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CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out mainly at its Experimental Centers at Turipaná and Carimagua. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research. During the current year these donors are the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the Canadian International Development Agency (CIDA), the W. K. Kellogg Foundation, the International Bank for Reconstruction and Development (IBRD) through the International Development Agency [illegible] and the governments

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Editor's note: Since the degree "Ingeniero Agrónomo" (Ing. Agr.) has no academic equivalent in English, we have written it in its Spanish form.

Foreword

Three major developments on the world scene significantly influenced CIAT's research, training and outreach program strategies for 1974 and beyond. One of these was the world-wide fertilizer and energy crisis and the attendant fast-rising prices for fertilizers, agrochemicals and fuel. The second was the high priority that international and regional technical assistance and agricultural credit agencies placed on programs designed to alleviate rural poverty through massive rural development efforts. The third was the international community's increased concern regarding the necessity of finding ways to stimulate and facilitate the research and production programs of developing nations.

All of these events and efforts served to reinforce and confirm the validity of CIAT's basic mission to accelerate agricultural and economic development and to increase agricultural production and productivity of the lowland tropics so as to improve the diets and welfare of the people of the world. In carrying out its mission, CIAT works in concert with governments, educational and research institutions, and private enterprise in both the developed and developing worlds. Initially, CIAT has concentrated its activities in Latin America; but with certain programs it operates on a world-wide basis.

CIAT's present strategy with respect to fertilizer assumes that current shortages are a result of fluctuations in the business cycles within the fertilizer industry rather than a shortage of raw materials. Rapid increases in the supply of phosphate and nitrogen fertilizers are expected to occur in two and four years, respectively. But relatively high fertilizer prices are likely to continue because of increased production costs and growing demands for the product.

Therefore, CIAT research has focused on the problem of higher fertilizer prices rather than absolute shortages. As the price of chemical fertilizer increases, it becomes more profitable to seek alternative sources of plant nutrients. Furthermore, the optimum quality of chemical fertilizer per unit of land decreases unless the fertilizer response is increased. In research being carried out at present by CIAT staff members, emphasis is placed on biological and organic sources, as well as ways of improving fertilizer efficiency.

Biological nitrogen fixation by **Rhizobium** and rhizosphere organisms and phosphate solubilization by organisms such as **Endogone** and **Thiobacillus** have shown promising possibilities as alternatives to chemical fertilizers. Tropical forage legumes, when properly inoculated, fix substantial amounts of nitrogen, as do tropical grain legumes. Microbial factors affecting phosphate solubility offer excellent possibilities for improved utilization of phosphate, but the inoculation of soil with endotrophic micorrhizal fungi must yet be tested under practical farm conditions.

CIAT's present microbiology research is limited to grain legumes, and short-term benefits from biological plant nutrition research and training on grain legumes are most likely to come from legume-**Rhizobium** studies. Lack of trained personnel is the principal limiting factor in this work in Latin America; this is taken into account when selecting persons for postgraduate training at CIAT.

Additional field testing is needed to assure that specific ecotypes of tropical pasture legumes, primarily **Stylosanthes**, are adapted to prevailing local ecological conditions.

Because of the importance of using green manure crops and crop residues in regions where land is relatively inexpensive and abundant, CIAT has initiated exploratory work on these in the Colombian Llanos.

Ongoing research at CIAT is aimed at improving technical and economic efficiency of chemical fertilizers through (a) breeding and selection for varieties with fertilizer response, particularly at low levels of application, and/or improved capacity to extract nutrients from the soil; (b) agronomic studies on fertilizer application practices; and (c) reduction of yield losses from diseases, insects, weeds and adverse rainfall conditions.

Specific research objectives along these lines, as well as progress made in 1974, are detailed in the commodity sections of this report. Attention to these matters has led CIAT to test promising material on low fertility soils without fertilizer, to give more attention to the timing and placement of fertilizer, and to carry out plant nutrition research as part of an agricultural research system in which the parts are highly related.

Research on improved weed control methods deserves particular attention. The economic payoff of weed control increases as nitrogen prices rise. Inexpensive nitrogen may be used to improve the crop's competitive position relative to weeds, thereby reducing the need for other weed control measures. Because of this, breeding emphasis in rice, for example, was changed to seek a somewhat taller plant that would be more competitive with weeds and more tolerant of water shortages and soil deficiencies.

Since international assistance agencies are making large investments in the developing countries, steps were taken in 1974 to link these efforts, both formally and informally, with those of CIAT and other international centers.

In March, 1974, the directors of the international agricultural centers met at CIAT with representatives of the International Bank for Reconstruction and Development and again at Washington, D.C., during International Centers' Week. They learned more about the work of the World Bank and explored ways whereby outreach programs might develop in concert with these efforts, particularly with respect to rural development programs being undertaken in many countries.

Later, the United Nations Development Programme and the Food and Agricultural Organization sponsored a workshop at CIAT, where representatives of some seven international and regional centers exchanged views with the UNDP–FAO representatives and their counterparts from Latin American countries on ways to accelerate the application of agricultural research developments in Latin America. Plans for a similar meeting involving the representatives of the United States Agency for International Development in Latin America were being developed at year-end.

In late 1973, the three international centers in Latin America (CIP, CIMMYT and CIAT) met with Interamerican Development Bank representatives and developed a basis for a continuing program of special project support for training and outreach activities of joint interest to the centers and IBD.

CIAT administration and staff, through such interactions, have been able to identify ways of operating more effectively in CIAT-country relationships. In addition, this interaction helps to establish research priorities and a within-country framework for sharply concentrated research and the recruiting and training of research workers and production specialists. This, in turn, enhances the likelihood that these persons will be utilized effectively after training.

Although CIAT attends initially to the problems of lowland agriculture in Latin America, it is also concerned with research and production problems in other areas, particularly with respect to those commodities for which no other center has major responsibility. At present, these commodities are beef, swine, cassava and field beans. In addition, working agreements with other centers provide mechanisms for the exchange of germplasm and information.

Many international agencies and countries have provided funds and technical assistance for national research and production programs of the developing countries for years, in fact long before the international agricultural research centers began operating. But continued pressures of population growth and the continuing world food shortages since 1972 have emphasized that the major burden for increasing food production falls on the national organizations of the developing countries. In addition to carrying on adaptive and applied research to tailor new varieties and technologies emerging from the international centers, the many socio-economic aspects of agricultural development can be handled only by the national agencies themselves.

These concerns have been articulated by the Technical Advisory Committee of the Consultative Group for International Agricultural Research, by the Consultative

Group itself, by the Bellagio VI Conference, and more recently, by the World Food Conference.

One of CIAT's major operational objectives is to be catalytic in collaborating and cooperating with national institutions throughout the lowland tropics. The administrative and scientific staff, through consultation with national leaders, the selection of young scientists and production specialists for training, the development of cooperative research programs, and the facilities for exchanging germplasm and information, contribute directly to helping national agencies not only to cope with the problems of today but also to increase their capacity to deal with the problems of tomorrow.

Directly related to this concern was the workshop on "Methods Used to Allocate Resources for Applied Agricultural Research in Latin America." This brought together some 35 agricultural research managers, agricultural scientists, donor representatives, national planners, systems engineers and economists at CIAT in November. Workshop analyses of methods currently used to establish priorities and allocate research priorities in four national and international research organizations clearly demonstrated the need for more information on the relative expected payoffs of alternative research strategies. The scarcity of information on relative importance of existing researchable problems at the farm level and the characteristics of technology preferred by the farmer was obvious. Furthermore, information on the expected contribution of alternative lines of research designed to achieve socioeconomic goals seemed almost completely lacking.

A few national research institutions are attempting to develop methods for improved resource allocation. These attempts seem to suffer from either excessively bureaucratic procedures for project selection or analytical frameworks which are too general to provide useful information. Relevant data are extremely scarce.

Over the past three years, CIAT has developed some methodologies for identifying and assessing the magnitude of production problems in various crops at the farm level. These studies, in turn, guide the scientists in carrying out trials to assess the relative economic importance of these problems. Once this has been determined, there is a more rational basis for determining the research programs necessary to find solutions to important problems. Through training activities and cooperative projects, CIAT has begun to share these methods with national programs as a contribution to helping national research managers determine how best to use their limited resources.

The following sections report highlights of research and development activities in CIAT's programs during 1974.

Beef. Marked increases in cattle productivity have been obtained through the use of improved grass and legume-grass pastures. Weight gains on molasses grass (**Melinis minutiflora**), a pioneer improved grass, have been four to five times greater than on native grass during the rainy season, although there were weight losses during the dry season. Even higher weight gains have been obtained on stylo grass-based pastures as compared with native grass. Stylo (**Stylosanthes guyanensis**), a tropical forage legume, is much higher in protein than grasses, is drought resistant,

and with soil **Rhizobia** can symbiotically fix atmospheric nitrogen in the soil. During the dry season, cattle on stylo-based pastures gained 310 to 370 grams/head/day, whereas cattle on native and improved grasses lost 202 to 610 grams/head/day.

Complete mineral supplementation increased calving percentages of cows grazing native grass by 50 to 75 per cent. Protein supplementation during the dry season enabled steers grazing molasses grass pastures to gain 10 kilograms, whereas non-supplemented steers lost 55 kilograms.

Early weaning of calves at 2 1/2 months enabled cows grazing native and molasses grass pastures (on a marginal level of nutrition) to rebreed. All early weaned calves were healthy and nearly as heavy as nursing calves.

Surveys have encountered the breeding diseases brucellosis, leptospirosis and infectious bovine rhinotracheitis in the Llanos Orientales. Incidence of the hemoparasite diseases anaplasmosis and babesiosis has been variable, anaplasmosis being generally endemic and babesiosis, spotty. On the North Coast, where there are higher cattle densities, both hemoparasite diseases appear to be highly endemic.

Swine. Studies on small farms show that the feeding of vitreous endosperm, high-lysine maize and a protein supplement made available through national institutions has greatly altered the efficiency and economics of swine production. Farmers' native and native crossbred pigs gained more than 400 grams per day and produced a 16 per cent net profit when the new feeding system based on farm-grown high lysine maize and a protein supplement was used.

Efficient feeding systems have been developed to use fresh cassava, cassava meal or cassava silage. Utilization of these three forms of cassava will make it possible to develop swine production in areas where cassava is the major source of energy for swine.

Offspring of native sows crossed with boars of an improved breed grew at a rate and efficiency equal to that of offspring of the improved breed. This improvement represents less time to market and more economical gains.

Animal health studies indicate that foot-and-mouth disease, diarrhea, abscesses, arthritis and abortions are the diseases that limit swine production the most in the region studied. Economic models of monetary losses were developed on three pig farms where outbreaks of foot-and-mouth disease occurred. The calculated losses of US$ 42,293; $ 37,007 and $ 7,339 on the three farms studied clearly indicate the severity and importance of this disease.

Cassava. A yield of 46 ton/ha of cassava was obtained after 12 months on relatively poor soils, using limited inputs on a farmer's field near CIAT. A variety similar to that which produced the highest yield recorded at CIAT has been used extensively in the breeding program.

The germplasm has now been completely evaluated for agronomic characters, and testing of the first hybrids is well under way. The most promising types selected so far are being field tested in 14 areas of Colombia.

Resistance to most major diseases and pests has been encountered, and rapid screening methods are being developed. Weeds can be controlled effectively by three hand weedings; however, less vigorous weed control is needed when plant population is increased.

The plant ideotype for cassava requires a balance between root and stem production so that a leaf area index of three to four is maintained through a long leaf life.

Tentative critical levels for nutrients in leaves have been determined and marked response to fertilizer was found, particularly to potassium.

An economics survey shows that most cassava in Colombia is grown under monoculture and is attacked by a large number of diseases and pests. Certain practices, such as plant density, appear to be less satisfactory than those used for optimum production.

Field Beans. Fertilizer and other chemical shortages, as well as imbalances in international trade, have increased the price of many farm inputs for both large and small farmers. To counter this, the program has stressed development of technology which would insulate farmers against changing economic and supply problems.

Yields of close to 3,000 kg/ha were obtained in replicated yield trials in Colombia. Disease-free seed was made available to a number of national programs. Using such materials, farmers in one area of Guatemala raised average yields from 515 to 1,545 kg/ha.

Varieties resistant to the leafhopper, **Empoasca**, and to plant pathogens such as common mosaic virus, web blight, rust and bacterial blight were identified.

With initial characterization of 10,371 accessions in the germplasm bank well under way, a crossing program was initiated with the most promising selections.

Studies comparing conventional maize-beans association with climbing beans grown on stakes or trellises showed that the latter system had a considerable yield advantage.

Maize. CIAT's limited staff concentrated on problems of maize production in the Andean zone, and thus served as an outreach activity in CIMMYT's international maize improvement network.

As brachytic short plant materials appear to be more stable for height expression over the photoperiod-temperature regions of the Andean zone, work on these was emphasized. Selection and crossing in two cycles in 1974 helped to identify useful combinations of characteristics in modified brachytic types.

Work continued on five CIMMYT hard endosperm varieties, and grain was produced for biological evaluation with swine in 1975.

In plantings with cassava and yams, drought stress showed no yield response from doubling the plant densities of brachytic, opaque and native varieties. A native variety failed to respond to the presence or absence of cassava or yams grown in association. In a maize-cowpea association trial, the opaque, hard endosperm variety VE-21 did not respond to densities between 30,000 and 70,000 plants per hectare. In addition, the gross income from the association was independent of the relative proportion of the two crops in the system.

Such results indicate the need of further study of associated plantings and the necessity of selecting a plant type that will serve the needs of maize in both monoculture and associated cultures.

Rice. Two varieties developed through the CIAT-Instituto Colombiano Agropecuario rice program, as well as other varieties introduced from IRRI, have made a significant impact on rice production throughout the irrigated areas of Latin America. Data from Colombia illustrate what is happening at a rapid pace in Latin America. Rice production has increased greatly, although total area in rice has not changed significantly. The area in irrigated rice is rapidly expanding and replacing upland rice. Whereas upland yields remain unchanged, yields of irrigated rice have risen from 3 to 5.4 tons per hectare since 1966. Dwarf rices have almost totally displaced traditional varieties and now occupy 98 per cent of the irrigated rice area of Colombia.

Blast resistance is now the primary objective of the program, and all crosses involve one or more blast-resistant parents.

In 1974, CIAT–ICA released CICA 6 as a blast-resistant, dwarf, improved grain quality variety. This stopgap variety lacks adequate vegetative vigor, and its blast resistance is not expected to prevail for more than one or two years of commercial planting.

Given the cost and unavailability of nitrogen fertilizer, breeders now seek material 15 to 20 centimeters taller than the usual height of present dwarf varieties. This increased height and vegetative vigor are expected to enable the rice plant to compete better against weeds without serious danger of lodging. At the same time, it seems likely that improved control will tend to replace liberal applications of fertilizer in farming practice.

Small Farm Systems. After exploratory studies of five sites in Latin America, the research unit selected two locations: La Máquina, a recent settlement on the South Coast of Guatemala, and Cacaotal, an established village on the North Coast of Colombia, for in-depth studies of the factors limiting production on small land holdings.

Experience during the past year has led to a focus on several critical issues which are basic to the goal of increasing production on the small farm, and these will be studied by the group. These factors include questions related to multiple cropping, choices among alternative inputs when capital is limited, efficiency of legume-based nitrogen in cereal-legume intercrop systems, integrated animal schemes based on crop residues, weed control in basic food crops, pest control in subsistence cropping systems, and appropriate mechanization for the small farm.

Training and Conferences. CIAT's growing international involvement was reflected in 1974 in the numbers and distribution of trainees—162 persons from 22 countries. More than 1,600 persons from many countries participated in some 20 national and international conferences, symposia, workshops and short courses.

Library and Documentation Center. In addition to expanding the library collection of books and journals, major activities of the year concentrated on documentation work. The Cassava Information Center reported 3,700 documents, approximately 2,200 of which are fully processed. Additional funding was obtained for documentation work in field beans and animal health. With the support of the Ford Foundation, the Economics Documentation Center for Latin American Agriculture was established in June.

International Programs

Mr. Roland E. Harwood was assigned to work with the Instituto de Ciencia y Tecnología Agrícola (ICTA), becoming the third CIAT staff member to work in this major outreach activity in Guatemala. Mr. Harwood serves as director of ICTA's experiment stations.

CIAT's role in working with this new organization responsible for agricultural technology and its application for increased production is to collaborate in program development, to contribute to institutional structure and policy, to give active and dynamic technological advice, and to provide training.

In cooperation with CIAT, ICTA has evaluated 3,000 lines of field beans and 427 lines of rice for blast resistance. In addition, it has assisted the Small Farms Systems group with a research program at La Máquina and established a swine improvement program.

Administrative Developments

Growth in programs and increased operational costs resulted in greater financial needs, the core and restricted-core operational requirements being met by most of the previous donors plus one new entity. This was the Interamerican Development Bank with a contribution of $ 900,000 to core operations in addition to its already established support for special projects.

With contributions to both capital and special projects, the United Kingdom was the only new donor participating in CIAT funding during 1974.

Terms of two charter members of the Board of Trustees, Mr. Julián Rodríguez Adame (Mexico) and Mr. Edgardo Seoane (Peru), were completed during the year. Elected to succeed them at the annual meeting in 1975 were Dr. Luis S. Paz Silva (Peru) and Dr. Victor Oyenuga (Nigeria).

Much of the Board's work concentrated on its search for a new director general to succeed Dr. U. J. Grant, who was to be recalled for duty with the Rockefeller Foundation before the end of 1974. Work of an active Search Committee culminated at a special meeting of the Board in July; and Dr. John L. Nickel, at that time Deputy Director General of the International Institute for Tropical Agriculture (Nigeria), was chosen as the new Director General of CIAT.

At a special ceremony held at CIAT headquarters November 18, the Board and staff paid tribute to and said farewell to Dr. Grant. On the following day, November 19, Dr. Nickel was installed in a formal ceremony.

The following scientists were named to the senior staff during the year: Dr. Julián Buitrago, nutritionist, swine; Dr. Douglas Laing, physiologist, field beans; Dr. Steven Temple, breeder, maize; and Dr. Kenneth Thompson, acarologist, animal health.

Visiting staff members during the year were Dr. Robert Booth, cassava; Mr. Hernán Rivadeneira, beef; Dr. Leslie Hunt, cassava; and Dr. Stillman Bradfield, small farm systems.

Mr. Petrus Spijkers, rural sociologist, joined the staff as a Dutch associate expert in February on appointment through the Food and Agriculture Organization. He worked with the small farm systems group.

Dr. Radmilo Todorovic arrived in August to lead the Texas A & M University group working with CIAT on animal health problems. Other new staff members from Texas were Dr. Carl T. Kyzar, veterinarian, and Mr. Ray Long, laboratory technician.

Through support from the Rockefeller Foundation, two postdoctoral fellowships were established for the field bean program and were awarded to Dr. Anthony Bellotti, entomologist, and Dr. Yoshikiko Hayakawa, physiologist.

Mr. Luis González, executive officer, resigned in November to accept a position with a commercial firm in Colombia. At year-end, his replacement had not yet been named.

Beef production systems

The basic goal of the Beef Program is to determine and demonstrate the role of beef cattle in the agricultural and economic development of the lowland tropics, in producing protein for human consumption, in creating jobs and generating income, and in facilitating area development.

Specific program objectives are to increase beef production on lands that are not suitable for crop production, as well as the shorter term utilization of potentially arable lands for grazing until necessary infrastructure for crop farming develops.

The specific program focus is on the extensive latosol grassland areas (approximately 250,000,000 hectares) in the Llanos of Venezuela and Colombia, Campo Cerrado of Brazil, Beni of Bolivia, as well as similar lands elsewhere. These soils are generally infertile, and many have limited potential for commercial crop production.

CIAT's principal field program is located at the Carimagua station of the Instituto Colombiano Agropecuario in the heart of the Eastern Plains of Colombia, frequently referred to in this report as the Llanos Orientales.

Marked increases in cattle productivity have been obtained through the use of improved grass and legume-grass pastures at Carimagua. Weight gains on molasses grass (**Melinis minutiflora**), a pioneer improved grass, were as high as 56 kg/ha/year as compared with approximately 15 kg/ha/year on native grass. However, even higher weight gains of approximately 200 kg/ha/year have been obtained when stylo (**Stylosanthes guyanensis**) is included in pastures. Stylo, a tropical forage legume, is much higher in protein than the grasses, is drought resistant, and hosts soil **Rhizobia** which can symbiotically fix atmospheric nitrogen in the soil. During the dry season, cattle on stylo-based pastures gained weight, whereas cattle on native and improved grasses lost weight.

Supplementation often increases productivity and profit in latosol grassland areas. Complete mineral supplementation has increased calving percentages of first-calf heifers grazing native grass. All native and improved grasses grown on these latosols, as well as stylo, are deficient in phosphorus. Protein supplementation during the dry season enabled steers grazing molasses grass pastures to gain weight while nonsupplemented steers lost weight.

Early weaning of calves at 2 1/2 months enabled cows grazing native and molasses grass pastures (on a marginal plane of nutrition) to rebreed. All early weaned calves were healthy and nearly as heavy as nursing calves.

Health status also limits productivity. Survey teams have encountered the breeding diseases brucellosis, leptospirosis and infectious bovine rhinotracheitis in the Llanos Orientales. Incidence of the hemoparasite diseases anaplasmosis and babesiosis has been variable, with anaplasmosis generally being endemic and babesiosis being spotty. On the North Coast, with higher cattle densities, both hemoparasite diseases appear to be highly endemic. Wild animal populations are being checked to determine potential health hazards to man and livestock.

The economists have concentrated on determining the economics of beef production systems in latosol grassland areas. Model simulations have been conducted to determine returns to low cost inputs, such as mineral supplementation, which can be applied in the short term. Companion studies indicate that the establishment of improved pastures, a higher cost input, is economically viable even though temporary negative cash flows are to be expected. Other activities have included a regional workshop on economic aspects of the livestock sector in Latin America and a benchmark study of the livestock sector in collaboration with national institutions in Peru and Ecuador.

A prototype of a family farm unit has been established to provide data and experience on how to make available technology work for small farmers in areas such as the Llanos Orientales. It includes a component to produce food for the farm family and feedstuffs for minor species and a beef cattle component as the principal commercial part of the enterprise.

Work at CIAT, Palmira, as related to the development of highly intensified systems for small farm units in fertile soil areas, indicates that liveweight gains of 2350 kg/ha/year can be produced with fertilized and irrigated napier (elephant) grass (**Pennisetum purpureum**).

A seminar sponsored by CIAT on potentials for increasing beef production in the American tropics was attended by 261 beef production specialists from Latin America and other parts of the world.

CIAT co-sponsored and served as host institution for a seminar on the management of soils and the development process in tropical America in February, 1974. There were 219 participants from 26 countries.

FEED SUPPLY

Malnutrition is the major factor associated with low productivity in beef cattle in the lowland tropics where pastures are markedly deficient in protein and energy in the dry season and often only marginally sufficient in the rainy season. Methods to improve nutrition of grazing animals include improved management of existing pastures, establishment of improved pastures, and supplementation—as necessary—to correct nutritional deficiencies of grazed forages.

Pasture plant introduction and evaluation

The search continues for legumes, both as a component of improved fodder quality and as a nitrogen source. Specific research objectives include selection of legumes for allic* soils with high adaptation to grazing. The genus Stylosanthes shows good promise for such low soil fertility situations. The perennial species **S. guyanensis** demonstrated its value under actual grazing conditions in experiments at Carimagua, where it produced more dry matter under grazing than the annual **S. humilis** cv 'Gordon.' Cumulative yields for the period January to September, 1974 were: **S. guyanensis** CIAT No. 18, 14,037 kg/ha; **S. humilis** cv 'Gordon,' 5,272 kg/ha.

New accessions were collected from sea level to 1,800 meters. Analyses of soils from collection sites indicate the adaptation of some species and biotypes of stylo to a wide range of soil pH, phosphorus and calcium status.

New accessions of stylo collected in Colombia and Venezuela in 1973 were evaluated in space-planted variety trials and in the glasshouse. To assess the genetic variability, yield and growth components of distinctive growth habit types of **S. guyanensis**, 21 accessions were studied in a glasshouse experiment.

A space-planted variety trial containing 37 accessions of **S. guyanensis** was established at Palmira to study dry matter production under a seasonal cutting regime. A similar experiment with 17 accessions was planted at Carimagua. At both sites, under widely different soil fertility conditions, anthracnose-resistant varieties produced high yields.

Stylo anthracnose (**Colletotrichum sp.**) is endemic and widespread in the tropics of South and Central America. Among 200 stylo biotypes observed in field plots or tested in plant house experiments, a high degree of resistance to anthracnose was found in only four **S. guyanensis**, six **S. hamata** and two **S. humilis**. Anthracnose resistance appears to have good potential for improving the performance of the stylos in tropical America by increasing persistence and pro-

* Allic soils are defined as extremely acid soils in which aluminum is always the predominant cation on the exchange complex. They are almost always low in phosphorus and other plant nutrients.

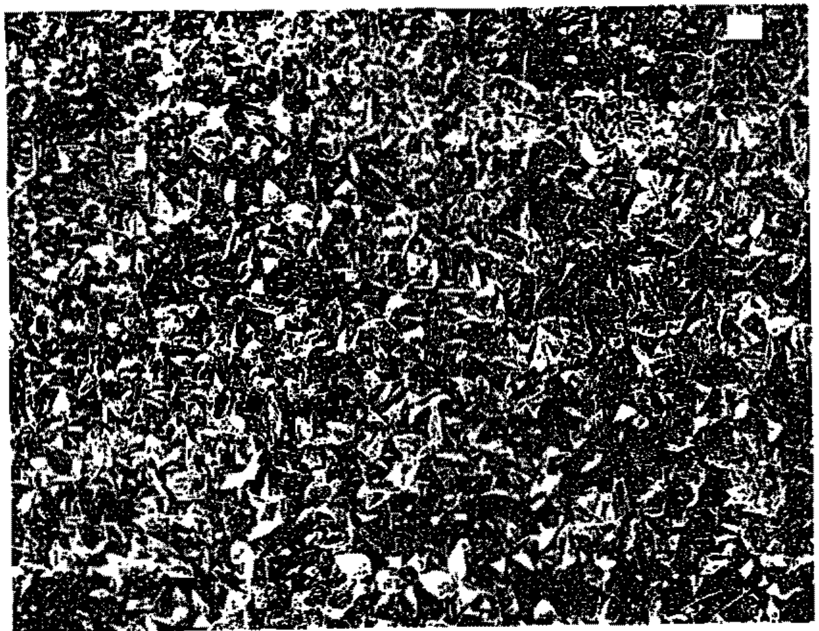


Figure 1. Indigenous Colombian Desmodium sp. shows a high level of resistance to insect attack combined with good forage characters.

ductivity. Consequently, selection of biotypes with increased disease resistance is economically important.

New accessions are first tested in a humidity-saturated chamber for resistance to anthracnose. To assess anthracnose resistance under field conditions, five resistant and two susceptible accessions of stylo established in small plots were inoculated with a suspension of conidia in water. A good correlation was observed between glasshouse and field test results.

Mature plants of **S. guyanensis** var. La Libertad,' currently used in grazing experiments, displayed satisfactory field resistance to stylo anthracnose, but the disease resulted in losses in seedling stands. This variety and similar robust, high-yielding growth forms, which develop a woody stem base with age, especially under lenient grazing or infrequent cutting, are vulnerable to defoliation at the advanced stages of growth. Selection pressure is directed toward plant types with a large number of crown branches and growing points well distributed along the stem axis.

Fifteen accessions of stylo were compared for seed yield at Palmira. Seed yields ranged from 30 kg/ha to 567 kg/ha.

Promising selections of **Centrosema, Desmodium** and **Macroptilium** are now available for testing in regional trials under a variety of ecologial conditions.

A Colombian ecotype of **Desmodium** sp., possibly a fortuitous hybrid, continues to show promise as a forage (Fig. 1). In addition to desirable forage characteristics, it is more resistant to leaf-eating insects than several accessions of **Desmodium intortum**. This **Desmodium** will be released for regional testing when adequate seed supplies are available. The strongly stoloniferous **Desmodium**

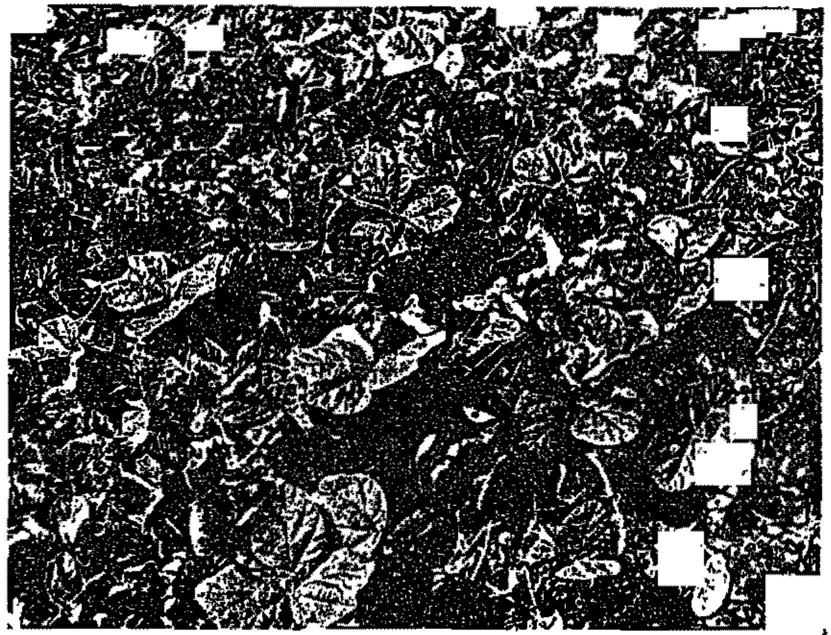


Figure 2. Macroptilium atropurpureum severely affected by rhizoctonia and bean rust.

heterophyllum warrants testing in combination with creeping grasses. This legume shows good forage potential and adaptation to local conditions.

Ample evidence from experimental plantings of **Macroptilium atropurpureum** cv 'siratro' indicates that this commercial cultivar adapts poorly to equatorial latitudes. It suffered badly from attacks of rhizoctonia and bean rust. Several experimental lines of **Macroptilium** sp. show promise as replacement cultivars for commercial siratro (Figs. 2 and 3).

A limited number of forage grass accessions established in observation plots include 14 **Cynodon** spp. and 2 **Andropogon guyanus. Cynodon** is performing well on alkaline soils at Palmira, and it is more vigorous than pangola grass (**Digitaria decumbens**). Test plots of **Andropogon** have been established at Carimagua.

Figure 3. Disease-resistant Macroptilium atropurpureum.

Figure 4. Strongly stoloniferous, disease-resistant Centrosema hybrid (F_6).

Forage plant improvement and breeding

F_5 and F_6 populations of the interspecific hybrid **Centrosema brasilianum** × **C. virginianum** are in the advanced stage of testing (Fig. 4). Selected F_5 families were assessed for stoloniferous development in sward plots in the dry season and again in the wet season. On both occasions, dry weight of stolon roots per square meter was significantly higher for the F_5s than for the

Table 2. Reaction of selected F_5 hybrids and C. pubescens ecotypes to Cercospora leaf spot and leaf mosaic virus.

Hybrids or C. pubescens	Mean number of disease-affected leaves per 0.8 m^2*	L.S.D.
17 - 33 (F_5)	1.03	
		.25
17 - 87 (F_5)	1.36	
		.46
C. pubescens (Ecuador)	3.60	
		.54
C. pubescens (Colombia)	5.76	

* Differences between any two means are highly significant (P = 0.01)

C. pubescens control (Table 1). The same F_5s exhibited significantly better resistance to common leaf diseases of, for example, centro cercospora leaf spot and mosaic virus than indigenous and introduced **C. pubescens** lines (Table 2). Seed increase areas of F_6 populations have been established, and bulked seed of F_7 s will be used for distribution and regional testing in 1975.

Seed production

Seed of the promising forage species being identified is required urgently to permit a rapid and thorough evaluation of both legumes and grasses for specific ecological-management situations and the determination of their impact on animal performance. As cultivars are identified and developed, attainment of new potentials of livestock performance will depend upon availability of vast quantities of good-quality seed at reasonable prices.

Table 1. Mean dry weight of stolon roots of two F_5 hybrids and C. pubescens.

Hybrids and control	Dry season	Wet season	Mean
C. pubescens (Colombia)	5.02	5.07	5.04
17 87 (F_5)	11.28	17.53	14.41
17 33 (F_5)	12.10	19.92	16.01
		L.S.D. (P = 0.01) =	7.24

Tropical pasture improvement has reached significant proportions only in terms of large-scale commercial sowings in parts of East Africa and northern Australia. Commercial seed production is highly developed in these same regions.

Many variables influence levels of seed production. Successful seed production areas will be those where suitable combinations of climatic, edaphic, labor and management factors exist to produce consistently reliable high seed yields and allow their efficent recovery at harvest. Such suitable locations need to be identified for each species.

Within tropical Latin America at present, there exists only a rudimentary production system of some grass seeds, whereas there is none of any tropical legume seeds. Grass seed is gleaned from naturalized pasture areas, and the product sold commercially is almost invariably of low purity and viability. What legume seed is available is imported, of excellent purity, but with viability dependent upon age and conditions of storage. Imported seed is not necessarily adapted, and imported seed of nonadapted germplasm provides no shortcut to providing seed for pasture improvement.

The Latin American tropics are the center of origin of various valuable forage legume genera, but the sampling of such genetic resources for utilization within the same region is virtually nil. It is highly critical that resources allocated to seed production are applied to germplasm which has proven to be adapted. Therefore, seed production cannot be an isolated, independent program but must be closely related to germplasm development and evaluation programs.

The pasture and forage seed production program has five basic objectives: (1) to maxi-

Figure 5. Hand harvesting Stylosanthes guyanensis for seed production.

Figure 6. Threshing a seed production area of *Paspalum plicatulum* following hand harvesting and field drying.

mize the rate of seed production of promising species and ecotypes for experimental purposes, (2) to produce foundation seed of new cultivars, (3) to identify and study the determinants of high yield of quality seeds, (4) to provide a field training experience for trainees interested in forage seed production, and (5) to assist, where possible, the seed production programs of national agencies.

The major emphasis during the past year has been on the establishment of new production areas at Palmira and Carimagua. In general, Palmira is used where close technical supervision and/or high labor inputs are required (Figs. 5 and 6).

Carimagua provides a location for the larger scale increase of species adapted to allic soils. Production systems are conducted there along more commercial lines. As seed becomes more available, production will be initiated at other sites with suitable cooperators.

Five introductions of **Stylosanthes guyanensis** are being increased at Palmira, where a total area of 1.5 hectares were established by transplanting seedlings into the field. At Carimagua, 5 hectares were established with six introductions by direct seed sowing. Three introductions of **Stylosanthes hamata** were transplanted into initial increase plots totaling 0.5 hectares at Palmira. Selected introductions of **Centrosema pubescens, Macroptilium atropurpureum, Desmodium canum, D. heterophyllum** and D. sp. have each been established in increase plots averaging 0.2 hectare.

Previously established areas of **Stylosanthes guyanensis** (1.5 ha), **Brachiaria ruziziensis** (0.5 ha), and **Paspalum plicatulum** (0.8 ha) were maintained and hand harvested at Palmira.

Pasture establishment

Phosphorus and calcium deficiencies limit the growth of most tropical forage legumes and grasses during establishment when planted on oxisols of the Colombian Eastern Plains (See Annual Report 1973, pp. 20-23).

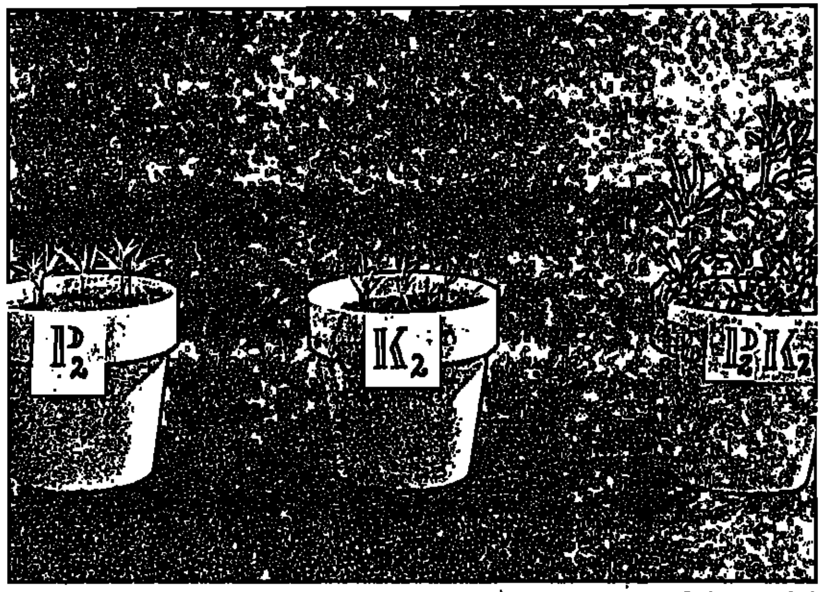


Figure 7. Effect of P and K and their interaction on growth of *S. guyanensis* on a Carimagua oxisol from which three crops had been previously harvested.

No potassium response was measured initially; but after three harvests, K greatly limited growth in a greenhouse trial conducted at Palmira with the soil described on page 49 of the aforementioned report. This striking response of **S. guyanensis** to P and K is shown in Figure 7.

The effect of K and P on dry matter yield and forage content of K and P are shown in Table 3. The K content of tissue is much lower and the P/K ratios are much narrower than in a similar trial on the same soil, but in the field.

This experience emphasizes the importance of K in many tropical soils, in which K-supplying capacity is often extremely low. Both grasses and legumes extract large amounts of K (Table 4).

Under grazing management, K and other nutrients are removed from the forage and concentrated in areas of urine and feces de-

Table 3. Effect of P and K on dry matter production and nutrient content of S. guyanensis on an oxisol from Carimagua, fourth harvest.

Treatments	Dry matter (g/pot)	(Percentage) P	(Percentage) K	(Percentage) P / (Percentage) K
+ P	0.17	0.34	0.36	0.94
+ K	0.43	0.10	1.36	0.07
+ P.K	2.69	0.14	0.43	0.33

posits. Although removal of K from the paddock is quite low, severe deficiencies can result because of uneven distribution.

Band seeding and band application of 300 kg/ha of basic slag (15% P_2O_5, 45% $CaCO_3$ equivalent), following seedbed preparation with two diagonal passes of an offset disc, resulted in good stands of *S. guyanensis* and *Indigofera hirsuta* seeded with *Paspalum plicatulum*. Seeding rates were 1.2, 1.5 and .3 kg/ha, respectively. Rows 45 centimeters apart followed the wheel tracks of the tractor and drill. Compaction was sufficient to assure capillary flow of water to the surface to supply the moisture requirements of the germinating seeds and young seedlings.

Cutter ants severely damaged a number of trials seeded with *S. guyanensis* and *P. plicatulum* in 1974. (See discussion of experience on family farm prototype unit, page 49). Their order of preference was observed to be *P. plicatulum* > *S. guyanensis* > *I. hirsuta*. Damage was greatest where seedbed preparation was followed immediately by seeding and where all native vegetation was destroyed (Fig. 8).

Table 4. Tissue content of N, P, K, Ca and Mg of tropical legumes and grasses grown on an oxisol at Carimagua, Colombia. Trial was established in April, 1973; harvested in June and October, 1973.

Species	Harvest date		N	P	K	Ca	Mg
Stylosanthes guyanensis	June		2.20	0.10	1.04	0.75	0.42
	October		2.71	0.15	1.75	0.89	0.42
		$\bar{x}$	2.46	0.13	1.40	0.82	0.42
Centrosema pubescens	June		2.87	0.11	0.92	0.35	0.26
	October		2.60	0.12	1.36	0.44	0.22
		$\bar{x}$	2.74	0.12	1.14	0.40	0.24
Desmodium intortum	June		2.46	0.12	0.73	0.65	0.47
	October		2.69	0.14	1.40	0.58	0.41
		$\bar{x}$	2.58	0.13	1.07	0.61	0.44
Calopogonium muconoides	June		2.70	0.10	1.02	0.42	0.38
	October		2.63	0.14	1.45	0.34	0.26
		$\bar{x}$	2.67	0.13	1.24	0.38	0.32
Melinis minutiflora	June		0.96	0.08	0.85	0.11	0.21
	October		1.35	0.11	1.37	0.07	0.21
		$\bar{x}$	1.16	0.10	1.11	0.09	0.21
Hyparrhenia rufa	June		1.15	0.06	0.88	0.20	0.29
	October		1.42	0.10	1.55	0.13	0.15
		$\bar{x}$	1.29	0.08	1.22	0.17	0.22
Paspalum plicatulum	June		1.09	0.08	1.05	0.28	0.47
	October		1.28	0.09	1.59	0.24	0.45
		$\bar{x}$	1.19	0.09	1.32	0.26	0.46
Brachiaria decumbens	June		1.08	0.06	0.87	0.19	0.30
	October		1.94	0.10	2.17	0.11	0.18
		$\bar{x}$	1.51	0.08	1.52	0.15	0.24
Legumes	$\bar{x}$ of 4		2.61	0.13	1.21	0.55	0.36
Grasses	$\bar{x}$ of 4		1.29	0.09	1.29	0.17	0.28

Figure 8. Leaf cutter ants destroyed 18 hectares of *S. guyanensis* and 40 hectares of *P. plicatulum* in the seedling stage on the family farm unit at Carimagua.

Pasture weed control

One of the problems in establishing forage legumes is initial weed competition.

Results from the trials on ranches on the North Coast of Colombia showed that Centrosema (*Centrosema pubescens*) was least injured by linuron (1 kg/ha), alachlor (2.5 kg/ha) and DNBP (3 kg/ha). Forty days after application, new weeds began to appear with these treatments. Diuron gave better control but also severely injured the legumes.*

In screenhouse trials at Turipaná, herbicide selectivity and weed control in perennial soy (*Glycine wightii*), siratro (*Macroptilum atropurpureum*) and Centrosema were studied. Common weeds of the area were seeded in the flats to assure a uniform population. The most selective and effective treatments were alachlor, linuron, fluorodifen + alachlor and fluorodifen + linuron. Applications of methazole and diuron were highly phytotoxic. In every case, more injury was observed when the legume seeds were broadcast on the surface than when seeded 1 to 2 centimeters below the surface.

At CIAT's farm, 18 compounds were tested in a selectivity trial with *Stylosanthes guyanensis*. Many herbicides known to be selective in other legume species were used. Adequate selectivity was demonstrated by DNBP (3 kg/ha, pre) and bentazon (1 and 2 kg/ha, post). DNBP gave fair weed control, and bentazon was excellent for all broadleaf weeds but did not control grasses.

Marginal selectivity was observed for H-22234 and perfluidone (each at 3 kg/ha, pre). Totally nonselective compounds included dinitramine, AC-92553, metribuzin, alachlor, fluorodifen, linuron, chloramben, S-6044, oryzlin, bifenox, oxadiazon,

* Names of substances used as herbicides in different chapters of this publication appear with initial letters in lower case. Names of commercial products appear with initial letters in capitals (Editor's note).

methazole, napropamide and CIPC + naptalam. **Commelina diffusa**, a common weed, was totally resistant to dinitramine, AC-92553, linuron, S-6044, oryzlin and napropamide but was susceptible to metribuzin, bentazon, fluorodifen, chloramben, perfluidone, methazole and bifenox.

Brush control continued to be the major concern on the North Coast of Colombia. As many species are resistant to foliar applications, cut-stump application techniques were tested. A special nozzle (called a "fork nozzle"), designed in cooperation with a local equipment company, directs a double stream of the diesel fuel-herbicide mixture to the cut stump. The fork nozzle was tested with various back-pack sprayers and sprayer operators on various sizes of cut stumps.

There was relatively little variation between the three operators and sprayers, which means that the applicators can be instructed to make uniform applications (Tables 5 and 6). There was considerable variation in the output among the three nozzle sizes. It appears that either the TK-2 or TK-3 would be recommended, as the TK-1 had a low output and the small orifice tended to plug.

Size of the cut stump also greatly influences the optimum amount of solution applied to each (Table 6). Changes in the diameter had less effect on the output than did changes in the length (15 and 26 per cent more, respectively, when the diameter

Table 5. **Comparison of nozzle size and sprayer operator on the quantity of solution applied to a standard size cut stump.**

Nozzle size	ml/stump by three applicators			Average for nozzles
	1	2	3	
TK 1	8.9	9.0	8.3	8.7
TK 2	13.8	14.0	11.4	13.1
TK 3	15.8	16.4	13.6	15.1
Average for operator	12.8	13.1	11.6	

or length was doubled). Shrubs of rather large diameter can be treated without greatly affecting the cost of the application. However, the height of the cut stumps should be closely controlled, as extra tall ones result in the application of more solution than required.

Several control trials were conducted using the fork nozzle for cut-stump applications and a cone nozzle for foliar applications. Two soil applied herbicides were evaluated. Control ratings taken every 30 days for six months indicate that the species "arrayan" (as yet unidentified) is resistant to all foliarly applied compounds. Only picloram + 2,4-D in 1 per cent solution of the commercial product killed 50 per cent of the shrubs treated; whereas 2,4,5-T, dicamba + 2,4-D; 2,4-D + 2,4,5-T, DPX-1108 and glyphosate were totally ineffective. Karbutilate and tebuthiuron applied to the

Table 6. **Comparison of three nozzle and four cut-stump sizes on the quantity of solution applied per stump.**

Nozzle size	ml/stump: cut-stump size (diameter/length): 20mm/15 cm	20mm/30 cm	40mm/15 cm	40mm/30 cm	Average for nozzles
TK 1	7.0	10.0	8.1	10.8	9.0
TK 2	10.2	13.6	13.0	16.4	13.3
TK 3	11.5	17.5	14.5	19.3	15.7
Avg. of stump/size	9.6	13.7	11.9	15.5	
Avg for diameter	20 mm = 11.6		40 mm = 13.7		
Avg for length	15 cm = 10.8		30 cm = 14.6		

soil at the base of individual shrubs partially defoliated but after six months had not killed any of the shrubs. Cut-stump applications of 2,4-D + 2,4,5-T + 2,4-DP in diesel fuel or 2,4-D + picloram in water gave complete control.

Methods of controlling two troublesome herbaceous species were studied. **Scleria pterota** is a nonpalatable sedge with a triangular cutting stem which spreads by rhizomes, thus making it hard to control. **Heliconia bihai** is not consumed by cattle and invades pastures via rhizomes. **Scleria** was completely controlled by diuron and glyphosate; whereas 2,4,5-T, diesel fuel, 2,4-D + 2,4,5-T, picloram + 2,4-D and DPX-1108 had no effect. **Heliconia** was more difficult to control; but glyphosate gave 85 per cent control, and the combination picloram + 2,4-D, 82 per cent. Fair control was obtained with 2,4,5-T, 2,4-D + 2,4,5-T and dicamba + 2,4-D. Diuron, DPX-1108 and diesel fuel gave no control. In other trials, pará grass (Brachiaria mutica) and angleton (**Dicanthium aristatum**) were successfully established after controlling **Scleria** and **Heliconia** with diuron and glyphosate, respectively.

Pasture and forage utilization

CIAT headquarters at Palmira

The grazing trial designed to measure the effect of nitrogen fertilization on beef cattle production continued.

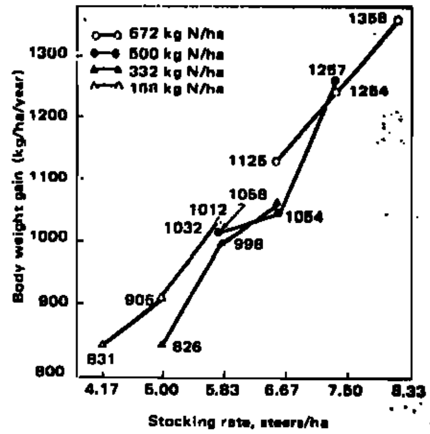


Figure 9. **Beef production on irrigated Pangola grass fertilized with nitrogen.**

Table 7 presents the daily gains obtained in 1974 and Figure 9, the gains per hectare. Weight gains were higher than in 1973 at all stocking rates within levels of nitrogen applied, reaching a maximum production of 1,358 kg/ha of weight gain with the application of 672 kilograms of nitrogen. Increments were larger at higher stocking rates (Table 8).

Internal rates of return were calculated for all treatments using current values of nitrogen and cattle prices with the accumulated production of the three years (1972 to

Table 7. **Average daily weight gain of steers grazing irrigated pangola grass fertilized with nitrogen (CIAT, 1973-1974).**

Level of nitrogen (kg/ha/year)	Stocking rate, steers/ha: 4.17	5.00	5.83 (g/day)	6.67	7.50	8.33
168	546	495	485			
332		453	469	435		
500			467	433	459	
672				462	458	447

Table 8. Increases in beef production obtained in 1974 over 1973 in pangola grass fertilized with nitrogen.

Level of nitrogen (kg/ha/year)	Stocking rate, steers/ha 4.17	5.00	5.83	6.67	7.50	8.33
	(kg/ha/year)					
168	31	24	297			
332		−117	29	169		
500			166	−30	238	
672				91	172	299

1974). Rates of return were in all cases low, the highest being 5 per cent in the 168 kilograms of nitrogen level per hectare with five steers per hectare. Two factors entered this year into the economics of cattle fattening: the increase in the cost of nitrogen fertilizer and the change in price of cattle. The price of nitrogen increased from US$ 0.31/kg in 1973 to 0.73/kg and cattle from 0.51/kg to 0.53/kg. The inflation rate was 25 per cent; thus, deflated price of cattle to 1973 level was US$0.40/kg and nitrogen was 0.58/kg. This combination of increased price of nitrogen and decrease in price of cattle resulted in low returns.

Table 9 presents a simplified calculation to determine the relative effect of these two factors on internal rate of return. Despite the apparently high increase in nitrogen prices, the decrease in cattle prices had a greater influence on economic return.

The grazing trial designed to measure beef production on nonirrigated pará grass fertilized with nitrogen was discontinued, as returns to fertilization were not economical.

Carimagua

The management study of the native tropical savanna, which was modified in 1972 and 1973, continued in 1974. This trial compared the effect of burning the total area of the savanna once each year to a sequential burning, dividing the savanna with fireguards into eight equal plots and burning each plot once a year, but in a sequential order throughout the year. Each treatment was tested with cattle under three stocking rates.

Table 10 presents this year's results. Weight gains in all treatments were lower than in 1973. The decrease was particularly great in the sequential burning treatments but rose as stocking rate increased. It would appear that the combined effects of yearly burning and higher stocking rates damage the productive forage species of the savanna although no apparent changes have occurred in botanical composition and yield. This is

Table 9. Internal rates of return of an intensive fattening system on irrigated pangola grass when calculated using prices of 1973 and 1974. */**

Cattle price	Nitrogen price 1973 (%)	1974 (%)	Decrease because of N price (%)
1973	23	15	8
1974	13	5	
Decrease due to cattle price (%)	10		

* Values correspond to a system using 168 kg of N/ha/year and five steers and include in all cases the production of three years of grazing.

** Nitrogen prices: 1973 US$0.31/kg
1974 US$ 0.73/kg

Cattle prices: 1973 US$ 0.51/kg
1974 US$ 0.53/kg

Inflation 1973 - 1974 - 25 per cent

Table 10. Productivity of the native savanna at Carimagua with two systems of burning (November, 1973 – November, 1974).

Stocking rate (steers/ha)	Daily weight change: Dry season (g/day/animal)	Daily weight change: Rainy season (g/day/animal)	Weight change in the period: Dry season (kg/animal)	Weight change in the period: Rainy season (kg/animal)	Weight change in the period: Year (kg/animal)	Decrease in gain from previous year (percentage)
One burning*						
0.20	48	236	6	57	63	32
0.35	−113	311	−14	75	61	35
0.50	−218	179	−27	43	16	78
Sequential burning**						
0.20	− 81	335	−10	81	71	40
0.35	−387	255	−48	61	13	88
0.50	−315	189	−39	46	7	91

* All the area was burned in November, 1972 and again in November, 1973.

** The area was divided by fireguards into eight plots with one plot burned at eight different times throughout the year.

not surprising, as changes in botanical composition and structure of the savanna generally occur over a prolonged period of time.

All of the advantages obtained last year with sequential burning were lost in 1974. With higher stocking rates, it will not be possible to burn every year because there is not enough dry forage on the ground to act as fuel. The decision was made to burn in the future only when there are at least 2 ton/ha of dry matter at the time of burning, independent of the burning treatment or stocking rate.

During the first two years of a molasses grass (*Melinis minutiflora*) grazing trial, it was found that initial fertilization with phosphorus and/or potassium had no effect on weight gain of steers, whereas the stocking rate had a marked effect on per animal and per hectare gain. Animals in all fertilized and stocking rate treatments lost from 350 to 550 grams of weight per day during the dry season.

With these results in mind, this trial was modified to test the use of a molasses + urea supplement during the dry season and the effect of resting the pasture during the dry season. The three previous fertilizer treatments were then transformed to: (a) grazing molasses grass year around, (b) grazing molasses grass year around with the animals receiving 400 grams of sugar cane molasses + 80 grams of urea (46 per cent nitrogen) per animal per day during 124 days of the dry season, and (c) resting the pasture during 124 days of the dry season (December 19, 1973 to April 22, 1974) and grazing during the rainy season. Table 11 presents the results obtained through October, 1974.

Animals grazing molasses grass without supplement during the dry season suffered severe weight losses. Molasses + urea supplementation prevented these losses and produced a small weight gain. Gains during the rainy season were good, particularly at low stocking rates. Resting the pasture during the dry season proved to be the best way to

Table 11. Productivity of molasses grass (Melinis minutiflora) under three management systems at Carimagua 1973-1974.

Stocking rate* (steers/ha)	Daily weight change/animal: Dry season** (g)	Daily weight change/animal: Rainy season (g)	Weight change/animal: Dry season (kg)	Weight change/animal: Rainy season (kg)	Year	Gain per hectare (kg/335 days)
Grazing all year, no supplement						
0.44	–529	731	–54	170	116	51
0.88	–539	451	–56	68	12	11
Grazing all year, molasses + urea during the dry period***						
0.44	112	532	12	123	135	59
0.88	93	395	10	63	73	57
Grazing during rainy season only ****						
0.44	–	619	–	143	143	63
0.88	–	441	–	102	102	90
1.30	–	287	–	67	67	87

* Stocking rate during the dry season in all treatments was from 0.44 to 0.38. Treatments of 0.88 steers/ha did not receive animals during approximately the first 70-75 days of the rainy season because of poor conditions of the pastures.

** Dry season of 103 days, rainy season 232 days

*** Supplementation consisted of 80 g urea + 400 g of molasses per day offered in a mixture containing 5 per cent water.

**** Animals were kept off the pastures for 124 days of the dry season.

use molasses grass, giving the highest productivity per animal and per hectare. In fact, this treatment permitted the highest sustained stocking rate (1.3 animals/ha) during the entire rainy season until December, 1974; whereas equivalent stocking rates were discontinued early in the rainy season in the other two treatments. Furthermore, establishment of the stocking rate of 0.88 animals/ha had to be delayed 70 to 75 days after being initiated in the rested pastures.

Table 12 presents a calculation of the compensatory weight gains obtained in the unsupplemented, year-around grazing group. Compensation was high (71 per cent) at low level of stocking but rather small at the higher level.

A grazing trial was started during the period from 1973 to 1974 to test the comparative productivity of the grasses *Hyparrhenia rufa*, *Paspalum plicatulum*, *Brachiaria decumbens* and *Melinis minutiflora* and the mixture of these grasses with the tropical legume *Stylosanthes guyanensis* var. 'La Libertad.' These grasses are commonly used throughout the American tropics, and *S. guyanensis* 'La Libertad' is a local collection (Fig. 10).

Because of difficulties associated with the availability of 'La Libertad' seed and problems of seed viability, this trial has not yet been totally established.

Only the results of the first year of grazing of the mixture of *S. guyanensis* with *Melinis minutiflora* and with spontaneous Gramineae (mainly native annual grasses) are reported. All plantings of *Paspalum plicatulum* alone or in mixture with *S. guyanensis* have suffered severe attacks from a stem borer insect and a subsequent infection of

Table 12. Compensatory gain of unsupplemented animals grazing molasses grass (Melinis minutiflora) at Carimagua 1973-1974.

Stocking rate (steers/ha)	Supplementation*	Dry season (kg)	Rainy season (kg)	Year (kg)	Compensation (percentage)
0.44	Unsupplemented	–54	170	116	
	Supplemented	12	123	135	
	Difference	66	47	19	71
0.88	Unsupplemented	–56	68	12	
	Supplemented	10	63	73	
	Difference	66	5	61	8

* 80 g of urea + 400 g of molasses per animal per day for 124 days. Total cost of the supplement per animal = US$7.80. Total value of weight not recovered at low stocking rate = US$10.10; at higher stocking rate = US$32.30.

Helmintosporium, which has made it impossible to stabilize grazing in this pasture.

Table 13 presents the weight gains obtained on pastures which contain *S. guyanensis*.

Compared with the native savanna and with introduced grasses that are suited for this environment, weight gains of cattle grazing *S. guyanensis* mixtures were excellent. It was particularly advantageous during the dry period when weight gains were obtained.

Figure 10. Good weight gains have been obtained with animals grazing nutritious stylo-based pastures. This legume shows great potential for efficient beef production in the tropics.

Table 13. Weight gain of steers grazing mixed pastures containing Stylosanthes guyanensis at Carimagua 1973-1974.

Stocking rate (steers/ha)	g/day				
	XII–73/IV–74	IV/VI–74	VI/VIII–74	VIII/X–74	IV/X–74
Stylosanthes guyanensis + Melinis minutiflora					
0.50	532	–	–	–	–
0.90	–	864	976	345	714
1.30	–	886	885	397	715
1.70	–	681	940	310	611
Stylosanthes guyanensis + spontaneous Gramineae					
0.50	446	–	–	–	–
0.90	–	1,140	976	397	773
1.30	–	1,182	952	379	800
1.70	–	1,209	855	310	703

Weight gains during the first four months of the rainy period were outstanding, with as much as 1 kilogram per day. From August to October, however, gains declined markedly. This decline can be associated with a decrease in the population of *S. guyanensis*, possibly associated with the presence of the fungus *Colletotrichium gloesporioides*, which may have reached a significant level at that time.

In addition, *S. guyanensis* was severely attacked by an unidentified stem borer insect, which killed many plants. This emphasizes the need to obtain varieties of *Stylosanthes guyanensis* adapted to these soil and moisture conditions and resistant to the fungus and insects. On the other hand, it demonstrates the outstanding potential of the species to increase beef production in allic soil regions, since on a yearly basis, weight gains as high as 200 kg/animal were attained.

Digestibility and intakes studies

Effect of nitrogenous supplements on utilization of dry season pasture forage. The native pasture of the Llanos Orientales is poorly utilized, especially in the dry season. Cattle are usually found grazing on recently burned savanna, and they lose weight if only unburned savanna is available. A trial with crated sheep was conducted to establish whether the utilization of more mature savanna forage could be improved with protein or nonprotein nitrogen supplements. The forage was harvested in January, five months after burning, sun-dried up to hay stage and transported to Palmira. Treatments and results are summarized in Table 14.

When the hay was offered with only minerals as a supplement, the intake of digestible dry matter was only 15 g/kg $W^{.75}$ because of a low intake of DM and an extremely low dry matter digestibility. When the same amount of hay was supplemented with cottonseed meal or molasses + urea, the total intake of DM increased by more than 20 grams; and in both cases, the rise in hay intake accounted for more than half of that.

Intake of digestible DM increased by 80 per cent with urea and nearly doubled with

Table 14. Effect of cottonseed meal and molasses + urea on the utilization of native savanna forage.

	Treatment		
	1	2	3
DM offered*			
Native savanna hay	88.6	89.2	89.0
Minerals	1.1	1.1	1.1
Cottonseed meal	–	9.3	–
Molasses + urea	–	–	7.0
DM consumed*			
Native savanna hay	45.4	56.3	60.9
Minerals and CSM or molasses + urea	1.1	10.4	8.1
Total	46.5	66.7	69.0
Dry matter digestibility (percentage)	32.2	44.2	39.7
Intake of digestible dry matter*			
Total	15.0	29.5	27.4
From hay + minerals	15.0	22.0**	22.0**

* All data in g/kg $W^{.75}$/day

** Estimated

cottonseed meal. Assuming reasonable figures for the digestibility of the supplements leads to the conclusion that with both supplements, the intake of digestible DM from the hay increased to 22 grams. This suggests that not only the consumption, but also the digestibility of hay increased as a result of the supplement.

Nutritive value of Stylosanthes guyanensis var. 'La Libertad.' Most of the literature on the nutritive value of *S. guyanensis*, as measured with crated sheep, indicates that this forage is of relatively low nutritive value. Contributing to this low value are a low intake of dry matter and a low dry matter digestibility. Results obtained at CIAT, however, indicate that stylo can provide a highly nutritive diet, even at advanced stages of growth (See CIAT's Annual Report, 1973). Subsequent trials confirm this conclusion.

Most of the literature's data is based on trials in which chaffed forage was offered. CIAT's data were collected in experiments with long forage. More detailed studies indicate that the difference between these results and those from the literature can partly be explained by the differences in methods. Figure 11 shows that when 5 1/2–month-old stylo was offered as long and as chaffed forage, the dry matter digestibility was seven units higher when long forage was offered. Animals on long forage more sharply selected for the more digestible leaves, but only 20 per cent of the difference in digestibility could be explained by that. The other 80 per cent, or 5.6 units difference in digestibility, can probably be attributed to a difference in selection among stem fractions.

Analysis for crude protein (CP) of offered and refused stem showed that sheep on long forage selected more than those on chaffed forage (Fig. 12). As a result of chaffing, the apparent digestibility of protein also decreased (Fig. 13).

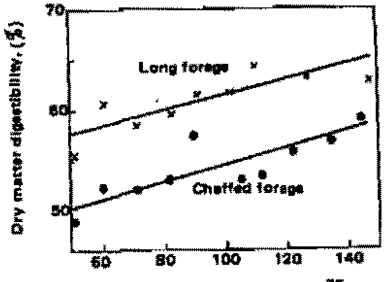


Figure 11. Effect of chaffing on the dry matter digestibility of Stylosanthes guyanensis var. La Libertad. (5 1/2 months' first growth).

The selection within stems was particularly pronounced in early flowering stylo (eight months' first growth after planting) when this was offered as long forage. While the whole stem contained 8 per cent CP, animals that were allowed to refuse 40 per cent of the total DM or 70 per cent of the stems consumed stems with 12 per cent CP while the refused stem contained less than 7 per cent (Fig. 14).

These data emphasize the importance of selective consumption and indicate that selection within stems might be equally as important as selection between leaves and stem.

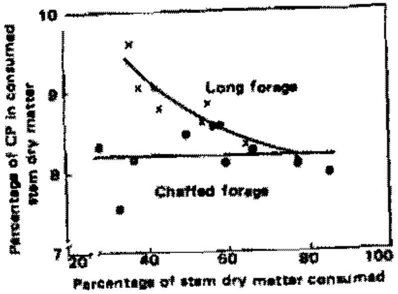


Figure 12. Effect of chaffing on the selection for stem with a higher crude protein content of Stylosanthes guyanensis var. La Libertad. (5 1/2 months' first growth).

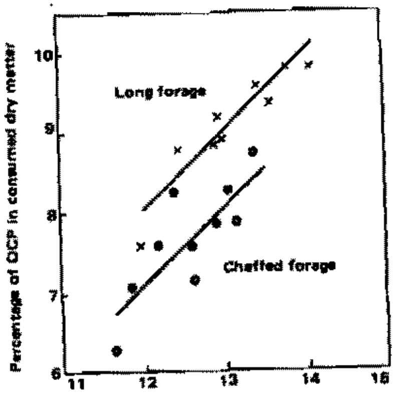


Figure 13. Effect of chaffing on the relationship between percentage of digestible crude protein and percentage of crude protein in the consumed dry matter of Stylosanthes guyanensis var. La Libertad. (5 1/2 months first growth).

The results also indicate that in screening varieties for nutritive value, it might be important not only to determine the leaf-stem ratio, but also to study the nutritive value of different stem fractions.

Feeding value of Desmodium distortum. Initial trials with Desmodium distortum have

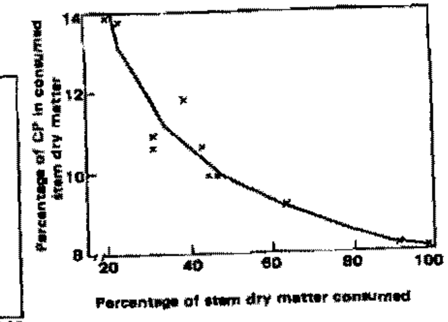


Figure 14. Effect of selection on the percentage of crude protein in consumed stem dry matter of Stylosanthes guyanensis var. La Libertad (8 months' first growth) when fed as long forage.

Table 15. Feed lot performance of Zebu x Santa Gertrudis steers fed chopped elephant grass ad libitum.

Experimental factors involved	Elephant grass alone A	Elephant grass +.5 kg CSM[1/] B	Elephant grass +.5 kg CSM + 2 kg molasses C
Animals (No.)	4	4	4
Initial weight (kg)	211.0	208.0	207.0
Final weight (kg)	399.0	420.0	462.0
ADG (g)[2/]	522.0	591.0	704.0
Total wt gain (kg)	752.0	851.0	1,014.0
DM (kg)/gain (kg)	11.6	11.0	10.0
Avg daily DM consumption (kg)	6.1	6.4	7.0 *

* Significantly greater than A or B (P(.01)

1/ Cottonseed meal

2/ Average daily gain

shown that this forage is well accepted by sheep and is also highly digestible. Young material, 90 cm high, containing 52 per cent leaf, 11.5 per cent petioles and 36.5 per cent stem and offered at 100 g DM/kg $W^{.75}$, gave an intake of 75 g DM with a digestibility of 68 per cent. More mature material, 180 to 200 cm long, with 21 per cent leaf, 8.5 per cent petioles, 2.5 per cent seed heads and 68 per cent stem, gave an intake of 60 g DM with a digestibility of 64 per cent when offered at 100 g DM. Varying levels of feeding showed a strong selection of leaves, petioles, inflorescence and younger stem fractions.

Intensive production systems

Intensive beef production research constitutes a minor portion of the overall beef program activities and focuses on the utilization of crop residue, by-products, and intensively produced tropical forages. The land area and machinery used are kept at a minimum so the information generated will be directly applicable to the small farm. To date, one trial has been completed with steers fed in individual stalls for 360 days using elephant grass (cut daily) as the only source of forage, supplemented with cottonseed meal and molasses (Tables 15 and 16). At this level of productivity, approximately 2,400 kg/ha/year of liveweight gain were produced with elephant grass alone.

A preliminary study is under way in which cassava tops as a protein source are fed to Zebu steers in combination with chopped elephant grass. This study was initiated after observing four steers being fed pure forage cassava for six weeks in which no visual disorders were noted in the animals. However, their average blood thyocianate level (mg percentage) was more than 200 per cent higher at the end of the six weeks than in similar steers on normal pasture.

Table 16. Performance of elephant grass produced from one hectare under an intensive management system.*

DM (kg) produced (360 days)	27,720.0
Cutting interval (days)	56.0
Nitrogen applied (kg/ha/year)	850.0
DM content (%)	13.2
Protein content (%) DM	11.2
Digestibility (%) (in vitro)	58.0

* Irrigated weekly during dry seasons

ANIMAL HEALTH

During the last year, emphasis has continued to be in the Llanos Orientales (Eastern Plains) of Colombia, where the work pattern has logically developed from experiences gained in the Villavicencio slaughterhouse, from visits to individual ranches traced from slaughterhouse findings, and from CIAT work at the ICA station at Carimagua.

Investigations were carried out on 36 farms in collaboration with the Colombian Caja de Crédito Agrario (agrarian credit bank). All the farms have cattle development loans and are distributed from Villavicencio in the Piedmont eastwards across the Departamento del Meta into the Comisaría del Vichada. The areas of emphasis within the animal health program were brought together into a single field team approach, and information on all farms was collected as regards breeding diseases (brucellosis, I.B.R., leptospirosis), hemoparasitic diseases (anaplasmosis, babesiosis), ectoparasites (ticks and "nuches"), management practices and economics. The data that have been processed to the time of this report are recorded separately below and referred to under the title "Caja/CIAT survey."

The first series of visits was carried out during the wet season. The farms will again be visited in the dry season with a modified pattern of approach determined by experience. For example, farms which have unexplained abortion or infertility problems will be visited to investigate other possibilities. In addition, the wild animal program will be oriented to the study of the epidemiology of bovine diseases in selected localities. As the results become available, they are discussed with the Caja's extension veterinarians, who then take over the responsibility of implementing control measures.

The same spectrum of subjects is being studied in two other ecologically *different* areas in Colombia. The first is a group of ten farms on the North Coast that collaborate with the CIAT livestock production specialist training program. The second is a group of ranches in the northern part of the Cauca Valley used by the School of Veterinary Sciences of the Universidad Nacional as on-farm training areas for undergraduate students.

The development of both research methodology and of the techniques necessary for disease control in these three regions makes them suitable areas for the training of graduate students. Such areas are required for the development of the animal health segment of outreach programs elsewhere in Latin America.

In the development of the special project in hemoparasites (USAID/Texas A&M), the principal effort concentrated on the on-farm testing of immunization for anaplasmosis and babesiosis. The complementary special project in ticks (UK-ODM) started in November.

The emphasis on epidemiology has resulted in a marked increase of accessions for the serum bank. The number of sera stored from field investigations relating to beef, swine and wild animal work is now 19, 341.

Table 17. Total number of cattle slaughtered in Montería, Palmira and Villavicencio slaughterhouses, each for a single period of examination in 1974, giving the ratio of males to females.

Place	Period of time	Total animals	Male (Percentage)	Female (Percentage)
Montería	March 8—April 25	695	91 (13)	604 (87)
Palmira	Dec. 19—Feb. 17	1,643	718 (44)	924 (56)
Villavicencio	March 11—March 15	257	102 (39)	155 (61)

Table 18. Total number of female cattle examined by CIAT animal health staff in Montería, Palmira and Villavicencio slaughterhouses and the ratio of pregnant to nonpregnant animals.

Place	Total females	Pregnant (Percentage)	Open (Percentage)
Montería	328	259 (79)	69 (21)
Palmira	405	276 (68)	129 (32)
Villavicencio	155	98 (63)	57 (37)

Breeding diseases

Investigations were carried out in three slaughterhouses: Villavicencio (Llanos Orientales), Montería (North Coast) and Palmira (Cauca Valley). Incidental and interesting information was again collected concerning the high proportion of female animals being slaughtered and the apparantly high pregnancy rate. For these three localities, Table 17 gives the ratio of male to female animals slaughtered, Table 18 the ratio of pregnant to nonpregnant animals, and Table 19 the distribution of age of pregnancy in female cattle. Table 19 gives the impression of randomly selected female stock, as all stages of pregnancy are represented.

Various factors may be involved although there is general recognition that a fall in price of beef leads to an increase in the sale of females of any age and vice versa. These *figures* are relevant to the ongoing investigations in the economics program. The pregnancy rates are important in the study of breeding diseases, and knowledge of the significance of the slaughterhouse figures in relation to farm conditions would be valuable.

Brucellosis

The apparent deteriorating brucellosis picture in the initially serologically "clean" cattle of the ICA/CIAT herd systems experiment at Carimagua was further investigated. Following agreement with ICA, six consecutive serum samples taken at two-month intervals from 105 cattle were sent to the Pan-American Zoonosis Center. The sera were examined by the tube test, complement fixation test and card test. With the tube test, 54 animals gave suspicious reactions. However, the complement fixation and card tests gave only two positive animals. The diagnosis given was that these two animals alone could be considered positive. All the other reactions were consistent with the animals having received brucella vaccine after the recommended eight months of age. However, the history of *any such* vaccinations prior to purchase is obscure, and the problem is still not entirely resolved as to the source of infection of the two positive reactors.

Table 19. Distribution of age of pregnancy in pregnant female cattle examined in Montería, Palmira and Villavicencio slaughterhouses by CIAT animal health staff.

Place	Ages of pregnancy in 30–day groups								
	0–30	to 60	to 90	to 120	to 150	to 180	to 210	to 240	to full term
Montería	3	18	53	22	19	59	44	29	12
Palmira	11	32	95	39	19	37	41	18	10
Villavicencio	7	6	21	4	5	9	26	13	4

In the Llanos Orientales, 3,005 animals in the Caja/CIAT survey were examined by the tube test. Reactors were confirmed by the complementary mercaptoethanol and card tests. Twelve farms out of the 36 examined had reactors. The overall percentage of reactors in adult animals was 1.9 per cent, a figure similar to previous findings by the ICA national brucellosis program. A figure for calves is not significant, as some farms practice vaccination.

On the North Coast, eight of the ten farms investigated were infected. The overall percentage of reactors in adult animals was 9.2 per cent of 2,963 samples, with 19 per cent doubtful reactions using the tube test only.

Over the past three years, assistance has been given to one North Coast farmer to control brucellosis. Testing in 1971 revealed 18 per cent positive and 32 per cent doubtful reactions. To date, there exist only 14 doubtful reactions, and the owner claims an increase in birth rate from approximately 50 per cent in 1971 to 70 per cent in 1974. Control is also being carried out on two other farms.

Trichomoniasis and vibriosis

On six of the North Coast farms, bulls were examined for trichomoniasis. Preputial washings were examined both directly and on the culture. Three animals were found positive for *Trichomonas foetus* by both means. No vibriosis investigations were undertaken in any area.

Leptospirosis

All the serological work on leptospirosis has been carried out by the Pan-American Zoonosis Center.

Two of the North Coast farms have been examined serologically. The first farm had severe abortion problems. Very strong reactions to the serotypes hardjo, wolfii and sejroe were found with weaker, but numerous reactions to serotype tarassovi. The second herd also showed strong reactions to hardjo, wolfii and sejroe, in that order. In addition, there were reactions to three other serotypes: pomona, canicola and icterohaemorragiae. These have not been found in cattle on any other farm investigated in Colombia or Ecuador.

Results are available from 13 of the 36 Caja/CIAT survey herds. Based on a 20-animal sample from each herd, all 13 farms had reactors. Serotypes hardjo, wolfii and sejroe were again the most prevalent, and weak reactions to hebdomadis and tarassovi were found. Three farms had a significantly higher proportion of strong reactions, and these may be situations where clinical infections can be expected and isolations made. A strenuous attempt to culture *Leptospira* spp. from animals in the Villavicencio slaughterhouse failed.

Sera from 55 wild animals captured at Carimagua were also sent for serological examination. Eleven sera had weak reactions (1/50 dilution), especially to serotypes sejroe and tarassovi (Table 20).

Following a request for assistance received through the USAID, sera were also sent to the Zoonosis Center from a farm near Quito, Ecuador. Strong reactions to serotypes hardjo, wolfii and sejroe were found with weak reactions to serotype hebdomadis. A single serum reacted to serotype pomona.

Infectious bovine rhinotracheitis/pustular vaginitis (IBR/IPV)

In addition to the four cases previously reported, a further isolation of IBR virus was made from the Villavicencio slaughterhouse, but the origin of the animal could not be traced.

A micro-indirect hemagglutination test was set up for use in the Caja/CIAT survey. A semipurified virus antigen was prepared using a "cloned" virus. Sera from 32 of the 36 farms have been examined, and only two herds failed to show any positive reactions. Taking hemagglutination in serum dilutions of 1 to 8 or more as being positive, 42.5 per cent of 640 sera examined reacted. Even at 1 to 32 dilutions, 12.8 per cent of the cattle still reacted. This might indicate the activity of the virus on those farms. As possible confirmation of this, one of the farms from

Table 20. Some parasitisms or infections of wildlife detected in the Carimagua area, additional to those reported in 1973.

Parasitism	Condition or infection	Mammalian species
Hemoparasites	*Trypanosoma evansi*	*Hydrochoerus hydrochoeris*
	Trypanosoma cruzi	*Cebus apella* *Hydrochoerus hydrochoeris* *Dasyprocta fuliginosa* ** *Cuniculus paca* *Proechymis* sp. * *Tamandua longicaudata* ** *Dasypus kappleri* *** *Priodontes giganteus* *Potus flavus* * *Odocoileus virginianus*
	Trypanosoma rangeli	*Cebus apella* *Tamandua longicaudata* *Potus flavus*
	a piroplasma	*Didelphis marsupialis*
	Bartonella-like sp.	*Zygodontomys brevicauda*
Endoparasites	*Echinococcus* sp.	*Dasyprocta fuliginosa*
Bacteria	*Leptospira* serotypes sejroe, tarassovi	*Proechymis* sp. *Didelphis marsupialis*

* New genus record
** New species record
*** New Colombian record

which virus was isolated (not included in the Caja/CIAT survey) had 45/77 animals giving positive sera (58.4 per cent) and of these, 35 had reactions to 1:32 dilutions of serum or higher.

The present importance of the virus in relation to respiratory problems or heavy abortion outbreaks in the Llanos has yet to be assessed. However, there are likely to be problems if any system of intensive feeding is set up in the Piedmont area.

Granular vaginitis

Cattle in the ICA/CIAT herd systems experiment at Carimagua continued to be examined every two months for this condition. Computer results were not available at the time this report was written so that any continued seasonality of symptoms and comments on the relationship to fertility cannot be reported. However, a comparison made between the presence of granular vaginitis and pregnancy data in the Montería and Villavicencio slaughterhouses revealed a negative correlation. This agrees with previous observations from Carimagua. Prevalence in the slaughterhouse cattle approximated 54 per cent.

One hundred and seventy-two (172) tissue sections have now been examined microscopically. Changes found were lymphocytic hyperplasia with intrafollicular hemorrhages and mucosal erosions in more advanced cases. Lesions were most often found in the ventral commissure of the vulva in the neighborhood of the clitoris. A better name for the condition, therefore, would be granular vulvitis, but granular vaginitis has been retained to conform with the literature.

Wildife studies

Studies at Carimagua continued with the collection areas extended to the neighboring ranch areas of Caviona, Nueva Colombia, Carraba, Altagracia, La Portuguesa and La Florida. The study facilities were made available principally to the International Center for Medical Research (ICMR), Universidad del Valle; but they were also given to the Department of Parasitology, University of Tulane and the Delta Primate Center. A consignment of ectoparasites was sent to the Gorgas Memorial Laboratory in Canal Zone, Panama.

Following the previous investigations into the range of parasitisms and infections to be found in the wild animals of the area, especially those of significance to man and domestic animals, work was concentrated on three main subjects. These were **Trypanosoma evansi** infections, **Trypanosoma cruzi** and **Trypanosoma rangeli** infections, and an **Echinococcus** sp. The mammalian species captured in addition to those recorded in 1973 were:

Marsupials	**Caluromys lanatus**	Woolly opossum
Edendates	**Myrmecophaga trydactila**	Giant anteater
Ungulates	**Tayassu albirostris**	White-lipped peccary
	Sus scrofa	Wild domestic pig

The number of mammalian species now known in Carimagua and the adjacent hunting areas is 58. Table 20 lists those infections or parasitisms additional to those included in CIAT's Annual Report, 1973.

Trypanosoma evansi **infection**

Following the discovery of two natural cases of **T. evansi** infections in dogs, routine search was made of other domestic and wild animals. Using the inoculation of blood intraperitoneally into laboratory rats as the diagnostic method, the total findings in the number of animals examined were as follows:

Hydrochoerus hydrochoeris (capybara)	7/30
Cuniculus paca (paca)	0/18
Proechymis sp. (spiny rats)	0/20
Domestic cattle (Zebu)	0/32
Domestic horses	2/16
Domestic dogs	2/2

This trypanosome has historically caused enormous mortality in horses in South America, but the survival of the parasite in endemic situations is commonly believed not to involve wild animals. In this instance, the **Hydrochoerus hydrochoeris** acted as a reservoir host.

Experimental infections of **Proechymis** sp. with aliquots that killed laboratory rats within ten days resulted in chronic, nonclinical, patent infections lasting at least five weeks. This phenomenon could make **Proechymis** a useful animal for experimentation.

Trypanosoma cruzi **and** Trypanosoma rangeli **infections**

Although CIAT staff carried out the hunting and trapping, the taking of specimens, and the recording of the animals' characteristics, the identification of these trypanosomes was carried out by the ICMR. These investigations are important to the health of ICA/CIAT staff at Carimagua station, as T. cruzi is the cause of Chagas disease in man. **T. rangeli** is another human trypanosome but is nonpathogenic. Base line sera were collected from staff on a voluntary basis and sent to the Instituto Nacional de Diagnóstico e Investigación de la Enfermedad de Chagas in Argentina; results are not yet available.

One vector of Chagas disease, the reduviid bug **Rhodnius prolixus**, has been found in the neighborhood of Carimagua, but none has been found breeding there.

Echinococcus

Continued investigation of echinococcus infections brought the running total of infections detected in **Cuniculus paca** to 38 of 94 animals (40.4 per cent), in **Dasyprocta**

fuliginosa to 2 of 15 animals (13.3 per cent), and in **Proechymis** to 0 of 363 animals. Cystic material was fed to cats and dogs in an attempt to complete the life cycle and identify the species. This is important in order to determine whether it is a species infective to man or cattle. Afterwards, cystic material was sent directly to the ICMR, where this collaborative work is centered. The human sera taken at Carimagua for Chagas disease investigation is also being sent to the Pan-American Zoonosis Center for serological testing for **Echinococcus**.

Other projects

Other projects involving CIAT hunters or facilities at Carimagua were:

1. Filariasis in monkeys: A variety of filaria was found in **Zebus** and **Aotus** monkeys (ICMR/Tulane/Delta Primate Center).

2. Filariasis in the capybara: A filaria has commonly been found to cause lesions (CIAT/Tulane).

3. Survey for **Culicoides**: Only **Culicoides insignis** was taken in large numbers (ICMR/Tulane/Delta Primate Center).

4. Study of the transmission of **Polychromatophilus**, a hemoproteid malaria parasite found in the bat **Myotis nigricans** (ICMR).

Hemoparasitic diseases

Two research approaches to the control of tick-borne diseases in cattle are the development of immunization techniques and the study of the vectors. Unless epidemiological studies are made of these diseases in relation to management, the relative needs of these two approaches cannot be identified, and research resources may not be correctly allocated. This philosophy is reflected in the development of the hemoparasite program. In addition to continuing work on immunization, an acarology (tick) section has now been established, and the epidemiological studies have been considerably expanded.

At the beginning of the year, the Texas A&M hemoparasite group was primarily concerned with the completion of field immunization experiments on the North Coast against anaplasmosis and babesiosis. Lately, prime attention has been paid to testing immunization techniques under farm conditions. However, the development of CIAT facilities has enabled a diversification into the epidemiology of these diseases on the North Coast and in the Llanos Orientales.

The field experiments designated Montería II, III and IV, carried out on the North Coast in collaboration with ICA, were completed. Montería II compared chemoprophylaxis (imidocarb dipropionate), chemotherapy (imidocarb dipropionate) and premunition for the control of hemoparasites in susceptible Normando calves introduced from a "clean" area (Sabana de Bogotá). Montería III complemented Montería II and compared only premunition and chemoprophylaxis in a group of susceptible Holstein calves. Montería IV was designed to determine whether any advantage could be gained from immunizing calves born in the highly endemic Turipaná area. The definitive results are being assessed, but in general, the hemoparasite control measures resulted in decreased mortality and increased weight gains in introduced calves, but were of no economic benefit in calves native to a highly endemic area. The conditions included a strict regime of control of gastrointestinal and pulmonary parasites and moderate control of external parasites.

Another experiment carried out at Palmira compared the antigenicity of three strains of **Anaplasma marginale**. Initial infections of susceptible cattle with each of the three strains required treatment with oxytetracycline to moderate them and achieve stability. Challenge infections with homologous or heterologous strains required no treatment even though the challenge infections were ten times the initial infection dose. The conclusion was that any one strain could be used as an immunizing agent against all three.

These formal experiments are now being followed by a field evaluation of premunition for the control of hemoparasitic diseases in the Cauca Valley of Colombia. This important extension of the work will continue to be done in collaboration with ICA. Currently, the Colombian isolates of *Anaplasma marginale*, *Babesia bigemina* and *Babesia argentina* to be used in this work are being prepared and standardized. The project will be carried out on commercial dairy farms, where anaplasmosis and babesiosis are identified as major problems. Six commercial farms have been visited, three have been sampled for determination of the prevalence of anaplasmosis and babesiosis, and more farms will be visited and sampled. Final selection will be made at the beginning of 1975.

Four serological tests used to diagnose *B. argentina* and *B. bigemina* infections are being compared for sensitivity, specificity and practicability. These are complement fixation, indirect fluorescent antibodies, passive hemagglutination and rapid card agglutination. In addition, the rapid card agglutination test is being evaluated for the diagnosis of *B. bigemina* infection under field conditions. These tests and comparisons are required for the epidemiological work on the North Coast and in the Llanos Orientales Caja/CIAT survey.

On the North Coast a study was made on four farms to determine the age at which calves are first infected with *A. marginale*, *B. bigemina* and *B. argentina*, in an area known to be endemic for all three infections. Thirty cows, all in their sixth to ninth month of pregnancy, were selected on each of the farms. Serum samples were collected prior to and immediately following calving to determine whether complement fixing antibodies against *Anaplasma* or *Babesia* hemoparasites were present. Blood and serum samples were collected and ticks counted on each calf within one week following birth and at biweekly intervals thereafter until each calf was six months of age. Age of first infection was determined by direct microscopic examination of blood and by serological testing. To the present time, results indicate that the majority of calves become infected with all three hemoparasites during the first three months after parturition.

In the Llanos Orientales, sera from all 36 Caja/CIAT survey farms were processed for *A. marginale* and *B. bigemina*. Although tests for *B. argentina* have not been carried out and a statistical analysis is presently in progress correlating prevalence with tick infestation and management factors, some observations can be made. Anaplasmosis appears endemic throughout the study area. On the other hand, *B. bigemina* has a variable prevalence between farms, and situations were given where movement of cattle could result in adult mortality from babesiosis.

Monitoring of the ICA/CIAT herd systems experiment at Carimagua continued. Principal attention was given to the calves. A similar endemic picture for anaplasmosis was revealed as present on the Caja/CIAT survey farms. However, only 2 of 160 calves tested in September showed complement-fixing antibodies for babesiosis. Tick infestations are also being monitored so that the degree of infestation is being kept at a level where epidemic babesiosis is unlikely. The absence of relationship between tick infestations and the prevalence of anaplasmosis, found both at Carimagua and the survey ranches, is an interesting observation on the ticks' lack of dependence for transmission.

The ICMR also participated in the Llanos survey work in order to investigate the possible involvement of the human population in the epidemiology of bovine babesiosis. Medical histories were recorded, physical examinations were conducted, thick and thin blood films were prepared, and sera was collected from 48 persons in five localities. One individual with *Plasmodium vivax* parasitemia (malaria) was identified. Sera have been sent to the Parasitic Serology Unit, Center for Disease Control, Atlanta, Georgia, where serologic tests for *Babesia* and *Plasmodium* species are currently being conducted.

Ectoparasites

Observations continue on the prevalence of *Dermatobia hominis* ("nuches") in the herd systems experiment at Carimagua. The specific foci of infection in the grazing areas were the same as in previous years. ICA animal health staff handled the treatments. Observations were also made on the 36 Caja/CIAT survey farms. Based on lateral observations on only one side of the cow, no nuches were seen on ten farms. On 21 farms, up to 25 per cent of the cattle examined were infected; on 4 farms, between 25 and 50 per cent; and on one farm, more than 50 per cent. This last farm also had the highest average number of nuches per infected animal (3.9). An uneven, but declining prevalence was found from west to east.

The major work was on ticks. The new acarology unit is closely integrated with the hemoparasitology and wild animal studies. Part of the epidemiological work is to collect ticks from both domestic and wild animals for identification and for the establishment of colonies at Palmira. At present 12 species of ticks have been identified from the Llanos

Table 21. Species of hard ticks (Acarina: Ixodidae) found in the Carimagua area up to November 30, 1974, and their mammalian or reptilian hosts.

Tick species	Host species	Common name
Amblyomma auricularium	*Sigmodon alstoni*	Cotton rat
	Dasypus kappleri	Kappler's armadillo
	Dasypus sabanicola	Armadillo
Amblyomma cajennense	*Odocoileus virginianus*	White-tailed deer
	Dasypus kappleri	Kappler's armadillo
	Myrmecophaga tridactyla	Giant anteater
	Tamandua longicaudata	Long-tailed tamandua
	Didelphis marsupialis	Common opossum
	Metachirus nudicaudatus	Rat-tailed opossum
	Hydrochoerus hydrochoeris	Capybara
	Gopherus sp.	Land tortoise
Amblyomma crassum	*Gopherus sp.*	Land tortoise
Amblyomma dissimile	*Iguana iguana*	Iguana
	Azotacola sp.	Azotacola
	Boa constrictor	Boa
Amblyomma rotundatum	*Hydrochoerus hydrochoeris*	Capybara
Amblyomma longirostre	*Coendou sp.*	Tree porcupine
Amblyomma maculatum	*Bos indicus*	Zebu
	Cerdocyon thous	Crab-eating fox
	Hydrochoerus hydrochoeris	Capybara
Amblyomma pacae	*Cuniculus paca*	Paca
Anocentor nitens	*Equus caballus*	Domestic horse
Boophilus microplus	*Bos indicus*	Zebu
	Odocoileus virginianus	White-tailed deer
	Hydrochoerus hydrochoeris	Capybara
Ixodes luciae	*Didelphis marsupialis*	Common opossum
Rhipicephalus sanguineus	*Canis familiaris*	Domestic dog

Figure 15. The common opussum is one of the many species of wild animals that serves as a host for ticks which transmit hemoparasitologic diseases.

Orientales (Table 21), and two colonies have been set up (**Boophilus microplus** and **Anocentor nitens**). The tick colonies will be used on vector ecology and hemoparasite transmission studies. To build up material for this work, colonies of both laboratory and wild animals are being developed to test their suitability as laboratory hosts. The following animals are currently being used: oxen (**Bos taurus**), domestic chickens (**Gallus** sp.), domestic rabbits (**Oryctolagus cuniculus**), common opossums (**Didelphis marsupialis**), (Fig. 15), hamsters (**Cricetus cricetus**), white mice (**Mus** sp.), spiny rats (**Proechymis** sp.), white rats (**Rattus** sp.) and cane rats (**Zygodontomys brevicauda**).

A common allegation from farmers is that **Melinis minutiflora** (molasses grass) has an adverse effect on tick populations. The basis for this could clearly be seen in the ICA/CIAT herd systems experiment. Quantitative observations made on six occasions at two-month intervals showed that the herds on molasses grass either part of the year or all the year had significantly fewer ticks than the herds on natural grazing. Whether or not the grass itself has a noxious effect was checked using small study plots of **Melinis minutiflora** compared with **Paspalum plicatulum**. Both immature and mature grass stands had no apparent adverse effect on repelling or inhibiting immature stages of **Boophilus microplus** from crawling to the leaf tip. These experiments continue.

Other diseases diagnosed

Monitoring of diseases at all work localities revealed the following additional conditions of interest. A parasite of the larynx and trachea of cattle (**Mammomonogamus laryngeus**) was found infecting 7/50 animals at Palmira. On three farms on the North Coast, **Demodectic mange** was detected. Ten per cent of the animals were infected clinically. **Squamus cell carcinoma** was diagnosed in a cow near Villavicencio that had been slaughtered because of the malignant tumor invading the spinal column.

A graduate student from Tulane University found 56 per cent of 41 cows at Carimagua and Caviona infected with **Onchocerca gutturosa** and 35 per cent of 20 horses infected with a parasite that was tentatively diagnosed as **Onchocerca cervicalis**.

ECONOMICS

Economic aspects of the livestock industry

As part of the development of a collaborative research program on the economic aspects of the livestock industry in Latin America, a seminar was held at CIAT in January of 1974,* in which approximately 20 economists and a number of CIAT specialists in animal production participated.

Two of the most significant issues which emerged from the papers presented are reported here. These issues relate to the potential for the domestic consumption of beef and to the investment behavior of cattle producers.

The high proportion of beef in the family budget is indicated in Table 22. In Brazil, for example, beef represents 25 per cent of the total food budget and almost 10 per cent within the general cost-of-living index. For the average-income family in the countries examined, beef is the single most important food commodity in terms of its weight in the family budget. There is, therefore, great pressure to introduce beef price controls and/or export quotas and taxes, hence lowering domestic prices below the international levels, as happened at least in Brazil, Colombia, Argentina, Mexico and Chile.

In regard to income elasticities, also shown in Table 22, there is a large difference between the low- and high-income groups in Brazil, Colombia and Chile. Within the low-income group, this elasticity is always higher than 1.0. The average-income elasticity is lower than 1.0, which shows that beef can be classified as a basic rather than a luxury consumption commodity.

With respect to investment behavior and farmer's supply response, previous empirical studies had found a negative supply elasticity of short-term sales; and from this they deduced that the elasticity was also negative for long-term sales. Thus, they concluded that cattle producers in Latin America did not respond to economic incentives.

One of the most important conclusions of the studies presented (summarized in Table 23) is that the long-run elasticity of supply is positive in all cases, with values of 1.0 to 1.5. However, it is true that in the short run, this supply elasticity is negative. When prices go up, the reduction in short-term sales of females is greater than for males. The period of adjustment for achieving a long-run, steady-state equilibrium takes at least four or five years.

Benchmark study of the livestock sector

CIAT's 1973 Annual Report included a brief description of this project. During 1974,

* A report by A. Valdés is available on request.

Table 22. Demand for beef in selected countries of Latin America.

Country	Share of beef in total food expenditure (%)	Share of beef in total family expenditures (%)	Elasticities: Income High	Income Low	Income Average	Price Short term	Price Long term
Argentina	25	15.0			0.41	−0.3	−1.0
Brasil	25	9.6	0.5	1.6			−0.9
Colombia	23	13.1	0.47	1.5	0.84	−0.8	
Chile	21.7 27.9	10.9 7.2	0.25	1.73	0.61	−0.9	
Income level	low high	low high					

Table 23. Estimates of elasticity of beef cattle supply in Latin America.

Elasticity of	Argentina			Brazil Short term	Brazil Long term	Chile Short term
Inventory						
Males				0.070	1.775	0.15
Females				0.046	0.788	0.18
Total				—	1.587	—
Sales (slaughter)	Females	Males	Total sales	Females	Males	−0.108 females −0.227 males −0.117 calves
Period						
0	−0.055	0.076	0.025	−0.575	−0.113	
1	−0.372	0.017	−0.161	−0.458	0.036	
2	−0.411	0.053	0.370	−0.347	0.037	
3	0.012	0.370	0.225	−0.243	0.107	
4	0.553	0.664	0.609	−0.146	0.174	
5	0.689	0.725	0.710	−0.065	0.238	
Long term	1.376	0.995	1.149	1.538	1.596	

Table 24. Technical coefficients: Stylosanthes and molasses grass and native savanna.

Years	0 *	1	2	3	4	5	6
Calving rate (%)	50	55	60	65	70	→	→
Calf mortality rate (%)	10	8	7	5	5	→	→
Weaning rate (%)	45	51	56	62	62	→	→
Mortality rate 8–20 months (%)	6	5	3	3	3	→	→
Mortality rate 20 months and over (%)	6	5	3	3	3	→	→
Bulls/100 cows	5	5	5	5	5	→	→
Culling rate, cows (%)	15	15	15	20	20	→	→
Heifers more than 20 months of age entering the breeding herd or sold (%)	–	30	60	80	80	→	→
Culling rate, bulls	–	20	20	20	20	→	→
Carrying capacity: hectares of native savanna per A.U. **	–	5	5	5	5	→	→
Carrying capacity: hectares of Stylosanthes-molasses grass per A.U.							
Rainy season	–	2	2	2	2		
Dry season		1	1	1	1	→	→

* Prevailing in the traditional system
** Animal units

the benchmark was started in Peru and Ecuador; and an agreement was reached to do it for Argentina, starting in January, 1975. There is a first draft available for Colombia.

Economics of beef production systems in savanna regions

The 1973 Annual Report included a short description of this project. During 1974, emphasis was on the development of the methodology and processing programs for the economic analysis of the small farm prototype and of case studies of large-scale ranches in the Carimagua region.

Family farm prototype*

The results reported below represent one set of assumptions regarding technical coefficients and pasture management, scale of operation and input-output prices.** However, what is being developed is a system which can be manipulated from a number of aspects, including the introduction of crops.

Tables 24 and 25 present the technical coefficients used and the resulting herd development and cash flows simulated for a breeding-fattening operation, which begins with an initial herd of 15 breeding cows and stabilizes at a predetermined maximum of 36 cows in the postdevelopment period.

* See section on Family Farm Project in this report for a physical description of the ranch. The steady-state composition of the herd corresponding to 36 cows was chosen for the Family Farm in T[illegible] (Carimagua).

** Those prevailing in mid 1974

Table 25. Family farm: Predicted cash flows for a breeding fattening operation* (initial herd of 15 cows).

	End of year														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13 ……	25
Cash receipts															
Sales		—		27,300	20,920	20,800	31,200	52,000	50,753	69,420	92,410	131,530	118,530	118,530	118,530
Loans	67,372	105,503	—					-			—		.	—	
Salvage value	-	-	--	-					-		—			-	400,530
Total cash receipts	67,372	105,500	-	27,300	20,420	20,800	31,200	52,000	50,760	69,420	92,410	131,330	118,530	118,530	519,060
Cash outlays															
Variable expenses	-	2,066	2,795	15,767	9,283	4,860	5,332	13,304	12,655	5,505	5,870	33,113	9,113	9,113	9,113
Investments	67,372**	105,500***	8,952		13,936	16,436	11,936	3,465		—	5,500	—	-	—	
Interest paid (8 %, real)	5,359	13,830	13,830	13,830	13,153	11,523	9,563	5,205	6,544	4,885	3,226	1,350	—	-	-
Principal repayment (in real terms)	-	-	—		5,385	20,745	20,745	20,745	20,745	20,745	20,745	23,438	16,880	--	—
Total cash outlays	72,761	121,396	25,577	29,597	44,437	53,564	43,376	56,222	39,844	34,135	36,541	57,901	25,993	9,113	9,113
Cash position:															
a) With credit	-5,359	-15,896	25,577	2,297	23,557	32,764	17,176	4,222	10,756	32,285	54,069	73,629	92,537	109,417	509,947
b) Owner financed****	-67,372	-107,566	-11,747	11,533	2,389	496	13,432	24,728	38,245	60,915	73,040	98,417	109,417	109,417	509,947

* Exchange rate at 25 pesos per dollar

** Includes pasture establishment, part of the cost of the farmhouse and some installations. Cows purchased at the end of the first year

*** Includes purchase of cattle ($97,000) plus the remaining cost of the house and other installations

**** Excludes financial charges on the development loan

It is expected that this size of herd (an example of one possible solution) would yield at least the predetermined minimum net family income.

The analysis of the "optimal" rate of pasture development and its implications for investment flows and risk considerations will be examined in future work.

The farmer buys 15 cows at the end of the first year; the herd stabilizes in the eleventh year, selling 21 head annually. Sensitivity analysis indicates that these results are sensitive to the calving rate assumption but only marginally sensitive to variations in the calf mortality rate. For example, a reduction from 10 to 6 per cent in the latter, increases sales in the postdevelopment period from 21 to 23 head per year.

Area of improved pasture to be established was determined as a function of herd size. During the first year (t_o), investment consists of buying the land, establishing improved pasture, and part of the cost of the house. The main investment during the second year (t_1) was in cattle although cattle were brought to the farm at the end of the previous year. No labor costs have been charged as cash outlays; all labor is supplied by unpaid family members. With respect to sources of capital, cash flows have been computed alternatively for (a) all cash outlays financed directly by the owner and (b) all cash outlays financed with credit, at a real interest rate of 8 per cent per year, with 4 years of grace and 12 years for repayment. Capital requirements are shown in Table 25. At year 25, the farm has a net value of approximately Col$ 500,000 (US$ 20,000).

When financed by the owner, the farm, with an initial herd of 15 cows, has a negative cash flow during the first six years, or eight years when initial capital is borrowed (Table 25). The internal rate of return for a 25-year period was estimated at 18 per cent.

Alternatively, starting with the steady-state size and composition of the herd of 36 cows and a total of 107 head, the farm has a negative cash flow during the first two years when owner financed and during t_o, t_6, t_6 and t_7 with credit. The corresponding internal rate of return was computed at 18 per cent.

One of the most difficult problems is the negative cash flow resulting during the first years. The unit, although economically viable as judged by the rate of return, has a financial feasibility which is still uncertain because of the present credit system in Colombia. Future analysis will examine the potential contribution of crops to the cash flow as part of the production system and will also examine alternative credit arrangements.

Production systems (larger farm) Carimagua region

A modeling effort, similar to that described for the analysis of the family farm, was applied to case studies of larger farms. The economists simulated the effect on production, cash flows and on the rate of return resulting from changing the system based on extensive grazing of savanna to a more intensive system, including improved pastures.

As is the case with the small farm, only one of the possible sets of assumptions with respect to prices and technical coefficients is reported here. An example of a traditional farm with a total herd of 240 head, including 100 cows, was selected.

For the intensive system, improved pastures are established on 120 hectares with *Stylosanthes* and molasses grass; native savanna is available at a carrying capacity of 5 hectares per animal unit. The same technical coefficients reported for the family farm were used. Under the intensive system, the herd stabilizes during the sixth year at a predetermined maximum of 100 cows and 276 head in total.

The effect on production, investment and cash flows are presented in Table 26 a and b.

Table 26a. Incremental cost and returns resulting from improved pastures on large commercial ranches, relative to the "traditional" farm.*

1. Net investment			
a. During first year			
Pastures (120 ha)		$ 195,000	or $ 2,291 per ha
Fences		80,000	
Other installations		18,000	
		$ 293,000	
b. During postdevelopment period		$ 7,000	every four years
2. Variable expenses	approx.	$ 57,000	per year
3. Annual sales (head)			
Cows and heifers		12	per year
Steers **		12	
4. Total cash receipts (postdevelopment)	approx.	$ 150,000 ****	per year, after the seventh year
5. Net cash position (postdevelopment)	approx.	$ 93,000	per year, after the seventh year, minus $7,000 every four years
6. Marginal internal rate of return *** (at mid-1974 prices)	approx.	14 %	

* Exchange rate 25 pesos per dollar

** Steers sold at 400 and 250 kilos on the intensive and traditional system, respectively

*** Defined as that discount rate which equalizes the present value of changes in benefits with the present value of changes in cost and investments, relative to the traditional system; in other words, it is the rate of return to the increment in expenditures, resulting from pasture establishment and related expenditures. All calculations were made on constant real prices.

**** Includes increase in cows, heifers and steers sold plus the gain in weight (over the "traditional" system) of steers sold. The latter is equal to 3,150 kilograms per year.

Risk considerations and other possible marketing constraints have not yet been taken into account. As it stands, *this model* tends to predict riskier behavior than we expect will actually occur.

As an integral part of this project, a farm management analysis of specific improved practices in other areas is under way. For example, as in 1973, the effect of nitrogen fertilization of grasses (under irrigation) in Palmira was examined in 1974 (See p. 14).

Table 26b. Effect of lime levels on N content of four green manure crops at Carimagua, 1974.

Lime levels (ton/ha)	Percentage N Indigofera	Cowpea	Velvet bean	Crotalaria
0	3.58	3.15	3.24	No yield
0.5	3.58	3.02	2.75	No yield
2	2.84	2.81	2.66	1.41
6	2.46	2.36	2.55	1.51

PRODUCTION SYSTEMS

Production systems research focuses on the development of life-cycle beef cattle production systems and family farm systems where beef cattle are a principal part of the farm enterprise. An integrated multidisciplinary team of agronomists, animal husbandrymen, veterinarians and economists is developing production practices and systems for the lowland tropics that will be applicable over a wide range of sizes and types of farm enterprises.

Food crop production

Green manure crops for allic soils

The price of nitrogen fertilizer on the world market has tripled in the last three years. The need for biologically fixed N, which has always been important in developing areas, is becoming all the more urgent. To evaluate potential green manure crops for use in rotations on allic soils, four legume species were planted across four lime levels in the first semester, 1974. Two varieties each of maize and sorghum were planted on the same area in the second semester, 1974, but have not yet been harvested.

Aboveground dry matter and N yields, determined by sampling just prior to incorporation of the green manure, are shown in Figure 16. Note the striking response of crotalaria to lime. It yielded nothing at 0 and 0.5 ton/ha of lime while producing more dry matter at 6 ton/ha of lime than any other species. In contrast, indigofera, cowpeas and velvet bean responded much less than crotalaria to lime beyond 2 ton/ha and yielded *well at lower lime levels*. Maximum N yields were obtained with indigofera. Crotalaria had a low forage N content (Table 26 a).

Phosphorus and lime interactions

Two phosphorus-lime experiments were established at Carimagua in 1970. Some of the effects of lime on soil properties are shown in Figure 17. Crop responses to lime

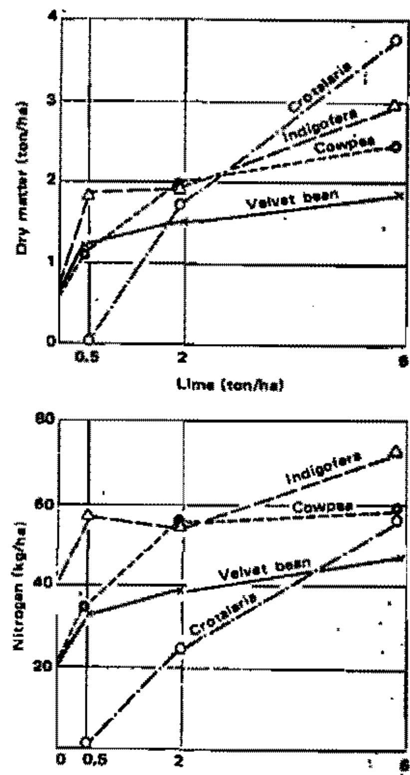


Figure 16. Effect of lime on forage and N yield of four green manure crops at Carimagua.

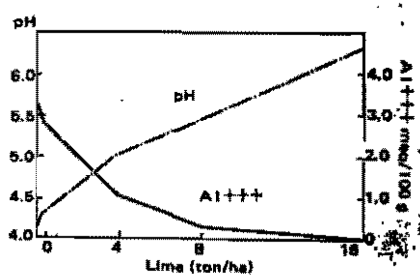


Figure 17. Effect of lime on pH and exchangeable Al in an oxisol in Carimagua. Samples taken one year after liming averaged over all P levels. From P x lime trial No. 1, Carimagua.

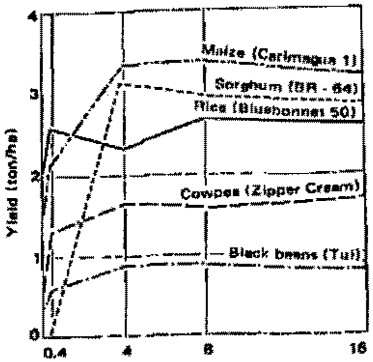


Figure 18. Effect of lime on crop yields of several species grown on an oxisol at Carimagua. Yields are averages over all P levels from P x lime trials, 1971-1974. Phosphorus at high rates has a liming effect, resulting in some yield at the 0 level with exception of sorgum. (Maximum P rate =600 kg P_2O_5 as initial basal application + 100 P_2O_5/crop).

are shown in Figure 18. With the exception of some rice varieties, maximum yields of maize, cowpeas, beans, sorghum and a number of rice varieties have been achieved at 4 ton/ha of lime with a soil pH of 5.0 and ≈ 25% Al saturation $\left(\frac{\text{Exchangeable Al} \times 100}{\text{Total exchangeable bases}}\right)$.

Several rice varieties and most cassava cultivars achieve maximum yields with 0.5 ton/ha of lime as do a number of cowpea cultivars, as detailed in earlier CIAT annual reports (Figs. 19 and 20).

Response to phosphorus varies among and within species. Figure 21 illustrates the marked difference in P response obtained at different lime levels for maize (Carimagua-1, selected for acid soil tolerance), two rice cultivars (CICA-4, selected on fertile, high pH soils, and Monolaya, a tall rice with good tolerance to soil acidity, grown for years in eastern Colombia) and cowpeas (Zipper Cream, also well adapted to acid soils).

Figure 19. Cowpeas (var. Zipper Cream) produce 1.5 to 2 tons of 25 per cent protein dry peas/hectare with applications of as little as 0.5 tons lime/ha on oxisols at Carimagua.

Figure 20. Maize (Carimagua 1) and cowpeas (Zipper Cream), together with vegetables such as squash, are grown in the food crop production unit at Carimagua.

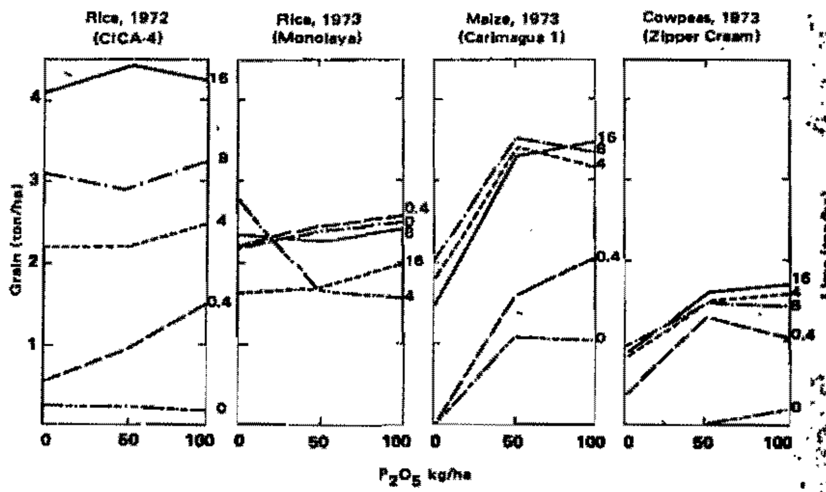


Figure 21. Response of maize, cowpeas and two rice varieties to P at different lime levels on an oxisol at Carimagua, 1971-1973.

The limited response of rice to P under field conditions is related in part to increased vegetative growth at higher P levels, accompanied by increased lodging of tall varieties and increased severity of disease (Pyricularia oryzae) in most of the semidwarf varieties tested. In the continuation of a trial reported in 1973 (CIAT Annual Report, pp. 215-216) three rice varieties (Line 1, IR-5 and T-442-2-58) were planted along a 0.5 per cent slope under conditions of natural flooding or high water table. Yields were excellent for all three varieties, and the response to 50 kg/ha of P (Fig. 22) was much greater than previously observed. Blast incidence was low, and there was essentially no bird damage this year. Two ton/ha of lime were applied to this field in 1973.

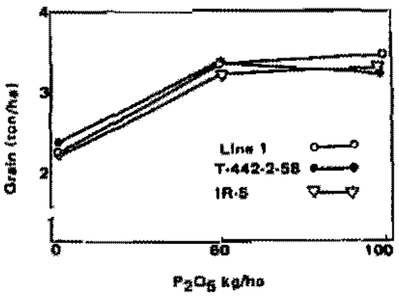


Figure 22. Response of three rice varieties to P grown under conditions of high water table to natural flooding at Carimagua, 1974.

Farm structures

Tomo house

The house on the family farm unit is constructed of native materials, taken from the gallery forest on the ranch, sand from the river and cement. The thin walls and ceilings are constructed with palm lathes and plaster, using a technique similar to reinforced concrete construction used for the stock watering tanks at Carimagua (1971 Annual Report, p. 113). The house is low cost, sturdy and easy to clean. The open, airy roof structure has apparently eliminated the problem of bats, common in many houses of the region. The space over the strong pole beam and plaster ceiling provides safe, dry storage for seeds and grains.

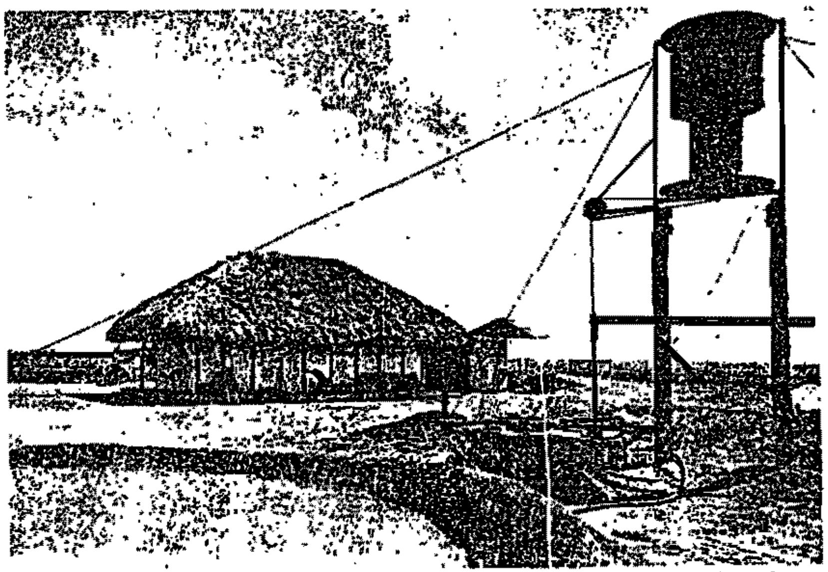


Figure 23. The Carimagua windmill and water tank on the Family Farm Unit. The house in the background is constructed of native materials.

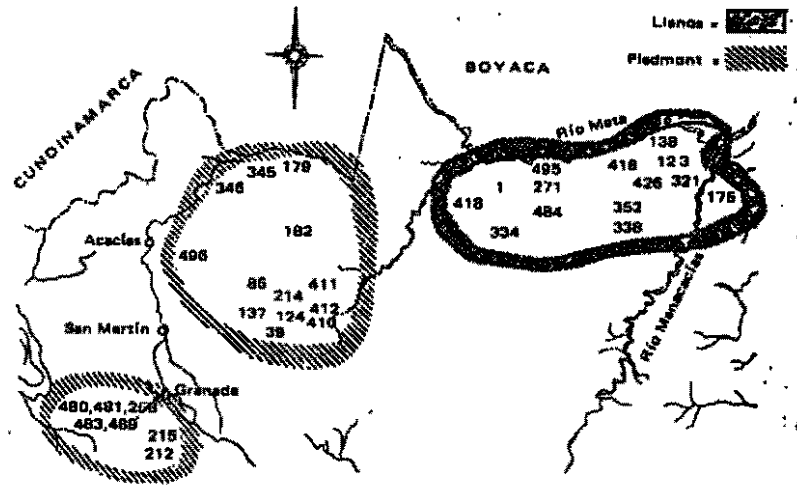


Figure 24. Location of farms by contract number in the Llanos Orientales (Eastern Plains) of Colombia. Plains farms (L) are east of Puerto López. Piedmont farms (P) are south of and west of Puerto López. Numbers in circled areas (P and L) refer to contract farms in the survey.

Carimagua windmill

The design change described in the 1973 Annual Report (pp. 50-51) has eliminated most of the problems encountered in the earlier models. The windmill is mounted on a simple, two-post tower. Concrete columns or light steel legs would be satisfactory where timber is not available (Fig. 23).

The mill now operates smoothly to rotor speeds of well in excess of 200 rpm. The 3:1 reduction from rotor to eccentric through the 5/8 inch V-belt provides a stroke length which can be varied from 2 to 8 inches by a simple change of attachment at the eccentric. The longest stroke is used during summer months when daytime wind velocities are consistently high, whereas the shorter strokes are used during the rainy season and transition periods when winds are lighter. The offset rotor halves assure starting torque regardless of wind direction relative to rotor at rest.

Herd production systems

Survey on small Llanos cattle farms

A field survey of 40 cow herds in the Piedmont and plains areas of the Llanos Orientales (Meta) was completed in 1973 in collaboration with the Fondo Ganadero (Meta) and ICA. The location of the farms is shown in Figure 24.

From ages of fetuses, determined by palpation, and estimated ages of nursing calves, a 52 per cent calving rate was estimated in the plains and 55 per cent in the Piedmont. Calving rates for farms varied greatly (Table 27). The range was 24 to 81 per cent for the Piedmont and 15 to 79 per cent for the plains. The standard deviation was 14 per cent and the coefficient of variation was 27 per cent. Within both zones,

Table 27. Fondo herds examined for pregnancy and lactational status and ranked in order of annual calving rate.*

Piedmont cows				Plains cows			
No.	Nursing (%)	Pregnant (%)	Herd calving rate (%)	No.	Nursing (%)	Pregnant (%)	Herd calving rate (%)
62	68	13	81	27	22	57	79
31	32	42	74	72	15	53	68
29	23	50	73	32	7	55	62
76	14	56	70	68	20	41	61
74	24	38	62	37	33	26	59
57	10	52	62	59	8	50	58
42	25	36	61	48	20	34	54
49	39	21	60	63	30	24	54
44	16	43	59	49	11	42	53
65	23	36	59	26	25	27	52
43	3	55	58	72	20	31	51
54	19	31	50	48	14	36	50
72	18	29	47	76	13	33	46
43	18	29	47	62	12	33	45
85	22	24	46	62	23	21	44
79	7	37	44	47	18	23	41
59	25	14	39	24	20	21	41
44	4	33	37	95	25	14	39
24	0	32	32	48	8	23	31
59	9	15	24	64	2	13	15

* Sum of percentage of cows nursing calves less than six months of age and per cent of cows pregnant more than one month

farms were divided into three groups according to calving rate: high, medium and low. For example, the best one third of the Piedmont farms averaged 69 per cent compared to an average of 63 per cent for the best one third of the plains farms.

Characteristics of farms, families and employees were summarized according to the high, medium and low calving rate groups. There were marked differences in farm size. Better plains farms were about twice as large as poorer farms. In contrast, best Piedmont farms were one third to one half the size of poorer farms and had a relatively high percentage of land in puntero (Hyparrhenia rufa), an improved pasture. Best plains farmers burned parcels of pasture in more months during the year. Although owners were in residence and managing more than half of

Table 28. Weight and condition estimates of principal breed groups.

Breed	Plains No.	Plains Wt kg	Plains No.	Plains Condition*	Piedmont No.	Piedmont Wt kg	Piedmont No.	Piedmont Condition*
	High**				High**			
Zebu	261	332	252	3.87	251	345	249	4.53
Criollo	13	320	13	3.85	25	311	25	4.00
Mixed	13	302	14	3.86	69	309	69	3.77
	Medium**				Medium**			
Zebu	227	290	238	3.71	279	304	277	4.17
Criollo	41	307	41	3.85	11	319	11	3.91
Mixed	51	298	51	3.84	51	314	50	4.16
	Low**				Low**			
Zebu	195	301	192	3.72	275	268	273	4.08
Criollo	43	293	43	3.65	19	308	19	3.68
Mixed	20	312	21	3.90	26	298	27	3.81

* Condition scores: 5 = Not fat, ribs barely visible; 4 = Thin, ribs apparent; 3 = Very thin, ribs very pronounced; 2 = Emaciated

** Reproduction rates: high, medium and low

the farms, there seemed to be no higher calving rate on owner-operated farms. Practically all farmers wished to expand by obtaining more cattle. There was little mechanization of farms, but this bore no apparent relationship to calving rates.

Estimated weights and condition by breeding groups (Table 28) indicated generally superior weights and conditions for cattle in the higher calving rate herds. Also, although there were few criollo cows in comparison to Zebu, they had higher estimated calving rates; and a higher percentage of nursing criollo cows were pregnant. There were definite indications that calving rate is associated with genetic differences as indicated by color and breed.

Conception occurred primarily in the dry season in the plains when presumably the cows had access to freshly burned lowland pasture and later in the dry season and early rainy season in the Piedmont. The marked seasonal nature of conception appears to be a reflection of seasonal variation in nutritional conditions. These are shown for the plains area in Figure 25.

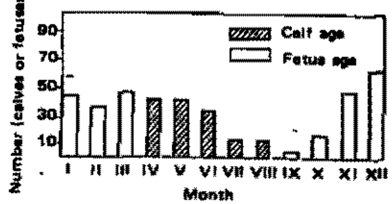


Figure 25. Llanos conception dates estimated from calf age and fetus age.

Life-cycle cattle production studies (Carimagua, Herd Systems I Project, ICA-CIAT)

As pointed out in the Fondo Ganadero survey, a key factor in explaining low herd productivity in the Llanos Orientales is the alternate year calving pattern because of the failure of nursing cows to rebreed. This has become a focal point of investigation. Poor body condition and poor growth rate are strongly implicated as limiting ability to reproduce. Time is prolonged for surplus males to reach an acceptable market weight and for heifers to reach breeding weight.

In the ICA-CIAT life-cycle cattle experiment at Carimagua, the variables being studied for improving reproduction and growth economically on a herd basis are minerals, improved pasture, protein (urea) supplementation in dry season, early weaning and crossbreeding.

The weight changes in all herds for about 18 months previous to calving are shown in Figure 26.

Minerals

Up to February, 1974, about 18 months after the experiment began and before the first calving, mineral-supplemented heifers weighed 1.20 times more than heifers receiving only salt. On a gain basis, mineral-supplemented heifers gained 1.63 times more than the heifers on salt only. In contrast to African results, mineral-supplemented heifers actually responded more to minerals in the dry season than during the wet season. It might be inferred from this that the lowland pasture used in the dry season was of somewhat higher nutritive value than the upland pasture grazed in the rainy season. The mineral comparison was limited to native pasture.

First-year calving and pregnancy rates were greatly different for the mineral-supplemented group. This amounted to 34 more calves born or predicted to be born per 100 cows; that is, 1.49 times more for the mineral-supplemented herd (Fig. 27).

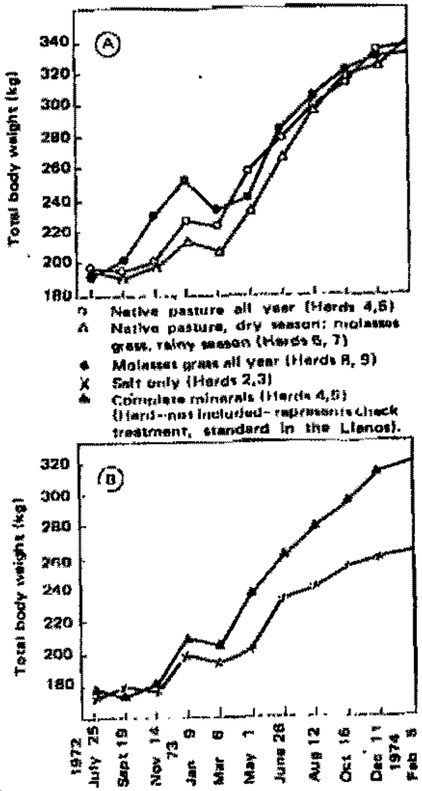


Figure 26. Two graphs representing: (A) changes in weights of heifers on different pasture systems. (B) Changes in heifer weights on native pasture as affected by minerals. Check treatment represents standard management systems in the Llanos. Graphs A and B both refer to the ICA-CIAT Herd Systems Project in Carimagua (1972-1974).

These early results reinforce the recommendations for feeding complete minerals, advocated for so long by all agricultural advisory agencies, public and private. It is difficult to understand why there has been so little adoption of mineral feeding. Perhaps an explanation such as that of Bauer (1968)* pertains. He found in the Beni region of Bolivia that the economics of mineral supplementation in cow herds was not favorable.

* BAUER, B. 1968. University of Florida, Cattleman's Short Course, Gainesville.

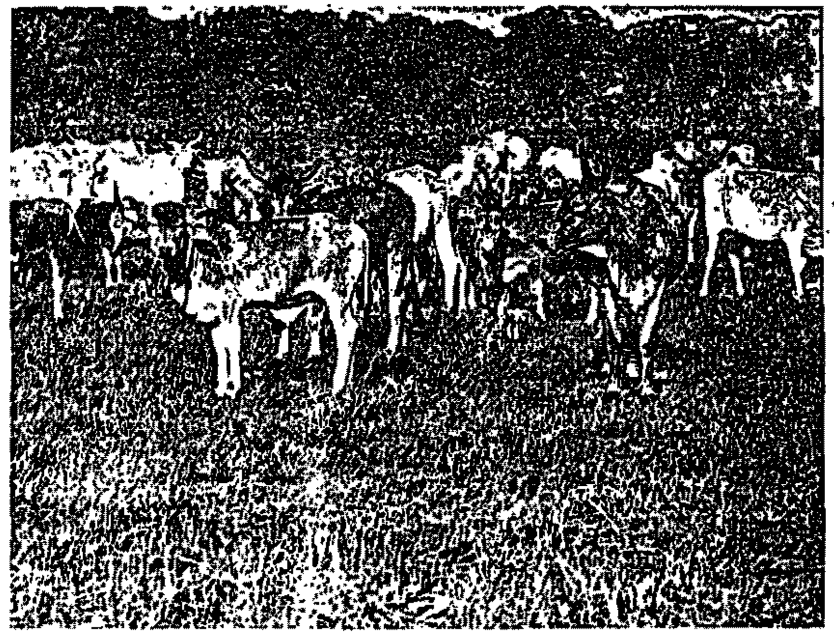


Figure 27. Herd 5 on native pasture and minerals. Twenty-nine calvings from 33 cows. Only two nursing cows were rebred.

However, in the present study with heifers, return on mineral investment is at least two to one. Comparative results with cows will become available in future years.

Consumption was about 10 kg/year/heifer for salt-only herds, 20 kg of complete mineral mix on native pasture, 30 kg of complete mineral mix on molasses grass pasture year round, and 25 kg of complete mineral mix per cow per year for herds on molasses grass only during the rainy season. The mineral formula was: 47% salt, 47% dicalcium phosphate, 6% trace mineral mix. The trace mineral mix was copper sulfate 1.95%, ferrous sulfate 5.0%, zinc oxide 1.24%, manganese sulfate 3.09%, cobalt sulfate .2%, potassium iodide .07%, wheat middlings 88.45%.

Improved pasture

Seeded, fertilized molasses grass (Melinis minutiflora) pasture is used exclusively for herds 8 and 9, and in the rainy season for herds 6 and 7 (Fig. 28). It now seems clear with heifers, as in the steer experiments, that molasses grass produces superior cattle growth in the rainy season but is inferior to the lowland savanna in the dry season when heifers continue to gain weight at about the same rate as in the rainy season on native pasture. Calving was earlier in molasses grass pastures, but it appears that on a first-year basis, the calving rate may be somewhat less than on native savannas (Table 29).

Urea-molasses supplementation in dry season

During January-March, 1974, herds 2, 4, 7 and 9 were allowed approximately 80 grams of urea, 4 grams of sulfur and 1/2 kilogram of molasses per day. In molasses grass pastures the cows consumed this amount readily, and a ratio of two-thirds water to one-third molasses-urea-sulfur mix was neces-

Figure 28. Herd 9 on molasses grass pasture; complete minerals; molasses-urea supplement during the dry season. 35 heifers produced 33 calves in 1974. By September, 1974 only two were rebred. Even well-managed heifers do not rebreed while nursing.

sary at times to prevent rapid consumption. Intake was much more leisurely in the native savanna pastures and less water was used. Supplemented Herd 9 (molasses grass) maintained weight during the dry season; whereas in unsupplemented Herd 8 on molasses grass, a loss of 54 kilograms was observed in 56 days. In contrast, on native pastures the difference was only 12 kilograms.

As of September, 1974, the rebreeding rate of nursing cows was 11 in 61 for

Table 29. Weight and calving-pregnancy percentage of cows in herd system experiment.

Treatments	Feb. 74 Weight cows (kg)	Sept. 74 Calving-pregnancy * No.	(%)
Control	316	29	58
Native pasture + salt	282	68	69
Native pasture + complete minerals	339	64	103
Native pasture + molasses grass + complete minerals	342	67	97
Molasses grass + complete minerals	333	70	92

* This refers to the percentage of cows in a breeding group that have calves plus those that will calve within a given year; includes 38 early-weaned cows.

urea molasses supplemented herds, and 9 in 57 for nonsupplemented herds. Thus, to date, supplementation has increased the rebreeding rate only about 2 per cent among nursing first-calf heifers.

Early weaning

Early weaning is one means of protecting the cow from lactational stress. Five calves were early weaned in each of the eight herds at an average age of 80 days in contrast to weaning other calves in the experiment at the age of nine months.

While to date there has been a higher rebreeding rate of nursing cows in the experiment (21 per cent) than in the Fondo herds (9 to 13 per cent), it is still low. In marked contrast, the cows with early weaned calves conceived rapidly; and 96 per cent were found pregnant, $X^2 = 81, P < .001$ (Fig. 29). Even in the nonmineral lots, the early weaned cows conceived. Early weaned cows gained 14 kilograms in the two months following weaning, whereas their herdmates lost 9 kilograms.

Preliminary exploratory experience with caring for early-weaned calves was favorable. Immediately after weaning, they were kept in a small shed for about two weeks. They received daily 1 kilogram of a 20 per cent protein dairy calf concentrate and ate an average of 7 kilograms of green chopped elephant and imperial grass (Axonopus scoparius), exclusive of the course stems refused. Later they were rotated among three 1 hectare pastures: stylo-pasto negro (Paspalum plicatulum); indigofera-pasto negro; molasses grass-puntero. They refused to eat the indigofera and preferred molasses grass to puntero. Stylo and pasto negro seemed highly palatable to them. Approximately one month following weaning, the concentrate was reduced to 1/2 kg/day,

Figure 29. Early weaned calves when about six to eight months old. Of the mothers, 96 per cent are pregnant in contrast to only 21 per cent of their nursing herd mates. These calves received .85 kg of concentrate and gained .46 kg per day. The average age at weaning was only 80 days.

Estimated daily costs including labor during the first four months after weaning were Col$4.80 (US$ .17) for a daily gain of .47 kg/day, with a cost of Col$10.21 per kilogram of gain, which compares favorably with the prices of feeder and fat cattle of about Col$15 per kilogram (Gómez, 1974).*

It is surprising that such high levels of reproduction were found in all treatments for the first-calf crop with the exception of the nonmineral herds. Also it has been surprising that on an annual basis, cows grazing native savanna have weighed as much and reproduced as well as on molasses grass. The palpation prediction for reproduction in the second year is much lower on all pastures. This reflects the stress of lactation on the first-calf heifer under these conditions. Even minerals and molasses-urea supplementation in the dry season seem to do little to overcome lactational stress in first-calf heifers.

On the other hand, indications are that rapid rebreeding of first-calf heifers will occur under all nutritional regimes with early weaning. For the savannas of Colombia, if a market could be developed for early weaned calves, a 70 to 90 per cent calf crop should easily be possible. In addition, the Llanos pastures presently occupied by feeder cattle could be used by more cows. Little immediate improvement in technology would be needed for this shift in the Llanos management if early weaners were to be sold rather than two- to three-year-old feeder cattle.

Should subsequent years of early weaning data not validate 1974 results, controlled weaning at a later age, such as nine months, may still give an appreciable improvement in calving rates in the Llanos. This requires the development of pastures and management for calf growing and fattening in the Llanos or in other traditional grass-fattening zones. Also this should result in improved meat quality through reduced age at slaughter and also lowered feed expenditure for maintenance.

Family farm unit

A prototype 250-hectare small farm unit was established at Carimagua in 1974 and will enter 1975 operating under theoretically steady-state conditions.

Fifty hectares of pasto negro (**Paspalum plicatulum**) associated with **Stylosanthes humilis** (21 hectares) and **Indigofera hirsuta** (29 hectares) were established and are ready for grazing. There are 2 hectares of food crops including upland rice, cassava, plantain and cowpeas, plus a small vegetable garden. Approximately 3,000 square meters will be irrigated during the dry season from the Carimagua windmill and earth storage tank, primarily for production of food legumes. The balance of the land remains in native savanna.

The steady-state herd consists of 36 cows, 2 bulls, 25 calves, 11 heifers and 12 steers of 18 months, and 6 heifers and 11 steers 30 months of age.

The prototype unit has provided valuable information regarding the integration of different components of technology into a commercial-scale production unit. It is also the only physical model of a series of production units being studied by the agricultural economics group to predict scale effect on production efficiency and economic feasibility of various herd development strategies (See pp. 33-35).

Pasture establishment began in April, 1974. Land was prepared by double disking native savanna with an offset disk, the second disking diagonal to the first. Seeding and fertilizer applications were done with a broadcast fertilizer spreader and grass seeder attachment, seeding in 45-centimeter rows following wheel tracks of the tractor and drill, plus two rubber press wheels for the two center rows. Germination and emergence were excellent.

* GOMEZ, J. et al. 1974. ICA-Carimagua (unpublished).

Figure 30. A walking cultivator greatly reduces time required for weed control in food crops on the Family Farm Unit.

An excessive leaf cutter ant population, apparently because of insufficient time between destruction of savanna grass and planting, almost entirely destroyed the pasto negro and stylo but left the indigofera unharmed. No **S. guyanensis** seed was available for reseeding, thus **S. humilis** was seeded with pasto negro to replace the **S. guyanensis** and pasto negro destroyed by the ants; and good stands resulted.

In future seedings, careful attention should be given to the cutter ant population. It will probably be necessary to allow more time between savanna destruction and pasture seeding. Land preparation could be done at the end of the rainy season, thus leaving four or five months for ant population to decrease before seeding the pasture at the beginning of the next rainy season.

There is little labor available, which limited food crop production more than was anticipated. To overcome this problem, a mule and walking cultivator were added (Fig. 30). The mule also pulls a 5-foot fertilizer spreader to apply lime and fertilizers on crops and basic slag on pastures.

It has been necessary to contract labor to establish the prototype unit in one year, a process that would normally take several years. To date, 438 man-days have been required for construction of the house, wall and fencing and for seeding pastures and food crops. The investment to date, not including land and cattle, is approximately US$ 3,000. This figure could be reduced by one half, producing pasture seeds on the farm and establishing pastures without using a tractor.

TRAINING

Livestock production specialist training

The third one-year course in livestock production specialist training (LPSTP) was completed August 31 with representatives from seven Latin American countries (See chapter on Training and Communication). A detailed outline of the objectives and activities of this course have appeared in previous annual reports.

At the end of the first phase of the course (three months), four men continued training at CIAT in swine production and research, while the others moved to the North Coast of Colombia for eight months. Their field training focused on beef cattle production, using commercial ranches as training laboratories.

These trainees, many of whom had never lived or worked on a ranch, had the opportunity to become an integral part of a livestock operation.

It is impossible to measure the magnitude of things these professionals learned during the eight months they worked with the people on the ranch and other professionals from the private sector. However, their concern and relevant questions demonstrate that they now have a better understanding of the complexities of beef cattle production in the tropics and how to cope with them.

In consideration of the fact that in-field training courses would have more relevance if carried out within each group's own country, the planning of future livestock production training courses will emphasize in-country training to the greatest extent possible in collaboration with national institutions. With this in mind, the livestock production course has had as one of its objectives "to train trainers" for national institutions. To date, the LPSTP has trained professionals from ten Latin American countries, who now receive follow-up assistance in developing in-country production training programs.

Postgraduate internships

During the year six professionals (Colombia 2; Bolivia 1; Ecuador 1; Guyana 1; Netherlands 1) received specialized training in tropical pasture research and evaluation techniques within three ecological zones of Colombia. One laboratory technician from INIAP, Ecuador, was trained in in vitro digestibility techniques in support of the national forage program in Ecuador.

The animal health group had four special trainees: three gained experience in the gathering of data to assess the prevalence of disease in the Eastern Plains of Colombia; the fourth received brief training in laboratory analysis techniques.

One student each from Ecuador, El Salvador, Colombia and the Dominican Republic received three months of intensive training in research and management techniques involved in pasture weed control. They also completed the one-year course in production before specializing in pasture weed control.

Research fellows and scholars

Two CIAT-funded students are presently working toward master's degrees in animal health at Colombian universities. A third student finished his master's degree in animal pathology at the Universidad Nacional in Bogotá at the end of the year and has rejoined the CIAT animal health team.

Three students are presently doing thesis work in partial fulfillment of the doctoral degree. One student from Germany and one from Chile are working on beef/economic related problems; a third student from Germany is doing research in pasture and forages.

OUTREACH

The seminar, "Tropical America: Potential to Increase Beef Production," was held at CIAT in February. Attendance included 153 invited participants and 108 observers from 20 Latin American and 9 other countries. This seminar helped to direct focus on the factors influencing development of the beef cattle industry, to identify techniques for increasing production, and to promote interchange of technology, information and ideas. A one-day meeting following the seminar was beneficial in considering CIAT's role in fostering collaboration among Latin American beef cattle production research and training programs.

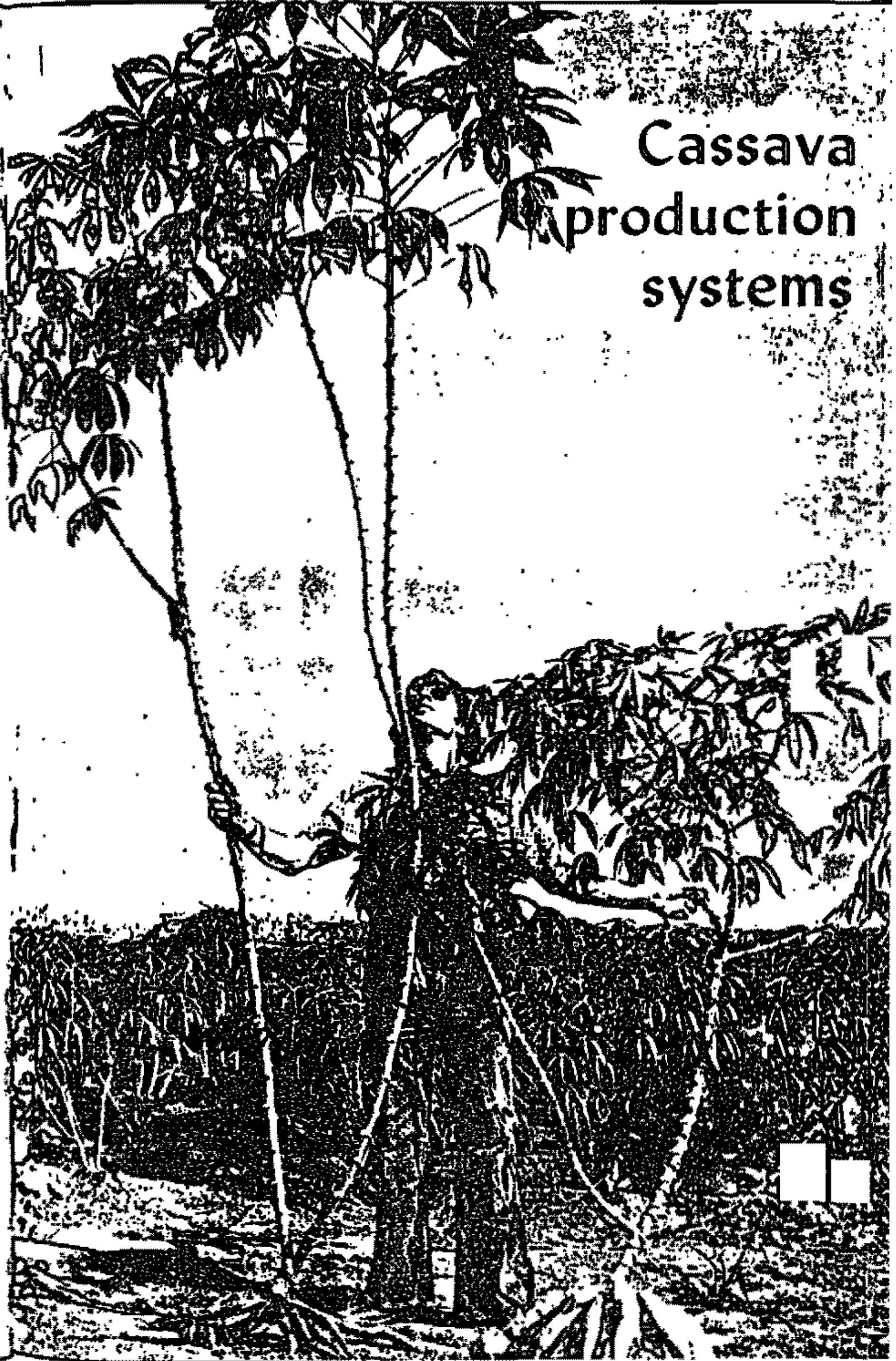
CIAT participates in the collaborative pastures and forages introduction and evaluation project including pasture and forage programs in Bolivia, Brazil, Colombia, Ecuador, Peru, Venezuela, IICA and CIAT. This has been complemented by a regional project initiated by CIAT to collect, evaluate, conserve and distribute selected genera of tropical forage legumes and grasses.

The CIAT beef program acts in an advisory capacity to the INIAP beef cattle program in Ecuador and the forage legumes program of the University of the West Indies in the Caribbean.

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

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

Cassava production systems



A yield of 46 ton/ha of cassava was obtained after 12 months on relatively poor soils, using limited inputs on a farmer's field near CIAT. A variety similar to that which produced the highest yield recorded at CIAT has been used extensively in the breeding program in an attempt to produce high-yielding, disease- and insect resistant types.

The germplasm has now been completely evaluated for agronomic characters, and testing of the first hybrids is well under way. The most promising types selected so far are undergoing field testing in 14 areas of Colombia.

Resistance to most major diseases and pests has been encountered, and rapid screening methods are being developed. In the case of hornworm, no varietal resistance has yet been found; but parasitism and hence control can be obtained readily and simply. Weeds can be controlled effectively by three hand weedings; however, less vigorous weed control is needed when plant population is increased.

The plant ideotype for cassava requires a balance between root and stem production so that a leaf area index of three to four is maintained through a long leaf life.

Tentative critical levels for nutrients in leaves have been determined, and marked response to fertilizer was found, particularly to potassium.

An economics survey shows that most cassava in Colombia is grown under monoculture and suffers from attack by a large number of diseases and pests. Certain practices, such as plant density, appear to be less satisfactory than those used for optimum production.

The clamp storage system has been developed further so that cassava can now be stored for up to two months, packed in moist sawdust in boxes.

Joint projects with Canadian institutes were continued, and Dr. L. A. Hunt (University of Guelph) visited us for one year on a joint physiological project. Dr. R. Booth (Tropical Products Institute) continued storage work at CIAT. Four doctoral candidates from Nigeria, the United Kingdom, Cameroons and the United States worked at CIAT during the year on thesis research in pathology, propagation and soils.

Students from Brazil, Venezuela and Nigeria spent varying intervals in training at CIAT. Some 20 Brazilians and 3 Venezuelans attended an intensive course on cassava research methodology and now form part of the comprehensive research network being formed on a world-wide basis.

PHYSIOLOGY

This section has continued efforts to define both a plant ideotype and optimal cultural practices for obtaining high yields. Last year, we suggested that lack of leaf area was one of the main reasons for low yields (Annual Report 1973).

Increasing plant population is a classic method of increasing leaf area index; however, when five varieties were planted at CIAT at different populations, the light interception (which is closely related to leaf area index) 4 1/2 months after planting was almost constant in all varieties except M Mexico 11 and M Colombia 22. Even in these two varieties, light interception at high populations was no greater than in the other varieties (Fig. 1).

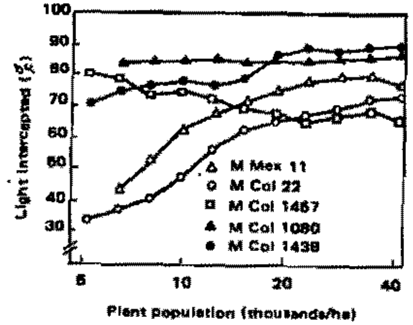


Figure 1. Relation between light interception and plant population on a cloudy day 4 1/2 months after planting.

Last year it was shown that shading decreased leaf life, and in another trial it was shown that leaf fall started earlier at higher plant populations (Fig. 2). Hence it appears that at higher plant populations in vigorous varieties, increased leaf production is balanced by increased leaf fall, and thus leaf area index is not increased. But in less vigorous varieties, such as M Mexico 11 and M Colombia 22, leaf area index can be increased by using higher populations.

Consequently, in the more vigorous varieties, total dry matter did not increase with increased plant population (Fig. 3); and in the most vigorous type, M Colombia 1467, it actually decreased, probably because of

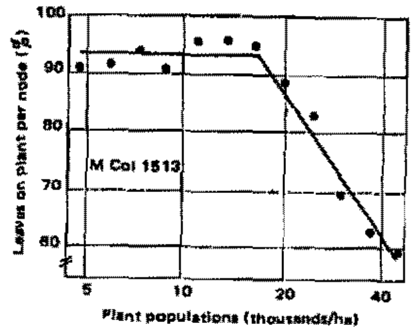


Figure 2. Effects of plant population on leaf fall at CIAT three months after planting.

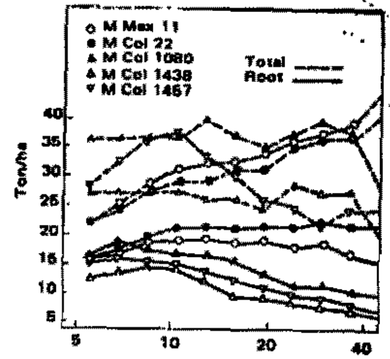


Figure 3. Total and root dry yield of five cassava cultivars at CIAT.

excessive leaf fall which was not collected at final harvest. The two varieties in which leaf area was increased also showed increased dry matter (Fig. 3).

Yield immediately divided the varieties into the vigorous and nonvigorous types. M Colombia 22 and M Mexico 11 showed a plateau-type yield/density response, whereas the others showed marked optima with lower maximum yield levels (Fig. 4). The dry matter root yield showed a similar trend with M Colombia 22 giving root dry matter yields 11 months after planting of 22 ton/ha. The decrease in yield of the vigorous types was due to a decrease in harvest index (Fig. 5). This suggests that they produced

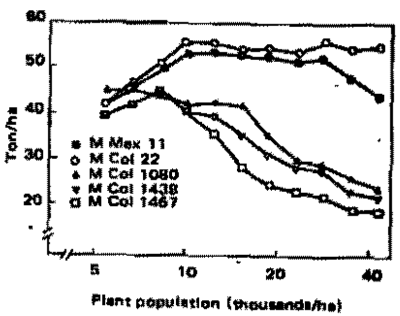


Figure 4. Fresh root yields of five cultivars at various plant populations at CIAT.

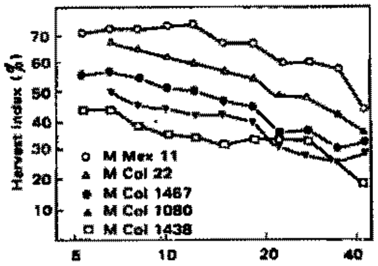


Figure 5. **Harvest index of five cassava cultivars at various plant populations at CIAT.**

excessive top growth, leaving no excess carbohydrate for root filling at higher populations. In M Colombia 22 and M Mexico 11, a decreasing harvest index of more than 10,000 plants per hectare was compensated for by increased dry matter production.

The two varieties, M Colombia 22 and M Colombia 1438, were planted in a less fertile soil of lateritic origin in La Zapata. Fertilizer was applied at the level of 100: 100: 100 NPK at planting. Unlike the CIAT trial, both varieties showed a plateau-type response curve (Fig. 6), and M Colombia 1438 outyielded M Colombia 22 at all densities. The plateau-type response curve was associated with an almost constant harvest index (Fig. 7), suggesting that at lower fertility

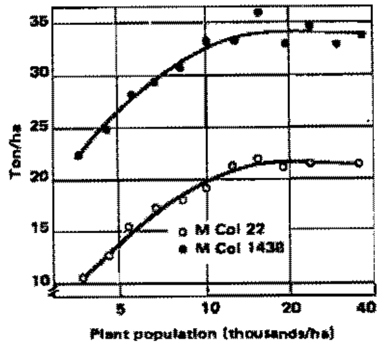


Figure 6. **Fresh root yield of two varieties at various populations at La Zapata 11 months after planting.**

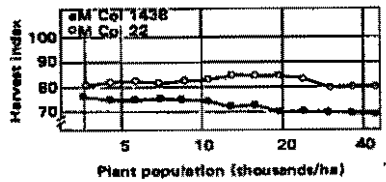


Figure 7. **Changes in harvest index at various plant populations at La Zapata.**

levels there is less mutual shading at higher plant population.

The optimal plant population for maximum yield of Llanera changed from 5,000 to 15,000 to 40,000 plants per hectare, whereas the critical level of M Colombia 22 increased from 10,000 to 15,000 plants per hectare when put in less fertile conditions.

It was also felt that leaf area might be increased by nitrogen application, thereby increasing yields in less fertile regions such as La Zapata. A systematic nitrogen application design was planted in La Zapata, using M Colombia 22 and M Colombia 1438 (Llanera) planted at 1 x 1.2 meters. Nitrogen applications were split at 0, 3 and 6 months after planting. At intervals during the growth cycle, light interception was measured but no nitrogen effects were observed; however, Llanera consistently intercepted more of the incoming radiation. Hence nitrogen apparently had little effect on leaf area. Nevertheless, M Colombia 22 showed a marked, almost

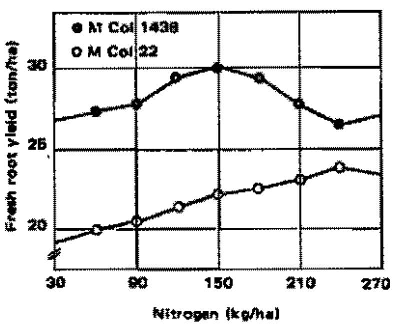


Figure 8. **Yield of two varieties at various nitrogen levels at La Zapata 11 months after planting.**

linear, fresh yield response to nitrogen; whereas Llanera showed an optimum level that was not significant at 5 per cent (Fig. 8). This tendency for yield to decrease was also found at higher N levels in a trial reported in the Soils section.

Although M Colombia 22 outyields Llanera at CIAT, this is not the case in La Zapata. The extremely low vigor of M Colombia 22 and its high harvest index are favorable characters on fertile soils where top growth may be excessive, but are a disadvantage under less fertile conditions. Apparently neither closer spacing nor nitrogen can fully compensate for this low vigor.

Leaf area can also be changed by varietal selection. Last year it was shown that M Colombia 113 maintains a large leaf area index throughout most of its growth cycle, and it was suggested that this might be because of its good leaf retention. However, maintenance of a large leaf area depends on a combination of a rapid rate of leaf production per branch, a large number of apices, leaf size and leaf longevity. A series of trials was established to study these factors.

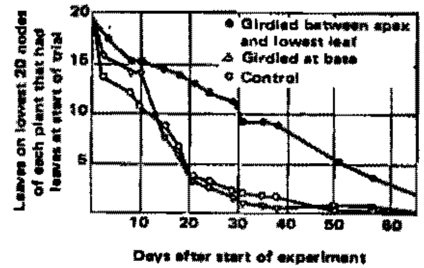


Figure 9. **Number of leaves on lowest 20 nodes of plant with leaves at the start of the experiment (M Colombia 72).**

Last year it was shown that leaf life was decreased by shading and increased by apex removal. Apex removal prevents formation of new leaves, thereby decreasing shading of lower leaves; and for this reason leaf life might have increased. When the phloem was cut between old and young leaves, the leaf life of leaves below the cut was increased (Fig. 9) even though new leaves were formed at the apex. Thus, the apex has a direct, probably hormonal effect on leaf

Table 1. **Effects of plant age on leaf longevity, number of apices and leaf production rate per apex of spaced plants of M Colombia 1438.**

Age of plant at time of leaf appearance (days)	Leaf longevity (days from leaf appearance to abscission)	Number of apices per plant	Leaves per apex 10 days
50–69	32	1	11.8
70–89	42	1	4.7
90–109	47	3	5.5
110–129	49	3	5.2
130–149	68	9	4.4
150–169	80	9	4.2
170–189	98	27	4.2
190–209	–	27	2.4
210–229	–	81	2.5
230–249	–	243	1.9

Table 2. Mean leaf life (days) of leaves formed at different plant ages in three varieties as spaced plants during rainy season.

Plant age (months)	M Colombia 22	M Colombia 113	M Colombia 1120
6	67	69	80
7	63	73	90
8	65	81	120

life. Girdling the plant between the roots and the lower leaves did not affect rate of leaf fall, once again demonstrating that leaf fall is not related to rapid root bulking.

Leaf life was studied on spaced plants over a period of time using single plants of M Colombia 1438. Leaf life increased with the age of the plant (Table 1). In other experiments at more normal spacings, this effect was not observed; however, more careful observations are needed.

Table 3. Percentage of newly formed leaves marked 125 days before experiment finished that had abscissed and mean leaf life of abscissed leaves.

Variety	Leaves abscissed (%)	Mean life of abscissed leaves (days)
M Colombia 22	73	73
M Colombia 29	77	66
M Colombia 113	65	88
M Colombia 1513	54	72

The longevity of leaves of different varieties was also studied. Results showed extreme variability from trial to trial (Fig. 10). In one trial using plants at wide spacing (Table 2) and in another with spacings from 10,000 to 40,000 plants per hectare, quite large varietal differences were observed (Table 3). The long leaf life of M Colombia 113, as compared with M Colombia 22, was not

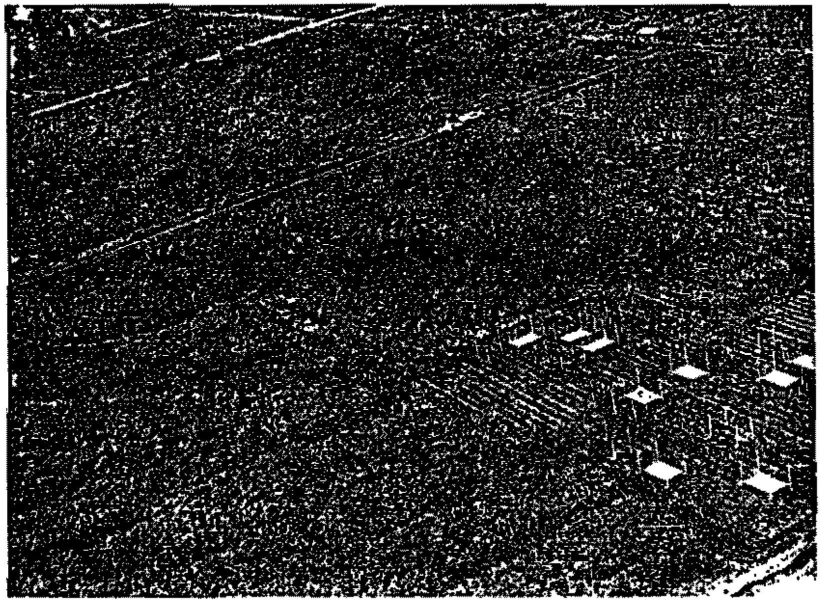


Figure 10. Physiologists try to see the effects of planting density and light intensity in wheel-field experiment and shading experiment, respectively.

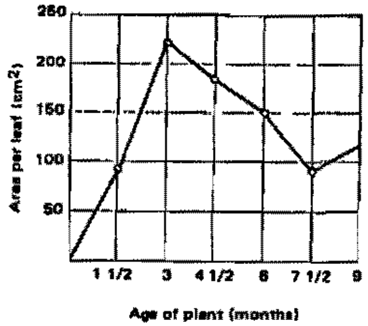


Figure 11. Average leaf size of M Colombia 1513 at different ages of the plant.

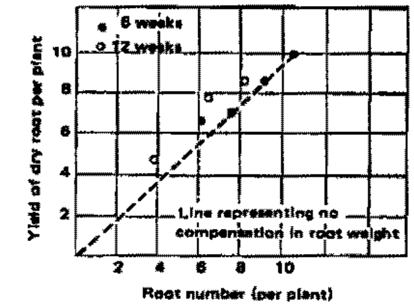


Figure 13. Relation between dry root yield and thick root number in M Col 1513, CIAT.

observed in any other trial. Thus, it seems that genetic variation does exist in leaf life but that the character depends on plant age and other as yet undetermined factors.

M Colombia 1513 was planted at 45-day intervals; and when the oldest plants were nine months old, leaf area per leaf was measured. Leaf size increased at first and then decreased markedly as plant age increased (Fig. 11).

The rate of leaf formation depends on the number of active apices and the rate of leaf production per apex. The number of apices increases almost logarithmically with time in a branching variety such as M Colombia 1438

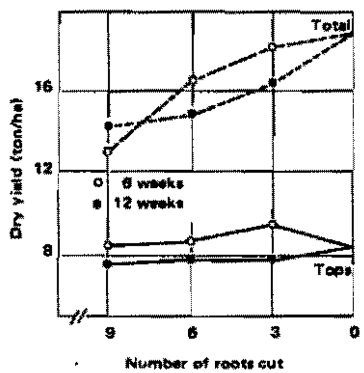


Figure 12. Dry matter yield of roots and total plant with different thick root number in M Col 1513, CIAT.

(Table 1); however, leaf production rate per apex decreases with time (Table 1) and shows large varietal differences.

Nevertheless, it is not enough to think only in terms of having sufficient and efficient leaf area for maximum dry matter production. The roots must have sufficient capacity to accept the dry matter produced. M Colombia 1438 was planted at 1 x 1 meter spacing; and at 6 weeks and 12 weeks after planting, three, six or nine thickening roots per plant were cut. Eight and a half months after planting, heavy rains and strong winds resulted in severe lodging, and plants were harvested the following day.

The root-clipping treatments had no visible effects on the aboveground plant parts, and light interception data showed only small differences, suggesting that the treatments had no effect on leaf formation and retention. There were no differences in node number per branch in any of the treatments, which further supports this view. At the final harvest, top weight was not affected by the clipping treatments (Fig. 12). Hence the number of roots per plant does not apparently affect top growth, suggesting that top growth may take priority over roots when limited carbohydrate is available and that excess carbohydrate passes to the roots.

Although top weight was not reduced, total root weight was markedly reduced by the treatments (Fig. 12). Thus, total production decreased as root number decreased, leading to the conclusion that root sink

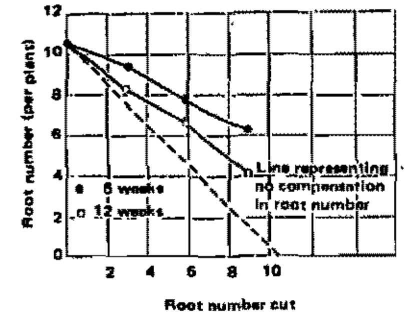


Figure 14. **Effects of thick root cutting at different times on number of roots per plant in M Col 1513 (CIAT) 8 1/2 months after planting.**

limitations may decrease total dry matter production.

The decrease in root weight per plant was mainly due to a decrease in root number (Fig. 13). The plants with roots cut at six weeks showed some compensation for roots cut which formed new thickened roots; but by 12 weeks, compensation reached a level of only two thick roots per plant even in the nine thick-root cut treatments (Fig. 14). The maximum compensation in root size for the reduced root number was only 30 per cent, whereas in order to have given equal yields to those of the controls, a compensation of 160 per cent would have been necessary (Fig. 15). Thus, the capacity of individual root expansion is limited and is not solely dependent on the supply of carbohydrate.

A further trial was planted to observe effects of the roots on plant growth. Plants

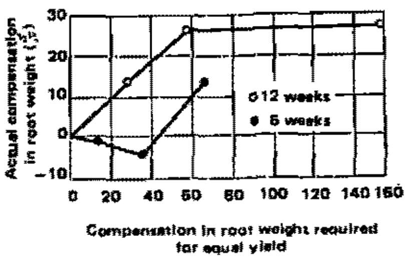


Figure 15. **Actual and required root compensation for equal yield.**

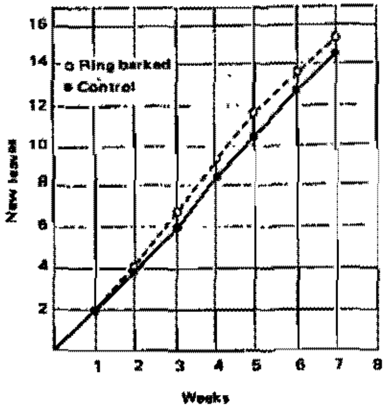


Figure 16. **Rate of leaf production per branch of M Colombia 22 when ring barked at stem base, CIAT.**

were ring barked at the stem base five months after planting to prevent movement of carbohydrate to the roots. Rate of leaf production was minimally affected (Fig. 16), and mean leaf size remained unaltered (0.5 g/leaf). However, unlike the previous trial, stem weight was markedly increased (Fig. 17), whereas root weight declined dramatically. The root weight decrease corresponds to a mean respiration rate of about 1 per cent of mean root dry weight per day, which is of the same nature as that reported for

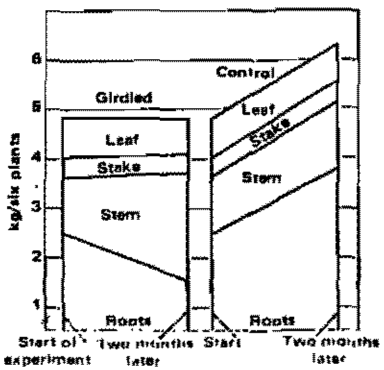


Figure 17. **Changes in weight of components of M Col 22 when ring barked at five months after planting.**

maintenance respiration in other crops. The crop growth rate of the ringed plants was essentially zero, whereas untreated controls increased weight by 1 1/2 kg/plant in two months (Fig. 17). Thus, root sink strength limits overall growth, has little effect on the rate of leaf area production and leaf life, but may in some cases affect stem weight.

A plant ideotype

Data collected over the last three years enable us to present a tentative plant ideotype as a guide to breeders. The plant should have a large root sink capacity; however, the method by which this can be determined is as yet unknown. It is suggested that the plant type should have at least nine

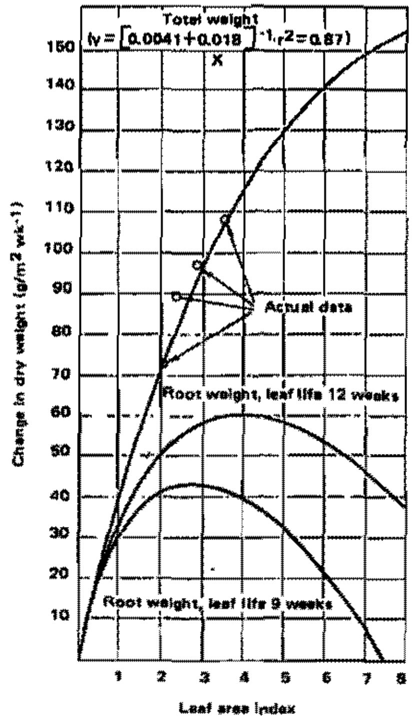


Figure 18. **Simulation model of growth of cassava plant.**

thick roots per plant, as reducing below this level has been shown to decrease yield.

The top growth appears to be relatively independent of the sink capacity of the roots; therefore, it can be assumed that the difference between dry matter utilized for top growth and total dry matter production is accounted for by root growth. Total growth per unit time can be described as a function of leaf area index; a curve was fitted to data from M Colombia 1148 (Fig. 18) to describe total dry matter production as a function of leaf area index. This curve favors high leaf area indexes, as the real curve is probably more flat topped. $W = (0.0041 + \frac{0.018}{L})^{-1}$ weight production per week in g/m² and L = leaf area index.

At a point when equilibrium is reached between leaf fall and leaf production so that leaf area index is constant, leaf area index can be described as L = R.E.A., where R = leaves produced per m² per week, E = expected life in weeks, and A = area per leaf in m². For each leaf it is necessary to have the full nodal unit, and it follows that stem weight increase S is given by $\dot{S}$ = R.N., where N is the weight per nodal unit including leaf blade, petiole and stem. Returning to the assumption that yield is the difference between top growth and total dry matter production, we find that:

$$\text{Yield} = W - S = (0.0041 - \frac{0.018}{L})^{-1} - (\frac{NL}{EA})$$

The average weight per stem nodal unit (without leaf blade plus petiole) of M Colombia 22 was 0.6 g when leaf (blade plus petiole) weight was 0.5 g with a leaf area of 0.07 m². Leaf life of M Colombia 22 is frequently of the order of nine weeks, and this value was used as a base with the arbitrary assumption that leaf life decreased by 0.2 weeks for each leaf area index unit because of shading. Putting these figures into the model, we arrive at the curve shown in Figure 18, showing an optimum leaf area index of close to 3 for dry root yield. This is lower than that suggested by last year's results in which M Columbia 113 had a leaf area index of about 5 during its last six months of growth. If, however, we change the leaf life figure to 12 weeks, as was found in one trial (Table 3), the optimum becomes less pronounced, greater (about 4), and yield increases markedly in comparison with plants with shorter leaf life (Fig. 18).

It is difficult to select for a specific leaf area index, but harvest index may be a better selection tool (Fig. 19). It appears that selecting for a harvest index of about 55 per cent coupled with longer leaf life may be easier.

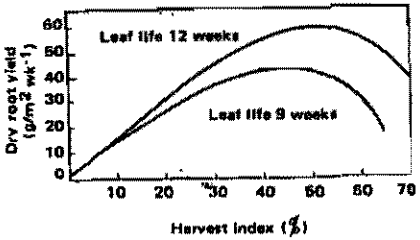


Figure 19. **Simulated yield of cassava roots as a function of harvest index with two leaf lives.**

PATHOLOGY

The cassava pathology program has concentrated on the four major diseases of this crop in America: cassava bacterial blight (CBB), phoma leaf spot, the superelongation disease and **Cercospora henningsii** leaf spot. Although several aspects on the etiology of the causal agents of these major diseases were investigated, main efforts were directed to study their epidemiology and control by searching for resistant varieties. Additional investigations on other known leaf spots, root rot diseases, the root-knot nematode, and stake treatments for cassava establishment were also conducted.

Although several unknown conditions have also been observed in several cassava plantations, only the "frog skin" disease has been studied.

New rooting method

To produce plants for cassava pathology investigations, a simple method for the rapid rooting of shoot tips was developed. Shoot cuttings, produced in propagation frames, such as described in the Annual Report 1973, were cut with sterile knives and put in vials containing sterile distilled water. These were placed under continuous fluorescent light at room temperature (24 °C, approximately). Roots developed in five to eight days, depending on the cultivar, after which plants were either transplanted into soil or nutritive solution, according to requirements.

Cassava bacterial blight

The presence of CBB in Thailand and Malaysia (MARDI)* was confirmed. Comparative studies have shown that isolates from Asia were physiologically similar to some American and African isolates.

Translocation of CBB inside the host

By using a streptomycin-resistant mutant, it was found that CBB moves inside the host mainly through the xylem tissues. This movement appears to be related to the susceptibility of the cultivar and the water content of the soil. Visual primary symptoms on stems following natural infection (cankers and gum exudation) appeared mainly on the green portion of the stem; the mature and old stem portions do not show symptoms, but the pathogen was regularly found inside the xylem vessels.

When primary infection took place on the upper part of the plant (leaf or stem inoculation), the pathogen also infected the xylem vessels located at the periphery of the pith tissues at the mature and old, bottom portion of the stem. In contrast, after root or stem base inoculation, the pathogen was found only in the epidermal tissues of the young, unlignified portions of the stem. Buds located on mature or old parts of infected plants were commonly healthy, and the sprouts (shoots) that arose from these buds generally remained healthy. However, translocation of CBB to the sprouts may take place, depending on the proximity of the stem-infected xylem vessels to the vessels of the sprouts. Since the vascular tissues of the sprouts are located on the periphery of the woody portion of the stem, the sprouts generally remain free of CBB during the first 20 days following their emergence.

* Malaysian Agricultural Research and Development Institute

After leaf spray inoculation, the pathogen moved through the petiole to the stem of susceptible and tolerant cultivars. The movement of CBB inside the petioles took place through the xylem vessels. The number of bundles infected was related to the distribution of leaf spots on the leaf lamina. The stem became infected by CBB movement through the trifurcated vascular strands of the petiole; the degree of stem infection was related to the number of infected petiole bundles. Once CBB is inside stem xylem vessels, it moves up or down following the strands of the vascular bundles. When plants of the resistant cultivar M Colombia 647 were leaf spray inoculated, the pathogen did not move to the stem and remained in the leaf lamina, inducing only angular leaf spots.

Screening for resistance

Screening for resistance under field conditions has given consistent results. Rows of test cultivars are planted alternately, 30 centimeters apart from susceptible spreader rows. Two months after planting, the susceptible spreader rows are leaf-rub inoculated. Disease dissemination takes place during the rainy season, and evaluation of test varieties can be made three months after inoculation.

Using previously proven resistant, tolerant and susceptible cultivars, a comparison was made of stem and leaf inoculation techniques using plants. Leaf inoculations gave better and more even bacterial establishment and development, provided that a high relative humidity (95-100 per cent) was maintained during the first 24 hours. Stem inoculations produced variable results even in those cultivars known to be highly susceptible.

CBB dissemination

Four possible alternative methods of CBB dissemination have been studied:

1. Root infection was achieved when a heavy suspension of CBB (5 x 10^8 to 10^9) was applied both to the soil and to wounded roots. But, considering the low percentage of root infection (7.0 per cent for susceptible cultivars and 2.7 per cent for resistant cultivars), the high bacterial population required for infection, and the relatively poor survival ability of CBB, it appears that this method of dissemination may occur only rarely in nature and then in heavily infected plantations only.

2. Soil splash infection was observed in heavily infested soil but only on those leaves that were located closest to the ground. Under controlled conditions with infested soils, CBB cells produced infection in cassava plants at all populations above 10^4 cells/g of soil, but below 10^3 cells/g of soil, infectivity was not obtained. The number of leaf spots induced decreased as cell number/g of soil decreased.

3. The following insect species were found to be able to disseminate CBB mechanically under controlled conditions: **Paratheresia claripalpis, Tabanus** sp., **Anasthrepha** sp., **Apis mellifera, Polistes** sp., **Erinnys ello** (larva), **Diabrotica** sp. CBB was isolated only from the outside of their bodies. These insect species were commonly found in infected cassava plantations in the Cauca Valley. Based on their activities on the plants and the presence of CBB cells on their bodies, the insects have been placed into two groups:

a. Incidental visitors that do not damage the plants. These insects are only present on the plants to collect the plant products, such as nectar and other sweet exudates; and during their feeding activities, they become contaminated and thereby disseminate the pathogen. This group includes **Paratheresia claripalpis, Apis mellifera** and **Polistes** sp.

b. Cassava pests. The damage these insects do may serve as infection sites for CBB; and if they themselves are infested, they then serve as ideal disseminators. This group includes **Diabrotica** sp., **Erinnys ello** (larva) and **Anasthrepha** sp.

4. Studies on CBB dissemination through true seeds are summarized in Table 4. These results indicate that CBB does not penetrate

seed tissues; and since the bacterium was not found on the seed coat, it also appears that it does not survive for a long period on the seed surface.

Table 4. Results on CBB presence inside true seeds. Isolations of samples taken from the endosperm and embrion.

Trials	Replication 1	2	3	Presence of CBB
Immature green seeds from infected plants	132	145	138	—*
Mature seeds from infected plants	135	140	132	—
Mature seeds soaked in a CBB suspension **	130	140	130	—

* Negative isolation

** Seeds dipped for 5 minutes in a bacterial suspension of 3×10^9 cells/ml and kept for 48 hours at 25°C period 90% RH. Isolation trials

CBB survival

CBB appeared to survive better and longer in sterile soils (35 days) than nonsterile soils (28 days). The optimum pH for survival appeared to be 6.0 to 6.5, in which CBB survived for 35 days under sterile conditions; a higher or lower pH reduced the degree of survival. CBB did not survive well in Popayán or Jamundí soils (with high organic matter content) but survived better in CIAT soil (low organic matter content and 6.8 pH) (35 days), which suggests poor competitive saprophytic ability. There were no differences between survival of washed and unwashed CBB cells in soil. However, flooding and dessication had deleterious effects on the survival of CBB. The cells survived for 7 and 14 days, respectively, in flooded and dry soil.

These results suggest the possible eradication of the pathogen from infested soils by land fallowing or crop rotation. Since CBB soil appears sensitive to dessication, its eradication may be more effective if land is cleared of infected cassava plants before a dry season. Also, since CBB can survive for more than six months in infected plant debris, the elimination by fire of all cassava debris and volunteer plants is suggested.

Phoma leaf spot

Etiological studies

The leaf spot disease present in the coolest cassava growing areas or during the cool growing season, which characteristically shows concentric rings on the upper surface of the infected leaves, has been reported to be induced by several **Phyllosticta** species. However, CIAT etiological studies have shown that isolates of the pathogen collected in Colombia are a species of Phoma, according to the recent taxonomic characteristics reported for this genus. The fungus produces conidiophores, which are flask shaped (80 μ length), with small elongated conidia without visible appendages. These conidia are 3.5μ (2.6-4.4) in width x 4.9μ (3.1-6.2) in length. Each pycnidium produces about 1.5×10^9 conidia on lima bean-dextrose agar at 20°C. Individual pycnidiospores clearly show two oil gutules inside the cytoplasma, which are located at each end of the spores.

Studies have shown that this fungus grows best at 20°C (10°C minimum; 20°C maximum). Better growth was produced on lima bean-dextrose agar than on other artificial media.

Screening for resistance

Evaluation for resistance under field conditions has given consistent results when test cultivars were planted in rows 30 centimeters apart and in cool areas (15-20°C). Spray inoculation (aqueous suspension of $6\text{-}8 \times 10^6$ spores/ml) was applied at the beginning of the rainy season when plants were two to three months old. Disease ratings were taken at the end of the rainy season (before the plants begin to depart from the symptoms in the dry season) by scoring the percentage of defoliation, die-back and death symptoms.

In cooperation with ICA, 696 cultivars of the CIAT and ICA cassava collections were screened. Nine of these cultivars were rated as resistant, 250 as tolerant and 437 as susceptible (Fig. 20).

Figure 20. Phoma leaf spot field resistant cultivar. Cultivars were planted in rows 30 cm apart in Popayán (10-20°C, approximately). Spray inoculation ($6\text{-}8 \times 10^6$ spores/ml) was applied at the beginning of the rainy season when plants were two months old.

Disease losses

Comparing the fresh root yield of the susceptible cultivar CMC-39, with and without chemical control, it was found that losses resulting from the disease were about 62 per cent (Table 5). The tolerant cultivars, CMC-92 and Nativa, produced 2.1 and 2.0 times more than the susceptible cultivar CMC-39 without fungicide application. Although the selected tolerant cultivar CMC-92 produced more than the native cultivar, this difference was not significant (Bet test) (Table 5).

Superelongation disease

This disease was first reported in 1972 and is known to be causing serious epidemics in widely separated areas of Colombia. The causal organism appears to be a species of the fungal genus **Sphaceloma**. Although several decades ago, a **Sphaceloma** species was reported as causing a disease on **Manihot esculenta** and **Manihot glasyslovii** in Nicaragua, Guatemala, the Dominican Republic and Brazil, no mention was made of an elongation of the internodes, which is characteristic of the present superelongation disease. Therefore, this may be a new or another and more serious manifestation of a previously established disease.

Table 5. Disease losses induced by Phoma leaf spot in three cassava cultivars.

Cultivar collection number	$\bar{x}$	
CMC-39 (without chemical control)	8.77*	a***
CMC-39 (with chemical control)**	23.33	b
CMC-92 (tolerant cultivar)	18.42	c
Nativa (tolerant native cultivar)		c

* Ton/ha calculated from six randomized plots of 25 plants/plot. Borders were eliminated.

** Benomyl application = the plants were sprayed to "run-off" with a 300 ppm suspension every ten days.

*** Data followed by the same letter are not significantly different at the 5% probability levels.

Dissemination

The disease appears to be disseminated largely by wind-borne spores: the spores are either blown freely, or within tiny moisture droplets. Disease spread within a cassava field or among neighboring plots can be rapid during the rainy season. During a recent epidemic, the disease spread at least 100 meters from one cassava plot to another in about two weeks. The viability of spores stored at a relative humidity of 75 was significant after 24 hours, and it appears that the spores are capable of surviving the rigors of wind dispersal.

Spore germination

The spores need free water to germinate. Germination is almost completely absent at a relative humidity of 100 per cent without free water present. There appear to be no significant self-inhibitory factors upon germination in aqueous spore suspensions (up to a concentration of 1×10^7 spores per milliliter). Optimum temperature for spore germination in vitro is approximately 28°C; and the optimum temperature for fungal growth lies between 24-27°C, with a minimum at about 5 °C and maximum at 36 °C. Germination was best on water agar. Agar containing 2 per cent *sucrose*, *mineral* solution or cassava leaf extract gave a lower per cent germination.

Regulating substance

An acetone extract of the pathogen growing in potato dextrose broth was made and concentrated by evaporation. An aqueous solution of the extract was sprayed on young lima bean plants and was compared with the effect caused by two gibberellin, a mixture of GA4 and GA7 and Gibrel x-47. Plants sprayed with the fungal extract at a high dilution produced rapid elongation of the lima bean plants similar to the effect caused by 100 ppm of the gibberellin comparisons. The fungal extract is gibberellin-like in its action.

Resistance

Evaluation of 179 cassava for resistance indicated 9 clones with high levels of resistance, 88 with moderate resistance (tolerance) and 82 susceptible.

Cercospora leaf spot

Although **Manihot esculenta** can be infected by at least three **Cercospora spp.**, investigations here concentrated on the disease caused by **C. henningsii**, the most serious and widespread of the cercospora leaf spots.

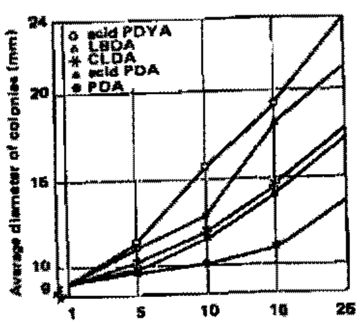


Figure 21. Cercospora henningsii mycelial growth on five media: acid PDYA=potato-dextrose-yeast extract-agar; LBDA=lima beans-dextrose-agar; acid and PDA=potato-dextrose-agar; CLDA= cassava leaf-dextrose-agar.

Etiological studies

The growth rate and the morphological characteristics in vitro were studied with 12 media. The best growth was observed on potato-dextrose-yeast extract-agar, acidified with lactate (0.02 per cent); on acidified potato-dextrose-agar alone, the growth was considerably slower. Generally, colonies were irregular and globose; their size and appearance varied according to the medium. The best mycelial growth was observed at 27 °C. Spore germination on water agar was 100 per cent at a pH of 6.5-7.0 (5.0 pH, minimum; 8.0 pH, maximum) at 25 °C.

Toxin production

C. henningsii induces considerable leaf yellowing shortly after the appearance of the necrotic angular spots. The degree of this yellowing and its systemic invasion appear to be related to the host cultivar.

Toxin production in vitro was examined in several liquid media. Ethyl acetate, chloroform and hydrochloric acid extracts were fractionated by thin-layer chromatography (TLC), precoated with silica gel and pretreated with 2 per cent phosphoric acid. Bioassays by inoculating susceptible cassava leaves with a constant Rf band always produced a lesion and yellowing, similar to that induced by the pathogen three days after inoculation (Fig. 21).

Screening for resistance

Of 121 cultivars screened for resistance under conditions of high relative humidity, 12 cultivars were classified according to the degree of defoliation as resistant, 64 as tolerant and 45 as susceptible.

"Frog skin" root disease

This heretofore unreported disease of cassava has been observed recently to induce severe losses of up to 90 per cent in a wide area of the Departamento del Cauca, Colombia. The disease results in abnormal root growth and thickening; sometimes the whole root system may be affected, but commonly only some of the roots show symptoms while others continue to grow and thicken normally. The disease appears to affect the deposition and storage of carbohydrates in the roots so that diseased plants produce fewer swollen roots, which are frequently distorted and show uneven thickening.

The internal tissue of diseased roots appears normal; but the epidermis is suberized, and there is often excessive accumulation of cork, which gives the roots a cracked and wrinkled appearance. In general, the appearance of the aboveground part of the plant is normal, except for a slight stunting and thickening of the stem base. Preliminary etiological studies indicate that the disease could be the result of early damage to potentially swollen roots by a fungal pathogen or pathogens.

Root-knot nematode

To assess losses caused by the root-knot nematode (**Meloidogyne incognita**), five cultivars were planted in a heavily infested plot. Crop infestation was up to 61.3 per cent, and M Colombia 113 plants produced essentially no root yield when infested. However, M Colombia 22 showed no infestation, which suggests the possibility of root-knot nematode resistance (Table 6).

However, soil samples after harvesting this plot showed that other parasitic nematodes were also present. In each 200 grams of soil, there were 17 of **Helicothylenchus sp.** and 1 of ***Xiphinema* sp.** Thus, the above results may have been influenced by damage induced by these other plant parasitic species.

Susceptible tomato (Manalucie) and bean (Azuki) varieties were inoculated with clean **M. incognita** eggs and females under controlled greenhouse conditions. They showed a heavy infestation two months after the inoculation. Cross inoculation from bean-tomato nematodes to cassava produced visible symptoms on M Colombia 113 five months after the inoculation.

The presence of **M. incognita** was assessed on some plant species growing in the infested plot. Only **Cucumis melo** was found severely infested by this nematode species.

Plants of susceptible cassava cultivars show that the primary symptoms (small root knots) appear five months after planting in heavily infested soil. Infestation of these plants was higher than 60 per cent.

Fungicide treatments of cassava stakes

Losses in establishment during the first two months after planting have been ob-

Table 6. Disease losses induced by the root-knot nematode (Meloidogyne incognita) in five cassava cultivars.

Cultivar collection number	Yield (kg/plant)	Potential number of swollen roots/ plant	Number of swollen roots/plant	Infestation (%)
M Colombia 10	0.70*	9.26**	0.66	61.3***
M Colombia 113	3.00	15.00	3.10	57.2
M Colombia 13	2.43	13.10	2.30	24.1
M Colombia 22	5.00	13.20	13.20	0.0

* 13-month-old plants

** Average of 20 plants/cultivars

*** Percentage of infestation = $\frac{\text{disease severity **** x 100}}{\text{Number of plants x 6}}$

**** Disease severity: 1 = healthy swollen roots; 6 = unswollen, knotted roots (used for calculating the potential number of swollen roots/plant) served to be higher than 20 per cent in many plots. These losses are mostly associated with several facultative parasites or saprophytes that are generally known to cause root rot, damping off or growth retardation. Thirteen fungicides were selected to treat cassava cuttings before planting. Preliminary results showed that germination in general was not inhibited by any of these chemicals, except by NC-5936 (Fisons experimental fungicide) at high concentrations. The growth rate of the germinated sprouts from treated cuttings was reduced by some fungicides at the high concentrations during the first two months after their emergence. Stored cuttings treated with the different fungicides showed variable levels of fungal infection. Fungicides, such as arasan 75 (tetramethylthiuram disulfide), macuprax (Mckechnie Chemicals Limited experimental fungicide) agallol (Metoxiyethyl mercury chloride) and NC-5936, appear to give the best protection according to the calculated intensity of infection.

Table 7. Leaf area, number of leaves and root yield of clones Llanera and CMC-84 under artificial defoliation.

Percentage defoliated	0	20	40	20	40
Months defoliated	0	2–10	2–10	6–10	6–10
Llanera					
Total leaves produced/plant	1,186	1,410	1,409	1,097	1,449
Leaves/plant at harvest	309	323	260	197	306
Average leaf area at time of each defoliation (cm^2/plants)	27,181	27,758	23,770	27,356	25,269
Yield (kg/plant)	4.7	4.3	4.1	4.7	4.3
CMC-84					
Total leaves produced/plant	1,242	1,339	1,231	1,127	1,247
Leaves/plant at harvest	459	435	338	387	525
Average leaf area/plant before each defoliation (cm^2)	36,725	34,503	31,602	31,453	36,565
Yield (kg/plant)	5.1	5.1	4.8	4.7	4.9

ENTOMOLOGY

Major emphasis was placed this year on determining yield losses associated with insect pests. Resistance evaluation to thrips was terminated, and emphasis will change to spider mite and shoot fly resistance. Biological control was also studied when resistance was not encountered. Stress was placed on identification and biological aspects of minor cassava pests that have the potential of being serious pests or disease vectors.

Cassava hornworm

The cassava hornworm population at CIAT was low throughout the year. The highest populations in weekly samplings of 75 plants were encountered, as last year, in February and from July to August. At CIAT, maximum egg population was 0.6 eggs per plant; at ICA, 4.5. The maximal larval populations were 0.2 and 1.0 larvae per plant, respectively. Frequently, no eggs or larvae were found per sampling period.

To simulate hornworm damage, plants were defoliated at different levels and times. Defoliation at the 20 per cent level from two to ten months decreased yield in Llanera but not in CMC-84. Defoliation at the 40 per cent level each month decreased yield in both varieties when carried out from two to ten months but only reduced yield slightly in the six to ten months' period (Table 7). Thus, quite severe defoliation during the later growth stages has little effect on yield; whereas at earlier stages it has greater effects. In no case was the yield reduction great. However, leaf area indexes in this experiment were consistently high (means of 2.7 and 3.7 for Llanera and CMC-84, respectively). It is probable that under lower fertility soil conditions, the effects would have been more severe.

The average hornworm consumes 1,107 cm^2 of leaf during its life cycle. The number of hornworm larvae that would have caused the defoliation in the experiment at different stages is shown in Table 8. Under the fertile, good conditions of this experiment, high levels of hornworms could be tolerated with little yield reduction: less than 10 per cent

Table 8. Number of hornworm larvae which can complete their development on the leaf area corresponding to various amounts of artificial defoliation.*

		% defoliated	20	40	20	40
Variety	Plant age (months)	Age defoliated (months)	2–10	2–10	6–10	6–10
Llanera	2		0.2	0.3	–	–
	3		0.9	1.6	–	–
	4		4.2	7.3	–	–
	5		8.5	14.3	–	–
	6		9.7	17.0	11.4	17.1
	7		7.0	11.1	5.8	10.2
	8		8.1	14.0	6.7	17.6
	9		1.5	3.0	1.8	4.3
CMC 84	2		0.3	0.6	–	–
	3		1.2	2.2	–	–
	4		4.4	7.9	–	–
	5		6.3	11.8	–	–
	6		9.5	20.2	8.9	26.2
	7		9.8	14.1	8.5	18.2
	8		13.8	23.4	10.0	27.3
	9		4.8	9.2	4.3	9.4

* One larva consumes an average of 1,107 cm^2 cassava leaves until pupation.

with 40 per cent defoliation each month from two to ten months.

The relatively high threshold population for yield reduction is favorable. Pesticides can be used at a minimum level. This will enhance biological control by Trichogramma and Polistes.

Egg parasitism by Trichogramma remained around 60 per cent, but reached 100 per cent in several counts. The egg parasite was identified as T. fasciatum. Of a sample of 323 parasitized eggs, an average of 23.7 T. fasciatum adults emerged per egg with a minimum of 6 and a maximum of 44 adults emerging from one egg.

Larval predation by Polistes canadensis, a paper wasp, was enhanced by placing two 2-meter high structures covered with palm leaves in the cassava fields. Five wasp nests, each containing about eight wasps, were placed in each structure. After six months, these two wasp houses contained a total of 83 nests with nearly 700 wasps. However, wasp parasites were found in the nest, parasitizing the Polistes pupae. This dipterous parasite was identified as Oxysarcodexia sp. (Sarcophagidae), which in turn is parasitized by a Hymenopterous parasite.

Despite this high level of biological control and the high threshold injury level, the hornworm population may reach economically serious levels. They should then be controlled with Bacillus thuringiensis, available in an insecticidal formation called Dipel. This does not damage the natural enemy complex.

Shoot fly

Silba pendula attacks the growing point of cassava, which subsequently dies. Another shoot fly was identified as Anastrepha pickeli. It attacks below the growing point, and damage symptoms are whitish excretions from entrance holes, tunneling in stems and sometimes die-back.

The economic importance of Silba was evaluated by simulating the damage. The treatments made were control, control with pesticides, 50 per cent of shoots cut, and 100 per cent cut. The last two were made under insecticidal protection and cut at monthly intervals. The shoot removal was made two to five months or six to nine months after planting.

The yield of the branching variety Llanera was slightly reduced at 100 per cent shoot

Table 9. Number of terminal buds and leaves produced per plant and root yield following shoot removal.

Variety	Time removed (months) / % removed	0 / 0	0* / 0	2–5 / 50	2–5 / 100	6–9 / 50	6–9 / 100
Terminal buds per plant							
Llanera		21.9	20.8	19.7	19.2	24.0	23.2
Mecu. 150		15.0	16.1	15.4	22.5	15.9	15.8
Total leaves per plant							
Llanera		1,135	945	816	845	1,000	1,013
Mecu. 150		1,191	1,193	991	1,175	1,193	1,600
Fresh root yield (ton/ha)							
Llanera		41.2	40.7	42.2	38.9	39.4	42.4
Mecu. 150		30.8	31.0	26.8	22.4	32.8	30.7

* Control protected with pesticides

Table 10. Relationship between thrips resistance and leaf-hairiness and cyanide content of 41 clones.

Number of clones	Damage score	No. thrips/ term. bud	Leaf cyanide (ppm)	Hairs/leaf lobe (Average)
9	0	0.7	752	21,540
6	1	3.4	567	12,730
8	2	1.2	942	5,270
7	3	1.6	928	58
7	4	3.8	894	65
4	5	4.4	925	618

removal at two to five months (Table 9). Shoot removal from six to nine months did not influence yield. The late-branching variety Mecu. 150 was more susceptible to shoot removal than Llanera at earlier stages but showed no effect of shoot removal at six to nine months. Removal of shoots did not increase the number of branches, except at 100 per cent removal from two to five months in Mecu. 150. The total number of leaves produced was not reduced, except in Llanera when shoots were removed from two to five months. The application of pesticides did not increase the root yield. Consequently, quite severe attacks of shoot fly can be tolerated under fertile conditions with little effect on yield.

Low levels of larval parasitism by Opius sp. were found on Silba and Anastrepha.

Thrips

The evaluation of the germplasm bank for thrips resistance was terminated. Approximately 50 per cent of the clones were grouped in resistance class 0 or 1, on a 0 to 5 resistance scale, with 0 as no damage. Last year's results, showing that resistance was related to hairiness of the expanding leaf, was confirmed (Table 10). Plant age did not influence leaf pubescence. Plants are usually more susceptible after flowering, which is related to decreased leaf pubescence (Table 11). In areas with dry seasons and thrips problems, resistant varieties should be planted.

To determine the economic importance of thrips, a trial was planted with two susceptible and two resistant varieties to thrips, with and without irrigation, with and without pesticidal protection (Table 12). Thrips levels were low even in susceptible varieties. In the irrigated trial the resistant varieties did not show yield increase because of the use of pesticides. The susceptible varieties gave a 2.2 ton/ha yield increase, which can be attributed to thrips control.

In the nonirrigated trial, yields of the resistant varieties increased by 1.7 tons with use of pesticides, the susceptible ones by 4.8. Thus 4.8 − 1.7 = 3.1 ton/ha yield

Table 11. Influence of flowering on thrips resistance and leaf pubescence.

Number of clones	Damage rating: Before flowering	Damage rating: After flowering	Hairs per leaf lobe: Before flowering	Hairs per leaf lobe: After flowering
3	3	3	13	0
4	0	2	17,530	2,220

Table 12. Yield of two susceptible (Mex 34 and Mecu. 117) and two resistant (Mex 29 and 31) varieties to thrips attack, with and without insecticidal protection and irrigation (ton/ha).

Variety	Irrigation		No irrigation	
	Insecticides	No insecticides	Insecticides	No insecticides
Resistant				
M Mex 29	27.3	31.8	36.2	33.2
M Mex 31	26.9	27.7	36.3	36.0
Average	27.1	29.9	36.3	34.6
Susceptible				
M Mex 34	32.3	27.9	34.1	27.9
Mecu. 117	35.3	35.2	41.5	38.0
Average	33.8	31.6	37.8	33.0

reduction results from thrips. This assumes that all varieties were equally attacked by the other cassava insects. However, the experiment was not exposed to an intensive dry season, and thrips attack generally reached damage grade 2 in the susceptible varieties, rarely reaching grade 3. Yield was reduced by 3 ton/ha even with these low levels of attack.

To explain differences in thrips attack in dry and wet seasons, thrips populations in the growing points were measured before and after sprinkler irrigation. There was no difference in numbers of thrips found per growing point after two hours of irrigation; however, emergence of thrips from the soil was reduced after heavy rains or irrigation (Table 13).

Spider mites

The mite species attacking cassava were identified. The four principal species are **Mononychellus (Mononychus) tanajoa, M. mcgregori, Tetranychus (urticae?)** and **Oligonuchus sp.** In the last species, the adult mites web a white cover in small areas along veins and leaf margins, under which the eggs and mites can be found. Under heavy infestation the older leaves will drop. It may be difficult to find resistance to several species of mites in one cassava clone.

Cutworms

Several trials were planted to evaluate various pesticides and methods of application for cutworm control, but cutworm infestations were not sufficiently high to be conclusive. To simulate cutworm damage, shoots were continuously cut at 5-,10- or 15-centimeter heights on cuttings of 10, 20 or 30 centimeters in length for two months. The experiment was done with Llanera and CMC-84. It appears that Llanera is more susceptible to shoot removal than CMC-84 (Table 14); and in areas with cutworm problems, it is recommended to use longer cuttings. Also cutworm-simulated attack was more severe at shoots of 5-centimeter lengths as compared with 10 or 15 centimeters. Cuttings from older plants were more susceptible to simulated damage than those from younger plants.

Table 13. Number of thrips emerged from 9 cm^2 of soil after rai n or irrigation.*

Treatment	Number of thrips	
	First experiment	Second experiment
Control	66.3	54.8
15 and 37.5 mm rain, respectively	70.8	24.1
Irrigation (until 12 cm water penetration)	16.0	10.3

* Average emergence in four days in three replicates

Table 14. Mortality of cuttings of different lengths of cassava after shoot removal for two months to simulate cutworm damage. Shoots were removed continuously when 5 cm long.

Cutting size (cm)	Mortality (%)	Cutting size (cm)	Mortality (%)
Llanera		CMC-84	
10	65	10	11
20	36	20	1
30	25	30	0

One method of insecticidal protection for cutworms, scale insects, termites, etc. may be the dipping of cuttings in insecticidal solutions, prior to planting. This method may also be applied to prevent spread of insects in planting material shipped to other areas. Various insecticides were used in lowest, average and highest commercial dosages. The cuttings were submerged for 5 or 20 minutes in these solutions. Neither pesticides nor length of treatment influenced germination or plant growth (Table 15). Only high dosages of pesticides reduced germination and plant growth.

Stored cassava

Dry cassava was stored in field and laboratory in burlap sacks or cotton bags. Of both varieties (Llanera and CMC-84) 2 kilogram samples of dried chips were exposed to natural infestation. The amount of powder produced by insect activity was higher for the sweet variety Llanera, when stored in burlap sacks (Table 16). The most important insect causing this damage was **Dinoderus minutus.**

Other insects

Several other insects attack cassava, but their damage is of little importance. There is a great lack of knowledge about them. Efforts are being made to identify them and study their biology at the USDA insect identification laboratory.

Anastrepha pickeli attacks the stems and fruits. This is a problem in hybridization. It

Table 15. Germination and plant growth of Llanera after treating cuttings with pesticides by submersion.*

Insecticide	% germination at		Leaves /plant	Fresh weight (g)
	20 days	60 days		
Low dosage	45.5	60.0	29	79.5
Average dosage	45.4	60.0	29	74.0
High dosage	35.0	48.5	25	65.0
Submerged 5 min	63.0	68.2	29	75.0
Submerged 20 min	58.4	66.1	27	70.0
Control	69.6	80.5	33	84.9

* Average of Parathion, Dimetoate, Basudin, Monitor and Sevin in the lowest, medium and highest commercial dosage recommendation

Table 16. Insect waste after storing dried cassava chips for three months (g per 2 kg dried chips).

Type of storage bag	Insect waste (grams)	
	Llanera	CMC-84
Burlap sack	54	23
Cotton bag	19	7
Average	36	15

prefers to oviposit in flowers rather than stems. Results indicated that of the attacked fruits none were attacked when flowers were covered three days after pollination with a bag, 28 per cent were attacked if left uncovered for six days, and 72 per cent when covered at ten days. Covering flowers five days after pollination will sufficiently reduce fruit fly attack and not cause flower abortion.

Cassava flowers were found to be attacked by the Lonchaeid, **Dasiops fumigatus.** Also, the biology of the tingid **Vatiga manihotae** was studied (Table 17). Leaf galls are frequently found on cassava; the fly causing these galls was identified as **Clinodiplosis** sp. (Cecidomyidae).

Table 17. Life cycle of Vatiga (Leptopharsa) manihotae under laboratory conditions (ca. 26 °C and 85 % RH).

Developmental stage	Duration in days	Standard deviation (days)
Eggs	8.1	0.3
1st instar	2.9	0.2
2nd instar	2.6	0.0
3rd instar	2.9	0.2
4th instar	3.3	0.2
5th instar	4.8	0.2
Adults	50.2	4.9
Eggs per female	61.3	28.0

Three species of whiteflies (Aleyrodidae) were identified and are being studied: **Aleurotrachelus** sp., **Bemisia tuberculata** and **Trialeurodes variabilis.**

A mealy bug (Pseudococcidae) ocurring on cassava stems was identified as **Phenacoccus gossypii.**

VARIETAL IMPROVEMENT

The general evaluation of approximately 2,000 clones of the germplasm collection was finished. About 230 selections from the germplasm are being evaluated in an advanced yield trial at CIAT and in regional observational trials outside CIAT. More than 35,000 F_1 seeds were produced by controlled hybridization. About 3,000 clones from these hybridizations are being evaluated in an observational yield trial, and about 10,000 F_1 plants are in a selection field.

In addition, studies of the genetic nature of the cassava plant and improvement of selection efficiency are under way.

Genetic nature of cassava plant

Heterozygosity

Variability in a population comprising plants from the open-pollinated seeds of one clone is substantially higher than the variation in the mother clone in the same field (Figs. 22, 23, 24). The same is true with a population derived from controlled

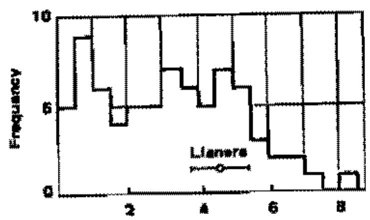


Figure 22. Segregation in root yield of Llanera open-pollinated population (Value of Llanera is shown with standard deviation).

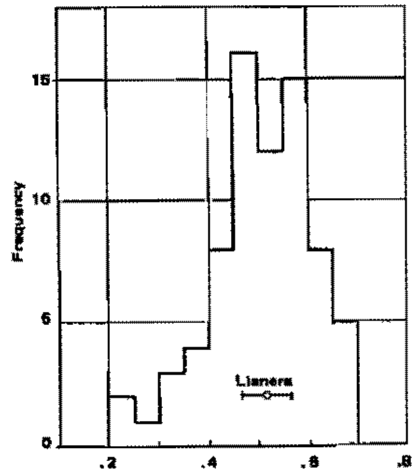


Figure 23. Segregation in harvest index of Llanera open-pollinated population (Value of Llanera is shown with standard deviation).

hybridization (Fig. 25) and also with a population of selfed F_1s (Fig. 26). These data show that cassava is a highly heterozygous plant.

Pollination habits

Using the color of the leaf vein as a marker character, an analysis of self- and open-

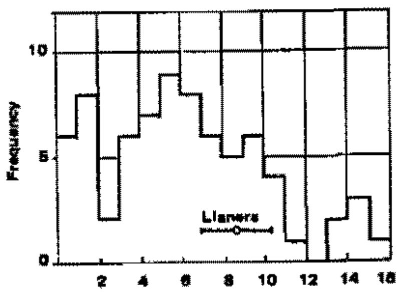


Figure 24. Segregation in total plant weight of Llanera open-pollinated population (Value of Llanera is shown with standard deviation).

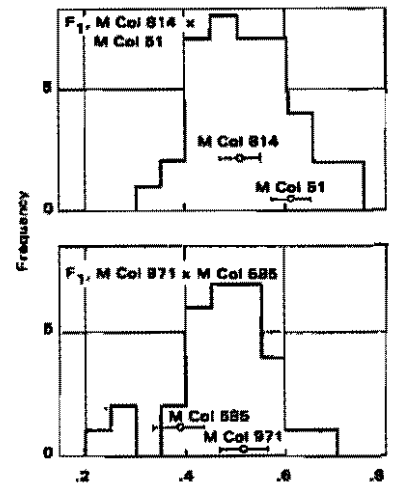


Figure 25. Segregation in harvest index of two F_1 populations (Values of the parents are shown with standard deviation).

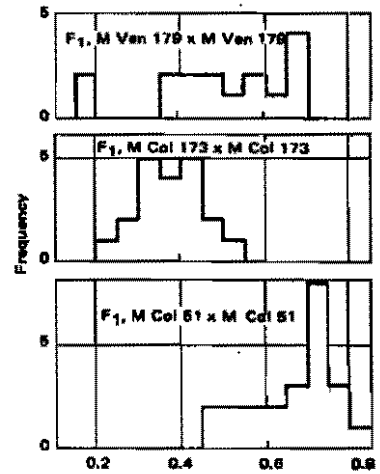


Figure 26. Segregation in harvest index of selfed F_1 cassava.

pollination was made in various types of populations. Llanera has red leaf veins. All the plants from open-pollination, controlled crosses, and selfing of Llanera have red leaf veins. M Colombia 1147 has green leaf veins, and selfing of this cultivar produced all plants with green leaf veins. All the F_1 plants of crosses between Llanera and M Colombia 1147 had red leaf veins. The great majority of the germplasm entries have red leaf veins.

Llanera and M Colombia 1147 were planted under various population arrangements. In one case, M Colombia 1147 was surrounded by eight Llanera plants, while in another it was placed in a context of four Llanera and four M Colombia 1147 plants. Various other combinations were used.

Llanera produced a moderate number of both male and female flowers, whereas M Colombia 1147 flowered profusely. Open-pollinated seeds of M Colombia 1147 were collected and sown. The seedling plants with red leaf veins were considered to be results of out-crossing and green ones of selfing. The highest percentage of out-crossing recorded in this trial was only 8 per cent. In the majority of M Colombia 1147 plants, selfing was more than 95 per cent.

This rather surprisingly high percentage of selfing may have been a result of incomplete coincidence of Llanera male flowers and M Colombia 1147 female flowers. Open-pollinated seeds from M Colombia 1147 and M Venezuela 179, a similar type to M Colombia 1147, were collected in the germplasm bank, where these plants were surrounded by many types, a majority of which had a red leaf vein and flowered continuously. The percentage of out-crossing was 41 per cent with M Colombia 1147 and 31 per cent with M Venezuela 179. Several pure stands of M Colombia 1147 were prepared with various isolation distances from other flowering cultivars. Thirty meters of isolation was sufficient to ensure that all the open-pollinated seeds in the pure stand were selfed.

Thus, the rate of self-pollination in cassava is quite high despite what might have been expected.

Inbreeding depression

Root yield, total plant weight, harvest index and plant height were measured on selfed F_1s, various F_1 crosses between these cultivars, crosses on these same cultivars with others and stake plantings of the parents (Table 18). Root yield and total plant weight were distinctly lower in selfed F_1s than in all the other populations. In many selfed F_1s, the plants failed to grow normally. Harvest index was not significantly affect-

Table 18. Comparison between selfed F_1 and outcrossed F_1 in yielding traits.

	No. of plant	Root yield (kg/plant)	Total plant weight (kg/plant)	Harvest index	Plant height (m)
Selfed F_1					
Llanera	9	2.4	4.1	0.52	1.27
Extranjera	12	0.8	1.3	0.58	0.91
M Colombia 9	6	1.8	5.9	0.33	1.90
M Colombia 51	23	1.4	2.2	0.67	1.21
M Colombia 173	20	2.3	5.9	0.37	2.07
M Colombia 562	14	0.7	1.4	0.51	1.56
M Colombia 688	10	1.1	2.1	0.52	1.72
M Colombia 971	15	4.2	7.3	0.58	1.90
M Venezuela 179	16	1.2	2.2	0.50	1.21
Total or average	125	1.8	3.6	0.51	1.53

Table 18 (Continuation)

	No. of plant	Root yield (kg/plant)	Total plant weight (kg/plant)	Harvest index	Plant height (m)
F_1 among parental cultivars					
Llanera x M Colombia 51	7	4.4	6.1	0.72	1.60
M Colombia 51 x Llanera	18	4.2	6.6	0.64	1.92
Extranjera x Llanera	11	3.6	5.4	0.66	1.75
M Colombia 173 x Llanera	15	4.2	7.2	0.58	2.23
M Colombia 688 x Llanera	14	1.7	2.5	0.67	1.21
M Colombia 971 x Llanera	6	6.2	8.6	0.72	2.14
M Venezuela 179 x Extranjera	30	2.9	5.9	0.53	1.96
M Colombia 9 x M Colombia 51	12	4.7	8.2	0.59	2.16
Total or average	112	4.0	6.3	0.64	1.87
Various F_1 with parental cultivars					
23 different F_1 with Llanera	361	4.3	6.6	0.65	1.82
6 different F_1 with Extranjera	96	3.4	5.8	0.59	1.82
4 different F_1 with M Colombia 9	58	5.0	11.0	0.48	2.36
9 different F_1 with M Colombia 51	133	4.1	6.7	0.63	1.77
5 different F_1 with M Colombia 173	104	4.5	8.9	0.54	2.38
2 different F_1 with M Colombia 971	37	4.8	7.4	0.64	1.93
3 different F_1 with M Venezuela 179	52	4.4	8.9	0.52	2.13
Total or average	841	4.5	7.9	0.58	2.03
Open-pollinated F_1					
Llanera	30	3.7	5.9	0.63	1.70
M Colombia 9	30	6.4	14.7	0.44	2.34
Total or average	60	5.1	10.3	0.54	2.02
Stake-planted parental cultivars					
Llanera	3	3.9	6.3	0.63	1.62
Extranjera	3	4.8	9.3	0.52	2.60
M Colombia 9	3	4.8	12.0	0.40	2.40
M Colombia 51	3	2.9	4.1	0.71	1.40
M Colombia 173	3	2.3	8.1	0.29	2.70
M Colombia 562	3	4.3	8.5	0.51	2.60
M Colombia 688	3	4.2	7.3	0.54	1.80
M Colombia 971	3	4.3	5.7	0.75	1.50
M Venezuela 179	3	5.5	13.2	0.42	2.80
Total or average	27	4.1	8.3	0.53	2.16

All the F_1 were transplanted at 1 x 2 m spacing at one month after germination and harvested at nine or ten months after sowing. All the stake-planted parental cultivars were planted at 1 x 1.4 m spacing and harvested at ten months after sowing.

ed by selfing, whereas plant height was somewhat lower in selfed F_1s.

In general, one cycle of selfing is enough to produce significant inbreeding depression in cassava. However, the degree of inbreeding depression differed among cultivars. Since there do not seem to be any genetic and physiological mechanisms to prevent self-hybridization, inbreeding depression appears to be a mechanism that maintains a high level of heterozygosity in cassava.

High occurrence of self-fertilization and sensitiveness to inbreeding of cassava should be taken into consideration when exchange of genetic materials among breeders is planned in the form of seeds. Any open-pollinated seed collected in pure stand is almost certainly a result of self-pollination, and the plants which come from these seeds are unlikely to grow normally, therefore failing to produce flowers in sufficient number to ensure further hybridization with other genotypes.

Germplasm evaluation

Soil on the CIAT farm is regarded as highly fertile. Throughout the evaluation period, the climate was quite favorable. There was no prolonged dry season, heavy rainfall, nor extreme temperatures for normal cassava growth. The CIAT farm is maintained free from two of the most destructive diseases; i.e., bacterial blight and superelongation. Thus, yield data from the evaluation may well represent yielding ability of each genotype under nearly ideal growing conditions for cassava.

Great genetic variability was observed in almost every character evaluated. Root yield at six and ten months varied from zero to 4.9 kg/plant (average of three plants planted at 1 x 1.4 meters) and from zero to 13 kg/plant, respectively. The range of variation in fresh weight harvest index and total plant weight at ten months after planting was 0.02 to 0.77 and 1.1 to 32.6 (kg fresh weight/plant), respectively. Some of the best selections are shown in Table 19. The great variability in leaf area retention after six months of planting is noteworthy.

There was a clear association between visual rating in leaf area retention at nine months after planting and total plant weight increase during the period from six to ten months after planting. Thus, leaf area maintenance is essential for obtaining high production rates at later stages of growth. However, there was a clearly negative correlation between plant weight increase during the six- to ten-month period and the proportion of root yield increase to total plant weight increase during the same period (Table 20).

These data come from the field where the vigorously growing genotypes are provided with better growing conditions because of serious intergenotypic competition. The negative correlation would be still more significant if all the genotypes were to be compared using the data from pure stand of each genotype. Thus, the importance of a good balance between apical growth and root growth is again emphasized. A substantial variation to root rotting after harvest was also observed in time.

At six months after planting, both total plant weight and harvest index were highly correlated with root yield (Figs. 27,28); these were fairly independent although the types with high harvest index tended to have small plant weight (Fig. 29). At ten months, total plant weight was also highly correlated with root yield (Fig. 30). However, the relationship between harvest index and root yield at ten months was different from that at six months. There seems to be an optimum harvest index to obtain high root yield at ten months (Fig. 31). The types with low and high harvest index failed to give high yields. The data suggest the difficulty of combining high harvest index with heavy total plant weight (Fig. 32).

Table 19. Yield data of some promising collections of cassava. *

	Root yield (kg/plant)	Harvest index	Total plant weight (kg/plant)
M Colombia 452A	12.5	.50	24.9
M Colombia 600	10.2	.65	15.6
M Colombia 655A	11.1	.66	16.7
M Colombia 873	9.3	.65	14.2
M Colombia 882	12.3	.62	19.7
M Colombia 914	5.3	.74	7.1
M Colombia 971	4.3	.75	5.7
M Colombia 991	6.8	.71	9.6
M Colombia 1684	7.9	.69	11.4
M Mexico 52	7.0	.64	11.0
M Mexico 55	6.4	.72	8.8
M Mexico 59	13.0	.58	22.3
M Venezuela 180	10.2	.57	17.9
M Venezuela 185	7.3	.74	9.9
M Venezuela 307	8.2	.62	13.2
M Ecuador 58	8.6	.63	13.6
M Ecuador 144	9.6	.53	17.9
M Ecuador 159	9.0	.61	14.7
M Panama 39	10.4	.56	18.7
M Puerto Rico 26	4.5	.63	7.2
M Brazil 3	7.3	.56	13.0
Llanera (control)	3.8	.62	6.0
M Colombia 22 (control)	3.5	.71	4.9

* Data taken at ten months after planting; spacing 1 x 1.4 m

Table 20. Cassava leaf area retention, plant weight increase and root weight increase at later stage of growth.

Leaf area retention rating at 9 months	Number of collections	Average total plant wt increase during 6 to 10 months (kg/plant)	Average root wt increase during 6 to 10 months (kg/plant)	% root wt increase in total wt increase during 6 to 10 months
1	13	0.81	0.78	96.3
2	412	2.56	1.52	59.4
3	948	4.23	1.99	47.0
4	348	5.77	2.54	44.0
5	60	9.10	2.76	30.3

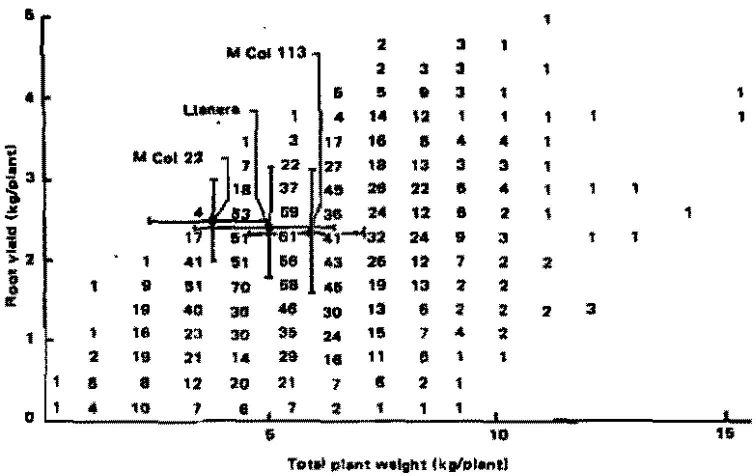


Figure 27. Relationship between total plant weight and root yield at six months after planting (Values of three control cultivars are shown with standard deviation).

Using picric acid paper, HCN in leaf and root was determined. Depending on the degree of coloring, grades of 1 to 5 were adopted. So far, no cassava cultivar with zero

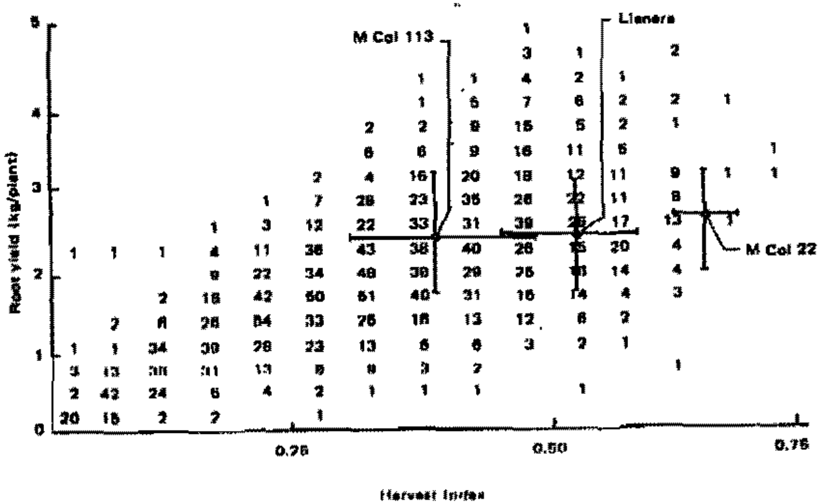


Figure 28. Relationship between harvest index and root yield at six months after planting.

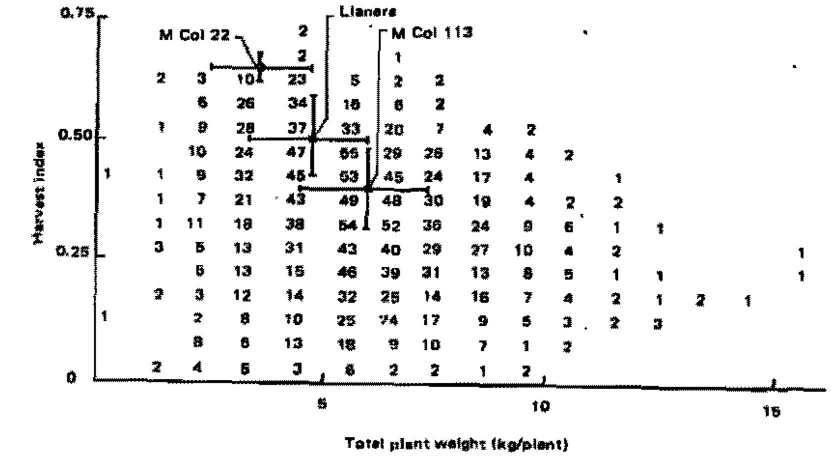


Figure 29. Relationship between total plant weight and harvest index at six months after planting.

HCN has been found. No meaningful correlation between HCN in leaf and root was found. So called "bitter cassava" could be detected by grade 5. Five percent of the collection fell into this category. Some of the nice-tasting cultivars, such as *Llanera*,

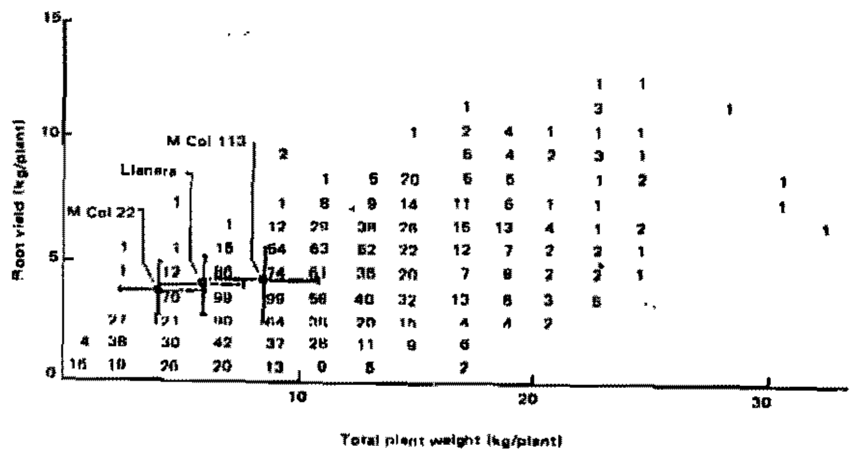


Figure 30. Relationship between total plant weight and root yield at ten months after planting.

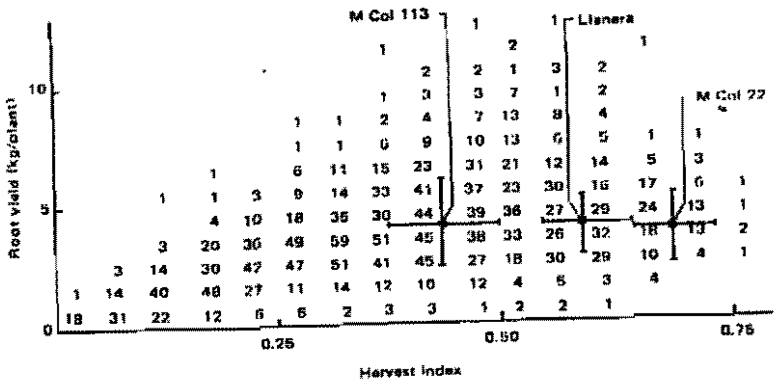


Figure 31. Relationship between harvest index and root yield at ten months after planting.

M Colombia 22, and M Mexico 55, were classified as grade 4; while the majority of cultivars were more or less evenly distributed between grades 1 and 4. There was no indication that bitter cassava had higher yielding ability (Table 21).

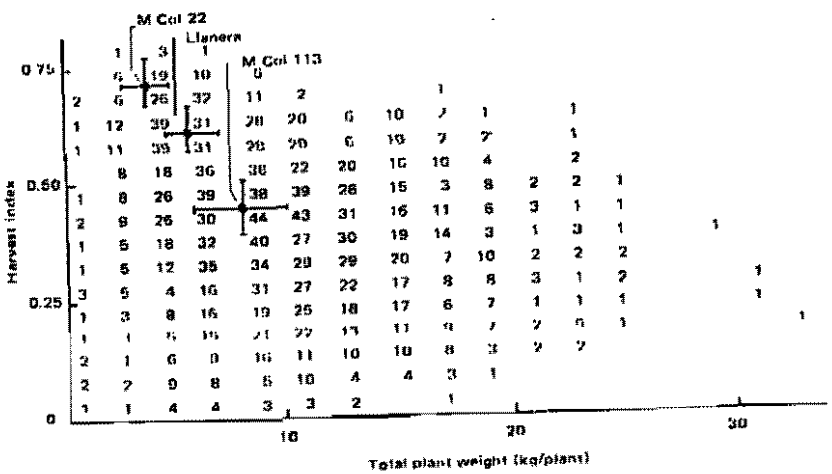


Figure 32. Relationship between total plant weight and harvest index at ten months after planting.

Table 21. HCN content in roots and yield of cassava.

HCN rating (root, 10 months)	No. of collections	Average root yield at 10 months (kg/plant)	Minimum root yield within rating class	Maximum root yield within rating class
1	25	4.56	1.9	10.2
2	341	4.22	0.4	11.8
3	709	4.33	0.1	13.0
4	641	3.84	0.1	10.4
5	127	3.49	0.1	9.4

Hybridization

Approximately 35,000 F_1 seeds of about 250 cross combinations were obtained out of about 30,000 female flowers artificially pollinated during the year. Some of the frequently used cultivars in hybridization are listed in Table 22, and the number of F_1 seeds in some representative crosses produced during the year are given in Table 23.

Table 22. Characteristics of collections frequently used in hybridization programs.

	Harvest index	Total plant weight	Leaf area retention	Early maturity	Easy harvest	CBB resistance	Superelongation resistance
Llanera	+					+	+
M Colombia 22	++			++	++		
M Colombia 113			++				
M Colombia 197						++	
M Colombia 647						++	
M Colombia 667						++	
M Colombia 755	+	+	++				
M Colombia 914	++			+			
M Mexico 23		+	+			+	+
M Mexico 55	++		+	++			
M Mexico 59	+	++	+				
M Venezuela 185	++	+					
M Venezuela 270	+	+					
M Venezuela 307	+	+					

Table 23. Some of the promising cassava hybridizations made at CIAT, 1974.

Crosses	Parent lines	Flowers pollinated	Number of F_1 seeds obtained	Seeds sown	Germination (%)
CM 305	M Col 113 x M Col 22	1,093	1,279	207	73
CM 309	M Col 22 x M Col 647	595	934	800	92
CM 310	M Col 22 x M Col 667	270	528	451	69
CM 321	M Col 22 x M Ven 270	281	523	472	90
CM 323	M Col 22 x M Mex 59	457	742	742	91
CM 325	M Col 22 x M Mex 55	190	301	223	90
CM 326	M Col 22 x M Ven 307	453	622	573	84
CM 327	M Col 113 x M Mex 55	1,328	1,322	690	80
CM 334	M Mex 55 x M Col 647	419	415	62	57
CM 336	M Mex 55 x M Ven 270	157	176	25	72
CM 337	M Mex 59 x M Col 914	100	75	47	75
CM 344	M Col 113 x M Ven 307	422	817	287	72
CM 345	M Col 113 x M Mex 59	93	164	132	76
CM 349	M Col 647 x M Ven 307	148	187	64	66
CM 350	M Col 667 x M Ven 307	173	229	126	64
CM 367	M Col 113 x M Col 647	1,202	1,947	—	—
CM 375	M Col 113 x M Col 1813	275	501	-	-
CM 378	M Col 113 x M Ven 270	286	531		
CM 407	M Mex 55 x M Ven 307	428	638		-
CM 411	M Mex 59 x M Ven 307	29	43	-	-
CM 412	M Ven 270 x M Col 647	109	87	—	—

A remarkably high correlation between parental average and F_1 average was obtained in harvest index (Fig. 33). The same type of correlations in total plant weight (Fig. 34) and root yield (Fig. 35) were low. While almost all the selfed F_1s failed to yield well or could not grow vigorously, plants of high harvest index produced selfed F_1s with high harvest index and vice versa (Fig. 33). Thus, the inheritance of harvest index is largely controlled by the additive gene effect, whereas that of total plant weight is complicated, possibly including genic interaction. This suggests that harvest index is an excellent character to take into account in planning a hybridization scheme.

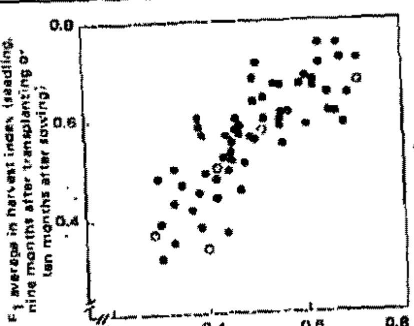


Figure 33. Regression of parental average on F_1 average in harvest index (Selfed F_1 is indicated by white circle).

The primary objective of hybridization is to upgrade the harvest index of population through controlled pollinations, without losing overall heterozygosity. Genes for resistance to important diseases are added gradually.

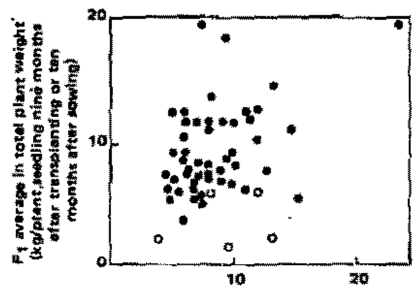


Figure 34. Regression of parental average on F_1 average in total plant weight (Selfed F_1 is indicated by white circles).

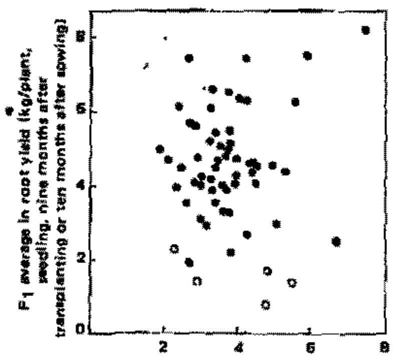


Figure 35. Regression of parental average on F_1 average in root yield (Selfed F_1 is indicated by white circles).

Selection

Seed germination rates of 80 to 90 per cent are easily obtained with a majority of cultivars without any special treatment. Seedlings are transplanted, between one and two months after sowing, at 1 x 2 meter spacing, which is so adjusted as to allow each genotype to express its maximum yielding poten-

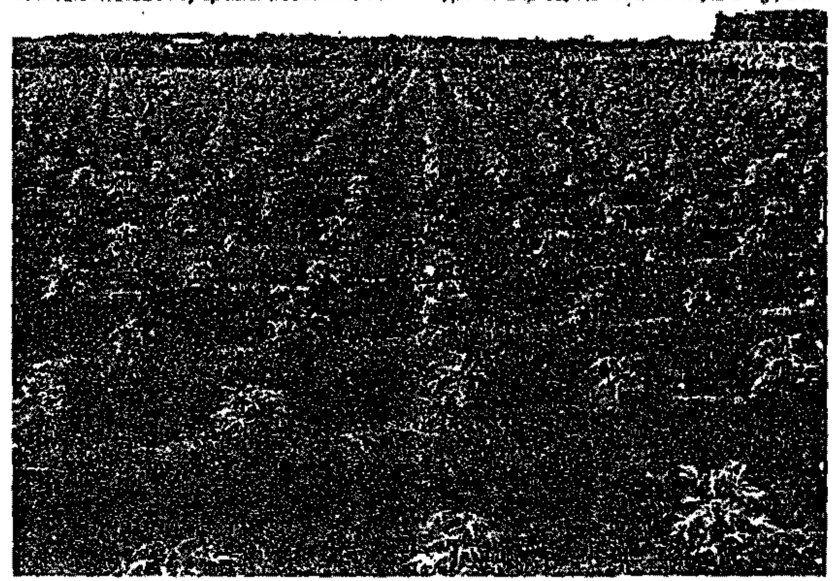


Figure 36. Field of F_1 hybrids. Selection with seedling plants is highly effective.

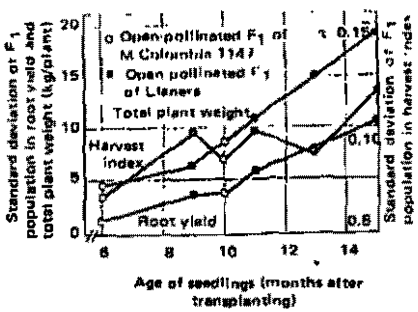


Figure 37. **Age of seedling and the size of genetic variations in yield traits.**

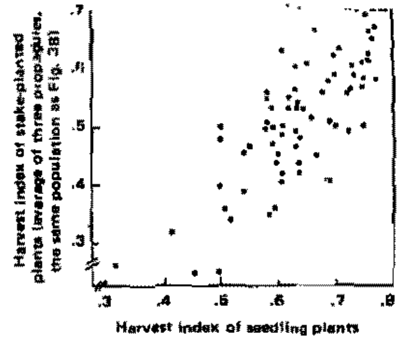


Figure 39. **Regression of data of seedling plants on that of the stake-planted plants of the same genotype in harvest index.**

tial and minimize the effect of intergenotypic competition. At six months after transplanting, the seedlings usually have a few well-formed roots; and several cuttings for planting can be made (Fig. 36).

It is necessary to know what correlation exists between seedling observations and those from stake-planted material. To answer these questions, cuttings from about 3,000 F_1 seedlings that came from the first group of controlled crosses and open-pollination were planted in an observational yield trial without selection at the seedling stage.

Variations of F_1 seedlings in root yield and total plant weight increased proportionately to the age of seedlings (Fig. 37). The variation in harvest index seemed to reach a plateau at about ten months after transplanting the seedlings. Ten months after transplanting the seedlings, the variation in root yield, harvest index and total plant weight were judged to be sufficiently great to ensure an easy field selection. Correlation between data from seedling plants and that from the stake-planted material was good in root yield (Fig. 38), harvest index (Fig. 39) and total plant weight (Fig. 40).

Since all the data suggest that selection with seedling plants is highly effective, an intensive selection will be imposed on the second group of F_1 seedlings, which include such genotypes as M Colombia 22, M Colombia 113, M Colombia 647, M Mexico 55, and M Mexico 59 as the parents. Since cassava requires a large space for the proper evaluation of each genotype, the number of genotypes that can be accomodated per unit of field area is limited. On the other hand, a reproduction of the same genotype can be readily made through stem cuttings. Thus, having distinct evaluation fields for different selection items is reasonable.

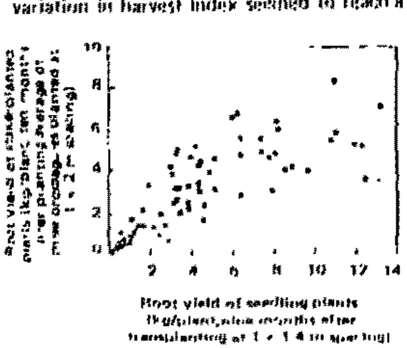


Figure 38. **Regression of data of seedling plants on that of the stake-planted plants of the same genotype in root yield.**

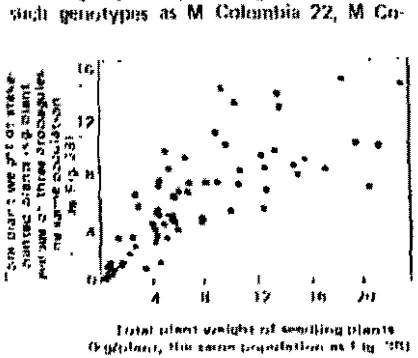


Figure 40. **Regression of data of seedling plants on that of the stake-planted plants of the same genotype in total plant weight.**

Hence an observational yield trial at Carimagua, Llanos Orientales renders a good selection opportunity for poor acid soils with a prolonged dry season. Another trial at Caribia, Santa Marta gives a selection opportunity under high temperatures where the vegetative growth is rapid. The pathology group evaluates numerous genotypes for cassava bacterial blight and superelongation disease outside CIAT while the initial selection with seedlings in CIAT is meant to be based on the maximum yielding potential of each genotype.

Material exchange

Cassava originated and diversified in Latin America. The CIAT cassava germplasm collection is the biggest and possibly the only one on an international scale at present. Thus, it is one of CIAT's responsibilities to provide genetic materials for other cassava breeding programs in the world. About 15,000 open-pollinated seeds from 203 collections were sent to the IITA program in Nigeria.

A much greater number of F_1 seeds can be produced than can be evaluated properly in the seedling field at CIAT. Thus, we are ready to supply seeds of F_1 hybrids that we consider as promising for other cassava breeding programs outside Colombia. So far, a total of about 3,500 F_1 seeds, which came from such crosses as M Colombia 113 x M Colombia 22, M Colombia 22 x M Colombia 647, M Colombia 22 x M Venezuela 218 and M Colombia 113 x M Mexico 55 were sent to ten interested breeder-agronomists in Brazil and at IITA.

AGRONOMY

Population and stake size

Trials were carried out at three sites: Media Luna (20 meters), La Zapata (1,200 meters) and Chinchiná (1,500 meters). Stakes of the most common local variety were used in each trial. The plots were fertilized according to soil analysis; weeds were controlled; and when insect attacks became serious, insecticides were applied. A severe attack of both bacteria (CBB) and superelongation disease occurred at Chinchiná.

In all trials it was observed that plants from longer stakes were larger up to four months after planting when they became more equal. Thus, larger stakes may help to give better weed control in the early growth stages.

At La Zapata, no significant interaction (at the 5 per cent level) between stake size and population was detected. Mean yield of fresh roots increased from about 31 to 36 ton/ha as plant stake size increased from 20 to 60 centimeters and decreased to 33.6 ton/ha, as stake size was increased to 80 centimeters (Fig. 41). These yield differences were small in comparison with those associated with population changes. Yield increased from 21.7 to 41.4 ton/ha as population increased from 5,000 to 40,000 plants/ha (Fig. 41). However, roots less than 25 centimeters long and 5 centimeters in diameter are generally not saleable on the Colombian market; and with more than 20,000 plants per hectare, the percentage of small, non-saleable roots was large (Table 24). Consequently, a population of 20,000 plants per hectare with 40 to 60 centimeter stakes would seem to be optimum.

Results from Chinchiná were similar, but more variable (Fig. 42). As in La Zapata, stake size had little effect on yield, and 40-centimeter stakes were long enough to give maximum yields.

Plant population increases led to large yield increases up to a level of 28 ton/ha. However, as in La Zapata, the number of commercial roots decreased markedly as

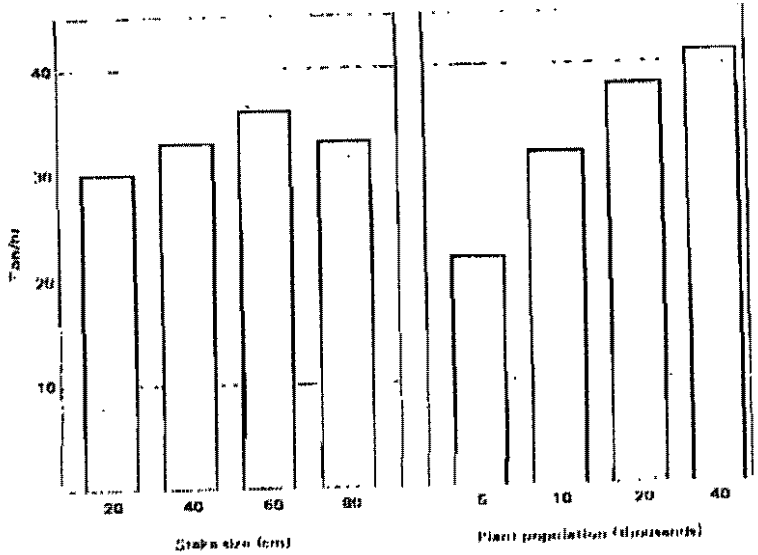


Figure 41. Stake size and plant population effect on yield at La Zapata, Valle.

plant population was raised to 40,000 plants per hectare.

In Media Luna, yields were extremely poor, possibly because of the severe dry season and a poor local variety. Results were extremely variable and difficult to interpret (Fig. 43). Once again, 40-centimeter stakes appeared best; but lower populations (10,000 plants per hectare) were optimal.

Table 24. Plant population effect on percentage of fresh commercial roots at La Zapata.

Population (plants/ha)	Commercial roots more than 25 cm long and 5 cm in diameter* (%)
5,000	100
10,000	100
20,000	85
40,000	20

* For Colombian markets, a root under this size is not considered commercial.

In all locations, it was observed that as plant population increased, yield also increased; but the number of roots per plant, size of roots and harvest index decreased, whereas natural control of weeds improved.

Yield trial

Table 26 illustrates how the same varieties behave in different locations and populations and in different years.

In 1973, nine varieties were planted in a replicated yield trial at CIAT (1,000 meters) in a fertile soil with pH 6.5. In 1974, the same nine varieties, plus the variety Tolima, were planted at La Zapata in a soil with medium to low fertility and pH 4.7.

M Colombia 22, a promising variety at CIAT and ranked first in the 1973 CIAT trial, had a yield reduction of 38.7 per cent and was ranked ninth at La Zapata in 1974. Most of the varieties showed differences in performance between locations and years; however, Llanera yielded equally well in both localities. Tolima (which resembles M Colombia 113 and which has shown good yields in one trial at CIAT) (Fig. 44) showed exceptional yield potential (Table 25).

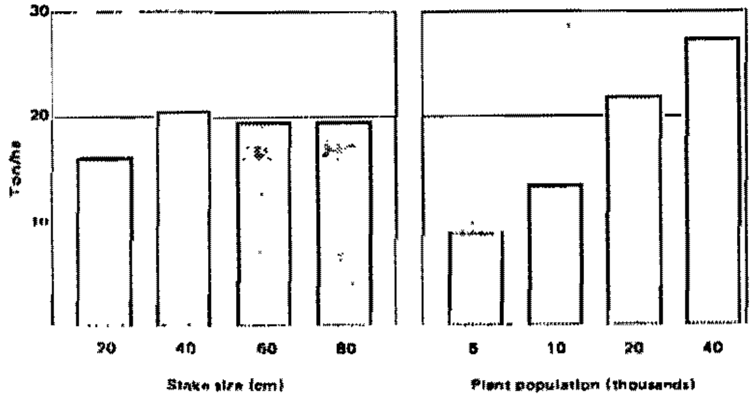


Figure 42. Stake size and plant population effect on yield at Chinchiná, Caldas.

The results stress the importance of conducting regional trials over a wide range of ecological conditions in several seasons using the same technology, so as to be able to select the best variety or varieties for any particular site. The results also indicate the possibility of identifying varieties that perform well under a wide range of conditions from the results of the regional trials already planted with promising varieties at 14 sites in Colombia.

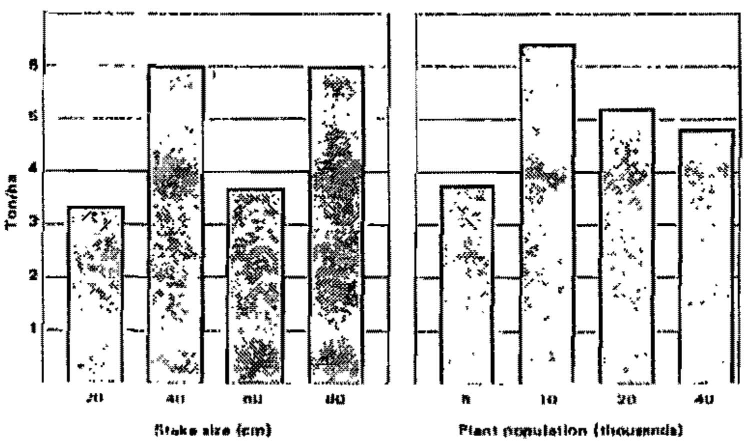


Figure 43. Stake size and plant population on yield at Media Luna, Magdalena.

Table 25. Yield performance of several cassava varieties at two locations in Colombia.

Ranking	Variety	Yield after one year (Fresh roots) 16,666 plants/ha (CIAT, 1973) (ton/ha)	Variety	Yield after one year 8,333 plants/ha (La Zapata, 1974) (ton/ha)
1	M Colombia 22	46.4	Tolima	46.8
2	CMC-84	40.8	Llanera Roja	31.8
3	Llanera	35.0	M Colombia 463	32.7
4	Llanera Roja	28.8	Llanera	32.2
5	M Colombia 65	29.0	M Colombia 645	32.1
6	M Colombia 645	25.8	CMC-84	28.7
7	Extranjera	24.6	Extranjera	28.2
8	M Colombia 463.	23.3	M Colombia 65	19.9
9	M Panama 64	16.5	M Colombia 22	18.0
10			M Panama 64	14.0

Figure 44. Yield trial outside CIAT. Agronomists selected 14 locations in Colombia for regional yield trial of promising lines.

Table 26. Chemical characteristics of the soils of three locations where cassava fertilizer experiments are conducted.

Location	pH	% O.M.	Bray II P ppm	Al	m Eq/100 mg Ca	Mg	K
Carimagua	4.3	3.6	1.6	3.0	0.3	0.1	0.08
Jamundí	5.2	4.5	2.4		10.0	5.4	0.13
La Zapata	4.3	7.4	3.6	2.6			0.14

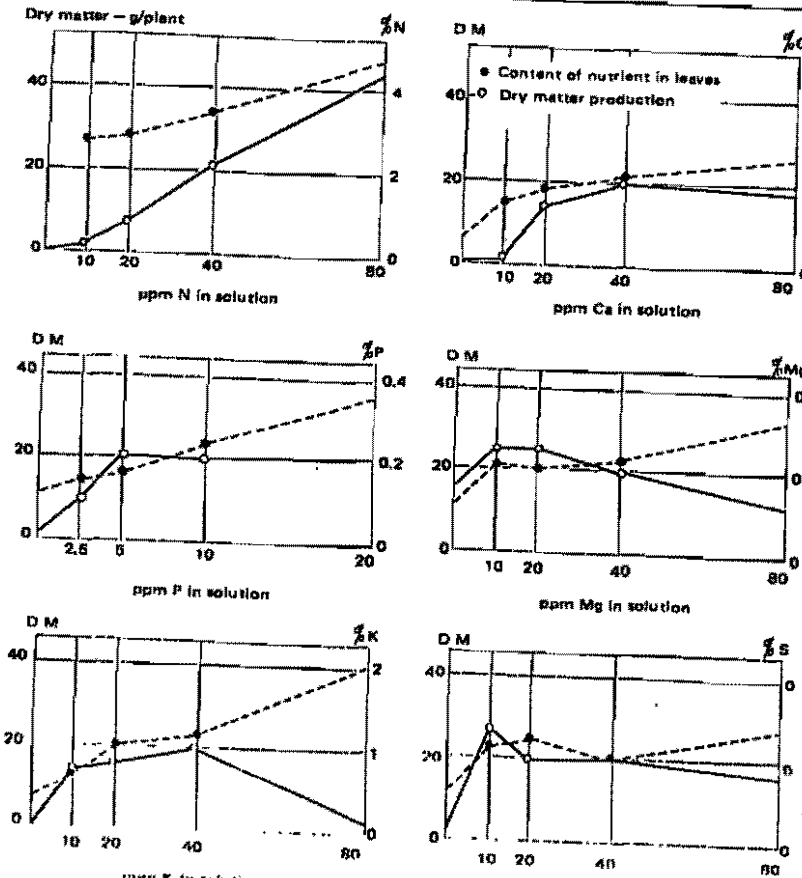


Figure 45. Total dry matter production and nutrient content of leaves of 3.5-month-old Llanera plants as related to the elemental concentration of nutrient solutions.

Optimal levels of various nutrients

The diagnosis of nutritional problems of cassava is difficult because of the lack of information on deficiency symptoms and optimal levels of essential nutrients in the plant.

Figure 45 shows the dry matter production and the corresponding nutrient contents in the leaves of 3.5-month-old Llanera plants grown without stakes (and thus with low nutrient reserves) at various levels of nutrients in sand-solution culture. The highest level of 80 ppm N was not sufficient to obtain maximum dry matter production. Definite maxima of total dry matter were obtained at 5 ppm P, 40 ppm Ca, 20 ppm Mg, and 10 ppm S in solution. The levels of nutrients in the plant that corresponded to maximum dry matter production were: ⟩ 4.65% N, 0.18% P, 1.14% K, 1.07% Ca, 0.42% Mg and 0.16% S (Fig. 46).

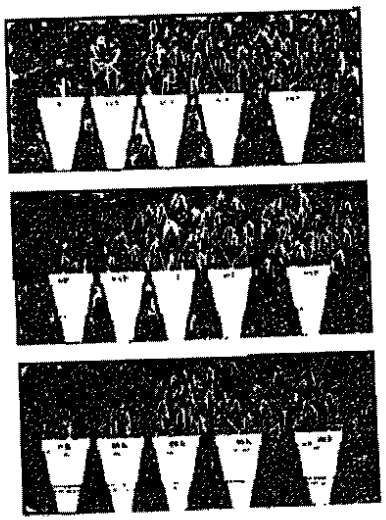


Figure 46. Response of 3 1/2-month-old Llanera plants to various levels (in ppm) of N, P and K in nutrient solutions.

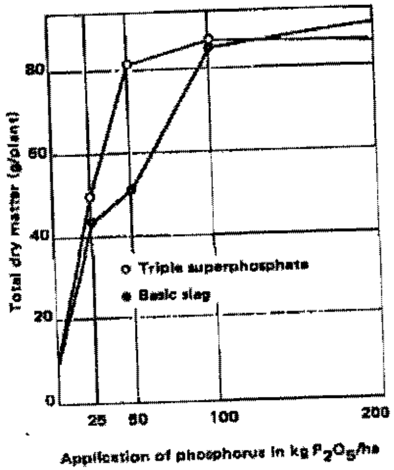


Figure 47. Total dry matter production of six-month-old Llanera plants as related to four levels and two sources of P applied to Carimagua soil in pots.

Numerous chemical analyses of cassava plants in the field at two to four months after planting indicate that normal nutrient contents in young, fully opened leaves are:

4.5 – 6.5% N	40 – 100 ppm Zn
0.2 – 0.5% P	15 – 40 ppm B
1.0 – 2.0% K	6 – 12 ppm Cu
0.75 – 1.5% Ca	50 – 150 ppm Mn
0.25 – 1.0% Mg	100 – 200 ppm Fe

Zinc deficiency symptoms normally appear when the leaves contain less than 20 ppm Zn. These levels may serve as a general guide but vary somewhat with varieties and age of plants.

Response to fertilization

Pot experiments with Carimagua soil

Figure 47 shows the response of cassava to various levels of P applied as triple superphosphate (TSP) or basic slag on Carimagua soil (Table 26). TSP was slightly superior at intermediate levels of application. The P content of the leaves corresponding to maximum production of dry matter was 0.18 to 0.22 per cent P. Dry matter production and P levels in the leaves were much lower than those obtained in the field (see above), indicating that root growth and nutrient absorption were seriously reduced by the limited volume of soil in the pot.

Another experiment showed maximum dry matter production with the application of 100 kg P_2O_5/ha as TSP which produced a P content of 0.22 per cent in the leaves. The same experiment showed that only at high levels of application was there any significant residual effect of P applied in the previous semester.

Figure 48 shows the response of cassava to various levels of K applied as KCl or K_2SO_4 to Carimagua soil. The K_2SO_4 was superior to the KCl, the latter producing a negative response at high levels of application. Maximum production of dry matter was obtained at a K level of 1.10 to 1.30 per cent in the leaves.

The negative effect of high KCl applications was substantiated by another pot experiment. This experiment also indicated the nearly negligible residual effect of even high rates of KCl applications.

The superiority of K_2SO_4 over KCl is most likely due to an S response of cassava grown in Carimagua soils. This was substantiated by a minor element pot experiment, which indicated a significant positive response to Ca, S and Zn, a slight response to Mg and Cu, and a negative response to B, Mo and Mn.

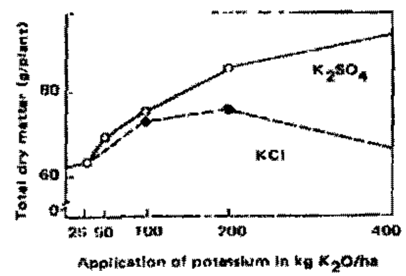


Figure 48. Total dry matter production of six-month-old Llanera plants as related to five levels and two sources of K applied to Carimagua soil in pots.

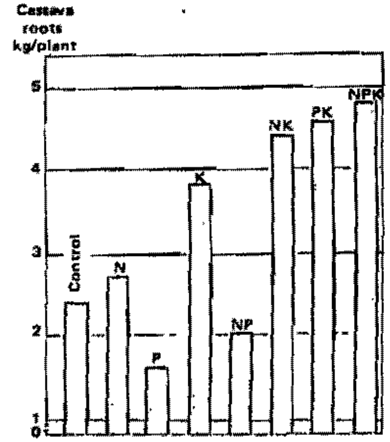


Figure 49. Root yield of Llanera as related to applications of 200 kg N and P_2O_5/ha and 300 kg K_2O/ha in Jamundí.

Field experiments

Cassava plants extract large amounts of K from the soil. Cassava's large K requirements were shown by an NPK factorial experiment in Jamundí, just south of Cali. Although these soils have an intermediate exchangeable K content (Table 26) and a low P content, the only significant response was to K, with a slight response to N and P in the presence of K (Figure 49).

In another soil low in P and of intermediate K content at La Zapata (Table 26), cassava responded mainly to applications of K and to a lesser extent to applications of P and N (Fig. 50). An analysis of the San Cristóbal design used indicated a significant response (at the 5 per cent level) to the application of each element. The equation of the response surface was calculated to be: yield = 24.3 + 0.49 N + 0.56 P + 1.71 K – 0.34 N² + 0.24 P² + 0.72 K² – 0.26 NP + 1.04 NK + 0.51 PK (P as P_2O_5 and K as K_2O, expressed as kg/ha, with yield expressed as ton/ha). This equation shows quantitatively the importance of K fertilization relative to that of N and P, even in a soil low in P and intermediate in K. It is also apparent that the response to N may be negative above an optimal level.

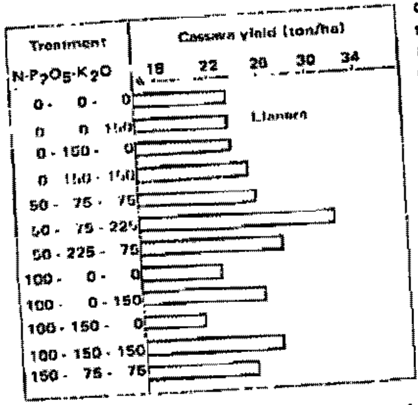


Figure 50. Response of Llanera to various levels of N, P and K applied at La Zapata.

In an adjacent field, beans showed a dramatic response to P applications (see page 145), indicating the importance of P for beans and K for cassava.

Field trials at Carimagua showed marked visual responses of cassava to applications of lime, Mg, N, P, K and S. Figure 51 shows the response of cassava to N levels applied as urea and S-coated urea (SCU). When fractionated, the urea was superior to the SCU, but when all the N was applied at once at 50 days, the SCU was inferior at the low level, but much superior at the high level of application. The S in the SCU had no significant nutrient effect since about 75 kg S/ha was applied to the entire experiment in the form of K_2SO_4.

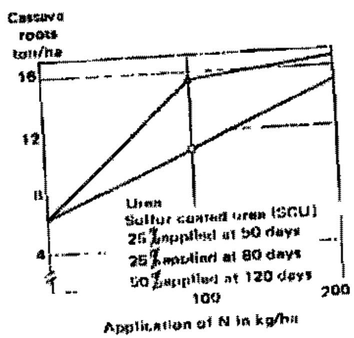


Figure 51. Response of Llanera to two levels and sources of N applied as split applications in Carimagua.

All trials planted at Carimagua between April and July, 1974 suffered to some extent from bacterial blight (CBB). Seriously affected plants lost many of their leaves by the age of six to seven months, followed by die-back of the growing points. This increased the weed growth and in some cases could seriously affect yields. Measurements of plant height, visual evaluations and foliar analyses at two and four months of age allowed the following tentative conclusions:

1. There was only a small positive response to N in CMC-84. Even without N application, the N content of leaves was as high as 5.40 per cent, which increased to 6.12 per cent with the application of 200 kg N/ha.

2. There was a significant positive visual response to P in Llanera to levels of 150-200 kg P_2O_5/ha. Without P application the P content of the leaves was 0.40 per cent, which increased to 0.54 per cent with the application of 150 kg P_2O_5/ha. P contents of cassava leaves were high compared with other crops (seldom above 0.2 per cent) even without P application.

3. There was a marked positive response to K applications, with K_2SO_4 being a superior source to KCl. Applications of KCl plus elemental S were superior to KCl alone, indicating the importance of S fertilization.

4. There was a marked positive response to Mg application, with $MgSO_4$ being superior to MgO. When band placed, the latter increased the soil pH excessively.

5. There was a marked positive response to lime up to 6 ton/ha in the Chirosa de Acacias variety. This is contrary to earlier observations, which indicated a negative response to high lime applications. Liming decreased the leaf contents of Mn, Zn and K. The N and P contents were little affected by liming. Earlier negative responses to liming resulted in typical Zn deficiency symptoms (Figure 52) and low levels of Zn in the leaves (11-15 ppm with 6 ton/ha of lime). On the contrary, this Chirosa variety produced no Zn deficiency symptoms and had a high Zn content of 49 ppm at the 6 ton/ha lime level. It appears that the negative response of cassava to high levels of lime is mainly due to Zn deficiency in Carimagua soil.

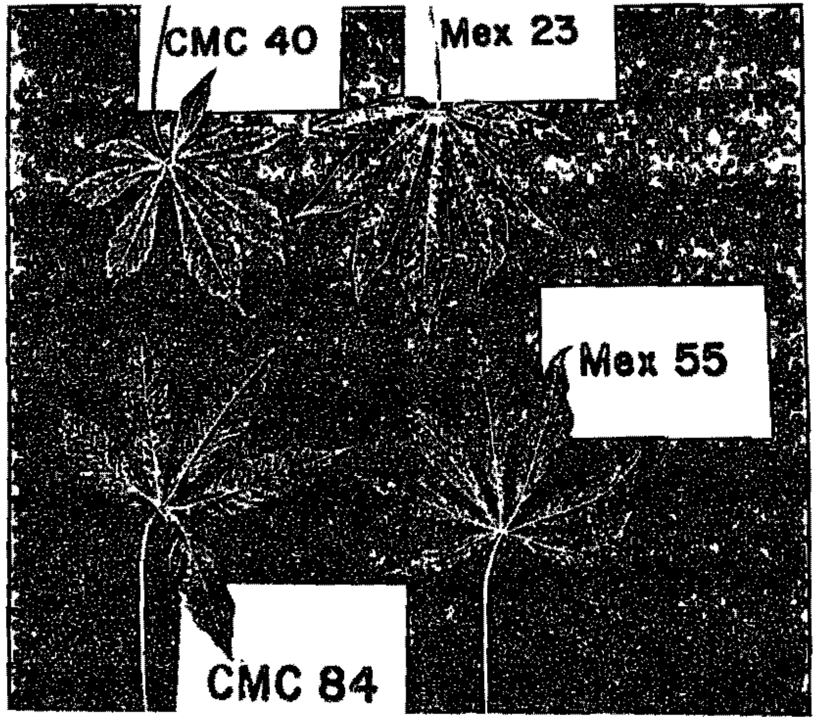


Figure 52. Zinc-deficiency symptoms in various cassava varieties.

6. Band placement of fertilizers in single or double, interrupted bands alongside the stake was much superior to broadcast placement. The latter method produced excessive weed growth and stunted cassava plants.

WEED CONTROL

Study of the interactions between weed control systems, plant populations and variety was continued. Using a systematic density design, the varieties CMC-39 and Mexico 11 were planted in densities ranging from 2,940 to 36,700 plants per hectare. Cassava, kept free of weeds with herbicides during the entire growing season, gave the highest yields (Fig. 53) and the maximum yield was reached at approximately 15,000 plants/ha.

Cassava, weeded once or twice (the normal commercial practice), gave its maximum yield between 15,000 and 25,000 plants/ha with Mexico 11 and between 25,000 and 30,000 with CMC-39. For both varieties, the yields of cassava weeded twice almost equaled those of the cassava kept weed free

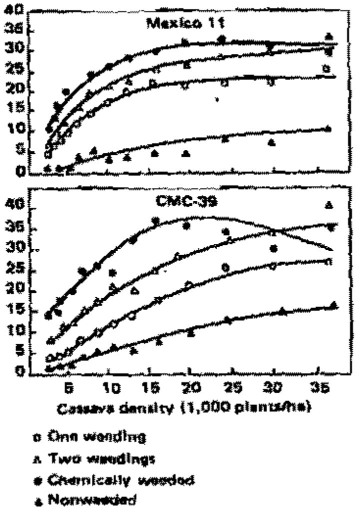


Figure 53. Effect of cassava density and weeding system on fresh weight of roots at ten months for Mexico 11 and CMC-39.

with herbicides, indicating that higher plant populations can be used to obtain maximum yield when the weed control inputs are limited. It also suggests that cassava kept totally weed free, especially during the early part of the growing season, can be planted at lower plant populations and still reach maximum production. Yields for nonweeded cassava were extremely low but also increased as the crop density increased.

Since cassava requires a minimum of 2.5 months and often up to 3.5 months to form a closed canopy, a single application of a preemergence herbicide will not give adequate control. With this in mind, ways of integrating various weeding methods into a logical system were studied.

The highest yield and best weed control were obtained with the traditional method of using three hand weedings (Table 27). The next highest yields were achieved when the application of diuron was complemented with one hand weeding either after (26.8 ton/ha) or before (25.4 ton/ha) applying the herbicide. The lowest yields were those where no control method was used after appying a preemergence treatment and where repeated postemergence applications of paraquat were made. The latter treatment injured the cassava stems even though it was directed toward the weeds and not the crop.

The only significant reduction in the harvest index was in the nonweeded cassava, which means that the root production, more than the foliage, was affected by the weeds. The lowest weeding costs per ton of root fresh weight produced were given by diuron in preemergence followed by one hand weeding, or by diuron applied after a hand weeding 40 days after planting (postemergence to the cassava); but the costs of these treatments per ton of cassava produced were not significantly different from the hand-weeded cassava. Hence, hand weeding is to be recommended where labor is available, as the extra costs over diuron plus one hand weeding is easily covered by the extra production. Where labor is limited, a preemergence application followed by a hand weeding is recommended.

Recently, many new herbicides have been developed for various crops. In continuation of a screening program initiated in 1972, 20 new herbicides were screened in cassava. At 30, 60 and 90 days after planting, observations were taken on germination, injury ratings and plant heights; and at 120 days, observations on the root and foliage fresh weights showed that 11 compounds (Table 28) were highly selective (no injury caused even by applying four times the recommended rate). Three compounds caused injury at the double rate and were classified as marginally selective. The nonselective treatments were primarily those applied in postemergence over the top applications, or those known to have a long residual effect (tebuthiuron and DPX-3674). Thus, many new herbicides can be added to the list of those safe to apply in cassava.

Herbicide selectivity is known to vary with soil texture. To determine if the selectivity of diuron and metribuzine in cassava is reduced as the soil texture becomes lighter, a screenhouse experiment was carried out. Diuron was applied at 1.6 and 3.2 kg/ha a.i and metribuzine at 0.5 and 1.9 kg (the high

Table 27. Weed control, weed weights, yield and harvest index and weeding costs for ten-month-old Llanera cassava plants grown under various weeding systems.

Weeding system	Rate (kg/ha) a.i.	Weed control 90 DAP[1] (%)	Weed Fr. Wt[2] (ton/ha)	Cassava Yield[3] (ton/ha)	Cassava Harvest index	Weeding Costs Pesos/ha[4]	Weeding Costs Pesos/ton
1. Alachlor + H.W.[5]	3.0	88	2.0	17.1	.83	880	51
2. Alachlor + Paraquat[6]	3.0 + 0.5	71	3.6	16.6	.81	980	59
3. Alachlor	3.0	35	4.2	10.0	.83	700	70
4. Diuron + H. W.	1.6	76	2.1	26.8	.83	460	17
5. Diuron + Paraquat[6]	1.6 + 0.5	75	3.0	14.9	.80	540	36
6. Diuron	1.6	36	3.0	10.7	.78	260	24
7. Alac. + Diur. + H. W.	0.8 + 1.5	90	2.0	17.0	.84	650	38
8. Alac. + Diur. + Paraq.[6]	0.8+1.5+0.5	79	2.5	21.0	.83	760	36
9. Alac. + Diur.	0.8 + 0.5	49	2.2	16.0	.82	480	30
10. H.W. + Diuron	1.6	56	5.6	25.4	.82	480	19
11. H.W. + Alachlor	3.0	30	12.1	18.9	.83	940	50
12. H.W. + Alac. + Diur.	1.5 + 0.8	58	4.0	21.2	.80	710	34
13. Paraq. + Diur.[6] + H.W.	0.5 + 1.6	91	3.2	20.5	.83	560	27
14. Paraq. + Paraq. + Paraq.[6]	0.5+0.5+0.5	52	7.7	12.2	.79	830	68
15. 3 hand weedings	—	85	0.8	31.1	.84	660	21
16. No weed control	—	0	7.4	2.8	.71	0	0

1 Days after planting
2 During the first 120 days
3 Fresh root weight at ten months
4 In Colombian pesos, June, 1974, including labor
5 H. W. = hand weeding
6 Applied in postemergence to the weeds

rate corresponds to twice the recommended dosage). A clay soil was used as the heavy texture soil and diluted with 20, 40, 60 and 80 per cent sand to obtain a wide range of soil textures. After two months the fresh weights of the aerial portion of the plant were determined.

Diuron at the recommended rate (1.6 kg) produced no phytotoxicity in soil mixed with up to 60 per cent sand and only slight growth reduction (14 per cent) in 80 per cent sand. The 3.2 kg/ha rate caused only slight growth reduction with 40 and 60 per cent sand, but serious injury was caused in 80 per cent.

Table 28. Classification of 20 new herbicides* according to their selectivity in cassava.

Highly selective	Marginally selective	Nonselective
bifenox (2, 4, 8)	CIPC + naptalam (2 + 2, 4 + 4, 8 + 8)	amitrol (2, 4, Post)
cyanazine (2, 4, 8)	metribuzin (.5, 1, 2)	bentazon (1.5, 3, 6, Post)
dinitramine (.75, 1.5, 3)	oxadiazon (1, 2, 4)	DNBP (1.5, 3, Post)
DPX--6774 (1, 2, 4)		DPX--1108 (2, 4, Post)
H--22234 (3, 6, 12)		DPX--3674 (1, 2, 4)
IT--5914 (1, 2, 4)		tebuthiuron (.5, 1, 2)
methabenzthiazuron (2, 4, 8)		
napropamide (2, 4, 8)		
perfluidone (2, 4, 8)		
prinachlor (4, 8, 16)		
S -2846 (1, 2, 4)		

* All herbicides were applied in preemergence unless otherwise noted. The rates in kg/ha a.i. are noted in parentheses.

This indicates that diuron can be used safely at the recommended rate in soils which have up to 60 per cent sand with no danger of crop injury. In soils lighter than this, it should not be used.

A similar trend was observed for metribuzine at 0.5 kg. It was selective in soil mixed with up to 40 per cent sand, but not in sandier soils. The high rate was not selective in any of the soils; therefore, this product is not considered sufficiently selective to be safely recommended in cassava.

Nearly all the herbicides effective against purple nutsedge (**Cyperus rotundus**), possibly the world's worst weed, must be soil incorporated after application because of their high volatility. This could present a problem when cassava is planted in ridges, as much of the incorporated herbicides could be accumulated in the ridge which might prove injurious to the cassava, leaving the area between the ridges with less herbicide and thus poorer weed-control results in these areas. To study these theories, two preplanting, incorporated herbicides effective in nutsedge control (EPTC and butylate) and another one excellent for grass control (trifluralin) were applied and incorporated. The recommended rate and double that rate were applied for each compound. Half of each plot was then ridged while the other half was not. Cassava was immediately planted, and weed control and cassava injury ratings and final yields were taken.

EPTC was more toxic to cassava planted in ridges than to cassava planted in nonridged soil (Table 29). Butylate responded similarly but was more selective than EPTC. Trifluralin caused no significant crop injury. Grass control was also reduced when ridges were made after the preplanting, incorporated treatments were applied, especially between the ridges. This did not occur with the preemergence herbicides diuron + alachlor, applied in combination after the ridges were formed and the cassava planted.

Fresh root yields were 10 tons higher for cassava planted in nonridged soil. The principal effect of ridging was to increase herbicide toxicity and thus lower yields. However, the yields for cassava in nonridged soil were also higher for the nontoxic treatment

Table 29. Effect of preplanting, incorporated herbicides on percentage of germination, injury rating, grass weed control, fresh root yields and harvest index of cassava plant in ridged and nonridged soil.

Treatment	Rate (kg/ha a.i.)	Planting system	Germination (%)	Injury rating*	Grass control (%)	Root yield** (ton/ha)	Harvest index
1. EPTC PPI***	4	Ridges	75	5.2	73	22.0	0.66
2. EPTC PPI	8	"	45	7.7	86	8.4	0.66
3. butylate PPI	4	"	77	0.7	36	33.0	0.65
4. butylate PPI	8	"	83	3.5	80	30.8	0.65
5. trifluralin PPI	1.5	"	94	1.5	62	35.8	0.65
6. trifuralin PPI	3.0	"	100	0	76	35.6	0.69
7. diuron + alachlor PRE****	0.8 1.5	"	96	0.5	100	27.9	0.66
8. Check --	--	"	94	0	0	18.3	0.64
Average for cassava in ridges:			83	2.3	64	26.5	0.66
9. EPTC PPI	4	Nonridged	92	1.5	98	41.7	0.57
10. EPTC PPI	8	"	64	1.2	100	33.1	0.63
11. butylate PPI	4	"	98	0	92	34.2	0.61
12. butylate PPI	8	"	79	1.0	96	39.0	0.55
13. trifluralin PPI	1.5	"	96	0	88	42.5	0.57
14. trifluralin PPI	3.0	"	94	0.5	93	42.6	0.58
15. diuron + alachlor PRE****	0.8 1.5	"	98	0	100	36.9	0.54
16. Check --	--	"	100	0	0	21.4	0.56
Average for cassava not in ridges:			90	0.5	83	36.4	0.58

* 60 days after planting; 0 = no injury; 10 = complete kill

** Ten months after planting

*** PPI = preplant incorporated

**** PRE = preemergence (not incorporated)

(trifluralin and diuron + alachlor), indicating a response to some other factor as well. No differences were observed in the harvest index within the planting systems because of any herbicide treatments, but cassava planted in nonridged soil had a consistently lower harvest index than that planted in ridges.

In summary, keeping cassava weed free until a closed canopy is formed is critical for achieving maximum yields. When nonintensive weed control methods are used (one or two hand weedings), yields can be increased by planting higher plant populations. When hand labor is limited, the use of a preemergence herbicide followed by one hand weeding gives acceptable results. Many preemergence herbicides can be safely recommended in cassava.

STORAGE*

Curing and wound healing

Observations on the wound-healing process in cassava have indicated that similar

* This work forms part of a two-year joint Tropical Products Institute/CIAT Cassava Storage Project, financed largely by the Overseas Development Administration, London.

Table 30. Effect of temperature on wound healing of cassava roots stored at 80 to 85 per cent relative humidity.

Temperature (°C)	Time to suberization (days)		Time to meristem formation (days)	
	Cortical tissues	Medullary tissues	Cortical tissues	Medullary tissues
25	2–3	3–4	5–7	6–9
30	1–3	2–4	5–6	6–8
35	1–2	2–3	4–6	5–7
40	2–3	2–4	3–5	4–6*

* Primary deterioration occurred in advance of meristem formation in some roots.

physiological and histological processes are involved, as occur in the curing of other root crops such as Solanum and sweet potatoes. In several of the outermost layers of cells near wounds, suberization occurs; in addition, certain of the deeper parenchymatous cells form a meristem (cork cambium) which, through multiplication, forms a new cork layer around the wound. This wound-healing process in cassava appears to prevent the onset of primary deterioration and thus prolongs the storage life of the roots.

At a relative humidity of 80 to 85 per cent, both suberization and meristem formation occur slightly faster as the temperature is raised from 25 °C to 30° to 35° to 40 °C (Table 30). However, although meristem formation occurs slightly faster at 40 °C than at 35 °C, primary deterioration frequently occurs in advance of this at the higher temperature. At all temperatures, both suberization and meristem formation occur more rapidly in the cortical tissues than in the medullary tissues. At 35 °C a complete meristem forms around V-shaped cuts in four to seven days.

At a relative humidity of 95 per cent, wounds rapidly became infected by a wide range of microorganisms; and at a relative humidity of 75 per cent, roots dried out rapidly, especially around open wounds; thus, no observations on wound healing were possible at either of these two humidities.

Simple storage techniques

Continued investigations into simple storage techniques have concentrated on determining the most suitable clamp design and box storage system that would provide rapid

Table 31. Design of field clamps for storing cassava.

Clamp type	Thickness of straw cover (mm)	Thickness of soil cover (mm)	Nature and number of basal ventilators	Nature of single, central, vertical ventilators
1	nil	150	nil	nil
2	10–50	300–400	nil	nil
3	150	150	nil	nil
4	150	300–400	nil	nil
5	150	300–400	4 straw bundles	straw bundle
6	150	300–400	2 triangular wooden frames	rectangular wooden frame

Table 32. Effect of clamp type on internal clamp temperature and cassava root outturn after four weeks' storage.

Clamp type* and replicate	Days of rainfall	Total rainfall (mm)	Final internal clamp temp (°C)	Days for internal clamp temp to exceed 40 °C	Total root weight loss (%)	Marketable roots Initial weight (%)	Marketable roots Final weight (%)
A. During Wet Season							
1A	12	178.6	40	–	16	74 **	88 **
1B			38	–	10	79 **	88 **
2A	11	173.0	39	–	12	80	91
2B			39	–	13	76	87
3A	10	142.5	40 +	19	17	60	72
3B			40 +	26	7	87	93
4A	11	160.3	37	–	17	78	94
4B			38	–	13	83	96
5A	8	130.9	39	–	15	75	88
5B			39	–	16	76	90
6A	7	116.2	32	–	16	76	90
6B			32	–	20	77	96
B. During Dry Season							
1A	2	20.1	40 +	28	14	61 **	71 **
1B			39	–	11	80 **	90 **
2A	1	17.8	38	–	17	73	87
2B			39	–	17	67	80
3A	1	17.8	40 +	5	15	11	13
3B			40 +	4	18	9	10
4A	1	17.8	39	–	3	90	93
4B			40 +	10	24	6	8
5A	1	17.8	39	–	8	84	92
5B			40 +	27	16	72	86
6A	1	17.8	36	–	17	71	85
6B			35	–	20	71	88

* See Table 31.
** High percentage of roots with secondary growing roots

curing and thus provide acceptable outturns after one month's storage.

Field clamp storage

Observational trials confirmed that it was possible to cure and store cassava roots in structures similar to European potato clamps although root outturns were variable. During hot, dry periods, outturns were variable and were consistently poor when the internal clamp temperature rose above 40°C; better and more consistent outturns were obtained during rainy periods when internal clamp temperatures were lower. During one prolonged cool, moist period, cassava roots were stored for nine months in a field clamp with little loss because of primary deterioration although after six months' storage, many of the roots were unacceptable because of a softening and drying out of the central root tissues. These observational trials also indicated that if the root outturn from field clamps was acceptable after two months' storage, then the outturn afterwards (usually three months) was only slightly worse.

The following clamp trials were designed to develop a clamp structure which would provide acceptable and reliable root outturns after a month's storage under the different ambient conditions prevailing at CIAT. The clamp types examined are shown in Table 31.

The effect of these clamp types on root outturn at CIAT during a wet and a dry season is shown in Table 32.

During the wet season, acceptable and consistent root outturns were obtained from clamp types 2 and 4 with thick soil covers and types 5 and 6 with thick soil covers and ventilators. Although the outturn from clamp type 1 was acceptable in terms of weight of sound roots, many of the roots, noticeably those in contact with the soil, produced many secondary growing roots which lowered their acceptability. In replicate A of clamp type 3, which gave a poorer outturn, the internal clamp temperature rose to more than 40°C in 19 days.

In the dry season, the most consistent outturns were obtained from clamp types 5 and 6, although acceptable outturns were also obtained from clamp type 2. In one or both replicates of clamp types 3 and 4, the internal clamp temperature rose rapidly to more than 40°C, and poor outturns were obtained.

The provision of wooden framed ventilators (clamp type 6) considerably lowered internal clamp temperatures in both wet and dry seasons; and although this also slightly increased the total root weight loss, the percentage of marketable roots was in all cases consistent and acceptable.

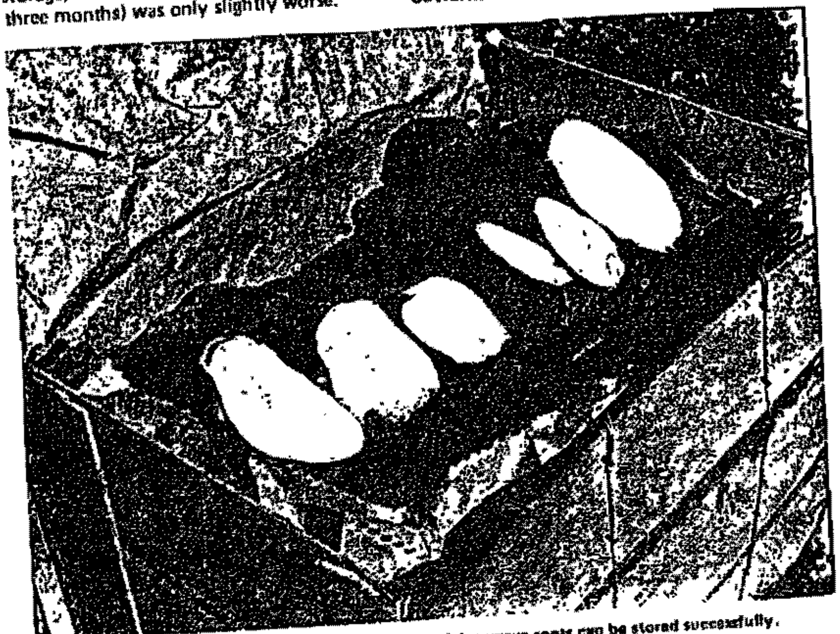


Figure 54. Using simple techniques and material, cassava roots can be stored successfully.

Box storage

Preliminary studies indicated that it was possible to cure and store cassava roots for varying periods when packed in boxes with sawdust or rice husks and the boxes kept in the laboratory. The root outturn from the boxes appeared to be affected by both the nature and the moisture content of the packing material. Trials were undertaken to develop a simple, practical box storage system which could be used for transportation, storage and marketing purposes.

The results of these trials have indicated that satisfactory and consistently acceptable root outturns could be obtained after a month's storage when roots were packed in moist sawdust (Fig. 54); packing in wet or dry sawdust considerably reduced the percentage of roots in acceptable condition (Table 33).

Because of the difficulty in moistening and maintaining an even moisture distribution in rice husks, these have not proved a successful packing material; and better outturns have always been obtained with moist sawdust (Table 34).

Dipping roots in a fungicide (benomyl) before packing in moist sawdust in boxes did not consistently improve root outturns. Similar outturns were obtained from boxes packed with moist sawdust when these were stored in the open, covered with a waterproof tarpaulin; or in the shade, in a simply constructed, bamboo-sided, thatched-roof shed.

Quality of stored roots

A joint trial was undertaken with the Instituto de Investigaciones Tecnológicas, Bogotá to investigate biochemical and biophysical changes during the storage of cassava roots in field clamps and storage boxes and to examine the effect these changes had on the acceptability of the roots for human consumption as a fresh vegetable. (Financial assistance for this project was received from the Programa de Desarrollo y Diversificación

Table 33. Effect of moisture content of packing material on root outturn from storage boxes.*

Treatment	Total weight loss (%)		Deterioration index (%)		Perfect roots (%)		Acceptable roots (%)		
	2	4	2	4	2	4	2	4	Weeks in storage
Control	20	32	65	73	23	21	29	26	
Dry sawdust (15 - 25%)	18	27	69	64	21	30	24	33	
Moist sawdust (50%)	4	11	25	23	63	60	79	79	
Wet sawdust (75 -- 85%)	+1	2	30	40	55	52	66	56	

* Mean results of three boxes, each containing an initial weight of 16 kilograms of cassava roots

Table 34. Effect of packing material on root outturn from storage boxes.*

Treatment	Total weight loss (%)		Deterioration index (%)		Perfect roots (%)		Acceptable roots (%)		
	2	4	2	4	2	4	2	4	Weeks in storage
Control	16	34	68	70	22	24	26	28	
Rice husks (moist)	5	26	55	77	37	17	43	22	
Sawdust (moist)	2	9	22	25	67	60	75	75	

* Mean result of three boxes, each containing an initial weight of 16 kilograms of cassava roots.

de Zonas Cafeteras, Federación Nacional de Cafeteros de Colombia.)

During storage in both field clamps and storage boxes, a considerable increase in the percentage of both total and reducing sugars and also a softening of the root tissues as indicated by "Instron" penetrometer studies were recorded. The magnitude of these changes was greater in the roots stored in field clamps than in those stored in boxes. In both cases, the bulk of the changes appear to occur during the early storage period, after which little further change appears to occur.

These changes resulted in a lowering of the quality of stored roots as compared with freshly harvested ones when consumed as a fresh vegetable; but throughout the eight-week duration of the trial, stored roots remained of acceptable quality. Roots stored in boxes were generally of a higher quality than those stored in field clamps.

ECONOMICS

Cassava production process in Colombia

This field survey project was described in the 1973 Annual Report along with some preliminary findings.* As of October 1, 1974, all sample farms (total 305) had been visited once; and 80 and 53 per cent had been visited two and three times, respectively.

These farms are located in five areas of Colombia and are identified in this study by zones: I, Cauca; II, Valle and Quindío; III, Tolima; IV, Meta, and V, Magdalena and Atlántico. At the end of the year, a higher percentage of farms had been visited for the third time in Zones I, II and V than in Zones III and IV. Hence, except for the data obtained during the first visit, the results are preliminary and subject to change as more farms are visited. The first visits refer to crops less than four months of age, while the second and third visits refer to crop ages of 4 to 8 and 8 to 12 months, respectively.

The altitude of the sample farms varies from more than 1,000 meters in Zones I and II to almost sea level in Zone V (Table 35). The farms are relatively large when measured in terms of total area. However, a large portion of the land is idle or in pasture; hence the cultivated area per farm is small. Although a few of the farms had large cassava plantations, the average cassava area per farm was estimated at about 5 hectares. Meta (Zone IV) shows the largest cassava area per farm. On the average, the farms visited had two lots planted with cassava.

The importance of other crops on the sample farms varied with location. Coffee and plantain, in most cases intercropped, were the most important crops in Zones I, II and III. Furthermore, sugar cane, maize and banana were of some importance in certain zones.

* The objectives and general description of a similar project carried out on beans are discussed on page 140.

Table 35. Altitude and land use on sample farms in cassava production survey.

	Zone I	II	III	IV	V	Average
Altitude of farm (m)	1,254	1,187	886	396	33	761
Total farm size (ha)	7.2	37.5	16.5	61.3	18.0	25.9
Area in crops (ha)	3.5	18.3	4.7	10.9	8.4	9.9
Area in cassava (ha)	2.9	6.4	2.0	9.4	5.3	5.2
Area in pasture and unused land (ha)	3.7	19.2	11.8	50.4	9.6	16.0
Number of cassava lots/farm	2.16	1.91	2.16	1.98	1.59	1.96
Size of cassava lot observed (ha)	1.30	3.35	0.90	3.37	2.16	2.22
Crops other than cassava on farms						
Coffee (% of farms)	32.4	61.4	31.6	10.0	0.0	28.7
Plantain (% of farms)	18.9	54.5	5.3	10.0	4.5	22.0
Maize (% of farms)	2.7	11.4	15.8	15.0	4.5	8.5
Sugar cane (% of farms)	5.4	0.0	26.3	0.0	0.0	4.3
Bananas (% of farms)	2.7	0.0	0.0	0.0	6.8	2.4
Other crops (% of farms)	0.0	9.1	5.3	10.0	18.2	9.1
Crop prior to cassava on lot observed						
Cassava (% of farms)	31.0	40.0	21.0	21.0	41.0	30.0
Maize (% of farms)	0.0	18.0	0.0	5.0	2.0	5.0
Other crops (% of farms)	0.0	23.0	0.0	4.0	12.0	10.0
Pasture or idle land (% of farms)	69.0	19.0	79.0	70.0	45.0	55.0

More than half of the sample farms planted cassava on land previously idle or in pasture. This is particularly pronounced in Cauca, Tolima and Meta. About one third of the farms planted two or more cassava crops sequentially on the same land. On the basis of these findings, it appears that cassava is frequently used as a frontier crop to bring new land into cultivation. Furthermore, except in Valle and Quindío, cassava does not seem to play an important role in continuous crop rotation.

Table 36 shows the most predominant cropping systems among the sample farms, the lot size, and plant population for each of these systems. A total of 14 crop combinations were identified at the first visit. More than half of the farmers grew cassava alone, and about one fourth grew cassava intercropped with maize. About 69 per cent of the area was planted with cassava alone. Although lot size varied greatly with cropping systems, additional data analysis is needed to determine the possible relationship between these two variables.

The plant population of cassava was found to be similar whether grown alone or intercropped with one other crop. However, when grown with two or more crops, the cassava plant population tended to diminish. A comparative economic analysis of various cropping systems for cassava has been ini-

Table 36. Cropping systems, lot sizes and plant population on farms in cassava production survey.

Cropping system	Percent of farms	Lot size (ha)	Percent of area	Plant population (plants/ha) Cassava	2nd crop	3rd crop
Cassava alone	60.0	2.5	69.3	9,811	---	---
Cassava -- Maize	24.5	1.4	15.8	9,421	5,578 *	---
Cassava -- Plantain	4.1	3.6	6.8	12,172	574	---
Cassava -- Beans	3.4	2.7	4.2	9,455	2,127	---
Cassava -- Maize -- Beans	2.2	0.6	0.6	8,988	5,113	7,813
Cassava -- Maize -- Plantain	1.3	2.0	1.2	7,617	3,583	833
Cassava -- Maize -- Sesame	1.0	0.6	0.3	7,333	4,133	4,283
Cassava with other crops	2.3	1.7	1.8	7,386	---	--

tiated to provide more information on this issue, including the factors determining the farmer's choice of system.

The incidence of insects, insect damage and diseases in cassava was estimated on the basis of direct field observations. The final results from the first visit, and preliminary results from the second and third visits are shown in Tables 37, 38, 39 and 40.

Thrips was the insect most frequently found, followed by gall midge and whitefly (Bemisia sp.) (Table 37). It appears that the occurrence of these insects and resulting visible damage are less frequent in crops more than eight months old. One explanation of this situation is that the crop in many cases outgrows the visual damage from the initial attacks. However, data are not yet available to determine whether in fact the attacks had any significant impact on yields.

While the occurrence of most insects and their visible damage seem to diminish as the plant grows older, the opposite seems to occur for some insects including whiteflies and mites.

The occurrence of each of the major insects varies considerably among zones (Table 38). For example, fruit fly (on stems), was found on 76 per cent of the farms in Zone II, while it was of little importance in the other zones. Leafhopper was important only in Zone V. Whiteflies (Bemisia sp.) were found on 70 per cent of the farms in Cauca, Magdalena and Atlántico (Zones I and V), while they were much less important in the other three zones.

The visible damage caused by diseases in cassava was most pronounced in crops between four and eight months of age. The diseases most frequently found were white leaf spot, phoma leaf spot, brown leaf spot, powdery mildew and cercospora leaf blight (Table 39). As in the case of insects, it appears that the cassava plant in some cases is capable of outgrowing the disease symptoms. However, the proportion of the lot affected increases with the age of the crop for most diseases. One possible conclusion might be that while lighter attacks tend to be overcome by plant growth, the somewhat more serious attacks continue to spread in the field. The relationship between rainfall conditions and diseases spread will be analyzed as more data are collected.

As in the case of insects, the occurrence of cassava diseases varies greatly among zones. Phoma leaf spot, the disease most frequently found during the second visit (in plantations four to eight months old), was found on about 70 per cent of the farms in Cauca, Valle and Quindío and only on 30 to 40 per cent of the farms in the other three zones. Superelongation, while of little or no

Table 37. Preliminary data on insect incidence on cassava in sample farms in production survey.

Insect	First visit * % of farms	% of lot	Intensity ****	Second visit ** % of farms	% of lot	Intensity ****	Third visit *** % of farms	% of lot	Intensity ****
Thrips	80.0	80.9	2	84.0	41.6	2	46.0	41.6	2
Gall midge	51.0	22.1	2	54.0	15.6	1	21.0	17.9	1
Whitefly (Bemisia sp.)	44.2	26.6	2	41.0	37.1	2	21.0	15.3	2
Shoot fly	16.7	25.0	3	16.0	15.9	2	1.0	10.0	1
Leaf cutter ants	14.4	35.2	4	12.0	14.2	2	10.0	25.3	1
Leafhoppers	12.8	15.9	2	4.0	15.6	2	0.0	--	
Fruit fly (in stems)	12.0	26.4	2	24.0	37.3	2	9.0	36.6	)
Hornworm	7.2	18.4	2	2.4	20.8	2	2.0	11.7	1
Whitefly	5.6	12.1	2	16.0	22.7	1	19.0	44.6	2
Chrysome lids	4.2	11.9	1	4.0	14.6	2	0.0	–	–
Tingids	3.6	22.7	2	8.0	18.8	2	4.0	15.7	1
Mites	2.0	3.5	2	25.0	41.0	2	27.0	60.0	3
Termites	1.0	36.7	2	0.0	–	.	2.0	27.5	1
Ants	0.6	10.0	2	2.0	14.0	1	0.0	–	–
Cutworms	0.6	45.0	1	0.0		-	0.0	–	–
Stemborers (lepidopterous)	0.3	15.0	1	0.4	30.0	2	0.0		-
Scale insects	0.0	–	–	0.0	--	.	1.0	35.0	2
Stemborers (coleopterous)	0.0	-	-	0.0			1.0	5.0	1

* 305 farms included
** 248 farms included
*** 162 farms included
**** Intensity of attack using scale of 1 - 4 with 1 being low and 4 high intensity

importance in four zones, was found on two thirds of the farms in Tolima. Likewise, the occurrence of cassava bacterial blight and white leaf spot differed greatly among zones.

It should be noted that the data from second and third visits are not complete and therefore subject to change.

During the first visits, 92 weeds were identified. Table 41 shows the most important ten weeds in terms of percentage of farms where they occurred. Pteridium candatum was found on one fourth of the sample farms, but the plant density was relatively low. It was most frequently found in Tolima (79 per cent of all farms) while it was not found in Magdalena and Atlántico (Zone IV).

Other agrobiological problems in cassava production assessed by the field team include

Table 38. Distribution of major insect occurrence among zones in cassava production survey. Second visit (percentage of farms).*

Insect	Zone I	II	III	IV	V
Thrips	61	89	100	100	83
Gall midge	25	46	68	68	85
Whitefly (Bemisia sp.)	70	10	24	26	71
Shoot fly	8	32	5	38	0
Leaf cutter ants	20	6	32	21	2
Leafhoppers	2	2	0	0	15
Fruit fly (in stems)	7	76	3	6	8
Hornworm	0	2	0	0	10
Whitefly	46	5	16	0	4
Chrysome lids	5	6	0	0	6
Tingids	15	3	13	12	0
Mites	7	8	38	15	44

* Preliminary data from 248 farms

scarcity or excess of water. It appears that excess of water was a severe problem, particularly in Valle and Quindío; while water scarcity appeared to reduce yields in Magdalena and Atlántico. The percentage of farms and areas within farms affected by scarcity or excess of water were estimated but excluded here. As in the case of insects and diseases, the yield impacts will be estimated when the data collection has been completed.

The data on cultural practices and input use are only complete for land preparation and planting. The majority of the cassava producers in Zones II, IV and V used mechanized land preparation, whereas manual land preparation was predominant in Zones I and III. No machinery was used for planting. About 87 per cent of the farmers planted one stake in each place while the rest planted two together. The planting of two stakes together is most common in Meta (35 per cent of the farmers), whereas no farmer in Magdalena and Atlántico was found to use this practice.

Table 39. Preliminary data on disease incidence in cassava in production survey.

Disease	First visit * % of farms	% of lot	Intensity ****	Second visit ** % of farms	% of lot	Intensity ****	Third visit *** % of farms	% of lot	Intensity ****
Brown leaf spot	34.4	22.3	2	53.6	32.9	2	34.6	36.0	2
White leaf spot	28.2	33.1	2	58.5	40.8	2	35.8	53.7	2
Powder mildew	19.0	39.7	2	43.1	42.3	2	20.4	56.8	2
Cercospora leaf blight	15.1	16.8	2	23.0	25.6	1	6.8	39.5	1
Phoma leaf spot	15.0	19.9	2	54.4	32.7	2	43.2	35.8	2
Superelongation	5.9	22.5	3	11.7	44.5	4	1.2	47.5	2
Cassava bacterial blight	4.6	26.7	2	12.9	38.3	3	9.3	44.7	3
Root rotting	1.3	42.5	3	1.2	15.0	3	0.0		
Leaf smut	0.3	10.0	1	2.4	42.3	3	1.9	26.7	1
Frog skin root disease	0.0	..		0.0			3.7	–	–

* 305 farms included
** 248 farms included
*** 162 farms included
**** Intensity of attack using a scale of 1–4 with 1 being low and 4 high intensity

Table 40. Distribution of major disease incidence among zones in cassava production survey. Second visit (percentage of farms).*

Disease	Zone I	II	III	IV	V
Brown leaf spot	28	32	79	68	83
White leaf spot	71	95	28	9	54
Powder mildew	43	57	84	15	10
Cercospora leaf blight	39	8	40	18	14
Phoma leaf spot	72	71	34	32	42
Superelongation	2	0	66	9	0
Cassava bacterial blight	2	0	11	24	37
Root rotting	2	3	0	0	0

* Preliminary data from 248 farms

The source of stakes traditionally used by the farmer may be an important variable in determining the best distribution system for improved planting material. Slightly more than half the farmers used stakes from their own harvest, 25 per cent obtained them free from friends and neighbors, and 20 per cent purchased them. The variation among zones was not pronounced except for Tolima, where two thirds of the farmers produced their own stakes, one third obtained them free, and no farmer purchased them.

The aforementioned data are preliminary. The data collection extends over a two-year period to cover two complete growing seasons, and most of the data analysis cannot be performed until a complete data set is obtained.

Once the data collection has been completed, attempts will be made in collaboration with the scientists in cassava entomology to estimate pathology and weed control and the relative economic loss associated with each of the major insects, diseases and weeds.

Table 41. The ten most important weeds in cassava in terms of proportion of sample farms where they occurred.*

Weed	Farms (%)	Weed density (plants/ha)
Pteridium caudatum	24	78,000
Sida acuta	18	90,000
Commelina difusa	17	136,000
Bidenas pilosa	16	102,000
Melinis minutiflora	14	134,000
Portulaca oleracea	12	168,000
Cyperus ferax	10	148,000
Rychardia scabra	10	84,000
Cyperus rotundus	10	188,000
Drymaria cordata	9	234,000

* First visit

Bean production systems

Initial program results and information from the 1973 seminar helped to define these program research priorities in 1974:

1. Yield increase was identified as the single major program objective, with studies on protein content and amino acid balance to be limited initially to a screening of promising varieties and crosses. This would ensure that existing protein levels would not deteriorate during breeding.

2. Four sites (Palmira, Montería and Popayán in Colombia, and Boliche in Ecuador) were selected for concentrated research (See CIAT 1973 Annual Report). As beans are at a competitive disadvantage with both cowpeas and peanuts in the Llanos Orientales, no further studies were undertaken at that location.

3. Work was restricted to *Phaseolus vulgaris* and to species crossing with it. No further work was or will be done on cowpeas or soybeans.

4. Fertilizer and chemical shortages, as well as international trade imbalances, have increased the price of many farm inputs for both large and small farmers. To counter this, the program has stressed technology which would insulate farmers against changing economic and supply problems.

Highlights of the bean research program during 1974 were:

- Yields of close to 3,000 kg/ha were obtained in replicated yield trials at CIAT and Popayán.

- Disease-free seed was made available to a number of national programs. Using such materials, farmers in one area of Guatemala raised average yields from 515 to 1545 kg/ha.

- Varieties resistant to *Empoasca* and to plant pathogens, such as common mosaic virus, web blight, rust and bacterial blight, were identified.

- As initial characterization of the germplasm bank was well under way, a crossing program was initiated with the most promising selections.

- Studies comparing conventional maize-bean associations with climbing beans grown on stakes or trellises showed that the latter system had a considerable yield advantage.

- Two workshops were held on rust-resistance nurseries and on program evaluation.

BREEDING

Germplasm evaluation

The CIAT bean germplasm bank currently contains 10,371 accessions of *Ph. vulgaris* and 155 of related *Phaseolus* species.

The evaluation of new bean introductions continued throughout 1974 with 1,572 accessions grown at Turipaná, Colombia and 1,098 at Boliche, Ecuador. From these sowings, 66 introductions with promising characteristics were selected. At Palmira, 96 lines were reevaluated to analyze promising characteristics which had been previously identified. The objective was to identify bean materials with high yield potential and a wide range of adaptation. Lines selected at Turipaná will be used in developing materials for the hot lowland tropics.

The characteristics of 544 accessions identified as promising during germplasm evaluation are given in Table 1.

Selection was based primarily on yield potential, or pod number per plant; but other specific attributes were included. These groups of bean selections are also being studied by other disciplines of the program.

Environmental effects

Growing habit

To study further the influence of environment on the growing habit of beans, 721 introductions were compared in plantings at Palmira and Turipaná. Similarly, 370 materials were compared between the Palmira and Boliche localities. The determinate growing habit is not modified by the environment (Tables 2 and 3). However, almost all beans with indeterminate growing habits changed under warmer weather and higher relative humidity conditions, with a tendency towards a more elongated vine type.

Three bean introductions (P212-A, P337-A and 73 VUL 3164), which represented only 2.3 per cent of the total studied, did not show modifications in their IB habit (Table 2). No variation in growth habit was observed in these varieties through four planting dates at Palmira.

Changes in growing habits tending towards the climbing type (IVF) occur at a higher frequency when the biotypes themselves have longer vines.

Formation of genetic bean populations

With the evaluation of a high number of bean collections almost completed, a hybridization program was started in mid-1974. The main objective was to use traditional, multiple crossbreeding methods to build bean populations with a high yield potential but with variation in grain characteristics.

Five bean composites will be developed (Table 4), using the ten progenitors whose characteristics are shown in Table 5. Three composites were black seeded; however, segregation in color characteristics in the other two composites is expected. The sequence by which these composite populations will be developed is shown in Table 6.

Table 1. Bean lines (*Phaseolus vulgaris*) selected on the basis of different characteristics at three ecologic zones (August, 1972 – August, 1974).

Selection characteristics	Ecologic zones under evaluation *			
	Palmira (Semihumid subtropics)	Turipaná (Semihumid tropics)	Boliche (Dry tropics)	Total
Yield potential (pods/plant)	120	91	79	290
Plant structure	66	4	0	70
Pods per raceme	35	1	16	52
Seeds per pod	12	1	24	37
Plant erectness	30	3	1	34
First node height	20	0	1	21
Hypocotyl thickness	13	4	2	19
Seed size	13	0	2	15
Vertical leaf position	4	0	0	4
Short peduncle	1	0	1	2

* Palmira and Turipaná, Colombia; Boliche, Ecuador

Table 2. Effect of the environment on the growing habit of 721 bean introductions (*Phaseolus vulgaris*) at Palmira and Turipaná (1974).

Palmira		Turipaná		
No. of introductions	Growing habit	No. of introductions	Growing habit	Change in growing habit (%)
164	IA determinate	164	IA	0.0
129	IB indeterminate short vine	3	IB	0.0
		39	IIC	30.2
		62	IIIE	48.1
		25	IVF	19.4
120	IIC indeterminate medium vine	0	IIC	—
		57	IIIE	47.5
		63	IVF	52.5
168	IIIE indeterminate long nonclimbing vine	46	IIIE	0.0
		122	IVF	72.6
140	IVF indeterminate long climbing vine	140	IVF	0.0

Table 3. Effect of the environment on the growing habit of 370 bean introductions (*Phaseolus vulgaris*) at Palmira and Boliche (1973).

Palmira		Boliche		
No. of introductions	Growing habit	No. of introductions	Growing habit	Change in growing habit (%)
42	IA determinate	42	IA	0.0
66	IB indeterminate short vine	0	IB	—
		7	IIC	10.6
		14	IIIE	21.3
		45	IVF	68.1
73	IIC indeterminate medium vine	0	IIC	—
		20	IIIE	27.4
		53	IVF	72.6
82	IIIE indeterminate long nonclimbing vine	0	IIIE	---
		82	IVF	100.0
107	IVF indeterminate long climbing vine	107	IVF	0.0

Table 4. Formation of five bean composites (*Phaseolus vulgaris*) from various progenitors to derive genetic populations, Palmira (1974).

Composite No.	Progenitors	Color	Characteristics of the lines
1	P5-I	Black	Yield potential and ample ecological adaptation
	P6-C	Black	
	P459-C	Black	
2	P568-A	Black	Resistance to *Uromyces*
	P566-A	Black	Yield potential and ample ecological adaptation
	P488-B	Black	Resistance to golden mosaic
	P459-C	Black	Tolerance to *Xanthomonas*; resistance to common mosaic virus; yield potential and ample ecological adaptation
3	P5-I	Black	Yield potential and ample ecological adaptation
	P459-C	Black	
	P566-A	Black	
4	P459-C	Black	Tolerance to *Xanthomonas*; resistance to common mosaic virus
	P568-A	Black	Resistance to *Uromyces*
	P8-C	Pink	Resistance to *Isariopsis*
	P567-A	White	Tolerance to *Xanthomonas*
5	P4-A	Red	Tolerance to *Xanthomonas*
	P459-C	Black	Tolerance to *Xanthomonas*; resistance to common mosaic virus
	P566-A	Black	Yield potential and ample ecological adaptation
	P569-A	Cream & Red	Resistance to *Uromyces*

In the initial crossing to develop the 24 F_1 single crosses, a total of 2,362 crosses was used with an overall pollinization efficiency of 31.5 per cent. Although this efficiency had increased to 55.5 per cent by the end of the crossing period, other techniques will be studied to obtain even higher values.

Other breeding projects

Relation between yield and yield components

The yield components of 66 bean selections planted in single rows of 50-meter lengths were studied at Palmira during the rainy season. The mean production per plant was determined for each row; the yield components were obtained by taking an average of five plants selected at random (Table 7). With this data, simple correlations, as well as partial correlations (keeping one or more yield components constant), were calculated.

Production per plant, racemes per plant, pods per raceme, pods per plant, and grains per pod presented a negative correlation with seed size in all cases. As would be expected, yield per plant depended on the number of pods present and also on the number of grains per pod. The highest correlation was between pods per plant and racemes per plant. A differential compensation with other components of yield was also observed (Table 7).

Natural cross-pollination

The experiment to determine the percentage of natural cross-pollination obtained at CIAT was concluded. Two groups of contrasting varieties (Guali-Tui or Guali-Jamapa) varying in hypocotyl color were

Table 5. Characteristics of progenitors towards the formation of five composites of beans (*Phaseolus vulgaris*) and derivation of genetic populations with high yield potential and ample ranges of adaptation in the tropics at Palmira, (1974).

Code No.	Identification	Localities and seasons when these lines have been outstanding	Yield components			Seed color	Growing habit	Resistance
			Pods/plant	Grains/pod	Seed size (g)			
P4-A	PI 310 878	Palmira 70B* Turipaná 73A	70	3.5	25.2	Red	IIC-IIIE	Xanthomonas (tolerance)
P5-C	PI 307-824	Palmira 72A Palmira 72C Palmira 73C Turipaná 72B Turipaná 73A Turipaná 74A Boliche 73A	55	5.7	20.6	Black	IIC-IIIE	
P6-C	PI 310-739	Palmira 72A Palmira 72C Palmira 73A Palmira 73C Turipaná 72B Turipaná 73A Boliche 73A	72	5.6	21.3	Black	IIIE-IVF	Common mosaic virus; chlorotic mottle
P8-C	PI 310-814	Palmira 72A Turipaná 73A	74	4.0	24.3	Pink	IIC	Isariopsis
P459-C	Jamapa (Venezuela)	Palmira 73A Turipaná 73A Boliche 73A	76	5.5	17.4	Black	IIC	Common mosaic virus; Xanthomonas
P566-C	Porrillo sintético (Honduras)	Palmira 74A Popayán 74A	—	6.8	23.5	Black	IIC	
P567-A	Tara	—	—	—	23.0	White	IIIE	Xanthomonas (tolerance)
P568-A	PR-5	—	—	—	15.0	Black	IIC	Uromyces
P488-B	Porrillo 70	—	—	—	20.2	Black	IIC	Golden mosaic
P569-A	Cacahuate 72	—	—	—	36.8	Cream & Red	IA	Uromyces

* A = planting date starting March-April (rainy season); B = planting date starting August-September (rainy season); C = planting date starting November-December (dry season)

Table 6. Planning of different stages for the development of genetic populations of beans (*Phaseolus vulgaris*) from five main composites for tropical areas, Palmira (1974).

Stages	Plants	Seeds	Estimated time
I	10 P crossings (Screenhouse)	(24 F_1) A_1, A_2 . . . Single crosses	July, 74 January, 75
II	24 F_1 crossings (Screenhouse)	(51 F_2) B_1, B_2 . . . Double crosses	January July, 75
III	51 F_2 populations (Field) 15 F_2 populations (with genotypes from all their progenitors): (B_1, B_2, B_3), (B_7, B_{10}, B_{15}), (B_{19}, B_{20}, B_{21}), (B_{26}, B_{28}, B_{32}), (B_{40}, B_{43}, B_{48})	(51 F_3)	August November, 75 Individual selections
IV	51 F_3 populations (Field)	F_4	November, 75 March, 76 Individual selections Yield trials in Colombia Entomology and pathology screening Outreach yield trials
V	F_4 populations	F_5	March July, 76 Individual selections Yield trials in Colombia Entomology and pathology screening Outreach yield trials
VI	F_5 populations (Field)	F_6	July - November, 76 Individual selections Yield trials in Colombia Entomology and pathology screening Outreach yield trials
VII	F_6 populations	F_7	November, 76 March, 77 Yield trials in Colombia Entomology and pathology screening Outreach yield trials
VIII		F_7	July, 77 To bean national programs

used. Guali has the homocygous recessive gene giving green hypocotyl, as compared with the purple hypocotyl in Tui and Jamapa varieties.

The Tui and Jamapa varieties were planted 10 and 15 days earlier than Guali to overlap blooming periods. At harvest, individual pods of Guali were obtained and seeds stored

Table 7. Partial correlations as well as simple correlations between "production per plant" and yield components on beans (Phaseolus vulgaris) at Palmira (1973).

Partial correlations		Constant yield component	Coefficients (1)
Pods per plant			.92
versus			.98
racemes per plant		Pods/raceme	.92
		Grains/pod	.91
		Seed size	
Production per plant			.54
versus			−.31 (*)
racemes per plant		Pods/plant	.56
		Pods/raceme	.49
		Grains/pod	.49
		Seed size	
Production per plant			.40
versus			.19 (NS)
pods per raceme		Pods/plant	.45
		Racemes/plant	.29 (*)
		Grains/pod	.34
		Seed size	
Pods per plant			.40
versus			.92
pods per raceme		Racemes/plant	.29
		Grains/pod	.27
		Seed size	
Production per plant	versus	pods per plant	.68
Production per plant	versus	grains per pod	.41
Pods per plant	versus	grains per pod	.39
Pods per raceme	versus	grains per pod	.39
Racemes per plant	versus	grains per pod	.25
Racemes per plant	versus	pods per raceme	.05 (NS)
Production per plant	versus	seed size	−.26
Racemes per plant	versus	seed size	−.37
Pods per raceme	versus	seed size	−.38
Pods per plant	versus	seed size	−.46
Grains per pod	versus	seed size	−.54

1/ The nonmarked coefficients are highly significant.

in separate envelopes. Then all seeds from Gualf were planted, and the hypocotyl of these seedlings was examined for the presence of pigmentation. A purple hypocotyl would indicate that the seed was hybrid, the hypocotyl color being controlled by a single dominant gene.

From 45,065 Gualf seeds planted, 79.1 per cent germinated. Six seeds produced plants with purple hypocotyl, and all came from one pod in the 90-centimeter plant spacing plot. The percentage of natural cross-pollination was calculated to be approximately 0.02 per cent.

Studies of drought tolerance

During the 1973-1974 dry season, 500 bean accessions were screened for drought tolerance. Irrigation was used to promote seed germination; a further amount of 296 millimeters of water came from rainfall during the growing cycle.

From these, 20 bean accessions were selected on the basis of total seed weight, mean production per plant, pods per plant, racemes per plant and seeds per pod. They were also reclassified into four types of roots: thick tap root, thin tap root, secondary root system and fibrous root system.

A further study was begun at Lima, Peru, where close to zero rainfall is the common pattern. The Grain Legume Program at La Molina Research Station collaborated.

Both the "normal" and "dry" plots were irrigated before planting with the same amount of water, setting an initial soil moisture level from 70 to 75 per cent field capacity. The "normal" plots received three extra irrigations (22, 65 and 85 days after planting), maintaining the available soil moisture close to 70 per cent. The "dry" plots received only one extra irrigation 65 days after planting when the available moisture in the soil had reached a value of 23 per cent. The bean plants at this time were blooming and fruiting under a water stress period of approximately 20 days. The complete growing cycle was 136 days.

Results are shown in Table 8, along with the root lengths of each line. The highest yield in the plots under water stress was obtained by the line 72 VUL 26,616, the root system of which is shown in Figure 1. Six lines had an index of efficiency for drought tolerance from 50 to 53 per cent. The most efficient bean lines tended to have a primary long-root system along with well-developed secondary roots.

PLANT PATHOLOGY

The program continued to work on screening for resistance, crop losses from diseases, chemical control, identification and

Table 8. Field evaluation of bean lines (Phaseolus vulgaris) for drought tolerance. Comparative root length and yield in "normal" and "dry" plot treatments at Lima (1974).

Bean lines	Root length (cm)		Yield (tons/ha)		Drought tolerance index *
	Normal	Dry	Normal	Dry	
72 VUL 26,616	12.1	15.4	2.04	2.21	52
73 VUL 3,084	14.6	16.5	2.16	1.94	47
73 VUL 3,075	11.2	17.5	1.84	1.92	51
73 VUL 1,962	12.8	17.7	1.75	1.79	50
72 VUL 26,155	12.3	15.0	1.70	1.73	50
73 VUL 3,146	13.2	14.7	2.21	1.13	33
72 VUL 26,604	11.9	15.0	1.89	1.10	36
73 VUL 3,043	11.1	12.6	1.59	1.23	43
72 VUL 25,260	12.3	15.9	1.46	1.27	46
72 VUL 20,514	13.9	15.7	1.24	1.44	53
73 VUL 349	13.1	14.7	1.51	1.05	41
72 VUL 20,478	10.0	12.0	1.71	0.84	32
72 VUL 25,212	13.0	16.0	1.31	1.19	47
73 VUL 2,277	11.7	13.3	1.40	1.03	42
72 VUL 20,630	11.1	13.4	1.31	1.11	45
73 VUL 2,056	8.9	9.7	1.04	0.88	45
72 VUL 26,676	7.4	12.5	0.92	0.81	46
72 VUL 24,176	10.6	10.0	0.85	0.79	48
73 VUL 562	8.8	11.8	0.89	0.66	42
73 VUL 2,034	9.9	10.6	0.53	0.56	51

* Efficiency of drought tolerance, as expressed by the formula:

$$\text{Index} = \frac{\text{yield in the dry plot}}{\text{yield in the dry plot + yield in the normal plot}}$$

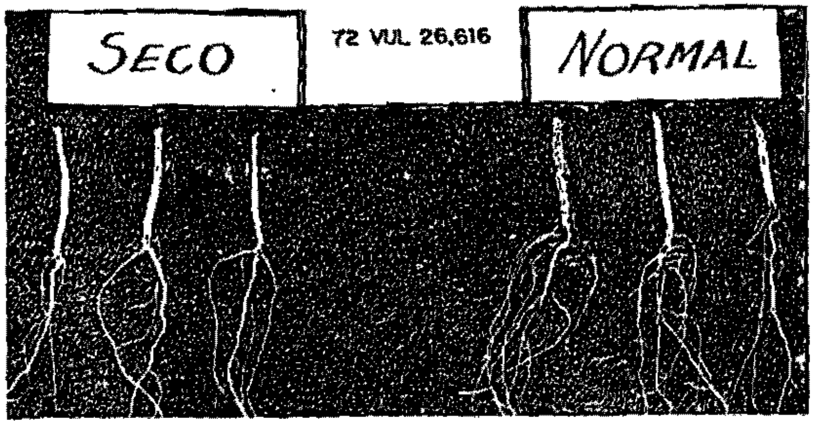


Figure 1. A promising line of beans, Phaseolus vulgaris (72 VUL 26,616), for drought tolerance. Root sections coming from a normal plot (right) and another plot under water stress (left).

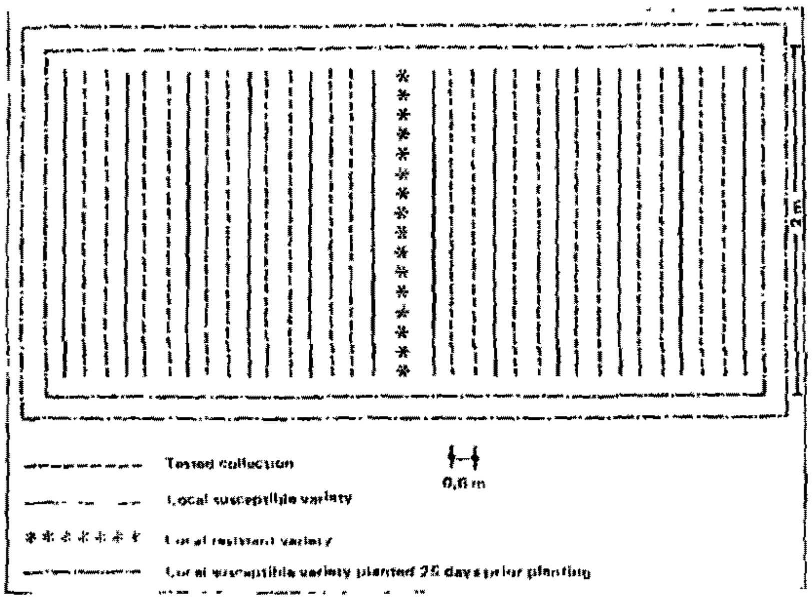


Figure 2. Pattern of planting for evaluation of resistance to bean rusts.

Table 9. Collections of beans tolerant to common bacterial blight (Xanthomonas phaseoli).

Name or pedigree		Reaction *
MSU	31,112-1	2
	31,128	2
	31,132-2	2
	32,349	2
	32,030	2
	32,033	2
	31,159-2	3
	31,169-2	3
	32,055	3
	32,060	3
	32,001	3
	32,019	3
	32,049	3
	4	2
	27	2
	94	2
	98	2
	206	2
	215	2
CIAT –	73 VUL 5,174-1-T-1	2
	72 VUL 20,665-M	3
	72 VUL 20,667-1	3
	72 VUL 24,010-1	2
	72 VUL 25,153-1	2
	Jamapa (Venezuela)	3
	72 VUL 24,454-1	2
	72 VUL 24,147-1	2
	73 VUL 3,233	2
	73 VUL 6,565-1-T-T	3
	73 VUL 4,683-1	3
	72 VUL 26,155 (Costa Rica)	3
	73 VUL 3,084 (Costa Rica)	3
	Nima	2
	Calima	2
	Tara	2
	Jules	2
	P I 207-262	2
	G.N. No. 1, sel 27	2
	Seafarer, a susceptible check	5
	Cowpea (Vigna sinensis)	1

* Rating: 1 No visible symptoms
2 Light infection
3 Moderate infection
4 Severe infection
5 Highly severe infection

characterization of bean viruses, and production of disease-free seed. A major effort sought to establish cooperative international nurseries testing varieties for broad spectrum resistance to the major, limiting bean diseases.

Resistance to common bacterial blights

A total of 330 CIAT collections and 243 from Michigan State University were screened in the field for resistance to **Xanthomonas phaseoli** and **X. phaseoli** var. **fuscans**. The screening pattern was similar to that for rust (Fig. 2). Plants were inoculated 30 and 45 days after planting with a bacterial suspension containing 2 x 10^8 cells/ml. Disease readings were taken 12 to 15 days after the inoculation; 68 accessions were tolerant and 91 moderately tolerant to the bacteria. The most tolerant lines are shown in Table 9.

A collection of 123 **Xanthomonas phaseoli**, **X. phaseoli** var. **fuscans** and **X. vignicola** cultures have been collected and lyophilized. Sources include the University of Nebraska (13), USDA, Puerto Rico (60), Michigan State University (12), Guatemala (1) and Colombia (37). Strains will be provided to those interested in screening or for studies involving these bacteria.

Rust

Resistance to rust

A method of screening was developed to test bean accessions against the fungus **Uromyces phaseoli** var. **typica** (See Fig. 2). Two rows of a highly susceptible variety were planted around the plot 25 days prior to planting the materials under test. Two tested lines or varieties were planted between susceptible checks; and every ten rows of tested lines, a local resistant variety was included. The spreader rows were inoculated by spraying a suspension containing 20,000 uredospores/ml plus 0.2 ml/liter Tween 20. The uredospores were collected locally in bean fields. The rows were 2 meters in length and 0.60 meters apart (Fig. 2). The readings were made at the beginning of flowering, and a 0 to 5 scale was used. From 346 tested, 28 lines were found resistant under CIAT conditions (Table 10).

Table 10. Varieties or collections resistant to bean rust.

Variety	Reaction
Ecuador 299	R
Mexico 309	R
Guatemala 487	R
Turrialba 4	R
Ian 5091	R
Trigo E	R
73 VUL 3,215 (PI 313-694)	R
73 VUL 3,231 (Puebla 87)	R
73 VUL 3,241 (Chiapas 2 A 3)	R
73 VUL 3,242 (Chiapas 3-A)	R
73 VUL 3,248 (Hidalgo 20)	R
73 VUL 3,285 (S-387 A-H)	R
73 VUL 3,287 (S-166-A H)	R
PR-5	R
PR-12	R
PR-15	R
PR-17	R
PR-18	R
PR-19	R
PR-20	R
73 VUL 5,506-1 (Frijol Chapin)	R
Compuesto Chimaltenango 2	R
Compuesto Chimaltenango 3	R
Rico Pardo 896	R
Ipala 72	R
73 VUL 150-1-1 (51,051)	R
73 VUL 5,375 (Line CH-11-198-6-C-3-C)	R
73 VUL 3,690 (Guatemala 209)	R

These resistant lines, together with 80 other collections suggested by scientists attending the Bean Rust Workshop, have been incorporated in an International Uniform Bean Rust Nursery, which aims to obtain broad spectrum resistant varieties. (See page 120).

Losses resulting from rust

ICA-Tui and ICA-Pijao were used as susceptible and resistant varieties, respectively, in studies of losses associated with rust.

The yield of the susceptible variety Tui was reduced 43 per cent when the infection

occurred in the first or second week after emergence and 31, 5, 5, 10 and 2 per cent after 3, 4, 5, 6 and 7 weeks, as compared with the tolerant Pijao, which was reduced 25, 19 and 18, 20, 12, 6 and 4 per cent, respectively. The losses after the fifth week were not significant.

The results suggest that early infections affect the young shoots, reducing total foliar area at flowering and pod formation. Infections initiated at flowering do not interfere with pod formation and grain filling, as it takes 12 to 15 days for the full development of the disease.

Web blight

Resistance

Web blight (mustia hilachosa), caused by **Thanatephorus cucumeris**, is a major factor limiting bean production in the lowland tropics, where high relative humidity and high temperature favor the development of the fungus. Most of the CIAT collections planted at Montería have collapsed following fungus attack. Of 2,952 selections screened, only one [73 VUL 7,189 (blanco)] has shown some resistance, and 17 have shown some tolerance.

Chemical control

Gualí (susceptible) and Tui (moderately tolerant) were used to test 19 fungicides for the control of web blight. Even under fungicide protection, the yield in Gualí was practically nil. An increase in yield of 370 per cent was obtained in Tui, using the systemic fungicides Benlate (0.15 kg/ha), NF-44 (0.5 kg/ha), Derosal 60 (1 kg/ha), and the preventive fungicide Brestan 60 (0.8 kg/ha).

Root rots

Screening for resistance to the root rot complex (**Pythium** sp., **Rhizoctonia** sp **Fusarium** spp., **Sclerotium rolfsii**) was continued. Among 74 collections tested, 73 VUL 3274 (Venezuela 40), 73 VUL 3650 (P I 313-737), 73 VUL 6525-1-T-T (P I 313-748), Compuesto Chimaltenango 3 Cuilapa 72, and Zamorano 2 were moderately resistant.

Viral diseases

Common bean mosaic virus

Seed transmission. Transmission of the virus through the seed was studied according to time of infection for the black-seeded, tolerant variety Tui and for the red-seeded, susceptible Gualí. From plants infected a week after germination, a transmission of 23 per cent was determined as compared with 52, 45, 32, 12, 20 and 17 per cent transmission from plants infected 2, 3, 4, 5, 6 and 7 weeks after germination, respectively, for Tui; and 86, 47, 42, 35, 16, 7 and 5 per cent, respectively, for Gualí.

Resistance to CBMV. Because the virus is highly transmissible through the seed and the vector is widely distributed in Latin America, control of the disease by resistant varieties is desirable. In this case, the source of resistance has to be either an immune or a hypersusceptible variety. Of 1,950 collections screened, only three (146-1-1, 165-M-1, and P I 146-800) have shown resistance to three strains of CBMV under greenhouse conditions. Top Crop and Pinto-UI-114, reported resistant in other countries, were found susceptible to one of the strains in Colombia.

Losses from CBMV. Economic losses resulting from this viral disease were determined in field trials by artificial inoculation of two red-seeded (Gualí and Duva) and two black-seeded varieties (Tui and Jamapa) at various times after germination. Yield reductions of 96, 58, 52, 51, 26, 18 and 8 per cent were determined for the two red varieties as compared with 39, 24, 17, 15, 14, 8 and 6 per cent for the two black tolerant varieties for the plots inoculated at 1, 2, 3, 4, 5, 6 and 7 weeks after germination, respectively (Fig. 3).

Root-knot nematode disease

Resistance

A screening method for **Meloidegyne incognita** was developed in collaboration with the Instituto Colombiano Agropecuario (ICA). Beds (20 x 1.20 meters) were prepared using a mixture sand:soil = 2:1. The beds were disinfected with methyl bromide, and

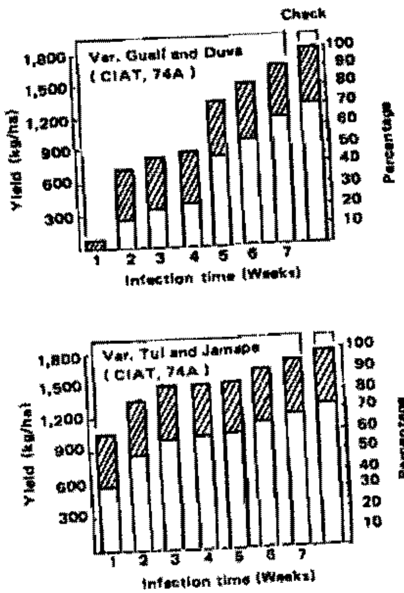


Figure 3. **Effect of common bean mosaic virus on bean yields.**

nematode populations were established by incorporation of diseased tissue and continuous plantings of susceptible beans and tomatoes. The evaluation was based on height, fresh weight of roots, the aerial part of the plant, knot-index, percentage of infection, number of pods and yield. Losses up to 94 per cent for the variety Calima, 90 per cent for Gualí and Duva, and 82 per cent for Huasanó were observed.

Preliminary screening of 20 collections showed four varieties relatively resistant to nematodes.

Production of seed free from pathogens

Cleaning seed of seed-borne pathogens continued as a priority project. A total of 1,115 varieties and collections were cleaned in the screenhouse and 525 were increased in the field. Clean-seeded materials permitted major yield increases in Guatemala (See page 151).

Preliminary experiments at CIAT have shown an 85 per cent increase in yield for varieties Gualí and Tui when disease-free and commercial seed were compared.

Artificial defoliation to estimate disease losses

Per cent versus time of defoliation

The 1973 bean defoliation experiments and their simulation of losses from leaf pathogens were continued.

Cuts were applied in several directions at four growth stages of plant development (when the plants have the first three trifoliate leaves, initiation of flowering, pod filling, and initiation of physiological maturity). The results (Table 11) comprise data from two harvests. The most critical stages are initiation of flowering and the pod-filling period, followed by the young stage. After 60 days–i.e., initiation of physiological maturity–defoliation has no effect on yield.

Artificial defoliation

Some foliar diseases are found mainly on the lower part of the plant. Partial defoliation of Gualí was affected leaf by leaf with removal of 30 and 60 per cent of the foliage either on the lower 50 per cent or on the upper 50 per cent of the plant.

The results confirmed last year's observations that loss of lower leaves, as compared with those of the canopy, had little effect on yield. At 20 days, a defoliation of 60 per cent of the higher leaves reduced yield 20 per cent. The same treatment at 40 days reduced yields by 26 per cent as compared with 6 and 10 per cent reduction, respectively, when the lower leaves were clipped.

Evaluation of fungicides

To evaluate fungicides, the varieties Gualí [resistant to rust, but susceptible to common bacterial blight, angular leaf spot, (**Isariopsis griseola**), and powdery mildew (**Erysiphe polygoni**)] and Tui (highly susceptible to rust) were used. During the second semester of 1973, angular leaf spot and rust were the main diseases in the CIAT fields; whereas in

Table 11. **Yields of Gualí in response to partial defoliation at different plant ages at CIAT, Palmira (1973B and 1974A).**

Stage growth of the plant	Per cent defoliation	Yield (kg/ha) 1973B	Yield (kg/ha) 1974A	Yield reduction (%) 1973B	Yield reduction (%) 1974A
First three trifoliate leaves	0	1,681	1,936	0	0
	10	1,541	1,793	8	7
	20	1,408	1,574	16	19
	40	1,408	1,488	16	23
	60	1,175	1,357	30	30
	80	1,175	1,195	30	38
	100	1,075	812	36	58
Initiation of flowering	0	1,700	1,886	0	0
	10	1,513	1,562	10	17
	20	1,462	1,533	14	19
	40	1,246	1,360	27	28
	60	1,175	1,238	31	34
	80	941	1,081	45	43
	100	834	745	51	61
Pod filling	0	1,700	1,907	0	0
	10	1,617	1,538	5	19
	20	1,471	1,462	14	23
	40	1,242	1,250	27	35
	60	1,121	1,095	34	43
	80	782	933	54	51
	100	458	383	73	80
Initiation of physiological maturity	0	1,652	1,893	0	0
	10	1,688	1,888	+2	0
	20	1,638	1,848	1	2
	40	1,608	1,824	3	4
	60	1,502	1,750	9	8
	80	1,442	1,625	13	14
	100	1,317	1,498	20	21

the first semester of 1974, rust was the main disease. In general, the second semester is more favorable for disease development in the Cauca Valley. Brestan 60, Daconil, Dithane M-45, Plant Vax and Derosal 60 gave the best protection (Table 12).

ENTOMOLOGY

Emphasis this year was again on screening for resistance to Empoasca kraemeri. Several sources were identified with higher tolerance levels than had been found before. The search was continued for resistance to spider mites and stored-grain pests, as well as insecticidal screening.

Empoasca kraemeri

Approximately 2,500 collections were tested for Empoasca resistance. Though high levels of resistance were not found, accessions varied from intermediate resistance to complete susceptibility. Five hundred collections were replanted to further eliminate susceptible material. The 50 most promising selections from this trial were studied in more detail with three replicates of each variety protected with pesticides and three replicates left unprotected. Yield increases resulting from protection against Empoasca were used as an indicator of resistance levels within varieties (Table 13).

Table 12. Effect of fungicides on rust control of the bean varieties Guali and Tui in two semesters at CIAT (1973B and 1974A).

Fungicides	Dosis (kg/ha)	Yield (kg/ha) 1973B	Yield (kg/ha) 1974A	Per cent increase over the check 1973B	Per cent increase over the check 1974A
Variety Guali					
Brestan 60	0.8	928	1,683	99	− 2
Daconil	1.5	931	1,722	99	0
Dithane M-45	3.0	836	1,771	79	3
Plant Vax	1.0	489	1,403	5	−18
Derosal 60 P.M.	1.0	814	1,498	74	−13
NF-44	0.5	807	1,662	73	− 3
Benlate	0.5	526	1,789	13	4
Piracarbolio	2.0	428	1,628	− 8	− 5
Tecto 60	0.5	618	1,656	32	− 4
Elosal	4.0	741	1,596	59	−19
Koccide 101	1.5	550	1,644	18	− 4
Agrimicin	200 ppm	516	1,850	10	8
Oil	1.5 gal	490	1,551	5	−10
Check		467	1,715	0	0
Variety Tui					
Brestan 60	0.8	1,227	1,391	81	27
Daconil	1.5	949	1,280	40	17
Dithane M-45	3.0	1,133	1,245	67	14
Plant Vax	1.0	945	1,354	39	24
Derosal 60 P.M.	1.0	897	1,041	32	− 5
NF-44	0.5	839	1,049	24	− 4
Benlate	0.5	813	1,170	20	7
Piracarbolio	2.0	772	1,189	14	9
Tecto 60	0.5	759	917	12	−16
Elosal	4.0	759	977	12	−11
Koccide 101	1.5	731	1,032	8	− 6
Agrimicin	200 ppm	659	931	− 3	−15
Oil	1.5 gal	592	1,030	−13	− 6
Check		679	1,093	0	0

The most resistant accessions were black seeded, including 73 VUL 3624, Brazil 1087, 73 VUL 3128, 73 VUL 3622, Brazil 343, PI 208-769 and Brazil 1096. These lines will be studied in detail to determine resistance mechanisms. Highest levels of resistance or lines with different mechanisms of resistance will then be crossed to increase resistance levels.

The resistance mechanism was studied by comparing three resistant and three susceptible varieties (Table 14). Results indicate that the adults preferred to oviposite on the susceptible varieties, as measured by nymphal hatch under both field and screenhouse conditions. Tolerance was also involved. Resistant varieties harbored more insects from 52 days onwards, as susceptible plants became less preferred because of Empoasca damage (Table 14). Under screenhouse conditions in free-choice tests, 13.4 nymphs per plant emerged from the susceptible varieties and 7.2 nymphs from the resistant plants.

To study the economic threshold level of Empoasca infestations, a trial was planted with Tui under dry season conditions. Nymphs were controlled when weekly counts of the populations had reached one, three or five nymphs per leaf, using either Dimetoato or Furadan at 370 or 160 g/ha a.i. and 1.5 and 0.75 kg/ha a.i., respectively. Results indicate that the economic threshold is below three nymphs per leaf for a variety with a low level of resistance (Table 15).

Insect population fluctuation studies were continued in 1974 with results similar to those of 1973. Empoasca counts were high in the dry season and were accompanied by low bean yields. The Empoasca nymphal population on beans associated with maize stayed below that of beans not in association (Fig. 4). This reduction in Empoasca nymphal

Table 13. Levels of resistance of several collections of the germplasm bank to Empoasca kraemeri, as determined by yield increases resulting from pesticidal protection (dry season planting).

Collection	Damage (scale : 0-5)	Yield per plant (g) Not protected	Yield per plant (g) Protected	Yield per plant (g) Increase (fold)
73 Vul 3,624	2.50	1.94	10.17	4.2
PI 208-769	2.25	1.97	11.43	4.8
Brazil 1059	2.50	1.13	8.00	6.1
72 Vul 25,096-1	2.75	1.90	14.95	6.9
Brazil 1074	2.50	1.65	13.84	7.4
Line 32	2.25	2.17	20.01	8.2
Bunsi	2.75	0.86	9.31	9.8
Brazil 1089	2.75	1.16	14.57	11.6
72 Vul 25,299-M	3.00	1.25	20.42	15.3
72 Vul 25,142-1	3.00	0.90	19.94	21.2
Calima	4.00	0.17	6.32	36.2

Table 14. Adult preference and oviposition preference under field conditions of Empoasca for susceptible varieties (Calima, Guali, Duva) over resistant varieties (72 Vul 25,096, Tui, Huasanó).

	Plant age (days) 17	27	37	46	52	62	72
No. of nymphs							
three susc. varieties	0.3	1.1	10.4	21.4	14.7	4.1	0.8
three resist. varieties	0.6	0.6	5.3	10.3	11.3	8.0	6.3
No. of adults							
three susc. varieties	6.5	8.9	12.5	8.0	8.8	4.1	0.3
three resist. varieties	2.1	4.0	4.6	3.9	7.4	7.0	6.0

Table 15. Yield of ICA-Tui when Empoasca was controlled at different levels of nymphal populations (kg/ha).

	No. of nymphs per leaf when pesticides were used 1	3	5
Furadan 1.5 kg/ha	1,672	1,615	1,568
Furadan 0.75 kg/ha	1,867	1,588	1,674
Dimetoate 800 cc/ha	1,721	1,659	1,617
Dimetoate 400 cc/ha	2,032	1,718	1,476
Control 1,301 kg/ha			

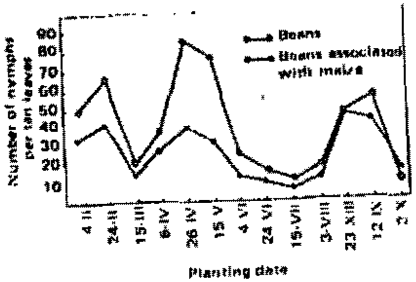


Figure 4. Empoasca kraemeri nymphal populations on beans and beans associated with maize.

population was most marked when maize was planted 20 days before the beans instead of on the same day.

Spider mites

The red spider mite in beans was identified as **Tetranychus desertorum**. Results of studies on their biology are given in Table 16. The duration of a generation is about 12 days, and the females begin oviposition upon emergence for a period of 15 days, averaging

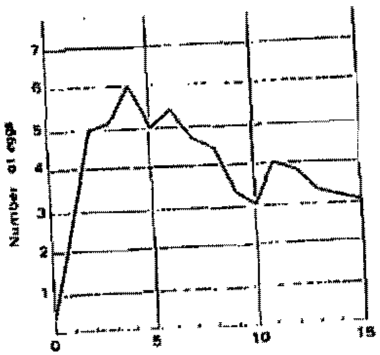


Figure 5. Daily oviposition of T. desertorum under laboratory conditions (26°C and 85% R.H.)

4.1 eggs per day (Fig. 5). Resistance was studied in seven varieties, using plants of different ages at the time of infestation. At 12 days after infestation, the total number of eggs, larvae, nymphs and adults was higher on older plants (Table 16a and b), indicating increased reproduction. Of resistance reactions tested, oviposition rate, damage and repellency did not differ significantly among the seven varieties; but time of locomotion prior to feeding did show significant differences.

Table 16a. Life cycle of T. desertorum females at about 26°C and 85% relative humidity.

Stage	Duration (days)
Egg	4.79 ± 0.97
Larval	1.05 ± 0.05
Nymphochrysalis	1.00 ± 0.00
Protonymph	1.09 ± 0.19
Deutochrysalis	1.05 ± 0.05
Teliochrysalis	1.02 ± 0.02

Insecticidal trials

More insecticidal trials were planted. Additional promising insecticides are Thiodan and granular Disyston. With Fundal, phytotoxicity was observed although bean yields were among the highest for the pesticides tested. Seed-coated, Furadan gave high yields but reduced germination. For 0.8 kg/ha a.i., 50 per cent more seed was needed; and for 0.4 kg/ha a.i., about 25 per cent more was needed to obtain a plant population equal to that of the control.

Table 16b. Mite population per leaf 12 days after infestation at different plant ages (average of seven varieties, six replicates per variety).

Plant age at infestation (days)	No. of eggs	No. of larvae	No. of nymphs and adults
20	82.0	67.7	150.0
40	201.8	47.7	136.3

Table 17. Number of adults and percentage of undamaged seed after three months' storage, protected by wood ash. Variety Calima in six replicates, infested with ten pairs of adults per 100 grams of seed per replicate.

Wood ash (g)	Ash applied before infestation		Ash applied three weeks after infestation	
	Adults (No.)	Undamaged seed (%)	Adults (No.)	Undamaged seed (%)
0	1,843	0.1	2,126	0.0
5	2,154	10.6	1,650	3.4
10	1,498	38.4	1,523	4.0
20	452	78.4	1,041	19.3

Application of 400 kg/ha sulfur to reduce the soil pH did not increase the effectivity of Furadan.

Stored-bean insects

Resistance to **Zabrotes subfasciatus** was encountered in preliminary trials in selections of Cargamanto. When placed on beans of this selection, adults died without laying eggs. This selection was replanted to test for maintenance of resistance. Additional sources of resistance are being sought.

To study the large variability among replicates in trials with **Zabrotes**, 1, 3, 5 or 7 pairs of adults were placed on 10, 25, 50 or 100 seeds of the variety Diacol-Calima. The results show an optimum number of insects per seed: seven pairs of adults per 100 seeds.

To control bruchid attack, local farmers mix wood ash with the beans in storage. Under experimental conditions, increasing the quantity of ash increased the physical barrier around the seeds, which resulted in lower percentages of infested beans (Table 17). The barrier to infestation was also evident in the distribution of undamaged seed. Of the upper one third of the jars, 3.6 per cent of the seed was undamaged, while in the bottom third, 20 per cent of the seed was free of Zabrotes damage.

Control of Zabrotes in the storage conditions of the bean germplasm bank (about 5°C) was tested. Adults, eggs, larvae and pupae were exposed to coldroom conditions in ventilated jars for 0, 1, 5, 15 or 30 days (Table 18). The egg stage was most susceptible to low temperature conditions, whereas the pupae or near pupal stage was most resistant. Some eggs were laid by adults in the coldroom or possibly after infestation until placement in the coldroom, but no development took place in seeds stored five or more days under coldroom conditions.

Chemical control was achieved by the use of pyrethrin compounds that are not toxic to mammals. The use of 1.5, 2.5 or 4.0 ppm of the products bioresmethrin-piperonyl butoxide and pyrethrum marc gave 100 per cent kill in two days when infested with adults either 1 or 40 days after application of the products. The kieselguhr talc bases gave good adhesion to the seeds; whereas the samples of ground pyrethrum marc gave poor adhesion.

Two new bean pests were encountered. **Gargaphia sanchezi** (Tingidae) became a pest in season-round plantings at CIAT;* elsewhere it does not reach pest status. The other is **Dasiops** sp. (Lonchaeidae). The larvae tunnel in at the growing point of the bean plant and are a serious problem in the area of Antioquia, Colombia.

* SCHOONHOVEN, A. VAN, F. BURBANO and R. ARENAS. Notes on the biology of the lace bug, Gargaphia sanchezi (Hemiptera, Tingidae), a pest of beans. Turrialba (In press).

Table 18. Oviposition and adult emergence after exposing various development stages of Zabrotes subfasciatus to coldroom conditions (ca. 3-5°C and 75 % R.H.).

Stage exposed	Time exposed (days)	No. of eggs	% emerged as adults
Adults	0	226.3	94.2
	1	175.5	90.0
	5	3.8	0.0
	15	0.7	0.0
	30	4.2	0.0
Eggs (four oviposition days)	0	109.8	94.7
	1	52.0	0.0
	5	37.7	0.0
	15	55.5	0.0
	30	51.5	0.0
Larvae (treatments ten days after infestation)	0	226.8	96.2
	1	191.3	77.8
	5	135.8	21.2
	15	156.5	0.0
	30	210.8	0.0
Pupae (treatment when vents in seeds)	0	282.6	94.7
	1	277.5	87.6
	5	318.0	87.8
	15	244.7	38.6
	30	227.0	0.0

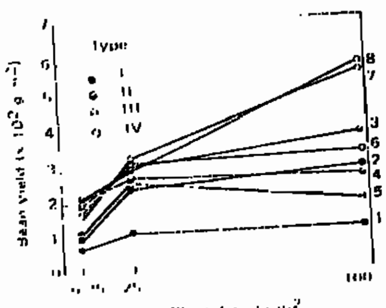
PHYSIOLOGY

The aim of this research is to provide an understanding of the physiological basis of yield in beans. These studies should improve the efficiency of selection of parents and of recombinants in the breeding program. Comparative physiological studies were continued on selected genotypes representing four of the five basic types in the germplasm bank at CIAT.

Plant type and density

The response of eight varieties (Table 19) to variation in plant density was evaluated in an experiment at Palmira, which was adequately fertilized, irrigated and protected [illegible]

dimensional grid made of twine with dimensions appropriate for the plant spacing; i.e., 10 x 10 centimeters, 20 x 20 centimeters or 40 x 40 centimeters.



[illegible] Yield response of eight [illegible] varieties to plant density. The numbers in the body of the figure refer to experimental variety number. Bean yield expressed on 12 per cent bean moisture [illegible]

Table 19. Entries in variety by density response experiment at Palmira (first semester, 1974).

Experimental variety (No.)	Collection (No.)	Variety name	Country of origin	Type	Habit
1	73 VUL 6,517	27R	El Salvador	IA	Determinate
2		ICA-Guali	Colombia	IA	Determinate
3	73 VUL 6,518	Nep 2	Costa Rica	IIC	Semideterminate medium guide
4	73 VUL 6,542	Rico 23	Brazil	IIC	Semideterminate medium guide
5	73VUL 6,550	Bayos	Chile	IIIE	Indeterminate nonclimbing
6	73 VUL 8,033	PI 310-740	Guatemala	IIIE	Indeterminate nonclimbing
7	73 VUL 6,560	Trujillo 2	Venezuela	IVF	Indeterminate climbing
8	73 VUL 6,561	Trujillo 3	Venezuela	IVF	Indeterminate climbing

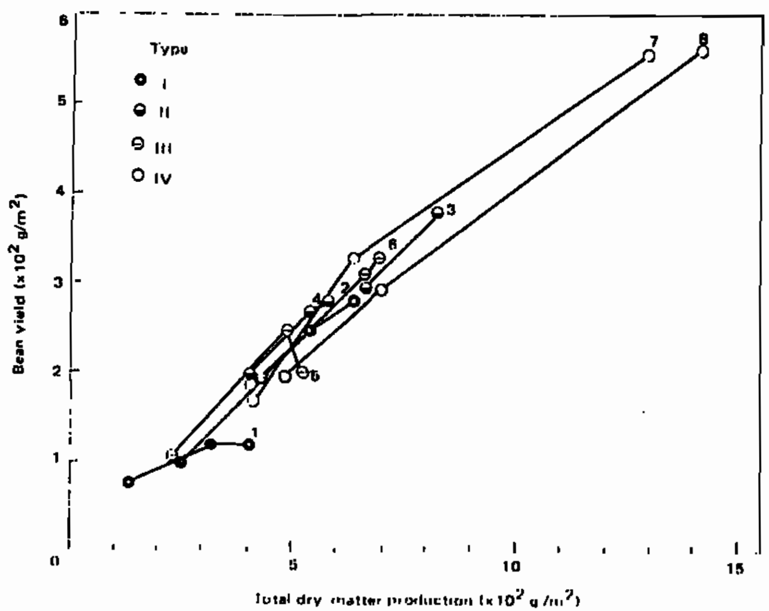


Figure 7. Bean yield versus total dry matter production (TDM) at maturity for eight varieties at three planting densities. Variety number in each variety is adjacent to datum for high density treatment. TDM includes stems, pods and beans at maturity plus total leaf dry matter at the postflowering stage.

Bean yield responses to plant density are shown in Figure 6. The most significant feature of the results was the high level of experimental yield obtained; i.e., equivalent to 5.64 ton/ha in 96 days for the climbing variety Trujillo 3 (var. No. 8) and 3.80 ton/ha in 75 days for Nep 2 (var. No. 3) from the nonclimbing group, both at a sowing density of 100 plants per square meter (equivalent to one million per hectare).

The type I, II and III varieties showed no significant response above 25 plants per square meter, while the response was apparently linear for type IV up to 100 plants per square meter.

Over the range of plant density treatments, bean yield was directly related to total dry matter production (Fig. 7), while harvest index remained relatively constant within

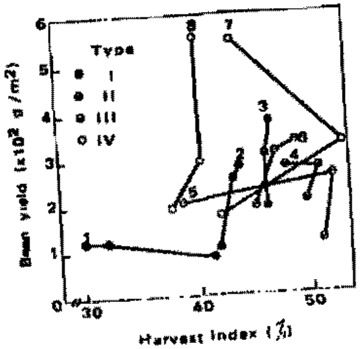


Figure 8. Bean yield versus harvest index. Variety number adjacent to datum for high density treatment. Harvest index = Bean yield/total dry matter (See Figure 7).

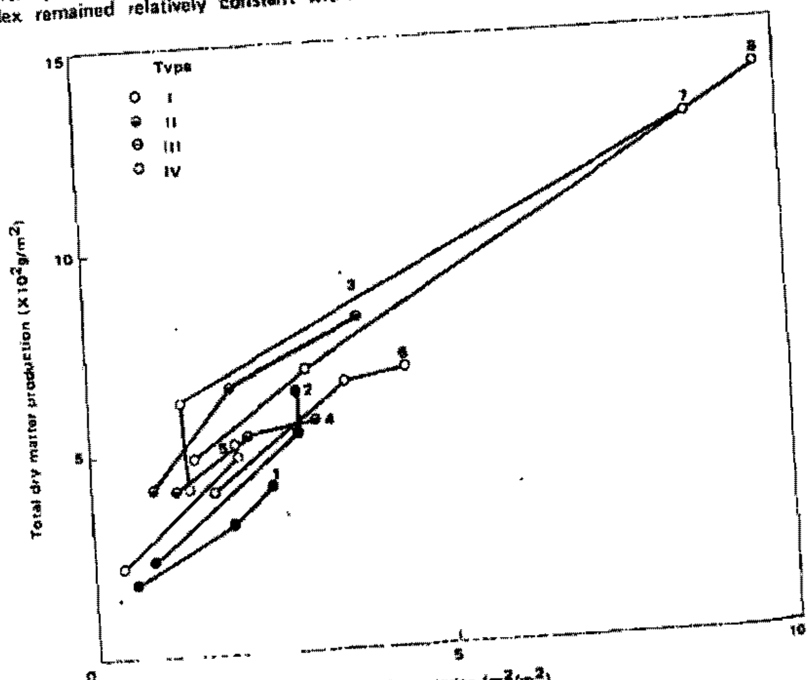


Figure 9. Total dry matter production versus postflowering (maximum) leaf area index. Variety number adjacent to datum for the high density treatment.

Table 20. Bean yield and other key physiological parameters for eight varieties of P. vulgaris grown at a plant population of 100/m² at CIAT, Palmira (first semester, 1974).

Character	Trujillo 3	Trujillo 2	Nep 2	PI310-740	ICA-Guali	Rico 23	Bayos	27R	LSD 0.05
Variety No.	8	7	3	6	2	4	5	1	
Type	IV	IV	II	III	I	II	III	I	
Bean yield (BY) (g/m²)	565	559	381	335	279	277	202	121	49
Total dry matter* (DM) (g/m²)	1,406	1,389	825	687	639	578	474	406	97
Harvest index (%)	40	43	46	49	44	48	43	30	5
Node density x 10²/m²	22.6	21.7	9.1	7.1	7.3	7.9	9.5	8.6	0
Raceme density x 10²/m²	4.0	3.7	3.1	2.6	1.9	2.6	3.2	2.4	0
Pod density x 10²/m²	5.5	6.0	4.9	3.9	2.2	4.1	3.6	1.4	0
Bean density x 10²/m²	30.2	32.0	24.1	17.5	4.9	16.1	8.8	3.0	2
Bean weight (mg/bean)	187	175	158	191	567	172	231	401	34
Leaf area** (m²/m²)	9.0	8.1	3.9	4.5	3.0	3.3	2.3	2.7	0
Main stem length (cm)	182	185	44	65	42	33	53	38	21
Days to flowering	45	47	39	35	31	34	32	34	1
Days to maturity	96	95	75	64	72	64	62	65	
BY efficiency *** (g/m²/day)	5.9	5.9	5.1	5.2	3.9	4.3	3.3	1.9	0
TDM efficiency **** (g/m²/day)	147	13.6	11.0	10.7	8.8	9.0	7.7	6.2	1
Main stem BY/Total BY (%)	100	100	96	84	71	91	66	83	11
Main stem DM/Total DM (%)	100	100	97	88	76	91	69	86	15

* Total dry matter: Stem, pod and bean dry matter at maturity plus leaf and petiole dry matter measured at postflowering stage

** Leaf area: Postflowering leaf area index

*** Bean yield efficiency: Bean yield/days to maturity

**** Dry matter efficiency: Total dry matter/days to maturity.

each variety as density increased (Fig. 8), except for Bayos (var. No. 5) and 27R (var. No. 1).

Total dry matter production was, in turn, related to maximum leaf area development (L) (Fig. 9), with the lowest yielding varieties having a lower total dry matter production per unit of maximum L even when days to maturity were similar (Table 20). Possible reasons for this result are many but are as yet undefined.

The number of vegetative nodes on branches, as well as on the main stem, expressed on a unit land area basis (node density per square meter) is one measure of basic crop structure. In the nonclimbing varieties, L tended to level off as node density increased (Fig. 10), suggesting an upper limit relative to the two varieties in the climbing group. Measurements of light interception (LTR per cent) at ground level showed little difference in the degree of total interception between treatments. The within-canopy light distribution of the climbing types at the high plant density must have been such that an L value of 9.0 was possible without excessive self-shading and premature leaf senescence in the base of the canopy. The relatively long

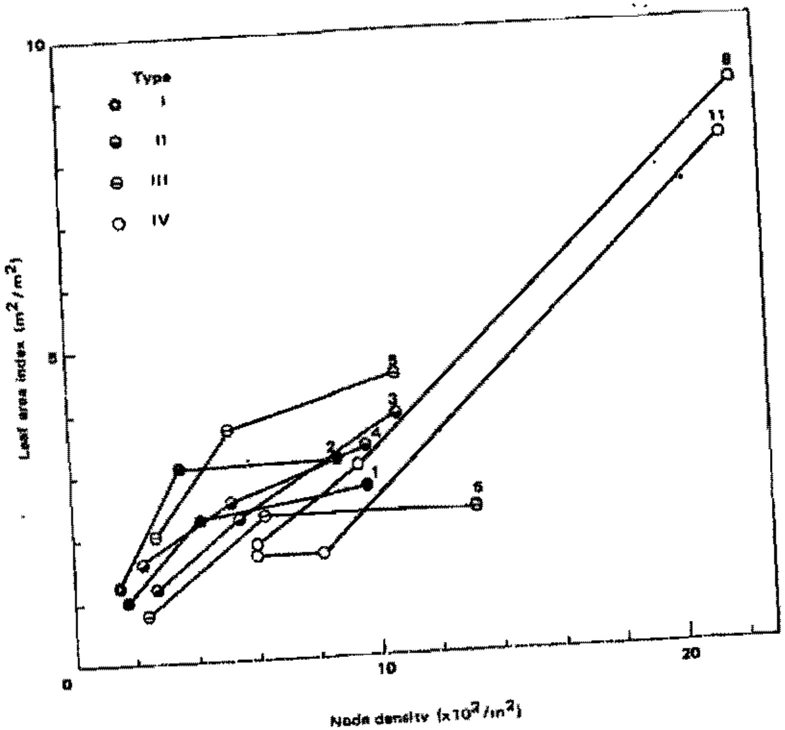


Figure 10. **Postflowering leaf area index versus node density/m^2 (includes all vegetative nodes on main stem and branches).**

period over which the leaf area was maintained tends to support this latter conclusion.

Among the various components of yield, raceme density per square meter represents the number of effective vegetative nodes bearing pods. Within each variety this was strongly related to node density as plant density increased (Fig. 11). There were large differences among the varieties with respect to the number of racemes per node. Pod density was, in turn, related to raceme density in each variety as plant density increased. Once again, there were large differences among varieties in the number of pods per raceme (Fig. 12) with the determinate varieties having conspicuously low raceme efficiency at high plant density. Bean yield was highly correlated with pod density (Fig. 13) and bean density (Fig. 14). Figure 15 shows a plot of bean yield versus bean weight (mg/bean).

The importance of overall plant size (as measured by node density) in determining the size of the potential sink is clearly illustrated by these data. Node density also limits leaf area development at least up to L values of 4 to 5 in the nonclimbing varieties. In the supported, climbing varieties, high L values were possible.

Interpretation of varietal yield differences

The data in Table 20 present a range of key parameters measured at the highest plant

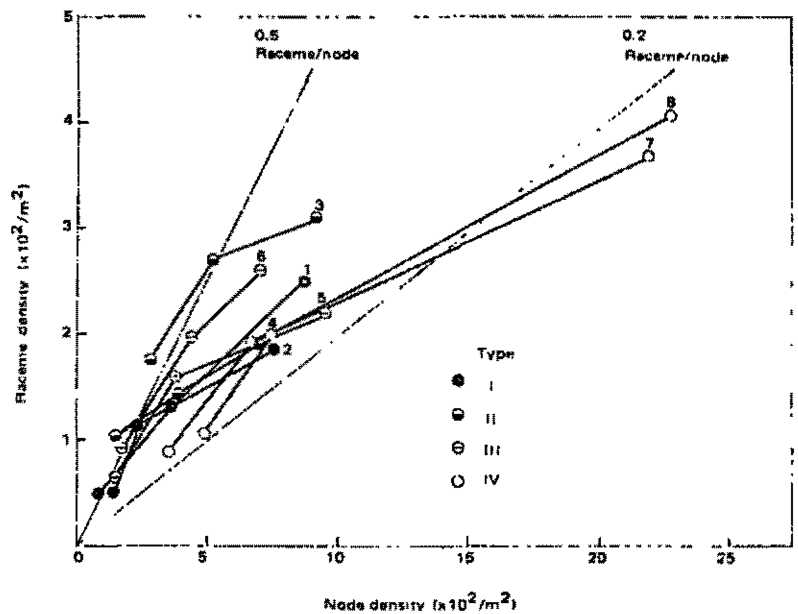


Figure 11. **Raceme density/m^2 versus node density/m^2. Variety number adjacent to high density treatment.**

density where the largest yield difference among varieties was recorded. The high yield of the type IV varieties was associated with a high level of total dry matter production, leaf area index and sink size as estimated by factors such as raceme density and thus bean density. Since bean size did not decrease as plant density increased (Fig. 15), these results suggest that the source of photosynthate at high plant density was apparently sufficient to service the increased sink available. The source and sink balance was thus maintained at the high plant density and high levels of bean yield were possible. The varieties in the indeterminate nonclimbing group (types II and III) showed a considerable bean yield variation from 202 to 380 g/m^2. Higher bean yield levels were also associated with increased total dry matter production and were not associated with differences in harvest index except in the case of the lowest yielding variety among the type II and III varieties, Bayos (var. No. 5).

In this latter variety, a large proportion of bean yield and total dry matter was borne on the branches, which could suggest a lower bean yield efficiency on the branches, as compared with production on the main stem. This variety was also the only entry to show a negative bean yield response above 25 plants per square meter. The high yield of Nep 2 was probably associated with the ability to produce a large sink and to fill that sink even though maximum leaf area was only 3.9. As there was no decrease in bean weight with increasing plant density, the results suggest again that the leaf area was able to service the available sink.

In the determinate group (Type IA), the two entries showed contrasting yield levels of 121 and 278 g/m^2 at the highest density

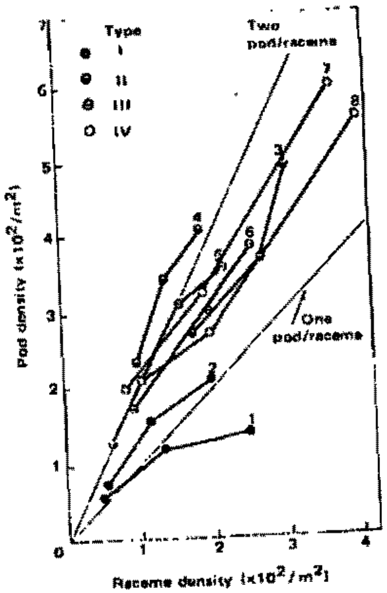


Figure 12. **Pod density/m^2 versus raceme density/m^2. Variety number adjacent to high density treatment.**

of sowing. The higher yield of ICA Guali (var. No. 2) was associated with both a higher dry matter production and harvest index as compared with 27R (var. No. 1). The yield advantage in this case appears to be associated with an increased sink size in terms of bean rather than raceme density. The low bean yield of variety 27R is associated with a low harvest index, suggesting that the sink was inadequate to accept the photosynthate available. Since bean weight decreased markedly as density increased with 27R (Fig. 15), the possibility of a simultaneous source limitation cannot be excluded. An increase in plant size—e.g., node density, which would lead to both an increase in sink and to increased leaf area—seems desirable if yields of varieties in the determinate group, such as 27R, are to be improved by breeding.

From these preliminary data, it would appear that in the lower yielding varieties,

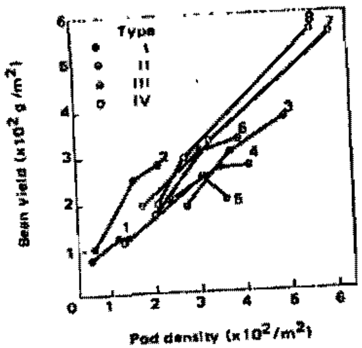


Figure 13. **Bean yield versus pod density (pod number/m^2. Variety number adjacent to high density treatment.**

sink and/or source could be limiting bean yield at high plant density. However, when both source and sink were increased by increasing node density, high experimental yields were possible, suggesting that source and sink limitations remained in balance. Bean yield improvement through breeding may thus partly involve genetic manipulation to increase node density among varieties in types I and II but without a commensurate increase in branching.

Although high yields were obtained with the supported, climbing varieties, this would of necessity require intensive labor, which could possibly be uneconomical.

Effects of phenology

There is little doubt that part of the reason for the high yields in type IV plants at high density is the longer pre- and post-flowering period in these varieties. The comparative similarity in phenology among the varieties in types I to III in this experiment suggests that factors other than phenological development were responsible for the yield differences recorded among these entries. However, if large increases in yield potential are to be achieved by breeding, one of the primary objectives should be the development of later flowering and later maturity in the nonclimbing varieties.

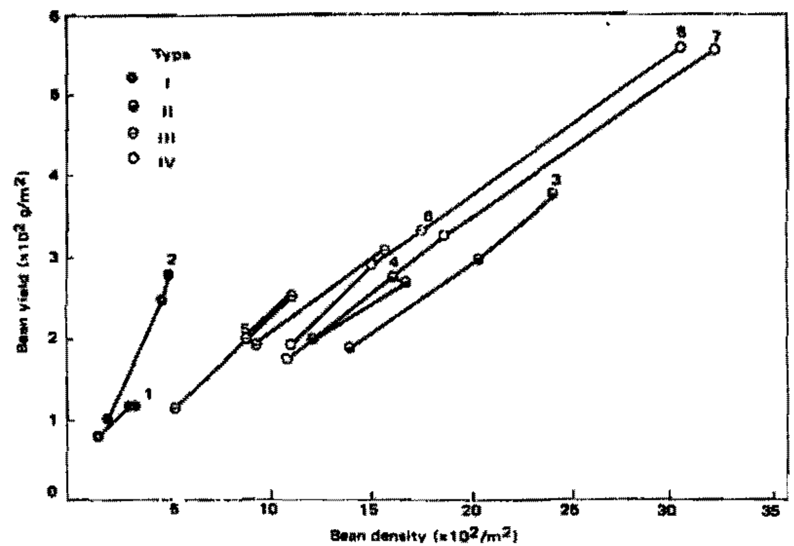


Figure 14. **Bean yield versus bean density (or bean number)/m^2. Variety number adjacent to high density treatment.**

Table 21 shows the frequency distribution of days to flowering (plant emergence to 50 per cent plants flowering) for 4,889 selections from the P. vulgaris germplasm bank at CIAT. In all growth habit groups, the vast majority of these selections flower in less than 40 days. In type IA at Palmira (determinate bush), two thirds of the collection flowers in less than 30 days. This probably reflects the emphasis for adaptation to longer days and short growing seasons among North American material. The collection does include sources of variation in the indeterminate types which have preflowering periods greater than 49 days. This latter material will be invaluable as parents, allowing the possible selection of later flowering and later maturing recombinants.

An increase in basic plant structures—e.g., node density, by delaying flowering to allow greater sink development followed by a long

Table 21. Distribution of days to flowering (emergence to 50 per cent plants flowering) by growth habit based on observations on 4,889 selections from germplasm bank at Palmira (1974).

Growth habit	No.	Days to flowering: <20	20-29	30-39	40-49	>49
		Per cent in each classification				
IA	1,041	0.3	66.5	29.7	3.4	0.0
IB	344	0.0	27.9	70.0	1.7	0.3
IIC	1,264	0.1	37.7	58.7	3.2	0.3
IIIE	1,047	0.2	54.5	44.9	1.1	0.0
IVF	1,193	0.8	53.4	42.6	3.5	0.4

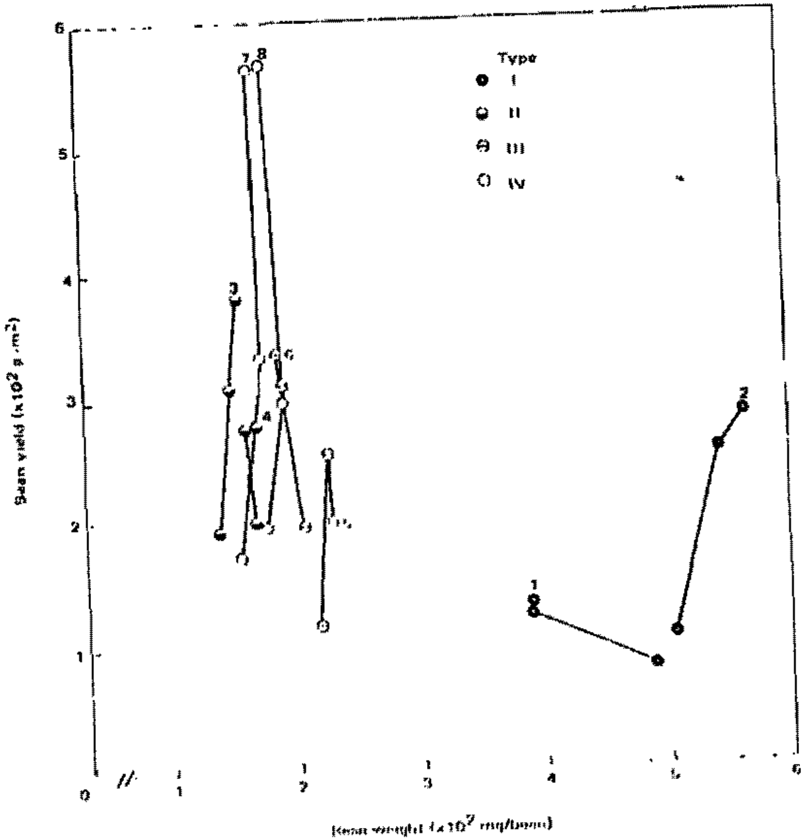


Figure 15. Bean yield versus mean bean weight (mg/bean). Variety number adjacent to high density treatment.

postflowering period in which to fill the available sink—should lead to significant yield increases among the determinate and semi-determinate material.

MICROBIOLOGY

Previous reports in soil microbiology emphasized pasture legumes and Rhizobium strain efficiency. In February, the microbiology group began to work full time on beans, and although some studies were continued with **Stylosanthes** inoculation, this was as a service to the pastures and forage group and not a major activity. Similarly, where strain isolation and testing for efficiency had been emphasized previously, major effort was now placed on the plant component of the symbiosis.

Field testing of bean inoculants

ICA-Lm was tested for response to inoculation and nitrogen fixation with six strains of **Rhizobium phaseoli**, known to be efficient under glasshouse conditions. Although the tests were carried out in two soils (La Zapata and Popayán) in which bean yields had responded to nitrogen application, no consistent response to inoculation was obtained. Neither nodulation nor initial fixation gains were to blame. The major difficulty appeared to be in the failure of the nodules, once they were formed, to persist and develop under field conditions.

Because the bean-**Rhizobium** symbiosis is one of the few which does not appear to work consistently under field conditions, the bean germplasm available at CIAT is now being screened for varieties which are more efficient in symbiosis with the present strains. Studies emphasize leaf area and duration, flowering pattern, and root structure and development.

Studies of soil phosphorus

Field and glasshouse studies considered the relationship between P, Ca and nitrogen fixation in phosphate-deficient soils from both La Zapata and Popayán. Four phosphorus levels (0.5 8.0 mm P/2 kg of soil) and three calcium levels (0-10.0 mm $CaCO_3$/ kg of soil) were used in both soils. Raising the calcium level increased nodule number per plant but had little or no effect on nodule or plant dry weight. At intermediate phosphorus levels, nodule and plant dry weight and the percentage of P in the tissues were even depressed. Increasing phosphorus, on the other hand, had a much greater effect on nodule and plant dry weight than on nodule number. Phosphorus application lowered the percentage of nitrogen in the plants, but increased total nitrogen (Fig. 16).

Because of high superphosphate costs in Latin America, studies then turned to microbiological methods to improve the availability of phosphate in soil. Experiments at La Zapata and Popayán compared response of beans to superphosphate or to mixtures of ground rock phosphate and sulfur. In the absence of pure cultures of **Thiobacillus** as an inoculant, it was hoped that soil microorganisms would reduce the sulfur and promote its solubilization at lower pH and on close contact with the rock phosphate.

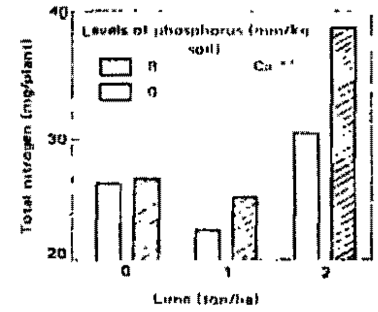


Figure 16. Effect of phosphorus and calcium on nitrogen fixation by beans (La Buitrera soil).

Results were encouraging in both soils with yields from the rock phosphate-sulfur mixtures which were 32 to 61 per cent above those of plants not receiving fertilization (Table 22). Strains of **Thiobacillus** have now been isolated from soil and are being used in further studies of phosphate fertilization.

Studies were continued on endotrophic mycorrhiza and their ability to provide phosphate for growing bean plants. Four **Endogone** cultures obtained from Dr. Mosse at Rothamsted were tested with four bean cultivars of different growth habits, but none enhanced growth. Numerous attempts were also made to isolate **Endogone** spores from

Table 22. Use of rock phosphate/sulfur mixtures as a phosphate source for Colombian soils.

	Yields (kg/ha)	
Treatment*	Zapata	Popayán
Superphosphate	1,567.5	2,201.9
Superphosphate + N	1,528.9	1,774.2
Rock phosphate/sulfur + N	1,336.1	1,509.0
Rock phosphate/sulfur	1,143.5	1,227.5
Rock phosphate + N	1,109.7	1,222.5
Check + N	893.7	511.6
Check	707.6	912.5
Rock phosphate	654.1	859.1

* P kept constant at 67.5 kg P_2O_5/ha. N [illegible] kg/ha, as urea. All treatments inoculated and lime pelleted.

local soils; but with few exceptions, these were unsuccessful. It was apparent that endotrophic mycorrhizal fungi were not evenly distributed in the soils studied. A detailed survey with more frequent sampling and considering different soil types and altitudes is in progress.

Temperature effects on growth and nitrogen fixation

Initial experiments using mulching or shading to lower soil temperature showed significant improvements in plant yield and also improved nodulation, nodule retention and nitrogen fixation. To determine whether yield increases were due solely to increased nodule activity, a mulching experiment was planted at the CIAT farm, where adequate nitrogen is available to the plants. Three levels (1, 2 and 5 tons/ha) of bagasse, rice straw or chopped rice straw were incorporated into the beds one month before planting and were irrigated twice weekly until planting.

Yield increases of up to 25 per cent were obtained in each mulching treatment (Fig. 17) even in the absence of nodulation; the greatest response was to low levels of sugar cane residue. At the 4 ton/ha bagasse, root rot was more prevalent and the percentage of seed germinating reduced. Yields in this treatment were not significantly greater than in the control plots.

Because such results could be due to effects of temperature, collaborative experiments have been established with the University of Giessen. These experiments are studying the effect of various day-night temperature combinations and of inoculation in several plant types. At the same time, studies are continuing at CIAT to establish more practical methods of minimizing soil temperature effects on the symbiosis.

Inoculation supply

CIAT continues operating the only legume-inoculant producing center in Colombia, and there is a constant demand for inoculants of all legume species. In 1974 inoculants were produced for medic clovers, beans, soybeans, siratro, stylo, cowpeas, Leucaena, Desmodium and peanuts. Inoculants were supplied to users in Bolivia, Ecuador, Peru, Venezuela, British Honduras, Costa Rica, Colombia and Argentina.

ECONOMICS

Bean economics research provides information useful in establishing research priorities. This information should reflect the needs of the farmer, as well as socioeconomic development goals, and should be useful to CIAT and national agencies.

Analysis of secondary data

The purpose of this work (Annual Report 1973) was to improve the information available on beans by collecting and analyzing the data available on production, consumption and international trade in beans.

Results of the analysis have been presented in three publications.*

The bean crop in Latin America

To obtain information on the bean sector in Latin America without making farm-level studies, a survey was carried out among professionals working on beans in this region. The survey was planned and carried out in collaboration with IICA and the economists of the CIAT bean program. Questionnaires were sent to scientists in 12 countries by IICA's official representatives.

The survey requested information on: (1) bean ecology, area, production and yields, (2) characteristics of the bean-producing farm and the production process, (3) occurrence of diseases, insects and weeds, (4) marketing and policies aimed at promotion, research and extension.

According to the information received (Gutiérrez et al.)* the bean crop in Latin America is produced primarily in small lots exploited by the farmer and his family. In El Salvador, 95 per cent of the bean-producing farms have an area of less than 5 hectares. In Panama, the average farm size among bean producers was found to be 2.6 hectares. In Colombia, 50 per cent of the beans are produced on farms of less than 7 hectares. In Haiti, the average bean farm is 1/2 hectare. Some exceptions are found in certain regions, such as the Valle del Cauca in Colombia, the coastal zone of Peru and the Dominican Republic, where there are bean farms larger than 30 hectares.

Generally, the bean is planted in association with other crops, particularly maize. In Colombia, 90 per cent of the beans are planted in association with maize and/or potatoes. In Brazil, intercropping represents 80 per cent. There are exceptions: In Honduras, for example, 95 per cent of the production is generated from a monocrop; and in Haiti beans are generally planted alone.

The use of certified seed is uncommon. In the majority of the cases, the farmer uses seed from his previous harvest. Planting is done manually. The planting density varies and depends more than anything on the cropping system utilized.

Among the diseases, those of virus origin are most frequent; mosaic viruses cause the

* GUTIERREZ, U., M. INFANTE and A. PINCHINAT. Situación del cultivo del fríjol en América Latina. (In press).
INFANTE, M.A., G.M. SCOBIE and E. GUTIERREZ. 1974. Producción y consumo de fríjol seco y su contribución a la oferta de proteínas con énfasis en América Latina. XX Reunión Anual de PCCMA. San Pedro Sula, Honduras.
SCOBIE, G. M., M. A. INFANTE and E. GUTIERREZ Z. 1974. Production and consumption of dry beans and their role in protein nutrition. Paper presented to USAID Nutrition Seminar, Washington.

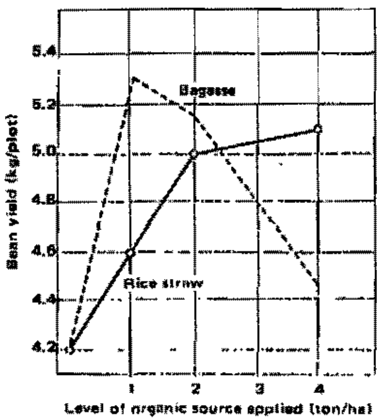


Figure 17. Influence of material used and level of application on yield benefits from mulching.

Table 23. Most important diseases in beans in Latin America according to surveys.

		Brazil	Colombia	Costa Rica	El Salvador	Guatemala	Haiti	Honduras	Nicaragua	Panama	Paraguay	Peru	Dom. Rep.	No. of Countries
1) Virus mosaic	(Mosaic virus)	X	X	X	X	X	X	X	X	X	X	X	X	12
2) Uromyces phaseoli var. typica	(Rust)	X	X	X	X	X	X	X	X	X	X		X	11
3) Colletotrichum lindemutianum	(Anthracnose)	X	X	X	X	X	X	X	X	X	X			10
4) Erysiphe polygoni (oidium)	(Mildew)	X	X	X	X	X	X			X	X	X		9
5) Isariopsis griseola	(Angular leaf spot)	X	X	X	X	X	X	X	X	X				9
6) Xanthomonas phaseoli	(Common blight)	X	X	X		X		X	X				X	7
7) Sclerotium rolfsii (Sclerotium sp.)	(Southern blight)	X	X					X		X			X	5

Table 24. Most important pests in beans in Latin America according to surveys.

		Brazil	Colombia	Costa Rica	El Salvador	Guatemala	Haiti	Honduras	Nicaragua	Panama	Paraguay	Peru	Dom. Rep.	No. of Countries
1) Empoasca kraemeri	(Green leafhopper)	X	X	X	X	X	X	X	X	X		X	X	11
2) Diabrotica spp.	(Diabroticas)	X	X	X	X	X		X	X	X	X		X	10
3) Cerotoma spp.	(Bean-leaf beetle)		X	X		X				X			X	5
4) Acanthoscelides spp.	(Cutworm)	X	X	X				X						4
5) Agrotys spp.		X	X			X					X			4
6) Stigmene spp.	(Hairy worm)		X			X		X	X					4
7) Tetranychus spp.	(Spider mite)	X	X			X		X						4

greatest economic loss in bean production in Latin America. A large number of other diseases were reported (Table 23). Among the insects most frequently found in beans in Latin America, the survey reports empoascas and diabroticas (Table 24). These findings support priorities of the CIAT bean entomology and pathology programs.

Water control is another important problem in bean production in Latin America. The majority of the survey countries report problems of drought, as well as flooding in the principal bean-producing regions.

With respect to bean marketing, the price fluctuations and scarcity of storage capacity were mentioned as principal problems and are obviously related. One of the most effective ways to reduce price fluctuations is to increase the storage capacity.

The survey data indicate that between 85 and 90 per cent of the beans produced in Latin America are used for direct human consumption.

With respect to external trade in beans, Nicaragua, Guatemala, Brazil and Colombia are exporters. Among the importers are Guatemala, Costa Rica, the Dominican Republic and El Salvador. Some of the countries which have traditionally imported large quantities of beans (i.e., El Salvador and Costa Rica) have launched strong promotional campaigns to increase internal production.

Bean production process in Colombia

The primary objective of this work is to describe and analyze the bean production process in Colombia and to identify the factors associated with low yields. The analysis focuses on (1) cropping systems; (2) occurrence and intensity of diseases, insect damage and weeds; (3) soil quality; (4) cultural practices; (5) resource use, costs and returns; (6) risk and farm objectives; and (7) bean utilization.

Data are being obtained from approximately 200 bean producers in various regions of Colombia.* Each farm is visited three times during a growing cycle by a team of agronomists and economists trained for this purpose. The data obtained are partially from field observations and partially from interviews with the farmers. Data collection was initiated in November, 1974.

* Additional information with respect to the type of data obtained from the survey is available in the article. A proposed model to improving the information base for research resource allocation, by P. Pinstrup-Andersen, R O. Diaz, M. Infante and N.H. de Londoño. This article was presented at a workshop on Methods used to allocate resources in applied agricultural research in Latin America, held at Cali, Colombia on November 16-17, 1974.

AGRONOMY

Maximum yield trials

To determine the yield potential of the genetic material under plot conditions, 50 to 60 of the most promising selections and varieties were seeded in maximum yield trials. Three were grown on the CIAT farm during different seasons, the others at Popayán, Montería and Boliche. Porrillo Sintético gave the highest yields in the three locations harvested so far, indicating its great adaptability and yield potential (Table 25). Other promising materials are ICA-Pijao (Line 32) and selection 6589-1-T-T (P512—A). All high-yielding varieties were black seeded and of either plant type I or IIC. It is possible that the particular plant spacing used was not favorable for plant type IIIE, and plant type IVF was not included in the trial. In the hot, humid climate of Montería, yields were low although plant growth was luxurious. The genetic material included in the trial had not been specifically selected for that location and was probably not adapted to high temperatures. There are some indications that climbing beans are better suited for those environmental conditions.

Boron deficiency

In 1972 a major problem in growing beans on the CIAT farm was identified as boron deficiency. Application of B to the soil resulted in dramatic improvement of plant growth and yields. Figure 18 shows the typical symptoms of B deficiency in contrast to a normal B-fertilized plant. During 1974, experiments were designed to define the best sources, methods and times of applications of B, as well as the residual effect and varietal differences in B response.

Figure 19 shows the response of Tui to B application, using two sources of B: borax and solubor. Yields increased nearly a ton of dry beans/ha for the application of 1 kg/ha of B. The results indicate that 1 kg/ha of B satisfies the plant's needs, but that 8 kg/ha of B as borax does not produce B toxicity in

Table 25. Yields, plant types, and seed colors of the highest yielding varieties and selections in the maximum yield trials.

Location	High yielding material	kg/ha	Plant type	Seed color
CIAT (Palmira) 56 materials	* Porrillo Sintético = P566-C	2,743	II C	Black
	150-1-1 = P560-B	2,720	II C	Black
	6630 var. 51052	2,653	I B	Black
	141-M-1 = P459-C	2,522	II C	Black
	* 6589-1-T-T = P512-A	2,342	II C	Black
	* ICA-Pijao (line 32)	2,341	I B	Black
Popayán 45 materials	Porrillo Sintético = P566-C	2,857	II C	Black
	6536-1-T-T = P538-A	2,714	I B	Black
	6589-1-T-T = P512-A	2,657	II C	Black
	6575-M-T-T = P362-A	2,655	III E	Brown
	ICA-Pijao (line 32)	2,626	I B	Black
Montería 36 materials	Porrillo Sintético P566-C	1,523	II C	Black
	Tui	1,184	I B	Black
	6545	1,104	II C	Black
	6514	1,095	II C	Black
	Line 29	1,074	I B	Black

* Most promising in various locations

Figure 18. Boron deficiency in plant on the right has a profound effect on yield. On the left, a plant of the same variety received 2 kg B/ha as borax.

this soil. There was no significant difference between the two sources. One kilogram of B costs about US$15, while one ton of beans is worth US$580.

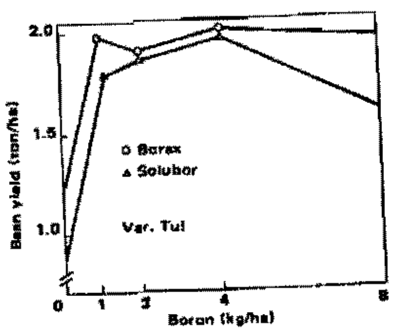


Figure 19. Response of beans (Tui) to the application of four levels and two sources of boron.

Figure 20 shows the effects of various methods of placement of B on yield. Again, the application of 1 kg/ha of B increased

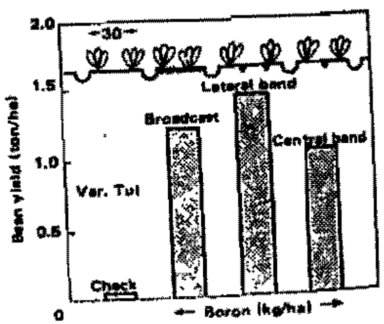


Figure 20. The response of beans (Tui) to various methods of applying boron fertilizer (borax) to the soil.

yields 1 to 1.5 ton/ha, with lateral placement alongside each bean row being superior to either the broadcast or central band placement. As long as the bean seed is not directly in contact with the fertilizer band, the borax can also be applied in the seed row without seriously affecting germination. Two foliar applications of a 0.5 per cent solution of solubor improved growth considerably, but were less effective than soil application. In acute B deficiency, plants die before developing sufficient foliage to intercept foliar application. Delaying B applications to the soil reduces yields considerably; the best time for applications is either before or at the time of planting.

Once applied and depending on source, method and level of application used, the borax may remain in the soil for several years. At CIAT the application of 2 kg/ha of B applied as borax satisfied the needs of ICA-Tui and Calima for at least two crops. Its long-range residual effect has not yet been determined. Among 14 promising varieties tested, ICA-Gualí and Calima were most tolerant to B deficiency while Porrillo Sintético was extremely susceptible.

Fertilization of beans with N,P and lime

Several fertilizer experiments were conducted at La Zapata, a private farm in the mountain range east of Palmira. The soil is acid (pH 5.0) and low in P.

Figures 21 and 22 show the response of beans to phosphorus fertilization. Yields increased from 0.7 to 1.8 ton/ha with the application of 200 kg/ha of P_2O_5 as triple superphosphate applied in bands. Basic slag was less effective, while the rock phosphates from Huila and Boyacá produced only a slight positive response.

A nitrogen fertilization trial showed a yield increase from 0.96 to 1.45 ton/ha with the application of 40 kg/ha of N as urea. Higher application rates did not further increase yields. Applying all the N at time of planting was slightly better than split applications.

A liming trial showed no positive response to lime applications up to 4 ton/ha in both

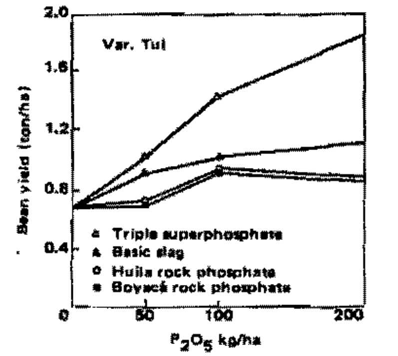


Figure 21. The response of beans (Tui) to the application of three levels and four sources of phosphorus at La Zapata.

Gualí and Tui. Previous experiments at Carimagua had shown that red beans, such as Gualí, do not yield at all until 4 to 6 ton/ha of lime have been applied (Annual Reports 1972, 1973). The lack of response in such an acid soil may have been due to a relatively low level of exchangeable Al and high levels of Ca and Mg, resulting in an Al-saturation percentage of only 8 per cent, as compared with 86 per cent in the virgin Carimagua soil.

Figure 23 shows the response to lime and P of Tui and two cowpea varieties at Carimagua. Line 28 responded exactly as Tui and is not shown. All four varieties responded up to 4 ton/ha of lime with no additional response up to 16 tons of lime. With 4 ton/ha of lime, the pH increased to 5.0 and the exchangeable Al content was 1.4 me/100 mg (30 per cent Al saturation). All varieties showed a marked response to P fertilization. Zipper Cream responded mainly to 50 kg/ha of P_2O_5, while Cabecita Negra and Tui responded to an application of no less than 100 kg/ha.

Weed control

In trials at Montería, where nutsedge is a serious weed problem, no herbicide tried was as effective as two hand weedings with machete. Among the herbicides, Vernan was most effective when applied at the rate of 12 liters/ha.

Figure 22. **Beans respond dramatically to applications of phosphorus on many volcanic ash and lateritic soils.**

Plant population

Figure 24 shows the results of a population trial with Tui at Popayán. High yields were obtained with a row spacing of 30 centimeters, with 9 centimeters between plants in the row. The same plant population and nearly the same yield was obtained with a row spacing of 45 centimeters with 6 centimeters between plants in the row.

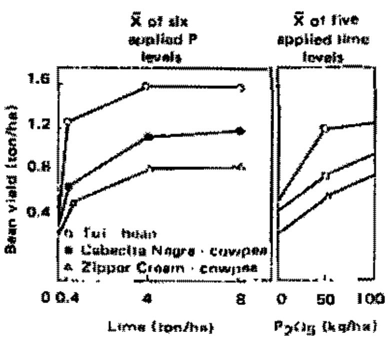


Figure 23. **The response of one bean and two cowpea varieties to the application of lime and phosphorus at Carimagua.**

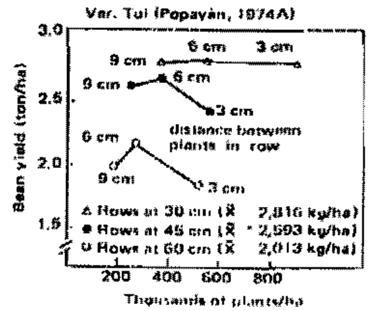


Figure 24. **Bean yields in relation to plant populations obtained by varying row spacings and spacings of plants within the row.**

Management of high pH soils

The traditional management practices of applying gypsum and sulfur had a negative effect on the production of maize (Annual Report 1972). The application of up to 40 ton/ha of gypsum had a slightly negative effect, while the application of up to 4 ton/ha of S had a slightly positive effect on beans. Jamapa and ICA-Pijao (line 32) produced reasonably well, while Rico Pardo was seriously affected by the high pH soil conditions.

Use of soil cover

A trial at Boliche carried out in collaboration with INIAP showed the beneficial effect of using residues of sesame, plantain, maize castor beans and rice to cover the soil surface between bean rows (Fig. 25). These cheap and easily obtainable residues serve to preserve soil moisture and reduce weed competition and soil temperatures. Bean yields were nearly tripled at Boliche by this simple practice.

Time of seeding

In many areas, the correct time of seeding is more important in raising bean yields than any other agronomic practice. A time-of-seeding trial at Carimagua showed that no beans could be harvested during the wet months of May to September because of pod rot. A similar trial at Popayán showed a yield decrease of 1.8 ton/ha by delaying seeding from March to June, mainly because of drought. Higher yields were obtained in the March seeding without any insect and disease control than in the April seeding with control (Fig. 26).

Multiple cropping

Different systems of intercropping beans and maize were tested in several locations. Figure 27 shows the results obtained at CIAT, when bean plants were grown in the empty spaces left between normally spaced maize plants. The beans had no detrimental effect on the maize, actually increasing its yield slightly; however, the maize did have a negative effect on the yield of beans. Seeding one row of beans on each side of a maize row gave the highest maize and bean yields of all intercropping systems tested. In a similar experiment at Boliche, maize yields decreased only slightly in the intercropped systems, but the yields of Gualí dropped from 2.48 ton/ha in monoculture to only 0.57 ton/ha in the intercropped system.

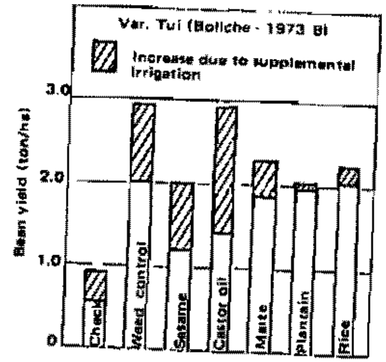


Figure 25. **Bean yields as influenced by various crop residues used as soil cover between rows, as well as by supplemental irrigation.**

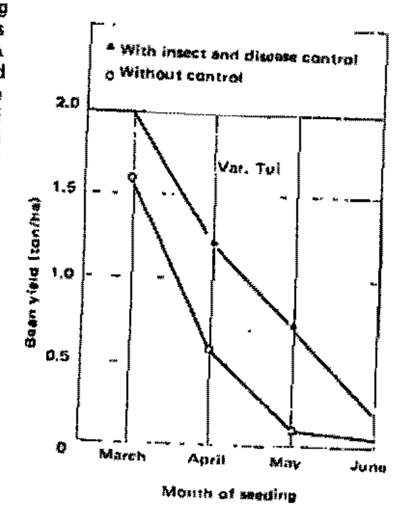


Figure 26. **Bean yield with and without control of insects and diseases as influenced by seeding dates in Popayán.**

Treatment	Plant density	Planting system	Yield (kg/ha)		Value * $ (Col. pesos)
			Maize	Beans	
Maize monoculture	44,400 plants/ha	90	3,707		14,691
Bean monoculture	222,000 plants/ha	30	-	1,226	17,370
Maize beans intercropped	44,400 maize plants/ha 111,000 bean plants/ha		4,130	806	27,079
Maize beans intercropped	44,400 maize plants/ha 111,000 bean plants/ha		4,162	673	25,300
Maize beans intercropped	44,400 maize plants/ha 222,000 bean plants/ha		4,239	1,008	29,736

* Value based on official Colombian market prices: maize, $ 3,900/ton, red beans, $ 13,100/ton.

Figure 27. Yields of maize (yellow brachytic) and beans (Guali) and their peso value in various maize-bean intercropping systems as compared with monocultures of maize and beans.

Table 26 shows the effect on bean yields of light competition from maize. Maintaining the maize and bean populations constant, light competition was incrementally reduced by increasing the space between maize hills and planting more maize plants per hill. This slightly reduced maize yields but increased bean yields to the point where they approached those of the bean monoculture system.

Table 26. The yields of maize (yellow brachytic) and beans (Guali) and their Colombian peso value as influenced by several maize-bean intercropping systems, with varying spacings of maize hills and plants per hill.

Treatment *	Yield (kg/ha)		Value **
	Beans	Maize	Col. Pesos
1. Bean monoculture	1,330		17,423
2. Maize-bean intercropped (25 cm between hills of one maize plant)	1,021	5,124	33,358
3. Maize-bean intercropped (50 cm between hills of two maize plants)	1,065	5,290	34,582
4. Maize-bean intercropped (75 cm between hills of three maize plants)	1,268	4,518	34,230
5. Maize-bean intercropped (100 cm between hills of four maize plants)	1,206	4,446	33,137

* Beans always planted in two rows per bed, 30 cm between rows, 90 cm between beds; 222,000 plants/ha.
Maize always planted in one row between two bean rows; 44,400 plants/ha.
** Value based on official Colombian market price: maize $3,900/ton; red beans $13,100/ton. (Prices in November, 1974).

The correct time of seeding beans relative to maize is important if one crop is not to dominate the other (Fig. 28). With bush beans, the beans should be planted simultaneously or slightly ahead of the maize, the correct timing depending mainly on local climatic conditions. If maize is used as support for climbing beans, the maize should be planted simultaneously or slightly ahead of the beans.

A trial comparing maize with several methods of artificial supports for climbing beans showed that artificial supports can greatly increase bean yields by permitting increased bean population and eliminating light competition from the maize (Fig. 29). However, the placement of artificial supports is expensive, so they would need to last several semesters in order to justify their cost. Similar physiology studies are presented on page 132.

COLLABORATIVE ACTIVITIES

In 1974 the Technical Advisory Committee of CGIAR requested CIAT to develop and coordinate a Latin American network for bean research. CIAT's Board of Trustees agreed in principle, but requested time to review the implications of this institutional relationship and its receptive budgetary effects. Interim funding by the Inter-American Development Bank has allowed the program to implement some aspects of the coordinative function.

Documentation service

In August, the program began a bean documentation service similar to that already operating for cassava. The service identifies articles on *Phaseolus vulgaris* or related species, prepares abstracts of the articles and then forwards these (100 to 200 at a time)

Figure 28. In intercropping systems of corn and beans, it is important to determine the correct time of planting of one in relation to the other.

to interested scientists or institutions. CIAT maintains photocopies of all articles referred. To date, more than 1,000 articles have been identified and abstracts for about 500 of these prepared and forwarded. A bimonthly listing of articles on Rhizobium is also forwarded to more than 60 scientists in Latin America.

Figure [illegible]. Yields of climbing beans can increase dramatically by using artificial supports instead of corn plants, so as to increase plant populations and decrease light competition.

Discipline workshops

The first in a series of discipline-oriented workshops to be organized by the bean program was held in October, 1974. The Rust Resistance Workshop with 24 participants from 15 countries considered the formation of international bean rust nurseries and established the terminology, standard scoring of symptoms and reference varieties necessary for such a nursery. CIAT accepted responsibility for (a) preparing the disease-free seed, fertilizer, and pesticide materials needed and (b) for coordinating experimentation, observation and distribution of results.

A Bean Program Evaluation Workshop, also held in October, presented the major activities of the bean program and solicited criticisms from the 19 scientists present. A steering committee of six bean scientists, four of whom are from Latin America, was elected at this meeting. They will serve during an initial three-year period as a review committee for the program.

Seed preparation and shipping

With documentation and coding of the accessions available in the germplasm close to completion, the program can now begin to satisfy the germplasm needs of Latin American national programs. During 1973 and 1974, more than 7,000 accessions were shipped to 22 countries. Early in 1975, a scientist will be appointed to maintain, extend and further characterize the germplasm bank. An information retrieval system will also be established, further extending the seed service available. Further details of the material and characteristics available in the germplasm bank are discussed by G. Hernández-Bravo and R. Hidalgo.*

Experimentation

CIAT collaborated in a number of experimental and seed production activities during 1974.

Foundation, disease free seeds of local varieties from Colombia, Ecuador, Guatemala and Peru were turned over to the countries of origin for local seed certification programs. In Guatemala, seed produced at CIAT was increased in the San Jerónimo Valley and then sown over 84 hectares in the Monjas and San Matías valleys. Yields in the region increased from an average of 515 kg/ha to 1,545 kg/ha. During the present semester, 500 hectares will be planted with disease-free seed; the single largest plantation of beans will be in Guatemala.

Selections from the ICTA and CIAT germplasm bank were also screened for golden mosaic virus in Guatemala. Of more than 3,000 screened to date, few have shown even limited tolerance.

Collaborative studies were also initiated on the swelling mosaic virus found in Guatemala and El Salvador and reported in Colombia. The virus has been isolated and partially characterized, in vitro and in situ. Screening of the germplasm for resistance to this pathogen was also initiated, and 235 of the 802 collections screened did not show systemic infection. It was also found that the virus was not seed borne but transmitted by at least several species of beetles.

Studies on rooting characteristics as related to drought are presented on page 118. These were done partly at CIAT, partly at La Molina, Peru.

TRAINING

Discipline-oriented training for graduate research scientists from national programs continued to be an important aspect of the bean program in 1974. During the year, the program received two postdoctoral students, four students undertaking doctoral degrees, and nine postgraduate interns from the United States, Germany, Japan and five Latin American countries.

* HERNANDEZ BRAVO, G. and R. HIDALGO. [illegible], 1974. Bancos de germoplasma y su uso. II Congreso Latinoamericano de Genética. Chapingo, México.

CIAT's swine program operates under the assumption that the 100,000,000 head of swine in Latin America play a role in agricultural economy and provide meat protein for humans. The outlook for improving swine production and thus total availability of pork is based on the knowledge that swine production efficiency is low and that it can be improved significantly through proper and adequate use of available feeds, genetic improvement of breeding stock and prevention and control of diseases and parasites. Significant improvements and increases in swine production are possible without increasing either the swine population or to some extent, the present level of feedstuffs being utilized.

Research focuses on development of life-cycle feeding systems based on available feedstuffs, prevention and control of swine diseases and parasites, and development and demonstration of complete swine production systems.

Dietary deficiencies of protein, vitamins and minerals not only are the principal causes of the low level of swine production and the inefficient utilization of major energy sources, but also are the principal factors which determine economics of production and herd health. The program emphasizes evaluation of commercially available and farm-grown protein and energy sources and development of life-cycle feeding systems based on these feed resources.

Demonstrations on small farms show that the feeding of vitreous endosperm high-lysine maize and a protein supplement made available through national institutions has greatly altered the efficiency and economics of swine production. Farmers' native and native crossbred pigs gained more than 400 grams per day and produced a 16 per cent net profit when the new feeding system based on farm-grown high-lysine maize and a protein supplement was used.

Efficient feeding systems have been developed to use fresh cassava, cassava meal or cassava silage. Utilization of these three forms of cassava will make it possible to develop swine production in areas where cassava is the major source of energy for swine. Economics of production will depend on the local demand and price structure of this product.

Offspring of native sows crossed with boars of an improved breed grew at a rate and efficiency equal to that of offspring of the improved breed. This improvement represents less time to market and more economic gains. Results of genetic studies with improved breeds suggested that it would be possible to select lines of pigs that could maintain near optimal performance at dietary protein levels lower than those normally used.

The animal health program has shown that foot-and-mouth disease, diarrhea, abscesses, arthritis and abortions are the diseases that limit swine production most in the region studied. Concentration on these diseases has made it possible to eliminate some of these diseases completely from herds and selected populations, thereby reducing economic losses.

Economic models of monetary losses were developed on three pig farms where outbreaks of foot-and-mouth disease occurred. The calculated losses of US$42,293; $37,007 and $7,339 on the three farms studied clearly indicate the severity and importance of this disease.

Other studies have shown that because of lack of feed resources and credit, it is difficult to improve swine production on

subsistence farms, but that it is more practical on larger farms where more farm-grown feed and credit are available.

Despite this potential for improved efficiency of production and the availability of much of the required technology, institutional and economic constraints—such as lack of trained personnel, deficiencies of infrastructure and regional development programs—are serious barriers to the swine industry.

For these reasons, the CIAT program places major emphasis on the identification of potential areas for swine development, the training of professionals within these areas, and the development of a network of national institutions that would collaborate in the transfer of new technology.

A swine research, teaching and demonstration unit was completed at the Universidad de Bolivia in Santa Cruz, and three professionals were trained to direct the program. Similar projects were initiated in Costa Rica with the Universidad de Costa Rica and with IVITA in Pucallpa, Peru.

HUSBANDRY

Nutrition

Cassava meal

Short—term feeding studies (four weeks) have shown that growing pigs consume less diet based on bitter cassava meal (containing approximately 92 mg/kg of HCN) than those containing sweet cassava meal. A longer term study (12 weeks) has failed to show any deleterious effects of feeding diets based on bitter cassava meal. Pigs fed 16 per cent protein-methionine supplemented diets containing 67 per cent bitter cassava meal during the growing period (20-50 kg) and 13 per cent protein-methionine supplemented diets containing 72 per cent cassava meal during the finishing period grew at an optimum rate and efficiency during the entire growing-finishing period and produced economic gains (Table 1). Neither growth rate, daily feed consumption, feed efficiency nor economic gain was significantly improved by adding either 15 per cent molasses or sugar. These results showed that bitter cassava meal can supply the major portion of the dietary energy and completely substitute for grain in practical diets if properly supplemented with protein and methionine.

Fresh cassava

Fresh cassava, even when it contains only a low level of cyanogenic glucosides, is poorly consumed by growing finishing pigs. Underconsumption of cassava and overconsumption of protein supplement increase the total cost of production.

Studies have continued to develop feeding systems that will make efficient, economical use of fresh cassava in life-cycle

Table 1. Effect of the addition of cane sugar or molasses to bitter cassava meal-based diets on the performance of growing-finishing pigs.

	Bitter cassava meal *		
Production parameters	Control	Sugar	Molasses
Daily gain (kg)	0.81	.82	0.81
Daily feed (kg)	2.65	2.59	2.57
Feed/gain	3.26	3.15	3.17
Feed cost/kg gain ***	13.45	13.23	12.23
Income over feed cost ***	10.55	10.77	11.77

* Sundried bitter cassava (CMC-84)

** Mean of two replications of four pigs each. 84-day trial; avg initial weight, 24.1 kg; avg final weight, [illegible] kg. Diets were isoproteic: 16.0% during first 35 days and 13.0% during last 49 days of trial.

*** Values expressed in Colombian pesos (US$1.00 = $28.20) and calculations based on the following prices per kg: maize, $[illegible]; cassava meal, $1.00; soybean meal, $[illegible]; sugar, $[illegible]; molasses, $[illegible]; rice meal, $3.20; market pigs, $34.00.

Table 2. Performance of pigs fed fresh sweet cassava and a 20, 30 or 40 per cent protein supplement free-choice; growing-finishing phases.

Parameters *	Control 16–13%	Cassava + supplement 20%	30%	40%
		Dietary variables		
Daily gain (kg)	0.63	0.70	0.67	0.66
Daily feed intake (kg)				
Fresh cassava		1.78	2.24	3.32
Supplement	2.08	1.39	1.00	0.79
Total as dry feed	2.08	2.08	2.07	2.04
Feed/gain	3.30	2.97	3.09	3.14
Per cent dry matter as cassava		33.2	51.6	63.0
Daily dig. energy (kcal)	7222	7026	6820	6648
Daily protein intake (kg)	0.27	0.27	0.30	0.31
Per cent protein in diet	14.3	14.6	16.6	17.3

* Mean of five individually fed pigs per treatment; [illegible]-day trial; avg initial weight, 21.1 kg; avg final weight, [illegible] kg

swine nutrition. A trial was conducted to establish the optimum economical level of protein supplement that should be fed free-choice with fresh cassava (Table 2). Each increase in level of protein in the supplements fed was associated with an increase in daily consumption of fresh cassava and a decrease in supplement consumption (Fig. 1). These changes in proportion of cassava-protein supplement consumption had no significant effect on pig growth but did affect feed efficiency, total protein and energy consumption, and percentage composition of the voluntarily consumed diet. The most efficient gains were obtained with fresh cassava and the 20 per cent protein supplement.

Calculations of feed cost for producing a kilogram of liveweight gain based on actual supplement prices and varying prices of cassava (Table 3) indicate that at low cassava prices, there is little variation in cost of production. It is more economical to use cassava and any of the supplements when fresh cassava is not more than one Colombian peso per kilogram ($1,000/metric ton). As the price of cassava increases, it is less desirable economically as a feed.

Ensiled cassava

Studies have continued in cooperation with ICA to develop feeding systems based

Table 3. Feed cost of producing a kilogram of liveweight gain at actual prices of the control diet (16–13 per cent) and of 20, 30 and 40 per cent protein supplement and varying prices of fresh cassava. *

Fresh cassava (price/kg)	Control 16–13% 4.44	Supplement–Price/kg 20% 5.07	30% 6.30	40% 7.54
–	14.35	–	–	–
0.50	–	11.32	11.36	11.30
1.00		12.59	13.40	13.86
1.50		13.87	15.43	16.42
2.00		15.14	17.47	18.97
2.50		16.42	19.50	21.53
3.00		17.69	21.54	24.08

* Values expressed in Colombian pesos (see Table 1) and calculations for the four treatments based on the following quantities of concentrate and cassava: (1) control, 3.30 kg; (2) 1.[illegible] kg of 20% protein supplement and 2.[illegible] kg cassava; (3) 1.48 kg of 30% protein supplement and 4.07 kg cassava; (4) 1.[illegible] kg of 40% protein supplement and [illegible] kg cassava.

Figure 1. Growing-finishing pigs in excellent condition being fed fresh, ground cassava and a protein supplement.

on cassava silage. This practice provides a solution to the frequent harvesting and storage problem of cassava, as well as a standard product that can be fed continuously. Ensiled cassava has been stored for more than a year with a minimum of wastage. This practice simplifies considerably the handling of large volumes of cassava.

A concrete trench silo with a 20-ton capacity has been used. Fresh cassava was chopped, packed into the silo and covered with plastic until the material was fed.

Ensiled cassava was the main energy source for pigs during the growing and lactation periods. Protein supplementation was accomplished by either mixing a 30 per cent protein supplement with the cassava at time of ensiling or by providing the protein supplement in a separate feeder at time of feeding.

Results of the experiment with growing pigs (Table 4) indicate that the performance of pigs fed cassava silage is comparable to that of pigs fed a maize-soybean diet or a fresh cassava-protein supplement diet. Daily gains and feed efficiency were not adversely affected by the use of ensiled cassava and protein supplement fed either mixed or fed free-choice in separate feeders. Mixing the proportions prevents overconsumption of protein and facilitates handling of the diet.

The use of ensiled cassava, plus a 40 per cent protein supplement, was evaluated during a 35 day lactation period and compared with a maize-soybean meal diet or maize and 30 per cent protein supplement fed free-choice (Table 5). All sows gained weight during lactation; however, the increment was larger for the group fed maize-soybean meal diets. Performance of baby pigs during lactation was not affected by the feeding treatment of sows. Litter size and litter weight at weaning were equal or better in the groups from sows fed cassava silage.

Table 4. Performance of growing pigs fed diets based on maize, fresh cassava or ensiled cassava and a 30 per cent protein supplement (P.S.).

Parameters *	Control maize + P.S.	Fresh cassava + P.S.	Fresh cassava Mixed with P.S.	Ensiled cassava + P.S.	Ensiled cassava Mixed with P.S.
Daily gain (kg)	0.68	0.63	0.67	0.65	0.62
Feed/gain **	2.84	2.76	2.98	2.98	2.44
Feed consumption					
Cassava		2.30	2.65	1.94	1.51
Protein supplement	1.93	0.86	0.99	0.97	0.75

* Means of two replications of four pigs each; avg initial weight, 20.2 kg; avg final weight, 52.7 kg

** Based on 90 % dry matter

Table 5. Performance of lactating sows fed maize or ensiled cassava and a 40 per cent protein supplement and compared to those fed a control maize-soybean meal diet.

Parameters *	Control maize-SBM	Ensiled cassava + 40% protein supplement	Maize + 30% protein supplement
Sows			
Farrowing wt (kg)	155.4	140.9	168.5
Weaning wt (kg)	179.7	151.2	182.3
Daily feed (kg) **	4.5	5.8	4.9
Progeny at farrowing			
No. pigs	10.8	10.6	10.0
Individual wt (kg)	1.12	1.09	1.16
Progeny at weaning			
No. pigs	8.1	8.2	7.0
Individual wt (kg)	5.3	5.5	5.0

* Based on 35-day lactation period; nine sows per treatment

** Based on 90% dry matter

Hydrocyanic acid toxicity

The use of cassava in both human and animal nutrition has been complicated by the presence, in both the roots and leaves of this plant, of cyanogenic glycosides which upon hydrolysis release hydrocyanic acid. This toxin can produce deleterious effects on the animal and has been implicated in several human maladies in areas where cassava provides a major portion of the daily food intake.

Previous reports (1973 Annual Report) have indicated that for growing rats and pigs, the level of hydrocyanic acid present in locally grown cassava varieties had little effect on animal health when fed in diets adequate in protein and iodine. It was shown that the animals were capable of detoxifying the HCN to form thiocyanate, which was excreted in the urine, and that methionine supplementation aids in increasing production and excretion of this detoxification compound.

The hydrocyanic acid content of the cassava roots was determined. The cassava sample is hydrolized by the addition of a crude homogenate preparation of linamarase; hydrocyanic acid is subsequently released by distillation and trapped in a carbonate solution. The hydrocyanic acid content is determined colorimetrically by titration with a saturated solution of picric acid. Results indicate that standard hydrolysis techniques without the addition of linamarase failed to estimate total hydrocyanic acid content (Table 6). It appears that a significant proportion of the hydrocyanic acid present in cassava roots is in the form of linamarin, which is not converted to hydrocyanic acid in commonly used analyses.

Recent studies have been established to measure the effect that naturally occurring and higher levels of cyanide may have on the female during gestation and on the health and livability of the fetus of both pigs and rats.

Life-cycle studies on rats fed either dried or fresh bitter cassava, CMC-84 (102 and 622 mg/kg of HCN dry matter, respectively), showed that the birth weight and litter size were not affected by the level of hydrocyanic acid in those treatments (Table 7). These data suggest that there is a placental barrier which protects the fetus from the elevated plasma levels of cyanide or its detoxification products during gestation.

Table 6. Effect of the addition of a crude homogenate of Linamarase on the hydrocyanic acid contents of fresh and dried bitter cassava (CMC-84).

Material	HCN content on: Fresh basis – Linamarase	Fresh basis + Linamarase	Dry matter basis – Linamarase	Dry matter basis + Linamarase
	mg/kg fresh		mg/kg dry matter	
Peel	168.8	272.1	557.0	954.8
Pulp	93.4	179.3	281.4	540.5
Whole tuber	134.0	172.6	482.7	621.8
Dried flour	37.9	92.1	42.1	102.4

When the dams were continued on their respective dietary treatments during lactation, a poorer performance to weaning was observed in offspring of dams on both the fresh and dried meal cassava diets with the poorest performance recorded for those receiving fresh cassava. At weaning, these offspring had an elevated serum thiocyanate concentration, but additional chemical analysis indicated that the activity of the enzyme rhodanese (responsible for the conversion of cyanide to thiocyanate) was not inhibited in either the liver or the kidney.

Postweaning performance and blood data indicate that growth, feed consumption, feed efficiency, protein efficiency ratio, and serum thiocyanate follow a pattern related to the level of hydrocyanic acid in the diet. Those receiving the highest level of hydrocyanic acid had higher levels of serum thiocyanate, but lower feed consumption, body growth and efficiency of protein and feed utilization.

Metabolic and slaughter studies on gestating rats fed the fresh and dried forms of this bitter cassava variety showed an increased urinary and blood thiocyanate, decreased serum protein-bound iodine, and body weight gain of the pregnant rats (Table 8). Slaughter and biochemical analyses

Table 7. Metabolic changes in gestating rats and their fetuses fed fresh and dried bitter cassava (CMC-84) during gestation.

Parameters	Maize starch (control diet)	Fresh cassava diet	Cassava meal diet
Dam			
Weight gain during gestation (g)	60.80	35.20	42.00
Amniotic fluid thiocyanate (mg/100 ml)	0.55	1.20	0.88
Plasma thiocyanate (mg/100 ml)	1.60	2.87	1.89
Urinary thiocyanate (mg excreted per day)	0.34	4.08	0.65
Serum protein bound iodine (µg)	3.50	2.60	2.90
Rhodanese activity (mg thiocyanate/min/g protein):			
Liver	28.09	32.61	28.97
Kidney	23.10	21.36	20.86
Placenta	0.60	0.60	0.55
Fetus			
Fetal rhodanese activity	3.71	3.91	4.01
Fetal thiocyanate (mg/g)	0.15	0.07	0.14

Table 8. Rat performance on bitter cassava diets during gestation, lactation and growth.

Parameters	Maize starch (control diet)	Fresh cassava diet	Cassava meal diet
Gestation and lactation performance			
Litter size (No.)	10	9	10
Birth wt (g)	6.2	6.3	6.0
Weaning wt (g)	34.2	28.7	30.1
Suckling rats			
Serum thiocyanate (mg/100 ml)	1.39	2.34	1.36
Rhodanese activity			
(mg thiocyanate/min/g protein):			
Liver	28.2	35.9	28.9
Kidney	25.2	23.5	23.0
Postweaning performance of offspring*			
Daily postweaning growth rate (g)	4.5	2.2	3.9
Feed consumption (g)	13.5	11.7	12.9
Feed efficiency ratio	3.0	5.3	3.3
Protein/gain	2.2	1.3	2.0
Serum thiocyanate (mg/100 ml) of rats 28 days postweaning	1.32	3.06	2.01
Rhodanese activity			
(mg thiocyanate/min/g protein):			
Liver	33.1	36.7	40.6
Kidney	28.2	25.2	28.9

* 28 day performance.

on these female rats in the last trimester of pregnancy indicate that even the high hydrocyanic acid cassava diets have no effect on the thiosulfate-cyanide sulfur transferase (rhodanese) activity of the liver, kidney, placenta and fetus. A slight rise in amniotic fluid thiocyanate was observed, but there was no increased thiocyanate transfer into the fetus of the rats fed the cassava diets. This finding confirms the generally accepted hypothesis that, in spite of the constant interaction between the maternal organism and the fetus, the placenta protects the latter by selective absorption of nutrients for its development. Studies are being continued with both pigs and rats to determine if higher levels of hydrocyanic acid break down the system and result in deleterious effects on the fetus.

Maize

Previous reports (1973 Annual Report) on the nutritive value of a vitreous endosperm high-lysine maize variety (VE-21) suggested that its slightly lower nutritive value was the result of a lower lysine content than that contained in the control maize, a soft endosperm opaque-2 (H-208). A rat-feeding trial confirmed the suggestion which was based on chemical analyses. Experimental diets prepared from whole kernels of the vitreous endosperm high-lysine maize variety (VE 21) were supplemented with either 0.05 per cent tryptophan and/or 0.1 per cent lysine and were compared to a control diet prepared from whole kernels of a soft endosperm opaque-2 (H-208). The performance of the rats fed the lysine-supplemented vitreous endosperm high-lysine maize diets was similar to those fed the opaque-2 diet, but the addition of tryptophan alone did not benefit performance (Table 9).

Rice meal

Rice is the most important food crop in Asia and plays an important role in the nutrition of millions of people in Latin America. The annual production is estimated to be more than 295 million metric tons in the world and more than 11.5 million in Latin America. A wide variety of by-products arise from the milling of paddy rice to produce polished rice for human consumption. In particular, the bran and polishings make valuable animal feeds.

The bran consists of the rice bran and germ. Rice polishings are the finely powdered materials obtained in polishing rice kernels after the bran and germ have been removed. In Latin America, the total production of these by-products amounts to more than 941 thousand metric tons per year.

Although there are some rice mills which produce both rice bran and polishings, many mills do not separate these two fractions; therefore, what is termed "rice bran" or "rice meal" is usually a mixture of bran, polishings and hulls.

It is generally agreed that for growing-finishing pigs, 30 to 40 per cent rice meal can be used in the diet without altering rate and efficiency of growth. Higher levels reduce feed intake, growth rate and reduce efficiency of feed utilization. It would be advantageous in many areas of Latin America and Asia to maximize the utilization of this by-product, especially in areas where its price is significantly lower than grain and other energy sources.

Studies have been initiated to determine the factors which limit the efficient utilization of high levels of rice meal in life-cycle swine feeding systems. Initially a trial was conducted to measure the effect of graded levels of rice meal on the performance of growing pigs (Fig. 2). Levels of 0, 15, 30, 45 and 60 per cent rice meal containing 13.2 per cent crude protein were included as a substitute for maize in the control diet. The results (Table 10) showed no significant change in performance at levels of rice meal up to 45 per cent. The highest level (60 per cent) significantly reduced pig growth.

Because of a crude protein level higher than that of maize or sorghum, for which it is substituted, small quantities of protein supplement (fish meal, soybean meal, etc.) are needed to provide the required protein level in the diet. This reduced level of supplemental protein required would suggest that the amino acid balance of the diet is altered. Table 11 summarizes the results of a second trial which indicate that neither level of supplemental protein nor amino acid balance appears to be a major factor in reference to the depression in pigs' performance, observed when high levels of rice meal are included in the diet. Similar results were obtained when 60 per cent rice meal was included in the diet at both 16 and 18.85 per cent dietary protein levels. The

Table 9. Effect of tryptophan and lysine supplementation on the nutritive value of vitreous high-lysine maize (VE-21) in rats.*

% dietary protein	Experimental variables	Total gain (g)	Feed/gain	PER**
9.8	Opaque 2 (H 208)	90.5	4.50	2.28
8.7	Vitreous high-lysine (VHL)	69.3	5.17	2.24
8.7	VHL + 0.05% Tryptophan (Trp)	66.4	5.39	2.18
8.7	VHL + 0.1% Lysine (Lys)	89.0	4.52	2.56
8.7	VHL + 0.05% Trp + 0.1% Lys	91.4	4.49	2.56

* Means of six rats per group; 28-day experimental period ; avg initial body weight, 57.4 ± 0.4 g
** Protein efficiency ratio.

Figure 2. Pigs receiving diets based on rice meal to determine the factors which limit its efficient utilization when fed at high levels.

performance of all groups of pigs fed high levels of rice meal was inferior to the control diet containing maize as the basic grain source. These high levels of rice meal reduced daily feed intake and improved feed efficiency. All diets containing 60 to 77.7 per cent rice meal supported more economical gains than the control (maize-soybean meal) diet.

Much of the variation in results observed in the performance of pigs fed diets containing high levels of rice meal is associated with the quality of the product. Rice meal is highly variable in quality, depending mainly on the quantity of hulls included. The deleterious effect of hulls results from their high fiber and silica content and their low digestibility which limit dietary energy concentration. Adulteration or poor mill efficiency is responsible for the hull content of rice meal.

In trials established to measure the effect of known levels of rice hulls in rice meal, it was shown that increasing levels of rice hulls in the rice meal had little effect on pig growth (Table 12). Each increase in hull level (0, 10, 20, 30, 40 per cent of rice meal) was associated with a linear increase in daily feed consumption and in quantity of feed required to produce a kilogram of liveweight gain. Even if rice meal prices are adjusted to reflect the lower quality associated with hull adulteration, because of reduced efficiency of protein and energy utilization caused by the incorporation of rice hulls, feed cost per unit gain increases as the level of hulls is increased.

Although lower gains and daily feed consumption were recorded when rice meal was used as the only source of protein and energy for finishing pigs (Table 13), these gains were more economical than those for pigs fed either rice meal supplement diets with higher protein or diets based on maize and soybean meal.

Although previously reported studies have indicated that diarrhea is a problem when high levels of rice meal are fed to pigs, at

Table 10. Performance of growing pigs fed varying levels of rice meal as a replacement for common maize.*

Treatments**	Avg daily gain (kg)	Avg daily feed (kg)	Feed/ gain	Feed cost/*** kg gain ($)
Level of rice meal (%)****				
0	0.70	1.91	2.71	11.30
15	0.71	1.85	2.59	10.57
30	0.70	1.93	2.78	11.09
45	0.71	1.83	2.57	10.05
60	0.62	1.81	2.89	11.04

* Mean of five individually fed pigs per treatment; 42-day trial; avg initial weight, 20.4 kg; avg final weight, 49.5 kg

** Isoproteic diets: 16% crude protein

*** Feed cost expressed in Colombian pesos. Feed costs based on values Table 1 (footnote ***).

**** Rice meal contained 13.2% protein.

Table 11. Performance of growing pigs fed rice meal diets* containing varying levels of protein supplementation.**

Protein level (%)	Rice meal level (%)	Average daily gain (kg)	Average daily feed (kg)	Feed/ gain	Feed cost/*** kg gain ($)
16.00	0****	0.73	2.05	2.81	11.97
18.85	77.7	0.60	1.56	2.62	10.56
16.00	60.0	0.64	1.76	2.74	10.66
18.85	60.0	0.64	1.73	2.72	11.26
16.00	60.0 + sugar	0.67	1.75	2.60	10.48

* Rice meal contained 13.2% crude protein

** Mean of two replications of four pigs per group: 42 day-trial initial weight 20.15 kg

*** Cost expressed in Colombian pesos. Feed cost based on values in Table 1 (footnote ***)

**** Control diet based on maize

Table 12. Performance of growing pigs fed rice meals containing varying levels of rice hulls.*

Rice hull level** (%)	Protein level*** (%)	Average daily gain (kg)	Average daily feed (kg)	Feed/ gain	Feed cost/ **** kg gain ($)
0	18.75	0.62	1.68	2.71	11.90
10	18.03	0.66	1.67	2.54	10.67
20	17.30	0.67	1.91	2.84	11.39
30	16.60	0.64	2.00	3.11	11.85
40	15.80	0.61	2.17	3.54	12.81

* Mean of two replications of five pigs per group, 49-day trial

** Rice hull level expressed as percentage of rice meal

*** All diets contained equal quantities of soybean meal.

**** Feed cost expressed in Colombian pesos and calculations based on values in Table 1 (footnote ***)

Table 13. High levels of rice meal in diets for finishing pigs.*

Dietary variables		Parameters			
Protein level (%)	Rice meal** level (%)	Average daily gain (kg)	Average daily feed (kg)	Feed/gain	Feed cost/*** kg gain ($)
12.5	0	0.80	2.81	3.51	13.76
15.3	87.45	0.70	2.36	3.36	12.30
12.5	95.20	0.64	2.25	3.52	11.86

* Means of two replications of three pigs each; 42-day trial;avg initial weight, 52.1 kg; avg final weight, 82.1 kg

** Rice meal contained 13.2% crude protein

*** Expressed in Colombian pesos. Feed cost calculations based on values in Table 1 (footnote ***).

no time was diarrhea observed in any of the experiments. This observation may reflect the fact that only fresh rice meal was used in the diets, and at no time was it allowed to become rancid.

Yams and malanga

Previously reported information (1973 Annual Report) indicated that the consumption of raw yams by rats resulted in gastrointestinal distension, whereas rats fed cooked yams did not exhibit this abnormality. A study was undertaken to determine the effect of cooking time on the nutritive value of yams (Dioscorea alata). Yams were boiled for 15, 30 and 45 minutes, respectively, and then oven dried at 60°C. These dried yams were ground and incorporated as the only energy source (78 per cent of diet) into rat diets prepared to supply 14.0 per cent crude protein. These diets were compared to similar diets prepared from raw yams (Table 14). Cooking time had no effect on the growth rate of the rats; a cooking period of 15 minutes appeared to be sufficient to eliminate the factor(s) responsible for the gastrointestinal distension observed when yams were fed raw. Rats fed the diet based on raw yams consumed significantly more diet than those fed cooked yams, but apparent body weight gains were lower.

Dissection of the experimental animals at the end of the feeding trial indicated that the weight of the gastrointestinal tract of rats fed raw yams was twice that of rats fed cooked yams (Table 14).

Raw yam meal was also poorly used by growing pigs; however, cooked yam meal

Table 14. Effect of cooking time on the nutritive value of yams (D. alata) for growing rats.*

Parameter	Raw yams	Yams cooked for (minutes) 15	30	45
Total wt gain (g)	118.60	122.30	124.80	124.90
Total feed (g)	653.40	420.30	473.50	441.80
Feed/gain	5.51	3.44	3.79	3.54
Final body wt (g)	163.60	167.20	169.80	169.90
Gastrointestinal tract (GIT) **				
Total wt (g)	23.9	10.6	13.9	11.2
Relative to body wt (%)	14.6	6.3	8.2	6.6

* Eight rats per group; 28-day experimental period. Diets calculated to contain 14.0% crude protein. Yams were oven dried at 60°C.

** Means of eight rats per group sacrificed at the end of the experimental period

Table 15. Nutritive evaluation of meals of raw and cooked yams in diets for growing pigs.*

Parameters	Control common maize	Experimental variable: Yam meal, Raw sun dried	Yam meal, Cooked ** oven dried
Daily gain (kg)	0.72	0.51	0.76
Daily feed (kg)	1.83	1.73	1.92
Feed/gain	2.53	3.40	2.53

* Means of two replications of three pigs each; 35-day trial;avg initial weight, 19.7 kg; avg final weight, 42.9 kg

** Boiled for 20 minutes, followed by oven drying at 60°C

could be used to replace common maize in the diet (Table 15). The feed consumption pattern of pigs fed the raw yam meal was different from that observed for rats, in that the pigs consumed less of this diet than they did of the cooked yam meal diet. Feed conversion for the pigs fed the maize and the cooked yam meal-based diets was similar.

A feeding trial with growing rats was established to determine the potential of malanga or taro (Colocasia esculenta) as an energy source for swine feeding. Rats fed diets containing either sun-dried or oven-dried raw malanga consumed significantly less feed and grew at a slower rate than with either the control diet based on cassava meal or the malanga meal diet prepared from boiled malanga (Table 16). Gastro-intestinal distension was not observed in rats fed raw malanga-based diets.

Grain legumes

Availability of protein sources for supplementing farm grown grains and other energy sources for efficient swine production presents a problem on small farms. Where possible, national organizations have prepared and made conventional protein supplements based on soybean meal, cottonseed meal, fish meal, etc. available in small quantities to small farmers. The development of farm-grown sources of protein to meet this need would greatly facilitate swine production on these farms.

The basic grain legumes grown in these areas that might meet this need are soybeans, cowpeas, beans and pigeon peas. Previously reported work (1973 Annual Report) has shown that cowpeas and soybeans can be used to supplement a variety of feedstuffs. Work has also established that the nutritive value of the locally available varieties of pigeon peas is too poor to provide adequate supplementation. Data are not available to assess the value of beans as a protein source for dietary supplementation, but studies have been concluded to indicate the nutritive value of cull black beans as a protein supplement for pigs' diets. Tables 17 and 18 summarize the results of these studies and provide evidence that the variety of black bean used was not an adequate supplement for sorghum-based swine and rat diets and that the concentration of anti-metabolites in this bean is high and requires more extensive processing before utilization.

The initial study with growing pigs (Table 17) demonstrated that the protein value of

Table 16. Effect of cooking and drying methods on the nutritive value of malanga (Colocasia esculenta) for rats.*

Experimental variable	% prot. diet	Total body gain (g)	Total feed intake (g)	Feed/gain
Cassava meal	14.2	131.5	439.7	3.34
Malanga meal				
Cooked, oven dried**	14.1	118.0	427.4	3.62
Raw, sun dried	14.4	93.0	339.4	3.65
Raw, oven dried	14.5	93.8	357.4	3.81

* Means of seven individually fed rats per group; 28-day experimental period

** Boiled for 30 minutes, oven dried at 60°C

Table 17. Value of one variety of cull black beans as a replacement for soybean meal in sorghum-based diets for growing pigs.

Dietary variables	Protein supplement: Soybean meal	Soybean meal + beans	Black beans
Diet composition *			
Sorghum (%)	75.3	66.7	56.5
Soybean meal (%)	19.9	10.8	–
Black beans (%) **	–	17.7	38.7
Production parameters ***			
Daily gain (kg)	0.6[illegible]	0.51	0.12
Daily feed (kg)	1.77	1.56	0.88
Feed/gain	2.55	3.02	7.56

* In addition, all diets contained the following ingredients: 4.0% bone meal, 0.5% mineral premix and 0.3% vitamin premix.
** Beans boiled for 20 minutes, then oven dried at 60°C
*** Mean of two replications of four pigs each; 14-day trial;avg initial weight,20.8 kg

cull black beans as a supplement to sorghum grain was less than 20 per cent of that of soybean meal when it supplies all or 50 per cent of the supplemental protein.

A subsequent study with rats (Table 18) established that these beans must be boiled at least 30 minutes–preferably 45–before the toxic antimetabolites were destroyed. Cull beans prepared in this way (boiling 45 minutes) were then included in diets for growing pigs to reevaluate their adequacy as a protein supplement to sorghum grain. These diets were prepared with and without sugar and the amino acids previously shown (1973 Annual Report) to be limiting (Table

Table 18. Effect of cooking time on nutritive value of black beans.*

Experimental variable	Total gain (g)	Feed gain	PER
Cooking time (minutes)			
0 **	–		–
15	0.5	126.3	0.02
30	18.6	12.1	0.93
45	21.3	11.0	1.04
60	22.7	8.6	1.20

* Mean of eight rats per treatment; 28-day trial
** All rats fed crude beans died before termination of experiment.

Table 19. Effect of the addition of sugar and amino acids to cull black bean and sorghum diets on performance of growing pigs.*

Dietary variable	Average daily gain (kg)	Average daily feed (kg)	Feed/gain
Sorghum + soybean meal (SBM)	0.82	2.33	2.83
Sorghum + SBM + beans**	0.57	1.84	3.22
Sorghum + beans	0.28	1.20	4.32
Sorghum + beans + sugar	0.16	0.96	6.11
Sorghum + beans + amino acids (AA)***	0.41	1.35	3.31
Sorghum + beans + sugar + AA	0.48	1.54	3.24

* Mean of two replications of three pigs per treatment
** Beans cooked for 45 minutes, then oven dried (60°C)
*** Amino acids added: 0.3% lysine, 0.2% methionine, 0.1% threonine and 0.05% tryptophan

Table 20. Effect of cooking and ensiling on the utilization of soybeans and cowpeas in cassava diets for growing rats.*

Treatment	Average daily gain (g)	Average daily feed (g)	Feed/gain	PER
Soybeans				
Soybean meal + cassava starch	2.55	10.8	4.3	2.24
Cooked soybeans + cassava **	2.26	9.1	4.1	2.61
Raw soybeans + cassava **	0.30	5.6	25.8	0.52
Cooked soybeans + ensiled cassava ***	1.64	7.3	4.6	2.24
Raw soybeans + ensiled cassava ***	0.55	5.4	12.4	0.92
Cowpeas				
Soybean meal + cassava starch	2.33	10.5	4.6	2.28
Cooked cowpeas + cassava **	2.10	10.1	4.8	1.79
Raw cowpeas + cassava **	1.56	9.0	5.8	1.63
Cooked cowpeas + ensiled cassava ***	1.35	7.6	5.8	1.54
Raw cowpeas + ensiled cassava***	0.45	5.3	12.8	0.76

* Mean of seven individually fed rats per treatment; 28-day trial
** Mixture oven dried without ensiling
*** Mixture ensiled for one month and oven dried at 60°C

19). It was shown that more complete processing and supplementation with lysine, methionine, threonine and tryptophan significantly improved growth, feed intake and efficiency of feed utilization. However, this improvement was not sufficient to make cull black beans either biologically or economically competitive with the control supplement (soybean meal).

Both cowpeas and soybeans have been shown to supplement adequately a variety of energy feeds for pigs. Because of the presence of antimetabolites, both require

Table 21. Effect of ensiling and methionine supplementation on the utilization of raw cowpeas-cassava for growing rats. *

Treatments	Average daily gain (g)	Average daily feed (g)	Feed/gain	PER
Raw cowpeas + cassava **				
0.0% methionine	1.33	8.8	6.7	1.37
0.1% methionine	2.79	11.7	4.3	2.12
0.2% methionine	3.09	12.3	4.0	2.36
Soybean meal + cassava starch	2.84	11.8	4.2	2.03
Raw cowpeas + ensiled cassava ***				
0.0% methionine	0.35	8.4	24.8	0.39
0.1% methionine	1.63	11.2	6.9	1.31
0.2% methionine	1.60	10.1	6.4	1.50
Soybean meal + cassava starch	2.51	11.7	4.7	2.02

* Mean of five individually fed rats per treatment
** Mixture oven dried without ensiling
*** Mixture ensiled for one month and oven dried at 60°C

heat processing for efficient utilization. Under farm conditions, boiling or other forms of heat processing introduce additional costs. Simpler, on-the-farm methods of processing, if workable, would provide the farmer with alternatives. It has been considered that two processing methods, germination and ensiling, might be feasible. Previously reported work (1972-73 Annual Reports) has shown that germination produces variable and insufficient improvement to justify its use at the farm level.

Results of studies undertaken to measure the effect of ensiling on the destruction of the antimetabolites of cowpeas and soybeans have not been promising. It has been shown, in fact (Tables 20 and 21), that the ensiling process not only fails to inactivate the antimetabolites, but also significantly reduces the nutritive value of both cowpeas and soybeans in the presence or absence of supplemental methionine. Methionine supplementation in raw or ensiled cowpea preparations was shown to improve animal performance significantly, but exerted a greater positive effect when fed with unprocessed raw cowpeas.

As in other protein sources, variations exist in cowpea varieties as far as their protein level, concentration of specific amino acids and antimetabolites, and nutritive value are concerned. The nutritive values of ten varieties of cowpeas grown at the same time and under the same soil and enviromental conditions were compared (Table 22). Results obtained clearly demonstrated the significant variations in nutritive value that exist among these ten varieties.

Table 22. Comparison of the nutritive value of different varieties of cowpeas (Vigna sinensis).

	Chemical analyses		Rat performance *			
	Protein (%)	Sulfur (%)	Total gain (g)	Total feed (g)	Feed/gain (g)	Protein gain (PER)
Raw Cowpeas						
Zipper Cream	24.52	.206	54.9	314.9	5.80	1.74
P7-PER15	27.81	.226	50.2	314.2	6.38	1.60
P10-PER23	25.85	.241	31.0	270.0	8.94	1.14
P11-PER24	25.83	.227	26.5	255.0	10.07	1.05
P13-VAL4	26.66	.263	14.7	242.9	17.84	0.61
P14-VAL5	27.73	.275	32.4	241.3	7.92	1.32
P15-VEN8S-1-M	26.75	.253	35.0	287.1	8.25	1.22
P16-VEN9	28.95	.262	20.4	219.1	11.38	0.92
P17-VEN12	25.95	.236	28.6	246.1	9.21	1.15
P18-VEN12A	27.81	.230	38.8	279.5	7.40	1.37
Average	26.79	.242	33.3	267.0	9.32	1.21
Cooked Cowpeas						
Zipper Cream	25.00	.199	84.8	380.3	4.52	2.22
P7-PER15	28.38	.220	69.2	338.8	4.98	2.03
P10-PER23	26.10	.241	68.0	350.8	5.17	1.94
P11-PER24	25.97	.237	59.5	325.1	5.49	1.83
P13-VAL4	29.18	.268	51.0	288.6	5.96	1.77
P14-VAL5	28.02	.273	67.5	312.4	4.66	2.16
P15-VEN8S-1-M	28.02	.230	73.8	354.1	4.82	2.09
P16-VEN9	28.77	.250	67.7	317.6	4.76	2.12
P17-VEN12	26.04	.233	82.7	381.5	4.64	2.17
P18-VEN12A	28.65	.232	66.3	352.8	5.35	1.89
Average	27.46	238	69.1	340.2	5.04	2.02

* Mean of eight individually fed rats per treatment except for treatments utilizing Zipper Cream, whic * had a mean of 24 rats

Table 23. Proximate analyses of the following meals: cassava leaf, Desmodium, Glycine wightii (perennial soy) and soybean.

Constituent	Cassava leaf (%)	Desmodium (%)	G. wightii (%)	Soybean meal (%)
Dry matter	93.1	91.5	90.0	90.0
Crude protein (N x 6.25)	20.6	19.4	17.4	49.0
Ether extract	5.7	4.9	4.6	1.6
Crude fiber	24.6	24.0	25.9	4.3
Ash	8.5	11.0	9.5	7.8

For example, Zipper Cream supported the highest rat performance when compared with the other varieties, either raw or cooked. On the other hand, P17-VEN 12 was among the varieties with lower nutritive value when fed raw, but similar to the best variety, Zipper Cream, when properly processed to detoxify the antimetabolites.

It has been indicated (1972 Annual Report) that the total sulfur content of beans is correlated with sulfur amino acid content and thus with the nutritive value of the bean; consequently, total sulfur determinations were made on these ten cowpea varieties, and the values obtained were correlated with the performance data of the rats. It was shown that both growth rate and feed intake are negatively and significantly correlated with total sulfur content (r^2 = -.42; r^2 = -.54, respectively). These negative correlations would appear to indicate that cowpeas do not follow the same pattern as beans; furthermore, much of the sulfur content is associated with the presence of trypsin-inhibitor and not with the sulfur amino acid content. This difference is further supported by the negative correlation between total sulfur and methionine contents.

Leaf protein sources

Protein-rich feedstuffs are usually the most expensive ingredients of swine rations, to the extent that some of them, such as fish meal, cannot be economically included in diets for domestic animals. Because of their nutritional and economic importance, the search for nonconventional protein sources which can completely or partially replace the conventional sources in practical diets for pigs was continued.

Forage legumes have been evaluated as possible sources of supplemental protein. The chemical compositions of the three studied are presented in Table 23. Desmodium meal has been used in rations (16 per cent crude protein) for growing pigs at levels of 10, 20 and 30 per cent of the diets. Each increase in level of Desmodium meal resulted in a proportional linear depression in body weight gain, feed intake and efficiency of feed conversion, as compared with those on the control diet (Table 24). These results confirmed experimental data obtained with growing rats (1973 Annual Report). Protein quality, digestible energy and palatability appear to

Table 24. Evaluation of Desmodium meal in diets for growing pigs.

Parameters *	Percentage Desmodium meal in diet **			
	0	10	20	30
Daily gain (kg)	0.71	0.64	0.57	0.50
Daily feed intake (kg)	1.93	1.82	1.77	1.56
Feed/gain	2.73	2.87	3.09	3.11

* Means of six individually fed pigs per treatment; 42-day trial; avg initial weight, 18.8 kg; avg final weight, 42.2 kg

** Desmodium meal contained 19.9% crude protein determined by Kjeldahl analysis; all diets were calculated to contain 16.0% crude protein.

Table 25. Effect of dietary replacement of soybean meal with perennial soy meal on the performance of growing rats.*

Dietary variable		Average daily gain (g)	Average daily feed (g)	Feed/ gain	P E R
Percentage of total protein					
Soybean meal	Perennial soy meal				
100	0	4.42	14.91	3.41	1.97
90	10	4.33	15.89	3.70	1.82
80	20	4.24	15.70	3.75	1.79
70	30	3.70	15.24	4.16	1.62
60	40	3.50	15.35	4.47	1.51
50	50	3.19	15.32	4.85	1.39

* Means of 10 individually fed rats per treatment, obtained during 28-day experimental period

be responsible for the growing pigs' poor utilization of high levels of meals prepared from forage legumes.

Preliminary observations have been obtained on the nutritive value of perennial soy (**Glycine wightii**) meal as a replacement for soybean meal protein in diets for growing rats. Replacement protein levels of 10 and 20 per cent resulted in performance of rats similar to that of rats fed the control diet (Table 25). Further increases in the level (30, 40 and 50 per cent) of perennial soy meal significantly depressed rat growth. The dietary treatments did not affect feed consumption greatly. Rats fed the diets containing perennial soy meal consumed consistently more feed than those on the control diet; consequently, feed conversion and protein efficiency ratio were significantly lower for the rats on perennial soy meal diets.

Measurements of the yield of cassava for forage production (1973 Annual Report) suggested that cassava tops or leaf production may have a potential for animal nutrition. Because of the present limited availability of cassava leaf material, growing rats were used in the initial nutritive evaluation studies. Replacement of 50, 75 and 100 per cent of the total dietary protein by cassava leaf protein drastically depressed rat growth. Rats fed a diet in which cassava leaf meal supplied all of the dietary protein gained only 18.1 grams in a 28-day experimental period, as compared with 93.9 and 83.0 grams of gain by rats receiving all the diets in which dietary protein was supplied by casein and soybean meal, respectively (Table 26). Feed conversion and protein efficiency ratio were depressed as the protein supplement levels by cassava leaf meal increased. These results indicate that diets supplying all or most of the protein, such as cassava leaf meal, would be inefficient for growing, monogastric animals.

Table 26. Summary of results of nutritive evaluation of cassava leaf meal in diets for growing rats.*

Percentage of protein combination		Total wt gain (g)	Feed/ gain	P E R
100% casein protein		97.9	3.23	3.12
Soybean meal	Cassava leaf meal			
100	0	83.0	3.96	2.55
50	50 **	54.1	5.42	1.87
25	75 **	41.4	6.25	1.64
0	100	18.1	10.84	0.94

* Means of seven rats per treatment, unless otherwise indicated; 28-day experimental period; avg initial body weight, 36.7 g

** Means of six rats per treatment

It has been suggested that methionine is the most limiting amino acid in cassava leaf material. Previous experiments have also indicated that at high levels of incorporation of forage meals, digestible energy is an additional limiting factor. In a factorial experiment, the effect was studied of methionine and maize oil supplementation of rat diets in which 50 and 75 per cent of the protein were supplied as cassava leaf meal. Levels of 0 and 0.2 per cent DL-methionine and of 2.0 and 12.0 per cent maize oil were used as the factorial variables. Results clearly indicate that methionine supplementation was nutritionally more important than the energy supplementation, in the form of maize oil, at both levels of cassava leaf meal in the diets (Table 27).

Rats fed the methionine-supplemented diets performed better at both levels of maize oil supplementation than those without methionine supplementation. The addition of 0.2 per cent DL-methionine to diets in which 75 per cent of the protein was supplied as cassava leaf meal produced results approaching those obtained with the basal diet containing 50 per cent of the protein as cassava leaf meal and 2 per cent maize oil. The addition of higher levels of maize oil (12.0 versus 2.0 per cent) was detrimental to rat performance, resulting in *a depression in both growth and feed intake.*

Life-cycle swine feeding

Feed cost is the most important economic factor in swine production, and the efficiency of production will depend mainly on the proper use of available feedstuffs. In most of the areas where a swine production potential exists, maximum utilization of locally available feedstuffs will have to be made throughout the life cycle of the pig. The program's stepwise evaluation of feedstuffs is oriented to the development of integrated life-cycle feeding systems.

Sufficient information is already available on the use of such ingredients as opaque-2 maize and cassava in swine feeding, but little information exists on their continued use during the complete life cycle of the pig. Superior protein quality of opaque-2 maize permits the formulation of efficient diets with lower protein levels than the requirement normally established, but insufficient information is available on the

Table 27. Effect of methionine and maize oil supplementation to cassava leaf meal (CLM)-based diets for growing rats.*

Dietary variable	Body gain (g)	Feed (g)	Feed/ gain	P E R
Control: soybean meal (SBM)	100.4	382.1	3.80	2.64
Percentage of protein combination				
50% SBM + 50% CLM				
0% Met + 2% maize oil	58.6	321.8	5.51	1.82
0% Met + 12% maize oil	35.4	227.4	6.53	1.56
0.2% Met + 2% maize oil	62.4	315.9	5.10	1.97
0.2% Met + 12% maize oil	43.2	237.4	5.80	1.78
25% SBM + 75% CLM				
0% Met + 2% maize oil	25.9	213.5	8.60	1.21
0% Met + 12% maize oil	14.6	167.7	13.36	0.86
0.2% Met + 2% maize oil	52.4	307.2	6.15	1.68
0.2% Met + 12% maize oil	41.1	256.1	6.73	1.57

* Mean of eight rats per group. All diets contained 10% crude protein; 28-day experimental period

Table 28. Scheme of dietary variables used to evaluate cassava meal, opaque-2 and common maize in life-cycle swine nutrition.

Life-cycle periods	Experimental variable * Common maize	Opaque-2	Cassava meal
	Percentage crude protein in diets		
Growing (20 50 kg)	16.0	13.0	16.0
Finishing (50 -90 kg)	13.0	8.9 **	13.0
Pre-gestation (90 120 kg)	13.0	8.9 **	13.0
Gestation	16.0	8.9 **	16.0
Lactation	16.0	13.0	16.0
Baby pig, starter (3–20 kg)	18.0	15.0	18.0

* Soybean meal will be used as protein ingredient in these diets.
** Opaque-2 was used as the only energy and protein source.

long-term effects. A similar situation also exists related to the long-term feeding of cassava meal.

A long-term experiment has been undertaken to study the use of sweet cassava meal and opaque-2 maize as basic ingredients in diets for life-cycle feeding programs and to compare them with a control feeding system based on common maize. Table 28 shows the sequence of the experimental diets for the different periods of the life cycle. Soybean meal was used as the common protein ingredient for all diets requiring protein supplementation.

Animals fed the cassava meal-based diets grew at a slightly slower rate than did pigs fed either common maize- or opaque-2 based diets (Table 29). This reduced growth rate was probably a consequence of a slightly lower feed intake during these periods. Animals fed the cassava meal-based diet utilized their feed less efficiently than the pigs of the other two groups. The average feed intake and quantities of maize, cassava meal and soybean meal consumed by each treatment group is presented in Figure 3.

Pigs fed opaque-2 maize-based diets needed only 29 per cent as much soybean meal as that required by the pigs on the control diet, whereas animals fed the cassava meal diets required twice the quantity of soybean meal as compared to the control group. Economical evaluation of feeding systems based on the use of cassava will be highly dependent on its cost as well as that of protein supplements, whereas feeding systems based on opaque-2 will be less dependent on the cost of protein ingredients.

Table 29. Cassava meal, opaque-2 and common maize in life-cycle swine nutrition. Performance of growing-finishing period.

Parameters *	Experimental variable Common maize	Opaque-2	Cassava meal
Crude protein in diets (%)	16.0-13.0	13.0-8.9	16.0-13.0
No. of gilts	15 **	16	16
Daily gain (kg)	0.77	0.76	0.71
Daily intake (kg)	2.38	2.33	2.30
Feed/gain	3.09	3.07	3.24

* Average initial weight, 21.4 kg; average final weight, 89.5 kg
** One gilt died a week after the end of the growing period.

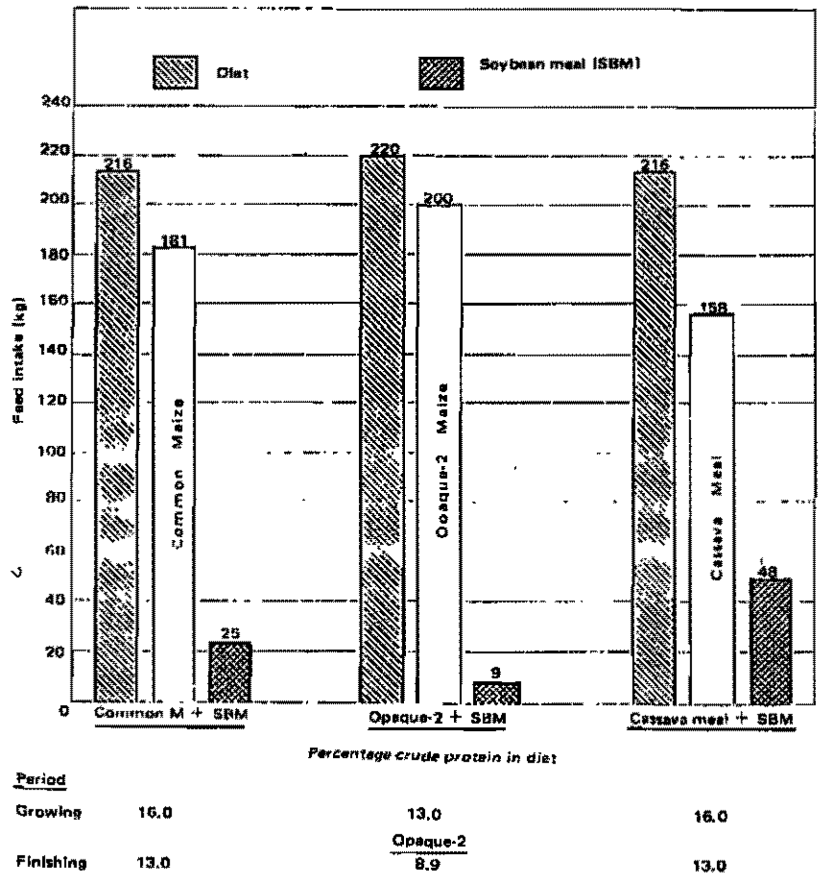


Figure 3. Sweet cassava meal, opaque-2 and common maize in life-cycle swine nutrition. Feed intake growing-finishing periods.

The experimental animals are now finishing the gestation period (Fig. 4) and the remaining information including the reproductive phase will be available in the near future.

Genetics

Genetic improvement of native breeds

Most pigs grown on small farms in Latin America are of native breeding. The performance of these pigs on farms is poor. However, the interaction of management, nutrition, health and genetics has made it difficult to determine the genetic potential of these animals. Studies have been established to measure the performance of these animals and to determine the value of crossing them with improved breeds. These studies are being carried out at the Turipaná Station in Montería, Colombia, in collaboration with the Instituto Colombiano Agropecuario (ICA).

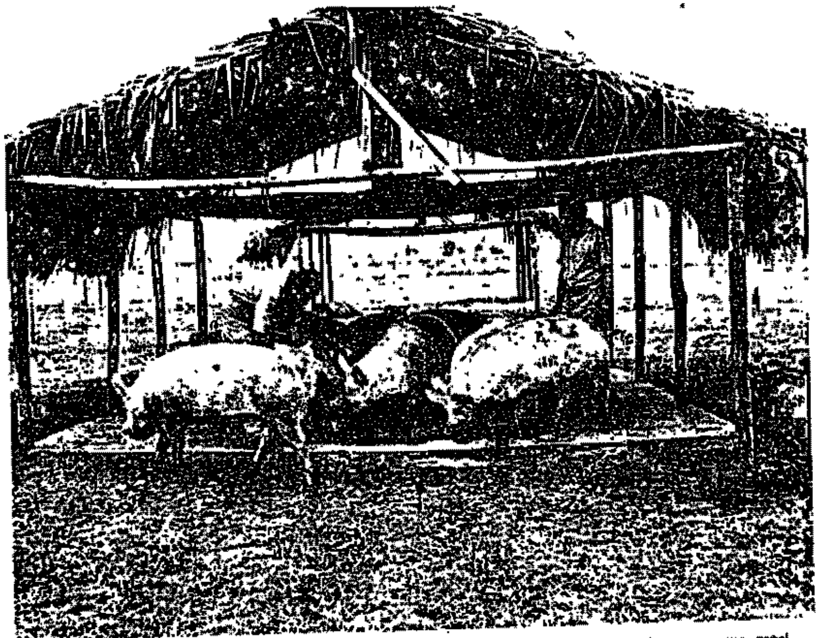


Figure 4. Gestating gilts that have been fed since weaning on diets based on cassava meal.

Native sows and boars, representative of the Zungo Pelado breed commonly raised in the coastal region of Colombia, were selected. Since research facilities were not adequate to compare the Zungo with several improved breeds, the Duroc breed which appears to adapt well to this hot, humid environment was selected. A total of 16 Zungo and 12 Duroc females were used. Female Zungos were bred to both Zungo and Duroc sires, as were Duroc females. These four groups were selected to provide data on the crossing ability of these two breeds, as well as a measurement of the maternal influence on reproductive performance.

Table 30. Reproductive performance of Zungo and Duroc gilts during gestation and lactation.*

Parameters	Z x Z	D x Z	Z x D	D x D
No. of litters	11	4	5	4
Performance at farrowing				
No. of pigs	7.80	7.50	9.20	11.53
Individual pig wt (kg)	0.97	1.09	1.19	1.27
Litter wt (kg)	7.57	8.18	10.95	14.61
Performance at weaning				
No. of pigs	7.10	6.00	8.40	10.00
Individual pig wt (kg)	10.35	10.15	12.80	9.95
Litter wt (kg)	73.50	60.90	107.50	[illegible]

* Group designation: Z   Zungo, D   Duroc; boar x gilt

Preliminary results of the gestation and lactation performance of the original animals are presented in Table 30. The Zungo dams used produced smaller and lighter litters than the Duroc dams, irrespective of the breed of sire. At weaning, the offspring of the Zungo dams were similar in weight to those of the Duroc sows but less numerous. The reduced number is reflected in a lowered total litter weight produced by the Zungo sows.

The mature weight of the Zungo sows was 83.2 kilograms as compared with 132.5 kilograms for the Duroc sows (Table 31). The Zungo sows consumed 50 per cent less feed during lactation. The interaction of lowered feed consumption and high milk production as reflected in equal pig weights at weaning resulted in greater body weight losses in the Zungo sows during lactation and an increased time required to return to estrus.

Pure Zungo pigs grew at a slower rate than did either the pure Duroc pigs or the Zungo-Duroc crossbreds (Table 32). Although daily feed consumption was similar, the pure Zungo pigs required approximately 18 per cent more feed to produce a kilogram of gain and approximately 19 additional days to reach 50 kilograms body weight than did the Duroc or Duroc crossbreds.

These studies are being continued to obtain complete life-cycle production and reproductive data on these different breeding groups, as well as carcass data at market weight from offspring of these four groups.

Table 31. Body weight change and feed intake of sows during gestation and lactation.

Parameters	Zungo *	Duroc *
Gestation		
Wt at breeding (kg)	83.2	132.5
Wt at 110 days gestation (kg)	109.4	165.4
Wt gain during gestation (kg)	26.2	32.9
Daily feed intake (kg)	1.0	1.5
Lactation (56 days)		
Wt at farrowing (kg)	96.2	148.2
Wt at weaning (kg)	81.1	142.4
Wt loss during lactation (kg)	15.1	5.8
Daily feed intake (kg)	3.0	4.5

* Average of 15 Zungo sows and 9 Duroc sows

Genetic selection of pigs for low protein requirements

Results of a study completed in collaboration with ICA suggest that it would be genetically possible to select lines of pigs that perform well at lower levels of dietary protein.

Two diets containing the same balance of amino acids but different levels of crude protein (16 and 10 per cent) were used. The same balance of amino acids was obtained by using a constant proportion of maize and soybean meal and diluting the 10 per cent diet with sugar. These diets were fed for 42 days to 53 pairs of females from the same litter and 13 pairs of males from the same litter. Figure 5 summarizes the results

Table 32. Performance of Zungo, Duroc and Duroc-Zungo crossbred pigs during the growing period.

Parameters*	Z x Z **	D x Z	Z x D	D x D
Duration (days)	91	72	71	73
Number of animals	20	19	19	20
Daily gain (kg)	0.445	0.555	0.575	0.545
Daily feed (kg)	1.54	1.65	1.75	1.54
Feed/gain	3.46	2.97	3.04	2.82

* Average initial weight, 10.8 kg; average final weight, 51.1 kg
** Group designation: boar x sow

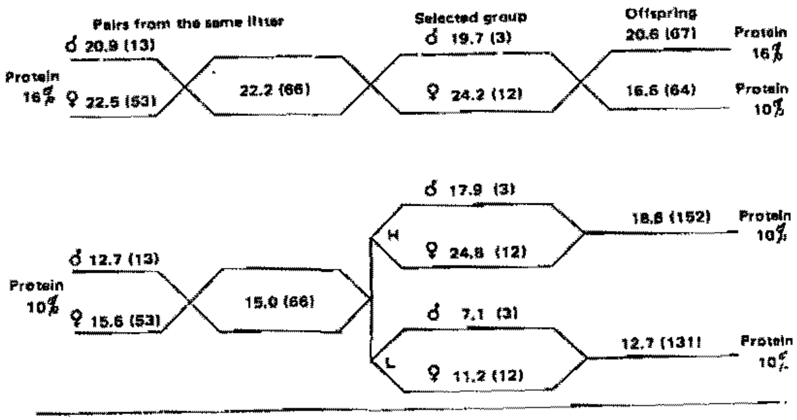


Figure 5. **Selection of pigs for low protein requirements.**

of this study. The 66 pigs fed the 16 per cent protein diet gained an average of 22.2 kilograms during the 42-day feeding period, whereas the 10 per cent protein group gained an average of only 15.0 kilograms.

Selections were made from each group to form the three breeding groups which were the control, the high-gaining group on a low protein diet, and the low-gaining group on low protein diet. Three males (average 19.7 kilogram gain) and 12 females (average 24.2 kilogram gain) were selected at random from the control (16 per cent) group. The three males with the highest growth rate (average 17.9 kilogram gain) and the fastest gaining females (average 24.8 kilogram gain) were selected to form the high (H) performance group on low protein and a similar selection was made to form the low (L) performance group (average 7.1 kilogram gain for males and 11.2 kilogram gain for females) on low protein. These animals were mated within selection groups and the offspring tested in a manner similar to the original test, with the exception that approximately one half of the offspring from the control group were fed the 16 per cent protein diet and one half were fed the 10 per cent protein diet.

Offspring from the control group (16 per cent protein), fed the control diet, gained an average of 20.6 kilograms during the 42-day feeding period. Another group of the same offspring were fed the 10 per cent protein diet. These animals gained 16.6 kilograms during the period as compared to 18.6 kilograms for the offspring from the group (H) selected to perform well on the low protein (10 per cent) diet. The data indicate that in one generation it was possible through selection to obtain an improvement in performance on low protein diets over that expected from the average of unselected pigs.

If it is an accepted fact that the normal protein requirements (16 per cent) were established to meet the requirements of the average pig, these data suggest that it would be possible to select a line or lines of pigs that could maintain normal performance at lower dietary protein levels.

Improvement of small farm swine production

In 1971, CIAT in collaboration with ICA initiated a study in the village of Cacaotal on the North Coast of Colombia to characterize swine production and to determine the level of acceptance and the impact that improved technology would have on this enterprise.

Figure 6. **Sow and pigs raised under traditional system in the village of Cacaotal.**

The efficiency of production as represented by reproductive performance, growth rates, feed efficiency and pig health was low. It was shown that six to nine pigs with an average weight of approximately 900 grams were born per sow, two to four pigs with an average weight of 4.5 kilograms were weaned per sow (Fig. 6), and 18 to 20 months and 550 kilograms of feed were required for each of these pigs to obtain a market weight of 60 kilograms. In addition, approximately 25 per cent of the animals tested were infected with brucellosis, and the major portion of the population was infected with internal parasites of various types. Management, feeding, breeding and hygiene of the pigs—100 per cent of native breeding--was complicated by the existing system of production which allowed the pigs to roam freely.

Initially, a program was established to demonstrate the effect that improved feeding and reduced disease and parasite infection would have on the performance of growing pigs. Simple corrals made with concrete floors and local materials including wooden posts, bamboo divisions and a palm-thatched roof were constructed. These initial trials established that pigs raised under the traditional system, which provided a diet of shelled or whole-ear maize and allowed them to roam freely and to scavenge for food, gained an average of 70 grams per day and required 9.4 kilograms of maize to gain a kilogram of body weight. With the prices (in Colombian pesos) that existed at that time (maize, $2.00 per kilogram and pigs, $8.00 per kilogram), a net loss of $12.00 per kilogram of weight gain was recorded.

Native growing pigs raised under the improved system and placed in complete confinement were provided a balanced diet including maize, vitamins, minerals and supplemental protein; they gained an average of 465 grams per day and required 2.6

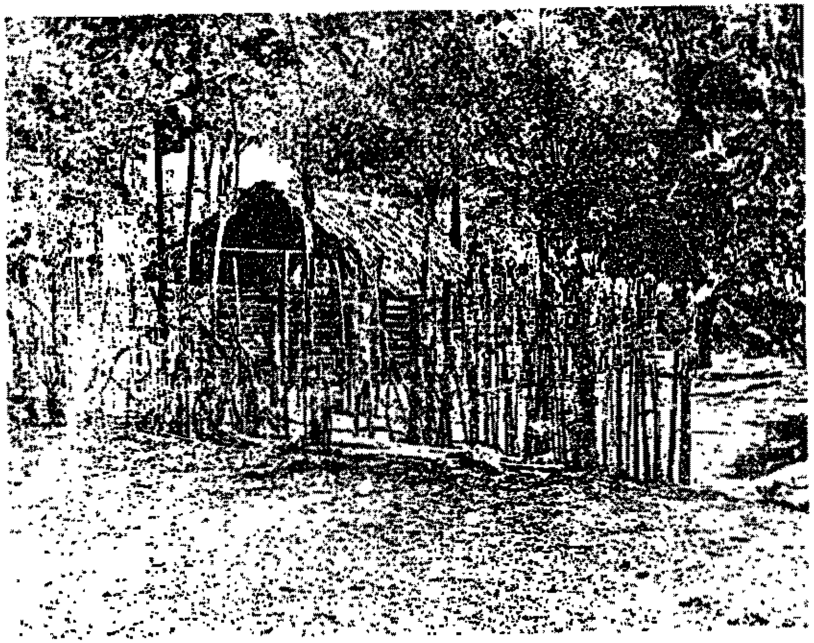


Figure 7. Farmers have rapidly accepted new technology and have constructed rustic, but efficient pig-growing facilities.

kilograms of feed to produce a kilogram of body weight gain. Under the improved system, a small but positive gross income (less than one Colombian peso/kg) over feed cost was recorded. Studies to improve these diets making maximum use of on-the-farm feeds and by-products continued.

The initial impact of these demonstrations and additional conferences was significant. Many farmers built corrals and placed their animals in confinement (Fig. 7), but continued to feed them in the traditional manner, using farm by-products such as cooking scraps, cheese whey, cassava and maize. The missing link in the system was the local unavailability of a protein-vitamin-mineral supplement that could be purchased in small quantities, and in some cases, the lack of available resources or credit with which to purchase the feed.

In collaboration with two national organizations—CECORA, a division of INCORA (Instituto Colombiano de Reforma Agraria) and ICA—it was possible to make this supplement available through a local cooperative. Swine production on the farms using this supplement was significantly improved.

Since protein is the most limiting factor in the pig feeding system, the value of high-lysine maize was demonstrated and introduced into the cropping system on some farms. This maize, a vitreous endosperm high-lysine variety from CIMMYT, is gaining acceptance in the village. On-the-farm pig trials with this maize have demonstrated that when used in a feeding system with small, but adequate quantities of supplemental protein, it produces efficient, economical pig performance. Two groups of locally grown pigs, one of native breeding

Table 33. Comparison of performance of growing-finishing Zungos and Zungo-Hampshire crossbreds fed opaque-2 or crystalline high-lysine maize on small farm in Cacaotal. *

Parameters **	Zungos	Crossed
Number of pigs	6	6
Initial weight (kg)	16.3	14.8
Final weight (kg)	70.3	76.7
Daily gain (kg)	0.40	0.46
Consumption maize (kg)	917.0	910.9
Consumption supplement (kg)	131.0	130.1
Feed consumption (kg)	1048	1041
Feed/gain	3.23	2.86
Backfat (cm)	3.43	2.59

* Data collected by Dale Fisher on farm of Reyes Barrios in Cacaotal

** Feeding period, 134 days

and one of native crossbred pigs, were fed. The results demonstrate that under farm conditions with good management and hygiene, the native pig gains at a rate similar to the crossbreds used, but converts feed into gain less efficiently (Table 33).

A detailed economic analysis of the pooled data from this study (Table 34) clearly demonstrates the profitability for the farmer. Using prices existing at the time the experiment was conducted, the farmer received a net profit of 165 Colombian pesos per pig or a 16-per cent return after all costs including labor, interest, feed, animals, drugs and depreciation. His return per pig from labor and investment was 210 Colombian pesos per pig, or 22 per cent.

In accordance with the original problem of a low level of swine production resulting from inadequate nutrition, parasite and disease infection and poor management, the program was interested in determining the farmer's level of acceptance of the introduced technology, the impact of this technology once it has been incorporated into the system, and the factors that limit improvement and expansion of swine production on these small farms.

A recent survey of 80 households within the village made by a rural sociology student, showed that 48 households (60 per cent) have one or more pigs. On these farms, there was a total population of 366 pigs which included 5 boars, 64 breeding females, 103 baby pigs and 194 pigs being finished for market.

Considerable improvement has been made in swine management. Of the 48 swine producers, 24 have constructed simple, but adequate swine facilities with concrete floor and concrete, wood or bamboo divisions, most of which have a palm-thatched roof. These pens have improved management and hygiene and have facilitated improved feeding and breeding. The majority of these new installations have been built by the farmers themselves and financed through long-term loans from the Caja Agraria (an agricultural bank).

Nutrition and feeding have also improved on some farms. Twenty per cent of the farmers are using the protein supplement made available through the cooperative program. It is estimated that a larger proportion would make use of this supplement if its availability and distribution were improved.

Table 34. Economics of swine feeding in Cacaotal utilizing farm-grown, high lysine maize and purchased supplement. *

Parameters **	Item	% of total cost
Cost of pigs	1,850	15.4
Cost of feed	8,086	67.3
Cost of drugs	115	1.0
Value of labor	588	4.9
Building depreciation	185	1.5
Interest on capital	1,191	9.9
Total cost	12,015	
Market value of pigs	13,947	
Net profit	1,932	16.0
Net profit per pig	161	
Net profit per kilo gain	2.78	

* Based on result of 12 pigs fed on farm in Cacaotal during 114 days

** Expressed in Colombian pesos

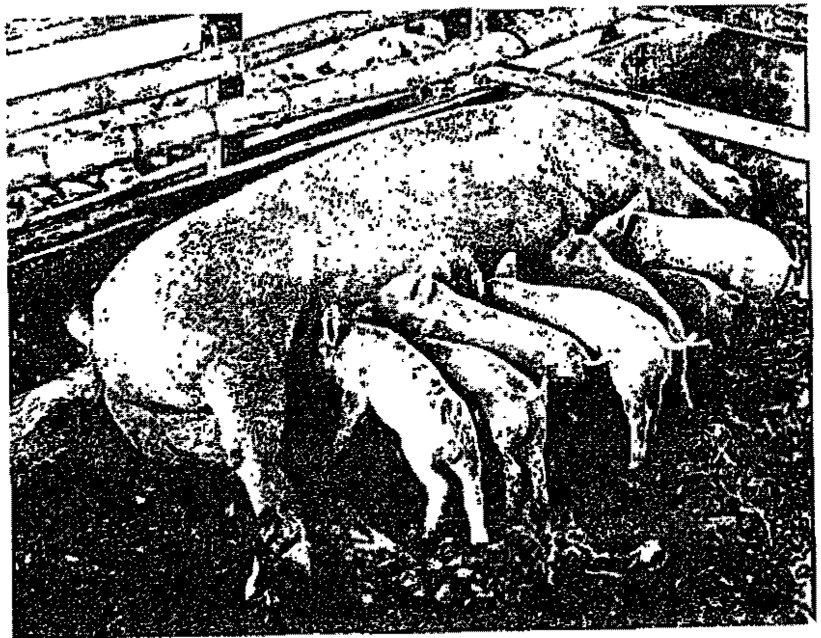


Figure 8. Improved breeds of swine are now being used by small farmers to improve their production.

At present it must be purchased in a neighboring village some 60 kilometers from Cacaotal.

The breeding of this swine population has undergone a significant change in three years. Originally, all pigs were Zungo Pelado. At the time of the survey, it was found that 165 of the adult pigs (62 per cent) were of improved breeding, either half breeds or purebreds. Of the breeding females, 32 (50 per cent) were of improved breeding (Fig. 8). This change represents a drastic improvement in genetic potential and pig quality.

Swine health and hygiene have also been significantly improved through the use of the veterinary service which has been made available one day per week in the village. This service is being used by 54 per cent of the farmers who raise swine. During the past three years, brucellosis has been eradicated from the village swine population. Whereas initially 25 per cent of 265 pigs tested were shown to have brucellosis, a recent test of 41 of the 64 sows in the village revealed that all were free from the disease. Sanitation, improved management and treatment with antihelminthics have also greatly reduced internal parasite infection.

Although the farmers are receptive to new technology and considerable impact has been made on the village swine population, many other factors directly affect the farmers' ability to increase and improve swine production. Prime among these are the farmers' financial resources (income and credit) and land area available for producing adequate grain, cassava and other farm products for swine feed, in addition to the quantity needed to feed their families

Table 35. Distribution of pigs and improvement on farms in Cacaotal as related to number of cattle owned. *

	No. of cattle				
	0–4	5–9	10–24	25 or more	Total
Number of pigs	Number of farms with pigs				
4 or less	20	4	6	2	32
5 to 9	5	1	–	–	6
10 or more	3	–	4	3	10
Improved breeds	15	1	6	4	26
Confinement facilities	15	2	5	2	24
Pig production with some improvement	20	2	7	4	33

* Data collected by Mr. Ton de Klerk, December, 1974

Of the 80 households surveyed, 32 did not raise pigs. The majority of these had little, if any, land for crop production and depended upon daily wages from agricultural work for their livelihood. Of the remaining 48 farmers who kept pigs, the lower income group—or those with less cattle—were more receptive to new technology and improvement (Table 35). Of the 28 farms in this category, 20 had made some improvement in their swine production system.

Economically, swine contribute in only a small way to the overall income of subsistence farms; this is a more practical and important enterprise on medium-sized farms that have more land for crop production and greater financial resources with which to develop the enterprise and to feed the pigs. Direct and complete economic analyses based on market values of all inputs and sales are essential for evaluating all farm enterprises. However, economic analyses of small-farm swine production often fail to evaluate the role of the pig as a system for utilizing and marketing farm products that would not be sold because of quality (size, weevil and field damage), market value or distance to market. In Cacaotal alone, it has been estimated that 15 to 20 per cent of the maize produced and at least 25 per cent of all cassava produced would have little, if any, economic value if not marketed through the pig.

As swine production on small farms must be considered as an integral and functional part of the overall farming system, the CIAT swine program terminated its project in Cacaotal in 1974. Future work on small farms will be carried out through, and in close collaboration with, the Small Farm Systems Program.

ANIMAL HEALTH

Further knowledge was accumulated of the total spectrum of swine diseases in different areas of Colombia (Table 36). Investigations focused on those problems which appeared to be of the greatest importance, and pioneer work continued in animal health economics and animal health documentation. Most information was derived from the 20 collaborating commercial pig farms in the Cauca Valley, which also formed the field training ground for graduate students specializing in swine diseases.

A stage has been reached where a preventive medicine program can be prepared specifically for the commercial pig farms in the Cauca Valley, which would provide guidelines for commercial operators elsewhere in tropical Latin America.

The areas of emphasis were the economics of foot-and-mouth disease; causes of diarrhea, particularly in young animals; the abscess-arthritis syndrome; and causes of abortion.

Table 36. Check list of swine diseases diagnosed by the CIAT animal health laboratory as of November 30, 1974.

Etiological group	Disease	Place
Virus	Foot-and-mouth disease (A and O)	Cacaotal
		Cauca Valley
	Vesicular stomatitis (New Jersey	Cacaotal
		Cauca Valley
	Transmissible gastroenteritis	Cauca Valley
	Teschenoid syndrome	Cauca Valley
	Hog cholera	Cauca Valley
Mycoplasma	Arthritis (M. granularum)	Cauca Valley
	Enzootic pneumonia (M. hyopneumoniae)	Cauca Valley
Bacteria	Arthritis (Haemophilus sp.)	Cauca Valley
	Swine dysentery (Treponema hyodysenteriae Vibrio coli complex)	Cacaotal
	Brucellosis (B. suis)	Cauca Valley
	Leptospirosis (L. pomona)	Cauca Valley
	Abscess – arthritis syndrome	Cauca Valley
	(Streptococcus Lancefield Group A and E)	Cacaotal
	Exudative epidermitis	Cauca Valley
	Atrophic rhinitis	Cacaotal
	Conjunctivitis (Streptococcus Lancefield Group A and E)	Cacaotal
	Food intoxication (Aeromona shigelloide)	Cauca Valley
Protozoa	Balantidiasis (B. coli)	Cauca Valley
Helminths	Cysticercosis (C. cellulosae)	Cacaotal
	Parasitic gastroenteritis	Cacaotal
		Cauca Valley
		Carimagua
	Parasitic bronchitis	Cacaotal
		Carimagua
Ectoparasites	Mange (Sarcoptes scabiei)	Cauca Valley
	Pediculosis (Haematopinus suis)	Cacaotal
		Cauca Valley
Congenital defects	Arrhinencephalia	Cauca Valley
	Palatoschisis	Cauca Valley
	Cryptorchidism	Cauca Valley
	Atresia ani	Cauca Valley
	Hermaphroditism	Cauca Valley
Defects directly due to husbandry	Heat stress	Cauca Valley
	Hepatosis dietetica	Cauca Valley
	Rickets and osteomalacia.	Cauca Valley
	Tail biting	Cauca Valley
Unknown etiology	Pytyriasis rosea	Cauca Valley
	Intestinal emphysema	Cauca Valley

Foot-and-mouth disease

Advantage was taken of the extensive outbreak of foot-and-mouth in the Cauca Valley in 1973 to undertake collaborative studies with the CIAT economists on the economics of the disease at the farm level. Data were collected from 11 pig farms where serological confirmation of infection had been obtained (ICA vesicular diseases reference laboratory) and from two other farms that had no past or present history of infection. The economics group prepared a model against which the monetary losses of the outbreaks on three infected farms were calculated. The calculated losses on these farms (1), (2) and (3) were US$37,007; US$42,293 and US$7,339 (Table 37). However, the losses on farm (1) were in reality greater, as the calculation was based on a nil mortality although some losses from death did occur. These figures clearly indicate why farmers fear the disease.

The causes of loss can be summarized as mortality, particularly in fetuses and young animals; loss of weight and of potential weight gain in fattening pigs; and drop in conception rate, as no females can be bred during the outbreak. There is also evidence of a lowered fertility of recovered gilts and sows, but this was not included in the economic analysis. Further analysis and comment is made in the economics section, page 191.

Table 37 lists the observed morbidity and mortality on all infected farms and the virus type involved. Epidemiological observations were accumulated in an attempt to explain the wide variations among farms. Variations were greatest in pigs in the two- to six-month age group.

Although variation can be expected in the characteristics of the infecting virus strains, methods of management strongly affected the spread of infection within individual herds. Four farms practiced vaccination even though the bovine vaccine is not recommended as being effective in swine, but the data available were inadequate to assess any benefits obtained.

Transmissible gastroenteritis (TGE)

No evidence exists of any spread of this disease from the premises found infected in 1973, in spite of continuous farrowing and contact between recovered and susceptible pigs. The original outbreaks were associated with the importation of breeding animals into Colombia.

The possibilities exist that carrier pigs shed TGE virus only when subject to a stress, such as a long journey; and also the virus may not survive in tropical or subtropical environments. If these two suppositions are correct, then the introduced disease would be of no subsequent importance in the tropics after initial devastating episodes.

Vesicular stomatitis

Diagnosis was made on a single occasion, both in Cacaotal and in the Cauca Valley (ICA vesicular diseases reference laboratory). Morbidity was low and mortality nil.

Porcine enteroviruses

This important group of viruses is associated with reproductive failure, encepha-

Table 37. Observed morbidity and mortality from foot-and-mouth disease (types O or A) on 11 commercial pig farms in the Cauca Valley, Colombia.

Pig farm	Number of animals at outbreak	Morbidity (%)	Mortality (%)	Virus type
1	4,100	78.0	*	A
2	1,068	98.0	25.8	A
3	164	61.0	40.4	O
4	802	80.0	18.4	O
5	774	5.9	0.5	O
6	391	65.0	15.6	O
7	1,100	70.0	3.4	O
8	548	100.0	37.8	O
9	252	60.0	9.0	O
10	499	29.0	0.2	A
11	220	73.0	6.0	A

* Unknown

lomyelitis, respiratory infections and myocarditis. Search for diseases associated with them resulted in the findings on one collaborating farm of a syndrome resembling Teschen disease. In a total of 118 pigs, there was a morbidity of 27.1 per cent and a mortality of 8.4 per cent. Symptoms were of a central nervous system disorder. Histologic lesions in the cerebrum, cerebellum and spinal cord were also compatible with those described for Teschen disease.

Thirty-two serum samples taken from sick and in-contact pigs were sent to the Plum Island Animal Disease Center, USDA. Although strongly positive serological results were obtained, final confirmation of the presence of Teschen disease and other viral diseases of this group must await virus isolation and characterization.

Enzootic pneumonia

Although enzootic pneumonia was common in the Cauca Valley in 1967, it has not been found on the collaborating farms during the two years of the present program. At that time, 100 of 500 animals studied at the Palmira slaughterhouse showed lesions, and **Mycoplasma hyopneumoniae** was isolated. The reason for the absence of cases is obscure.

Arthritis associated with Mycoplasma granularum

A single pig farm had several animals with arthritic problems. One animal was necropsied and the **Mycoplasma** isolated from the swollen joints. Speciation was made in collaboration with the Veterinary Investigation Laboratory, Iowa State University. The condition was found to be reproducible in white laboratory rats. Arthritis from this cause is important elsewhere in the world; the significance in Colombia is not known.

Arthritis associated with a Haemophilus sp.

Another necropsy was carried out on a different farm with arthritic problems. On this occasion a **Haemophilus** sp. was isolated, but characterization has not yet been made. Here again it was possible to reproduce the condition in white laboratory rats.

Swine dysentery (Treponema hyodysenteriae-Vibrio coli complex)

Two outbreaks occurred on different farms. In the first, 378 pigs between two and four months of age became sick, and 11 died in the first week of the outbreak (2.9 per cent). On the second farm, 243 pigs of the same age became sick, and 15 died before treatment could be started (6.1 per cent).

The etiology of these outbreaks was at first obscure, as the routine antibiotic treatment had no effect. Large numbers of **Treponema** were seen on histology, and a specific drug was imported.* Response to therapy was immediate.

The **Treponema** was isolated on culture and at first was assumed to be the sole pathogen present. However, **Vibrio coli** was later observed on the same cultures. The **Treponema** is considered to have been the more important of the two, first because of the gross numbers seen in the intestines of infected animals, second because of the initial therapy having at least suppressed the **Vibrio coli**, and third because of the immediate response to the specific drug.

Transmission studies are being carried out to determine the conditions under which clinical outbreaks of this disease occur, including any interrelationship between the two pathogens. These are the first recorded outbreaks in Latin America.

Balantidiasis

After it was discovered that the normally nonpathogenic protozoan **Balantidium coli** was capable of causing important episodes of diarrhea in the Cauca Valley, a postgraduate intern from Bolivia worked on the parasite.

The organism was cultured in the laboratory and attempts were made to infect laboratory animals. Anal and oral routes of infection were used with rats and hamsters. Only the latter could be infected if large numbers of organisms were used, but death was rapid from acute enteritis and chronic infections were not achieved. Attempts to immunosuppress the rats and hamsters by inducing concurrent infections with **Trypanosoma evansi** also failed. Clean pigs could be infected, but none showed clinical symptoms.

Balantidium coli isolated from clinical cases were initially 20 to 30 μ in size while those from healthy animals ranged between 50 and 60 μ. On culture, however, isolations from both sources had the upper range of size.

There is evidence that management is important in the control of this condition. Where clinical cases have been diagnosed, a balancing of the ration accompanied by oral tetracycline has resolved the situation.

Food intoxication

An outbreak of dysentery in a group of 30 gilts on one Cauca Valley pig farm was found to be associated with bone meal contaminated with **Aeromona shigelloide**. Three animals died. This bacterium is one of the causes of human dysentery, and diagnosis was confirmed in collaboration with the enteric diagnostic section of the Department of Microbiology, Universidad del Valle. The disease was reproduced experimentally in hamsters.

Abscess-arthritis syndrome

The syndrome continued in the imported herd of pigs, which suffered serious losses in 1973, but the second generation of breeding females appeared to be less susceptible. Similar episodes are commonly reported to have occurred with other importations of breeding animals into tropical environments, but there is a paucity of recorded information. There may be significance in the fact that the herd under investigation was imported as specific pathogen free (SPF). Any further episodes associated with the CIAT swine outreach program in South America would be a serious setback, and for this reason experiments were carried out on immunizing procedures.

A bacterin was prepared from the strains of staphylococci and streptococci Lancefield A and E isolated from the abscesses, but it failed to give adequate protection under one level of experimental challenge. Two further vaccines are under trial at present: One is a live attenuated vaccine incorporating streptococci Lancefield A and E prepared in the CIAT animal health laboratory, and the other is an imported commercial live avirulent streptococcus group E vaccine. A postgraduate intern from Peru was involved in this area of experimentation.

Brucellosis

Having determined that brucellosis was present on all 20 collaborating pig farms, a program was instituted in 1973 to determine the methods of control and eradication most acceptable to farmers. Eight pig farms were chosen. Eradication has been achieved on four farms and is close to success on the remaining four. This was accomplished through the examination of 1,923 serum samples. The requirement of identifying, numbering and recording animals has resulted in an improvement in overall management on all farms.

At one farm it was noticed that two dogs ate aborted fetuses. Serological examination found them positive to brucellosis. A report that dogs may eliminate **Brucella** in their urine is being followed up in these two cases. Dogs may be a factor in the epidemiology of the disease.

Leptospirosis

Following the isolation of **Leptospira pomona** reported in 1973, further investigations have been carried out on three farms with the collaboration of the Pan American Zoonosis Center. Serologically positive reactions have been obtained from 138 samples submitted, representing six serotypes, the most prevalent being **pomona** and **autumnalis**. If on future investigation prevalence continues to be low, eradication by slaughter alone is an economic possibility.

Exudative epidermitis (Greasy pig disease)

Four more outbreaks occurred in the same herd of imported SPF animals recorded

* Ronidazole (Merck Sharp and Dohme)

in 1973. Of 117 suckling pigs affected, 18 died. **Staphylococcus epidermidis** was repeatedly isolated from affected animals, and material has been stored for virus isolation. The etiology remains obscure.

Sarcoptic mange

Two pig farms were found infected in the Cauca Valley. The first had 130/600 animals of all ages infected (21.6 per cent) and the second 170/1,100 animals (15.4 per cent). Treatment was effective.

Pediculosis

The swine louse **Haematopinus suis** is widespread in Cacaotal but confined to a few farms in the Cauca Valley. The parasite can cause intense irritation associated with loss of condition and may assist the entry of pathogens.

Congenital malformations

Close inbreeding on one farm resulted in congenital malformations. These were arrhinencephalia, hermaphroditism, palatoschisis and cryptorchidism.

Rickets and osteomalacia

On one pig farm with a total of 900 animals, 98 were found to suffer from rickets and 7 sows from osteomalacia. The sows were sent for slaughter, and the young animals recovered after adjusting the diet.

Tail biting was observed on the same farm. Control measures, reported to be successful elsewhere in the world, have been instituted. These measures consisted of removing the tails of all sucklings, changing and balancing the diet, and hanging chains in the pens for the pigs to bite.

Pytiriasis rosea (Skin necrosis)

No further cases were seen in the Cauca Valley, but dramatic cases were observed on the North Coast. The lesions were again characterized by the intense infiltration of mononuclear cells and eosinophils in the upper dermis. If the papules become contaminated with bacteria, the condition of an animal deteriorates rapidly. The etiology is still unknown.

Intestinal emphysema

An accidental finding on several necropsies on one farm, of academic interest only, has been gas-filled vesicles in the lymphatics of the mesentery, principally near the jejunum and ileum. A similar condition occurs in man.

Zoonotic infections

Some of the diseases described in this report also involve man. Some investigations were made. Three workers on one farm were found infected with brucellosis and four with balantidiasis at another location. Leptospira infections also need to be checked.

ECONOMICS

Economics of swine on small farms

Analysis of the economic contribution of swine on small farms was emphasized. Data collected from lowland areas of Colombia suggest that the possibilities are limited for raising farm family incomes through an improvement in the level of technology in swine production. This appears to be especially true for subsistence farmers and those whose livelihood depends entirely on the production from their farm. However, it is not known to what extent the market conditions prevailing during 1974 were exceptionally unfavorable for swine production in the regions examined; hence they do not necessarily reflect a long-term situation. Furthermore, the sample of farms studied is not statistically representative of the population of swine producers in Colombia.

Higher adoption rates are expected among medium- and large-size farms. Among the factors limiting significant improvement in swine production on small farms, the following appear to be important: small scale of operation (one or two sows per farm), distance from marketing centers and sources of protein, presence of capital rationing, high unit costs associated with marketing of a small number of pigs, and with the

Table 38. Proportion of farms with pigs, by size and region (cassava producers, Colombia, 1974). *

Farm size (ha)	Cauca	Valle Quindío	Tolima	Meta	Atlántico Magdalena	Weighted average (%)
Less than 5	1/21**	0/9	2/5	0/3	5/31	12
5 – 9.9	2/9	1/9	1/2	0/1	1/3	23
10 – 14.9	1/1	2/4	1/4	0/2	1/2	45
15 – 19.9	0/0	2/5	2/2	0/1	0/1	28
20 – 24.9	3/3	1/2	1/1	1/2	0/1	60
More than 25	1/3	2/15	2/5	8/11	0/6	32
Weighted average (%)	43	27	59	21	17	–

* Producing areas above 1,000 meters of altitude have been excluded.
** Denominator represents number of farms interviewed.
Source: CIAT cassava survey 1974

provision of adequate technical assistance. Since these factors represent the institutional and environmental realities facing the small subsistence producer, the prospect of any major changes in swine production technology on these farms appears limited.

Some of the results supporting these conclusions are presented below.

The proportion of farms with pigs varies more according to region than to size of farm (Table 38). In general, this proportion is low on cassava-producing farms and even more so on those of less than 10 hectares. The present sample only covers producers of cassava (1974) and opaque-2 maize (1971). Similar data are being collected for field bean growers. This information is still not available for other producers, except as reported below for Cacaotal.

In terms of pigs per farm, the small scale of operation among cassava producers (1974) is shown in Table 39.

For the Tolima region in Colombia, Table 40 shows the number of farms classified according to number and type of animal. Some farms had more than three pigs in each category or type of animal.

Cacaotal

A village study was undertaken in Cacaotal, where part of the swine team has been working for some years as part of an effort to study the potential contribution of swine on small farms.*

A general economic characterization of all families in Cacaotal (including Las Cruces) is presented in Table 41.

Data from this study indicate that (a) there is a considerable degree of variation in the level of income and capital among families in Cacaotal; (b) overall family income in Cacaotal is significantly higher than average family income in most other rural communities in Colombia; this is partly due to the fact that except for tenants, the average size of farms is relatively larger in Cacaotal; (c) categories two (tenants) and three (small farm owners), comprising 50 per cent of all families, appear to be the most appropriate target population for a development program such as CIAT's present activities in the area; (d) limited supply of land suitable for crop cultivation appears to be the most limiting factor for an expansion of swine production in Cacaotal; and (e) the relative importance of cattle in the farm economy, except for tenants, was much higher than expected.

A simulation of the potential impact of expanding swine production on family income and the required investment per farm

* A report by R.D. Estrada and A. Valdés is available on request.

Table 39. Number of pigs per farm, by size and region * (cassava producers, Colombia, 1974).**

Farm size (ha)	Cauca	Valle Quindio	Tolima	Meta	Atlántico Magdalena
Less than 5	1 (1)	*	1.5 (2)	*	7.4 (5)
5 9.9	2 (2)	1 (1)	1 (1)	*	6 (1)
10 14.9	1 (1)	6 (2)	1 (1)	*	1 (1)
15 19.9	*	4.5 (2)	4 (2)	*	*
20 24.9	2 (3)	1 (1)	5 (1)	1 (1)	*
More than 25	1 (1)	4.5 (2)	1 (2)	4.7 (6)	*

* Only of those which have pigs (see Table 38). Figure in parentheses represents number of farms interviewed in each cell.
** Source: CIAT cassava survey 1974

is presented in Table 42. Given the cropland available for tenants and small farm owners, it has been assumed that not more than 25 per cent of their maize and either 50 per cent or all of the unmarketable part of their own cassava production can be used for swine. The rest being used for on-the-farm, human consumption, poultry, and/or sold.

According to the farmer's capital, the potential increase in annual family income (value added by swine) is between 1.1 and 5.9 per cent for tenants and between 0.7 and 4.0 per cent for small farm owners, respectively. In addition to studies on credit versus owned capital, sensitivity analyses included (a) selling baby pigs for fattening versus raising for breeding and (b) sows fed only on unmarketable cassava versus fresh cassava. Selling for breeding, a possibility for a limited number of farms, increases family income by approximately 13 and 9 per cent for tenants and small farm owners, respectively.

Some economic considerations

An international price comparison for Colombia, Ecuador and Peru is presented in Table 43, with 1969 as the base year for comparison. Some traded commodities that are potentially important for the swine industry were chosen. Data for an international price comparison are not available for feedstuffs usually used by the swine industry. This is the case, for example, with cottonseed meal, rice bran, molasses, sorghum, wheat bran and others.

The price situation faced by pig producers is both unstable through time and differs significantly in the countries analyzed. The export price of these feedstuffs has increased proportionally more than the

Table 40. Classification of swine-producing farms by type of animals (cassava producers, Tolima, Colombia, 1974). *

Type of animal	Number of animals: 0	1	2	3	Greater than 3
Sows	13	9	2	0	9
Unweaned piglets with sow	24	0	0	0	9
Feeders (until four months)	13	7	3	1	6
Fattening pigs	13	7	3	1	6
Boars	21	3	9	0	
Total number of farms	[illegible]	10	9	3	-

* 62 farms were surveyed, 34 of which had pigs (Source: CIAT cassava survey, 1974).

Table 41. Income, capital and farm size in Cacaotal, Colombia (1974).

Categories [1]	No. of families	Annual gross income [2] ($1,000)	Working capital ($1,000)	Income from: Crops	Income from: Livestock [3]	Hectareage [4]: Crops (ha)	Hectareage [4]: Pastures (ha)
Hired laborers [5]	15	4.0	0.8	4.0	0	0.2 (0.0)	0 (0)
Tenants	20	47.5	14.8	40.5	7.0	2.0 (0.0)	0.1 (0.1)
Small farms owners	41	89.0	117.8	52.0	37.0	2.6 (2.3)	16.0 (16.0)
Farmers with investment outside agriculture	11	115.4	140.8	49.2	37.0	2.5 (0.1)	5.0 (5.0)
Farm managers	18	45.1	46.0	29.3	10.8	1.5 (1.2)	2.6 (2.6)

1/ Including seven heads of households not working in agriculture and nine women, heads of households; the village comprises 121 households in all.
2/ Excludes imputed rent for the house. Values expressed in Colombian pesos (US$ 1.00 = 28.20)
3/ Income from cattle only
4/ Owned and/or rented, both in and outside of Cacaotal and Las Cruces. Figure in parentheses represents owned land in Cacaotal and Las Cruces.
5/ The income figure represents the gross income from their small plot in Cacaotal. Wage earnings are not included. Average daily wage was $30 (May, 1974).

price of swine to domestic producers. Domestic prices are not equivalent and do not follow a constant equivalence to export prices.

Domestic consumption of sugar and fish meal is clearly subsidized; i.e., domestic prices are significantly below export prices— but in the case of fish meal, quantitative restrictions limit domestic consumption. This subsidy is revealed in the high proportion of sugar evidenced in the least-cost diets (estimated at CIAT) and also in the intensive use of sugar by swine producers in Colombia.

The domestic price of maize in Colombia and Ecuador is higher than its export price. In Colombia maize is partly imported. However, the price of maize in Colombia is lower than the imputed price of dry cassava (based

Table 42. Costs and income per farm from an expansion of the swine herd (Cacaotal).

	Investment ($1,000)*: Tenants	Investment ($1,000)*: Small farm owners	Increase in income per farm (%)**: Tenants	Increase in income per farm (%)**: Small farm owners
Fresh cassava				
Credit	12.0	15.6	2.3	1.6
Own capital	12.0	15.6	5.0	4.0
Unmarketable cassava				
Credit	5.2	6.8	1.1	0.7
Own capital	5.2	6.8	3.5	1.7

* Including the investment on pigs only and excluding the opportunity cost of own capital.
** The opportunity cost of cassava and maize has been deducted from gross income. Interest payments are included as costs in the situation with credit. The cost of concentrates are included in all four cases.

Table 43. Price comparison of various swine feedstuffs (US$/ton).*

	Export				Domestic price											
					Ecuador				Peru				Colombia			
	1969	73	74	Δ%**	1969	73	74	Δ%	1969	73	74	Δ%	1969	73	74	Δ%
Fish meal	180	542	523	190	128	191	225***	75	–	–	–	–	252	375	391	55
Sugar	64	209	420	556	–	–	–	–	–	115	113	–	95	113	134	41
Soybean meal	106	302	208	96	194	226	–	–	–	–	–	–	121	234	276	128
Maize	53	98	127	139	69	126	150	117	–	97	123	–	73	135	158	116
Swine (paid to producer US$/kg)					.38****	.48	.65	.71	.62****	.65	.78	25	.46****	.64	.76	65

* At the official exchange rates
** Δ% represents the percentage change in 1974, relative to 1969.
*** For Santo Domingo de Los Colorados
**** 1970

Table 44. Percentage of morbidity and mortality by age and sex from foot-and-mouth disease 11 farms, Cauca Valley).

Category	Morbidity		Mortality			
				Increment in mortality because of FDM****		
	Median* (%)	Weighted average** (%)	Without FDM*** (%)	Median (%)	Weighted average (%)	Mean deviation (%)
Baby pigs	80	73	21	37	28	25
Growing	60	53	9	3	11	11
Finishing	73	51	3	0	2	3
Sows	80	81	1	1	2	4
Boars	80	73	1	0	1	2
Total	70	51	9	16	9	12

* 50 per cent farms) (70 per cent morbidity
** Weighted by size of swine herd
*** Annual average during the year preceding outbreak (taken as the average of bimonthly rates on three farms)
**** Mortality attributed to FDM on 11 farms during the first two months after the outbreak, relative to preoutbreak size of the swine herd

on historical prices of fresh cassava). Maize and cassava did not appear in the least-cost diets computed using 1973 prices for the Departamento del Valle, Colombia.

This preliminary information suggests that there is a considerable degree of government intervention in prices. In some countries, such as Ecuador, there are direct price controls on swine meat. In others, such as Colombia, price interventions are directed towards inputs. For example, it can be noted in Table 43 that in Colombia sugar is an artificially cheap source of energy, relative to its export price, as a result of export controls; in fact, sugar is widely used by swine producers. On the contrary, maize and soybean meal have been protected relative to world prices; since 1969 their domestic prices have risen significantly more than the price paid to the producer for swine. Consequently, these two ingredients have become expensive for the swine industry.

Economics and animal health

A current study is assessing the net private and socioeconomic benefits of alternative policies to control foot-and-mouth disease (FMD) in Colombia.

Because of the strong interdependence among species, control or eradication of FMD should be attacked simultaneously in all relevant species. However, for analytical purposes, it is useful to approach the study of the economics of FMD in the sequence swine, dairy cattle and finally, beef cattle.

The first stage of this study consisted of estimating the net (private) economic losses resulting from FMD on large* commercial pig farms in the Cauca Valley. An extensive epidemic of FMD occurred in this area between August, 1973 and February, 1974. Data were collected from 13 farms: 11 infected and 2 noninfected. An economic analysis made for three infected farms provided the required data on preoutbreak conditions and information on physical losses and repercussions of the FMD outbreak.

Table 44 presents data on morbidity and mortality because of FMD for the farms in the sample where the disease occurred. A large dispersion among farms is observed. It is also evident that the FMD viruses can cause high mortality in the young stock.

* With 200 or more pigs

Table 45. Economic losses because of FDM on three farms in the Cauca Valley (Colombia).

	Unit	Farm A	Farm B	Farm C
Size of swine herd *	No.	3,863	838	225
Losses **	US$	37,007	42,293	7,339
Expected loss ***	US$	6,661	7,612	1,321
Expected loss as percentage of preoutbreak net income	%	29	56	85

* Preoutbreak stationary-state size of herd

** Refers to the actual loss of the last outbreak. It is measured by the present value of the losses, using a 12 per cent discount rate. Actual loss, rather than the expected (probabilistic) loss. Exchange rate: 25 pesos per dollar approximately.

*** Actual loss multiplied by 0.18, which is the probability of outbreak for the sample

The methodology developed combines cost-benefit techniques with a simulation approach. Using a simple mathematical model, the swine herd inventory (by age and sex) and the corresponding cash flow can be projected in bimonthly intervals, under diverse production and health conditions.

Preoutbreak data is used to simulate the normal stationary-state herd size and composition and the related flow of net income over time. The types of data which have to be fed into the model are size of the breeding herd, fertility, preoutbreak death rates by age and sex, average number of pigs reared per sow per year, liveweight gains, age and weight at slaughter, unit costs, rations per age and function, and the price of pork. Then, for a situation with FMD, data required includes morbidity, mortality, abortions, farrowing, liveweight losses, unit costs and prices. The model then simulates the evolution of the swine herd and cash flows for a situation with and without FMD.

Economic losses because of FMD are estimated as the present value of the difference between the flows of net income with and without the disease. An appropriate discount rate is used.

Actual losses were converted into expected losses to account for the probability of an FMD outbreak in any given year. The computed probability is 0.18; that is, a pig farm in the Cauca Valley runs a probability of having FMD once every 5 1/2 years.*

Table 46. Breakdown of the economic losses because of FDM (percentage of gross sales).

	Farm A*	Farm B	Farm C
Mortality	0	40	55
Reduction in farrowing	0	51	32
Loss in weight **	30	1	1
Loss in price	0	0	1
Premature sales	70	8	11
Total economic loss	100	100	100

* Percentage of increment in mortality on this farm was 0.

** Underestimated because main impact in feed costs was excluded here.

Table 45 presents the estimated economic losses caused by the last outbreak for three of the farms. They fluctuated between $180,000 and one million Colombia pesos (US$7,200 and US$40,000 respectively), and so represented a decrease in their net incomes which varied between 30 and 85 per cent of net incomes without FMD. On the average, expected economic losses were $130,000 (US$5,200) per farm.

Table 46 provides a breakdown on the economic losses because of FMD. The main economic effects were deaths and decrease in birth rate resulting from the forced postponement of farrowing, which explained 80 and 90 per cent of losses, except for farm "A" where there were no additional deaths nor decline in number of births. In the latter, premature sale of fattening pigs explained 70 per cent of losses; the remaining 30 per cent was from loss in liveweight gains of growing pigs.

* During the 1974 outbreak, CIAT's Animal Health Program certified that the disease was foot-and-mouth; but there is no way of checking whether farmers were correct in assessing previous outbreaks as FMD.

OUTREACH AND TRAINING

The present cooperative programs with national institutions include projects in Bolivia, Peru, Costa Rica, Colombia and Ecuador. Invitations from other countries and institutions (especially from Guatemala, Brazil, Paraguay and Panama) have been received, but the lack of additional resources limits expansion of the program in the near future.

Training of professionals from national institutions where outreach programs are being developed is stressed. In addition to training of the scientists who will be in charge of the national program, continued technical assistance is given by means of periodic visits of CIAT senior staff members to the collaborating institutions.

Core budget and special project (IDRC) funding have provided financial support for this technical assistance to collaborating institutions plus the financing of physical facilities in Bolivia and Costa Rica.

The main outreach activities in 1974 are summarized by country as follows:

Bolivia

A complete swine unit has been constructed for 40 to 50 sows at the El Prado Station in Santa Cruz in collaboration with the Universidad Gabriel René Moreno (UGRM) and the Heifer Project.

This is the first swine research center to be developed in Bolivia. Research, training, demonstration, distribution of improved breeds and extension will be the main programs conducted through the swine unit.

Two professionals from UGRM were trained at CIAT during 1974: one in swine production and the other in swine health. Both professionals returned to Bolivia and with a former trainee form a three-man team that will direct the swine program.

Costa Rica

A swine unit for 40 to 50 sows is being constructed at the new Universidad de Costa Rica Regional Center being developed near the town of Turrialba and adjacent to CATIE (Centro Agrícola Tropical para Investigación y Enseñanza). Development of swine production projects are being planned in cooperation with the Universidad de Costa Rica. Students from the Universidad de Costa Rica will be trained in swine production as part of their regular university program. Research, extension, distribution of improved breeds, training and demonstrations will be conducted through the swine unit.

Two professionals have been selected for training in swine production at CIAT in 1975. They will be in charge of the work at the Turrialba unit and will cooperate with the Ministry of Agriculture in extension and development projects of swine in the Central Plain of San José and in the banana zone (Atlantic Coast).

Peru

Cooperation in Peru has been conducted through IVITA (Instituto Veterinario de Investigaciones Tropicales y de Altura) of the Universidad de San Marcos for development of a regional program in the Amazonian jungle zone (Pucallpa, Loreto). A swine unit for about 30 sows will be constructed in Pucallpa in collaboration with IVITA. The final plans have been approved, and the construction of facilities should start early next year. Research, training, demonstrations, distribution of improved breeds and extension work will be conducted through the swine unit in an integrated, jungle-zone, development program. A professional trained in swine production at CIAT is in charge of developing the swine unit in Pucallpa.

Invitations from the Ministry of Agriculture and AID have been received during the year to develop similar cooperative projects in Tarapoto, San Martín (Amazonian zone) and Jaen, Cajamarca (rice-producing zone). SAIS (Sociedad Agrícola de Interés Social), a Peruvian Government institution, has also requested technical assistance to analyze the feasibility of swine production and to participate in a large development-colonization project located in the Amazonian region of Pucallpa.

Colombia

Cooperation in Colombia has been conducted through ICA's (Instituto Colombiano Agropecuario) National Swine Program.

A special ICA-CIAT research project at the ICA-Turipaná Station is evaluating performance and physiological parameters of the criollo breed (Zungo) versus improved breeds. This information is being used as a doctoral thesis project by a CIAT research fellow from the Technical University of Berlin, Germany.

On the North Coast (Cacaotal, Córdoba), the project on swine production systems on small farms was continued (See page 24).

Ecuador

Cooperation in Ecuador has been conducted through INIAP (Instituto Nacional de Investigaciones Agropecuarias) in coordination with the swine programs in Santa Catalina and Santo Domingo, both in the Provincia de Pinchincha.

Special emphasis has been given to training of professionals from INIAP. Two trainees returned to Ecuador in 1974 after completing programs at CIAT; and one additional trainee arrived at CIAT during 1974. A research scholar has finished course work for a master's degree at the ICA-Universidad Nacional graduate school in Bogotá and will conduct his thesis work at CIAT during 1975.

An invitation to cooperate in a regional development project to be conducted in the region of El Oro was received from the Ministry of Agriculture.

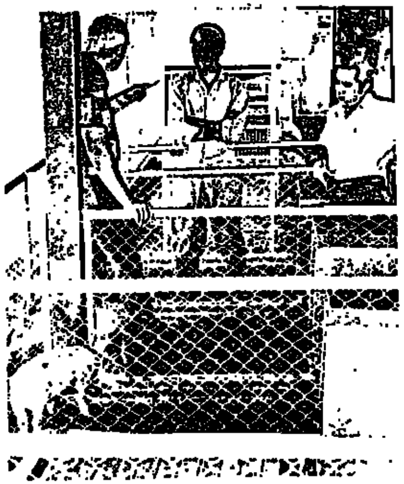


Figure 9. Training in both production and research is given major emphasis in the swine program.

Guatemala

Technical assistance has been requested by the Instituto de Ciencia y Tecnología Agrícola (ICTA) of the Ministry of Agriculture to support programs with small swine producers in the eastern and southeastern regions of Guatemala. Initial evaluation of the zone by CIAT swine team members has been accomplished by visits to swine-producing areas and small swine producers.

Other training

Although the training program has been initially integrated with the specific outreach projects of Bolivia, Peru and Costa Rica, two other professionals from Paraguay and Bolivia have been trained.

There is also a cooperative program with the University of Ibadan in Nigeria; two doctoral candidates are conducting their thesis work at CIAT (Fig. 9).

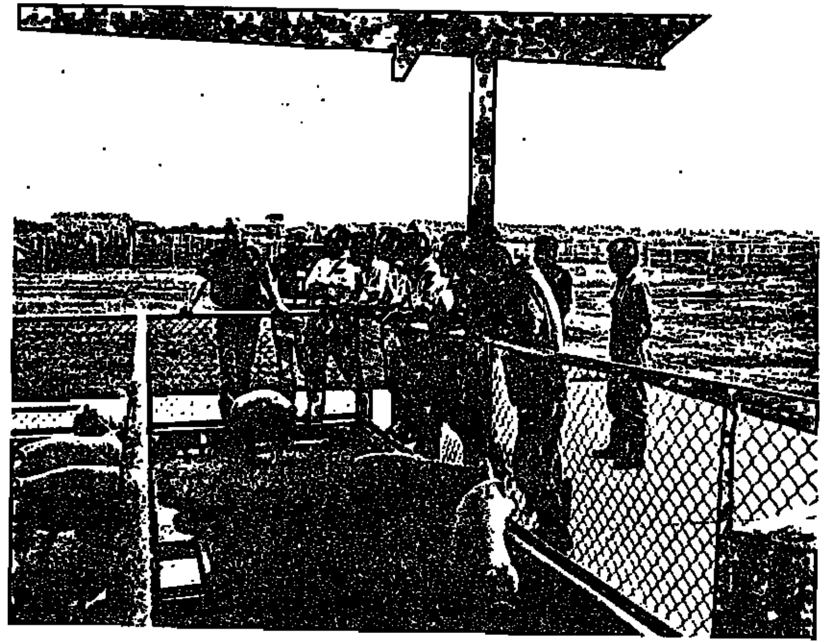


Figure 10. A team of swine experts reviewed the Swine Program in November, 1974

PROGRAM REVIEW

The Swine Program was extensively reviewed during November of 1974. The review was conducted by a team of swine experts selected from Canada, the United States, Ireland and Brazil (Fig. 10). The recommendations of the team have been received, and copies of the same are available at CIAT.

PLANT IMPROVEMENT

Commercial maize fields in countries of the Andean zone often yield more than 4 metric tons per hectare, but national averages of between 1 and 2 tons suggest that many farmers produce less than a ton per hectare on a noncommercial or subsistence basis. In a part of the world where maize is a basic food crop, some 50 per cent of the growers are small farmers who obtain very low yields.

Many problems limit maize yields in the Andean zone. Some materials are not adapted across temperature regimes that vary greatly from the coast to the mountains. Native types are generally tall and inefficient in terms of percentage of dry material stored as grain and are also susceptible to lodging. Few materials have been selected for yield stability under a variety of soil fertility conditions, response to higher plant densities, resistance to limiting insect pests, or tolerance to drought or excess water. Finally, the protein quality of varieties or hybrids currently grown are inferior to the value of opaque-2 materials. The frequency and severity of these limitations are being identified in the results of a survey initiated in 1970 by CIAT economists and described earlier (Annual Report 1973).

An important result of the maize survey, which involved small farmers in three zones of Colombia, is the indication that more than 40 per cent of the maize grown by those farmers was associated with other crops. This factor necessitates a broad, integrated approach to maize improvement.

In collaboration with CIMMYT, institutions of higher education and national maize programs in the zone, the maize program compiles all available information to be applied to the most significant production problems in the Andean zone. Taking into account the unique regional aspects, major research areas cover plant improvement, plant protection, maize associations and agronomy.

Selection in white and yellow maize populations is aimed principally at reducing plant height and improving protein quality. Because of the high cost of hybrid seed and the inherent danger posed by numerous tropical insects and diseases to genetically uniform material, the breeding program concentrates exclusively on open-pollinated varieties.

Reduced plant height

Two means have been used in public and private breeding programs to obtain shorter maize varieties. Populations from both short plants (multiple genes, each with a small effect) and brachytic short plants (a single recessive gene with large effects) have been tested and further selected in the breeding program.

Brachytic short plant materials appear to be more stable for height expression over the photoperiod-temperature regimes of Colombia (and likely the Andean zone) and have therefore received more emphasis than those of short plants. Table 1 summarizes the performance of brachytic varieties compared to high-yielding, but taller ICA hybrids in several trials planted at Palmira, Cacaotal and Montería. Although some of the brachytic plant densities were suboptimal, it may be concluded that brachytic plant densities have the potential to give yields comparable to well-adapted commercial hybrids, with the added advantage of reduced lodging from damaging wind and rain.

Within brachytic populations, a useful range of variability exists in the expression of brachytic-related characteristics (Fig. 1), such as plant height, leaf width and attitude, internode length, and stalk diameter. Selection and crossing in two cycles during 1974 was designed to identify useful combinations of characteristics in modified brachytic types

Table 1. Summary of maize yields from trials comparing brachytic materials with taller commercial genotypes.

			Check			Brachytic		
Trial	Date	Location	Name	Density *	Yield (ton/ha)	Name	Density*	Yield
Entomology	1974A	Palmira	ICA H–207	44	5.12	Comp. Am.	44	5.44
Entomology	1974A	Turipaná	ICA H–207	44	2.09	Comp. Am.	44	2.28
Varieties				27	.90	Comp. Am.	27	.19
associated	1974A	Cacaotal	ICA VE- 21	54	.72	Comp. Am.	54	.72
Doubling stalk	1974A	Palmira	ICA H -207	43	5.73	Comp. Am.	66	3.84
Spacing-fertilization	1974A	Palmira	ICA H -207	32	4.01	ICA HE 24	32	3.68
				50	4.90	ICA HE- 24	50	6.16
				95	6.58	ICA HE 24	95	8.37

* In thousands of plants per hectare

Protein quality

Breeding work with opaque-2 materials seeks to identify and increase the frequency of hard endosperm modifiers in locally adapted populations that maintain opaque-2 protein quality. Experience at CIAT, CIMMYT and academic institutions has dem-

Figure 1. Variability in brachytic materials: original short plant and two modified plant types.

Table 2. Yields of hard endosperm opaque varieties, Turipaná (1974A).

Identity	Source	Days to flower	Yield (ton/ha)
Tuxpeño x La Posta	CIMMYT	54	2.65
Veracruz x Antigua x Venezuela	CIMMYT	54	2.28
White hard endosperm	CIMMYT	55	2.67
Yellow hard endosperm	CIMMYT	56	2.18
Composite K	CIMMYT	56	1.94
ICA VE--21	ICA, CIAT	53	2.38
		Average	2.35

onstrated the necessity of continuous laboratory work to make sure the protein quality is retained in hard endosperm materials. Plants from agronomically superior families are selected in the field for crosses and selfs. After harvest and examination in the laboratory with both chemicals and the light table, crosses from families that are most uniform for hard endosperm and high-quality protein are advanced to the next generation of crossing.

Selfs from selected families in 1974B will be recombined for one generation and released as open-pollinated, hard endosperm varieties for more thorough agronomic testing. Selection of recombinants from crosses of brachytic to opaque have concurrently been selected for hard endosperm, and these populations are nearing the performance testing stage.

A preliminary yield test of five CIMMYT hard endosperm, opaque varieties was conducted at Turipaná in 1974A in cooperation with ICA (Table 2). In a cooperative CIAT-CIMMYT feeding trial, these same five materials have been increased to provide grain for biological evaluation with the swine program in 1975. It is anticipated that the CIAT maize team will function in an outreach role in laboratory standardization and germplasm exchange among several protein chemistry scientists recently trained at CIMMYT and currently working in national maize programs in the Andean zone.

Short plant and protein-quality materials have been selected for additional characteristics whenever possible. These include ear position, prolificacy, reduced leaf width and resistance to lodging (caused both by Diatraea spp. and stalk rot). Experience to date with brachytic trials indicates that these materials are particularly sensitive to soil moisture and fertility extremes and not necessarily responsive to higher plant densities. Some of the CIMMYT opaques appear sensitive to problems of soil fertility, unfavorable pH and drainage. This suggests the need for further breeding work with these populations. Finally, all promising materials must be more extensively tested agronomically to determine optimal densities and performance in association with other crops, field beans in particular.

PLANT PROTECTION

Data from the maize economic survey have reinforced evidence that **Spodoptera frugiperda** and **Diatraea** spp. are the most serious and widespread pests in Colombia. To further determine the relative economic importance of each species, a field study—conducted in collaboration with the Faculty of Agronomy, Palmira—observed the effect on yield of selective control of each insect by means of chemicals (methyl parathion to control **Spodoptera** and Furadan to control **Diatraea**). Results showed that during the period under study, damage from Diatraea was small but economically significant, while that from **Spodoptera** was unimportant (Table 3). The same trial, planted at Turipaná, suffered from low plant populations; and no significant differences in treatments were observed.

Table 3. Yield (ton/ha) of H-207 and brachytic, with and without specific chemical control of Diatraea spp. and Spodoptera frugiperda (1974 A).

Treatment	Palmira H–207	Palmira Brachytic	Turipaná H–207	Turipaná Brachytic
Control Diatraea	5.36	5.49	2.19	2.37
Control Spodoptera	4.85	5.34	2.45	2.15
Control Diatraea, Spodoptera	5.52	5.78	1.48	2.23
Check (no control)	4.76	5.16	2.24	2.36

These results are not surprising, as natural populations of both **Spodoptera** and **Diatraea** fluctuate greatly during the growing season. This supports evidence from CIMMYT and Cornell University that artificial inoculation, accompanied with control of natural populations, is necessary to test for field resistance to stalk borers. Furthermore, a study of progenies from the 23 entries reported in 1973 to exhibit genetic resistance to **Spodoptera** damage showed that "escapes" had in fact been selected.

The 1974 studies at Palmira and Turipaná reconfirmed the effectiveness and selectivity of methyl parathion for control of **Spodoptera** and Furadan for control of **Diatraea**. Methyl parathion reduced **Spodoptera** infestations from 77.3 to 4.9 per cent of plants infested, on an average; and Furadan reduced the intensity of **Diatraea** damage from 17.6 per cent to 6.4 per cent of observed internodes. Results from several years of study show that the principal (and perhaps only) losses to **Spodoptera** are at an early seedling stage in the form of reduced populations. There are also indications that **Spodoptera** damage is more pronounced if the young plant is simultaneously subjected to an additional stress, such as drought.

Weed control was one of the most important factors limiting maize production as shown by the economic survey. Weeds limit both production-per-unit-area of land cultivated per man-year. Results of a collaborative study with the swine program clearly demonstrate the potential payoff for the use of recommended herbicides (Table 4).

ASSOCIATION OF MAIZE WITH OTHER CROPS

Several trials conducted cooperatively with the swine program provide insight into the problems of improving the productivity of maize grown in association with other crops. In plantings with cassava and yams, drought stress resulted in no-yield responses from doubling the plant densities of brachytic, opaque and native varieties. In

Table 4. Economic return from the use of herbicides in maize cultivation, Caccotal (1974).

Treatment	Herbicide value*	Man-days weeding	Weeding value*	Maize Prod.**	Maize value*	Returns-inputs *
Machete	–	115	3,450	0.16	528	–2,922
2,4,5-T and Gesaprim	428	80	2,400	1.10	3,630	802
Gramoxone + Gesaprim	540	74	2,200	1.40	4,620	1,880
Roundup	–	–	–	1.20	–	–

* In Colombian pesos
** Metric tons per hectare

Table 5. Results from international maize trials planted at CIAT (1974A).

Name of trial	Number of entries	Number of reps	Avg yield (ton/ha)	Best entry	Yield best entry (ton/ha)	Source of best entry
IMAH (CIMMYT)	50	2	4.70	T-27	7.51*	Mexico
PCCMCA - ME	43	2	5.56	T-59	8.60	Poey (Mex)
PCCMCA - BA	30	2	5.16	T-31	8.12	Poey (Mex)
PCCMCA - OP	10	2	4.13	CIMMYT O_2	6.57	CIMMYT
IOMT (CIMMYT)	25	3	4.48	Ver. 181 x Ant. Gpo. 2 x Ven 1	7.28	CIMMYT
EAMVT (Kenya)	30	3	2.26	H-501	5.06	Kenya
CIMMYT Progenies						
Composite IACA Am.	256	1	5.23	—	13.44	—
Composite Centro-americano Am.	254	1	5.34	—	12.22	—
Est. Crist. Dent. Sel. Den. Am.	253	1	3.94	—	9.96	—
Tuxp. Crist. (Inv. Ver.) P.O.	251	1	4.54	—	10.83	—
La Posta P.B.	241	1	4.92	—	12.92	—
Est. Crist. Dent. Sel. Cri. Am.	256	1	4.58	—	9.78	—
Cruzas Fam. Sels. Blancas	256	1	6.89	—	11.70	—

another study, a native variety showed no significant response to high levels of fertilization with urea. This same variety also failed to respond to the presence or absence of the cassava and yams grown in association.

Preliminary observations in a nearby field indicate that the improved opaque, hard-endosperm variety VE-21 shows a more positive response to nitrogen, but this must be verified in 1975. In a study of maize-cowpea associations, however, the same VE-21 did not respond to plant densities between 30,000 and 70,000 plants per hectare. Furthermore, the gross income from the maize-cowpea association was independent of the relative proportion of the two crops in this system. Information on maize associations is necessary to select a plant type that will serve the needs of maize in both monoculture and associated cultures.

AGRONOMY

Yield tests

Results of six replicated varietal tests grown at CIAT during 1974A demonstrate the potential for excellent maize production in the Cauca Valley environment under favorable soil conditions and with some irrigation (Table 5). In particular, a number of Mexican entries from CIMMYT and commercial sources performed well. Yields of opaque materials (IOMT trial) have risen substantially from those of 1973, which averaged only .29 tons per hectare.

A large number of progenies from several CIMMYT populations were also tested in 1974A. These materials, planted at the same time as the variety trials, received the same optimal conditions as the yields show (Table 5). The best yields are high, partly the result of unreplicated, single-row plots of 5 meters. These trials were also planted early enough to avoid the heavy lodging losses from wind and rain that affected late-planted trials. In collaboration with ICA, the CIAT maize program has planted 14 CIMMYT progeny trials in 1974B. Each has 256 entries with two replications. Remnant seed from the best-yielding families will be recombined to provide tropical source populations for each of the 14 materials (Fig. 2).

Figure 2. Harvest of international trials.

Agronomic practices

Table 6 presents results of the third and final cycle of a study on residue management and tillage. Earlier cycles (1973 Annual Report) showed no significant differences

Table 6. Grain and dry matter production, soil moisture, and soil temperature for three cycles of maize residue management in ICA H-208.

Residue treatment	Production (ton/ha)*		Soil moisture (%)		Soil temperature (C°)			
					Bed		Furrow	
	Grain	Dry matter	0–30 cm	30–60 cm	5 cm	10 cm	5 cm	10 cm
Removed	3.35	17.7	22.6	23.5	31.8	29.7	33.7	29.9
Burned in place	3.49	19.5	24.4	26.7	31.7	28.7	32.7	29.2
Cut in place	3.40	19.5	26.9	27.0	29.0	26.9	30.4	27.9
Intact	3.38	18.9	27.4	29.4	29.0	27.2	29.8	27.8

* Averages for 1972B, 1973A, 1973B

among systems of tillage, as long as beds were included in the tillage method. As with tillage studies, yields for various systems of residue management do not differ significantly. Of greatest importance are the lower temperatures and higher moisture content of soils in treatments where the residue is left in place, as opposed to removal or burning. In parts of the tropics where hot, dry soils have reduced germination and early growth of maize, these results could be useful. Combining recent results from residue management and minimum tillage studies, the following factors related to reduced or minimum tillage are recognized: advantages of soil temperature and moisture; advantage of firmer soil to resist root lodging; disadvantage of centipedes and soil insects reducing germination; and weed problems.

In a second cycle of the planting systems study begun in 1973, a similar yield advantage for either double or single beds was demonstrated (1973 Annual Report). With irrigation and manual weeding, the condition and height of double beds is much easier to maintain than that of single beds.

Several additional agronomic practices were studied in 1974, including folding over the stalk or ear, which is common in parts of Latin America where birds are a threat to crops. Nonfolded controls were generally higher yielding, which indicates that in seasons and locations where birds and fungi

Table 7. Yield (ton/ha) and percentage of check for treatments removing the female inflorescence of ICA H–302.

Treatment	Yield	Percentage/ control
Remove upper ear	1,651	67
Remove lower ear	2,837	114
Control	2,481	100

are not serious (as in 1974A, Cauca Valley), the practice—in addition to consuming time—reduces yield. Yields from folding over the ear were significantly lower than those after folding the stalk. The probability of bird and fungi damage, which is apparently location- and season-specific, must be weighed against the costs of this practice.

The feminine inflorescence of maize, prior to fertilization, is harvested as a fresh vegetable in parts of Latin America. Using ICA H-302, a uniform and prolific material, the superior or inferior inflorescences were physically removed. Removing the superior inflorescence decreased yield, while removing the inferior inflorescence raised yield slightly (Table 7). It appears that these results would vary considerably with both the variety and the growing season. Thus, the commercial value of the practice needs study in greater detail befor making recommendations.

A study of the agronomic characteristics of six maize genotypes was conducted to

Table 8. Agronomic characteristics of growth for several genotypes during the 1974A season.

Character	Source					
	H-208**	HE-24***	Doble 6	H-255**	HE-25***	Doble 2
Days to differentiation*	24	17	17	26	26	24
Days to flower*	54	56	51	60	60	60
Days to physiological maturity*	105	109	103	107	111	109
Final number of leaves	20	19	21	23	21	21
Final plant height (cm)	275	160	265	230	152	235
Final ear height (cm)	145	90	142	125	72	122

* From emergence
** Opaque-2 hybrids
*** Brachytic-2 experimental hybrids

show possible differences in growth patterns (Table 8). The ICA experimental brachytic hybrids HE-24 and HE-25 demonstrated a much lower plant height and ear height than nonbrachytic commercial hybrids. Such a study reveals those growth characteristics in the field that are related to photoperiod and temperature sensitivity and insensitivity and suggests means for recognizing genotypes with a minimal amount of variation in plant type across environments and across seasons. The alternative—namely, to grow all genetic materials anually in the various environments—is more laborious, but perhaps necessary.

The use of a fan design for determining optimal plant densities was evaluated in a preliminary study. The advantages of studying a large number of genotypes over a wide range of densities are sought using a minimum of land and labor. However, several problems limit the usefulness of this method. The beds must be formed by hand, which makes construction of level furrows for irrigation a difficult maintainance problem. The compaction of soils resulting from labor in the plot is intensified toward the center of the fan, creating a gradient that is important for row irrigation. The results from this design would be most reliable under natural rainfall. The fan would serve better for most materials if it were "opened up" into sectors to facilitate more densities that are realistic alternatives. The trial demonstrated the approximate densities at which different genotypes begin to show barrenness, which appears to be essential in work with brachytic materials. Differing reports on the response of brachytic materials to high plant densities, in terms of optimum yield and the onset of barrenness, make this design a potentially useful tool. More detailed studies, using the modifications suggested above, are necessary to establish both confidence in and efficiency of the method.

Results from a trial examining the responses of normal and brachytic hybrids to four levels of nitrogen in nine combinations of row and plant spacings are presented in Table 9. No yield response to nitrogen was observed, but the effects of increasing plant populations are apparent. An important response of ICA H-207 to narrower row spacing is the tendency to lodge. ICA HE-24, the brachytic version of H-207, showed no lodging at densities up to 95,000 plants per hectare. Additional data for plant height, height of upper ear, and stalk diameter are being analyzed in an attempt to explain how two maize hybrids, differing only with respect to the brachytic gene, alter (or fail to alter) their plant types in response to increased plant density. In combination with the agronomic study of maize plant growth characteristics for different genotypes, a picture will emerge as to the plant selection characteristics that will facilitate identification of brachytic maize varieties that respond favorably to high plant densities.

Several of these agronomic studies have demonstrated the potential of short plant materials and brachytics to respond favorably to high plant densities. Sufficient seedling populations are necessary to obtain high plant density; and seedling populations in the lowland tropics vary according to seed quality, soil, ants and centipedes, rootworm and cutworm larvae, soil fertility and drainage (which, in turn, are dependent on land preparation practices), and weed competition. Overplanting by a factor of two, followed by hand thinning, is a common practice in areas where the above constraints are problematical. The costs of overplanting and the subsequent labor of thinning seriously limit the acceptance and use of improved seed. Studies of maize zones that present these limitations, followed by practical agronomic recommendations aimed at reducing the problem, will enhance the acceptance of improved materials.

TRAINING

The maize team presented a series of lecture-discussions as part of the crop production specialist course and helped to design and conduct maize field experiments at CIAT and on the North Coast. In particular, one study, using the best information available from a number of the aforementioned trials, emphasized the cost-benefit relationships for utilizing tillage, N fertilizer, improved seed, herbicides, and insecticide recommendations for improving maize yields.

Table 9. Yield of brachytic and normal maize hybrids at nine combinations of row/plant spacings, four levels of nitrogen.

Treatment			ICA H–207 (normal)						ICA HE–24 (brachytic)					
			Yield (ton/ha) at level of nitrogen *						Yield (ton/ha) at level of nitrogen *					
Row spacing (cm)	Plant spacing (cm)	Density (1,000 plants/ha)	0	40	80	160	Avg	Lodging	0	40	80	160	Avg	Lodging
70	15	95	8.17	5.69	6.51	5.93	6.58		8.11	8.84	8.06	8.49	8.37	
70	25	57	6.23	5.37	5.73	6.28	5.90	90	5.28	4.99	5.07	6.14	5.37	0
70	35	41	4.64	3.84	4.59	4.03	4.28		5.27	5.37	5.22	5.20	5.26	
80	15	83	8.57	7.53	8.87	8.41	8.34		7.73	8.15	8.13	8.13	8.04	
80	25	50	4.71	4.22	5.10	5.56	4.90	70	6.20	5.92	6.49	6.01	6.16	0
80	35	36	4.49	3.76	5.66	4.76	4.67		4.29	4.75	4.60	4.75	4.60	
90	15	74	7.05	5.79	7.29	6.16	6.57		5.29	4.04	5.55	5.74	5.16	
90	25	44	5.69	4.63	4.50	4.70	4.88	40	4.96	6.63	4.79	5.44	5.45	0
90	35	32	4.45	3.81	3.82	3.95	4.01		3.79	3.70	3.73	3.50	3.68	

* kg/ha of urea (46 %)

Planted by six trainees at contrasting locations on the North Coast (near Montería) in 1974B, these experiments are not yet complete. Preliminary indications show that production-limiting factors differ for each location. This will influence the relative payoff for the several technical inputs. The same trial has been replicated at CIAT and at ICA-Turipaná. In addition to the immediate training value, the study of inputs, which are flexible, can be modified by the trainees to answer fundamental questions in their work in national programs.

Two of CIAT's junior staff spent short periods at CIMMYT. The opportunity to interact with CIMMYT scientists in protein improvement and plant protection—their fields of special interest—is conducive to the personal development of young maize scientists in the Andean zone.

A search for new maize mutants affecting protein quality was completed, using several materials from the Andean region as source populations. A study of possible methods in field analyses for protein quality has been more recently initiated.

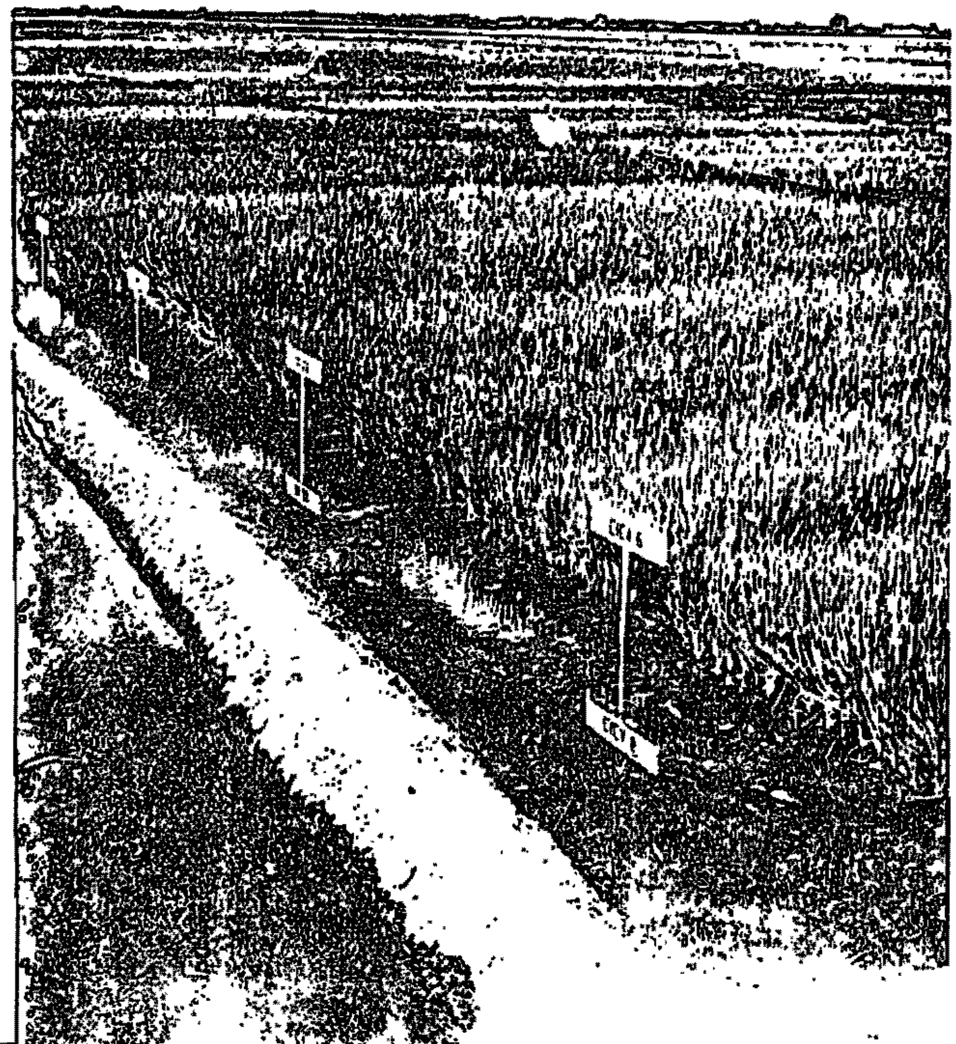
OUTREACH

The regional newsletter "El Maicero" was published twice in 1974 with reports of relevant maize research results from CIAT and national programs. A newsletter, published by the Peruvian "Programa Cooperativo de Investigaciones en Maíz, "is also serving the region. Plans are to combine these into a single newsletter.

The Sixth Workshop of Andean Zone Maize Workers was held in Maracay, Venezuela in September, 1974. More than 70 maize researchers from eight countries attended, including representatives from the five Andean zone programs. In-depth discussions of work in breeding for insect resistance, breeding for protein quality, and other factors limiting maize yields were further supported by the participation of speakers from CIMMYT and the academic community (Chapingo, Cornell and Purdue). A report of papers and discussions from Maracay is being prepared for publication and distribution to participants, national maize programs and libraries within Latin America.

As an important result of the Maracay discussions for improving maize production within the Andean region,a universal interest was created in the exchange of germplasm that is in an unpolished or "crude" form, as compared with selected hybrids and varieties of more traditional variety trials. CIAT, in cooperation with national scientists interested in this effort, will assist in the assimilation and distribution of such materials. Short plant and protein quality germplasm would be of demand in such a project. CIAT materials from recent cycles of selection have been sent to Andean zone researchers, and progenies from current cycles will similarly be available.

Scientists gathered at Maracay also felt it was very important to have greater access to technical and semitechnical information. Possible means for improving this fundamental objective are being explored, most likely through the distribution of abstracts and interpretive summaries of maize literature significant to Andean-zone maize workers.



The cooperative CIAT/Instituto Colombiano Agropecuario rice program, established in 1967, has had a significant impact on regional rice production. It is appropriate to review the results obtained to redefine goals and strategies for the coming years. Figures 1 to 4 present data from Colombia. Although adequate data are not available from other countries, similar progress has been noted in Peru, Ecuador, Venezuela, Costa Rica and Mexico. Indications of initial adoption of the new technology are apparent elsewhere in Central America, Paraguay and limited portions of Brazil.

Figure 1 shows an upsurge in rice production since 1969, while total area has not changed significantly in ten years. Nevertheless, the irrigated area is rapidly replacing upland rice (Fig. 2) indicating clearly the inferior competitive position of upland culture. Whereas upland yields are stagnant, irrigated yields have risen from 3 to 5.4 ton/ha since 1966 (Fig. 3). The varietal changes in Figure 4 show the nearly total displacement of traditional varieties by dwarf rices, which now occupy 98 percent of the irrigated rice area of Colombia.

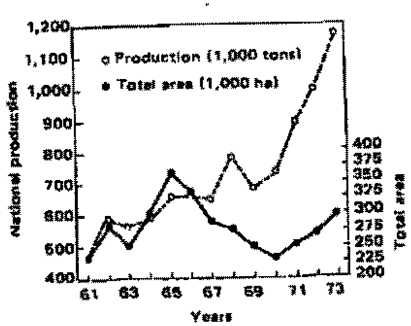


Figure 1. Changes in Colombian rice production and area from 1961 to 1973.

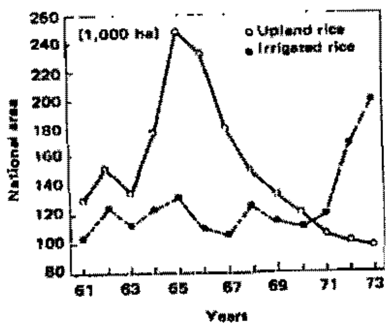


Figure 2. Changes in Colombian irrigated and upland rice areas from 1961 to 1973.

These gains in productivity, while spectacular, contain elements of future problems. Large increases in yield cannot be expected to continue, even should good blast-resistant varieties be developed. Production cannot increase further through additional adoption of the new technology as the irrigated area is essentially covered with high-yielding varieties. Further gains in regional production must come from improvement in the upland or from expansion of the irrigated area into the immense reserves of periodically flooded, alluvial coastal plains. These two areas, however, have been largely neglected by research workers in Latin America.

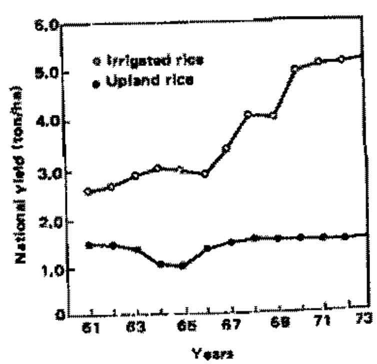


Figure 3. Changes in national Colombian yields of irrigated and upland rice from 1961 to 1973.

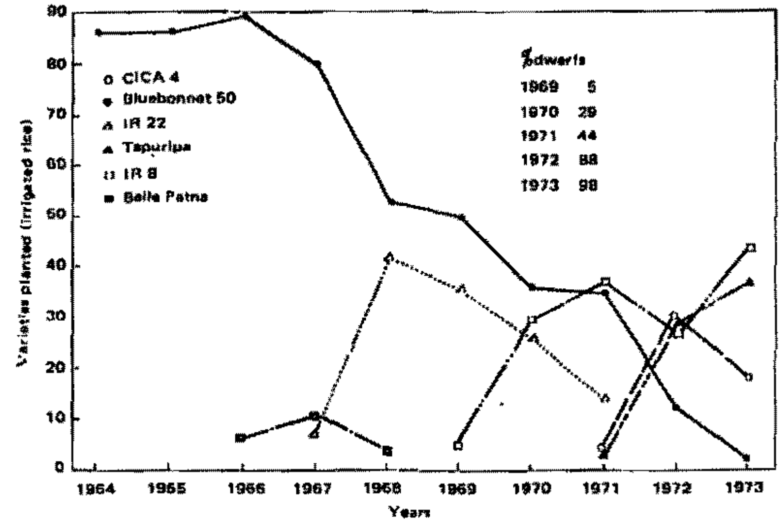


Figure 4. Changes in rice varieties in the Colombian irrigated areas from 1964 to 1973.

BREEDING

CICA 6, a new rice variety

The CIAT/Instituto Colombiano Agropecuario rice program jointly released CICA 6 as a new rice variety in May, 1974, following several semesters of international evaluation. The variety corresponds to the line P723-6-3-1 selected from the cross IR930-2 x IR822-432 made at Palmira in 1969. The

Table 1. Yields of CICA 6 and other rices in five ICA regional trials in Tolima and Huila, Colombia, 1974 (ton/ha).

Variety	Test locations					Average
	Ambalema	Ibagué	Palermo*	Espinal*	Purificación	
CICA 6	8,789	9,289	7,082	7,402	7,755	8,063
P738–137–4–1	10,101	8,659	5,011	7,559	9,201	8,146
CICA 4	7,965	8,729	4,975	7,611	8,521	7,560
IR 22	8,059	9,097	2,834	3,652	8,163	6,360
IR 8	10,642	10,912	4,324	7,264	10,250	8,678

* Severe blast damage

parental line IR822-432 has maintained its blast resistance in Colombia and elsewhere for several years. CICA 6 was released as a blast-resistant, dwarf, improved grain quality variety. It has shown good adaptability to the blast epidemic, acid soil and upland culture of the Llanos. In irrigated areas it has yielded more than commercial varieties in the presence of blast but usually yields less than IR8, CICA 4 or IR22 in the absence of blast. Representative yields for CICA 6 in comparison with other varieties are presented in Table 1.

The continuing epidemic of blast in much of the Americas was the leading justification for releasing CICA 6. The variety lacks adequate vegetative vigor, and its blast resistance is not expected to last for more than one or two years of commercial planting. CICA 6 is considered to be a stopgap variety until a variety with stable blast resistance is released.

CIAT multiplied 28 tons of foundation seed of CICA 6. About 16 tons were provided at cost to the Instituto Colombiano Agropecuario for distribution to seed producers in Colombia, and the remainder was supplied to other countries for evaluation and multiplication. The Instituto Colombiano Agropecuario produced a larger quantity of foundation seed for distribution within Colombia.

Modifications in breeding philosophy

The basic breeding objectives of past years remain in effect. However, the successful recombination of the dwarf plant type, resistance to **Sogatodes** plant hopper, and acceptable milling and cooking quality in the bulk of the breeding material—coupled with the release and farmer adoption of high-yielding varieties—has resulted in certain changes in priorities among the breeding objectives.

1. **Blast resistance.** This is now the primary objective of the program, and all crosses involve one or more blast-resistant parents. Changes in procedures related to development of blast-resistant varieties include:

a. All F_1 plants of backcrosses and multiple crosses are tested for resistance in blast beds. Susceptible plants are discarded, and resistant ones are transplanted into pots for production of F_2 seed.

b. Seed of all F_2 families is sown in blast beds, and only resistant seedlings are transplanted in the breeding nurseries.

c. All F_3—F_5 rows rated as segregating for blast resistance on the basis of evaluation of a duplicate seedling test are discarded. Plants are selected only from homozygous resistant rows.

d. A modified multiline variety approach was initiated to supplement development of pure-line resistant material. Mixtures of equal quantities of F_7 lines carrying distinct sources of resistance (Tetep, Colombia 1, Dissi Hatif, C46-15), but uniform for agronomic characters were planted in replicated yield trials in four locations in Colombia and in Guatemala and Venezuela. CICA 4 and the individual F_7 components of the mixtures were included as checks. The initial objectives included evaluation of yielding ability, uniformity and blast resistance in the mixtures of lines. A second study involving two of the above mixtures, in which the percentage of the component lines was varied in several combinations, was planted with largely similar objectives.

2. **Plant height.** The expense and unavailability of nitrogen fertilizer is expected to affect adversely the yield of the new high yielding varieties. It seems likely that improved weed control will tend to replace liberal applications of fertilizer in farming practice. Improved weed control with reduced rates of applied nitrogen should ob-

viate yield depressions. Thus, any means of controlling weeds deserves consideration.

Hence we have changed our selection criteria and seek material 15 to 20 centimeters taller than the usual height of present dwarf commercial varieties. Essentially, all of our recent material is now taller than formerly, although all carry the dwarf genotype. It is expected that the increased height and vegetative vigor will compete better against weeds without serious danger of lodging. This taller material is also needed for the high rainfall and high water table upland areas where control is difficult and normal dwarfs suffer a competitive disadvantage.

3. **Floating rices.** Since a large proportion of Colombia and neighboring countries have adopted the high-yielding varieties, little scope for further increases in production is foreseen for these areas. Enormous potential exists for exploitation of the millions of hectares of alluvial coastal lands that annually flood to depths up to one meter, where conventional dwarfs cannot withstand these conditions. We have constructed a deep water field in Palmira for evaluation and selection of dwarfed floating rices capable of moderate levels of production under excess water stresses ranging up to 80 centimeters in depth. Initially, evaluation will commence with bulk F_2 crosses from IRRI to be followed by hybridization with Palmira material to improve quality characters and resistance to **Sogatodes** and **Pyricularia**.

Breeding nurseries

During the report period, nurseries of segregating material (F_2 – F_6) were planted in February, April, May, July, August and twice in October. This material is largely the product of backcrosses and multiple crosses for blast resistance. All selections were evaluated for several critical characters as described in previous reports. Seed of the better segregating lines was sent to Brazil, Guatemala, El Salvador, Venezuela and Ecuador for local selection.

Yield trials

The most promising advanced material in the program to date comprises selections from multiple crosses made in 1971 involving the blast-resistant parents Tetep, Colombia 1, Dissi Hatif and C46-15. In February, 160 F_6 lines were planted in replicated observation nurseries in Palmira and in unreplicated trials at ICA stations in Colombia (four locations), Brazil (two locations), Costa Rica, Guatemala, Panama, Ecuador and Venezuela. In addition, two sets were evaluated for blast resistance at IRRI.

Good blast ratings were obtained from Palmira and La Libertad (Colombia), Costa Rica, Guatemala and IRRI. Useful agronomic data, including yield, were reported from most of the other locations. Strenuous effort was expended in culling out the inferior material with special emphasis placed on blast, yield, maturity, vegetative vigor and milled grain appearance. Sixty-one lines were selected and advanced to yield trials. An F_6 nursery was planted in February, and 150 panicles of each selected line in the observation nurseries were selected from uniform F_6 rows. This seed was used for seeding yield trials and for establishing a purification and multiplication block for each selected line.

The replicated yield trial and the seed multiplication blocks were seeded in August in Palmira, in five other locations in Colombia and in Guatemala, Venezuela, El Salvador and Ecuador.

Most of these remaining 61 lines have superior combinations of agronomic traits. In many locations the majority have been resistant to blast since the F_2 although perhaps 15 are doubtful in reaction. It is expected that 15 to 20 of the more resistant lines will be selected for large-scale international regional trials in 1975, concurrent with multiplication of breeder seed of each. The program expects to release one or more blast-resistant varieties from this material late in 1975.

Rice agronomy conducted research on nitrogen application–water management relationships; evaluation of weed and insect control practices with and without nitrogen applications; evaluation of herbicides for weed control in rice; and methods, rates and timing of herbicide applications for the control of volunteer rice, red rice and weeds.

Major emphasis was given to weed control work; and in these experiments, volunteer rice and red rice were considered to be undesirable weeds.

Delayed flooding after nitrogen applications

Earlier work showed that a delay in flooding for three, six and nine days after the application of nitrogen resulted in a loss in effectiveness of the nitrogen of up to 75 per cent as compared to the application of the nitrogen and the flooding of the field on the same day. However, in 1974 the soil was extremely dry when the nitrogen was applied, and the results differed from those of the earlier experiments (Table 2).

Losses of applied nitrogen during the 1971 and 1972 experiments are explained by high nitrification rates since temperature,

Table 2. Effect of delayed flooding on the response of rice to nitrogen applications.*

Delay in flooding after N application (days)	Yield following delay in flooding after nitrogen application	
	1972	1974
	(kg/ha)	
0	6,923	6,737
3	6,300	6,811
6	6,064	6,839
9	5,400	6,534
Applied in water	-	7,094
No. nitrogen	5,800	5,657

* 100 kg/ha of nitrogen

soil moisture and soil pH were favorable for the nitrifying bacteria. The nitrogen was rapidly converted to nitrates that were lost by volatilization after flooding. However, in 1974, the soil moisture was very low in the soil surface, and no nitrification occurred during the three- and six-day delayed flooding treatments. There was a small loss in the nine- day treatment as a small quantity of rain fell on or about the sixth day of the treatment. It is probable that nitrogen applications can also be made to strongly acid soils or during cool temperature periods without loss of nitrogen by denitrification since these conditions are unfavorable for the nitrifying bacteria.

In the 1974 experiment, the application of nitrogen in the water was superior in yield; but in prior experiments this treatment was slightly inferior. The data indicate that whenever fields cannot be rapidly flooded after nitrogen fertilization, it is better to wait until the fields are flooded before applying the nitrogen

Weed and insect control

This experiment was designed to determine the loss in yield resulting from weed competition and insect damage in the absence and presence of nitrogen fertilization. The granular insecticide, carbofuran, was used both as a seed treatment and broadcast in the irrigation water; and carbaryl was used twice during the reproductive and ripening cycles to provide insect control. Although some minor insect pests were noted in the untreated plots, the major damage was caused by the stink bug, **Oebalus ornata**. The principal weed problem was barnyard grass (**Echinochloa colonum**), derived from grass seed broadcast in each plot along with the rice seed. Weeds were controlled by propanil supplemented with some hand weeding. The nitrogen rate used was 100 kg/ha of actual nitrogen.

There was considerable lack of uniformity in the weed population within the ex-

Table 3. Effect of weed and insect control and nitrogen fertilization on yield of rice.

Cultural practice	Yield (kg/ha)	Difference from check plot
Check	3,333	----
Nitrogen	2,956	- 377
Weed control	3,853	+ 520
Insect control	3,567	+ 234
Nitrogen + weed control	4,602	+1,269
Nitrogen + insect control	4,310	+ 977
Weed + insect control	3,451	+ 118
Nitrogen + weed + insect control	5,103	+1,770

periment because of inadequate leveling and drainage. Nevertheless, the yield data clearly indicate response to the different treatments (Table 3).

Results indicate that fertilization with nitrogen without efficient weed control reduces yield and that weed and insect control without nitrogen fertilization gives only small increases in yield (Figs. 5, 6). When all of the practices were combined, an average increase of 1,770 kg/ha over the check plot was obtained.

Averages over all treatments showed that weed control increased yield by 710 kilograms while insect control gave an increase of 422 kilograms, and nitrogen fertilization increased the yield 692 kg/ha.

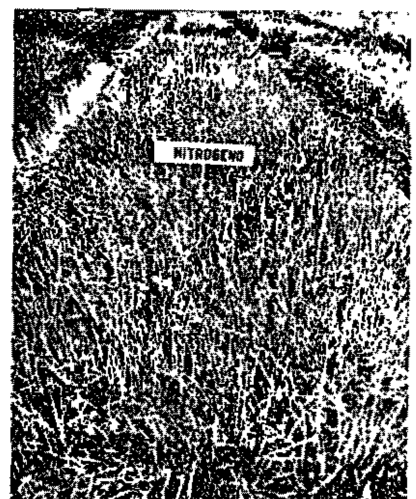


Figure 5. Nitrogen applications in this plot stimulated grass and reduced yields.

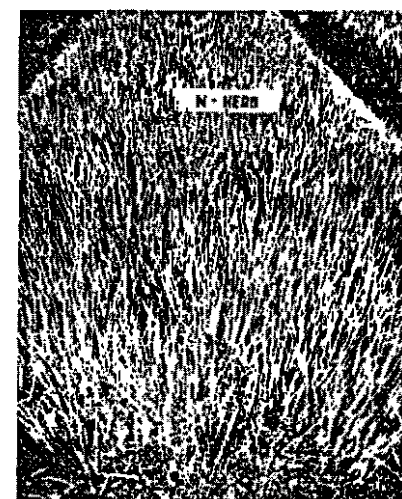


Figure 6. Good response to nitrogen was obtained in this plot when herbicides were applied.

Weed control experiments

Ten experiments involving different methods of planting times and rates of applications of herbicides, preplanting herbicide applications, and combinations of preflooding and preplanting herbicide applications were conducted. In some experiments, the control of volunteer rice and red rice received attention. New methods of applying herbicides were studied under a wide range of adverse conditions to provide efficient control of various weeds, volunteer rice and red rice.

Rates and times of propanil application

Normally propanil is applied at the two- to four-leaf stage of the weeds or about 15 to 20 days after seeding. In the following experiment, three rates of propanil were applied early and at the normal time of application. The dosages were 0.5, 1.0 and 2.0 times recommended rates, applied 5, 10 and 15 days after seeding.

The results indicated that the 0.5 rate, when applied five days after seeding, efficiently controlled all weeds, including aquatic, broadleaf grasses and sedges without damaging the rice seedlings. Later applications were less effective; some weeds developed resistance as they became older. The normal (1.0) rate resulted in no appreciable damage to the rice, but the double dosage damaged seedlings in the 10- and 15-day applications. The 0.5 rate applied early has been tested on commercial fields at CIAT with excellent results.

Preplanting herbicide applications

Since the recommended rice herbicides were developed to control weeds growing in competition with rice, they were selected to have the greatest effect on weeds and to have little or no effect on rice. These herbicides, as presently used, have no significant effect on the control of volunteer rice or red rice. Volunteer rice and red rice can greatly reduce the yields and value of the rice crop. They require the purchase of new seed each year. In the past, much productive land has been abandoned or put in long rotations in attempts to eliminate red rice. This problem was approached in two ways, as follows.

1. The use of flooding for a two- to three-week period prior to planting with the subsequent tillage under water or the application of contact herbicide after draining the water prior to planting. Earlier work showed that flooding alone reduced the red rice populations by more than 90 per cent.

2. The use of contact and residual effect herbicides to kill the weeds, volunteer rice and red rice prior to planting.

To check the effects of flooding and herbicides on weed and rice control, the land was prepared and the tall variety, Bluebonnet 50, was seeded over the entire area. Herbicides were applied and the field flooded. Parts of the field were drained at two-week intervals to check the duration of the residual effect of the herbicides. The herbicides used were trifluralin, nitrofen, 2,4 D, benthiocarb, atrazine, oxadiazon and butachlor.

The herbicides had no effect on volunteer rice. Nevertheless, few Bluebonnet 50 rice plants developed because the flooding treatment controlled the volunteer rice plants. Apparently, the flooding had nullified the effects of the herbicides. The effects of flooding on the germination and establishment of the Bluebonnet 50 rice plants are shown in Table 4.

Table 4. **Effect of water depth (flooding treatment) on the germination and establishment of volunteer rice plants.**

Treatment	No. of rice plants/m²	Control (%)
Dry seeded and flushed	210	0
Flooded		
0 5 cm depth	16	92.8
6 10 cm depth	15	92.9
11 15 cm depth	2	99
16 20 cm depth	1	99.5

Postplanting applications of herbicides

The rice was planted and the herbicides applied from 4 to 7 days to 20 to 25 days after seeding. The timing of the herbicide varied according to the nature of the herbicide and the size of weeds.

In the first experiment, the rice was seeded both in rows and broadcast and was covered with about 2 centimeters of soil. The herbicides were applied seven days after seeding. The method of seeding did not affect weed control.

Results indicated that early applications of low rates of propanil gave from 80 to 93 per cent weed control. Other herbicides giving good weed control were benthiocarb, oxadiazon, DPX 6774 and MC 4379. The 2.0 kg/ha rate of oxadiazon and DPX 6774 resulted in some damage to the rice.

In another experiment, eight herbicides were applied seven days after shallow seeding of rice.

All herbicides, except propanil, damaged the stands and yield of rice, the damage ranged from slight with MC 4379 to severe with butachlor and DPX–6774. The surviving rice plants recovered after flooding, but in most cases weeds developed and the yields were lower than in the check plot. It was concluded that only propanil can be safely used on shallow-seeded or surface-seeded rice.

The effects of flooding and flushing were compared in adjoining plots, the results of which are shown in Table 4.

The flooded fields were free from grass and broadleaf weeds, but had a high population of mud plantain (**Heteranthera reniformis**). The dry-seeded and flushed plot was heavily infested with barnyard grass and various broadleaf weeds (Figs. 7, 8).

Figure 7. **Thick stands of volunteer rice and weeds resulting from flushing after land preparation on weedy field.**

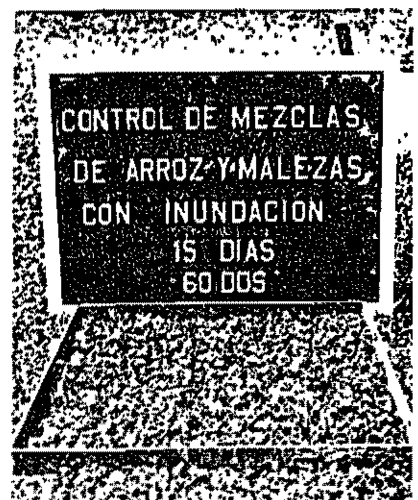


Figure 8. **Good control of volunteer rice and grassy weeds resulting from three weeks of flooding.**

Results suggest that preplanting flooding is a good practice to eliminate many troublesome weeds and reduce greatly the problems of red rice and volunteer seedlings.

At the end of the experiment, the land was worked in water to destroy the few volunteer Bluebonnet 50 seedlings and the mud plantain. Pregerminated seed of IR22 was sown, and a normally productive crop was produced without weed competition, volunteer rice, or phytotoxicity from the herbicides.

Preplanting herbicide applications

Both contact herbicides and residual-effect herbicides were used in several preliminary preplanting experiments. The land used was heavily infested with weed seed. To evaluate the effect of the herbicides on volunteer rice germination, Bluebonnet 50 seed was broadcast over the entire area and disked into the soil. The soil was cloddy and dry at the time of the application of the residual effect herbicides. Irrigation water was applied to stimulate germination of the weed and rice seed.

The data show that at the 15-day evaluation, atrazine and DPX–6774 controlled broadleaf weeds and that trifluraline, oxadiazon, atrazine, butachlor and benthiocarb reduced the grass weeds but that none were effective in controlling the rice plants. At the 30-day period, only atrazine was 100 per cent effective in controlling all types of vegetation. With all of the other herbicides, broadleaf and grassy weeds increased. The atrazine did not prevent weed and rice germination, but once the root systems were established, the seedlings were killed by the herbicide.

Under normal conditions these treatments would have been followed by the reseeding of a dwarf variety; but since only one herbicide was effective, the experiment was destroyed. As a prior experiment has demonstrated that the residual effect of the herbicides is destroyed by flooding for a two week period, the reseeding would not have been a problem. Without flooding the residual effects of atrazine may last for four to five months.

In another experiment, the land was prepared for dry seeding, Bluebonnet 50 rice was broadcast and disked into the soil, and the soil was flushed thereafter at frequent intervals to promote good germination and growth of both the weeds and rice. After 34 days, contact herbicides were applied to destroy both the rice and the weeds.

Only the atrazine + paraquat mixture controlled the rice and all classes of weeds. The DPX 6774 + paraquat mixture appeared to control broadleaf weeds but was not effective against rice and other grassy weeds. The mixture of alachlor and paraquat killed the rice plants but was only mediocre in the control of other grasses and broadleaf weeds. This experiment is being continued and expanded in an attempt to find a preplant herbicide or herbicide mixture suitable for both upland and lowland conditions.

TRAINING

One trainee each from Guatemala and Brazil received training under the supervision of the rice agronomist, while four trainees (from Guatemala, El Salvador, Venezuela and Brazil) worked with the rice breeder.

The senior scientists visited 12 countries during the year to identify problems, make recommendations, and follow up with trainees in national rice programs.

Small Farm Systems

To increase the production and income of small farmers in the Latin American tropics is a complex challenge. The potential for introduction of new agricultural technology into a traditional farm environment depends on the selection and design of a technology consistent with the farmer's objectives and feasible within his physical, economic, cultural and political environment.

In this report, the Small Farm Systems research team presents examples from Colombia, Guatemala and other countries to illustrate the complexity of small farm agriculture and outlines the potentials for increasing food production in the lowland tropics. It also details a model for the evaluation of technology using a case study from a rural zone on the Pacific Coast of Guatemala. It examines the role of institutional policies in promoting increased production in this same zone and focuses on several issues that influence the design of new technology.

Historical perspective

Grants of the Spanish Crown to the conquistadors laid the basis for the agrarian structure of most Latin American countries. The purpose was administrative control of the population; but out of these grant holders, there arose a small minority of land owners. At the beginning of the last century, this process gained momentum after the introduction of new land legislation modeled on 18th-century European concepts. Under this new legislation, the traditional structure of communal land ownership broke down.

In the higher, more densely populated regions of Latin America, a specific type of agricultural organization emerged—the hacienda. These units were devoted to cattle or agricultural production for local consumption. Laborers living on these estates received a small plot of land for family food production as a reward for labor. This constituted one of the origins of today's small farmers.

Another origin stems from the farmers who worked on the large-scale, commercial- and export-oriented farm enterprises. In the Caribbean area, including the Colombian North Coast, the farmers' cultural patterns and agricultural methods are of African origin. Generally, the patterns of land distribution in Latin America date from the 16th and 17th centuries in the higher elevations and from production of export crops in the 18th and 19th centuries.

Within this historical perspective are found the bases for the complexity of small farmer agriculture in the Latin American tropics. The situations in Colombia and Guatemala serve as partial illustrations.

The situation of the small farmer

Colombia

A major portion of the total basic food production—maize, beans, wheat, potatoes, cassava and plantain—comes from small farms. More than 60 per cent of all small farmers are found in the five typically Andean Departamentos*: Boyacá, Cundinamarca, Antioquia, Santander and Nariño. About 25 per cent of the small farms in Colombia are located in the lowlands.

Typical of Latin America, as can be seen in Table 1, the distribution of land ownership in Colombia is drastically skewed for the entire country and in Córdoba, a De-

* Departamento is a Colombian political division similar to a state or a province.

Table 1. Distribution of number of farms and total area by farm size in Colombia* and the Departamento de Córdoba.**

Farm size (ha)	Colombia (1970)		Córdoba (1971)	
	Farms (%)	Area (%)	Farms (%)	Area (%)
Less than 5	59.5	3.7	66.0	4.6
More than 5	40.5	96.3	34.0	95.4

* Source: Departamento Administrativo Nacional de Estadística (DANE). Bogotá, June, 1974.
** Source: DANE, Bogotá, 1971.

partamento on the North Coast. Net income of farmers is positively correlated with farm size, resulting in a skewed distribution of incomes in the agricultural sector of Colombia: 70 per cent of the total income is concentrated in 30 per cent of the agricultural population.

Current small farm land tenure in Colombia is characterized by ownership (67 per cent), while rented land and other types of agreements are much less important. Furthermore, it is estimated that more than 50 per cent of the small farmers in Córdoba are owners.

National statistics and other studies conclude that there is a high percentage of unemployment or underemployment in the agricultural sector. In Colombia, this level may reach 25 per cent of the total economically active population. This is a complex situation, however, in which there is a labor deficit in specific regions and during certain seasons because of the cropping cycles and peak labor demands for such critical operations as planting, weed control and harvest.

Agricultural credit in Colombia comes from four main sources: commercial banks, a government land reform agency, a government agricultural bank and private moneylenders. Commercial loans generally go to the large farming operations at commercial rates. Through the government agencies, loans are available at subsidized interest rates to small farmers for such activities as land purchase and clearing, irrigation and drainage; however, production credit for this group is limited. Although nominally available, this credit may not reach most small farmers because of their lack of knowledge or confidence in the system or preoccupation about risk on both the farmer's and the institution's part. In addition, there are difficulties in informing a large number of small farmers and managing many small loans. To avoid the time and complications of a government loan, small farmers will go to private moneylenders who are willing to accept the high risk of small loans and charge corresponding market rates of interest.

The farm family on the North Coast of Colombia is typical of the Caribbean zone in the decision-making structure of the family. Because of the instability of the nuclear family unit, the continuity of the mother's role in many families places increasing responsibility on her to sustain production and a food supply for the family. Here, the typical small farm is dedicated to basic food crops. The predominant cropping systems involve the intercropping of plantain, bananas, cassava, yams, sweet potatoes, maize, cowpeas, rice and various other fruits and vegetables. Chickens, ducks and turkeys are common and subsist on crop residues and occasional grain discards.

The family diet consists mainly of the low protein foodstuffs. Maize and rice are also consumed. Meat is too expensive and even eggs are sold rather than eaten. Crop sales include plantain, cassava and yams. On those small farms with additional food or fiber crop production, maize, rice, cotton or sorghum are produced for sale.

The possibilities for education for small farmers and their children are limited. Some rural communities do not have schools, and low incomes limit the small farmers' ability to educate their children. The availability and quality of education in rural areas is a

major constraint, which limits the development of human resources and consequently the opportunities for using new technology.

The majority of small farms in this zone do not have running water, electricity and sewage systems. There is a lack of medical services, and diseases endemic to the Coast include malaria, smallpox and measles.

Guatemala

As in other Latin American countries, the ownership of land is distributed unevenly. Farms of less than 7 hectares represent almost 90 per cent of all farms in Guatemala; yet they have only 19 per cent of the land area, the average farm size being about 2 hectares. The number of small farms increased 20 per cent between 1950 and 1964 (the years of agricultural census), reflecting subdivision of existing holdings in the highlands and the incorporation of new land for small farmers in the coastal regions.

The traditional subsistence sector probably contributes less than 20 per cent of the value of agricultural output, and its contribution to total production has been small and declining, currently representing an estimated 5 per cent. Hence the sector is of minor significance in the national economy. Agricultural output in Guatemala is concentrated in the large farm sector which supplies the principal sources of the country's export earnings, primarily coffee and cotton. Although its total economic contribution is small, the traditional farm sector provides between 50 and 60 per cent of the national output of maize and beans.

It is estimated that 50 per cent of the Guatemalans live in the traditional agricultural sector. As population growth rates have exceeded the rate of growth of output from this sector, their per capita production has been nearly halved in the last 20 years. With increased man-land ratios in the highland areas, there has been both a seasonal and permanent shift of agricultural population toward the low, humid, tropical, coastal areas. During the last 25 years, maize output in the southern coastal region has risen from about 40 to 120 per cent of highland production, reflecting the zone's increased importance.

There is a concentration of small farmers in the highlands and an increasing importance of lower zones where land is available in Latin America. Factors limiting production and economic development are distinct in these two situations, as discussed in the following section.

Increased food production in the lowland tropics

Data from recent attempts to evaluate the experience of rural development projects in the highlands of Mexico, Peru and Colombia suggest that agriculture—although an important and obvious element in the subsistence and income of farm families—is often only a minor part of their total income. Furthermore, the situation of small farmers in the highlands is often characterized as one of limited land and a lack of a well-developed infrastructure. This situation frequently amounts to one of rural poverty. Efforts to ameliorate that poverty should focus on the development of rural industries, rural education, rural public works programs, and nutrition supplementation.

The role of new agricultural technology in promoting the welfare of these rural poor is limited and in many zones would be of lower priority than other programs mentioned above. Furthermore, the agriculture of the highlands has evolved over long periods of time on relatively fertile soils and is believed to be operating at a level near its potential. With these traditional but efficient systems, the probability of substantially increasing food supplies through new agricultural technology is low.

The lowlands appear to have a greater potential for increasing the small farm's total food output and improving family incomes because of the natural conditions which allow two or more crops per year where rainfall is available or water is controlled and because the vegetative cycle of most basic food crops is shorter. Furthermore, some factors known to limit production are subject to manipulation through the development and application of new agricultural technology. These limiting factors include less fertile soils in some regions and a prevalence of insects, diseases and

Table 2. Comparison of rankings on production-limiting factors made by farmers and agricultural technicians at five sites.*

Ranked by farmers	Yurimaguas	La Máquina	Cacaotal	Altamira	Llanos
1	Low prices for products (9)	Lack of machinery (4)	Water for irrigation (1)	Poor health (6)	Lack of transportation (1)
2	Lack of credit (4)	Pests and diseases (2)	Lack of land (8)	Lack of seeds and fertilizers (4)	Low prices for products (8)
3	Lack of seeds and fertilizers (1)	Low prices for products (3)	Lack of seeds and fertilizers (3)	Lack of transportation (1)	Lack of seeds and fertilizers (2)
4	Lack of machinery (8)	Lack of labor (6)	Lack of machinery (13)	Low prices for products (2)	Lack of machinery (2)
5	Weeds (3)	Lack of seeds and fertilizers (1)	Lack of feed for animals (7)	Pests and diseases (3)	Lack of credit (7)

* Number in parentheses indicates ranking of this factor by agricultural technicians working in the area.

weeds. Water control is a frequent problem in many areas.

These problems are being solved through genetic improvement of crops and development of improved agricultural practices. Many new lands being brought into production are in lowland regions for which technology is being developed. Increases in total food output and economic development can be expected from appropriate technology, which makes land and labor more productive.

Complexity of small farm agriculture

The Small Farm Systems team made anthropological surveys in five sites in the lowland tropics to assess the factors limiting production and to find out how these were perceived by farmers and agricultural specialists. Table 2 presents a comparison of the importance of various production-limiting factors in Yurimaguas (a development site in the Peruvian jungle), La Máquina (a recent settlement on the South Coast of Guatemala), Cacaotal (an established village on the North Coast of Colombia), Altamira (an "Agrovila" on the Trans Amazónica highway in Brazil) and the Llanos (east of the Manacacías in Colombia).

These rankings of limiting factors were obtained in a paired comparison test of 14 such factors said to limit production. The questions were asked of small farmers and agricultural technicians in each location. The five most important factors in each site have been presented in the order ranked by farmers. The factors and their rankings are not the same across sites; factor rankings differ by zones. Furthermore, there is a discrepancy between the rankings the factors were given by the farmers and by the technicians. This illustrates the complexity faced in designing improved agricultural technology for small farmers, and it also shows that those responsible for the design and delivery of agricultural technology in each zone perceive the limiting factors differently from the farmers.

The role of the CIAT Small Farm Systems Team is to study this complexity to understand how these factors interact and thus be able to help design appropriate technology for the small farmer in the lowland tropics.

Agricultural technicians have generally designed technology to be either land saving or labor saving. It may be that the criteria used by the farmer to evaluate his own agricultural technology are more complex, including such measures as (1) quantity and quality of a variety of agricultural products for consumption and sale, (2) cash income, (3) return to labor, and (4) security.

Farmers apply these performance criteria in an intuitive way. However, in order to design production technology that is appropriate for small farmers, scientists must clearly understand how these various criteria interact and what is the relative importance the farmer gives to each.

Selection and design of technology

The selection and design of appropriate technology for the small farmer implies taking into account knowledge and understanding of his complex physical, biological, economic, cultural and political environment. A methodology is needed for selecting from among many potential alternative technological changes those which are most compatible with the small farmer's needs, criteria and capabilities and therefore those most likely to be adopted.

One approach to evaluating technology is to use a systems model to simulate proposed production technologies under varying ecological and socioeconomic conditions. The model is designed to relate the effec-

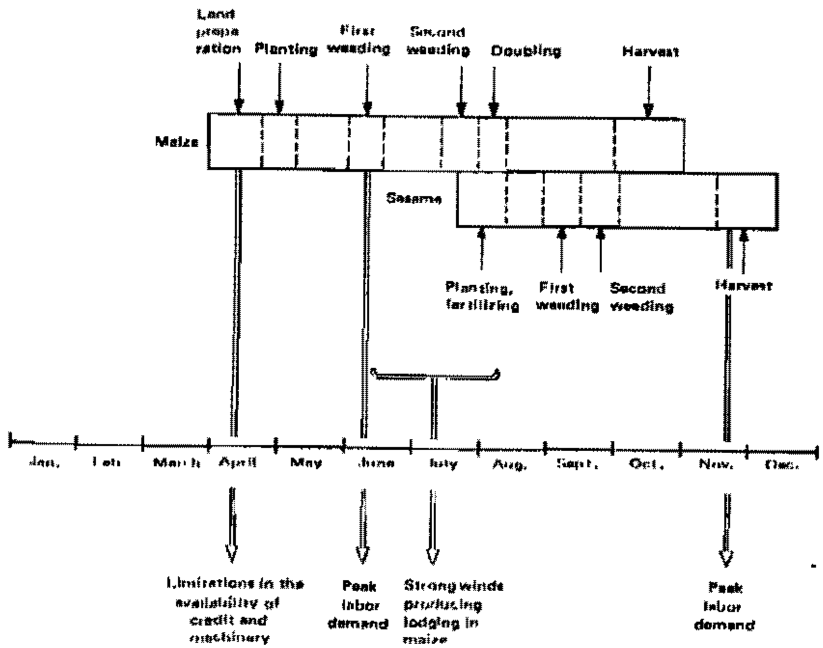


Figure 1. Typical cropping cycle at La Máquina, Guatemala.

tiveness of a production system to the farmer's criteria and to test the efficiency of a proposed production system against the utilization of scarce resources. It is used to explain the dynamic behavior of the small farm system as a function of its input/output relationship with external biological, ecological and institutional systems in order to identify agricultural technologies required to stimulate changes in farm performance.

Part of the characterization of a production technology would include a "best" statement of a function relating agronomic inputs to production. The characterization includes (1) cropping sequence, (2) planting dates, (3) fertilizer and insecticide use, (4) weeding requirements, (5) use of machinery, (6) rain and winds, and (7) cost of harvesting.

As an illustration of selection of production technology, a specific case study is hereby described.

A case study at La Máquina, Guatemala

At the request of the Instituto de Ciencia y Tecnología Agrícola (ICTA), one production zone was selected as a research site. This zone, known as La Máquina, was established as a land settlement project in 1956. It comprises 34,500 hectares divided into 1,485 farms, the majority of which are exactly 20 hectares. The principal crop is maize, and the region produces about 4 per cent of the national maize output.

As part of the collaborative research with ICTA's production team, 100 farms were surveyed in October. The principal objective was to provide a base line of agronomic and economic data to use in the allocation of research resources for the design of improved agricultural technology for basic grain production in the region. Some preliminary results are presented below. In addition, the data were used for the simulation model.

The cropping system (Fig. 1) consists principally of maize sown in the first season, followed by an interplanted crop of sesame in the second season. Some second-season

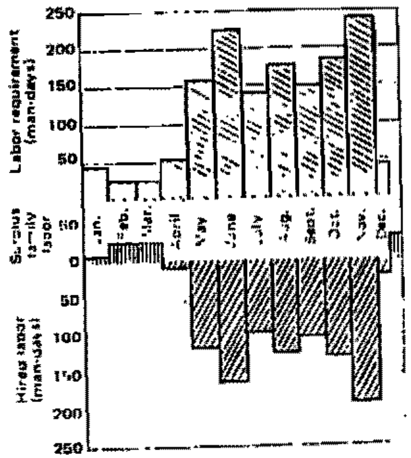


Figure 2. Flow of labor by month for a typical farm at La Máquina.

maize is grown, as well as small fields of rice, field beans and a range of other crops. About 50 per cent of the farms surveyed had cattle, and most had one or two pigs and about 30 domestic fowl. From the survey results, a "typical" farm was described, and Figures 2 and 3 show two aspects of this farm.

In Figure 2, the labor flows are shown, indicating that for the majority of the year the farms are in a "labor-deficit" state, using hired labor to sow, weed and harvest the crops. These operations are performed principally by a migratory labor force from the highlands. Any proposed changes in technology must consider the absence of surplus family labor and the social question of potential displacement of migratory workers.

Figure 3 shows the uneven flow of cash income and expenditures. Other cropping systems which generate a more even flow of receipts may warrant attention.

The following distribution of per capita incomes during 1973 was estimated from the survey data for the total resident rural population of the zone, indicating more than 60 per cent of the people had income

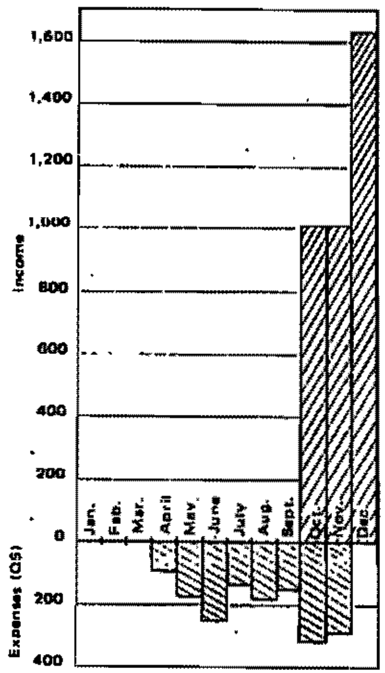


Figure 3. Flow of income and expenditures by month for a typical farm at La Máquina, Guatemala.

ess than the national average, which was Q$414.70

Per capita income (Q $)	Per cent
0 - 75	8
76 - 145	19
146 - 220	19
221 - 330	18
331 - 730	22
731 - 1,460	12
1,461 and more	2

Table 3 presents the results of classifying the sample into the lower and upper terciles on the basis of net income per capita and on the basis of yield of maize in the first season. The analysis demonstrates some of the characteristics associated with higher levels of income and yield. In the case of net income per capita, the levels of education, ownership of machinery, greater areas and yields of maize and sesame, more cattle enterprises and more credit appear to be associated with higher economic performance. The use of improved varieties or hybrids, closer plant spacing and more labor input appear to contribute to higher yields of maize. Differences in the use of agrochemicals are small, and use of credit does not appear to be associated with higher yields. A more detailed analysis of this data is in progress.

Results of the simulation study

A production function was used to represent the crop production subsystem for a typical farm in La Máquina. The model also uses the number of family members living on the farm to compute a family consumption index. The model is being utilized to evaluate different combinations of technology, including the use of improved seeds, fertilizers and other agrochemicals.

Output from the model includes sales of crops and animal products, use of credit, family consumption, family consumption costs, credit costs, production costs, cash on hand and the family consumption index. The model displays the price trajectory for agricultural products, time of occurrence of the various events during the cropping cycle, as well as the occurrence of the various risk factors such as lodging and the delay in the start of the rainy season. Production is measured in quintals of maize equivalents from the maize-sesame cropping system shown in Figure 1.

The model was used to simulate the behavior of a typical farm over a period of five years under varying assumptions regarding the use of agricultural technology and levels of credit, prices and land utilization. Figure 4a presents the production trajectories at the current level of land utilization (11.4 hectares) and at the full 20 hectares, with and without a complement of technology (seed, fertilizer, herbicide) and credit. Figure 4b presents the net farm income trajectories simulated under the two land utilization conditions. Increasing the land under cultivation to almost twice the present level increases both production and

Table 3. Characteristics of the sample farms at La Máquina: average for low and high groups according to two criteria (1973).

Characteristics	Net income per capita		First season maize yields	
	Low	High	Low	High
Social				
Family size (no.)	12	6	11	9
Number of family workers (no.)	3	2	3	2
Average years of education per person (years)	0.8	2.1	0.8	1.5
Technical				
Area of 1st season maize (ha)	9.9	12.5	10.4	11.6
Area of sesame (ha)	3.8	8.6	4.0	7.6
Per cent owning machinery	3	18	9	8
Per cent using machinery to sow maize	18	42	21	30
Per cent using improved or hybrid maize seed	6	24	6	17
Distance between hills of maize plants (cm)	73	55	71	55
Number of head of cattle (no.)	5	10	3	10
Per cent using fertilizers in 1st season maize	6	12	6	11
Per cent using insecticides in 1st season maize	42	52	42	47
Yield of maize, 1st season (kg/ha)	1,391	2,099	1,199	2,505
Yield of sesame seed (kg/ha)	341	569	356	541
Economic				
Amount of labor used in principal crops (man-days/ha)	71	85	64	82
Cost of first hand weeding in maize ($/ha)*	12	12	11	14
Expenditures on fertilizers ($)	14	26	16	30
Expenditures on insecticides ($)	12	54	12	21
Expenditures on herbicides ($)	2	3	5	3
Price received for sesame seed ($/kg)	0.26	0.34	0.28	0.34
Value of maize sales ($)	1,023	2,573	1,075	2,522
Value of sesame seed sales ($)	527	1,985	589	1,669
Value of sales of animals ($)	38	389	54	331
Per cent with credit from Agr. Devel. Bank	18	30	24	22
Amount of credit ($)	184	400	234	253

* All figures in this section are in quetzales, equivalent to one U.S. dollar.

income by 25 per cent. Use of modern production factors and the associated credit increases production and income. However, the impact of these changes on the family consumption index presented in Figure 5 indicates that this index would drop substantially if the farmer should try to bring his full 20 hectares into production. This lies in the fact that bringing more land into production would require a reallocation of cash and other resources that would cause a reduction in total family consumption, even with the use of credit. Since the farmer will try to satisfy his subsistence needs first, it is apparent that he has little incentive to increase production by expanding the area planted.

Figures 6a and 6b present the comparative production and income trajectories using fertilizer and herbicide. The farmer was presumed to have Q$500 credit available f·

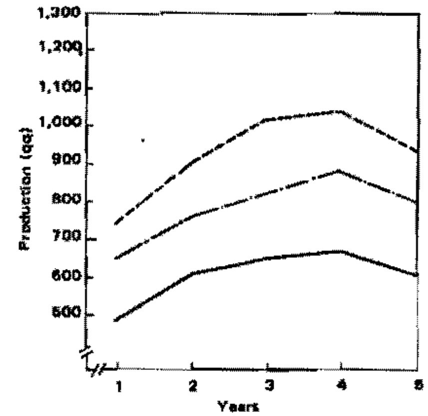


Figure 4a. Simulated five-year production trajectories for three levels of resource use.

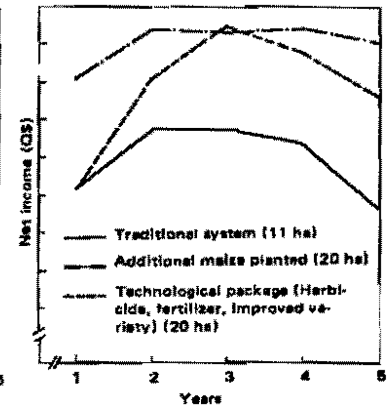


Figure 4b. Simulated five-year income trajectories for three levels of resource use.

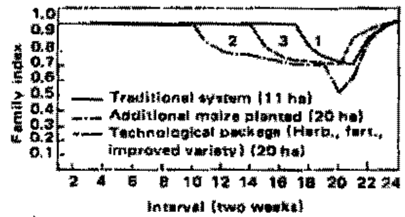


Figure 5. Simulated family consumption index for the first year at three levels of resource use.

finance the required investment. The simulated increases in production and net income are relatively small. There appears to be little incentive for increased production through the use of these two factors. These results indicate that with the technology available in the zone prior to ICTA's accelerated research program, farmers have had little or no incentive to expand the use of modern factors of production or credit. Thus, there appears to be a critical need for new technology appropriate for the zone.

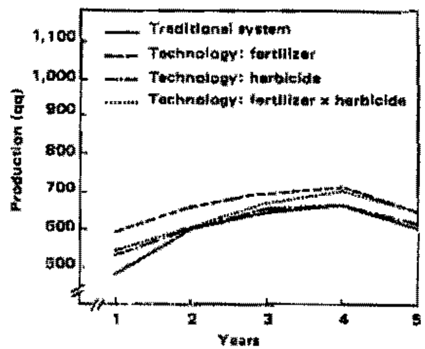


Figure 6a. Simulated five-year production trajectories for three combinations of agrochemicals.

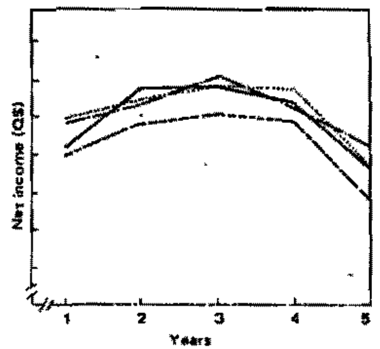


Figure 6b. Simulated five-year income trajectories for three combinations of agrochemicals.

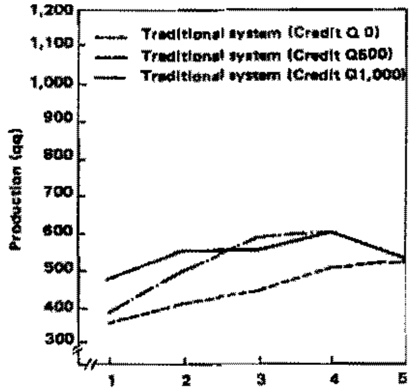


Figure 7a. **Simulated five-year production trajectories for three levels of credit use on a typical farm at La Máquina.**

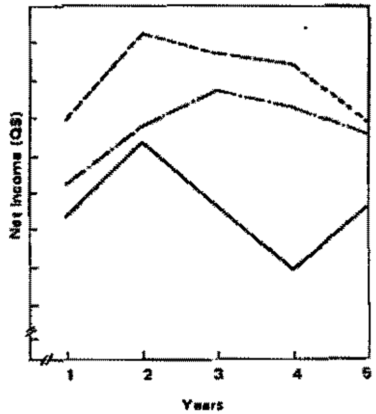


Figure 7b. **Simulated five-year income trajectories for three levels of credit use on a typical farm at La Máquina.**

Credit use is evaluated in Figures 7a, 7b and 8, indicating that where credit has been used, it was to finance family food consumption rather than to augment production.

Role of institutional policies

Expansion of basic grain production includes both the development of relevant agricultural technology and an appropriate set of institutional policies to ensure profitable adoption. The Small Farm Systems team focuses research on both of these areas. The following preliminary analysis relates to the role of institutional policies in promoting the adoption of new agricultural technology.

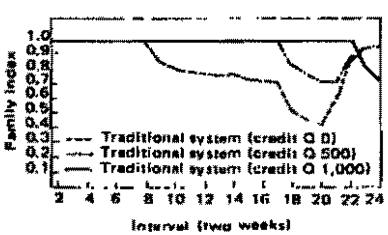


Figure 8. **Simulated family consumption index for the first year under three levels of credit use.**

Data from 156 farms in La Máquina were obtained from the Public Sector Planning Office in Guatemala. These farms were members of the supervised agricultural credit program in 1973. A standard production function analysis evaluated the profitability of fertilizer use in the maize-sesame production system prevalent in the zone. A condition for obtaining credit from the Agricultural Development Bank is that the farmer must apply fertilizer and other inputs in accordance with the practices recommended for the region.

Based on an analysis of the response of output to fertilizer applications, the value of an additional dollar invested in fertilizer was calculated (Fig. 9) as a function of fertilizer expenditures (assuming average output levels). The results imply that the return on the last dollar invested in fertilizers for the average level of fertilizer expenditures in 1973 (F_{73}^a = $73) was 80 cents, while the optimum would have come from equating the price of a unit of fertilizer to the value of additional product obtained; i.e., F_{73}^o = $58,70. Assuming constant product prices, the value F_{74}^o = $29,40 indicates the optimum fertilizer expenditure with 1974 fertilizer prices at twice their 1973 level.

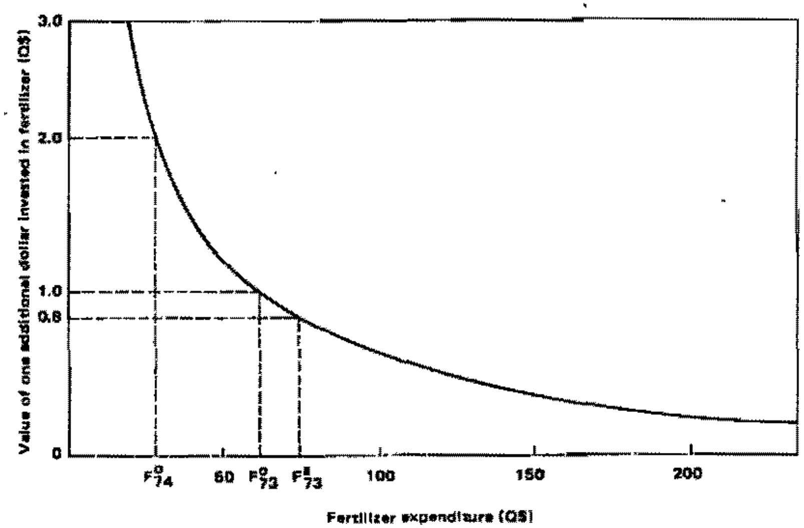


Figure 9. **Value of additional fertilizer expenditures at La Máquina, Guatemala.**

These optimum levels have been derived from a static analysis and reflect the highest possible levels that correspond to maximizing profits; incorporation of risk as a determinant of optimum fertilizer levels would undoubtedly reduce these values.

This preliminary analysis suggests that the supervised credit program encouraged fertilizer use on the average beyond its economic optimum level in this zone although the total cost of this misallocation for the 156 farms was not substantial. This example demonstrates the more general problem of "forced adoption" of new agricultural technology, and further work is currently under way to examine the social costs and benefits of such policies.

The problem has special significance in the Guatemalan context where credit and input supplies are allocated across five crops in 18 subregions of the country. It is possible that changes in this allocation could result in increased basic grain output with no corresponding increase in the total resources used.

TRAINING

Special emphasis was placed on active participation by the team with the training activities in the areas of economics, biometrics and problem identification, with additional classes on the social and agronomic aspects of small farm agriculture. Five Guatemalan production trainees have returned to ICTA to work in the intensive programs, including La Máquina, to increase basic grain production. A Guatemalan economist is completing a thesis project for a master's degree under supervision of the program economist.

Although specific research projects of the Small Farm Systems Program concentrate on key issues which affect the use of technology by the small farmer, the realization of this work will continue to emphasize collaboration and integration with CIAT commodity and training programs and will be carried out whenever possible in specific production zones with the appropriate national agency.

General agricultural research

In accordance with CIAT's commodity program orientations, every effort is made to plan and budget for specific research projects to be undertaken as part of and in support of specific commodity programs. From time to time, however, individual scientists undertake certain research projects which, although limited in scope, are of significant general interest or application. The results of such activities are reported here.

AGRICULTURAL ENGINEERING

The agricultural engineer and the farm superintendent jointly completed a manuscript describing "A Continuous Rice Production System," published as Information Bulletin No. 2 in March, 1974.

This system of rice production was continued under Station Operations supervision for land rehabilitation, production and training. Over a four-year period (1971-1974), 1,036 tons of rice were produced from 42 lot plantings on the CIAT farm. Lots ranged in size from 0.8 to 8.8 hectares. Overall average yield was 5.9 ton/ha or 44 kg/ha per day. The number of days from planting to harvest averaged 134, with a range of 122 to 168. Production per day ranged from 30 to 59 kg/ha.

The highest yield recorded (8.37 ton/ha) came from the smallest plot (0.8 hectares), but the next two highest yields (7.50 and 7.58 ton/ha) were harvested from the largest plots, 8.8 hectares each.

During 1974, several agronomists and tractor operators were trained in these production techniques, and the method is now being used on several private rice farms.

These same rice land leveling techniques were introduced on the ICA Station at Turipaná. The 100-hectare development program was completed in July. Data on production will be published by ICA.

The Agricultural Engineering section continued supporting other CIAT and ICA programs at the Turipaná Station. Equipment was purchased and serviced. An operator, instructor, research associate, technician and an engineer were at Turipaná a major part of the year. A cooperative agreement involving CARE, INCORA, ICA, CIAT and a farmers' cooperative was initiated to purchase equipment, to train an operator, and to provide technical assistance in leveling and preparing the wet areas on the cooperative farm. The farmers had completed 10 hectares in November.

INCORA, ICA and CIAT initiated preliminary work with a group of small farmers adjoining the Turipaná Station.

The agricultural engineer advised other CIAT programs as requested, particularly the Small Farm Systems activities.

WEED CONTROL

Purple nutsedge

Purple nutsedge (**Cyperus rotundus**) is a tremendous problem in many crops. Although Cyperus rotundus was known to produce growth inhibiting substances in its tubers, the importance of these inhibitors in the field had not been studied. Tubers were collected from infested fields for trials in screenhouse facilities using the same weed densities as observed in the field. Sorghum and soybeans served as indicator crop plants.

Purple nutsedge inhibited growth of sorghum and soybeans when crushed tubers were present in the soil, but not when foliage was incorporated. Sorghum growth was more seriously retarded than that of soybeans, but seed germination was not affected. Delaying planting after the nutsedge had been mixed into the soil reduced the inhibition, indicating that inhibitors did not persist long. The inhibiting compounds were leached from the tubers, but the concentration did not significantly affect sorghum or soybean growth. Soil microorganisms did not degrade or activate the inhibitors under the conditions of these trials.

Great reductions in plant height and weight of both crops were associated with the presence of **Cyperus rotundus**, indicating that the quantity of N, P and K per plant was reduced. However, leaves of sorghum and soybeans from plants in competition with purple nutsedge had the same percentage of N, P and K as the control plants, indicating that efficiency of nutrient extraction was not affected.

Field observation suggests that purple nutsedge is not a shade tolerant plant. Once the crop produces a closed canopy, it ceases to compete. Under controlled conditions, **Cyperus rotundus** growth was seriously affected by shade. The plants under 80-90 per cent shade grew three times taller than those in sunlight, but dry weights were three times less. The number of tubers produced was reduced 27 per cent under 65 per cent shade and then dropped sharply as the shade increased. The number of inflorescences produced was greatly reduced (83 per cent) under a shade of only 44 per cent. In every aspect, a nutsedge from the Sinu Valley was more vigorous than one from the Cauca Valley, indicating that biotypes do exist. Results also show that an 80 per cent reduction in the sunlight reaching the purple nutsedge is necessary before its growth is significantly affected.

Two herbicides, 2,4–D and glyphosate, are known to kill emerged purple nutsedge. An attempt was made to develop a production system based on repeated application of the herbicides, with and without soil tillage after application.

Two applications of 2,4 D without soil tillage before planting maize did not reduce the number of nutsedge plants and allowed a 100 per cent increase in tubers per hectare at the end of the experiment, but only an 11 per cent increase when the soil was tilled two weeks after application. Without tillage, glyphosate reduced the number of plants by 86 per cent and the number of tubers by 70 per cent, reflecting its effectiveness as a translocated herbicide.

Five applications of 2,4–D without planting maize reduced the plant and tuber populations 97 and 86 per cent, respectively, when the land was tilled after application. In contrast, five applications without tilling the soil resulted in 62 and 102 per cent increases in plant and tuber number, respectively. It is important that the land be tilled after applying 2,4 D.

Glyphosate needed to be applied only three times, as the first two applications were extremely effective. The tuber population was reduced 38 and 72 per cent in the non-tilled and tilled treatments, respectively, showing again the added benefit of integrating soil preparation with the herbicide. Glyphosate also induced dormancy in those tubers remaining in the soil.

Morning glory

Another serious weed in the tropics is morning glory (**Ipomoea** spp.). Its twining habit makes it particularly competitive, and the seeds can germinate from depths of 10 centimeters or more, making it difficult to control with most current preemergence herbicides.

Metribuzin (.7 kg/ha) controlled 86 per cent of the morning glory 30 days after application; and 35 kg/ha in combination with either alachlor (1.5 kg/ha), dinitramine (.35 kg/ha), trifluraline (.75 kg/ha) or H-22234 (2 kg/ha) gave 75 per cent control. All the above mixtures also gave excellent grass control, and no treatment caused any injury to the soybean corp.

Postemergence applications of bentazon (2 kg/ha) in the four-leaf stage of soybean also gave acceptable morning glory control (78 per cent). Earlier applications and 1 kg/ha of bentazon were less effective; and for all rates and times of spraying, grass control was zero. This problem could be solved with the application of a preemergence herbicide effective against grasses.

Build-up of resistant species

No data is available to confirm how rapidly the continued use of the same herbicide in a field causes a rapid build-up of resistant species in the tropics. A four season trial was started in 1971, using maize and soybeans in continuous production or in rotation with the continuous use, rotation, or combination of various herbicides.

Maize plots were treated for four seasons with the following applications: (1) atrazine or alachlor each season, (2) the rotation atrazine-alachlor atrazine-alachlor, or (3) the combination of atrazine + alachlor each season. Soybeans in continuous production were treated with (1) linuron or alachlor each season, (2) the rotation of the two herbicides, and (3) the combination linuron + alachlor each season. Hand-weeded and weedy checks were included for each crop.

No weed species increased in maize treated for four seasons with atrazine. In fact, weeds were never present in more than 0.5 per cent of the area 60 days after planting in any season. Alachlor applied during four consecutive seasons, however, allowed for a 36 per cent increase in broadleaf weeds as compared with the initial population, although excellent grass control was maintained. When atrazine and alachlor were rotated, broadleaf weeds tended to increase in the two seasons alachlor was used, but the atrazine applied the following season stopped the build-up. Equally effective in not allowing a broadleaf build-up was the continued use of atrazine + alachlor. Excellent weed control was obtained each season.

Greater weed build-ups resulted in soybeans. An 80 per cent increase in broadleaf weeds (primarily **Euphorbia hypericifolia**) occurred when linuron was applied for four consecutive seasons. Broadleaves also increased with the continued use of alachlor, but the species were principally **Ipomoea** spp. and **Cucumis melo.** Rotation of the two herbicides tended to present high grass populations when linuron was used and high broadleaf populations with alachlor. The herbicide rotation in soybeans was much less effective in controlling weeds than it was for maize. Four seasons of linuron + alachlor gave excellent control up to 30 days, but at 60 days the broadleaf control decreased markedly. For both maize and soybeans, two hand weedings for four seasons tended to reduce the weed population the following year.

When maize was hand weeded, the grasses were greatly reduced, and hand weeding soybeans reduced the grasses slightly; but the greatest reduction was in the broadleaves (36 per cent less in the fourth season). Thus, a good manual or mechanical weed control program can keep annual weed populations in check.

Experiment station operations

Personnel provided service to the commodity programs, reclaimed land, trained eight professionals and operated the experiment station.

With the objective of increasing the area suitable for research within the CIAT farm, 44 hectares were leached and leveled. In the process, rice was produced on a commercial basis (See Agricultural Engineering). In addition, 4,206 square meters of irrigation canals were lined with a soil-cement mixture.

Areas of the farm not in research in any season were planted with crops to control weeds and keep the land in production. During 1974, the unit produced 55 hectares of rice, 37 of beans, 6.5 of sorghum, 9 of soybeans and 8 of cassava.

Operation of the station included care of 37 kilometers of roads, 35 kilometers of drainage canals, 35 kilometers of irrigation canals and 37 kilometers of fence.

In cooperation with the cassava agronomist, a study was established to determine the effect of four methods of land preparation and planting on yield. Exploratory work was launched on planting beans and other crops in beds separated by small furrows, thus making it easier to drain and irrigate the lots. The furrows provide sufficient space for tractor and implement tires to operate, thus reducing soil compaction in the crop area.

Training and Communication

Activities in training, conferences and communication illustrate the rapidly expanding international scope and impact of CIAT's programs and staff.

CIAT staff members regard training as one of the major channels for communicating the results of their research, as well as research methods and philosophies, to personnel of national programs. During 1974, 162 persons from 22 countries were enrolled, including 45 as postgraduate interns in research, 62 as production specialists, 19 as master's degree students, 15 working on doctoral dissertations and 21 special short-term trainees (See Tables 1 through 5).

The performance of CIAT trainees after return to their own countries and work organizations and the growing awareness of CIAT throughout the world has influenced significantly the growth of the training program, the kinds of persons applying for training, and the availability of support for trainees. Of the 162 persons enrolled in 1974, only 63 were supported by CIAT funds directly (Table 6). Other principal sources of support were the Interamerican Development Bank (25) and national interests of various countries (36).

During the year, more than 1,600 persons from many countries participated in some 25 international and national conferences, symposia, workshops and short courses.

Growing volumes of editorial, graphic, photographic and reproduction demands from the commodity programs, training, conferences and administration necessitated increases in the Information Services staff and budget.

TRAINING

Most of the specific training activities directly related to commodity programs are reported in the sections relating to the specific commodities. In addition to supervising the training activities in their respective areas, the coordinators for plant and animal science training are also responsible for assisting in the development of conferences and symposia in their respective areas.

Training in plant sciences

Production training

Crop production training at CIAT is directed to the preparation of technically capable agronomists who are prepared to transfer technology generated by CIAT and national programs to farmers in their different countries. They are also expected to multiply these capabilities by training the large numbers of professionals needed to work with these farmers.

A 12-month crop production specialist training course and a 6-month course in seed production finished on February 28, 1974. The latter part of both these courses emphasized training directly in farmers' fields. An evaluation of the courses by the trainees showed that this approach is rated high, but the risk of failure is considerable unless the professional has been previously trained in the required technical and economic competencies.

Participants from both courses joined in a series of presentations and discussions as the final activity. Their behavior during these events, plus that in two field days conducted earlier, dramatically demonstrated their ability to address audiences with confidence, to make well-organized presentations, and to participate actively in discussions.

A survey made four months after they returned to their countries indicated that 19 of 26 were actively working in development projects or research institutions concerned with CIAT's commodity programs. Six were occupied full time in training programs or instruction in higher education, and one had left his employing institution for special reasons. Although the 19 were not involved in full-time training activities, they all reported some activities contributing to the training of other professionals in classroom and field situations.

Recruiting of candidates for the ten-month crop production course initiated in March, 1974, produced the largest number of participants to be admitted to any production course at CIAT over the past four years. Of the 25 enrolled, 23 completed the ten months, while 2 participated for the first six months.

Instruction concentrated on beans, cassava, rice and maize. Soybeans, sorghum and vegetables were included for trainees from countries where these crops are used in rotation with the principal crops mentioned. The same two-phase sequence of training described in earlier reports (Annual Report 1973) was followed. For the first five months, activities centered on assigned 10-hectare "training farms" within the CIAT experimental farm; and the second five months used commercial, subsistence and cooperative farms and farmers on the North Coast of Colombia, with headquarters at the Turipaná station of ICA. This second phase permitted trainees to conduct on-the-farm replicated trials as training in how to adapt technology for a specific region.

Sixty-four scientists from CIAT and several Colombian institutions provided instruction in various fields of specialization.

In-country developments

The ultimate aim of the crop production training program is to facilitate multiplication of quality, production-oriented training at various levels in the developing countries. The most outstanding involvement in this direction involved three CIAT graduates who were responsible for organizing a postgraduate-level training project in crop production in Ecuador.

With limited assistance from the CIAT training staff, this course was organized by INIAP with the cooperation of other national institutions, particularly CEDEGE. Eighteen agronomists were enrolled in a six-month course based at the Boliche experiment station. Thus, the trainees were involved in training activities on the station as well as with commercial and cooperative farms in the neighboring areas.

While a similar version of a crop production training course is being developed in the Dominican Republic, former CIAT trainees from that country are actively involved in part-time instructional events in their national institutions.

Specific commodity training

All training activities directly related to a specific commodity are reported in the sections: Cassava, Field Beans, Rice, Maize and Small Farm Systems. This includes a special short course for cassava research workers.

Training in animal sciences

All of the activities involving training in animal sciences are reported in the Beef and Swine sections, respectively.

COMMUNICATION RESEARCH AND TRAINING

The number of persons involved in these activities decreased this year for several reasons: (1) The Small Farm Systems program absorbed some activities normally carried out by the unit; (2) a study of former CIAT trainees was completed; and (3) contracts of two temporary assistants expired.

Personnel concentrated on supporting the production training courses, making some evaluations of CIAT conferences and symposia, and participating to a limited extent in activities of the Asociación Latinoamericana de Desarrollo Rural.

Participation in the production specialist training courses involved methodological and administrative aspects. It was observed that training was more productive when the learning process rather than the teaching process was emphasized. In other words, training became more dynamic and the level of performance and satisfaction increased when the trainees had a structure of learning opportunities available.

Training in the traditional methods of agricultural extension, such as field days and method and result demontrations, was de-emphasized. Instead, successful meetings for mutual learning were organized at CIAT and on the North Coast. In these, trainees, instructors, technicians and farmers had the opportunity to contribute and to learn, as well as to exercise decision-making abilities.

In the communication approach of these courses, emphasis was on interpersonal communication. This tended to neglect the written forms of communication important in the work of agricultural production technicians, which will be corrected in future courses.

Personnel directed some attention to ways of organizing and administering the crop production course, looking forward to the possibility of reducing the present 12-month course to 7 months. Because of the complex administrative aspects involved in organizing and managing an intensive course, development of a carefully planned organization is important, with assigned personnel having definitely defined duties and responsibilities.

Evaluation of the seminar on potentials to increase beef production in tropical America included data from 101 technicians in 18 countries. These data indicated that there is a great potential for increasing interaction and improving cooperation among the network of beef research workers in Latin America.

At the request of the organizers of the UNDP/FAO Workshop on the Application of Agricultural Research in Latin America, an end-of-workshop evaluation was conducted and reported to them.

Personnel spent a limited amount of time helping the Asociación Latinoamericana de Desarrollo Rural organize international seminars on the critical components of rural development projects. This included a seminar on family improvement in Mexico and one on project evaluation in Cali.

CONFERENCES AND SYMPOSIA

The Conferences and Symposia facilities and services were involved in 59 events during 1974; and more than 1,600 persons from outside CIAT were enrolled in events sponsored by CIAT or jointly with other organizations.

CIAT-sponsored or co-sponsored meetings included Seminar on Economics of Beef Production (co-sponsored with the Ford Foundation), Seminar on Soil Management and the Development Process in Tropical America (co-sponsored with North Carolina State University), Seminar on the Potential to Increase Beef Production in Tropical America, Seminar on Communication Strategies for Rural Development (co-sponsored with Cornell University), the Bean Rust Workshop, the Bean Program Evaluation Workshop, and the Workshop on Methods Used to Allocate Resources in Agricultural Research (co-sponsored with the Agricultural Development Council).

The two production specialist training programs ran throughout most of the year. Further courses were held for cassava research workers; and together with ICA, a course was given on soils and fertilizers.

Nineteen lectures were presented by CIAT technical staff and visiting scientists in biweekly seminars.

Requests from outside CIAT for the use of the conference facilities increased. In April the United Nations Development Program and the Food and Agriculture Organization held a workshop on the application of agricultural research in Latin America, for their regional representatives and 25 persons representing 22 national institutions in ten countries.

Many universities, as well as national institutions concerned with agriculture, forestry, education, marketing and development, held meetings, courses and workshops at CIAT.

As experience is acquired by CIAT conference organizers in establishing objectives and purposes, in selecting participants and in laying out and running programs, a pattern of planning, execution and evaluation is emerging.

INFORMATION SERVICES

The production of printed materials, photographs, charts, tables, displays and other visual materials increased considerably in 1974. The accelerated expansion in research, training, conferences and symposia, plus the initial efforts of CIAT's outreach program, required expanded production of such materials. Information Services processed an increased amount of printed documents produced by CIAT's commodity and discipline programs.

The established series of publications were reclassified under a new codification system to comply with current information cataloging schemes in agricultural libraries. Most of the materials published within these series are published in Spanish and English and distributed on a world-wide basis under commodity/discipline criteria of individual information interests.

CIAT's limited printing facilities worked on a full-time basis to meet the increased demands generated by the programs. In addition, publications requiring higher quality printing were contracted out with commercial firms.

In order to expedite operations and reduce costs, electronic typesetting equipment was ordered towards the end of the year and is expected to be installed early in 1975.

In June, 1974, the new photo laboratory was put into operation. Presently all black and white photographs are processed at CIAT, although color processing is still contracted with commercial firms.

Table IA. CIAT trainees appointed and/or completed training January 1, 1974 to December 31, 1974, by category of training, country, and field (C = completed course).

Name	Country	Program/Subject	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Postgraduate interns				
Alburez, Carlos	Guatemala	Rice	1.5	C
Arturo M., Herman	Colombia	Rice Production	4.5	C
Calle de C., Sonia	Peru	Beef Animal Microbiology	9	C
Camacho, Carlos A.	Peru	Swine/Production Systems	9	C
Castedo, Antonio A.	Bolivia	Swine/Production Systems	8	C
Franco, Luis C.	Colombia	Rice Production	4.5	C
Gómez C., José	Peru	—/Soils Microbiology	3	C
Gianella, Héctor	Bolivia	Beef/Animal Pathology	3.5	C
Guerrero, Luis A.	El Salvador	Rice/Breeding	5	C
Gutiérrez, Uriel	Colombia	Beans/Agr. Economics	3	C
Kueneman, Eric A.	USA	Beans	6.5	C
Mejía P., Rubén	Peru	—/Weed Control	2	C
Moscoso, Patricio	Ecuador	Swine	2	C
Oliva, Francisco G.	Ecuador	Swine	3	C
Otero, Carlos E.	Colombia	—/Station Operations	2	C
Quintero, Bolívar	Ecuador	Beef Pastures & Forages	3	C
Restrepo, Manuel	Colombia	Beef Pastures & Forages	6	C
Rico, Germán R.	Venezuela	Rice Agronomy	6	C
Ríos M., Edgar	Guatemala	Beans/Breeding	6	C
Saldarriaga, Alvaro	Colombia	Beef Pastures & Forages	6	C
Takatsu, Armando	Brazil	Cassava/Plant Pathology	6	C
Teixeira de C., Geraldo	Brazil	Rice	1.5	C
Trujillo, Rubén	Colombia	Cassava/Agr. Economics	3	C
Zambrano, Oswaldo	Ecuador	—/Soils Microbiology	4 days	C
Alvarado, Fabian	Ecuador	Swine Production Systems	6	–

Name	Country	Program/Subject	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Postgraduate interns				
Bandeira, Coracy	Brazil	Rice	3	–
Caicedo, Marino	Colombia	—/Station Operations	4.5	–
Cárdenas, Moisés R.	Mexico	Beans/Plant Pathology	9	C
Castaño, Mauricio	Colombia	Beans/Plant Pathology	6	C
Ceballos, Luis F.	Colombia	—/Crop Production	4	–
Díaz Ch., Antonio	El Salvador	Beans/Plant Pathology	2.5	C
Dos Santos, María A.	Brazil	Cassava/Agronomy	10.5	–
Escobar M., Rodrigo	Colombia	Cassava/Agr. Economics	11	C
Gastao M., Orival	Brazil	Beans/Breeding	3.5	–
Giraldo, Hernán	Colombia	Beans/Agr. Economics	5.5	–
Gutiérrez P., John	Colombia	Beans/Agr. Economics	6	–
Hurtado, Erwin O.	Bolivia	Beef/Pastures & Forages	5	–
Ibe, Donatus G.	Nigeria	Cassava/Biometrics	5	–
Morales, César G.	Peru	Beans/Agronomy	4	–
Narváez, Ramiro	Colombia	—/Station Operations	3.5	C
Nobre, Adilson	Brazil	Cassava/Agronomy	5	–
Prager M., Martín	Colombia	Beans/Agr. Economics	5.5	–
Toro, José Z.	Ecuador	Beef/Weed Control	4.5	–
Concha O., Alfredo	Colombia	—/Weed Control	2	–
Salazar, Luis C.	Colombia	Beans Biometrics	1.5	–
Production specialists				
Alvarado, Juan R.	Ecuador	Seed Production	2	C
Balarezo, Sergio	Ecuador	Seed Production	2	C
Medrano A., Néstor	Ecuador	Seed Production	2	C
Quimi, Freddy E.	Ecuador	Seed Production	2	C
Puga, Wilson	Ecuador	Seed Production	2	C
Sarmiento, Walter	Ecuador	Seed Production	2	C

Name	Country	Program/Subject	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Production specialists				
Alvarado, Aquiles	Ecuador	CPSTP/Crop Production	3	C
Bello R., Carlos	Dom. Rep.	CPSTP/Crop Production	2	C
Camilo, Antonio	Dom. Rep.	CPSTP/Crop Production	3	C
Carcelén, Raúl	Ecuador	CPSTP/Crop Production	3	C
Castro, Luis J.	Colombia	CPSTP/Crop Production	2	C
Cea V., Jaime	El Salvador	CPSTP/Crop Production	3	C
De León, Rodolfo	Dom. Rep.	CPSTP/Crop Production	2	C
Díaz, Rafael	Dom. Rep.	CPSTP/Crop Production	2	C
Herrera D., Fernando	Colombia	CPSTP/Crop Production	2	C
Jiménez, Ramón	Dom. Rep.	CPSTP/Crop Production	2	C
Livingston, Jorge	Ecuador	CPSTP/Crop Production	3	C
Pérez R., Germán	Colombia	CPSTP/Crop Production	2	C
Ruiz E., Arturo	Ecuador	CPSTP/Crop Production	3	C
Valverde, Félix	Ecuador	CPSTP/Crop Production	3	C
Veintimilla, Manuel	Ecuador	CPSTP/Crop Production	3	C
Venegas, Fausto	Ecuador	CPSTP/Crop Production	5	C
Alvarado, Leopoldo	Honduras	CPSTP/Crop Production	9.5	C
Arias, Luis O.	Colombia	CPSTP/Crop Production	9.5	C
Bernal, Juan L.	Paraguay	CPSTP/Crop Production	9.5	C
Cano L., Carlos	Ecuador	CPSTP/Crop Production	9	C
Castañeda, José R.	Guatemala	CPSTP/Crop Production	9.5	C
Cevallos A., Alvaro	Colombia	CPSTP/Crop Production	9	C
Chaverra, Diómedes	Colombia	CPSTP/Crop Production	9.5	C
Estrada, Rodrigo	Colombia	CPSTP/Crop Production	5	C
Flores C., Orestes	Peru	CPSTP/Crop Production	10	—
Fonseca, Roberto	Guatemala	CPSTP/Crop Production	9.5	C
Gutarra, Jorge	Peru	CPSTP/Crop Production	5	C
Ibañez A., Ramiro	Panama	CPSTP/Crop Production	9	C

Name	Country	Program/Subject	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Production specialists				
La Torre L., Vicente	Bolivia	CPSTP/Crop Production	10	—
Leaño, Edgar	Colombia	CPSTP/Crop Production	9	C
Licuona Z., Mario	Bolivia	CPSTP/Crop Production	9.5	—
Martínez, Oscar	Guatemala	CPSTP/Crop Production	9.5	C
Maldonado, Marco	Guatemala	CPSTP/Crop Production	10	—
Mojica, Arnulfo	Panama	CPSTP/Crop Production	9	C
Morales, Javier	Peru	CPSTP/Crop Production	9.5	C
Moreno, Alberto	Panama	CPSTP/Crop Production	9	C
Rodríguez, Rolando	Bolivia	CPSTP/Crop Production	9.5	C
Ruiz A., Miguel	Paraguay	CPSTP/Crop Production	9.5	C
Ruiz, Hernán	Ecuador	CPSTP/Crop Production	9	C
Sánchez, Roberto H.	Paraguay	CPSTP/Crop Production	2	C
Valle, Raúl R.	Honduras	CPSTP/Crop Production	9.5	C
Velásquez, Alfonso	Guatemala	CPSTP/Crop Production	9.5	C
Acevedo, Fernando	Colombia	LPSTP/Livestock Production	8	C
Alva N., Alejandro	Peru	LPSTP/Livestock Production	5.5	C
Arias, Ramón	Dom. Rep.	LPSTP/Livestock Production	11	C
Bardales, Enrique	Peru	LPSTP/Livestock Production	8	C
Berganza, Maximiliano	El Salvador	LPSTP/Livestock Production	11	C
Bogado, Benigno	Paraguay	LPSTP/Livestock Production	8	C
Carrión, José F.	Ecuador	LPSTP/Livestock Production	8	C
Cortés, Miguel	Bolivia	LPSTP/Livestock Production	5	C
Montán, Tirso	Dom. Rep.	LPSTP/Livestock Production	3.5	C
Ravelo, Guillermo	Dom. Rep.	LPSTP/Livestock Production	8.5	C
Riveros, Antonio	Paraguay	LPSTP/Livestock Production	8	C
Velasco, Francisco	Bolivia	LPSTP/Livestock Production	9	C
Villalba, Juan F.	Paraguay	LPSTP/Livestock Production	7	C
Villegas, Carlos	Colombia	LPSTP/Livestock Production	11	C

Name	Country	Program/Subject	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Special trainees				
Aldana de M., Edna	Guatemala	-Library	2	C
Cabezas, Luis A.	Ecuador	---/Agr. Engineering	.5	C
Caicedo P., Elizabeth	Colombia	---/Agr. Economics	4.5	—
Cappes, Adolph	Netherlands	Small Farm Systems	5	C
De Klerk, Antonius	Netherlands	Small Farm Systems	7.5	C
Ferbert, Hugh Dalsen	USA	Beef/Animal Health	2	C
Ferraz, Lucas	Brazil	Cassava	3	C
Gonzaga, Severino	Brazil	-/Weed Control	.5	C
Gonzalez, Jose A.	Venezuela	Cassava Plant Pathology	2	C
Gore, Thomas	USA	Beef/Animal Health	2	C
Londoño, Amanda	Colombia	Beef/Animal Microbiology	1	C
Lourido, Luis C.	Colombia	Cassava Agr. Economics	5	C
Mendoza, Beatriz	Ecuador	Beef/Pastures & Forages	3	C
Nápoles, Víctor M.	Ecuador	---/Agr. Engineering	.5	C
Oliver, Thomas	USA	Beef/Animal Health	2	C
Paul, Compton L.	Guyana	Beef/Pastures & Forages	2.5	C
Pazos, Walter R.	Guatemala	Rice/Breeding	2.5	C
Roeleveld, Alexander	Netherlands	Beef/Pastures & Forages	.5	C
Samper, Raúl	Colombia	Beef/Pastures & Forages	8	—
Tolkamp, Berend	Netherlands	Beef	11	C
Vianna R., Maria	Brazil	Rice	1	C

Table I B. CIAT trainees appointed and/or completed training January 1, 1974 to December 31, 1974, by category of training, country, and field (C- completed course).

Name	Country	Program/Subject	Institution where enrolled	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Research scholars					
Gabela A., Francisco	Ecuador	---/Weed Control	Oregon State University	4	C
García M., Adriano	Colombia	---/Agr. Economics	Univ. Católica de Chile	5	C
Guzmán R., Víctor H.	Colombia	Beef/Animal Pathology	Esc. Graduados ICA, Colombia	9	C
Lucena, Juan Manuel	Peru	---/Weed Control	Esc. Graduados ICA, Colombia	9.5	C
Ríos R., Mario J.	Colombia	Cassava/Breeding	Esc. Graduados ICA, Colombia	9	C
Villegas, Gustavo	Colombia	---/Horticulture	Univ. of Guelph, Canada	3.5	C
Zuluaga E., Hernando	Colombia	---/Agr. Economics	New Mexico State University	9	C
Acuña, Luis G.	Colombia	---/Crop Production	Univ. of Guelph, Canada	8	—
Alvarez P., Camilo	Colombia	---/Agr. Economics	Univ. Católica de Chile	12	—
Castaño Z., Jairo	Colombia	Rice/Plant Pathology	Esc. Nal. Agricultura, Mexico	12	—
Ceileri, Walter H.	Ecuador	Swine/Nutrition	Esc. Graduados ICA, Colombia	12	—
Dominguez, Carlos	Colombia	---/Crop Production	Univ. of Guelph, Canada	4	—
Garcés R., Carlos	Colombia	---/Agr. Engineering	Esc. Graduados ICA, Colombia	3	—
Morales, Leopoldo	Colombia	---/Weed Control	Esc. Graduados ICA, Colombia	3	—
Ramírez, Luis E.	Colombia	Beef/Animal Microbioloby	Univ. de Antioquia, Colombia	11.5	—
Rivas, Libardo	Colombia	---/Agr. Economics	Univ. Católica de Chile	12	—
Rueda H., Camilo	Colombia	Beef/Animal Health	Esc. Graduados ICA, Colombia	12	—
Santos, Jorge	Colombia	Swine/Nutrition	Univ. of Guelph, Canada	12	—
Santa María, Gilberto	Guatemala	---/Agr. Economics	Esc. Graduados ICA, Colombia	9	—

Name	Country	Program/Subject	Institution where enrolled	Months of training completed as of Dec. 31, 1974	Status as of Dec. 31, 1974
Research fellows					
Danso, Seth	Ghana	---/Soils Microbiology	Cornell University	19 days	C
Ikotun, Babatunde	Nigeria	Cassava/Bacteriosis	Imp. Col. Science & Technology, England	6	C
Kelly, James D.	U. Kingdom	Beans	University of Wisconsin	6	C
Lehner, Dietrich	Germany	Rice/Physiology	Justus Liebeg Univ., Giessen, Germany	6	C
Whitey, Douglas	U. Kingdom	Cassava	Univ. of West Indies	8	C
Fitzsimons, John G.	U. Kingdom	---/Communication	Univ. of Western Ontario, Canada	11.5	C
Job, Titus	Nigeria	Swine	Univ. of Ibadan, Nigeria	8	–
Kleeman, Gunter	Germany	Swine	Technical University of Berlin, Germany	12	–
Krause, Joseph	USA	Cassava/Plant Pathology	Cornell University	5.5	–
Nganji, Amos George	Cameroon	Cassava	Cornell University	11.5	–
Rubinstein de, Eugenia	Chile	Econ./Animal Health	University of Minnesota	11.5	–
Schellenberg, Rupprecht	Germany	Beef	Technical Univ. of Berlin, Germany	2.5	–
Schultze-K., Rainer	Germany	Beef/Pastures & Forages	J. Liebeg Univ., Giessen, Germany	12	–
Stolberg, Alexander	Germany	Beans/Production Systems	J. Liebeg Univ., Giessen, Germany	12	–
Tewe, Olumide	Nigeria	Swine	Univ. of Ibadan, Nigeria	8	–

Table 2. CIAT trainees appointed and/or completed training by field of specialization and category of training (January 1, 1974 to December 31, 1974).

	Postgrad. interns	Production specialists	Research fellows	Research scholars	Special trainees	Total
Rice	3				1	4
Rice/Production	2					2
Swine/Production Systems	3					3
Beef/Animal Microbiology	1			1	1	3
Beans/Agr. Economics	4					4
---/Soils Microbiology	2		1			3
Beef/Animal Pathology	1			1		2
Rice/Breeding	1				1	2
Beans	1		1			2
---/Weed Control	2			3	1	6
Swine	2		3			5
Station Operations	3					3
Beef/Pastures & Forages	4		1		4	9
Beans/Breeding	2					2
Rice/Agronomy	1					1
Cassava/Agr. Economics	2				1	3
Cassava/Plant Pathology	1		1		1	3
Beans/Plant Pathology	3					3
Crop Production	1	42		2		45
Cassava/Agronomy	2					2
Cassava/Biometrics	1					1
Beans/Agronomy	1					1
Beef/Weed Control	1					1
---/Horticulture				1		1
---/Agr. Economics				5	1	6
Cassava/Breeding				1		1
Rice/Plant Pathology				1		1
Beef/Animal Health				1	3	4
Swine/Nutrition				2		2
Rice/Physiology			1			1
Cassava/Bacteriosis			1			1
Cassava			2		1	3
Beans/Production Systems			1			1
Economics/Animal Health			1			1
- -/Communication			1			1
Beef			1		1	2
Seed Production		6				6
Livestock Production		14				14
- /Library					1	1
Small Farm Systems					2	2
Agricultural Engineering				1	2	3
Beans/Biometrics	1					1
Totals	45	62	15	19	21	162

Table 3. Trainees processed by CIAT classified by field of specialization (January 1, 1974 to December 31, 1974).

Trainee category	Field of specialization: Animal Sciences	Plant Sciences	Agricultural Economics	Agricultural Engineering	Communication Social Science	Total
Postgraduate interns	12	24	6	3		45
Production specialists	14	48				62
Research fellows	5	8	1		1	15
Research scholars	5	8	5	1		19
Special trainees	9	5	2	2	3	21
Totals	45	93	14	6	4	162

Table 4. Trainees processed by CIAT classified by country of origin (January 1, 1974 to December 31, 1974).

Country	Postgrad. interns	Production specialists	Research fellows	Research scholars	Special trainees	Total
Brazil	6				3	9
Bolivia	3	5				8
Cameroons			1			1
Colombia	17	10		15	4	46
Chile			1			1
Dominican Republic		8				8
Ecuador	6	16		2	3	27
El Salvador	2	2				4
Germany			5			5
Ghana			1			1
Guatemala	2	5		1	2	10
Guyana					1	1
Honduras		2				2
Mexico	1					1
Netherlands					4	4
Nigeria	1		3			4
Panama		3				3
Paraguay		6				6
Peru	5	5		1		11
United Kingdom			3			3
USA	1		1		3	5
Venezuela	1				1	2
Totals	45	62	15	19	21	162

Table 5. Trainees in training during 1974, completed training as of December, 1974, and continuing in 1975.

Classification	In training during 1974	Completed as of December, 1974	Continuing in 1975
Postgraduate interns	45	29	16
Production specialists	62	58	4
Research scholars	19	7	12
Research fellows	15	6	9
Special trainees	21	20	1
Totals	162	120	42

Table 6. Trainees processed by CIAT classified by source of support (January 1, 1974 to December 31, 1974).

Source of support*	Postgrad. interns	Production specialists	Research fellows	Research scholars	Special trainees	Total
International interests						
Agency for International Development		5				5
Banco Interamericano de Desarrollo		25				25
Bookers Sugar Estates, Guyana					1	1
Comisión de Estudio para el Desarrollo del Río Guayas (CEDEGE), Ecuador		4				4
Centro Internacional de Agricultura Tropical (CIAT)	34	7	3	14	5	63
Cornell University			3			3
Ecumenical Scholarship Program, West Germany		1				1
Food & Agriculture Organization (FAO)		1				1
Ford Foundation					1	1
Foreign Area Fellowship Program			1			1
German Foundation for International Development	1					1
Government of West Germany			4			4
Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala	2	2		1	2	7
International Development Research Center (IDRC), Canada	4		3			7
Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador	1	6		1		8
Instituto Rio Grandense do Arroz, Brazil					1	1
Ministry of Agriculture, Paraguay		2				2
Universidad de Loja, Ecuador		1				1
Subtotals	42	54	14	16	10	136

* Indicates all or bulk of financial support provided by or through organization indicated

Continuation Table 6. Trainees processed by CIAT classified by source of support (January 1, 1974 to December 31, 1974).

Source of support*	Postgrad. interns	Production specialists	Research fellows	Research scholars	Special trainees	Total
Brought forward	42	54	14	16	10	136
Colombian interests						
Corporación Autónoma Regional del Valle del Cauca (CVC), Colombia		1				1
Federación Nacional de Arroceros, Colombia	3					3
Instituto Colombiano Agropecuario (ICA), Colombia				2		2
Instituto Colombiano de Reforma Agraria (INCORA),Colombia		1				1
Instituto Politécnico, Colombia		1				1
Universidad Nacional, Colombia				1		1
Servicio Nacional de Aprendizaje (SENA), Colombia		3				3
Universidad de Caldas, Colombia		1				1
Self-supported		1	1		11	13
Totals	45	63	15	19	21	162

Library and Documentation Services

As of the end of the year, the Library collection stands at 30,358 volumes; and 55 new journal subscriptions have been added, bringing the total number of journal titles to 1,187. Bibliographic exchange agreements exist with 523 institutions from 71 countries.

The Cassava Information Center closed the year with a total of 3,708 documents, approximately 2,200 of which are fully processed. Additional funding was obtained to strengthen documentation activities in field beans and animal health, as well as to start an Economics Documentation Center for Latin American Agriculture (CEDEAL).

The total number of photocopies the Library sent to users was 94,000. These requests were initiated by users in response to the Library's documentation services and to the journal contents pages service described in CIAT's 1973 Annual Report.

CEDEAL

1. Objectives

CEDEAL's immediate objective is to increase region-wide awareness and availability of research materials produced in the rural social sciences, primarily agricultural economics, by upgrading acquisitions programs and services provided by national agricultural libraries. In the long run, the program is expected to assist Latin Americans in identifying common areas of research, in planning comparative studies, and in developing their own standards of research quality and relevance.

2. Location and operation

CEDEAL operates as a part of the CIAT Library. CEDEAL's staff is composed of a director (CIAT's Library Director), an executive officer (an agricultural economist-documentalist at the M.S. level) and the three senior staff members of CIAT's Agricultural Economics Program. In addition, CEDEAL's staff receives professional assistance from an advisory group composed of six social scientists from the region.

3. Advisory group

The advisory group is conceived of as having the following functions:

a. To review both the materials collected by them in their own country, as well as materials channeled to them (through CEDEAL) from other countries, and to produce either national or topic annual reviews to be presented at CEDEAL's annual meeting, to be published as an Annual Review of Agricultural Economics in Latin America, together with an updated bibliography.

b. To collect, evaluate and forward to CEDEAL selected published, unpublished, and unlisted materials with possible regional relevance. Other standard mechanisms for collecting pertinent literature are also used by CEDEAL. In view of the fact that only a very minor portion of the information produced in the developing countries ever reaches established dissemination channels, this function of CEDEAL's advisory group members is particularly important. Consequently, CEDEAL encourages through its advisory group members the establishing of similar information networks at the country level.

c. To select a limited number of basic bibliographic materials each year and recommend to CEDEAL's director that they be provided free of charge to a core of depository libraries and institutions.

4. Activities

CEDEAL performs the following activities for major agricultural libraries and selected scientists in the region:

a. Produce free of charge abstract cards on all published, unpublished and unlisted nonbook materials of regional relevance in agricultural economics and development, received by CEDEAL during the year. The Center obtains a copy of the original document; key-words it for future retrieval; searches for an abstract, if available, or makes one when not available; and translates it in order to produce cards for distribution both in English and Spanish.

b. Have available xerox copies of the original documents summarized on abstract cards for purchase by request; these are charged at cost.

c. Make available free xerox copies of tables of contents of the 25 most pertinent agricultural economics and rural development journals to all libraries and persons participating in the system.

d. Provide free of charge copies of key materials to a limited number of libraries, on the basis of selections made by CEDEAL's advisory group, as mentioned previously.

This integrated system of services offers numerous advantages for the researcher, planner, teacher and student. It widens the scope of literature coverage by taking advantage of a collaborative effort on the part of the institutions involved. Thus, literature indigenous to these countries, which is very rarely disseminated region-wide, will be available, thereby reducing duplication of efforts and promoting cooperative undertakings instead. In addition, it will enable libraries serving specific programs to reproduce and complement these services at a minimal cost, thereby increasing the number of people who will benefit from them.

In June, 1974, CEDEAL's advisory group was set up; and a meeting to organize activities was held at CIAT on June 20 and 21. The following persons are members: Dr. Lucio Recca (Argentina), Dr. Guilherme Leite da Silva Dias (Brazil), Dr. Helio Tollini (Brazil), Dr. Mario Valderrama (Colombia), Dr. Rodrigo Mujica (Chile), and Dr. Lloyd Rankine (West Indies). In October CEDEAL hired an executive officer who began to lay down the basic infrastructure of the program. It is anticipated that the actual offering of services will start in January, 1975.

International centers information network

During the meeting of Directors from International Centers held at CIAT in February, 1974, the idea of having a workshop of the respective library and documentation programs was accepted as a means of improving and promoting excellence in these services through the interchange of ideas. Following the Directors' recommendations, the first workshop of Center librarians was held at CIAT from August 5 to 9, 1974. The following persons attended the meeting:

John L. Hafenrichter, USAID
T.H. Hwang, AVRDC
T.C. Jain, ICRISAT
Steve M. Lawani, IITA
Lina Manalo-Vergara, IRRI
Fernando Monge, CIAT
Dorothy Parker, Consultant RF, USAID
Carmen de Podestá, CIP
L. Réchaussat, ILCA

The Centers' librarians greatly appreciated the presence and participation of Dr. Dorothy Parker, special consultant, Rockefeller Foundation and USAID, and of Mr. John L. Hafenrichter, USAID, and their interest in the current efforts to develop a dynamic network of center libraries and documentation units.

Some general policy issues were discussed regarding the need for continuity in any library and documentation program carried out by the Centers, as well as to the type of participation the Centers should have in world-wide information projects, such as AGRIS. Upon discussion of collaborative projects that could be started on a short-term basis, the Centers agreed to give first priority to requests coming from the members of this network. Some bibliographic tools to facilitate the mutual use of the Centers' collections, such as a Union List of Periodicals and a Union Catalog of Theses, are presently under preparation.

Finally, the Centers' librarians agreed to work toward and seek additional funding for establishing commodity-specialized documentation centers along lines similar to CIAT's Cassava Information Center and IITA's Food Legume Documentation Center.

Finance

Price Waterhouse & Co.

APARTADO AEREO [illegible] CALI, COLOMBIA

February 27, 1975

To the Board of Trustees of

Centro Internacional de Agricultura
Tropical (CIAT)

We have examined the balance sheet of Centro Internacional de Agricultura Tropical (CIAT) as of December 31, 1974 and the related statement of revenue and expenditures and unexpended funds for the year. Our examination 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.

We stated in our opinion dated April 11, 1972 on the financial statements for the year ended December 31, 1971 that we regard the inclusion in Core program expenditures of commitments for future expenditures amounting to $156,000 as not being in accordance with generally accepted accounting principles.

In our opinion, the accompanying financial statements examined by us present fairly the financial position of Centro Internacional de Agricultura Tropical (CIAT) at December 31, 1974 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 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, 1974, which are presented as supplementary information, and, in our opinion, these schedules present fairly the information shown therein.

Price Waterhouse & Co

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
BALANCE SHEET
(Expressed in thousands of U.S dollars — Note 2)

	December 31			
	1974	1973	1972	1971
ASSETS (NOTE 3)				
CURRENT ASSETS:				
Cash	623	139	272	450
Accounts receivable:				
Donors (Note 4)	531	497	499	471
Employees	85	69	73	29
Others	718	289	287	334
	1,334	855	859	834
Inventories (Note 1)	199	100	54	7
Prepaid expenses	8	5	17	
Total current assets	2,164	1,099	1,202	1,291
FIXED ASSETS (Note 1):				
Revolving fund balances (Note 5)	94	42	64	51
Equipment	1,346	802	758	618
Vehicles	568	305	314	257
Furnishings and office equipment	901	378	369	236
Buildings	4,429	3,950	2,359	1,276
In transit	9	883		
Total fixed assets	7,347	6,360	3,864	2,438
Total assets	9,511	7,459	5,066	3,729
LIABILITIES AND FUND BALANCES				
CURRENT LIABILITIES:				
Bank overdraft	317	137	7	
Accounts payable	286	351	181	423
Payable to donors		25	25	25
Others	385	127	100	
Total current liabilities	988	640	313	448
GRANTS RECEIVED IN ADVANCE	115	117		
FUND BALANCES:				
Invested in fixed assets	7,347	6,360	3,864	2,438
Unexpended funds (deficit):				
Core —				
Unrestricted	32	(37)	(12)	77
Working fund grant	100	100		
Capital grants	628	175	691	703
Special projects —				
Donors	301	144	35	63
Other		(40)	(25)	
	1,061	342	689	843
Total fund balances	8,408	6,702	4,753	3,281
Total liabilities and fund balances	9,511	7,459	5,066	3,729

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
STATEMENT OF REVENUE AND EXPENDITURES AND UNEXPENDED FUNDS
(Expressed in thousands of U.S. dollars — Note 2)

	Year ended December 31			
	1974	1973	1972	1971
Revenue:				
Core:				
Operating grants —				
Unrestricted	3,475	2,672	2,286	2,144
Restricted	1,030	790	433	352
Working fund grant		100		
Capital grants	1,365	1,779	1,614	312
Total Core	5,870	5,341	4,333	2,808
Special projects	631	404	98	191
Earned income	310	168	98	8
Total revenue	6,811	5,913	4,529	3,007
Expenditures:				
Core Programs:				
Direct research —				
Beef	724	661	417	
Swine	230	202	177	
Cassava	399	330	309	(1)
Beans	374	282	114	
Rice	133	135	240	
Maize	83	121	150	
Small farm systems	185	36	110	
	2,128	1,747	1,517	1,338
Training and communications	520	518	371	300
Total direct research	2,648	2,265	1,888	1,638
Support operations:				
Library, documentation and information services	[illegible]76	139	77	88
Other services	746	521	347	117
General administration	559	340	314	230
Total support operations	1,581	1,000	738	435
General operating costs	274	365	265	285
Total Core programs	4,503	3,630	2,891	2,358
Special projects	602	305	166	128
Purchases of fixed assets	987	2,496	1,426	1,086
Total expenditures	6,092	6,431	4,483	3,572
Excess of revenue over expenditures:				
Unrestricted funds	69		(89)	140
Working fund grant		100		
Capital grants	453	(717)	188	(774)
Special projects	197	99	(53)	63
	719	(518)	46	(565)
Unexpended funds at beginning of year	342	889	843	1,408
Grants receivable for prior years written off		(29)		
Unexpended funds at end of year (see balance sheet)	1,061	342	889	843

(1) Comparative figures for 1971 are not available.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
NOTES TO FINANCIAL STATEMENTS
DECEMBER 31, 1974

NOTE 1:

The following significant accounting policies and practices of CIAT are set forth to facilitate the understanding of data presented in the financial statements:

Inventories —

Inventories are stated at the lower of cost or market value, cost being determined on an average basis.

Depreciation —

In conformity with generally accepted accounting principles applicable to nonprofit organizations, CIAT does not record depreciation of its property and equipment.

NOTE 2:

All foreign exchange transactions are controlled by the Colombian government and, accordingly, all foreign exchange received in Colombia must be sold through official channels. The following exchange rates were used to translate Colombian pesos (P) to U.S. dollars ($):

	P/$1	
Peso balances included in current assets and current liabilities	28.63	Approximate year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	26.07	Average monthly rate of exchange applicable to sales of dollars

NOTE 3:

CIAT operates under an agreement signed with the Colombian government, the most important stipulations of which are as follows:

1. The agreement is for ten years from October 1967 but may be extended if so desired by the parties thereto.
2. CIAT is of a permanent nature and termination of the agreement would not imply cessation of CIAT's existence.
3. If CIAT ceases to exist, all of its assets will be transferred to a Colombian educational or other institution considered appropriate by the parties to the agreement.
4. CIAT is exempt from all taxes.
5. CIAT is permitted to import, free of customs duties and other taxes, all the equipment and material required for its programs.
6. The government provides land for CIAT's purposes under a rental contract for ten years, at a nominal rent. This contract may be extended by mutual agreement.

NOTE 4:

Accounts receivable from donors as at December 31, 1974 comprised:

	$000
Interamerican Development Bank:	
Balance of 1974 grants:	
Unrestricted Core	150
Capital	100
	250

The Rockefeller Foundation:	
Balance of capital grants	140
Allocations for expenses	12
	152
Government of the Federal Republic of Germany:	
Grant for 1974 received in January 1975	89
Others	40
	531

NOTE 5:

The account denominated revolving fund is used to record CIAT's livestock operations. The movement on the fund for the year ended December 31, 1974 was as follows:

	$000
Inventory of livestock - December 31, 1973	42
Purchases during the year	89
Sales during the year	47
Inventory of livestock - December 31, 1974	94

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
ANALYSIS OF GRANTS AND RELATED EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1974
(Expressed in thousands of U.S. dollars)

	Balance from previous year	Income and grants received	Expenditures: Direct research	Expenditures: Support Operations	Expenditures: General Operating	Expenditures: Fixed assets	Expenditures: Total	% of Support and General operating to Direct	Unexpended balance
Unrestricted Core:									
The Ford Foundation		750							
The Rockefeller Foundation		750							
Agency for International Development		950							
Government of the Netherlands		125							
Interamerican Development Bank		800							
Balance from previous year	(37)								
Income applied in year		67							
Total unrestricted Core	(37)	3,542	2,104	1,157	212		3,473	65	32
Restricted Core:									
International Development Research Centre		750	457	248	45		750	64	
The W.K. Kellogg Foundation		280	171	92	17		280	64	
Total restricted Core	—	1,030	628	340	62		1,030	64	
Working fund grant	100								100
Capital grants:									
The Rockefeller Foundation		446							
Government of Switzerland		70							
Overseas Development Agency		59							
International Development Association		600							
Interamerican Development Bank		100							
Government of the Federal Republic of Germany		89							
Balance from previous year	175								
Income applied in year		76							
Total capital grants	175	1,440				987	987		628
Special projects:									
Interamerican Development Bank		171	75				75		96
Overseas Development Agency		71	24				24		47
The Rockefeller Foundation	34	113	97				97		50
The Ford Foundation		69	19				19		50
The W.K. Kellogg Foundation	52		52				52		—
International Development Research Centre	37	194	174				174		57
Others	(19)	181	161				161		1
Total special projects	104	799	602				602		301
Total grants and expenditures	342	6,811	3,334	1,497	274	987	6,092		1,061

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1974
(Expressed in thousands of U.S. dollars)

Sources of earned income:		
Interest on deposits		64
Sale of farm produce		188
Use of CIAT facilities		58
		310
Applied to:		
Core programs	67	
Capital	76	
Special projects	167	316

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
COMPARISON OF APPROVED EUDGET AND ACTUAL EXPENDITURES
FOR THE YEAR ENDED DECEMBER 31, 1974
(Expressed in thousands of U.S. dollars)

	Core unrestricted		Core restricted		Special projects		Capital	
	Approved budget	Actual	Approved budget	Actual	Approved budget	Actual	Approved budget	Actual
Programs								
Research:								
Beef	700	709			28	7		
Swine	63	68	183	177	116	103		
Cassava	98	119	290	280	127	91		
Beans	380	374			213	27		
Rice	132	133						
Maize	87	83						
Small farm systems	196	185						
Training and communications	527	433	176	171	267	288		
Support operations	1,061	1,157	300	340	43	15		
General operating costs	154	166	72	62				
Other	75	46			98	71		
Total	3,473	3,473	1,030	1,030	892	602		
Capital								
Fixed assets							1,529	987
Total							1,529	987
Analysis of variances								
Budget surpluses:								
Unexpended balance						301		628
Grants not received						156		76
Total						457		704
Deficits:								
Covered by -								
Additional grants						(167)		(86)
Increased earned income								(76)
Total						(167)		(162)

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION
DATES OF RECEIPT OF GRANTS
FOR THE YEAR ENDED DECEMBER 31, 1974
(Expressed in thousands of U.S. dollars)

	January	February	March	April	May	June	July	August	September	October	November	December
Unrestricted Core:												
The Rockefeller Foundation	442	24	24	24	24	24	24	24	24	68	24	24
The Ford Foundation		188		187			188		187			
Government of the Netherlands						125						
Agency for International Development						219			431	300		
Interamerican Development Bank							500				250	
	442	212	24	211	24	368	712	24	642	368	274	24
Restricted Core:												
International Development Research Centre						375					375	
The W.K. Kellogg Foundation					280							
					280	375					375	
Capital grants:												
The Rockefeller Foundation						300						
Overseas Development Agency				44				15				
International Development Association		275					175			150		
		275		44		300	175	15		150		
Special projects:												
Interamerican Development Bank				2								98
Overseas Development Agency								28				43
The Ford Foundation		7	12			12			13			25
Cornell University							7					
International Development Research Centre	106			17					24			
The Rockefeller Foundation			51	16		41						
Others							4					4
	106	7	63	35		53	11	28	37			168
	548	494	87	290	304	1,093	898	67	679	518	649	192