultures, coupled with their freedom from microorganisms, small space requirements and relatively simple handling procedures, make it feasible to utilize these tissue culture systems for the maintenance and international exchange of cassava germplasm.

Research was initiated this year in the Genetic Resources Unit, in cooperation with the Cassava Program, aimed at developing cassava meristem culture methods for: (1) conservation of cassava genetic resources in clonal form for long periods of time and free of diseases; (2) international transfer of valuable cassava germplasm in disease-free conditions; and, (3) rapid multiplication of materials. The cycle from meristem to plants in the field, passing through the test tube and greenhouse stages, has been completed during the year.

Development of Meristem Culture Methodologies

In various experiments, meristem and shoot tips of 10 cassava varieties were subjected to an array of concentrations of cytokinins, gibberellins and auxins as supplements, either singly or in combinations, to the mineral salt and vitamin medium of Murashing-Skoog (with 2% sucrose). The differentiation of a 0.4-0.6 mm meristem tissue into a complete plant (Fig. 1, A-C) was highly dependent upon the appropriate regime of growth regulators and, to a certain extent, upon the cassava variety. Low levels of benzyl aminopurine (BAP) combined with low gibberellic acid (GA) concentratións were suitable for the differentiation of shoots in 90% of the varieties, but rooting was generally inhibited. Addition of 0.1 mg/liter naphthalene acetic acid (NAA) to the culture medium favored shoot and root differentiation in three of the varieties when acting together with GA and in 80% of the material when combined with BAP and GA. Slight increases in the concentration of BAP favored shoot growth, but reduced rooting; however, the exposure of cultures to low temperature (20°C) tended to overcome the inhibition of rooting due to BAP. On the other hand, transfer of rootless shoots to 0.1 mg/liter of both GA and NAA, with 3% sucrose and at 28-30°C, strongly promoted rooting in 90% of the material.

Thus, the reponse of different cassava varieties to meristem culturing seems to be mainly related to their rooting capability. Based on the types of responses observed at this stage, two different media have been designed: one contains the three hormones at the lowest concentrations and the second contains only GA (0.05 mg/liter) and BAP (0.02 mg/liter). For all practical purposes, the latter should induce shoots in most materials, while the former was designed to promote both shoots and roots simultaneously.

In separate experiments nodal segments, which comprised an axillary bud and its subtending little leaf, were cut from the shoots that developed *in vitro* and were cultured to form "nodal cultures". A medium that contained 0.01 mg/liter BAP, 0.1 mg/liter NAA and 0.2 mg/liter GA plus 3% sucrose supported rapid development of the nodal cultures into complete plants in 90% of the varieties. Depending upon the number of well-developed axillary buds, three to six plants could be grown from each shoot within a month.

Three varieties were used to obtain higher multiplication rates in meristem

Figure 1. Sequential development of cassava plants from meristem culture: (A) A dissected shoot apex showing the dome-shaped apical meristem flanked by two primordial leaves (X40). (B) Differentiation of shoot and root from a meristem after three weeks of culture (X1.2). (C) A five-week-old plant derived from meristem culture (X1.0). (D) A plant derived from meristem tissue, after potting at eight weeks (X0.5).

Effect of temperature on the growth of cassava shoot tips after four months in culture. (E) Incubated at 30°C day and 25°C night temperatures (C0.8). (F) Incubated at 20°C (X0.8).

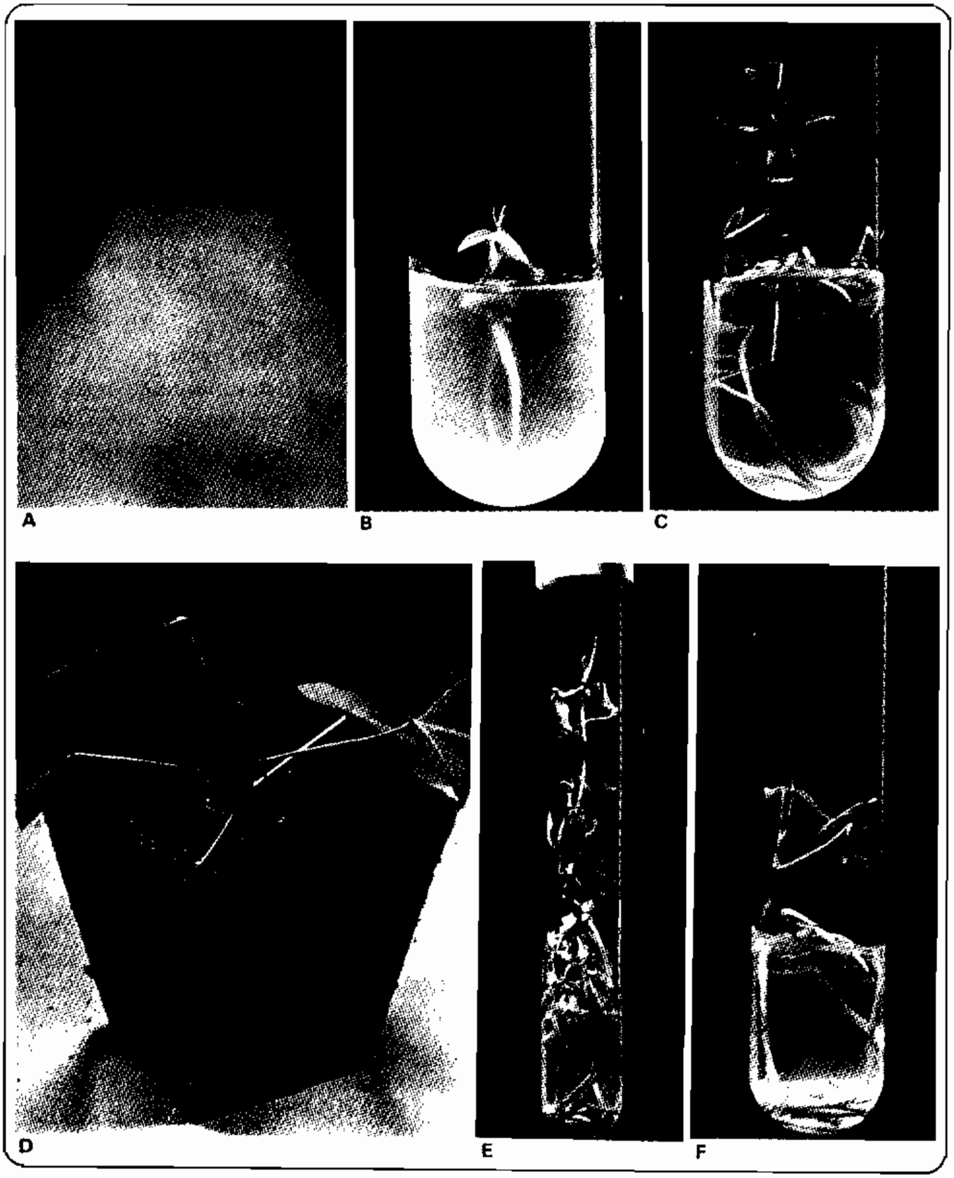


Figure 1.

cultures. Under the influence of high levels of BAP (0.05-0.2 mg/liter), multiple shoot cultures developed from a single isolated shoot apex in two of the varieties. Up to 20 shoots could be produced due to higher rates of branching when the cultures were rotated in liquid media. Chemical and physical means will be sought which could enhance the formation of multiple axillary and/or adventitious shoots in meristem cultures.

During the incubation of the cultures, the temperature was controlled at 28°-30°C during the day and at 24°-25°C during the night. Illumination was kept at about 1000 lux at the beginning of the incubation, then raised to about 2000 lux for the next three to five weeks of culture; photoperiod was controlled at 14 hours.

The survival of plants during potting was raised from 50 to 90% by a hardening treatment which consists of increasing the illumination to 5000 lux and loosening test tube caps one week prior to potting. A potting substrate of vermiculite, fine sand and gravel (1:1:1 v/v) was used. After one week in the laboratory, the pots were transferred to the greenhouse for further growth (Fig. 1,D) and gradual exposure to ambient conditions before field transplanting.

Disease Eradication

The use as planting material of cassava stem cuttings infected with the frog skin disease results in highly significant yield losses (CIAT Annual Report, 1977). The use of meristem culture in combination with thermotherapy for the eradication of the frog skin disease from infected varieties has been initiated. Temperatures may exist at which pathogen host combinations should be grown to obtain maximum inactivation of the pathogen. Hence, both the intensity and the duration of the thermotherapy applied prior to or during meristem culture are being investigated. Also, the effect of the size of the meristem tissue on the eradication of the disease is under study. The objective of this work is to develop improved techniques to routinely clean up valuable materials (Fig. 2).

Conservation of Genetic Resources

Meristem cultures could be very valuable for the long-term conservation of germplasm since large collections could be stored in small spaces, with the risks of disease contamination practically eliminated and maintenance costs greatly reduced. Two systems of the storage of cassava germplasm as meristem cultures are being studied.

Freeze-storage. A project has been initiated, in cooperation with CIAT, in the Prairie Regional Laboratory, Saskatoon, Canada to investigate the feasibility of preserving cassava shoot apices at the temperature of liquid N (-196°C). Rates of freezing and thawing, as well as the use of cryoprotective and hardening treatments, will be evaluated for their effects on the survival of the meristematic cells.

Minimum growth storage. Work is under way at CIAT to develop methods for the maintenance of cassava meristem cultures at a minimum growth rate for protracted periods of time. Nodal cultures of two cassava varieties were used as starting explants for storage. Results after four months of storage indicate: (1) the rate of growth of the shoots in cultures maintained at 20°C can be reduced from 5.5 cm/month (at 30°C day and 25°C night) to 0.5 cm/month (Fig. 1, E and F); (2) growth could be further reduced, with 100% survival of the cultures, to the rate of 0.2 cm/month if the sucrose level of the

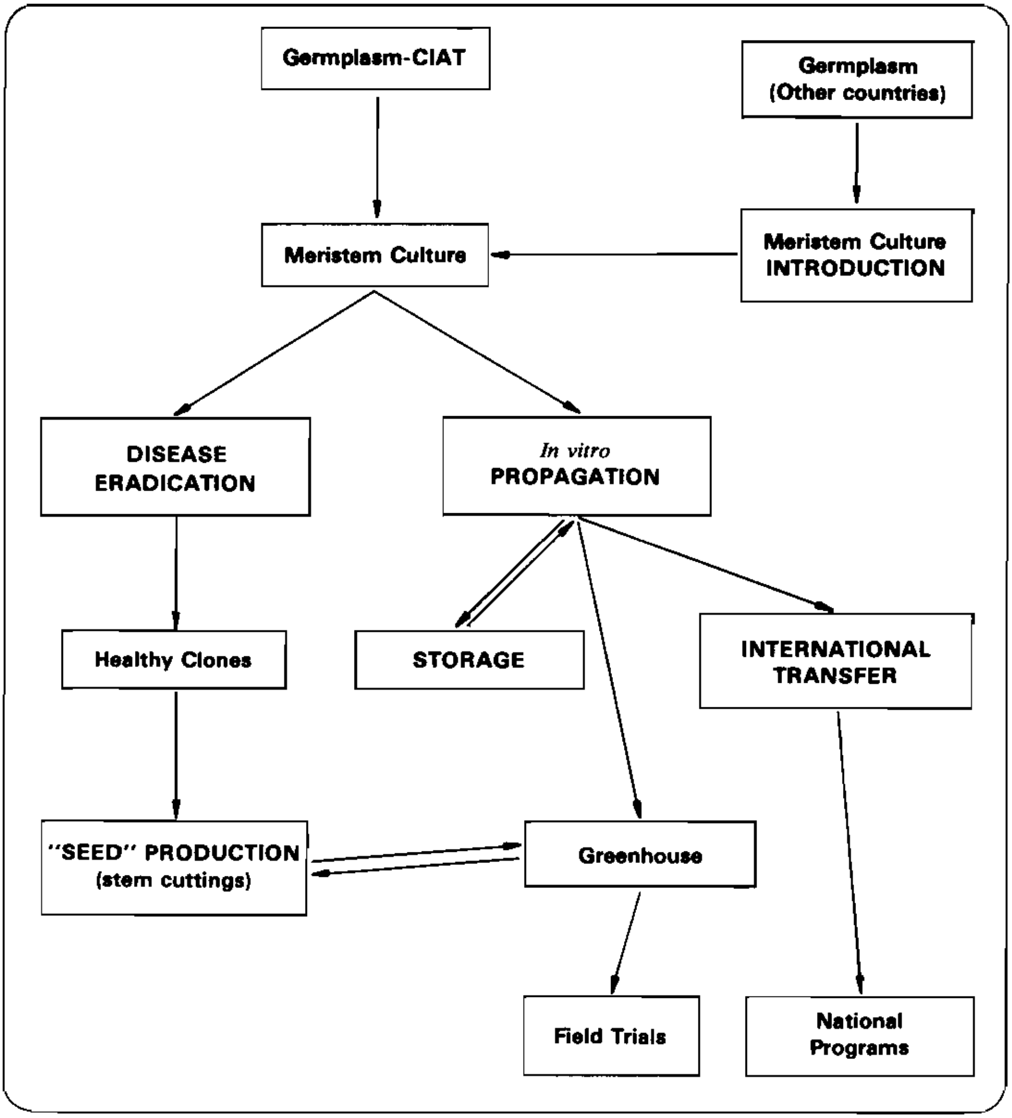


Figure 2. Outline of the various steps in the application of meristem tissue culture to cassava.

culture medium is increased to 5%, but higher sucrose levels tend to reduce the survival of the cultures; (3) the addition of low concentrations of BAP to the culture medium slows down the growth even further without reductions in survival; (4) cultures maintained at 15°C became gradually chlorotic and senescent after one month of storage.

Further research should provide definite information on optimal temperatures, kind and size of explants for storage, propagation rates and genotype stability of the materials recovered from storage.

International Transfer of Germplasm

Tissue cultures initiated from 0.4-0.6

mm shoot apices should be free of insects, nematodes, and most fungi and bacteria. Obligate parasites, such as viruses, should be eradicated by thermotherapy and meristem culture prior to shipment *in vitro.*

Simple methods will be developed to distribute cassava germplasm as aseptic meristem cultures from CIAT to other countries. Similarly, these procedures would allow introduction of new germplasm to CIAT without disease risks (Fig. 2).

Training of personnel from recipient countries in the appropriate techniques for recovery and multiplication of stocks will be a very important aspect of the program.

PUBLICATIONS

Luse, R. A. 1978. Transfer of forage germplasm (Chap. VIII) and, Preservation of forage germplasm (Chap. IX). *In* Handbook for the Collection, Preservation and Characterization of Tropical Forage Germplasm Resources. G.O. Mott, Ed. CIAT, Cali, Colombia. (in press).

Luse, R. A. 1978. The need for food utilization and processing studies to supplement nutritional evaluation. *In* Proc. XI Intl. Cong. of Nutrition. Rio de Janeiro, Brazil. (in press).

Luse, R. A. and **Rachie, K.O.** 1978. Seed protein improvement in tropical food legumes. *In* Proc. Symp. on Seed Protein Improvement in Cereals and Grain Legumes (Neuherberg, Fed. Rep. Germany, Sept. 1978). Intl. Atomic Energy Agency, Vienna, Austria. (in press).

Rachie, K.O. and **Luse, R. A.** 1978. Support systems for climbing food crops. *In* Proc. Intl. Wing Bean Conference (Los Baños, Philippines, Jan. 1978). (in press).

Singh, S.R., Luse, R. A., Leuschner, K. and **Nangju, D.** 1978. Groundnut oil treatment for the control of *Callosobruchus maculatus* (F.) during cowpea storage. J. Stored Products Res. 14(2/3): 77-80.

Song, L. and **Rawal, K.** 1978. Data management of forage germplasm (Chap. X). *In* Handbook for the Collection, Preservation and Characterization of Tropical Forage Germplasm Resources. G.O. Mott, Ed. CIAT, Cali, Colombia. (in press).

Roca, W.M. 1978. Introducción de germoplasma como cultivo de meristemas. *In* Proc. II Latin American Botanical Cong. (Brasilia, Brazil, Jan. 1978). (in press).

Roca, W.M., Espinoza, N.O., Roca, M. R. and **Bryan, J.E.** 1978. A tissue culture method for the rapid propagation of potatoes. Amer. Potato J. 55: 691.

Roca, W.M., Bryan, J. E. and **Roca, M. R.** 1979. Tissue culture for the international transfer of potato genetic resources. Amer. Potato J. 56: 1-10.

Special Studies Unit

During 1978 the Special Studies Unit concentrated on germplasm evaluations. Trials initiated in previous years on cowpea *(Vigna unguiculata)*, pigeon pea *(Cajanus cajan)* and sorghum *(Sorghum vulgare)* were continued. Promising cowpea and pigeon pea lines were selected in order to prepare international yield trials for both of these crops. Trial sets are being distributed in Latin America and results should be available in 1979.

Studies were initiated on lima bean *(Phaseolus lunatus)* accessions in cooperation with the Genetic Resources Unit. Trials were planted in several locations to test adaptability and yield potential. These preliminary data will be used to orient future breeding experiments.

Investigations were begun on intercropping with cassava. These are being done by a Postdoctoral Fellow working directly with the Cassava Program.

Evaluation of Cowpea Germplasm

At the beginning of the year final selections were made of the best cowpea *(Vigna unguiculata)* materials evaluated in semesters 1976B, 1977A and 1977B. Of the 30 most promising lines planted in 1977B, eight had average yields of 3 t/ha. All except one line showed good or moderate resistance to virus and bacteria attacks.

A second group of cowpea lines were received from the International Institute for Tropical Agriculture (IITA) for evaluation. These lines were planted in 1977B and observed for adaptability, resistance to diseases and pests, yield and other agronomic characteristics. Yields were reduced by virus infection, high populations of *Cyperus rotundus* and by the fact that cowpeas had been planted in the same plot for four consecutive semesters. The best determinate lines were: Tvx-7-5H, Tvx-309-1G, Tvx-1193-9F, Tvx-1836-19E, Tvx-1836-90E and the local variety ICA Mocari; yields for this group were between 2.5 to 3.2 t/ha. All lines had some virus infection. The best indeterminate lines were Tvx-33-1G and Tvx-1836-157G with average yields of 2.3 and 2.5 t/ha, respectively.

The best materials (a total of 32 lines) were planted in 1978A for final evaluation before preparing a yield trial. The plot where the plants were located had a high population of *C. rotundus* which was controlled by two applications of glyphosate. However, because of its aggressiveness, vigor and rapid development, cowpea appears to be a legume which is rather resistant to *Cyperus*, under conditions of the Cauca Valley region.

Table 1 summarizes the yields of the 10 best lines over two years. From the data it is evident that yields have increased as the virus-infected plants were eliminated from the lines. Virus appeared to be a major limiting factor in yielding potential. In 1978A the overall average yield was 3.7 t/ha.

From the results of the observation trials, 10 of the best lines were selected for distribution in Central America by the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA). The principal objective of the trial is to test the adaptability of the promising materials under different environmental conditions in comparison with local varieties. Lines selected were the same ones shown in Table 1. Two of the trials were planted at CIAT in 1978B at densities of 83,500 and 66,666 plants/ha; results will be available in 1979.

Table 1.

Yields of selected lines of cowpea *(Vigna unguiculata)* at CIAT-Palmira, 1976-1978

	Yield (t/ha)			
Line[1]	1976B	1977A	1977B	1978A
Tvx-66-2H	3.6	2.8	1.8	3.6
Tvx-456-01F	3.6	2.4	-	3.9
Tvx-30-1G	3.6	3.0	2.6	3.4
Tvx-966-01B	2.6	2.8	-	4.1
Tvx-13-2E	1.7	-	2.1	3.4
Tvx-1836-90E	-	-	2.7	3.5
Tvn-354-1B	3.6	3.4	3.3	4.1
Tvn-157-1E	2.9	2.6	-	4.3
Tvn-1190-E	3.1	-	3.1	3.7
Tvn-201-1D (Vita 1)	3.0	3.0	-	3.6

1 All lines originated at the International Institute for Tropical Agriculture (IITA).

Germplasm evaluation continues on the remaining cowpea lines, which were also planted in 1978B. Selections will be made based on plant structure, seed quality, growth habit and plant health and vigor.

Evaluation of Pigeon Pea Germplasm

Evaluations of pigeon pea *(Cajanus cajan)* materials began in 1977 with the multiplication of seeds from 26 lines introduced from IITA. In the first semester of 1978, 14 of the highest yielding lines were selected and planted. Most of these lines are determinate, but some promising indeterminate materials have also been identified. At the same time, 10 new accessions from the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) were received. The best-adapted lines from the total of 24 planted in 1978A were: ICRISAT materials 2786 and 14769, and IITA selections TCc numbers 2263, 2308, 3D-8111, 3D-8126, 3D-8129 and 4F-38, with average yields of 3 t/ha.

From the materials planted in 1977B and 1978A, eight lines were selected for the preparation of a uniform yield trial for distribution by PCCMCA. The main objective of this trial is to test the adaptability of these promising materials under different environmental conditions. One trial was planted at CIAT in 1978B. Results are expected in early 1979.

At the same time, other selections were made and planted from the 24 lines studied in the previous semester. Selection was based on plant structure, color and size of the seed and other agronomic characteristics. These results will also be ready in early 1979

Evaluation of Sorghum Germplasm

Replicated agronomic trials were carried out with 10 sorghum *(Sorghum vulgare)* lines selected in the second semester of 1977 from 71 materials initially obtained from ICRISAT and All-India Coordinated Sorghum Improvement Program (AICSIP). Selections were made on the basis of estimated yields, plant height, size and vigor of the panicle, and earliness.

The materials 5Dx61/6/2-14 and 5Dx61/6/2-2 had certain desirable characteristics, such as seed bitterness, which caused them to be resistant to bird attack. However, the materials A-22791 and 5Dx36short-18 did not have bitter seeds and showed high and moderate susceptibility, respectively, to attack by birds.

Evaluation of Lima Bean Germplasm

In early 1978, observations on more than 300 lines of lima beans *(Phaseolus lunatus)* then held by CIAT were carried out to continue work initiated by the Genetic Resources Unit. The majority of these materials (about 90%) were indeterminate in growth habit and came from Brazil. Some determinate lines from Peru and the United States were also studied. From the total, 95 promising lines were selected on the basis of agronomic characteristics and planted at CIAT-Quilichao in May 1978.

The experiment at CIAT-Quilichao indicated that, with the possible exception of cowpea, lima beans and several other legumes tested were not adapted for growth on the virgin soil there (pH 4.0). Growth virtually ceased after a few weeks and almost nothing was harvested from the untreated soil plots, possibly due to Mn toxicity (19.4 ppm). Lines planted on soils with residual fertilizer effects (pH 4.25, complete fertilizer applied in the previous semester with 5 t/ha of lime) performed considerably better. These plots were harvested twice and yields recorded. The 30 best-yielding lines averaged 2.65 t/ha, despite the rather poor soil conditions. In general, the plants were remarkably free of disease and insect problems. In plantings at CIAT-Palmira and CIAT-Quilichao, the major problems have been bacterial blight, leafhopper and, to a lesser extent, bean common mosaic virus. However, disease and insect problems were not so serious as those observed in *Phaseolus vulgaris* planted nearby.

In the latter half of 1978, further agronomic trials were initiated with the 30 best-yielding lines selected the previous semester. An experiment was planned for climbing lima beans to test the yield and adaptation under different environmental conditions. Six *P. vulgaris* lines were included in the same experiment (two lines adapted to cool temperatures, two adapted to moderate temperatures, and two adapted to high temperatures) for comparisons. The experiment was planted at CIAT-Palmira (moderate temperatures) and Patia (high temperatures). Results will be available in early 1979.

Bush limas were planted at CIAT-Palmira in the latter half of 1978 to test yield and other agronomic characteristics, however, due to poor germination, this trial was discontinued and the plots were used to increase seed supplies of the bush varieties.

Fifty promising lines were given to the Bean Pathology Section for rust screening at CIAT-Palmira. Similar cooperative testing is also planned for bacterial blight and leafhopper (by the Bean Pathology and Entomology Sections, at CIAT-Palmira) and for golden mosaic virus (by Bean Program personnel in Costa Rica).

Thirty-five accessions were analyzed for cyanide content by the Laboratory Services group at CIAT. While most lines showed very low cyanide levels, two contained more than 10 mg total cyanide per 100 g dry matter (11.8 and 28.4 mg/100 g). (The maximum content permitted in lima beans for human consumption in the United States is 20 mg/100 g.) Further cyanide evaluations will be made on promising materials in the next semesters.

Using data from the above evaluations and detailed plant character evaluations under way in the Genetic Resources Unit, breeding studies with lima beans are planned for initiation in early 1979.

Data Services Unit

Because of the continued expansion of computing services and the pending installation of CIAT's IBM S/34 computer, the former Biometrics Unit was renamed the Data Services Unit and reorganized into two major sections during 1979 — the Statistical Services and Computer Services Sections. Leaders of both sections report to the coordinator of the Unit.

The Statistical Services Section provides statistical consulting for the planning, design, analysis and interpretation of scientific experiments or projects developed in CIAT. This section also develops and implements quantitative techniques applicable to the research needs of the Center and provides training in quantitative methods, through group or individual instruction.

The Computer Services Section develops activities in the area of information systems and programming support to satisfy the needs of the various administrative and research programs of the Center. In addition, personnel of the section are responsible for operating and maintaining the computing equipment of the Unit.

COLLABORATION WITH RESEARCH PROGRAMS

Beef Program

Evaluation of Beef Production Systems Project. The Unit has provided assistance in systematizing the information collected on farms included in this study. The data bank for the project contains files for: (1) static descriptions of each farm; (2) variable information for each farm; (3) animal inventories according to paddocks; (4) individual performance of breeding cows; (5) individual performance of bulls; and, (6) economic costs and returns.

Up to now, information from the first two data collecting visits to 17 farms selected in the Colombian Llanos Orientales have been processed and analyzed. Detailed information on activities and data available may be found in the Animal Management and Animal Health Sections of the Beef Program, in this Annual Report.

Management of Breeding Herds and Experimental Herd. The Data Services Unit has collaborated in these two projects from the planning stages. Both projects were initiated at Carimagua in 1977.

The principal objective of the Breeding Herds Project is to evaluate improved pastures and to study their utilization during critical periods of the reproductive cycles of the animals. Information is generated bimonthly in this project and includes measurements of reproductive parameters and physiological variables of the herds. Through the end of 1978, information from six weighing periods has been processed and analyzed.

Study of the Ecosystems of West-central Brazil. In 1977 the Beef Program initiated a Target Area Survey. The first area selected for evaluation was the west-central region of Brazil; information utilized was collected at 83 meteorological stations within the region. Objectives were to classify and construct maps of the soil resources of the region, to facilitate the development of realistic strategies for developing and transferring technology and to identify priority geographic areas. The Computer Services Section is developing a system for compiling, up-dating, manipulating and retrieving the information collected for each land system of the study.

Pasture Utilization Experiments. In 1978 an overall analysis was made of experiments done at Carimagua between 1972 and 1978. This experimental series consisted of the following projects: (1) Management of the native savanna in the Colombian Llanos; (2) Burning management in the native savanna of Colombia; (3) Effect of fertilization on the weight gain of steers grazing *Melinis minutiflora* at Carimagua; and, (4) Management of *Melinis minutiflora:* Nitrogen supplementation and resting during the dry season. In addition, the Unit collaborated in the statistical analysis of the data generated by research on the prediction of digestibility of tropical forages based on the cellulose enzyme.

Other Projects. Complete statistical consulting has been provided for the different evaluations of rock phosphates and for experiments done by the Grass Agronomy and Legume Agronomy Sections of the Beef Program.

Bean Program

Bean Information System (SIFRI). During 1978 this system's services of assistance to scientists in the CIAT Bean Program increased both in magnitude and scope. For this reason, the name of the information system was changed from the Information System for Bean Breeding (SIFFRI) to its present designation as a general system serving the entire program.

The system provides assistance in developing activities to help meet the main objectives of the Bean Program. This assistance consists of maintenance and distribution of information from the various disciplines derived from trials done in the various selection cycles of materials. These cycles are: (1) crossing and selecting; (2) Uniform Evaluation Nurseries (VEF); (3) Preliminary Yield Trials (EP); (4) International Bean Yield and Adaptation Nurseries (IBYAN); and (5) International Trials of Elite Selections (ESE). Figure 1 shows how SIFRI interacts with the various selection cycles.

In each of these trials, the different sections of the Bean Program conduct evaluations that are compiled and distributed through SIFRI to all members of the bean team. Compilation of all information relating to a given material and its

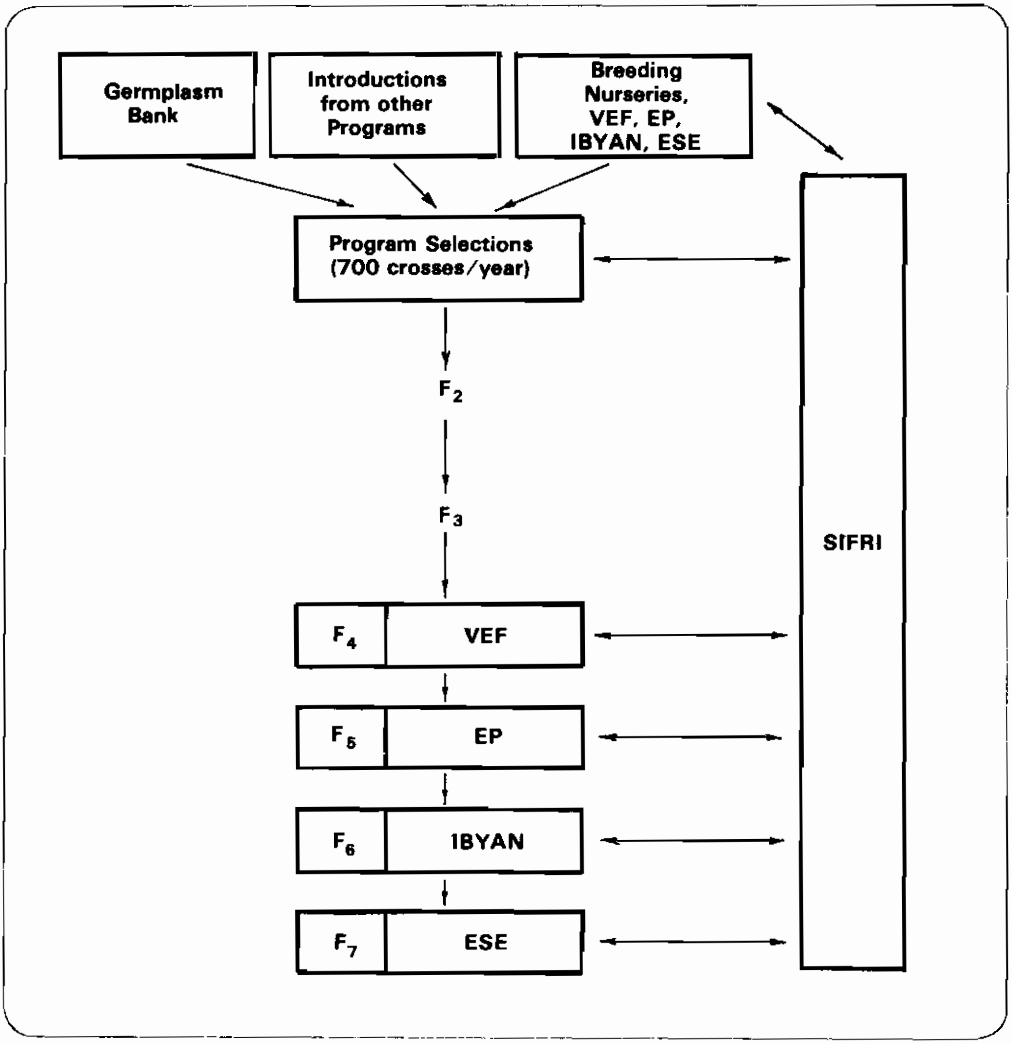


Figure 1. Interaction of Bean Information System (SIFRI) with the development and simultaneous and sequential evaluation of bean germplasm.

distribution is of great importance during the process of selecting improved varieties. For example, it is hoped that in the VEF and EP trials SIFRI would produce a series of reports to facilitate selecting material that should continue in the selection process. Results from a trial run of the process proved the operation of SIFRI.

Successively, a series of important functions has been delegated to SIFRI, including the assignment of materials for the field and simplification of data collection. To utilize these features, it is envisioned that as soon as materials to be included in a trial are known, SIFRI can determine their assignment to the field; provide labels for distribution of the seed and produce field books for collecting the data according to the disciplines involved in operating the trial.

Because SIFRI is an expanded version of SIFFRI, it provides such informational services as producing crossing information to accompany seed sent to national programs and producing reports solicited by these programs. Other information on the earlier SIFFRI features (now incorporated in the new system) is discussed in the Biometrics Section of the CIAT Annual Report, 1977.

The SIFRI data base has been expanded, especially with respect to the files for yield and the evaluations of the accessions in the bean germplasm bank. Presently, the data base contains the following files: germplasm bank, crossing bank, bank of promising varieties, bank of disease reactions of promising material over planting season and various locations, percentage germination and vigor of accessions in the germplasm bank, accessions evaluated by the Genetic Resources Unit, and other special files.

When new computational equipment is installed, it is planned to maintain some segments of the system locally, therefore offering better service to users.

International Bean Yield and Adaptation Nursery (IBYAN). Through November 1978, 54 experiments from 1976, 53 from 1977 and 12 from 1978 had been processed for these nurseries. The following reports are provided for each IBYAN experiment: preliminary reports of lists of inconsistencies and suspicious data; overall statistical elements and tables of analyses of variance; a summary table containing general information; statistics by variety for yield, yield components and other physiological variables; and a table of precipitation and maximum and minimum temperature data. Also, combined analyses are made to evaluate the adaptability and stability of the materials utilized.

Data analyses for the IBYAN which do not require the capacity of a large computer will be converted to run locally, for processing by the new computer to be installed at CIAT. In addition, because of the wide potential for using the information generated in the IBYAN's, a variety of studies are anticipated for the future. In particular, it is planned to utilize multivariate techniques that permit the exploitation of the essential tri-dimensional character of IBYAN information — over space, time and response.

Border Effects, Plot Size and Numbers of Replications in Climbing Bean/Maize Associations. Work done during 1978 was a continuation of cooperation between the Agronomy Section of the Bean Program and the former Biometrics Unit, to study effects of different plot techniques in bean research.

Border effects: Two types of experiments were conducted at CIAT-Palmira to measure effects of broders in climbing bean/maize systems.

The objective of the first trial was to study the effect of varietal competition and non-seeded spaces on the yield of 36 varieties of climbing beans associated with the maize hybrid ICA H-210. Effect of competition was measured by comparing yields of plots with side borders with yields from plots without side borders, considering one bed on each side as the border (lateral border effect). The effect of unplanted spaces was measured by comparing yields of plots in which 50 cm of head border was harvested to yields from plots which had unharvested head borders (head border effect).

The experimental design used was a 6 x 6 lattice with three replications, The experimental unit was a plot of 24 m² (four beds 6 m long with two bean rows and one maize row per bed).

Average yields for each type of plot are shown in Table 1. The analysis of variance for yield indicates that effects from side borders were not significant, and that there was no effect of varietal competition on the expected yield per plot. On the other hand, effects of head borders were significant at 1%; the average yield of plots in which head borders were harvested (1021 kg/ha), surpassed yields from plots in which head borders were not harvested (739 kg/ha) by 38.2%. This effect, however, was not uniform for all varieties, as is indicated by the significance (at 5%) of the interaction for variety x head border, and the significance (<0.01) of the regression of the over-estimation of yield including the head border on the yield of beans without head rows. This regression shows that highest yielding varieties show less over-estimation of yield than those that yield low, apparently due to their different competitive ability.

One can conclude that in experiments of climbing beans/maize associations there is no effect from varietal competition but there is an effect from unplanted spaces. Thus, side borders are not necessary but it is advisable to leave head borders, given the differential effects between varieties.

In the second experiment, a more detailed study was conducted at CIAT-Palmira to discover the range of effect of unplanted spaces in bean monoculture and climbing bean/maize associations, utilizing one bean variety and one maize variety. The experimental plot was an area 11 x 11 m, consisting of 11 furrows, 11 m long. Crops were harvested in 1 m^2 units. From the yield data the average yield per ring (numbered from 1 to 5) was estimated. Ring 1 was made up of plants seeded on the perimeter of the plot and Ring 5 was the intermost ring. The trial thus permitted the measurement of the range of effect of unplanted spaces at the levels of 0, 1, 2, 3, and 4 m toward the interior of the plot.

Trials were planted in two seasons. The first one, planted in October 1977, utilized the bean line P589 of growth habit IV and the maize variety ICA H-207, a tall material susceptible to lodging. In the second seeding, in March 1978, the same bean line was planted with the maize variety ICA H-210, a short brachytic material resistant to lodging.

Table 1.

Average yields of 36 varieties of climbing beans in plots with and without side and head borders.

Harvest treatment	Plot area (m^2)	Avg. yield (kg/ha)	SD. (kg/ha)	CV. (%)
Harvesting side and head borders	24	1034	233	22.5
Harvesting side borders and excluding 50 cm of head border	20	736	191	26.0
Not harvesting side borders but harvesting head borders	12	1008	234	23.3
Not harvesting side and head borders	8	742	203	27.3

Although a statistical analysis was not done on results from the first planting because of partial losses from lodging, bean yields by ring, in association, and in monoculture, and maize yields by ring in association decreased inwards to Ring 3 and then were constant from there on. In the case of monoculture maize, yields decreased between Ring 1 and Ring 2 only (Table 2). Maize yields in monoculture in the first three rings were inferior to those of associated maize, due to the greater amount of lodging. The large range of border effects, especially for beans in association, was surprising and could be attributed to the fact that the maize planted was a tall variety.

Results from the second planting were more reliable and were analyzed statistically. Table 2 shows the average yield per ring in each planting system, and Table 3 shows the results of the analysis of variance. The effect of unplanted spaces on beans in association was more moderate than in the first trial, probably because the maize chosen was a short-growing one. Yields of beans in monoculture, beans in association, maize in monoculture and maize in association decreased significantly between Rings 1 and 2, although yield differences among the remaining rings were not significant. The yield recorded in Ring 1 surpassed yields of the interior rings by averages of 31, 39, 27 and 29% respectively for monoculture beans, beans in association, maize in monoculture and maize in association. Also, an analysis of variance was done on yields of 1 m² plots, to study whether the effect of non-planted spaces was different according to the shape of the plot. This model furnished three sources of variation: replication; position of the plant within the row; and, the interaction row x position. Results of the analysis of variance for each system indicate that the effect of the shape of the plot was not significant.

Results show that non-planted spaces significantly affect yields in both monoculture and in associated climbing bean/maize systems and that effects are independent of the shape of the plot. Given that the yield decrease was significant up to Ring 2, it is recommended to leave 1 m of

Table 2.

Average yields by ring in bean monoculture, maize monoculture and bean/maize associations, in studies on the effects of unplanted spaces.

	Yields (kg/ha)							
	Beans in monoculture		Beans in association		Maize in monoculture		Maize in association	
Ring	Oct. 1977	Mar. 1978	Oct. 1977	Mar. 1978	Oct. 1977	Mar. 1978	Oct. 1977	Mar. 1978
1	3323	5710	1648	3209	4708	5943	6102	2953
2	2523	3791	664	1957	4428	4741	4657	2171
3	2263	3885	428	1931	3934	4306	4134	1840
4	2375	4132	330	1908	3786	4305	3655	2209
5	1965	3864	265	1970	3896	4028	3404	2100
L.S.D. at 5% (kg/ha)	-[1]	407	-[1]	486	-[1]	935	-[1]	573

1 In the trial planted in October 1977, some yield was lost due to lodging and final yields were not analyzed statistically.

Table 3.

Results of analyses of variance for yield by ring in four replications, in studies on the effects of unplanted spaces on bean and maize yields in monoculture and association (March 1978 planting).

Source of variation	Degrees of freed-dom	Beans in monoculture		Beans in association		Maize in monoculture		Maize in association	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Replications	3	283,253	4.1*	244,679	4.9*	2,654,249	7.2**	2,193,098	15.8**
Rings	4	2,634,648	37.7**	1,287,261	25.8**	2,301,775	6.2**	1,302,970	9.4**
Error	12	69,820		49,822		368,472		138,423	
Total	19								
L.S.D. at 5% (kg/ha)		407		486		935		573	
L.S.D. at 1% (kg/ha)		571		682		1311		804	

border in adjacent plots and non-planted spaces both in monoculture and associated systems.

Optimum Plot Size and Number of Replications. Based on results obtained in the trial planted in March 1978, described above, another study was conducted to determine optimum plot size and number of replications in each of four planting systems — climbing beans in monoculture, climbing beans in association with maize, maize in monoculture, and maize associated with climbing beans. Methodology employed was according to Hatheway [1].

Data in Table 4 permit the researcher to decide, for each system, the optimum combination of replications and usable areas of each plot, according to the significance of difference one wants to detect, as a percentage of the mean (d). For example, in monoculture beans, for value of d = 24%, the following alternatives exist: (r = 2, X = 14.14), (r = 3, X = 8.09), (r = 4, X = 5.44), (r = 5, X = 4.00) and (r = 6, X = 3.11). From these, the researcher may choose a combination according to the total space available. Generally, for the same level of precision (represented by d), the plot size for climbing beans in monoculture is less than that required for climbing beans in association; likewise, the size of the plot required in trials of monoculture maize are smaller than those required to evaluate maize in association.

For climbing bean/maize associations in which the main interest is the performance of the beans, it is recommended to use the plot size and number of replications according to the results calculated for beans in association; a similar case holds for maize. If one is interested in performances of both crops, then the maximum plot size and number of replications should be chosen between those recommended for associated beans and associated maize.

Cassava Program

Uniform Yield Trials. During 1978 data from four Uniform Yield Trials were processed for the Agronomy Section, to study the heterogeneity of plots utilized

1 Hatheway, W.H. 1961. Convenient plot size. *Agron. Journal* 53: 279-280

Table 4.

Useful plot area for various combinations of replication (r) numbers and differences (d) to be detected as a percentage of the mean for climbing beans in monoculture, maize in monoculture and climbing beans and maize associations.

		Useful plot areas (m²)					
r	d=	15%	18%	21%	24%	27%	30%
		51.60[1]	31.22	20.42	14.14	10.22	7.64
2		48.80[2]	32.09	22.52	16.57	12.54	9.92
		56.45[3]	38.91	28.41	21.63	17.01	13.72
		121.84[4]	81.97	58.63	43.86	33.95	27.00
		29.52	17.86	11.68	8.09	5.85	4.37
3		30.62	20.14	14.13	10.39	7.93	6.22
		37.33	25.72	18.78	14.30	11.25	9.07
		78.42	52.76	37.74	28.23	21.85	17.38
		19.86	12.02	7.86	5.44	3.93	2.94
4		22.00	14.47	10.15	7.47	5.70	4.47
		27.83	19.18	14.01	10.66	8.39	6.76
		57.36	38.59	27.60	20.65	15.98	12.71
		14.60	8.84	5.78	4.00	2.89	2.16
5		17.02	11.19	7.85	5.78	4.41	3.46
		22.16	15.28	11.15	8.49	6.68	5.39
		45.01	30.28	21.66	16.20	12.54	9.98
		11.36	6.88	4.50	3.11	2.25	1.68
6		13.80	9.08	6.37	4.69	3.57	2.81
		18.40	12.68	9.26	7.05	5.54	4.47
		36.92	24.84	17.76	13.29	10.29	8.18

1 Beans in monoculture
2 Beans in association
3 Maize in monoculture
4 Maize in association

and to determine the size, shape and number of replications appropriate for yield trials. Table 5 shows the principal characteristcs for the four trials.

Each trial had four replications to allow investigations of effects of borders and unplanted spaces. Each replication consisted of 16 rows of 16 plants each, providing 256 plants or unitary plots. For each plant, several variables were recorded including: total weight of roots, weight of commercial roots and weight of aerial parts.

Table 5.

Principal characteristics of locations and planting and harvesting information for four trials to study experimental methods for cassava yield evaluations.

	Trial 1	Trial 2	Trial 3	Trial 4
Location	CIAT-Palmira	CIAT-Palmira	Carimagua	Carimagua
Variety planted	M Mex 11	M Mex 59	M Mex 59	M Col 22
Planting date	Jan. 4, 1977	Dec. 14, 1976	May 13, 1977	May 13, 1977
Harvest date	Nov. 16, 1977	Nov. 16, 1977	April 16, 1978	April 16, 1978
Age at harvest	316 days	337 days	338 days	338 days
Unitary plot	1 x 1 m	1 x 1 m	0.8 x 0.8 m	0.8 x 0.8 m

To describe the procedure of analysis utilized, only details for the variable "total root weight" will be discussed, for the first trial. The layout of this trial is shown in Figure 2.

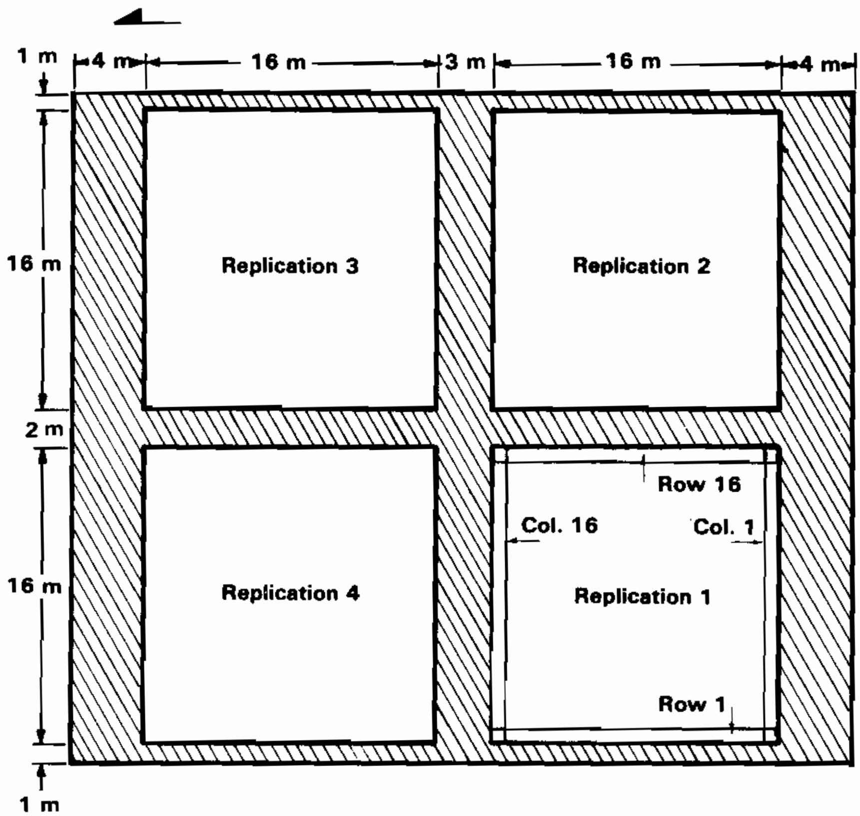


Figure 2. Arrangement of experimental field for studying effects of borders and unplanted spaces in cassava (Trial 1).

Border effects of cassava. First, a graphic analysis of the plot was made by constructing fertility maps. Figure 3 shows the fertility map for total root weight in the first replication. Note that in Row 16 and Columns 1 and 16 the two plantings of greatest response predominate, suggesting border effects. On the other hand, border effects are not pronounced in Row 1. These results clearly show the effects of unplanted spaces. In Figure 3, one can see that the areas where border effects are evident correspond to the sides of the perimeter contiguous with unplanted spaces more than 1 m wide; Row 1, however, which does not show border effects, is adjacent to an unplanted corridor only 1 m wide. Note also the presence of patches of varying fertility, suggesting the heterogeneous character of the soil in the plot.

To confirm what the fertility map suggests, an analysis of means of the rings was done. A ring was defined as the contiguous plants at the same minimum distance from the border of the replication; that is, Ring 1 is the exterior ring of the replication; Ring 2, plants in Rows and Columns 2 and 15, etc.

Table 6 is the table of analysis of variance of total root weight in the first trial. Both the Duncan multiple range test and the minimum significant differences test show the seven interior rings to be homogeneous and different from the exterior ring. Consequently, for the analysis of size and optimum form of the

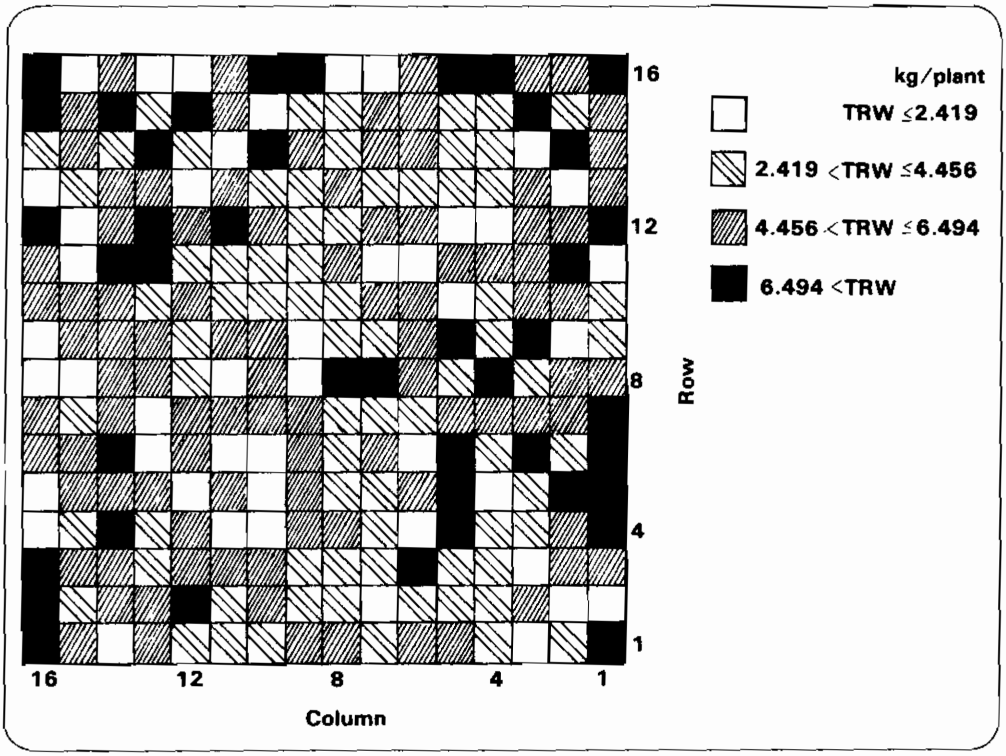


Figure 3. Fertility map for the variable Total Root Weight (TRW), for Replication 1, Cassava Uniform Trial 1, for studying effects of borders and unplanted spaces in cassava (see Fig. 2).

Table 6.

Analysis of variance for Total Root Weight in Cassava Uniform Trial 1.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Rings	7	7.086	1.012	2.93*
Error	24	8.294	0.346	
Corrected total	31	15.380		

plot, the exterior ring can be elimated from each replication, leaving 196 (14 x 14) plants available for each replication. Figure 4 is a graphic display of the mean yields by ring in Trial 1.

Table 7 summarizes the border effects for total root weight in each of the four trials. Generally, one border ring appears sufficient, but in trials of confirmatory nature, it is recommended to leave two border rows.

Plot Size and Shape, and Replication Number. Adjacent plants were grouped into 49 shapes, each one of which simulates one partition of the replication. The 49 shapes correspond to the possible combinations of length and width: (1, 1), (1, 2) . . . (1, 7); (2, 1), (2, 2) . . . (2, 7); (7, 1), (7, 2) . . . (7, 7).

For each simulated partition, the coefficient of variation between the plots corresponding to that partition was determined. Figure 5 shows the graph of C.V. versus plot area. It is clear that in this replication, it is of little advantage to use plots larger than 16 m² for the harvested area.

To analyze the effect of the shape of the plot, the partitions (1, 6), (2, 3), (3, 2) and (6, 1), all with areas of 6 m² are selected; the corresponding C.V.'s are 20.36, 14.08, 12.24 and 12.88%, respectively. Consequently, being restricted to using plots of 6 m², it would be desirable to use the partition (3, 2) with the smallest C.V. However, considering the other replications where the effect of the shape is less marked, given that definite gradients are absent, then the effect of the shape of the plot is of little importance. In these cases, square plots should be used unless some other shape offers better advantages for managing the experiment.

To determine the coefficient of heterogeneity of the soil, the method

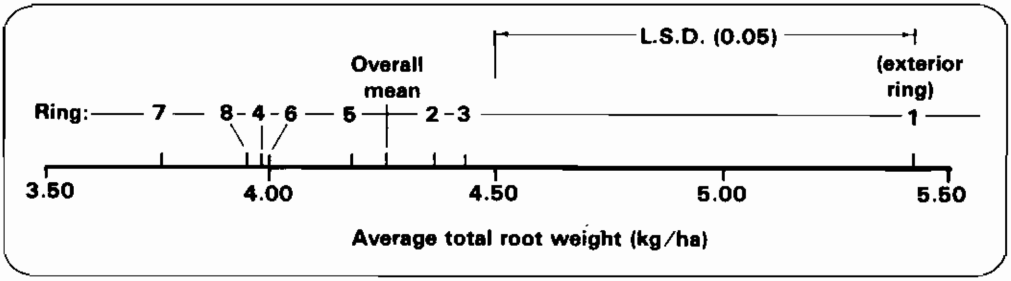


Figure 4. Mean yields by ring in Cassava Uniform Trial 1.

Table 7.

Summary of border effects for Total Root Weight in four cassava uniform trials.

Trial	Results of Duncan multiple range test[1]								Conclusions
1	7	8	4	6	5	2	3	1	Significant border effect in exterior ring
2	6	5	7	3	4	8	2	1	Significant border effect in exterior ring and lesser effect in 2nd ring
3	8	7	5	6	3	4	2	1	Significant border effect in exterior ring and much less effect in 2nd ring
4	7	4	6	5	3	2	8	1	No significant border effect

1 Numbers identify the rings evaluated; ring numbers linked by a line are not significantly different.

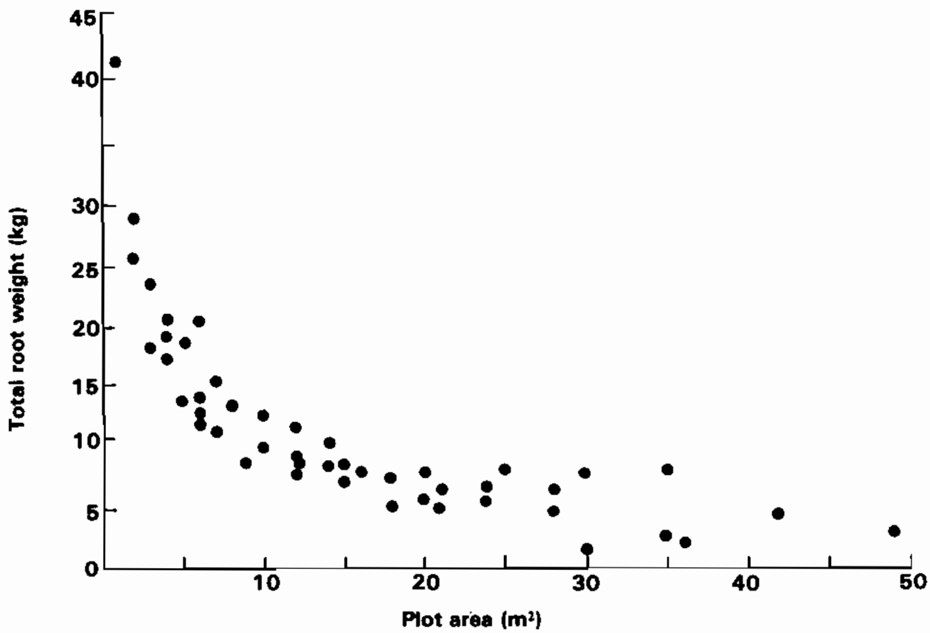


Figure 5. Coefficient of variation of Total Root Weight versus Plot Area, for Replication 1, Cassava Uniform Trial 1, for studying effects of borders and unplanted spaces in cassava (see Fig. 2 and 3).

proposed by Federer[1] and the regression equation of Smith[2] were used. Table 8 presents the averages over replications of b, b', and the CV. of unitary plots obtained for each response variable in each of the four uniform trials. The values of b and b' larger than 1 indicate interspecific competition, which is to be expected when cassava plants are spaced 1 m or less apart. Utilizing b' and the method proposed by Hatheway[3], the data in Table 9 was obtained which summarizes results in the first trial for total root weight. Note that when d and r are fixed, the areas required remain almost constant for $t > 10$. Utilizing this fact, the curves in Figure 6 were contructed to relate t, d and r. These curves are conservative approximations of the plot size when (t - l) x (r - l) is larger than 14.

In the second trial (Fig. 6 B), the CV between plots required was too large to be practical. The great variability observed in this trial can be explained because the type of plant utilized (variety M Mex 59) is not recommended for the CIAT-Palmira ecosystem. The variety is a profusely branching, vigorous type under high fertility conditions and good management, resulting in excessive vegetative development to the detriment of root production.

Stochastic Model for Cassava Hornworm Studies. During 1978 a model was constructed that attempts to adequately represent the behavior of the cassava

1 Federer, W.T. 1963. *Experimental design.* MacMillan Book Co. New York.

2 Smith, H.F. 1938. An empirical law describing heterogeneity in the yields of agricultural crops. *Journal of Agric. Sci* 28(1): 1-23.

3 Hatheway. *op. cit.*

Table 8.

Averages over replications for the coefficient of heterogeneity (b), according to Smith[1], (b'), according to Federer[2], and for the Coefficient of Variation (C.V.) between unitary plots.

Trial	Response variable	b	b'	C.V. (%)
1	Total weight of roots	1.463	1.257	42.34
	Weight of commercial roots	1.427	1.236	47.07
	Weight of aerial parts	0.947	0.990	34.25
2	Total weight of roots	0.754	0.889	108.13
	Weight of commercial roots	0.685	0.871	120.15
	Weight of aerial parts	1.354	1.221	72.77
3	Total weight of roots	1.169	1.141	72.80
	Weight of commercial roots	1.170	1.139	85.83
	Weight of aerial parts	1.166	1.170	47.01
4	Total weight of roots	1.061	1.071	54.73
	Weight of commercial roots	1.023	1.052	80.19
	Weight of aerial parts	1.086	1.010	37.85

1 Smith, H.F. 1938. An empirical law describing heterogeneity in the yields of agricultural crops. J. Agric. Sci. 28(1): 1-23.

2 Federer, W.T. 1963. *Experimental design.* MacMillan Book Co. New York.

Table 9.

Size of plot required as a function of the number of treatments to compare (t), number of replications to use (r) and the actual difference to be detected as significant (d, expressed as a percentage of the mean).[1] (Cassava Uniform Trial 1 for Total Root Weight data.)

		r						
d	t	2	3	4	5	6	7	8
	5	242.1	137.9	101.9	82.4	69.8	60.9	54.2
5%	10	185.7	122.3	94.3	77.8	66.7	58.7	52.5
	15	173.4	118.4	92.4	76.6	65.9	58.1	52.1
	20	168.0	116.6	91.4	76.0	65.5	57.8	51.8
	5	80.3	45.7	33.8	27.3	23.2	20.2	18.0
10%	10	61.6	40.6	31.3	25.8	22.1	19.5	17.4
	15	57.5	39.3	30.6	25.4	21.9	19.3	17.3
	20	55.8	38.7	30.3	25.2	21.7	19.2	17.2
	5	42.1	24.0	17.7	14.3	12.1	10.6	9.4
15%	10	32.3	21.3	16.4	13.5	11.6	10.2	9.1
	15	30.2	20.6	16.1	13.3	11.5	10.1	9.1
	20	29.2	20.3	15.9	13.2	11.4	10.1	9.0
	5	26.7	15.2	11.2	9.1	7.7	6.7	6.0
20%	10	20.4	13.5	10.4	8.6	7.3	6.5	5.8
	15	19.1	13.0	10.2	8.4	7.3	6.4	5.7
	20	18.5	12.8	10.1	8.4	7.2	6.4	5.7
	5	18.7	10.6	7.9	6.4	5.4	4.7	4.2
25%	10	14.3	9.4	7.3	6.0	5.2	4.5	4.1
	15	13.4	9.1	7.1	5.9	5.1	4.5	4.0
	20	13.0	9.0	7.1	5.9	5.1	4.5	4.0

1 $b = 1.257$, $C_1 = 42.34\%$, $= 5\%$, $P = 80\%$.

hornworm *(Erinnyis ello),* of considerable economic importance in cassava production, and two of its biological controls — the egg parasite *Trichogramma* spp. and the larval predator Polistes spp.

This model has as entries the foliar area of the cassava crop at a given moment, the temperature, and parameters representing certain biological characteristics of the insects such as life cycles, fecundity, sex ratios, fertility, predator/capture relationship, host parasite relationship, etc. Presently, work is being done in the experimental estimation of these parameters for later validation of the model. The stochastic model was chosen due to the characteristics of the problem, especially its great variability and complexity.

Using the model, it is hoped to represent quantitatively the biological knowledge now known for this natural system. This

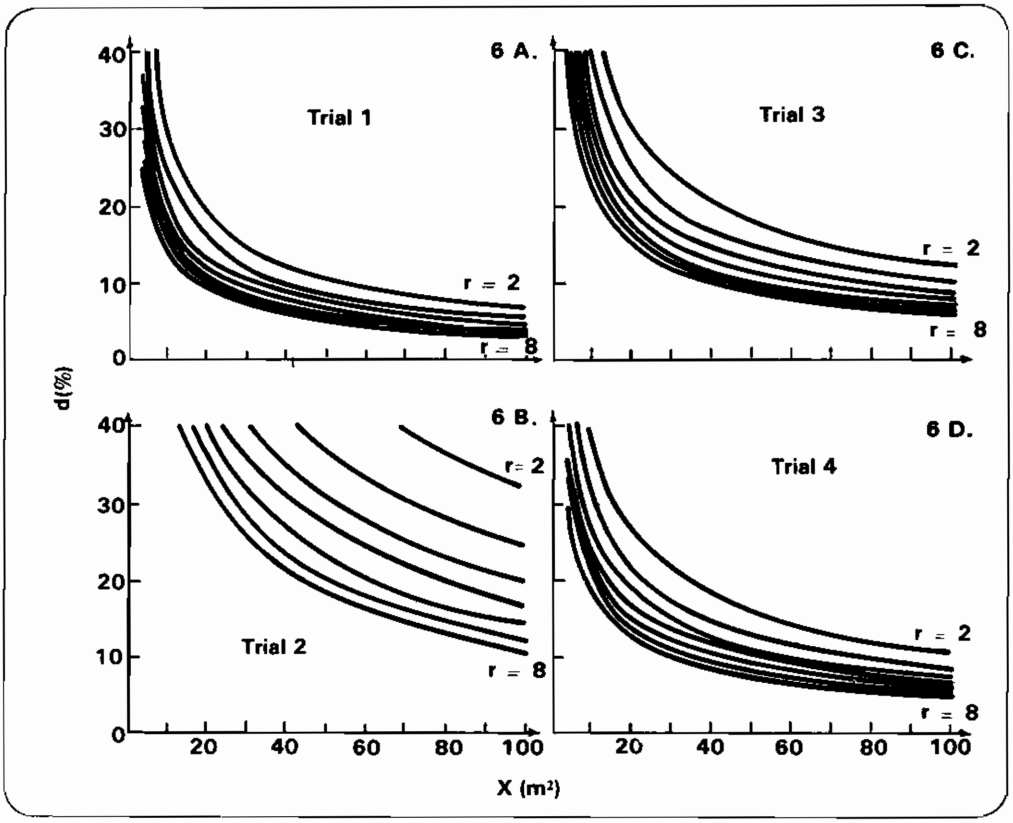


Figure 6. Approximate relationships between the plot size required (X), the number of replications to use (r) and the actual significant difference to be detected (d, as a percentage of the mean), for four Cassava Uniform Trials.

representation, together with some initial conditions (population, foliar area of cassava, etc.) and control policies (quantity and moment of liberating the *Trichogramma*, etc.) will permit the model to predict the tendencies of the hornworm, *Trichogramma* and *Polistes* populations, as well as effects on the foliar area of the cassava.

Other Projects. During 1978, the Varietal Improvement Section of the Cassava Program has reinitiated the task of completing and updating existing information about the cassava germplasm bank. The Computer Services Section is working in the design and analysis of a system similar to the one used in the Bean Program which will permit meeting the needs of the Cassava Program.

Also, in 1978, a series of experiments was processed on planting density evaluations utilizing a systematic trapezoidal design. Experiments of cassava/bush bean associations were also analyzed to evaluate weed control effectiveness in monoculture and associated conditions. Results suggested that the cassava/bush bean association is an effective cultural practice for controlling weeds. More detailed results for both of the experiments may be found in the Cultural Practices Section of the Cassava Program report.

Rice Program

International Nurseries. The Data Services Unit collaborated this year in planning and conducting statistical analyses of five international rice nurseries: the International Rice Yield Nursery for Latin America (VIRAL-76), with 15 experiments; the VIRAL for Early Varieties (VIRAL-T), with 17 experiments; the VIRAL for Very Early Varieties (VIRAL-P), with 18 experiments; the VIRAL for Upland Varieties (VIRAL-S), with 14 experiments; and the International Rice Nursery for Tolerance to Sheath Blight (VIAVAL-77), with 9 experiments.

For each nursery an analysis was done by location and a combined analysis done over all locations; also, adaptability of the varieties was measured using methodology proposed by Eberhart and Russell[1]. A program of stochastic dominance was utilized to analyze the combined data. In addition, a FORTRAN program was written that produces tables with the most important statistics for each location. More detailed information may be found in the Rice Program report.

TRAINING

During 1978 the Unit participated in the following production courses: two intensive cassava courses, two bean courses, two rice courses, one pastures and forages course, and one swine course. In these courses, conferences covering the following subjects were offered: general introduction to statistics and experimental design; designs most utilized in the respective disciplines and programs; and illustrative examples.

In October 1978, the Unit conducted a short course on the Statistical Analysis System (SAS) for scientific personnel and trainees of CIAT. In this course, general concepts of the SAS language and most used system procedures were introduced and illustrated through practical examples.

Also during the year consulting was provided to biometrics personnel of the Instituto Colombiano Agropecuario (ICA) in the manipulation of information, techniques of multivariate analysis and analysis of unbalanced designs using SAS.

1 Eberhart, S.A. and Russell, W.A. Stability parameters for comparing varieties. *Crop. Sci.* 36: 36-40.

Station Operations

The Station Operations Unit is responsible for providing machinery and irrigation services to support research and other crop production activities at the CIAT-Palmira and CIAT-Quilichao stations. In addition, the Unit constructs and maintains all the roadways, fencing and irrigation and drainage structures. Services provided during 1978 are discussed in the following sections.

CIAT-Palmira

Agricultural Machinery Utilization

A summary of the machinery services provided to programs is presented in Table 1. Machinery was utilized an additional 6986 hours for cropping and otherwise maintaining fields not assigned to research (3310 hours), maintenance of plots and borders of land assigned to research (1596 hours), maintenance of roadways (911 hours), development and improvement of new lots on the southern part of the farm (621 hours), and upkeep of canals and ditches (548 hours). In summary, of the total time machinery was utilized, 36% was for maintenance and improvement of the station, 33% was for producing crops maize, sorghum, beans, rice and cassava) on land not assigned to research programs and the remaining 31% was for research support.

Irrigation Services

Irrigation services were provided for a total of 1101 ha planted to crops other than rice. Another 22 ha were flood-irrigated for the Rice Program for a total of 200 days. Irrigation was provided to programs according to the following breakdown: Beans, 494 ha; Station Operations, 410 ha; Cassava, 110 ha; Beef, 56 ha; Special Studies, 13 ha; Maize 11 ha; and Maintenance, 7 ha.

In order to know more about the moisture status of soils on the station, Bouyoucos blocks were installed in several plots over the farm. After one year of observations, it appears that moisture in the CIAT soils drops from 100 to 60% over an average of eight days. This knowledge will permit irrigations in experimental crops to be made on a timely basis.

Irrigation and Drainage Systems

A total of 750 m of drainage ditches were constructed and 30 km of ditches including culverts under roads were cleaned of sediment. A total of 360 m of concrete irrigation canals were constructed to bring this system to a total of 1200 m of canals.

Table 1.

Machinery services provided for research support and other requests during 1978, CIAT-Palmira.

Program or Unit	Machinery utilization					
	No. of requests		Area prepared (ha)		Time (hours)	
Bean Program	172	(46.0)[1]	299.5	(59.6)	1505.9	(48.0)
Cassava Program	85	(22.7)	84.2	(16.8)	791.0	(25.2)
Beef Program	48	(12.8)	36.6	(7.3)	202.7	(6.5)
Rice Program	25	(6.7)	50.4	(10.0)	505.8	(16.1)
Special Studies Unit	20	(5.3)	15.4	(3.1)	30.8	(1.0)
Swine Unit	12	(3.2)	-	-	34.1	(1.1)
CIMMYT CIAT Maize Unit	8	(2.1)	16.2	(3.2)	65.3	(2.1)
Maintenance	4	(1.6)	-	-	-	-
Total	374	(100)	502.3	(100)	3135.6	(100)

1 Values in parentheses are percentages.

Other Improvements

A program was initiated to re-level many of the research lots on the station in order to provide more efficient gravity irrigation. The Unit also located steel posts on each of the research lots with the name of the lot and the survey coordinates contained on a plaque.

Seed Production

In collaboration with the Rice Program, 23,350 t of rice (CICA 8) were produced to provide basic supplies of this new variety. Under an agreement with the Instituto Colombiano Agropecuario (ICA) 37,850 t of IR 22, 17,500 t of CICA 7, and 42,650 t of CICA 8 were produced as basic seed increases.

Training

During 1978 five professionals (one each from Bolivia, Brazil, Colombia, the Dominican Republic and Honduras) were trained in management of research stations within the Unit.

CIAT-Quilichao

Table 2 shows a summary of labor inputs at the CIAT-Quilichao substation during 1978. In addition to the considerable amounts of time shown for maintenance of the station, several other improvements were completed during the year in an effort to upgrade this research site.

A deep well (170 m) was drilled to provide irrigation capacity for the station. Flow is at a rate of 94 liters per second. A large pump was installed and a storage pool constructed to receive and distribute the water. Also, a conduction system was built to distribute irrigation water and water for watering cattle.

Two existing buildings on the station were repaired and are being used as an operations office and a storage building. Other features constructed include a machinery shed, corrals, a metabolism unit for the Beef Program, a shed for housing a forage dryer and sanitary facilities for employees.

Table 2.

Labor utilization in support of research and other operations during 1978, at CIAT-Quilichao.

Program or Unit	Tractor (hours)		Irrigation (hours)		Man-hours	
Beef Program	235	(43.0)[1]	1580	(67.0)	987	32.5)
Bean Program	13	(2.4)	243	(10.3)	90	(3.0)
Cassava Program	42	(7.6)	274	(11.6)	208	(7.0)
Phosphorus Project	-	-	243	(10.3)	64	(2.0)
Special Studies Unit	-	-	10	(0.4)	1	-
CIMMYT/CIAT Maize Unit	3	-	7	(0.2)	26	(1.0)
Station Maintenance	256	(46.5)	-	-	1663	(55.0)
Total	549	(100)	2357	(100)	3039	(100)

1 Values in parentheses are percentages.

Carimagua

The responsibility for providing station operations services at the Carimagua station is assigned to the office of the Executive Administrator at CIAT. Given the organizational structure at Carimagua, the station operations superintendent administers the human, physical and financial resources of the station in basic support of the research work carried out by scientists from both CIAT and the Instituto Colombiano Agropecuario (ICA).

Human Resources

During the year, the number of support staff increased 37% to reach a total of 130 employees providing 17,651 man-days of work. Nevertheless, an additional 14,000 man-hours of overtime was needed between January and October.

Physical Improvements

A considerable amount of time and effort was placed on repairing and maintaining roads on the station. A total of 3570 loads of gravel was excavated and hauled for road construction and repair. This amount equalled more than 13,000 m^2 of material placed on 43 km of roads in addition to the construction of another 16 km. Twenty-four new drains were also installed.

A total of 38.1 km of new fences were built and another 51.5 km repaired. Also, in animal paddocks, seven new watering tanks were built and three repaired. A large water storage facility was constructed in the pasture utilization area of the farm and 2575 m of polyethylene tubing installed to distribute water to animals. Ten natural watering holes were excavated or modified, in efforts to prevent animal losses from cattle falling into these areas and being lost.

Two new corrals were also constructed and various salt boxes and feeders built and installed.

Machinery

Four new tractors were added to the fleet during the year to bring total capacity to 607 HP. Utilization was 1475 hours/machine/year over 1978 including three months of the dry season when little field work is done and days lost to rains during some six nonths. A total of 10,325 hours were worked with tractors.

Other Services

Among other services for which the station superintendent is responsible is that of health care, not only to Carimagua personnel, but also to people of the nearby region. Dental services were provided to a large number of persons during a campaign. Work was also done to guarantee purity of the water on the station by eliminating some faults in the treatment system.

A large vegetable garden was established to help the station become self-sufficient in production of these foods.

In cooperation with the Library from CIAT-Palmira, the local library was enlarged and the number of loans increased, both of technical and recreational materials.

A small school was organized for children living on the station. It is planned to offer some simple adult education during the next year.

Climatology

CIAT's meterological service completed its first full year of operation, with funding by the Special Studies Unit and operational maintenance by the Station Operations Unit. Primary activities in 1978 were: (1) to establish a complete meterological station at CIAT-Palmira; (2) to transfer the Corporación Autónoma Regional del Cauca (CVC) meteorological station from nearby Hacienda San Julián to the CIAT-Quilichao substation; (3) to obtain agreements with the CVC and the Instituto de Hidrografía, Metereología y Adecuación de Tierras (HIMAT), whereby CIAT personnel would take responsibility for maintaining instruments and analyzing data from the stations at CIAT-Quilichao and Carimagua, respectively; (4) to create a meterological data bank with complete long-term daily data from ICA-Palmira, CIAT-Quilichao and Carimagua; and (5) to modify and test a standard computer simulation model to estimate the transpiration and soil-water balance of crops.

General Observations

The 1977 CIAT Annual Report may be consulted for comprehensive long-term mean monthly precipitation, temperature, potential evaporation, relative humidity and hours of sunshine for the principal CIAT research sites. General meteorological observations for the November 1977 to October 1978 reporting year follow.

CIAT-Palmira

Mean monthly temperatures were near normal; however mean daily variation was 1.2°C less than normal, reflecting a reduction in the mean maximum and an increase in the mean minimum temperatures.

Except for April and May 1978, the period from November 1977 to October 1978 was relatively dry. This was primarily due to below-normal precipitation since potential evaporation was near normal (Fig. 1).

CIAT-Quilichao

Although the mean annual temperature from November 1977 to October 1978 was normal, mean monthly temperatures were below normal from November 1977 to April 1978 and slightly above normal from May to October 1978. Mean maximum temperatures were, with the exception of November 1977 and July 1978, slightly higher than normal during the warm months and slightly below normal during the cool months. Mean minimum

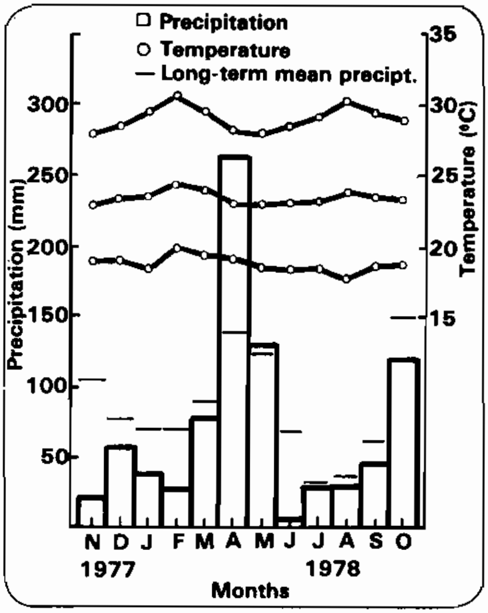


Figure 1. Monthly totals and long-term means of precipitation and monthly maximum, minimum and mean temperatures at CIAT-Palmira. (Long-term data from ICA-Palmira; 1977-1978 data from CIAT-Palmira.)

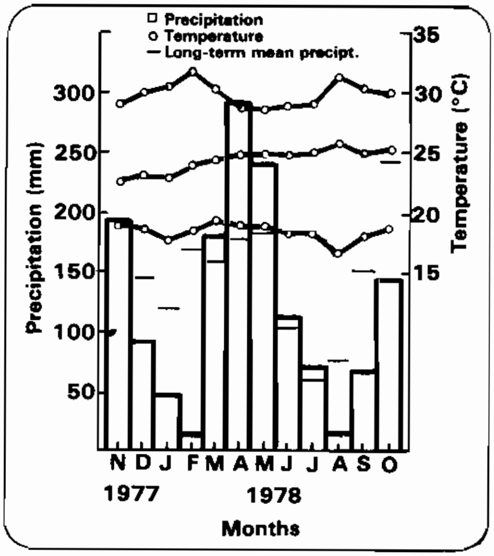


Figure 2. Monthly totals and long-term means of precipitation and monthly maximum, minimum and mean temperatures in CIAT-Quilichao. (Long-term and November 1977-March 1978 data from Hacienda San Julian; April - October 1978 data from CIAT-Quilichao.)

temperatures were very close to long-term means (Fig. 2).

In terms of the difference between potential evaporation and precipitation, the period from November 1977 to October 1978 was the driest November to October period of the past five years. This was due both to low rainfall and high potential evaporation. The two periods in which deficits occurred were from December 1977 to March 1978 (-264 mm) and from June to October 1978 (-370 mm).

Carimagua

The monthly maximum, minimum and mean temperatures were similar to long-term averages (Fig. 3).

With the exception of March, April and May 1978, monthly precipitation was slightly below normal.

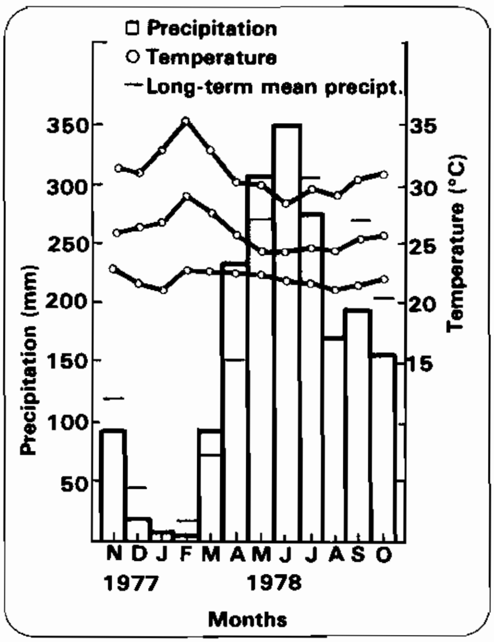


Figure 3. Monthly totals and long-term means of precipitation and monthly maximum, minimum and mean temperatures, at Carimagua.

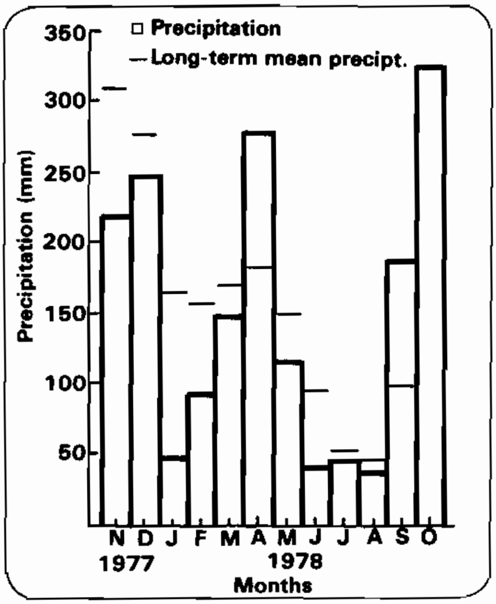


Figure 4. Monthly totals for the period November 1977 to October 1978 and long-term means of precipitation, at Popayan.

Popayan

Except for April, September and October 1978, precipitation was below normal. This was especially evident in January 1978 when rainfall was less than 30% of normal and was the driest January in 25 years (Fig. 4).

Precipitation

Figure 5 shows the long-term tendency for precipitation in Palmira. From 1930 to 1977 both rainfall and rainfall frequency have tended to increase. When five-year moving averages are calculated, an approximate 11-year rainfall cycle is evident. Although data from many more years would be needed to confirm such a cycle, it is probable that the next three or four years will have below average rainfall. During the past 47 years the 12 consecutive months

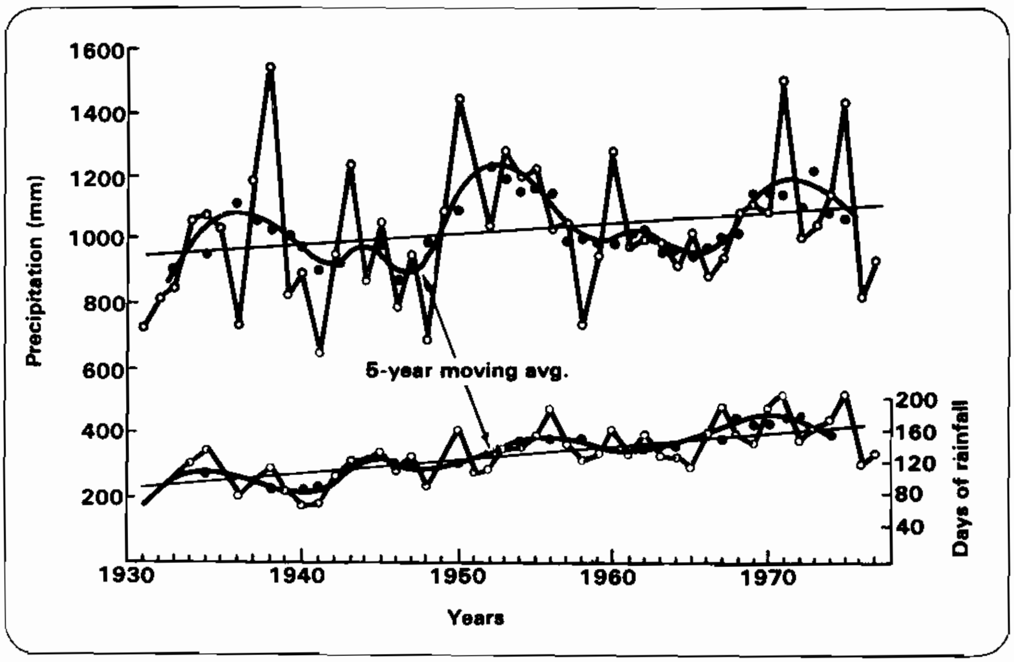


Figure 5. Actual and five-year moving averages for annual total precipitation and days of rainfall from 1930 to 1977, at CIAT-Palmira.

with the highest precipitation were September 1937 through August 1938 (1645 mm). May 1958 through April 1959 were the driest 12 consecutive months (574 mm).

Table 1 gives the monthly rainfall at CIAT-Quilichao, CIAT-Palmira, Popayan and Carimagua as percentages of the long-term means and the 1977-1978 totals. Rainfall from November 1977 through October 1978 was approximately 20% below average in CIAT-Quilichao and CIAT-Palmira and about 10% below normal in Carimagua and Popayan.

During the last two years there has been considerable discussion about the existence of a significant dry season in CIAT-Quilichao. Long-term data from Santander de Quilichao (25 years) and Hacienda San Julian (11 years) indicate that the January-February dry season normally observed at CIAT-Palmira does not occur in the region of Santander de Quilichao. Nevertheless, analysis of the last four years (1975-1978) shows that the mean rainfall in January and February has been below average at Popayan, CIAT-Quilichao and CIAT-Palmira (Table 2). During the last two years the rainfall during January and February at these three stations has without exception been below normal. Despite the general lack of precipitation in 1977-1978, there is currently no reason to believe that the January-

Table 1.

Monthly 1977-1978 rainfall as a percentage of long-term averages at four CIAT research stations.

	Station							
	CIAT-Quilichao		Palmira		Carimagua		Popayan	
Month	long-term	Nov 1977 Oct 1978	long-term	Nov 1977-Oct 1978	long-term	Nov 1977-Oct 1978	long-term	Nov 1977-Oct 1978
Nov. 1977	12.49	10.70	10.25	2.15	5.70	4.42	15.67	11.10
Dec.	8.04	5.05	7.62	5.76	2.07	.85	13.96	12.55
Jan. 1978	6.60	2.72	6.93	3.81	.24	.28	8.39	2.28
Feb.	9.37	.83	6.93	2.64	.80	.24	7.96	4.74
Mar.	8.82	9.93	8.79	7.71	3.44	4.42	8.64	7.51
Apr.	9.87	16.14	13.57	25.88	7.20	10.92	9.32	14.09
May	10.15	13.36	12.11	12.70	12.81	14.50	7.65	5.94
June	5.16	6.21	6.74	.58	19.44	16.38	4.84	2.01
July	3.32	3.99	2.73	2.73	14.41	12.99	2.59	2.30
Aug.	4.27	.89	3.61	2.93	11.49	8.05	2.30	1.86
Sept.	8.43	3.83	6.06	4.49	12.76	9.13	4.99	9.46
Oct.	13.48	7.93	14.66	11.72	9.64	7.39	13.69	16.46
Percent	100.00	81.58	100.00	83.10	100.00	89.57	100.000	90.30
Total rainfall (mm)	1803	1471	1024	851	1967	1777	2124	1903

Table 2.

Mean rainfall in 1975-1978 and long-term averages during January and February in stations with bimodal distribution.

	Rainfall (mm)					
	January			February		
Site	1975-1978	1977-1978	long-term	1975-1978	1977-1978	long-term
CIAT-Palmira	42	46	71	61	20	71
CIAT-Quilichao	69	64	119	142	57	169
Popayan	101	71	165	122	125	157

February dry season is more than an occasional phenomenon in the area of Santander de Quilichao.

Water Balance Model

In conjuntion with the Grass Agronomy Section of the Beef Program, a computer simulation model for estimating profile moisture content on a daily basis was obtained and adapted to tropical conditions. The good agreement between simulated and actual values makes feasible irrigation scheduling and the simulation of soil-water content and transpiration in previously executed experiments.

International Cooperation

International relations and technology transfer functions, comprising the area of International Cooperation at CIAT continued to support the Center's research objectives of increasing physical and economic productivity in beans, beef, cassava, maize, rice and swine. These activities have been directed to establishing closer links with national programs and other international institutions, to secure support and cooperation for facilitating CIAT's mission.

By coordinating the use of the resource components below, all under the administration of the Associate Director General for International Cooperation (ADG/IC), the Center is capable of working collaboratively with national programs in their own countries to help them solve technological problems impeding expansion of food production. Units and other personnel resources within the International Cooperation sector are the following: (1) Training and Conferences; (2) Documentation Services Unit; (3) Communication Support Unit; (4) Seed Unit; (5) CIMMYT/CIAT Regional Andean Maize Unit; and (6) outreach specialists of the commodity programs and outposted regional or bilateral outreach specialists.

International Cooperation in 1978

Activities of the first five groups above are discussed in their respective section reports which follow this introduction. In addition, the annual reports of the various commodity programs contain discussions of their respective work in this area. Other International Cooperation activities during 1978 included the following accomplishments.

Outreach Specialists

Under funding from the United Nations Development Programme (UNDP) two senior staff members were located in Costa Rica (one in rice and one in beans) and one posted to Brazil (in tropical forages) during 1978. Those in Costa Rica are assigned to serve the Central American and Caribbean area, and the latter one, Brazil.

By the end of the year, the following numbers of staff were outposted:

Brazil: one in cassava entomology; and three in tropical pastures and animal management.

Costa Rica: one in rice and one in beans.

Guatemala: two in beans and two that are assigned to the cooperative Instituto de Ciencias y Tecnología Agrícola (ICTA)/CIAT project.

Philippines: one in cassava.

Venezuela: one for the diagnostic study of beef cattle enterprises.

Agreements

CIAT signed agreements for cooperation with the following countries and institutions during 1978. In Venezuela, a general agreement was made with the national government while another agreement of collaborative support action in Venezuela was signed with the Instituto Interamericano de Ciencias Agrícolas (IICA). Both general and specific agreements for collaborative outrearch action in seed technology (beans and maize) were signed with the Centro Nacional de Tecnologia Agropecuaria (CENTA), in El Salvador.

In Colombia, new special agreements were made with ICA for work at the Caribia Station in cassava, on basic seed production of rice, on collaboration in the ICA/CIAT rice program, and on improving pre- and post-quarantine systems of disease and pest prevention for CIAT-produced or exported genetic material.

Special outreach projects on models for cassava and bean technology validation on farmers' fields were developed and conducted by ICA and CIAT in Colombia.

Country Relations

Excellent collaborative links continued with many countries in Latin America.

In all of the Central American, several of the Caribbean countries, and most of South America, CIAT administrators and research and outreach scientists have made numerous visits and contacts, exchanging information, pinpointing opportunities for collaborative work, identifying trainees, and in general, developing a series of actions which have lead to a significant improvement in outreach activities of CIAT.

Exploratory Studies

In preparation for added outreach activities, initial contacts made in 1978 by the Director General and the ADG/IC in Kenya, concerning an East African Bean Outreach Program will be complemented in 1979 by another study mission in several countries in East Africa, carried on most likely with participation of a Dutch Government representative and bean scientists. A similar study will be conducted in English-speaking countries of the Caribbean with a UNDP representative, also in 1979.

Training and Conferences

CIAT has reached a stage in its evolution when an increasing number of technological components are becoming available for transfer to national instituciones. Germplasm selections and new hybrids, as well as associated technology from the Center's commodity programs are entering validation trials at many locations in client countries.

Training activities help satisfy three important objectives which must be met if technology transfer is to be successful. Training first helps accomplish inter-institutional transfer of technology. Secondly, it helps to link research and extension activities in target countries. Finally, training strengthens national institutions for acting cooperatively as well as independently in matters of adapting and validating CIAT-generated technology. In all three dimensions, training offers a product—capable professionals— as well as a means to an end— the transfer of CIAT's technology, which are both parallel and intimately related to the technology itself.

CIAT's commodity programs and other units helped to meet the growing demand for trained professionals by selecting and accepting 314 persons into the various types of training programs during 1978. This total was a significant increase over the 195 enrolled during 1977 (Fig. 1). Participants came from 22 countries in the Americas, 5 Asian countries and 2 European countries.

Training Philosophy

Training for Research Networks

CIAT commodity programs are giving increasing attention to consolidating technology validation networks, regionally as well as nationally. In the cases of tropical forages for acid, infertile soil regions, beans and rice in Central America, cassava in Latin America and Asia, and swine in Latin America, these networks are being coordinated by regional outreach specialists. Through these networks, the purpose of the training and the task of followup are integrated with cooperative research and validation trials. Research networks are now closely monitored in each program in a process of transfer of technology materials, information and design and of feedback of information on results.

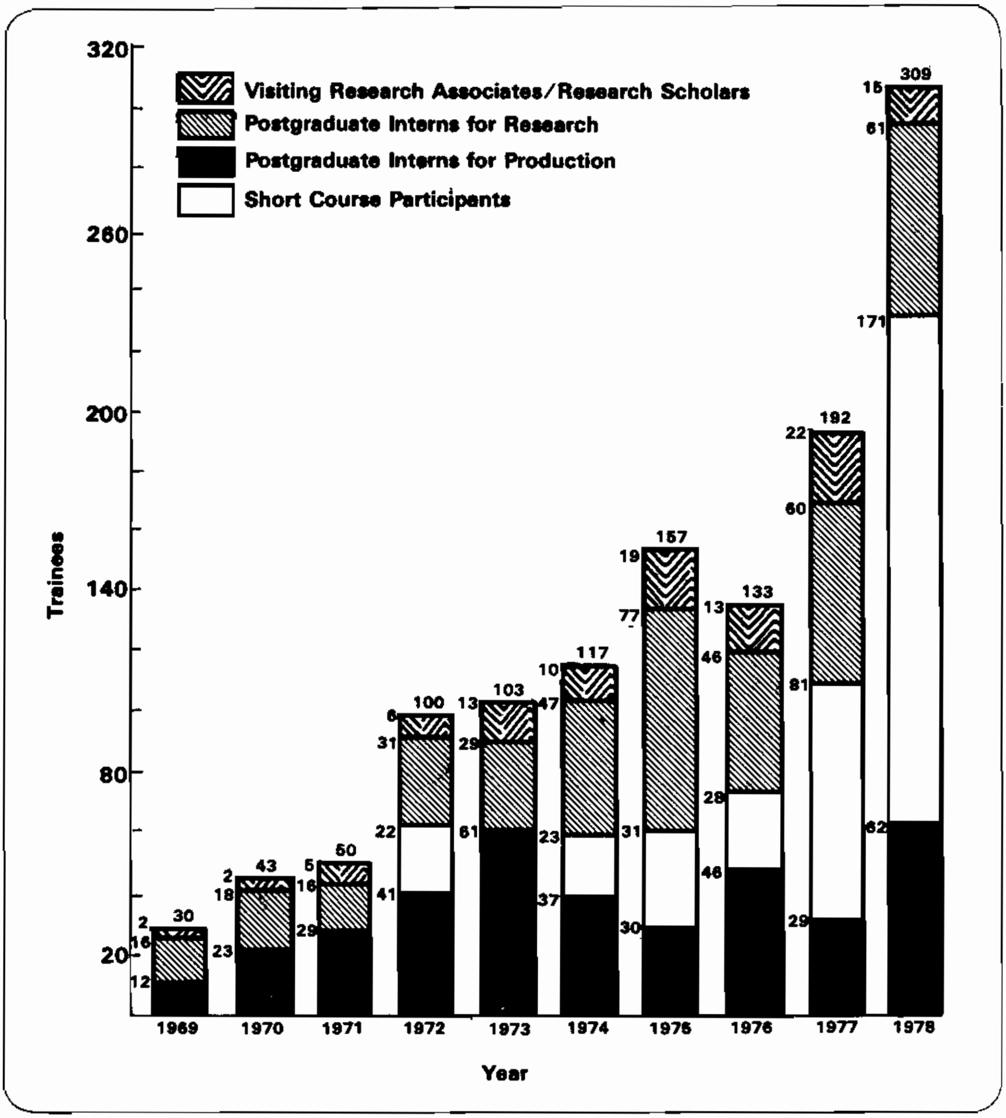


Figure 1. Number of CIAT training participants by training categories, 1969-1978.

Need to Achieve Critical Mass

Before actions can be successfully applied and quality results obtained in adaptative and validative research networks, a minimum number of professionals are required for each country. It is preferable that they are organized as a team. For this reason, CIAT's programs are giving preference to creating critical masses by offering training primarily through intensive 4-5 week courses. These short courses are multidisciplinary, covering the entire production spectrum for a commodity. They are primarily intended for research scientists having substantial experience.

During 1978, 117 of the 314 professionals trained at CIAT participated in five of these courses: two in cassava, two in beans and one in seed technology. Twenty-two percent of the training time, 188 man-months, were in this category.

Demand for Short-term Training

While longer-term training is desirable for equipping scientists from national programs with solid knowledge, effective research skills and efficient working habits, frequently national programs can not spare the time of their few scientists for more than one or two months, or the scientist does not wish to leave his job and family for a longer period. These factors create a strong demand for short, intensive courses. CIAT staff recognizes that short-term training has disadvantages for younger, inexperienced professionals and has serious limitations for developing research skills and work habits, as the short time invested does not facilitate learning by doing.

Importance of Medium- and Longer-term Training

While more than half the professionals trained in 1978 participated in short courses, still 143 persons received medium-term (4-6 months) or longer training. These trainees represented 658 man-months or 78% of the total time invested in training by the Center. The categories of Postgraduate Interns, MSA and PhD thesis scholars, and other post-master Visiting Research Associates still constitute the core of CIAT's training endeavors and are expected to have the most lasting and deep effects on national programs over the long run.

Appropriate Balance in Training Duration

An adequate balance between the various lengths of training is constantly sought, with a major determining factor being the specific needs of each country, in each commodity.

All training is conducted within each commodity program or other unit and more detailed information is given in those respective sections. Table 1 shows the numbers of professionals enrolled in training at CIAT during 1978, according to commodities, training categories and man-months.

Disciplinary Training versus Production Training

Some of the needs of national programs require specialized training along a given discipline. Individualized, in-service training categories serve this purpose well. Other needs of both the national programs as well as CIAT, mostly regarding technology validation and transfer, are best served by a multidisciplinary approach where all relevant disciplines are focused on the commodity from a research standpoint. This approach is especially suitable for training for validative testing as a first step in transferring CIAT's technology. This latter approach is the one applied to the so-called production courses. Figure 2 shows the schedule of these courses in 1978. Table 2 shows the distribution by programs and disciplines and Table 3 shows the relative attention to countries assisted. Table 4 lists all persons participating in training at CIAT during 1978.

Assistance to Within-country Training

CIAT continued to provide assistance to within-country training in interested countries. A three-month course on rice was

Table 1.

Number of professionals trained at CIAT in 1978 by commodity program.

Program		Category of Training							
		Posdoctoral Fellows	Visiting Research Associates	Research Scholars	Postgraduate Research Interns	Postgraduate Production Interns	Special Trainees	Short Course Participants	Total
Beans		2 (10)[1]	2 (12)	4 (27)	28 (97)	-	2 (6)	59 (59)	97 (211)
Cassava		2 (7)	-	-	8 (59)	-	2 (13)	68 (70)	80 (149)
Rice		-	1 (4)	-	1 (4)	21 (85)	6 (16)	-	29 (109)
Beef		-	2 (5)	4 (35)	3 (19)	20 (101)	1 (6)	-	30 (166)
Swine		-	-	-	1 (1)	21 (81)	-	-	22 (82)
Others									
Biometrics		1 (8)	1 (5)	-	-	-	-	-	2 (13)
Seed Production		-	-	-	-	-	-	29 (29)	29 (29)
Soils		-	-	1 (12)	(4)	-	-	-	3 (16)
Library and Information Services		-	-	-	-	-	1 (7)	15 (30)	16 (27)
Station Operations Management		-	-	-	5 (29)	-	-	-	5 (29)
Laboratory Management		-	-	-	1 (5)	-	-	-	1 (5)
TOTAL	1978	5 (25)	6 (26)	9 (74)	49 (218)	52 (267)	12 (48)	171 (188)	314 (846)
	1977	3	15	7	38	29	24	81	195

1 Numbers in parenthesis are man-months of training.

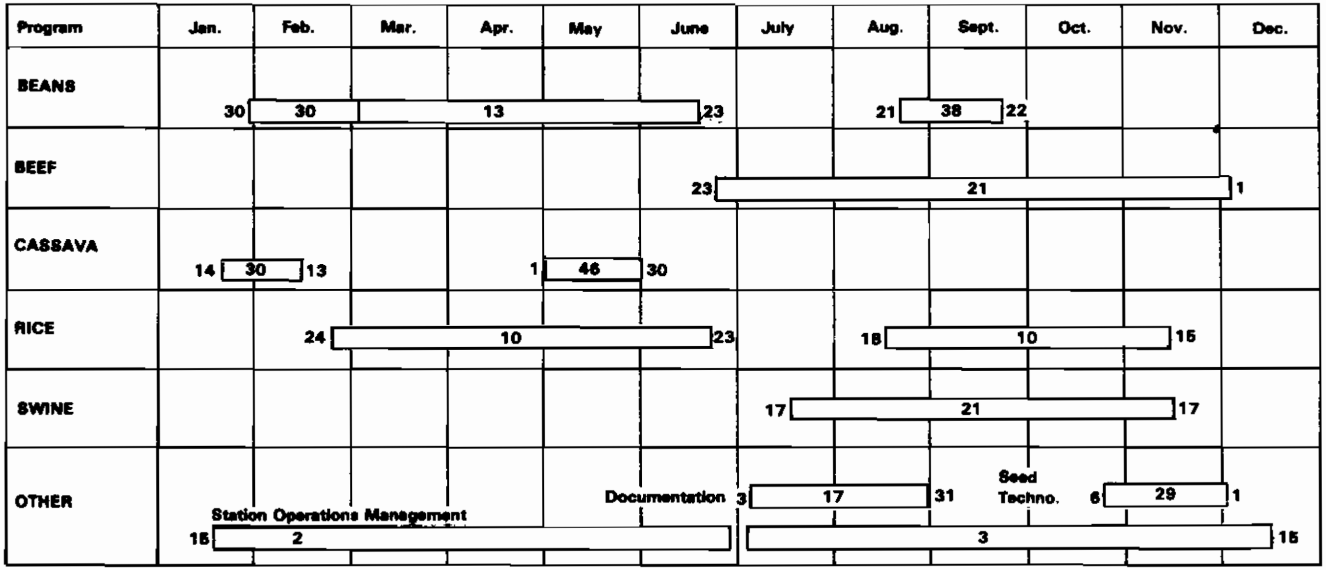


Figure 2. Schematic design of CIAT postgraduate training program during 1978. (Numbers in blocks are participants in the classes.)

Professionals trained at CIAT in 1978 by commodity/discipline of specialization and category of training.

Commodity/discipline of specialization	Category of training								
	Post-doctoral fellows	Visiting research associates	Research scholars	Postgraduate research interns	Postgraduate production	Special trainees	Short course participants	Sub-program totals	Total commodity programs
Beans/agronomy	-	1 (8)[1]	-	10 (39)	-	-	-	11 (47)	
biometrics	-	-	-	1 (2)	-	-	-	1 (2)	
entomology	-	-	-	3 (15)	-	1 (5)	-	4 (20)	
plant breeding	1 (8)	-	1 (5)	5 (12)	-	-	-	7 (25)	
plant pathology	-	-	3 (22)	5 (12)		1 (1)	-	9 (35)	
plant physiology	-	-	-	1 (4)	-	-	-	1 (4)	
crop association	-	-	-	2 (9)	-	-	-	2 (9)	
production	1 (2)	1 (4)	-	-	-	-	59 (59)	61 (65)	
germplasm	-	-	-	1 (4)		-	-	1 (4)	
Beans Total	2 (10)	2 (12)	4 (27)	28 (97)	-	2 (6)	59 (59)		97 (2'11)
Cassava/agronomy	-	-	-	2 (14)	-	-	-	2 (14)	
biometrics	-	-	-	-	-	1 (12)	-	1 (12)	
economics	1 (6)	-	-	-	-	-	-	1 (6)	
plant breedings	-	-	-	1 (9)	-	-	-	1 (9)	
plant pathology	-	-	-	2 (7)	-	-	-	2 (7)	
plant physiology	1 (1)	-	-	1 (10)	-	-	-	2 (11)	
soils	-	-	-	1 (9)	-	1 (1)	-	2 (10)	
production	-	-	-	1 (10)	-	-	68 (70)	69 (80)	
Cassava Total	2 (7)	-	-	8 (59)	-	2 (13)	68 (70)		80 (149)
Rice/plant breeding	-	-	-	-	1 (4)	2 (2)	-	3 (6)	
production	-	1 (4)	-	-	20 (81)	1 (2)	-	22 (87)	
communication	-	-	-	1 (4)	-	1 (1)	-	2 (5)	
rural sociology	-	-	-	-	-	2 (11)	-	2 (11)	
Rice Total	-	1 (4)	-	1 (4)	21 (85)	6 (16)	-		29 (109)

1 Figures in parenthesis are man-months of training.

Table 2. (continued)

Commodity/discipline of specialization	Category of training							Sub-program totals	Total commodity programs
	Post-doctoral fellows	Visiting research associates	Research scholars	Postgraduate research interns	Postgraduate production	Special trainees	Short course participants		
Beef/biometrics	-	-	-	1 (6)	-	-	-	1 (6)	
economics	-	-	1 (4)	-	-	-	-	1 (4)	
soil microbiology	-	1 (2)	-	1 (3)	-	-	-	2 (5)	
production	-	1 (3)	1 (12)	-	11 (54)	-	-	13 (69)	
animal health	-	-	2 (19)	-	-	-	-	2 (19)	
pastures & forage breeding	-	-	-	1 (10)	9 (47)	-	-	10 (57)	
pastures & forage utilization	-	-	-	-	-	1 (6)	-	1 (6)	
Beef Total	-	2 (5)	4 (35)	3 (19)	20 (101)	1 (6)	-		30 (166)
Swine/production	-	-	-	-	21 (81)	-	-	21 (81)	
animal nutrition	-	-	-	1 (1)	-	-	-	1 (1)	
Swine Total	-	-	-	1 (1)	21 (81)	-	-		22 (82)
Other units or disciplines:									
biometrics	1 (8)	1 (5)	-	-	-	-	-	2 (13	
seed production	-	-	-	-	-	-	29 (29)	29 (29)	
soils	-	-	1 (12)	2 (4)	-	-	-	3 (16)	
library and information services	-	-	-	-	-	1 (7)	15 (30)	16 (27)	
station operations management	-	-	-	5 (29)	-	-	-	5 (29)	
laboratory management	-	-	-	1 (5)	-	-	-	1 (5)	
Total other units or disciplines	1 (8)	1 (5)	1 (12)	8 (38)	-	1 (7)	44 (59)		56 (129)
	5 (25)	6 (26)	9 (74)	49 (218)	62 (267)	12 (48)	171 (188)		314 (846)

Table 3.

Professionals trained at CIAT in 1978 classified by country of origin and commodity in which trained.

Country	Commodity or program						Library and Information Services	Station Operations Management	Others	Total
	Beans	Cassava	Rice	Beef	Swine	Seed production				
Latin America and the Caribbean										
Argentina	1	-	1	1	1	-	1	-	-	5
Belize	1	-	2	-	-	-	1	-	-	4
Bolivia	2	1	1	1	3	4	1	1	1	15
Brazil	20	22	1	9	1	-	1	1	-	55
Chile	5	-	1	-	-	2	1	-	-	9
Colombia	12	7	1	8	4	7	2	1	1	43
Costa Rica	6	4	2	-	-	1	-	-	-	13
Cuba	2	2	2	1	-	1	1	-	-	9
Dominican Rep.	4	1	-	1	-	2	1	1	-	10
Ecuador	5	3	4	-	2	4	-	-	2	20
El Salvador	2	1	-	-	-	-	2	-	-	5
Guatemala	5	-	-	-	1	3	2	-	-	11
Guyana	-	2	-	-	-	-	-	-	-	2
Honduras	9	-	1	-	-	1	-	1	-	12
Mexico	2	3	3	-	1	-	-	-	-	9
Nicaragua	2	1	-	2	-	-	1	-	-	6
Panama	4	1	-	2	-	3	1	-	-	11
Paraguay	-	-	-	-	3	1	-	-	-	4
Peru	6	1	6	3	3	-	1	-	1	21
Trinidad & Tobago	-	1	-	-	-	-	-	-	-	1
Venezuela	4	3	1	1	2	-	-	-	-	11

(continued)

Table 3. (continued)

Country	Commodity or program									
	Beans	Cassava	Rice	Beef	Swine	Seed production	Library and Information Services	Station Operations Management	Others	Total
Other countries										
England	2	-	-	-	-	-	-	-	-	2
India	-	5	-	-	-	-	-	-	-	5
Indonesia	-	5	-	-	-	-	-	-	-	5
Malaysia	-	4	-	-	-	-	-	-	-	4
Netherlands	1	-	2	-	-	-	-	-	-	3
Phillipines	-	4	-	-	-	-	-	-	-	4
Rep. of Seychelles	-	1	-	-	-	-	-	-	-	1
South Africa	-	1	-	-	-	-	-	-	-	1
Thailand	-	6	-	-	1	-	-	-	-	7
USA	2	1		-	-	-	-	-	-	3
West Germany	-	-	1	1	-	-	-	-	1	3
Total	97	80	29	30	22	29	16	5	6	314

conducted in Panama, in cooperation with the Ministerio de Desarrollo Agropecuario (MIDA), and a two-month course in rice was provided in Ecuador, in cooperation with the Instituto Nacional de In vestigaciones Agropecuarias (INIAP). In Guatemala, CIAT has been involved in a six-course cycle for rice and beans which the Instituto de Ciencias y Tecnología (ICTA) has operated since 1976. This cycle was concluded in mid-1978, and ICTA will continue to operate the training program.

Financing of Training

Almost one-half (151) of the professionals trained at CIAT last year were funded from the Center's core budget, with the remainder sponsored by public and private donors of which the United Nations Development Programme (UNDP) was the major funding source. Table 5 shows the donors and number of training participants in each category financed by each major source.

CONFERENCES

Several major conferences, seminars and workshops were held during 1978 which directly or closely supported various CIAT program strategies. Conferences, dates and attendances are given in Table 6.

In January, the Center hosted a Workshop on International Bean Breeding Trials in Latin America. This conference had 43 participants from 21 countries.

In April, the Beef Program co-sponored a Seminar on Pasture Production in Acid Soils of the Tropics, with an attendance of 185 persons. Immediately before this seminar, a Workshop on the Collection, Preservation, Distribution and Characterization of Germplasm Resources of Tropical Forages was held. This meeting, held in collaboration with the University of Florida (U.S.A.) and the United States Agency for International Development (USAID), had 115 participants.

Twenty-one specialists attended the International Development Research Centre (IDRC)/CIAT Workshop on Cassava Harvesting and Processing, also in April.

In May, coinciding with the annual meeting of the CIAT Board of Trustees, the Center sponsored its annual Seminar on Advances in Research. Directors of research from Argentina, Colombia, Ecuador, Guatemala, Peru, Trinidad and Venezuela attended, as did representatives of the Canadian International Development Association (CIDA), the Swiss Government, the Inter-American Development Bank (BID), the Instituto Interamericano de Ciencias Agrícolas (IICA), the Kellogg Foundation and USAID.

In November, an IICA/CIAT workshop was convened to review and evaluate the Latin American Agricultural Economics Documentation Center (CEDEAL), operated by CIAT's Documentation Services Unit. Twenty-three economists, communicators, documentalists and agricultural scientists from eight Latin American countries, the United Kingdom and Canada attended.

During the year, CIAT staff presented 26 internal seminars. The Conferences Office also provided considerable logistical support to training courses, the Public Information Office and commodity programs.

A total of 22 events were also held in the Conference facilities by organizations outside of CIAT (Table 6).

Table 4.

Professionals trained at CIAT during 1978.

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Visiting Research Associates				
Arcia, Gustavo	Nicaragua	Beans/economics	2	P
Beebe, Esthepen	USA	Beans/production	5	C
Bernd, Anette	West Germany	Rice/plant breeding	5	C
Byrne, David	USA	Cassava/entomology	12	P
Clark, Anne	USA	Beans/physiology	12	C
Debouck, Daniel	Belgium	Beans/plant breeding	12	P
Delgadillo, Guido	Canada	Beef/pastures & forages breed.	12	P
Díaz, Jorge Luis	Nicaragua	Beef/pastures & forages util.	12	P
Elango, Fritz	Cameroon	Cassava/plant pathology	8	P
Galwey, Nicholas	Unit. Kingdom	Beans/agronomy	9	C
García, Aurora Susana	Argentina	Beans/plant breeding	12	P
Gepts, Paul	Belgium	Beans/germplasm	4	P
Jansen, Hendrik	Holland	Beef/pastures & forages breed.	12	P
Jenrich, Herbert	West Germany	Beef/production	4	C
Laberry, Rafael	Peru	Cassava/plant pathology	12	P
Levine, Joel Martin	USA	Beef/economics	9	P
Lohr, Bernhard	West Germany	Cassava/entomology	7	P
Lyman, Judith Mapes	USA	Beans/plant breeding	12	P
Plessow, Christoph	West Germany	Others/biometrics	5	C
Roldán, Diego	Colombia	Rice/economics	6	P
Sánchez, Luis Fernando	Argentina	Beef/soil science	12	P
Scholles, Dercio	Brazil	Beef/soil microbiology	2	C
Strobosch, Peter Jan	Holland	Cassava/rural sociology	5	P
Veltkamp, Hendrik Jan	Holland	Cassava/plant physiology	4	P
White, Jeffrey	USA	Beans/plant physiology	12	P
Research Scholars				
Alvarez, Germán	Colombia	Beans/plant pathology	12	P
Calvo, Favio Alberto	Colombia	Others/soil science	12	C
Cárdenas, Moisés	Mexico	Beans/plant pathology	1	C
Charry, Alvaro	Colombia	Beef/economics	5	C
De Cantillo, Stella	Colombia	Cassava/plant physiology	12	P
Galindo, José	Colombia	Beans/plant physiology	9	C
García, Edmundo	Colombia	Beans/plant breeding	5	C
García, Omar	Colombia	Beef/animal health	7	C
Gómez, William Felipe	Colombia	Beef/production	12	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Madruga, Claudio R.	Brazil	Beef/animal health	9	P
Moncada, Hemerson	Colombia	Beef/animal health	12	C
Peña, Jorge	Colombia	Cassava/entomology	12	P
Restrepo, Luis Fernando	Colombia	Beans/economics	12	P
Rolando, Carlos Xavier	Ecuador	Beef/pastures & forages util.	3	P
Stabile, Martin Francisco	Argentina	Beans/economics	7	P
Postgraduate Research Interns				
Abarca, Edgar	Costa Rica	Beans/agronomy	3	C
Acuña, José William	Ecuador	Beans/plant breeding	3	P
Aeschlimann, Jorge E.	Chile	Beans/agronomy	4	C
Alberini, Joao Luiz	Brazil	Beans/plant breeding	2	C
Alvarez, Guillermo A.	Honduras	Beans/agronomy	6	C
Apolitano, César Artemio	Perú	Beans/plant breeding	3	C
Araujo, Marco Antonio	Costa Rica	Beans/agronomy	3	P
Baruco, Camilo Augusto	Panama	Beans/plant pathology	3	C
Bonilla, Pastora	El Salvador	Cassava/plant pathology	4	C
Casco, Eusebio	Honduras	Beans/crops association	5	C
Castro, Edmundo C.	Ecuador	Rice/communication	4	C
Chiriboga, César	Ecuador	Beans/plant breeding	1	C
Ciotti, Elsa Mercedes	Argentina	Beef/pastures & forages breed.	12	C
Claure, Daniel	Bolivia	Others/laboratory management	3	C
Da Costa, Felix Antonio	Brazil	Beans/plant pathology	2	C
De la Cruz, Jesús H.	Peru	Beans/plant breeding	3	P
De Souza, Lindaurea	Brazil	Beans/entomology	7	C
Ekmahachai, Panya	Thailand	Cassava/agronomy	9	C
González, Rafael Darío	Dom. Rep.	Beans/agronomy	4	C
Hammond, Samuel	Panama	Beef/soils microbiology	3	C
Hernández, Julio César	Nicaragua	Beans/entomology	3	P
Hernández, Luis Alfredo	Colombia	Others/station operations manag.	6	C
Hohmann, Celso Luiz	Brazil	Beans/entomology	6	C
Kano, Yoshiaki	Japan	Cassava/plant breeding	12	P
Lezama, Francisco	Honduras	Beans/entomology	3	C
Machado, José	Brazil	Beans/plant pathology	3	C
Menénez, Oscar E.	El Salvador	Beans/agronomy	5	C
Mora, Bernardo	Costa Rica	Beans/plant pathology	4	C
Motato, Nelson	Ecuador	Others/soil phosphate	2	C
Nakavirojama, Chumpol	Thailand	Cassava/soil	9	C
Nieto Carlos Alberto	Ecuador	Beans/agronomy	3	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Nugroho, Hardono	Indonesia	Cassava/agronomy	5	C
Oliveira, Elias	Brazil	Beans/plant breeding	1	C
Ordoñez, Luis Factor	Guatemala	Beans/plant breeding	5	C
Ordoñez, Leonardo	Honduras	Beans/germplasm	4	C
Ortíz, Ruben	Panama	Beans/agronomy	3	C
Osaki, Flora	Brazil	Beef/biometrics	6	C
Pacheco, Rafael	Venezuela	Beans/agronomy	4	C
Pino, José Angel	Cuba	Cassava/plant pathology	3	C
Pinzón, José	Ecuador	Beans/agronomy	5	C
Portes, Tomás de Aquino	Brazil	Beans/plant pathology	4	C
Prada, Franklin Moisés	Bolivia	Others/station operations manag.	6	C
Quintero, Edgar	Colombia	Beans/biometrics	3	C
Reyes, Juan	Dom. Rep.	Others/station operations manag.	6	C
Rodríguez, Jesús H.	Mexico	Rice/plant breeding	3	P
Sañudo, Benjamín	Colombia	Beans/plant pathology	2	C
Sepulveda, Héctor	Chile	Beans/agronomy	1	C
Tavarez, Eliton	Brazil	Others/station operations manag.	5	C
Tongsri, Somsak	Thailand	Cassava/plant breeding	9	C
Torres, Justo Domingo	Honduras	Others/station operations manag.	6	C
Ubilla, Claudio Hernán	Chile	Beans/crops association	4	C
Uechiewcharnkit, Kasidit	Thailand	Swine/animal nutrition	2	C
Valverde, Franklin	Ecuador	Others/soil phosphate	2	C
Villavicencio, Angel	Ecuador	Cassava/production	10	C
Watananonta, Watana	Thailand	Cassava/plant physiology	9	C
Postgraduate Production Interns				
Abaunza, José Arkangel	Nicaragua	Beef/pastures & forages prod.	6	C
Aguirre, Luis	Bolivia	Beef/pastures & forages prod.	6	C
Alvarado, José Roberto	Chile	Rice/production	3	C
Alvarez, Mario	Bolivia	Swine/production	4	C
Ampuero, Antonio	Peru	Swine/production	4	C
Ampuero, Sabino	Bolivia	Swine/production	4	C
Aróstegui, Miguel H.	Argentina	Rice/production	3	C
Asaff, Jorge	Bolivia	Swine/production	4	C
Báez, Oscar Rubén	Paraguay	Swine/production	1	C
Benitez, Usciel	Colombia	Beef/pastures & forages prod.	6	C
Buitrago, Gabriel	Panama	Beef/pastures & forages prod.	6	C
Carrasco, Alejandro	Peru	Swine/production	4	C
Carvajal, Luis Lorenzo	Cuba	Rice/production	3	C

Table 4,(continued)

Name	Country	Program Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Chamorro, Leandro Leon	Colombia	Swine/production	4	C
Crivelli, Leopoldo	Honduras	Rice/production	4	C
Cruz, Francisco	Cuba	Rice/production	3	C
Cuesta, Pablo Antonio	Colombia	Beef/pastures & forages prod.	6	C
Duque, Jairo	Colombia	Swine/production	4	C
Eslava, Efraín	Colombia	Beef/pastures & forages prod.	6	C
Flores, Adalberto	Venezuela	Beef/pastures & forages prod.	6	C
Gavidia, Carlos Eusebio	Peru	Swine/production	4	C
Gómez, Joel Francisco	Venezuela	Swine/production	4	C
González, John Jairo	Colombia	Swine/production	4	C
Guillen, Edgardo	Guatemala	Swine/production	4	C
Guillen, Jorge Arturo	Costa Rica	Rice/production	4	C
Guimaraes, Raimunedo N.	Brazil	Beef/pastures & forages prod.	6	C
Justino, Pedro Ubirajara	Brazil	Beef/pastures & forages prod.	6	C
López, Washington	Peru	Beef/pastures & forages prod.	6	C
López, Gonzalo	Mexico	Rice/production	5	C
López, Jorge Raul	Mexico	Swine/production	4	C
Marcolina, Luiz	Brazil	Swine/production	4	C
Mascarenhas, Raimundo	Brazil	Rice/production	3	C
Menéndez, Juvenal	Cuba	Beef/pastures & forages prod.	6	C
Montás, Tomás Alfredo	Mexico	Rice/production	5	C
Moreno, Miguel Arturo	Ecuador	Rice/production	4	C
Morera, Jorge	Costa Rica	Rice/production	4	C
Muehlmann, Luiz Danilo	Brazil	Beef/pastures & forages prod.	6	C
Navarrete, Franklin	Ecuador	Rice/production	6	C
Ortegón, Julián Faín	Colombia	Beef/pastures & forages prod.	6	C
Oyola, José Abilio	Peru	Rice/production	4	C
Parsi, Jorge Armando	Argentina	Swine/production	4	C
Pérez, Alejandro	Paraguay	Swine/production	4	C
Pinedo, Luis Alberto	Peru	Beef/pastures & forages prod.	6	C
Possato, José Roberto	Brazil	Beef/pastures & forages prod.	6	C
Pozo, Melvin	Bolivia	Rice/production	4	C
Ramos, Clide Edgardo	Peru	Rice/production	4	C
Reátegui, Keneth	Peru	Beef/pastures & forages prod.	6	C
Rengifo, Octavio	Colombia	Swine/production	4	C
Rodríguez, John Kleber	Ecuador	Swine/production	4	C
Rosales, Carlos Renán	Nicaragua	Beef/pastures & forages prod.	6	C
Saavedra, Victorino	Peru	Rice/production	4	C
Salih, Alberto José	Venezuela	Rice/production	3	C
Scavone, Hugo César	Paraguay	Swine/production	4	C

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Scott, Patrick	Belize	Rice/production	3	C
Silveira, José Nilson	Brazil	Beef/pastures & forages prod.	6	C
Sobrinho, José Marcelino	Brazil	Beef/pastures & forages prod.	6	C
Torres, Victor Manuel	Venezuela	Swine/production	4	C
Tzul, Franco	Belize	Rice/production	4	C
Veladares, Alencar	Brazil	Beef/pastures & forages prod.	6	C
Ventura, César Manuel	Peru	Rice/production	6	C
Vilchez, Luis	Peru	Rice/production	4	C
Villavicencio, Marco A.	Ecuador	Swine/production	4	C
Special Trainees				
Boonekamp, Gerardus,	Holland	Beans/entomology	5	C
De Díaz, Sonia	Nicaragua	Others/library and docum.	7	C
Delgado, Lilia	Mexico	Rice/plant breeding	1	C
Doorman, Frans	Holland	Rice/rural sociology	5	C
Gomes de C., Jaime	Brazil	Cassava/soils	1	C
Jarrin, Eduardo	Ecuador	Rice/communication	1	C
López, César Ernesto	Dom. Rep.	Beef/pastures & forages util.	6	C
Luna, Gloria	Costa Rica	Beans/plant pathology	1	C
Marín, Javier	Colombia	Beef/soils	12	P
Rocha de V., Alicia	Peru	Rice/plant breeding	1	C
Rubio, Carlos Alberto	Colombia	Rice/production	2	C
Saldarriaga, José Alfredo	Colombia	Cassava/biometrics	12	C
Van Dorsten, Frank	Holland	Rice/rural sociology	6	C
Short Course Participants				
Abarca, Edgar	Costa Rica	Beans/production	1	C
Acuña, José William	Ecuador	Beans/production	1	C
Adam, Clifford	Seychelles Rep.	Cassava/production	1	C
Agudelo, Orlando	Colombia	Beans/production	1	C
Aguilar, Roberto	Costa Rica	Cassava/production	1	C
Aguilera, Ciro	Bolivia	Cassava/production	1	C
Aquino, Jorge Alfonso	Mexico	Cassava/production	1	C
Almeida, Evandro	Brazil	Cassava/production	1	C
Alves, Valmiro	Brazil	Cassava/production	1	C
Alves, Pedro	Brazil	Cassava/production	2	C
Alves, Sebastiao	Brazil	Cassava/production	1	C
Angulo, Néstor	Colombia	Beans/production	1	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Apolitano, César	Peru	Beans/production	1	C
Araujo, Marco Antonio	Costa Rica	Beans/production	1	C
Argasasmita, Muchtar	Indonesia	Cassava/production	1	C
Arguello, Hernando	Colombia	Others/seed production	1	C
Asenjo, César Augusto	Peru	Beans/production	1	C
Awe, Elias Ajib	Belize	Others/library and docum.	2	C
Aya, Germán	Colombia	Beans/production	1	C
Balarezo, Sergio Raul	Ecuador	Others/seed production	1	C
Barbosa, Eduardo	Brazil	Cassava/production	1	C
Barrios, Luis Mario	Colombia	Others/seed production	1	C
Barros, Luis Erasmo	Chile	Others/seed production	1	C
Bartra, Ana	Peru	Others/library and docum.	2	C
Baruco, Camilo Augusto	Panama	Beans/production	1	C
Bernardo, Emiliana	Philippines	Cassava/production	1	C
Bertoli, Eduardo	Paraguay	Others/seed production	1	C
Bin Baharom, Baharuddin	Malaysia	Cassava/production	1	C
Borges, Lesbia	Venezuela	Beans/production	1	C
Bravo, María Verónica	Chile	Others/library and docum.	2	C
Buenaño, Jorge	Venezuela	Cassava/production	1	C
Bustamante, Guadalupe	Colombia	Others/library and docum.	2	C
Caballero, Rene Carlos	Bolivia	Others/seed production	1	C
Candal, Joao	Brazil	Beans/production	1	C
Carcelen, Raul Alberto	Ecuador	Cassava/production	1	C
Carnero, Felipe	Peru	Beans/production	1	C
Carvajal, Gastón	Bolivia	Others/seed production	1	C
Casco, Eusebio	Honduras	Beans/production	1	C
Castillo, Ceferino	Ecuador	Cassava/production	1	C
Castro, César Modesto	Colombia	Others/seed production	1	C
Chang-Yau, Vielka	Panama	Others/library and docum.	2	C
Chantanakom, Niyom	Thailand	Cassava/production	1	C
Checo, Andrea Maljori	Dom. Rep.	Others/library and docum.	2	C
Chellamma, Mohankumar	India	Cassava/production	1	C
Chew Wee, Yong	Malaysia	Cassava/production	1	C
Cojulun, Rene Rolando	Guatemala	Beans/production	1	C
Cruz, Mario	Mexico	Cassava/production	1	C
Da Costa, Felix Antonio	Brazil	Beans/production	1	C
Da Silva, Corival	Brazil	Beans/production	1	C
Da Silva, Antonio	Brazil	Cassava/production	1	C
Dabien, Said	Cuba	Beans/production	1	C
Daphne, Paul	South Africa	Cassava/production	1	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Dávila, Amilcar	Guatemala	Others/seed production	1	C
De Carvalho, Walbert	Brazil	Cassava/production	1	C
De la Torre, Jaime	Colombia	Cassava/production	1	C
De Lima, José Otavio	Brazil	Cassava/production	1	C
De Moraes, Osmar	Brazil	Cassava/production	1	C
De Oliveira, Sebastiao	Brazil	Cassava/production	1	C
De la Cruz, Jesús H.	Peru	Beans/production	1	C
Delgadillo, José	Bolivia	Others/seed production	1	C
Dhiauddin, Jantan	Malaysia	Cassava/production	1	C
Díaz, Juan Leonel	Panamá	Cassava/production	1	C
Díaz, Arnulfo	Colombia	Others/seed production	1	C
Duangpatra, Piya	Thailand	Cassava/production	1	C
Dueñas, Juan José	Bolivia	Others/seed production	1	C
Duron, Carlos	Honduras	Beans/production	1	C
Escalada, Rodolfo	Philippines	Cassava/production	1	C
Espindola, Evaristo A.	Brazil	Beans/production	1	C
Flores, Juan Antonio	El Salvador	Others/library and docum.	2	C
Fraser, Ronald	Guyana	Cassava/production	1	C
Furtado, Marcio José	Brazil	Cassava/production	1	C
González, Rafael Darío	Dom. Rep.	Beans/production	1	C
González, Carlos	Colombia	Others/seed production	1	C
Guerra, Agnes Cristina	El Salvador	Others/library and docum.	2	C
Gutiérrez, Rosendo	Bolivia	Others/library and docum.	2	C
Guzmán, Cayetano	Panama	Others/seed production	1	C
Herazo, Fernando	Colombia	Cassava/production	1	C
Hermosilla, Jaime	Chile	Others/seed production	1	C
Hernández, Freddy	Guatemala	Beans/production	1	C
Hernández, Julio César	Nicaragua	Beans/production	1	C
Him, Calixto	Panama	Others/seed production	1	C
Ibarra, Ivan	Ecuador	Others/seed production	1	C
Jaldin, Jaime	Bolivia	Beans/production	1	C
Junqueira, Arnoldo	Brazil	Beans/production	1	C
Kempff, Francisco	Bolivia	Beans/production	1	C
Lescuoflair, Marie-Ange	Costa Rica	Cassava/production	1	C
Libreros Cilia	Colombia	Others/library and docum.	2	C
Lorenzi, Jose Omar	Brazil	Cassava/production	1	C
Lozada, Jesús Efren	Colombia	Cassava/production	1	C
Luna, Julio Enrique	Argentina	Beans/production	1	C
Luna, José Moisés	Colombia	Cassava/production	1	C
Mancini, Simeone	Colombia	Beans/production	1	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Mark, Joseph	Nicaragua	Cassava/production	1	C
Martínez, Ildeberto	Guatemala	Others/seed production	1	C
Martínez, Mirna	Venezuela	Cassava/production	1	C
Martinotto, Valentim	Brazil	Beans/production	1	C
Matheus, Luis Alberto	Venezuela	Cassava/production	1	C
Mayacela, Celso Eduardo	Ecuador	Others/seed production	1	C
Medal, Julio César	Nicaragua	Beans/production	1	C
Menéndez, Oscar Edgardo	El Salvador	Beans/production	1	C
Molina, Mario Alberto	Costa Rica	Others/seed production	1	C
Mondardo, Euclides	Brazil	Cassava/production	1	C
Montilla, Bienvenido	Dom. Rep.	Beans/production	1	C
Mora, Bernardo	Costa Rica	Beans/production	1	C
Morales, Palmira	Guatemala	Others/library and docum.	2	C
Morales, Salvador	El Salvador	Others/library and docum.	2	C
Moreira, Marco Aurelio	Costa Rica	Cassava/production	1	C
Moseley, Elio Partenio	Cuba	Others/seed production	1	C
Muñoz, Miguel Angel	Colombia	Beans/production	1	C
Muñoz, Tarquino Gilberto	Ecuador	Others/seed production	1	C
Murgas, Rafael	Colombia	Beans/production	1	C
Muthukumara, T.	India	Cassava/production	1	C
Navarro, Francisco	Mexico	Beans/production	1	C
Nunes, Joao Licinio	Brazil	Cassava/production	1	C
Nunes, Alba Rejane	Brazil	Cassava/production	1	C
Ochoa, Francisco	Mexico	Cassava/production	1	C
Oliveira, Elias	Brazil	Beans/production	1	C
Ordoñez, Leonardo	Honduras	Beans/production	1	C
Ordoñez, Luis Factor	Guatemala	Beans/production	1	C
Orellana, Silvestre	Guatemala	Beans/production	1	C
Ortiz, Ruben	Panama	Beans/production	1	C
Pacheco, Rafael	Venezuela	Beans/production	1	C
Palomar, Manuel	Philippines	Cassava/production	1	C
Peairs, Frank	Honduras	Beans/production	1	C
Pereira, Joao Eduardo	Brazil	Cassava/production	1	C
Perim, Sirval	Brazil	Cassava/production	1	C
Pinzón, José	Ecuador	Beans/production	1	C
Placido, Dirceu	Brazil	Beans/production	1	C
Ponjuan, Gloria Irene	Cuba	Others/library and docum.	2	C
Portes, Tomás de Aquino	Brazil	Beans/production	1	C
Puga, Bernardo	Panama	Others/seed production	1	C
Rajendran, Patterimadom	India	Cassava/production	1	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Ramírez, Alonso	Colombia	Cassava/production	1	C
Ribeiro, Leda Goes	Brazil	Others/library and docum.	2	C
Ribeiro, Jairo	Brazil	Cassava/production	1	C
Ríos, Manuel José	Colombia	Beans/production	1	C
Rivera, Rene	Cuba	Beans/production	1	C
Rodríguez, Sergio Juan	Cuba	Cassava/production	1	C
Rosario, Maritza	Dom. Rep.	Beans/production	1	C
Sadasivam, Pillai	India	Cassava/production	1	C
Sánchez, Elio Menandro	Dom. Rep.	Others/seed production	1	C
Segura, Luis	Costa Rica	Cassava/production	1	C
Sepúlveda, Héctor	Chile	Beans/production	1	C
Silva, Carlos Arturo	Colombia	Others/seed production	1	C
Silva, Antonio	Brazil	Cassava/production	1	C
Silveira, Pedro	Brazil	Beans/production	1	C
Smith, José	Belize	Beans/production	1	C
Soenaryo, Roberto	Indonesia	Cassava/production	1	C
Solórzano, Alfredo	Peru	Cassava/production	2	C
Speroni, Julia Hebe	Argentina	Others/library and docum.	2	C
Stewart, Brenda	Guyana	Cassava/production	1	C
Suárez, Miguel Arturo	Colombia	Others/seed production	1	C
Tamin, Senawi	Malaysia	Cassava/production	1	C
Tassinari, Gilberto	Brazil	Cassava/production	1	C
Taveras, Máximo A.	Dom. Rep.	Others/seed production	1	C
Then, José Francisco	Dom. Rep.	Cassava/production	1	C
Thirumalai, Ramanujan	India	Cassava/production	1	C
Torres, Heloisa	Brazil	Beans/production	1	C
Torres, Mario Fidel	Guatemala	Others/seed production	1	C
Ugas, Fernando Dionisio	Chile	Beans/production	1	C
Urdanivia, Renzo L.	Peru	Beans/production	1	C
Vallejo, Guillermo	Colombia	Cassava/production	1	C
Vieira, Balbino	Brazil	Cassava/production	1	C
Viera, Otoniel	Honduras	Others/seed production	1	C
Villanueva, Marianito	Philippines	Cassava/production	1	C
Voss, Marcio	Brazil	Beans/production	1	C
Westphalen, Segui Luiz	Brazil	Beans/production	1	C
Williams, Darwin	Trinidad & Tobago	Cassava/production	1	C
Wiroatmodjo, Joedojono	Indonesia	Cassava/production	1	C
Zelaya, Nelson Arnulfo	Honduras	Beans/production	1	C
Zerega, Luis Oswaldo	Venezuela	Beans/production	1	C

Table 4.(continued)

Name	Country	Program/Discipline	Months of training completed as of Dec. 31, 1978	Status as of Dec. 31, 1978
Posdoctoral Fellows				
Calderón Mario	Colombia	Beef/entomology	12	P
Cardona, César	Colombia	Beans/entomology	7	P
Davis, Jeremy	Unit. Kingdom	Beans/plant breeding	9	C
Hegewald, Bodo	West Germany	Others/special studies unit	8	P
Hershey, Clair	USA	Cassava/plant breeding	6	P
Jones, Peter	Australia	Beans/physiology	12	P
Lenne, Jill Marrie	Australia	Beef/soil microbiology	6	P
Lynam, John	USA	Cassava/economics	7	C
Mendoza, Gastón	Peru	Others/biometrics	9	C
Morales, Francisco	Colombia	Beans/plant pathology	6	P
Reyes, Jesús	Colombia	Cassava/entomology	10	P
Rubinstein, Eugenia	Chile	Beef/animal health	12	P
Swindell, Richard	USA	Beans/production	2	C
Thung, Michael	Indonesia	Cassava/plant physiology	1	C

Table 5.

Professionals trained at CIAT in 1978 classified by source of support and category of training.

Source of support[1]	Category of Training: Postdoctoral Fellows	Visiting Research Associates	Research Scholars	Postgraduate Research Interns	Postgraduate Production Interns	Special Trainees	Short Course Participants	Total
National and International Interests								
Agency for International Development-AID, USA	-	-	-	2 (10)	1 (4)	-	4 (5)	7 (19)
Agricultural University, Wageningen, Holland	-	-	-	-	-	3 (16)	-	3 (16)
Agropecuaria Gaviria y Guzmán, Colombia	-	-	-	-	-	1 (2)	-	1 (2)
Anglo American Corporation, South Africa	-	-	-	-	-	-	1 (1)	1 (1)
Asociación de Crédito y Extensión-ACARPA, Bahía, Brazil	-	-	-	-	1 (5)	-	-	1 (5)
Banco Ganadero, Colombia	-	-	-	-	1 (5)	-	-	1 (5)
Banco Nacional de Nicaragua	-	-	-	-	1 (5)	-	-	1 (5)
BRASCAN-NORDESTE, Bahía, Brazil	-	-	-	-	-	-	1 (1)	1 (1)
Caja de Crédito Agrario Industrial y Minero, Colombia	-	-	-	-	-	-	2 (2)	2 (2)
Centro de Investigación para la Caña de Azúcar-CENICAÑA, Colombia	-	-	-	-	-	-	1 (2)	1 (2)
Centro Internacional de Agricultura Tropical-CIAT	4 (19)	1 (2)	6 (56)	42 (167)	22 (92)	8 (30)	68 (83)	151 (449)
Colombiana de Semillas-COLSEMILLAS, Colombia	-	-	-	-	-	-	2 (2)	2 (2)
Comisión de Estudios para el Desarrollo de la Cuenca del Río Guayas—CEDEGE, Ecuador	-	-	-	-	-	-	1 (1)	1 (1)

1 All or bulk of financial support provided by or through organization indicated
2 Figures in brackets show months of training

Table 5. (continued)

Source of support[1]	Category of Training: Postdoctoral Fellows	Visiting Research Associates	Research Scholars	Postgraduate Research Interns	Postgraduate Production Interns	Special Trainees	Short Course Participants	Total
Empresa Brasilera de Pesquisa Agropecuaria-EMBRAPA, Brazil	-	-	-	-	-	-	4 (4)	4 (4)
Empresa de Pesquisa Agropecuaria de Ceara-EMPACE, Brazil	-	-	-	-	-	-	1 (1)	1 (1)
Empresa Maranhense de Pesquisa Agropecuaria-EMAPA, Brazil	-	-	-					
Empresa Pernambucana de Pesquisa				-	-	-	1 (1)	1 (1)
Agropecuaria-IPA, Brazil	-	-	-					
Fondo Nacional de Investigaciones				-	-	-	1 (1)	1 (1)
Agropecuarias-FONIAP, Venezuela	-	-	-	-	-	-	2 (2)	2 (2)
German Foundation for the International Development	-	1 (5)	-	-	-	-	-	1 (5)
German Society Technical Cooperation	-	1 (3)	-	-	-	-	-	1 (3)
Inter-American Development Bank-IDB	-	-	3 (18)	-	-	-	-	3 (18)
Instituto Agronómico de Campinas, Brazil	-	-	-	-	-	-	1 (1)	1 (1)
International Development Research Centre-IDRC, Canada	-	-	-	5 (41)	-	-	18 (18)	23 (59)
Ministerio de Agricultura, Cuba	-	-	-	-	-	-	2 (2)	2 (2)
Ministerio de Agricultura y Ganaderia, Ecuador	-	-	-	-	-	-	2 (2)	2 (2)
National Science Foundation, USA	-	1 (4)	-	-	-	-	-	1 (4)
Rockefeller Foundation, USA	1 (6)	-	-	-	-	-	-	1 (6)
Seminarios Panamericanos de Semillas, Chile	-	-	-	-	-	-	1 (1)	1 (1)
Technical University of Berlin, Germany	-	1 (4)	-	-	-	-	-	1 (4)
The Royal Society, London	-	1 (8)	-	-	-	-	-	1 (8)
United Nations Development Programme UNDP	-	-	-	-	36 (156)	-	58 (58)	94 (214)
	5 (25)	6 (26)	9 (74)	49 (218)	62 (267)	12 (48)	171 (188)	314 (846)

[1] All or bulk of financial support provided by or through organization indicated

[3] Figures in brackets show months of training

Table 6.

Major events held in CIAT's conference facilities during 1978.

Date	Event	No. of participants
CIAT sponsored or co-sponsored scientific exchanges		
16- 19 Jan.	Workshop on International Bean Breeding Trials in Latin America	54
11 - 14 April	Workshop on Coordinating and Planning for the Collection, Preservation, Distribution and Characterization of Germplasm Resources of Tropical Forages	115
17 - 20 April	Seminar on the Production and Utilization of Forages in Tropical Acid and Infertile Soils	185
25 - 27 April	Workshop on Cassava Harvesting and Processing	21
9 - 11 Oct.	Bean Program Advisory Committee Meeting	6
1 - 3 Nov.	Workshop on Documentation Systems in Agricultural Economics and Rural Development in Latin America	21
CIAT organizational events		
20 Jan.	ICA-CIAT Phytosanitary controls	20
8 - 10 May	Seminar on Advances in Research at CIAT	100
1 - 2 Dec.	Special UNDP/CIAT Project Advisory Committee	12
11 - 15 Dec.	Internal Program Reviews	80
CIAT training courses		
14 Jan. - 13 Feb.	Cassava Short Course for Asians	31
30 Jan. - 3 March	Bean Production Short Course	30
27 Feb. - 15 Nov.	Rice Production Course	10
3 - 30 May	Cassava Intensive Course	48
26 June - 30 Nov.	Pasture Management Course	21
3 July - 3 Aug.	Documentation Short Course	16
17 July - 17 Nov.	Swine Production Course	20
21 Aug. - 22 Sept.	Bean Production Short Course	34
25 Sept. - 6 Oct.	ICA-CIAT Rice Production Short Course	25
October (4 days)	Statistical Analysis System Course	104
6 Nov. - 1 Dec.	Seed Technology Short Course	29

Table 6 (continued)

CIAT hosted events, sponsored by other institutions		
13 - 17 Feb.	Union of Banana Exporting Countries — First Meeting on Coordinated Research Program	44
22 - 24 Feb.	Fondo Ganadero del Valle — Utilization of Agricultural Sub-products for Animal Feed	120
29 - 30 March	ASOCAÑA - Sugar Cane Harvesting	70
7 - 9 June	Meeting of ICA Regional Directors	40
24 - 31 July	Regional Meeting Catholic Relief Services	62
11 - 12 Aug.	Association Veterinary Aviculture Specialists — Incubation	110
14 - 18 Aug.	UNIVALLE/Harvard School Medicine — Medical Education and Curriculum	40
6 - 8 Sept.	Annual Meeting of ICA Parasitologists	15
8 - 10 Nov.	TECNICAÑA - Water-Soil-Plant Relationship	100

Documentation Services Unit

Although previously, efforts had been concentrated on collecting a great deal of information, primarily in support of CIAT's commodity programs, during 1978 the Documentation Services Unit entered a stage of expanded diffusion of its information products and ideas due to the success of its new approach to information management.

This tendency towards transferring informational services capacity to the different countries was also evident in the first Agricultural Documentation Course, held during July and August with 16 representatives from 11 Latin American countries.

The documentation service for Agricultural Economics and Rural Development in Latin America entered a stage of institutional complementation and collaboration during the year. Preliminary talks with the Instituto Interamericano de Ciencias Agrícolas (IICA) and their AGRINTER Network, as well as results from a workshop on user needs, indicated the convenience of giving this system a more collaborative approach, with gradual decentralization of input towards national institutions, which are AGRINTER network nodes.

Within this same framework, the Unit provided consultancy services to the International Crops Research Institute for the Semi-arid Tropic (ICRISAT), for the initiation of a sorghum and millet documentation center.

As a part of this expanded effort, a new documentation service was begun in the area of Tropical Pastures, following the same philosophy of **consolidated information** which had already produced encouraging results in other services, covering areas of cassava and field beans.

Services

The documentation service for Tropical Pastures was started in early 1978, following the basic principles of the Center of offering support in specialized information to CIAT's research programs. A total of 314 persons subscribed to this new service starting in March. Monthly delivery of abstract cards in the three additional areas covered by the Center continued as before. This year brought a considerable increase in the number of subscribers in these three areas: 600 in Cassava; 700 in Beans; and 400 in Agricultural Economics.

The number of photocopy requests continued to increase for the Contents Pages in Agricultural Sciences, Animal Sciences and Agricultural Economics. This year photocopies of 11,500 articles of the Contents Pages were requested, in the following areas: Agricultural Sciences — 5045, Animal Sciences — 5676, and

Agricultural Economics— 779. In addition, photocopies were requested of 983 documents as a result of abstracting services.

Presently, the Contents Pages are being distributed through two channels — deliveries to institutions in various Latin American countries and direct deliveries from CIAT to persons or institutions. In this way, a larger audience is reached and distribution is decentralized to a certain extent. A total of 1300 issues are being sent through agencies in nine countries and 1867 issues directly from CIAT. The demand for this service is constantly increasing, which indicates the use that it has as an awareness service for Latin American technicians and scientists.

The service of specialized searches conducted by the Documentation Center has also experienced an increasing demand. During 1978, 134 searches were processed, distributed in the following areas: 59 in Cassava, 45 in Beans, 26 in Agricultural Economics and 4 in Tropical Pastures. Besides the specialized searches processed in the Documentation Center, the Library Reference service prepares short bibliographies on specific subjects at the request of CIAT scientists. Fourteen of these short bibliographies were prepared during the year.

Processing continued of serial publications of scientific institutions and agricultural experiment stations, as well as supplementary material in the form of pamphlets. A total of 1417 papers were processed and 985 pamphlets classified under general subject titles and stored in the vertical file.

Cassava Newsletter

Numbers 3 and 4 of the Cassava Newsletter were published this year in English and Spanish. This publication has awakened great interest among technicians working in this area. Numerous contributions were received from users, indicating that the publication is meeting its fundamental objective of serving as a medium of diffusion for the professional activities being conducted and as a communications medium among cassava workers throughout the world. The newsletter is distributed free to subscribers of the Cassava Information Center and to other interested persons and institutions working in the different areas of cassava production.

Other Publications

Following the principle of **consolidated information** which guides the general activities of the Unit, the Cassava Information Center published, in English and Spanish, *Cassava Pests and Their Control* by entomologists Anthony C. Bellotti and Aart van Schoonhoven; this monograph is a critical review of literature on the subject. In addition, *Cassava Drying,* written by former CIAT visiting scientist Rupert Best, was published in English and Spanish as well.. This manual describes a simple, small-scale method for drying cassava.

The proceedings of the Cassava Protection Workshop, held at CIAT in November 1977, were also edited and published early in 1978 by the Cassava Information Center.

Consultancy Services

During June, the Unit Coordinator served as a consultant to ICRISAT to help establish a documentation center on sorghum and millet, being financed by the International Development Research Centre (IDRC), Canada. The Center's mandate follows CIAT's Cassava Information

Center which has proven to be a viable, well-suited model for developing countries.

For two weeks, ICRISAT personnel were trained in handling the Termatrex information storage and retrieval system presently used at CIAT, and in preparing analytical abstracts. Also, Dr. Donald Leatherdale, from IDRC, prepared a sorghum and millet thesaurus, an essential element for indexing and retrieving information contained in the collection of 13,000 documents that ICRISAT already has.

Agricultural Documentation Course

The role of Information Sciences in national and international research institutions and in universities, is now being recognized in Latin America, and is being manifested by the growing need to train personnel in this area. In response to this demand and with the objective of normalizing in-service-training, which had been offered upon request from the different institutions, the Documentation Services Unit conducted a nine-week short course for agricultural documentalists.

The course was oriented towards practical knowledge of basic elements and operations of an agricultural documentation center, and emphasized activities conducted by CIAT's Documentation Center. It was designed for professionals and technicians working in the field of agricultural information. Sixteen trainees from the following Latin American countries participated: Argentina, Belize, Bolivia, Brazil, Colombia, Cuba, Chile, the Dominican Republic, El Salvador, Guatemala, Nicaragua, Panama and Peru.

The 12-unit course covered the following areas: status of information in Latin America, social research methodology, study of information units, nature and type of documents, preparation of bibliographical citations, information search systems, procedures for selecting and purchasing materials, overall classification and cataloguing, general concepts and preparation of thesauri, guides and practice in preparing analytical abstracts, information storage and retrieval systems, and information dissemination methods, the latter emphasizing preparation of Contents Pages.

At the end of the course each trainee prepared a paper designed to evaluate documentation knowledge acquired and to assist in identifying his aptitude within the reality of his country and institution and facilitate on-the-job application of the newly acquired knowledge.

Evaluation of Documentation Services

As a part of the periodic evaluations conducted in the Program and on the occasion of the CEDEAL Workshop, a survey was conducted among CEDEAL users for evaluating some aspects of present services. The study had four objectives: (1) to determine subject areas of greatest interest for users; (2) to evaluate the usefulness of the Contents Pages and Abstracts services; (3) to determine who was using the services according to profession, academic studies, country and type of work being done; and, (4) to obtain information on the nature of documents on which CEDEAL should place more emphasis, as viewed by the users.

From the answers received, the following general preliminary conclusions were reached. One half of the users of the CEDEAL services are economists or agricultural economists, and almost four out of five have advanced degrees, with

72% working in research. A large majority of the respondents believed the services to be very useful, and in fact, many kept materials such as the Contents Pages for later retrospective searches. Regarding those documents that CEDEAL should emphasize, users suggested the following three in order of importance; journal articles, theses and dissertations, and mimeographed pamphlets or internal reports of limited circulation (non-conventional materials). This can be interpreted as an even greater need for primary literature, an unanticipated finding. This would indicate that, at least in the social sciences, Latin American technicians do not even have sufficient access to journal articles and much less to semipublished or unpublished information.

CEDEAL Workshop

In November 1978, IICA and CIAT conducted a workshop, the main objective of which was to analyze the possibility of combining efforts between IICA, CIAT and respective Latin American countries to start a collaborative documentation program on agricultural economics and rural development. Thirty-one persons attended the meeting, representing IICA regional offices, universities in Argentina and Brazil, international institutions and documentation and research centers, in addition to CIAT representatives.

The most important conclusions were as follows:

1 There was general consensus on the need and usefulness of the documentation services rendered by CEDEAL.

2 It was recommended that CEDEAL's original objectives be maintained but that they should be limited to covering material of Latin American origin.

3 It was suggested to decentralize the input of documents to CEDEAL gradually through IICA's regional offices and in the latter case through national institutions making up the AGRINTER network.

4 There was general assent regarding the complementary character existing between the services rendered by AGRINTER and CEDEAL. In other words, CEDEAL fulfills the functions of Level II centers of the AGRINTER system.

5 The participants specifically suggested that the abstracts and annual cumulative volumes continue being the major concern of CEDEAL's services. They also recommended that the Contents Pages service continue due to its large demand and usefulness as an awareness service.

Communication Support Unit

In an effort to ensure that the various publics interacting with CIAT are provided with systematic and relevant information on the Center's objectives, activities, achievements, and future plans, the Communication Support Unit was created in the International Cooperation sector, in July 1978. The principal functions of this Unit are: (1) to package and disseminate the results of CIAT's research to appropriate audiences; (2) to maintain and improve CIAT's image with donors, client countries, and the general public; and, (3) to serve the publications needs of other CIAT programs and units.

The Unit is comprised of sections devoted to: (1) analysis of information needs of the various client publics served by CIAT; (2) message development (both for print and non-print media); (3) message production—composition/printing, photography, graphic arts; and, (4) distribution of informational materials.

Serial Publications

In close collaboration with the Center's various research programs and units, especially the Documentation Services Unit, the Communications Support Unit produced the serial publications listed in Table 1.

Production of Training Materials

Throughout the year, efforts to produce didactic audiovisual sets (i.e., so-called audiotutorial units) were continued. At the end of the year a total of 21 audiotutorial units had been completed (Table 2); 12 more were in final stages of production, and another 24 units were in early stages of production.

Many of the units were successfully utilized in various training courses offered by CIAT throughout the year. During the second semester of 1978, the audiotutorial playback facilities (with 18 individual stations) became fully operational. Thus, many training participants at the Center could take advantage of the selection of units for study on an individual basis.

Also, in the second semester of 1978, the Communication Support Unit began to distribute duplicated sets of these audiotutorial units to national institutions and other centers of agricultural training. While this information dissemination effort was still very modest last year, it will constitute a major part of the efforts to be expended in the area of training materials in 1979. Although audiotutorial units are still only produced in Spanish, it is

Table 1.

Publications issued in the established CIAT series during 1978.

Code	Title	Language	Pages	Press run
	CIAT-wide			
02SE1-77	Annual Report 1977	Eng./Span.	424	3700
02SE2-77	Highlights 1977	Eng./Span.	64	6000
01SE-3	Noti-CIAT	Eng./Span.	4	8000
	CIAT Visitors Brochure	Eng./Span	20	8500
	Commodity-specific			
02SE1R-77	Annual Report Rice	Eng./Span.	21	1050
02SE1C-77	Annual Report Cassava	Eng./Span.	76	2900
02SE1G-77	Annual Report Beef	Eng./Span	124	1350
02SE1B-77	Annual Report Beans	Eng./Span.	94	1500
02SE1S-77	Annual Report Swine	Eng./Span.	16	1460
02SE1Tr-77	Annual Report Training	Eng./Span.	21	400
06SB-2	Limiting Factors on Bean Productivity in Colombia	Span.	44	2500
06SB-1	Evolution of Bean Production in Latin America during the last Decade	Span.	48	3500
07ESB-1	Field Problems of Beans in Latin America	Eng./Span.	136	6000
06SG-1	The Economics of Foot and Mouth Disease	Span.	53	1000
03ESR-1	International Rice Testing Program for Latin America: Report of the Second Conference, November 1977: Cali, Colombia	Eng./Span.	37	1000
03EG-4	Proceedings of a Workshop on the Ecology and Control of Ectoparasites on Bovines in Latin America: August 1975: Cali, Colombia	Eng.	186	1000
03SG-3	Proceedings of a Workshop on Hemoparasites, March 1975. Cali, Colombia	Span.	137	1000

(continued)

Table 1. (continued)

Code	Title	Language	Pages	Press run
03EC-1	Proceedings of a Workshop on Cassava Protection, November, 1977: Cali, Colombia.	Eng.	244	1000
05-SS6	Utilization of Rice Polishings in Growing and Finishing Rations for Hogs	Span.	26	2330
09ESC-2	Cassava Pests and their Control	Eng./Span.	76	3000
05ESC-4	Cassava Drying	Eng./Span.	26	4000
	Documentation publications			
01ESC-3	Cassava Newsletter # 3	Eng./Span	18	3500
01ESC-4	Cassava Newsletter # 4	Eng./Span.	18	3500
08ESC-4	Abstracts on Cassava, Volume IV	Eng./Span.	174	3000
08ESB-3	Abstracts on Field Beans, Volume III	Eng./Span.	272	3000
08SE-3	Abstracts on Agricultural Economics in Latin America	Span.	260	1500

recognized that at some future time these units must also be made available in English and Portuguese. In the case of the latter language, initial arrangements have been made with the Empresa Brasileira de Asistencia Técnica e Estencão Rural (EMBRATER), the Brazilian national agricultural extension organization whereby this organization will produce all CIAT-generated units in Portuguese. By the end of 1978, EMBRATER had already started to work on the first 10 units supplied by CIAT.

Other Message Products

During 1978, the Communication Support Unit also produced three audiovisual programs to provide systematic information about CIAT's operations to visitors. Three displays were assembled to represent CIAT at various events in Colombia. Finally, a limited number of articles about the Center and its programs were produced and placed in various magazines, news organs of professional associations, and in general newspapers in Latin America.

Visitors' Services

During the year, the Public Information Office of the Unit received and guided 6350 visitors through the Center. These included scientists, government representatives, production specialists, farmers and general visitors from throughout the world, but especially Latin American countries. The number of visitors received in 1978 was 70% above the number hosted the previous year.

Communication Services to CIAT

The Communications Support Unit and the former Information Services Section (during the first half of the year) provided extensive communication services to the

Table 2.

Audiotutorial units completed as of Dec. 31, 1978. (All are available only in Spanish.)

Code No.	Title
	Units in Rice
04SR-01. 02	Preparación de suelos para el cultivo del arroz bajo el sistema de inundación
04SR-05. 01	Latencia y pregerminación de la semilla de arroz
04SR-05. 02	Morfología de la planta de arroz
04SR-07. 04	Evaluación de la resistencia varietal del arroz a sogata y al virus de la hoja blanca
04SR-07. 03	Evaluación de la calidad del arroz
	Units in Beans
04SB-08. 02	Cruzamiento del fríjol
04SB-05. 01	Descripción y daños de las plagas que atacan el fríjol
04SB-06. 04	Enfermedades causadas por virus y su control
04SB-12. 03	Semilla de fríjol de buena calidad
	Units in Cassava
04SC-03. 01	Descripción de las enfermedades de la yuca
04SC-06. 01	Sistema de propagación rápida de la yuca
04SC-04. 01	Control de *Erinnyis ello* (gusano cachón de la yuca)
04SC-02. 01	Un tipo ideal de planta de yuca para rendimiento máximo
	Units in Weed Control
04SW-03. 01	Principios básicos para el manejo y control de las malezas en los potreros
04SW-03. 01	Guía práctica para el control químico de las malezas en los potreros
04SW-01. 01	Principios básicos para el manejo y control de las malezas en los cultivos
04SW-01. 05	Factores que condicionan la eficiencia de los herbicidas
04SW-01. 04	Herbicidas: Modo de actuar y síntomas de toxicidad
04SW-01. 02	Información básica sobre la competencia entre las malezas y los cultivos

Center's research programs, support units and the administration. These services included manuscript editing, photography, graphic arts, typesetting and printing, and all of the Center's photocopying work.

Immediate Future Plans

While continuing to fulfill its everyday services to the Center, the Communication Support Unit has also identified certain areas where expanded informational efforts are needed.

The Annual Report and the Research Highlights publications will continue to be the main vehicles for providing the scientific community and the public at large, respectively, with technical information about all of CIAT's activities. The Unit does, moreover, publish technical information in several of the established series; during 1979, the Unit will attempt to increase the number of these technical publications made available to research collaborators and other contacts.

More emphasis will also be directed to commodity-specific newsletters intended for bi-monthly publication. Two such newsletters will be started in 1979.

In the area of training materials, production of audiotutorial units will begin in two new areas — beef production (especially tropical forages) and seed technology, to supplement those being produced in cassava, beans, rice and weed control.

To help keep the general public informed of CIAT's goals, activities and achievements, the Unit plans to produce a set of informational brochures on the Center and on specific commodity programs. Also, planned are a 16mm film and selected audiovisual programs for visitors. Increased efforts will also be directed to producing and disseminating an increased number of articles to existing mass communication channels.

Seed Unit

During late 1977 and most of 1978 the Seed Unit functioned primarily with the support of The Rockefeller Foundation. In November 1978, an overall plan for development of the Unit was ratified with the signing of an agreement between the Swiss Development Cooperation of the Swiss Confederation and CIAT. The agreement provides total support for three years with funds earmarked for two additional years.

Background

As CIAT and other international and national research centers succeed in generating improved technology, the need for a greatly accelerated effort in seed production and supply becomes increasingly clear. Progress has been slow in developing strong seed programs in Latin America and the Caribbean area during the past 20 years. Factors contributing to this slow development have been lack of trained personnel, unclear and inconsistent policies, limited Breeder and Basic Seed supplies for further multiplication by seed enterprises, problems in producing and storing seed, and poor marketing systems.

Many individual countries in the region have difficulty in overcoming these problems. It is difficult for technical assistance agencies and donors to provide the long-term planning and support required to each country needing assistance in seed technology. Thus, a location in the region is needed to provide special training opportunities, to offer technical collaboration to countries, to solve problems adversely affecting the quality and quantity of seed, and to provide seed supplies of promising and improved varieties for extensive testing and multiplication.

CIAT offers many advantages as an institution and location in the region for meeting these needs. Excellent training facilities and information services exist. The technical base of the commodity programs provides a solid core of production information needed for successful seed programs. Links with commodity programs to solve seed technology problems are possible. Some seed production capability exists with the Station Operations Unit. The Genetic Resources Unit exists and several collaborative activities are possible. A rapidly developing commercial Colombian seed industry exists in the area and a well-developed quality control program is operating from the Instituto Colombiano Agropecuario (ICA). Thus, CIAT provides many advantages as a center from which a wide range of assistance can be provided to seed programs in the region.

Objectives

Based on the above needs and available resources, the Seed Unit will work to accomplish the following four objectives.

(1) Train personnel in government and private institutions primarily from all Latin American and Caribbean countries in various aspects and at different levels of seed industry and program development and seed technology.

(2) Extend technical collaboration to countries in the region to meet a wide range of needs with the aim of expanding the production of high quality seed of improved varieties with the emphasis on but not restricted to the commodities with which CIAT works.

(3) Conduct research in seed technology primarily in collaboration with CIAT commodity programs and relevant to problems of the region.

(4) Provide a single seed multiplication and distribution capability which can: (a) cooperate with commodity programs in multiplying, drying, processing, storing and distributing advanced experimental material and Breeder and Basic Seed to collaborating countries for farmer trials and further multiplication; (b) relate closely to training activities in order to make training as relevant and practical as possible; and, (c) assist in the propagation and introduction of seed in the Latin American and the Caribbean area of commodities of sister International Agricultural Research Centers.

Activities in 1978

In addition to overall planning and development of the Unit, the following related activities were accomplished in 1978.

(1) A four-week training course was organized for 29 professionals from 12 countries. The course was partially supported by the United States Agency for International Development (USAID) and three staff members from Mississippi State University (U.S.A.) assisted with conducting the course. Other assistance came from ICA, in Colombia, the Instituto de Ciencias y Tecnología Agrícolas (ICTA), in Guatemala, and Dr. Ronald Echandi of the University of Costa Rica.

(2) The Unit Coordinator participated for three weeks on the Panamanian Seed Review Team during preparation of a report to the government of that country.

(3) Assistance was provided in a training course at the University of Costa Rica.

(4) The Coordinator also participated in the First Andean Sub-regional Symposium on Seeds and the Andean Maize Producers Meeting, both in Lima, Peru.

(5) Basic information was gathered on seed programs in various countries of the region, with special emphasis on Panama, Guatemala, Colombia and Peru.

(6) Assistance was provided in the preparation of audiotutorial training units.

CIMMYT/CIAT Andean Regional Maize Unit

During 1978 staff of the CIMMYT/CIAT Andean Regional Maize Unit dedicated 80% of their time to international cooperation activities and 20% to research at CIAT-Palmira and CIAT-Quilichao. Some 260 days were spent outside of CIAT, conforming to the philosophy under which the Unit operates to reinforce national maize programs.

RESEARCH IN CIAT

Breeding for Reduced Plant Height

One of the reasons for the lack of yield stability in tropical varieties of maize is their excessive height which makes them susceptible to lodging, in turn, causing high rates of ear rotting. This problem is aggravated in modern agricultural zones were crops receive sufficient inputs, especially fertilizers. There maize grows vigorously and is more susceptible to lodging. Where maize is harvested mechanically, losses from lodging can approach 40% when harvestors can pick up little of the fallen maize. All maize breeding programs in the Andean countries are working to reduce plant height in their materials.

Because of the favorable agro-climatic conditions in the Cauca Valley of Colombia, maize plants grow higher than in most other localities of the Andean Zone, making this area an ideal one for selecting for plant height. All maize materials being bred and improved in CIAT have plant height as a selection criterion. For two groups of materials — La Posta and the CIMMYT Germplasm Pools — plant height is the primary selection criterion.

La Posta

La Posta is a variety with very good yield potential (11 t/ha at experimental levels), but also with excessive plant height (3 m) when planted under high technology. When planted under low fertility conditions with deficient or excessive moisture its height is reduced but the size of the ear, and thus yield, does not decrease proportionately.

Up to now, this variety has been subjected to a half-sib improvement system but results with plant height have not been promising although yield potential has been maintained. In the next planting cycle, a full-sib improvement system will be used to try and lower plant height of this promising variety.

CIMMYT Germplasm Pools

These pools are basic breeding materials with a wide genetic base. At CIMMYT they are managed in a half-sib system. In the second semester of 1978, eight of these pools were planted at CIAT and several full-sib crosses made between the lowest plants. In this cycle, plant height was reduced an average of 36 cm in the eight groups (Table 1).

Breeding Populations with High Protein

Common maize generally contains 9 to 11% of a low-quality protein deficient in two basic amino acids — lysine (2% of the protein) and trytophan (0.4%).

Protein quality of maize can be improved by incorporating the opaque-2 mutant gene. Although an opaque-2 maize contains about 4% lysine and 1% trytophan, it has several other drawbacks: (1) yield decreases (5-15%) in relation to normal maize because opaque-2 endosperm is soft or floury and weighs less than that of normal maize; (2) most consumers do not like it because of its appearance; and, (3) the soft endosperm is attacked more easily in the field and in storage by pathogens such as *Fusarium* and *Diplodia,* as well as insects.

Despite these problems, genes that modify the opaque-2 gene to produce a hard endosperm grain are available. Action of modifier genes is influenced

Table 1.

Selections made for plant height in eight germplasm complexes from CIMMYT, CIAT 1978B.

Material	Plant height (m)			
	$\bar{X}$ Popul.	Range	$\bar{X}$ Selec.	Range
Pool 15 - Tropical Early White Flint	2.18	1.65-2.65	1.85	1.65-2.05
Pool 16 - Tropical Early White Dent	2.17	1.65-2.60	1.84	1.65-2.00
Pool 17 - Tropical Early Yellow Flint	2.13	1.60-2.55	1.84	1.60-1.95
Pool 18 - Tropical Early Yellow Dent	2.19	1.65-2.45	1.85	1.65-2.00
Pool 19 - Tropical Intermed. White Flint	2.32	1.65-2.60	1.96	1.65-2.05
Pool 20 - Tropical Intermed. White Dent	2.41	1.85-2.75	1.99	1.85-2.10
Pool 21 - Tropical Intermed. Yellow Flint	2.38	1.80-2.75	1.95	1.80-2.10
Pool 22 - Tropical Intermed. Yellow Dent	2.48	1.90-2.75	2.04	1.90-2.19

somewhat by the environment and for this reason, it was considered necessary to initiate an opaque-2 breeding program in CIAT. The maize population PD (MS_6) HE O_2 was chosen as the base because it was one of the most stable populations available when the experiment was begun.

Up to now selections have been made through three cycles using a half-sib system. For each cycle a sample of ears selected for hard or crystalline endosperm has been sent to CIMMYT for protein and tryptophan analyses; only materials with the highest values are planted in the next cycle.

Through the three cycles grown, protein content in the population has been increased from 8.50 to 9.18% while tryptophan levels have remained the same at about 0.72%.

Yield Trials

Maize yields in the Cauca Valley of Colombia provide a good indication of a variety's yield potential in other parts of the Andean Zone, and, therefore, materials are always tested at CIAT to obtain some indication of their value. Six yield experiments were planted in 1978 with results available for three of them.

Suwan-1

This is a yellow flint population from Thailand which has been selected in Colombia for its yield and resistance to downy mildew *(Cenicilla)*. In 1977 1 kg of Suwan-1 seed was planted in an isolated lot and 250 plants were selected from the group at harvest. Selected material was essentially half-sib families. In the first semester of 1978, these families were planted in replicated trials.

Yields of the families indicated the high potential for this population with the overall average being 6.5 t/ha and 54 families surpassing 7/ha.

The average height of the plants is still relatively high (2.56 m), however, 118 families had height less than or only equal to the average, indicating the possibility for substantially reducing height.

CIAT Brachytic Materials

The former Maize Program at CIAT had produced a number of materials incorporating the br_2 gene for shortness. All these materials are being evaluated fully with the objective being to select and distribute the best ones in the Andean Zone.

In the first semester of this year, 33 materials from CIAT were planted and evaluated. Eight groups out-yielded the local check (ICA HE-212), producing from 6.7 to 8.2 t/ha.

Early Materials

Maize materials that mature early are needed for several locations in the Andean Zone. A project for earliness was initiated in the first semester of 1977 when 595 relatively early families from CIMMYT materials were planted at CIAT. From that cycle 186 families were selected for earliness, plant height and yield potential. In the next semester, only 20 of the 186 families were selected for planting in a yield trial in 1978.

All materials proved to be early-flowering, having a range of 49 to 52 days, compared to the earliest control (variety Minita from Venezuela, 48 days) and the latest, Suwan-1 (55 days). One of the early selections yielded the highest (7.33 t/ha, 15% grain) in the test, 36% higher than Minita. Nine other selections also out-yielded the 5.39 t/ha of Minita.

Development of Maize Tolerant to Low Soil pH and High Aluminum Saturation

It is estimated there are some 850 million ha of acid soils on the South American continent. Up to now, it has not been possible to produce maize economically on these types of soils because heavy applications of lime are needed if plants are to develop normally. No maize varieties exist that are completely tolerant to acid soil conditions.

In the second semester of 1977, a project for breeding materials tolerant to acid soils was initiated at the CIAT-Quilichao substation. The soil there is an Ultisol with pH slightly above 4 and Al saturation of over 80%. A total of 192 materials from several sources were planted in single furrows 5 m long in two replications, one with 5 t/ha of lime applied and the other without lime. All plots received 163 kg/ha urea, 10 kg/ha Borax, 22 kg/ha zinc sulfate and 300 kg/ha of triple superphosphate.

In the first harvest a total of 76 ears were selected from both replications. The crop did not develop well because of dry conditions when irrigation was not available, and for this reason, few ears could be selected.

Because of these problems, in 1978A it was decided to again include some genotypes that had shown an acceptable vegetative development in the first cycle although yields had been low. Forty-five varieties as well as the 76 selections were planted in a half-sib system in which the pollenizer was a balanced mixture from ears selected in both replication (with and without lime. No treatments received lime this cycle but other amendments were supplied as in the first trial. From the 1978A cycle, 120 plants were selected from both replications and were planted again in a half-sib pattern.

The reasoning for this breeding system is that because lime was only applied at the beginning of the project, the plot receiving lime is gradually becoming more acid and the Al saturation level is increasing after being lowered by the original liming. By selecting under these conditions and recombining the genotypes selected, it is believed that genetic recombinations will be obtained that are more tolerant to these types of soils. Selections made each cycle from the plot not receiving lime also contribute some genotypes with tolerance to acid soils.

Maize/Sugar Cane Associations

Last year partial results were reported (CIAT Annual Report, 1977) on an experiment to plant maize with sugar cane to take advantage of the abundant solar radiation available while the cane is in early development.

In August 1978, the cane was harvested (17 months after planting). Results showed that although the maize had yielded from 1.6 to 3.2 t/ha, the cane was not affected by the association. The average yield of the controls (cane alone) was 151 t/ha of cane and 17.1 t/ha of sugar. The average yields of all plots with maize in association was 151.5 t/ha of cane and an average production of 17.0 t/ha of sugar.

INTERNATIONAL COOPERATION

Germplasm

One function of the CIMMYT/CIAT Regional Andean Maize Unit is to promote the exchange of germplasm between the Andean countries. During visits made within the zone, varieties, collections and populations are identified that could be of general usefulness, and these, together with materials from CIMMYT and CIAT sent to different countries to be tested in observation trials.

In 1977-78, 72 normal tropical materials from Colombia, Peru and CIMMYT were sent to Bolivia, Ecuador and Venezuela. These materials were tested in Bolivia and Ecuador exclusively for yield and adaptation. In Venezuela, the materials were inoculated with oospores of *Cenicilla* to test their reaction to downy mildew disease.

Results of the introduction trial planted in Bolivia, at Saavedra and Mairana in the state of Santa Cruz are shown in Table 2. Results indicated that the varieties Tuxpeño Caribe, Pool 25 and Tuxpeño 1 are adapted at both locations and yielded substantially more than the best Bolivian variety Cubano Amarillo.

At Pichilingue, Ecuador, some of the materials from Colombia showed good yield potential. Two populations, MB-219 and MB-29, yielded 6.2 and 6.1 t/ha, respectively. Some of the CIMMYT materials also showed good yield potential at this site. Seven varieties yielded more than INIAP 515 (4.9 t/ha) and one outyielded Pichilingue 504 (5.5 t/ha), the two local checks.

In the trial at Maracay, Venezuela, under artificial infestation of oospores of

Table 2.

Maize varieties from Colombia, Peru and CIMMYT that performed the best in a introduction trials at two locations in Bolivia, 1977-78

		Yield (kg/ha) at:			
Variety	Origin	Saavedra	% of control	Mairana	% of control
Tuxp. Caribe	CIMMYT	7956	161	5333	125
Pool 25	CIMMYT	6185	125	5120	120
Tuxpeño-1	CIMMYT	6615	134	4267	100
ETO Blanco	Colombia	5382	109	4693	110
Blanco Cristalino	CIMMYT	6491	131	4053	95
Mezcla Amarilla	CIMMYT	6025	122	4053	95
PM-701	Peru	5236	106	4267	100
MB 225	Colombia	4882	99	4053	95
Pob.-1	Peru	4863	98	4053	95
Cubano Amarillo	Bolivia	4954	100	4267	100

downy mildew, 10 materials (seven from Colombia and three from CIMMYT) showed good resistance to the disease.

From the results of these introduction trials and trials of experimental varieties from CIMMYT, in 1979, INIAP is testing nine varieties from which one or more could be released to the farmers.

At the end of 1977, 36 varieties of hard endosperm, opaque-2 maize were sent to Ecuador, Bolivia and Peru to be planted in an observation lot. These materials came directly from the opaque maize program at CIMMYT. Results were provided for the plantings at two locations and showed that Mezcla Tropical Blanco HEO_2 and Mezcla Amarilla HEO_2 were the best yielders at over 6 t/ha at the two locations.

Regional Trials

The year 1978 was the second year for planting Regional Trials of Tropical Varieties (ENZAT) and Regional Trials for Highland Varieties (ENZAS). These trials include the best varieties and the best open pedigree hybrids from each Andean country. Each country contributes six materials.

For the ENZAT trial information was obtained from three of seven locations where it was planted and is presented in Table 3. The table includes only the three highest yielding varieties or hybrids for each country.

Information is available for two of the five locations where the ENZAS trial was planted. The best variety at both locations was Pairumani Compuesto 10, which was also the best yielder in the 1976-77 ENZAS in three of the four locations where it was planted.

Breeding Methods

One of the responsibilities of the CIMMYT/CIAT Andean Regional Maize Unit is that of advising and collaborating in the implementation of breeding methods for maize that will permit better use to be made of the facilities available in the various countries, the people of each country and the diverse ecological zones making up the tropical and highland Andean region.

In this respect, a full-sib breeding program has been initiated in which the Suwan-1 population is subjected to cyles of progeny trials in the five Andean countries and one cycle of regeneration of the population in accord with the data obtained in the localities the progeny trials were planted.

Suwan-1 was chosen for the project because it has a good yield potential and resistance to downy mildew. At Maracay, Venezuela, 37% of the families from Suwan-1 were resistant to *Cenicilla* (0 to 10% of plants affected). Another 28% of the families showed an intermediate reaction (11 to 20% of plants affected) and 35% were susceptible (21 to 80% reactions).

Integrated Control of Heliothis zea

Perhaps one of the most pressing problems affecting maize in the Andean highlands is attacks from the corn earworm, *Heliothis zea*. Because maize is almost totally planted under subsistence conditions in the highlands, the use of insecticides for controlling this insect is considered very difficult to bring about because of the high cost and due to the risk of environmental contamination.

For these reasons, the Maize Unit is cooperating in the implementation of an

Table 3.

Results of the 1977-78 Lowland Variety Trial (ENZAT) in three locations of the Andean Zone.

			Yield (t/ha)			
			Bolivia		Peru	Avg. at all sites
Variety No.	Identification	Origin	Abapo	Saavedra	San Ramon	
1	ICA V-105	Col.	2.34	3.66	5.56	3.85
4	ICA H-210	Col.	3.11	3.22	5.28	3.87
5	ICA H-302	Col.	1.28	3.11	5.83	3.40
8	Comp. Semicrist. 71	Ven.	2.40	3.51	5.33	3.74
11	Var. Simeto White	Ven.	2.13	3.66	5.19	3.66
12	Comp. Intervar. 68	Ven.	1.18	3.78	4.94	3.30
14	PMC-5	Peru	1.97	3.01	5.66	3.54
16	POB-1	Peru	2.03	3.66	4.34	3.34
18	PMC-747	Peru	2.14	3.77	5.15	3.68
19	Suwan-1	CIAT	2.32	4.60	4.52	3.81
20	Ant. x Rep. Dom.	CIMMYT	2.90	4.01	5.79	4.23
22	Var. 3 Pichilingue	Ecua.	2.61	4.00	4.33	3.64
24	Pichilingue 513	Ecua.	1.50	2.90	5.58	3.32
26	INIAP 515	Ecua.	2.30	3.41	4.44	3.38
27	Tuxp. P.B.C-2	Bol.	1.03	4.22	5.86	3.70
29	Cubano Amarillo	Bol.	2.22	4.41	5.03	3.88
30	Comp. BR2 Yellow	CIAT	1.90	2.41	5.11	3.14
	X		1.87	3.45	4.73	
	C.V. (%)		29.6	24.2	27.1	
	L.S.D. (0.05)		0.89	1.34	2.05	

integrated control system for controlling *H. zea* by integrating biological, chemical and cultural control methods. Work jas been started to identify varieties of maize that are resistant to this pest in five localities and trials with selective insectivides and biological agents such as *Bacillus thuringiensis* have been initiated at eight sites.

Training

The CIMMYT/CIAT Andean Regional Maize Unit has the responsibility, along with national program leaders, of identifying and interviewing candidates to receive in-service training at CIMMYT, Mexico. Up to the present, 46 professionals from the Andean Zone have received training in research and production at the Center. Of the 22 who have been sponsored by the Andean Regional Maize Unit, 20 are still working in maize in their respective countries. Of the 24 sent to Mexico before 1976, only 8 are still working in maize. Nine visiting scientists sponsored by the Maize Unit have visited the maize program at CIMMYT.

Development and Transfer of Technology

The long-range effectiveness of a national program is more probable when

Table 4.

Results of 1977-78 Highland Variety Regional Trial (ENZAS) grown at two locations.

		Santa Catalina, Ecuador			Cajamarca, Peru		
Var. No.	Identification	Days to flowering	Plant height (cm)	Yield (t/ha)	Days to flowering	Plant height (cm)	Yield (t/ha)
1	PMC-561	113	189	3.0	99	243	5.2
2	UMUTU	123	204	3.5	110	270	6.0
3	PMV-461	129	236	5.2	114	253	5.0
4	PMS 635	92	147	2.2	87	166	2.7
5	Comp. Amarillo Duro	112	205	6.3	100	203	5.1
6	B.U. x O	118	182	3.2	104	211	5.2
7	ICA 453	133	215	4.1	116	265	5.3
8	ICA V-506	123	237	3.5	106	259	3.2
9	ICA V-505	114	220	4.3	102	249	4.0
10	MB 54-MPR-VII	116	237	5.7	102	243	4.4
11	ICA V-555	120	215	3.6	105	238	3.4
12	Morocho Amarillo	131	236	2.8	124	257	1.6
13	INIAP 176	131	264	5.8	120	281	4.4
14	INIAP 126	105	210	5.3	94	230	3.9
15	INIAP 125	117	241	4.2	107	261	3.4
16	INIAP 153	118	220	6.4	104	282	4.3
17	INIAP 128	125	207	4.3	108	269	2.6
18	INIAP 178	131	234	5.0	112	281	5.0
19	Pairumani Choclero-1	108	185	1.8	97	222	4.2
20	Pairumani Choclero-2	104	145	3.1	97	232	4.3
21	Pairumani Comp. 10	123	214	6.7	104	260	7.2
22	Pairumani Aychasara-2	113	188	4.6	100	246	4.3
23	Pairumani Comp. 13	113	178	3.8	96	212	4.6
24	Pairumani TC-1	101	129	2.8	92	170	4.7
25			INIAP 101			Bco-Imperial	
		90	166	4.3	92	203	3.1
	Averages	100	167	4.2	90	166	4.3

it: (1) is independent of outside aid for continuity; (2) efficiently utilizes all internal resources; (3) recognizes and answers the needs of the small farmer; and, (4) maintains the flexibility to permit changes for meeting various problems encountered. Using this philosophy, the primary objective of the CIMMYT/CIAT Andean Regional Maize Unit is to assist national leaders in developing production programs which are autonomous, integrated, small farmer-oriented, and flexible.

The strategy being used to attain these objectives is in four phases: surveying farmers by regions, planning of the regional program, placing on-farm trials, and diffusing recommendations through on-farm demonstration trials. The CIMMYT/CIAT team directly participates in the first three phases. Programs using this strategy are underway in three countries.

Program Development

Peru. In collaboration with the Programa Cooperativo de Investigación de Maíz (PCIM) and the Ministry of Agriculture a production technology program is in various stages of development in five highland areas.

In the area of Callejón de Huaylas the farmer survey was conducted in 1977 and the first set of verification trials were harvested in 1978. These trials were designed to compare improved varieties from PCIM with local varieties under three levels of management. Although the data are inconclusive due to rather large experimental error, indications are that the PCIM varieties are not significantly better than local varieties under any system of management tested. Trials were re-designed with the hope of diminishing the experimental error to an acceptable level and were planted in October of 1978.

In the Cuzco area, the agro-economic survey was conducted. This survey included the Valleys of Urubamba and Vilcanota and the zone of Anta-Maras. Seven recommendations domains were identified and the relative importance of maize in each domain was determined. With the exception of the Valley of Urubamba and the irrigated region of Anta, maize is grown for family consumption. In the two regions mentioned, 40 and 29%, respectively, of the maize is sold commercially.

Limiting factors in maize production vary across recommendation domains with insects and diseases being major factors at the lower altitudes and frost damage at higher altitudes. One factor which is limiting across all domains is use of fertilizer.

The agro-economic survey was also completed in the Valley of Mantaro. Since this area constitutes one agroclimatic zone, recommendation domains were determined by agronomic practices with two domains— irrigated and non-irrigated systems — being identified. Limiting factors in maize production are use of unimproved varieties, lack of adequate fertilization, corn earworm and frost.

Trials planted in these three areas plus the areas of Ayacucho and Cajamarca included the following.

Fertilizer Trials: 3 x 3 x 2 factorial with three levels of N, three levels of P and two levels of K.

Nitrogen x Density: 3^2 factorial with three levels of each factor.

Verification; Randomized block comparing improved and local varieties at different management levels.

Levels of factors vary in accordance with farmer practices within the area.

Colombia. The program in Colombia has centered around the identification of superior varieties for two distinct maize areas — the Departmentos of Antioquia and Cauca. This work is carried out in collaboration with both ICA and DRI in Cauca and the Secretary of Agriculture and ICA in Antioquia. Variety trials consisting of ICA varieties, CIMMYT experimental varieties, and local checks were planted in both regions, during 1978.

The first in-service training course was held in Medellin in August and the second in December with 15 agronomists in attendance. A training course was planned for personnel of Cauca, but was cancelled and is now scheduled for 1979.

A preliminary survey was made of the Urabá region of Antioquia and the decision made to concentrate more on this major maize area. A more detailed survey is planned for 1979. The initial survey indicates the limiting factors in maize production are scarcity of labor for land preparation and inadequate fertilization. Development of an adequate minimum tillage system which includes economically sound fertility levels is one goal for the program.

Having tentatively identified superior varieties the program is now expanding to include fertilizer trials and fertilizer x density trails.

Ecuador. The production technology program, under the direction of INIAP with CIMMYT collaboration, completed the first cycle of on-farm testing harvesting ten trials in the region of Imbabura. In variety trials INIAP 101, derived from Cacahuazintle, was 45 days earlier than the local variety. In the initial farmer survey this was shown to be a desirable characteristic. Earliness allows the farmer to market his "choclos" at a higher price, while also allowing him to use the residual moisture for a second crop such as peas. The results of fertilizer trials were variable across location indicating the need for better definition of recommendation domains with respect to this production factor.

In September, the second cycle of on-farm testing was begun with the planting of 26 trials in 13 locations. These trials were planted as a part of the in-service training course conducted by INIAP and attended by 25 agronomists from INIAP, the Ministry of Agriculture and the Agriculture Bank. The second phase of the training course was held in November.

The litoral trials were placed in the area of Balzar. The most significant result of these trials was that the economic analysis showed the level of fertilizer application used by the farmer was, in fact, the most practical and economic choice.

Bolivia. Preliminary work has been carried out in Bolivia with plans to initiate a collaborative production technology program in 1979.

Venezuela. Collaborative research will begin between the CIMMYT/CIAT Andean Regional Maize Unit and FONAIAP in early 1979. Farmer surveys will be done in the state of Portuguesa and the area of Valle de la Pascua, by FONAIAP. Collaborative efforts will be centered in these areas for 1979 with the establishment of fertilization trials.

Price Waterhouse & Co.

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

February 16, 1979

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, 1978 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, 1978, 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	1978	1977	1976
CURRENT ASSETS: -			
Cash	3,540	2,481	1,481
Accounts receivable:			
Donors	93	288	1,616
Employees	92	91	57
Others	992	1,091	425
	1,177	1,470	2,098
Inventories	678	549	345
Prepaid expenses	9	10	11
Total current assets	5,404	4,510	3,935
FIXED ASSETS:			
Equipment	2,450	2,104	1,963
Airplane	664		
Vehicles	1,575	918	685
Vehicles (replacements) in transit	74	192	149
Furnishings and office equipment	1,177	1,103	938
Buildings	5,616	4,954	4,773
Other	160	69	25
Total fixed assets	11,716	9,340	8,533
Total assets	17,120	13,850	12,468
LIABILITIES AND FUND BALANCES			
CURRENT LIABILITIES:			
Bank overdraft	182		18
Short-term portion of long-term debt	200		
Accounts payable	1,702	1,542	807
Total current liabilities	2,084	1,542	825

	December 31		
	1978	**1977**	**1976**
Forward	2,084	1,542	825
LONG-TERM DEBT	650		
Less - Short term portion	200		
	450		
GRANTS RECEIVED IN ADVANCE	667	228	180
FUND BALANCES:-			
Invested in fixed assets	11,716	9,340	8,533
Unexpended funds (deficit):			
Core -			
Unrestricted	82		70
Working fund	206	700	600
Capital grants	763	1,689	1,964
Special projects -			
Donors	1,216	442	315
Other	(64)	(91)	(19)
	2,203	2,740	2,930
Total fund balances	13,919	12,080	11,463
Total liabilities and fund balances	17,120	13,850	12,468

The notes on pages I-6 and I-7 are an integral part of the financial statement.

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		
	1978	**1977**	**1976**
Revenue: —			
Core:			
Operating grants -			
Unrestricted	9,307	7,847	4,500
Restricted	320	310	1,145
Working fund grant	100	100	
Capital grants	786	498	1,858
Total Core	10,513	8,755	7,503
Special projects	2,107	785	725
Earned income	502	499	339
Total revenue	13,122	10,039	8,567
Expenditures: —			
Core programs:			
Direct research -			
Beans	1,102	931	698
Beef	1,754	1,258	831
Cassava	939	743	573
Rice	204	239	206
Swine	180	144	150
Genetic resources	221	139	
Special studies	55	62	
	4,455	3,516	2,458
Research support	1,262	1,011	602
Total research	5,717	4,527	3,060
International cooperation:			
Training and conferences	754	798	634
Library and information services	853	693	515
Total international cooperation	1,607	1,491	1,149

	Year ended December 31		
	1978	**1977**	**1976**
Administration expenses	966	836	670
General operating costs	1,687	1,471	999
Technical Advisory Committee - Expenses of quinquennial review		63	
Total Core programs	9,977	8,388	5,878
Special projects	1,306	730	710
Purchases of fixed assets	2,376	1,111	418
Total expenditures	13,659	10,229	7,006
Excess of revenue over expenditures:			
Operating grants	82	(70)	(233)
Working fund	170	100	
Capital grants	(1,590)	(275)	1,779
Special projects	801	55	15
	(537)	(190)	1,561
Transfer between funds:			
From working fund	(664)		
To capital grants	664		
	(537)	(190)	1,561
Unexpended funds at beginning of year	2,740	2,930	1,369
Unexpended funds at end of year (see balance sheet)	2,203	2,740	2,930

The notes on pages I-6 and I-7 are an integral part of the financial statement.

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	41.00	Year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	39.11	Average monthly rate of exchange applicable to sales of dollars.

NOTE 3 - OPERATIONS:

The agreement with the Colombian government under which CIAT operated expired in October 1977 and is in the process of being renewed. Officials of CIAT are of the opinion that the original agreement will be extended for an as yet undefined period of time.

NOTE 4 - ACCOUNTS RECEIVABLE FROM DONORS:

Accounts receivable from donors as at December 31, 1978 comprised:

	$000
Government of the United Kingdom: Balance of 1978 grant (operating)	59
Others (special projects)	34
	93

NOTE 5 - LONG-TERM DEBT:

The long-term debt is payable to the Bank of America, New York in three instalments between June, 1979 and June, 1981. The interest rate is 1¼% above the prime rate of the Bank of America.

This debt is guaranteed by pledge of CIAT's airplane.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPLEMENTARY INFORMATION
ANALYSIS OF GRANTS AND RELATED EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1978
(Expresed in thousands of U.S. dollars)

SCHEDULE 1

	Total funds available	Expenditures: Fixed assets	Expenditures: Total research	Expenditures: International cooperation	Expenditures: Adminis-tration	Expenditures: General operating	% of administration and general operating to research and international cooperation	Transfer to unexpended balance
Unrestricted Core:								
Government of Australia	182							
Government of Belgium	157							
Canadian International Development Agency	982							
The Ford Foundation	200							
Government of the Federal Republic of Germany	1,096							
Inter-American Development Bank	2,400							
International Development Association	203							
Government of Japan	200							
Government of the Netherlands	200							
Government of Norway	207							
The Rockefeller Foundation	300							
Government of Switzerland	228							
United States Agency for International Development	2,600							
Government of the United Kingdom	352							
Income applied in year	432							
Total unrestricted Core	9,739		5,717	1,373	934	1,633	38	82
Restricted Core:								
The W.K. Kellogg Foundation	320							
Total restricted Core	320			234	32	54	37	
Working fund:								
International Development Association	100							
Income applied in the year	70							
Balance from previous year	700							
Transfer to capital grants	(664)							
Total working fund	206							206

SCHEDULE 1
page 2

	Total funds available	Expenditures: Fixed assets	Total research	International cooperation	Adminis-tration	General operating	% of administration and general operating to research and international cooperation	Transfer to unexpended balance
Capital grants:								
Inter-American Development Bank	235							
International Development Association	520							
Others	31							
Balance from previous year	1,689							
Transfer from working fund	664							
Total capital grants	3,139	2,376						763
Special projects (1):								
Government of Belgium	91		8					83
CIMMYT (Canadian International Development Agency)	123			66	8	9		40
The Ford Foundation	55			14				41
German Agency for Technical Cooperation, Ltda.	70		63					7
Inter-American Development Bank	72		10	62				
International Board for Plant Genetic Resources	25							25
International Development Research Centre (Canada)	336		155	43	13	12		113
International Fertilizer Development Center	83		76		6	6		(5)
International Rice Research Institute	88			83				5
The Rockefeller Foundation	70			20				50
Government of Switzerland	637							637
United Kingdom - Ministry of Overseas Development	8		8					
United Nations Development Programme	699			483	19	18		179
United States Agency for International Development	56			93	6	7		(50)
Others	45		3	15				27
Total special projects	2,458		323	879	52	52	9	1,152
Total grants and expenditures	15,862	2,376	6,040	2,486	1,018	1,739	32	2,203

(1) Includes balances brought forward from previous year of US$351,000.

SCHEDULE 2

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1978
(Expressed in thousands of U.S. dollars)

Sources of earned income:	
Interest on deposits	171
Sale of farm produce and services	102
Use of CIAT facilities	159
Charges to programs for use of airplane	70
	502
Applied to:	
Operations	432
Working fund	70
	502

SCHEDULE 3

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
COMPARISON OF APPROVED BUDGET AND ACTUAL EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1978
(Expressed in thousands of U.S. dollars)

	Core unrestricted		Core restricted		Capital	
	Aproved budget*	Actual	Approved budget*	Actual	Approved budget*	Actual
Programs						
Direct research:						
Beans	1,072	1,102				
Beef	1,929	1,754				
Cassava	959	939				
Rice	300	204				
Swine	196	180				
Genetic resources	250	221				
Special studies	98	55				
Research support	1,286	1,262				
International cooperation:						
Training and conferences	632	598	215	209		
Library and information services	799	775	25	25		
Administration	903	934	29	32		
General operating costs and other	1,565	1,633	51	54		
Total	9,989	9,657	320	320		
Capital						
Fixed assets					2,444	2,376
Total					2,444	2,376
Analysis of variances						
Budget deficit:						
Transfer from working fund						(664)
Budget surplus:						
Increase of approved budget not used		250				
Transfer to unexpended balance		82				732
Total		332				68

* 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, 1978
(Expressed in thousands of U.S. dollars)

	Rec. at beg. of year	1978 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at yr. end	1979 rec. in adv.	Net 1978 grants
Unrestricted Core:																	
Government of Australia				182													182
Government of Belgium	(149)		149											157			157
Canadian International Development Agency								982									982
The Ford Foundation					50	50			50			50					200
Government of the Federal Republic of Germany			187			319			317			273					1,096
Inter-American Development Bank					960				576		144		720				2,400
International Development Association												453				(250)	203
Government of Japan							200										200
Government of the Netherlands						133	67										200
Government of Norway						207											207
Government of the United Kingdom					144		72					59		18	59		352
The Rockefeller Foundation			154	9	9	9	9	7	8	10	8	7	60	10			300
Government of Switzerland		228												300		(300)	228
United States Agency for International Development					650			650		600	550		150				2,600
	(149)	228	490	191	1,813	718	348	1,639	951	610	702	842	930	485	59	(550)	9,307
Restricted Core:																	
The W.K. Kellogg Foundation						320											320
						320											320
Working fund:																	
International Development Association												100					100
												100					100

SCHEDULE 4

page 2

	Rec. at beg. of year	1978 rec. in adv.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Rec. at yr. end	1979 rec. in adv.	Net 1978 grants
Capital grants:																	
Inter-American Development Bank					100				60				75				235
International Development Association				500								137				(117)	520
Government of the United Kingdom	(48)		48														
Others						7								24			31
	(48)		48	500	100	7			60			137	75	24		(117)	786
Special projects:																	
Government of Belgium	(41)		41		(28)	(8)								88			52
CIMMYT (Canadian International Development Agency)				59						23	30			14			126
German Agency for Technical Cooperation, Ltd.			17	8			27					19					71
Inter-American Development Bank											(33)	67					34
International Board for Plant Genetic Resources														25			25
International Development Research Centre (Canada)						58		36	58	48				29			229
International Fertilizer Development Center											30			11			41
International Rice Research Center	(8)		8		82	(26)		22						21			99
The Rockefeller Foundation							(15)	2									(13)
Government of Switzerland														637			637
United Kingdom - Ministry of Overseas Development														(18)			(18)
United Nations Development Programme						174		373					174				721
United States Agency for International Development								48		16	27			13			104
Others	(42)		3			3	3		3			1	5	(11)	34		(1)
	(91)		69	67	54	201	15	481	61	87	54	87	179	809	34		2,107
	(288)	228	607	758	1,967	1,246	363	2,120	1,072	697	756	1,166	1,184	1,318	93	(667)	12,620

Communication Support Unit staff
cooperating to produce this report were:

Editor:	Charles E. Bower
Editorial Assistant:	Alexandra Walter
Production supervisor:	Walter Correa
Cover and graphics:	Didier González Correa
Design supervisor:	Carlos Rojas Vale
Mounting:	Oscar Idárraga
	Camilo Oliveros
Text composition:	
(programming) supervisor:	Orfa Vásquez Orejuela
(perforating):	Janeth Loaiza Tamayo
	Yolanda de González

PRINTED BY
editorial XYZ
CALI - COLOMBIA