Annual Report

1972

Centro Internacional de Agricultura Tropical, CIAT

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* as of December 31, 1972.

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CIAT Senior Staff

(as of December 31, 1972)

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C. A. Francis, Ph. D.	*Associate Plant Breeder* *Coordinator, Maize Production Systems*
G. E. Gálvez, Ph. D.	*Associate Plant Pathologist* *Leader, Crop Protection*
L. M. González, M.B.A.	*Executive Officer*
P. H. Graham, Ph. D.	*Associate Soil Microbiologist*
B. Grof, Ph. D.	*Pastures and Forages Scientist*
M. Gutiérrez, Ing. Agr.	*Assistant Scientist; Editor*
P. R. Jennings, Ph. D.	*Plant Breeder (Study leave)*
L. Johnson, M. S.	*Agricultural Engineer* *Leader, Agricultural Engineering and Station Operations*
A. H. Jonkers, M. D.	*Virologist*
J. H. Maner, Ph. D.	*Animal Scientist* *Leader, Swine Husbandry* *Coordinator, Swine Production Systems*
F. Monge, Ph. D.	*Associate Communication Scientist* *Librarian*
C. P. Moore, Ph. D.	*Associate Scientist* *Coordinator, Animal Science Training*
O. Paladines, Ph. D.	*Animal Scientist*
J. M. Spain, Ph. D.	*Soil Scientist* *Leader, Agronomy*
J. C. Toro, M. S.	*Assistant Agronomist (Study leave)*
E. A. Wells, Ph. D.	*Hemoparasitologist* *Leader, Animal Health*

Special Appointments

D. Bushman, Ph. D.	*Associate Ruminant Nutritionist*
J. H. Cock, Ph. D.	*Assistant Physiologist* *Coordinator, Cassava Production Systems*
R. L. Cheaney, M.S.	*Associate Agronomist*
J. Doll, Ph. D.	*Assistant Scientist; Weed Specialist*
G. Gómez, Ph. D.	*Assistant Animal Scientist*
G. Hernández-Bravo, Ph. D.	*Associate Scientist (Field Beans)*
R. Howeler, Ph. D.	*Assistant Soil Scientist*
K. Kawano, Ph. D.	*Associate Plan Breeder*
C. Lozano, Ph. D.	*Assistant Pathologist (Bacteriologist)*
G. Morales, Ph. D.	*Assistant Pathologist*
A. van Schoonhoven, Ph. D.	*Assistant Entomologist*
H. H Stonaker, Ph. D.	*Animal Scientist* *Leader, Beef Husbandry*
A. Villacorta, Ph. D.	*Assistant Entomologist*

Affiliated Staff

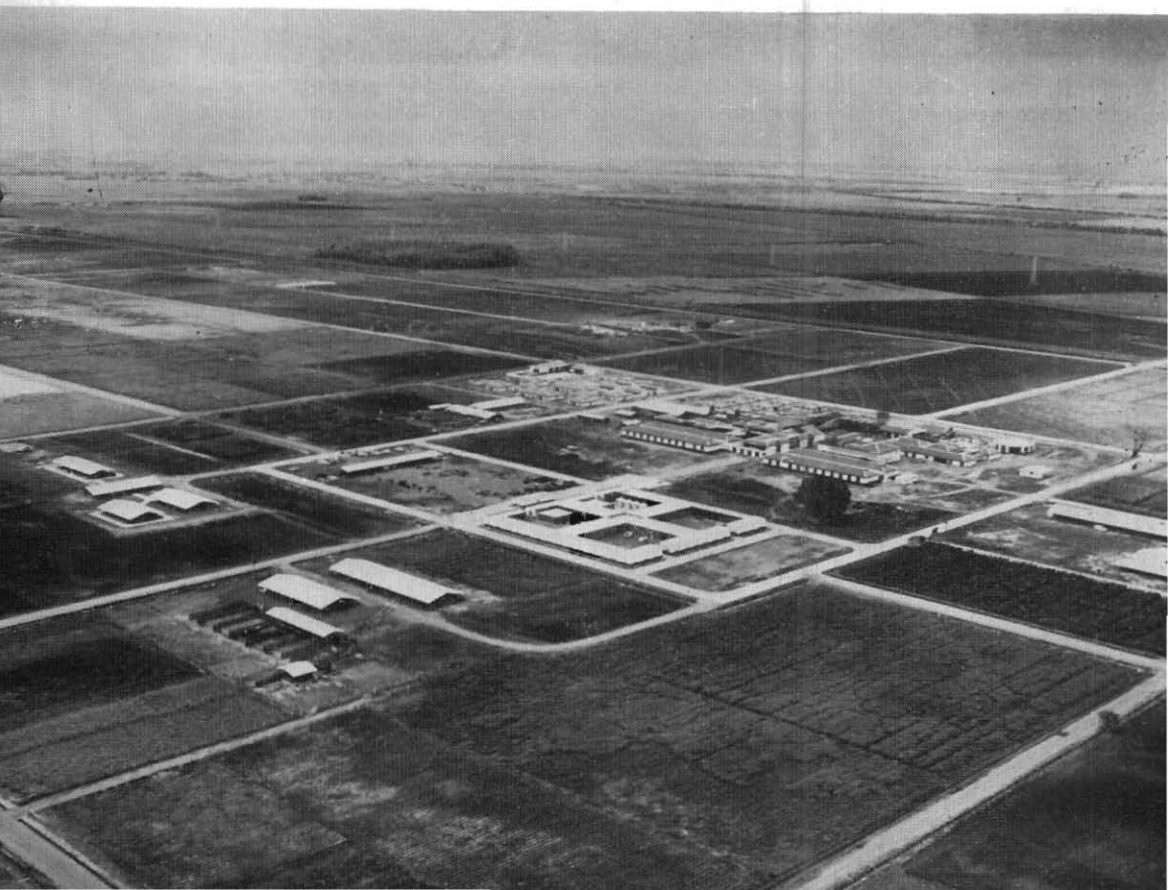
R. Booth, Ph. D.	*Visiting Scientist, Cassava Pathology*
A. J. Clawson, Ph. D.	*Visiting Scientist, Swine Nutrition*
T. J. Galvin, D.V.M., Ph. D.	*Parasitologist, Texas A&M University Project*
N. Mac Lellan	*Photographer, Rockefeller Foundation*
A. Pradilla, M. D.	*Visiting Scientist, Nutrition*
G. Zemmelink, Eng.	*Visiting Scientist, Ruminant Nutrition*

Foreword

Consolidation and concentration of commodity program efforts, begun in 1971, were accelerated during 1972. Multi-disciplinary commodity program teams were reorganized, where necessary, so that a senior staff member would not be responsible for work in his discipline in more than two programs. As a result, senior staff time will be concentrated, to an increasing extent in 1973 and 1974, on those programs for which CIAT has primary responsibility – – – beef, cassava, swine, field beans, and agricultural systems for the lowland tropics of Latin America.

While this action does not reflect a reduction in the number of senior staff assigned specifically to rice and maize, it does mean that less senior staff time is available to those programs. In future years, CIAT will rely more heavily upon the resources of the International Rice Research Institute and the International Center for Improvement of Maize and Wheat for assistance in solving production problems with these two crops.

Aerial view of CIAT headquarters near Palmira. (Photograph: O. Moll Gonzalez).



In addition to its own periodic internal reviews, the CIAT management and staff were aided in program analysis in 1972 by the Board of Trustees' Program Review Committee, the visits of representatives of the Technical Advisory Committee and the Consultative Group for International Agricultural Research, and discussions in Washington in connection with International Centers' Week.

All of these activities helped generate appropriate perspectives for viewing the wide range of CIAT program and commodity thrusts. In this light, the beef program can be regarded as a long-range effort with the ultimate objective of making more effective use of vast areas of relatively undeveloped, unexploited land. On the other hand, the work in cassava, field beans, rice and maize is directly concerned with increasing, as rapidly as possible, the yields and nutritional qualities of these crops.

Some of the technology developed in these commodity programs can and will be adapted, through the agricultural systems program, for the direct benefit of subsistence and small farmers. Similarly, the swine nutrition and management results are expected to help both small farmers and commercial swine producers.

The following paragraphs present a few highlights of the accomplishments and activities in CIAT's major programs during 1972.

Beef. Ways to provide adequate feed supplies received attention with emphasis on the effects of tillage and fertilizer application on methods of establishing grass and grass-legume pastures. At CIAT, nitrogen fertilization increased beef production on Pangola and Para pastures. Increasing the nitrogen on Pangola from 200 to 800 kg/ha increased live-weight gains from 576 to 943 kg/ha during a 308-day period. Increasing the nitrogen on Para from 200 to 600 kg/ha increased live-weight gains from 528 to 718 kg/ha during a 336-day period.

At Carimagua in the latosol area, **Melinis minutiflora** pastures fertilized with basic slag at the time of seeding were ready for grazing several months before non-fertilized pastures. Cattle grazing on **Melinis minutiflora** gained about eight times more than those grazing on native grass. The cost-benefit ratio is highly favorable with establishment costs of US$ 23 per hectare and additional annual returns of US$26 per hectare in comparison with native grass.

Some 80 genotypes of the tropical legume **Stylosanthes guyanensis** have been assembled and typed. Selection continues for cultivars and species that have desirable growth characteristics and resistance to the fungus disease anthracnose **Collectotrichum** sp. Large plots of **Stylosanthes guyanensis** and **Paspalum plicatulum** and smaller plots of other grasses and legumes have been planted for seed increase.

Major emphasis is continuing on the collection and testing of strains of **Rhizobia** to facilitate local production of inoculants for legumes. Inoculation and seed pelleting is being investigated under acid soil conditions.

Economists and animal scientists completed analysis of a study of 487 beef cattle farms on the north coast of Colombia. More than half of the ranches were smaller than 200 hectares, and 14 percent were larger than 500 hectares. Cow-calf operations predominate, but about one-third of the total revenues on small farms come from the sale of milk and milk products from the beef animals. This and similar studies planned for other areas help CIAT and national agencies determine research and training priorities.

Animal health studies continued to focus on determining the disease status of cattle on low levels of management, and identifying and monitoring changes in health status when management systems increase population density. Work is continuing in representative groups of cattle in various locations.

Cassava. Additions to the staff during the year accelerated progress and increased the scope of CIAT's work on this major commodity.

The germ plasm bank, consisting of more than 2,000 collections, was freed of bacteria using a green shoot propagation method. Breeding work in the future will be accelerated through a rapid method of clonal multiplication developed through the use of mist propagators. Thus single plants can be rapidly multiplied and screened for desirable characteristics.

Agronomic trials on the CIAT farm demonstrated that yields of 30 tons per hectare can be obtained in less than one year with little difficulty. But the search for higher yielding types continues.

While data gathered in 1972 is preliminary, it suggests ways can be found to exploit the production potential of the crop. Ten varieties were identified as being potentially high yielders. Certain varieties show some acid soil tolerance, and several potentially useful herbicides and weed control systems were identified.

Studies of the storage problem produced a simple and inexpensive on-the-farm method for keeping harvested cassava roots in soil-covered piles, similar to those used for storing potatoes.

The Cassava Program Review Conference, held early in the year, brought together more than 40 scientists from 15 countries concerned with cassava to help CIAT define its cassava program and to stimulate interest among institutions in cooperative efforts.

Swine. Through an intensive study of swine production on small farms, swine specialists gained first-hand data and experience about such operations. High cost of feeds and inefficient production practices combine to make such small farm swine operations a marginal venture at best. But 80 to 90 percent of Latin America's 100 million head of swine are produced under such conditions.

Work on this project clearly demonstrated the difficulties of transferring available technology into practical, acceptable production systems. Package programs were provided and demonstrated, but generally farmers adopted only parts of the program. This indicates the need for a step-by-step introduction of proved practices, each as an aid to improved production.

Swine nutritionists continued studies to find answers to the high feed costs and local unavailability of protein sources, the principal factors influencing the economic potential of swine production in the lowland tropics. Studies continued on bananas, cassava, maize, cottonseed, pigeon peas, and cowpeas.

Field Beans. The Board of Trustees in May approved a program for work on field beans, **Phaseolus vulgaris**, at the regional level in Latin America and the Caribbean. By October, a group of scientists had been organized into a production team to study ways of improving the yields of this crop, frequently the principal source of protein for many people in Latin America.

Evaluation of the USDA/ARS bean collection continued, and from a total of 3,780 collections, 1,097 were selected as resistant to rust, 355 to the leaf bacterial complex, and 214 to the virus complex.

The germ plasm collection being studied at CIAT includes 3,010 of the species **Phaseolus vulgaris.** These are being observed for 23 characteristics.

Early experimental work in soil microbiology focuses on producing locally, high quality effective inoculants, capable of remaining viable under the conditions in which they are transported and stored in the tropics. In early tests, inoculation of **P. vulgaris** influenced grain yields by as much as 100 percent.

Rice. New improved plant type varieties released in 1971 now are being tested or grown on a commercial scale in many countries. CICA 4 was distributed under that name in Colombia, Venezuela, Brazil, Panama, Costa Rica, Jamaica, Honduras, and Guatemala; as INIAP 6 in Ecuador, and as Avance 72 in the Dominican Republic. IR22 is being distributed under that name in Colombia, Venezuela, Panama and Guatemala; as INIAP 2 in Ecuador, and as Navolato A 71 in Mexico.

Yield trials of 15 promising lines indicated that most of these are susceptible to blast and sheath blight disease. But as they are superior to CICA 4 in grain and milling quality and shattering, more extensive tests will be made.

Preliminary tests to seek understanding of the problems of growing rice under upland conditions identified a local variety, Monolaya, well adapted to acid soils.

Pathologists developed a new method to obtain high infection of **Pyricularia oryzae** in areas of low humidity as a means of evaluating varietal resistance of rice to the blast pathogen. This made possible the closing of the testing facilities at Corinto.

Continuous production of rice throughout the year was initiated on the CIAT farm as a test of a system for reducing unemployment and increasing income in various lowland tropical areas of Latin America. Resulting data permit projection of a number of possible rice production systems at various levels of magnitude and labor intensity on a year-round basis, from harvesting 0.2 hectares every 14 days to a commercial 120-hectare operation, mechanized, and employing 32 laborers steadily harvesting six hectares weekly.

Maize. To overcome problems of farmer and consumer acceptance of opaque-2 corn, efforts continued to provide a maize more similar to the flint types currently grown and consumed in the tropical lowlands. The first promising modified–endosperm opaque-2 population from CIMMYT was increased and tested with children, rats, and in a pilot plant study. The protein quality appeared to be good, and commercial companies had no unusual processing problems.

Excessive plant height of maize grown in coastal regions in the Andean zone limits yields by reducing efficiency of dry matter production and complicating harvest by lodging. Brachytic and short plant selections both with yellow and white endosperm, selected for their yield over a range of climatic zones, are being increased to provide sufficient seed of each family for wide distribution throughout the zone.

These trials, planted in national programs in collaboration with CIAT, provide further data on the range of adaptation and potential for each combination, as well as being a new source of valuable germ plasm with short stature for each participating program. This system is perhaps the most efficient way to introduce new germ plasm of this type within the zone.

Agricultural Systems. Bulk of the activity in this area in 1972 concentrated on staff analyses of various approaches, these leading to a comprehensive proposal for presentation to the Board of Trustees in 1973 for approval. Essentially, the new approach proposed concentrates on development of a process for the analysis of existing agricultural systems as a prelude to additional research or to recommending changes. As outlined, the agricultural systems team would include specialists from at least the following fields: agronomy, agricultural economics, rural sociology and anthropology, systems engineering, agricultural engineering, with additional inputs, as necessary, from soils, animal science, geography, ecology, and related fields.

Soils. Recognizing the need for improved soil management practices in the tropics, soils specialists initiated a study of different methods of tillage, planting, and residue management. First year experience confirms that "zero" tillage dramatically reduces the time required between crops as well as the cost of production, assuming other means of weed control are available and not too costly.

Results of the continuing program to screen crops for acid soil tolerance indicated that cowpeas appear to be the most tolerant food legume. Corn and black beans are intermediate while the non-black beans are the poorest. With upland rice, some traditional varieties barely respond to the first increment of lime while the majority of the new semi-dwarf varieties respond strikingly to lime and produce practically nothing in its absence.

International Activities. More than ever before, CIAT in 1972 operated internationally. New staff members travelled widely to become familiar with national programs and problems, while earlier arrivals concentrated on developing cooperative and collaborative programs in various countries. Conferences, symposia, and short courses attracted several hundred people to CIAT, in addition to the many visits of decision-makers and professionals. Another 118 from 20 countries were enrolled in training activities of three months or longer duration, the bulk of them for one year.

Administrative Developments

The appointment of a Deputy Director General early in 1972 made it possible to give greater attention to international activities and development of outreach programs. In addition, he coordinated discussions and developments of the new approach to agricultural systems research being recommended to the Board of Trustees in 1973.

At year's end, negotiations with the government of Guatemala were nearly completed for a project in which CIAT will cooperate in the development of an integrated research-education-extension organization in that country. When completed, the arrangements will provide for stationing two CIAT staff members in Guatemala for an extended period.

Work on the new buildings moved ahead rapidly. Additions to the capital budget included US$ 750,000 from The Kresge Foundation to support the communication services building, US$ 718,000 from the Rockefeller Foundation toward completion of the overall construction program, and 800,000 (Colombian pesos) from the sale of the house at Girardot. This property, owned by the Rockefeller Foundation, was donated to CIAT this past year.

All of the outlying buildings for swine and beef were put into operation during the year, as well as the Small Animal Colony and the green– and screen– houses.

Development of the farm continued with emphasis on rehabilitating problem soil areas, leveling areas for experimental plots and extension of the irrigation system.

Most of the roads around the new building complex were paved under the direction of the agricultural engineer.

There were no new donors to the operational core budget in 1972, with the funds being supplied by the Ford, Rockefeller and W. K. Kellogg Foundations, the United States Agency for International Development, the Canadian International Development Agency, and the government of the Netherlands.

Funds for outreach and other special projects came from the International Development Research Centre of Canada, the Interamerican Development Bank, and the W. K. Kellogg Foundation.

At year's end, the W. K. Kellogg Foundation announced that its Board of Trustees had approved a grant of US$ 1,500,000 toward support of the training and communication activities of CIAT over a five-year period beginning January, 1974.

Eight appointments brought the senior staff to near full strength by the end of the year. During the same time, one member of the staff, Dr. Roy Thompson, agronomist, resigned and returned to a position at the University of Minnesota.

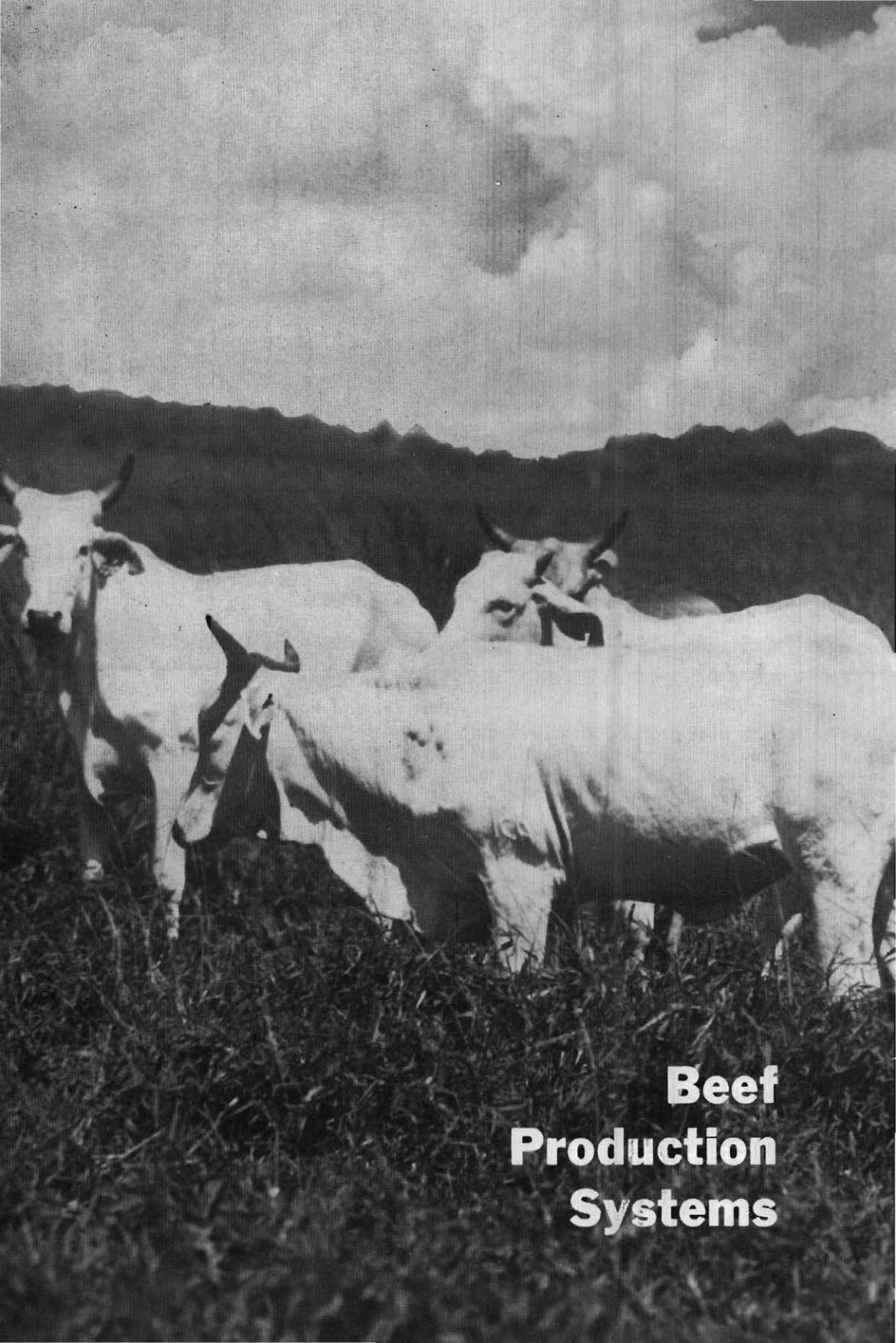
New staff appointments were Dr. A. Colin McClung, Deputy Director General; Dr. H. H. Stonaker, animal science; Dr. Eric Wells, animal health; Dr. Guillermo Hernandez-Bravo, bean breeding; Dr. J. Carlos Lozano, cassava pathology; Dr. Aart van Schoonhoven, bean and cassava entomology; Dr. Guillermo Gomez, swine, and Dr. Gustavo Morales, animal pathology.

Special appointments were made to Dr. Robert H. Booth, Tropical Products Institute, for work on cassava storage; Dr. Albert J. Clawson, swine nutritionist on sabbatical leave from North Carolina State University, and Dr. Alberto Pradilla, pediatrician from the Universidad del Valle on sabbatical leave for nutrition studies with opaque-2 maize.

Other staff changes included the arrival of Dr. Thomas J. Galvin, veterinarian, who replaced Dr. Gary Adams and Dr. Radmiro Todorovic, animal health specialists, on the Texas A&M University project, at the end of their tours of duty. Mr. Kenneth Buhr, visiting scientist, completed his work with food legumes at CIAT and returned to Iowa State University.

Mr. David Franklin, systems engineer with the Harvard University nutrition project in Bogota, was employed on a consultative basis throughout the year to help the staff with statistical design and analysis problems as well as in the development of the agricultural systems approach.

The International Bank for Reconstruction and Development provided a consultant, Mr. Michael Ruddy, who assisted in further development of the budget and accounting procedures of CIAT. Using his experience with CIAT as a base, he later proposed procedures for use by the various international centers.



Beef Production Systems

Government and private sectors are increasingly aware of the beef production potential of the lowland tropics, and of the benefits that would arise from an expanded beef industry. Additional protein would be available for human consumption. Gross national product would be increased creating more jobs and raising **per capita** income. And beef cattle would offer an efficient and practical method of initially opening up undeveloped lands, and in utilizing lands that have little potential for growing crops.

Although beef production is increasing, supply falls short of demand. Actually, this deficit has been increasing, principally in consequence of deficiencies in public policy and production technology. Insufficient attention has been given to road construction, to investment incentives in agriculture and to agricultural credit. Many agricultural inputs and services such as grass and legume seeds, phosphorus fertilizers and livestock supplies have not been readily available at reasonable prices. Available technology has been poorly applied in putting together practical and profitable farming enterprises. And in addition, certain technological barriers have prevented realization of the production potential of available land and animal resources.

Research objectives are: 1) to provide adequate feed supply, 2) to control disease and parasitism and 3) to develop economical systems of production. Particular attention is given to improving reproductive performance since long-term increases in beef production will depend principally on increasing the calf crop, providing more females for breeding and more males for fattening.

Training objectives include training of livestock production specialists and research workers engaged in agricultural development programs.

ADEQUATE FEED SUPPLY

Pastures and Forages Systems

Dietary deficiencies of protein, energy and minerals are the principal causes of low reproductive performance and slow growth, and increase susceptibility to disease and parasitism. Therefore, major emphasis is placed on providing a nutritionally adequate pasture forage at all times, with supplementation when necessary. A team of soils, soil microbiology, weed control, agrostology, pastures and forages utilization, and ruminant nutrition specialists collaborate in developing this program.

Tropical legume evaluation

Stylosanthes. A collection of some 78 genotypes of the perennial species **Stylosanthes guyanensis** has been assembled. The preliminary 'typing' of the material, using morphological and agronomic characteristics was made in space-planted nursery plots and in the plant house.

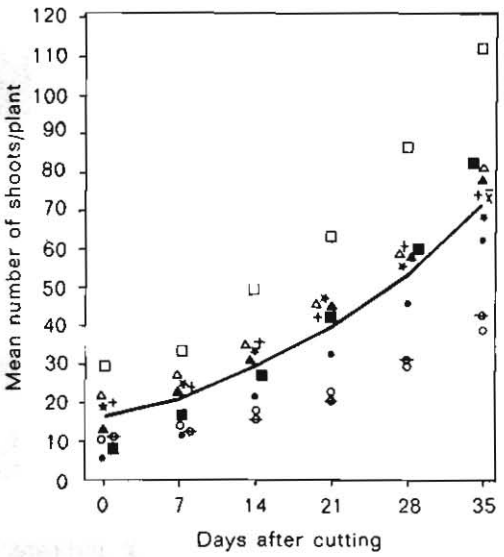


Fig. 1. The number of shoots present in nine **Stylosanthes guyanensis** varieties (represented by different symbols in the graph). Data were collected weekly over 35 days after cutting plants at five cm above soil level.

The collection includes a wide array of ecotypes collected in Colombia from sea level to 1,700 m elevation. In a sample of nine ecotypes of **S. guyanensis**, there was a three-fold range in shoot numbers between 'types' (Fig. 1). These new accessions were obtained from acid soil regions of the Cauca Valley, eastern Llanos and the Atlantic coast of Colombia and a number of introductions were received from Costa Rica and Panama.

An important recent advancement was the successful identification and isolation of the pathogenic fungus disease anthracnose, caused by **Colletotrichum** sp., responsible for an anthracnose disease which affects several species and ecotypes of **Stylosanthes**. The incidence of this devastating stylo disease was reported in Bolivia as early as 1965. Recent observations and reports confirm the presence of stylo anthracnose in Florida, Costa Rica, Panama, Venezuela and Colombia.

Studies were conducted in the plant house designed to screen species and ecotypes of **Stylosanthes** for resistance to anthracnose. Cultures of **Colletotrichum** sp. were isolated from diseased plants at Palmira and Carimagua. These cultures were used as sources of inoculum. Seedlings three to four weeks

Introduction plot of the tropical legume Stylosanthes **at CIAT.**

TABLE 1. **Reaction of** Stylosanthes guyanensis **to** Colletotrichum.

CIAT accession number or cultivar	Origin	Anthracnose rating (means of 16 plants)
41	Panama	0.2
21	Colombia	0.3
18	Colombia	0.5
50	Colombia	0.7
42	Panama	1.2
Cook	Commercial Australian	1.5
20	Colombia	2.2
30	Panama	3.0
Schofield	Commercial Australian	4.0
Endeavour	Commercial Australian	4.5

Severity scale: 0 = no infection.
5 = dead plant.

old, as well as mature plants, were inoculated with **Colletotrichum** by spraying plants with a suspension of conidia. Plants were maintained under polyethylene cover for 3 days and scored for severity of infection after 7 and 14 days.

Mean anthracnose scores varied among species and ecotypes and variations in susceptibility to various isolates of the pathogen were observed between and within species (Tables 1 and 2, photo p. 15). An introduction of **Stylosanthes guyanensis** from Costa Rica (C.P.I. 34,000) and a local variety (La Libertad) were highly resistant. **S. subsericea** (C.P.I. 37274) and local **S. hamata** displayed complete resistance to all isolates of anthracnose. Schofield, Cook and Endeavour, the Australian commercial cultivars of stylo which are the source of nearly all seed traded internationally, were all moderately to highly susceptible to the disease.

Anthracnose resistance has great importance. Preliminary results indicate that it should be relatively easy to select anthracnose resistant stylo. The existence of several strains of the pathogen and finding that species and ecotypes differ in their resistance to various isolates of the pathogen suggest that the available gene pool of **Stylosanthes** should be increased to provide a broader base for selection.

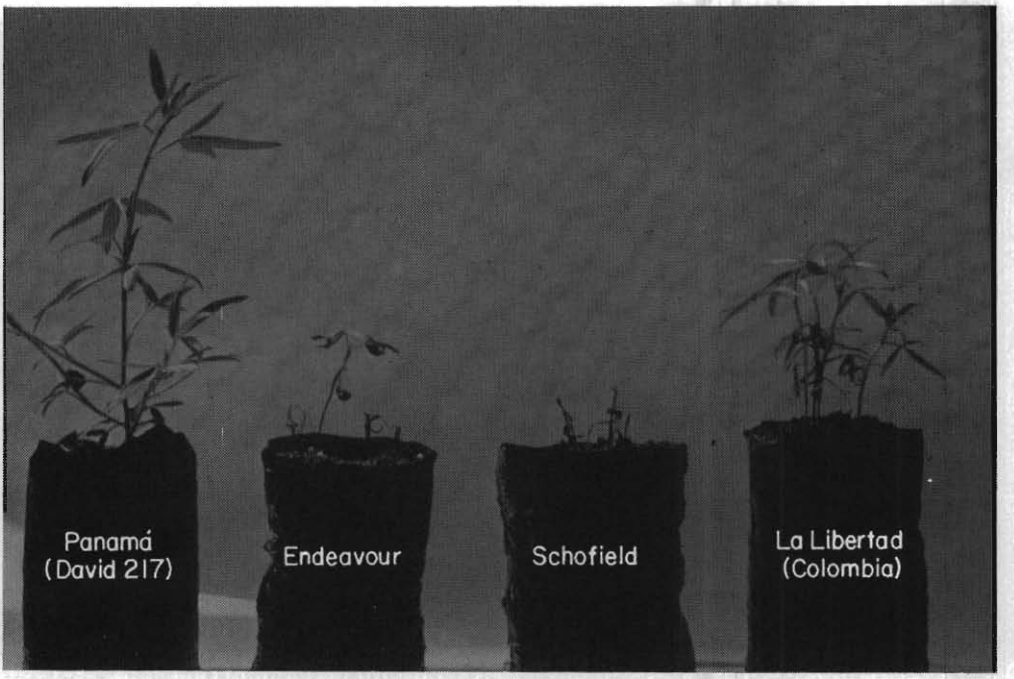
Centrosema. Selections from F_4 generation hybrid derivatives of the cross **C. brasilianum** x **C. virginianum** are being compared with a commercial variety and two indigenous centro lines in a

TABLE 2. **Reaction of** Stylosanthes **spp. and varieties to three isolates of** Colletotrichum.

Species or variety	Nº	Anthracnose rating* Isolate Nº ** 35	34	48
S. subsericea	C.P.I.37274	0	0	0
S. hamata	CIAT 58	0	0	0
S. guyanensis	Q.8442	0	1	1
S. guyanensis	C.P.I.40255	0	1	1
S. guyanensis La Libertad	CIAT 18	1	1	1
S. guyanensis Schofield		1	1	2
S. guyanensis	CIAT 68	0	1	4
S. guyanensis	CIAT 48	0	1	4
S. guyanensis	CIAT 45	0	1	4
S. guyanensis	CIAT 44	0	2	4
S. guyanensis	CIAT 69	1	2	4
S. guyanensis	CIAT 71	1	1	5

* Severity scale based on: 0 = no infection.
5 = dead plant.

** Isolates 34 and 35 are from Carimagua; 48 is from Palmira.



The two center plants, being highly susceptible, show the characteristic symptoms of the fungus, anthracnose, in Stylosanthes, while the two plants at the ends are relatively resistant.

small plot experiment. Dry matter production and stoloniferous development are the parameters used for evaluation.

Desmodium intortum. In equatorial regions, the lack of seed is a major problem with the commercial cultivar 'greenleaf' **Desmodium** and with other ecotypes originating from high latitudes. Introductions from Ecuador and Panama are being compared with the local ecotype in small plots in search of more prolific types.

Soil microbiology

Major emphasis has been placed on the collection and testing of strains of **Rhizobia** in order to facilitate local production of high quality inoculants. To insure continued viability during transit and storage, organic carrier media of local origin are being tested.

Strain selection and testing

During 1972, some 400 isolations were made from nodules of both native and commercially grown legumes. The **Rhizobia** obtained were characterized and preserved by lyophilisation. The collection includes strains for **Alysicarpus, Phaseolus** species, **Pisum, Rhynchosia, Sesbania, Stizolobium, Stylosanthes** and **Trifolium.** Tests to determine the nitrogen fixing ability of each strain are underway, the smaller plants being grown in sterile seedling agar, the larger ones in Leonard jars. Weakly effective strains are eliminated after this preliminary screening; the more effective strains advance to comparative pot and field studies.

Early results indicate the importance of screening **Rhizobia** for effectiveness under specific climatic and soil conditions. The strain CB756 is used in Australia as a wide spectrum strain effective with plants as different as **Arachis hypogea, Vigna sinensis, Calopogonium** sp. and **Stylosanthes.** Its effectiveness

under initial trial conditions was limited and will necessitate further testing for temperature effects and alternate strains. This isolation and testing program will be continued into 1973, when CIAT expects to have established suitable inoculant strains for most of the legumes important to the lowland American tropics.

Organic carrier media for inoculants

To be suitable as inoculant carriers, substances must maintain high viability of **Rhizobium** for periods up to three months, be neutral or neutralizable in pH, and have high water holding capacity. Materials high in organic matter generally give best protection to the **Rhizobia.** Peat is the most common inoculant carrier. Materials from six locations were selected as potential inoculant carriers and are presently being compared. Inoculants produced during 1972 were sent to farmers in Sibundoy peat, in bagasse, or in mixture of the two. The excellent survival of strains in these media is shown in Fig. 2.

Pelleting of seeds

Extreme soil acidity encountered in many lowland tropical areas can adversely influence rhizobial survival in soil and result in nodulation failure. Because of this we examined the need of inoculation and pelleting of seeds to improve nodulation under acid soil conditions using **Stylosanthes guyanensis** and **Leucaena leucocephala** as test plants. Results are shown in Fig. 3. These may be summarized as follows:

a) All strains tested needed inoculation to assure adequate nodulation.

b) Seed pelleting with either ground limestone or rock phosphate as the pelleting agent resulted in good nodulation of all species, even with applied lime levels as low as 0.5 ton/ha.

c) Basic slag was generally unsatisfactory as a pelleting agent.

d) Strain differences in susceptibility to adverse conditions were encountered in **Leucaena** and selection of strains for acid resistance in this and in other species may be justified.

Provision of inoculant cultures

During 1972, inoculants were provided for over 3,000 kilos of seed, including **Centrocema** (800 kilos), **Desmodium** (300 kilos), **Stylosanthes** (600 kilos) and **Leucaena.**

Antisera have been prepared against all inoculant strains and quality control procedures will be introduced as routine in 1973.

Plant improvement

Pennisetum. The production of an interspecific hybrid between pearl millet (**Pennisetum typhoides**) and Elephant grass (**Pennisetum purpureum**) was attempted by intercrossing Tift 23A male sterile millet and a local variety of Elephant grass. Such a hybrid is attractive from the agronomic point of view, with the added advantage of viable seed. Seed was harvested from the male sterile millet planted in alternate rows with Elephant grass, and on planting gave rise to vigorous seedlings. Determination of the percentage of Elephant grass-type perennial hybrid plants and their agronomic value in a seeded field plot is in progress. (photos pp. 19 and 20).

Brachiaria. An investigation of the mode of reproduction of **Brachiaria ruziziensis** is being conducted. (photos p. 21). This species demonstrated sexual recombination in both manual cross-pollination and natural open-pollination experiments, with degree of cross-pollination being as high as 90 percent. Various clones when open-pollinated have averaged 30 percent of spikelets with caryopses. The same clones when self-pollinated have shown only 0.5 percent fertility. Progenies derived from self-pollination have had

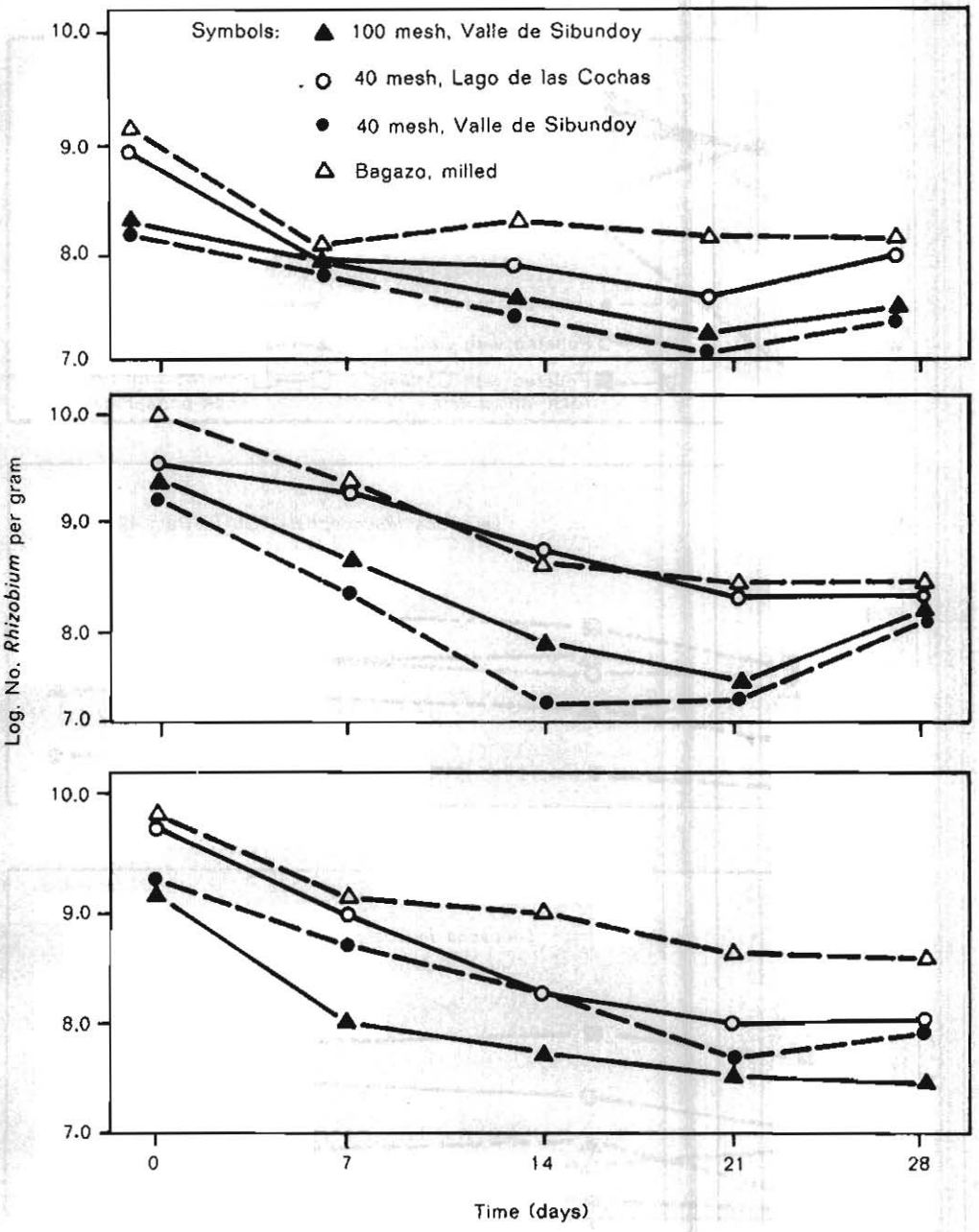


Fig. 2. Survival of strains CIAT 92 (top), 57 (center) and 44 (bottom) in organic carrier media at 28ºC.

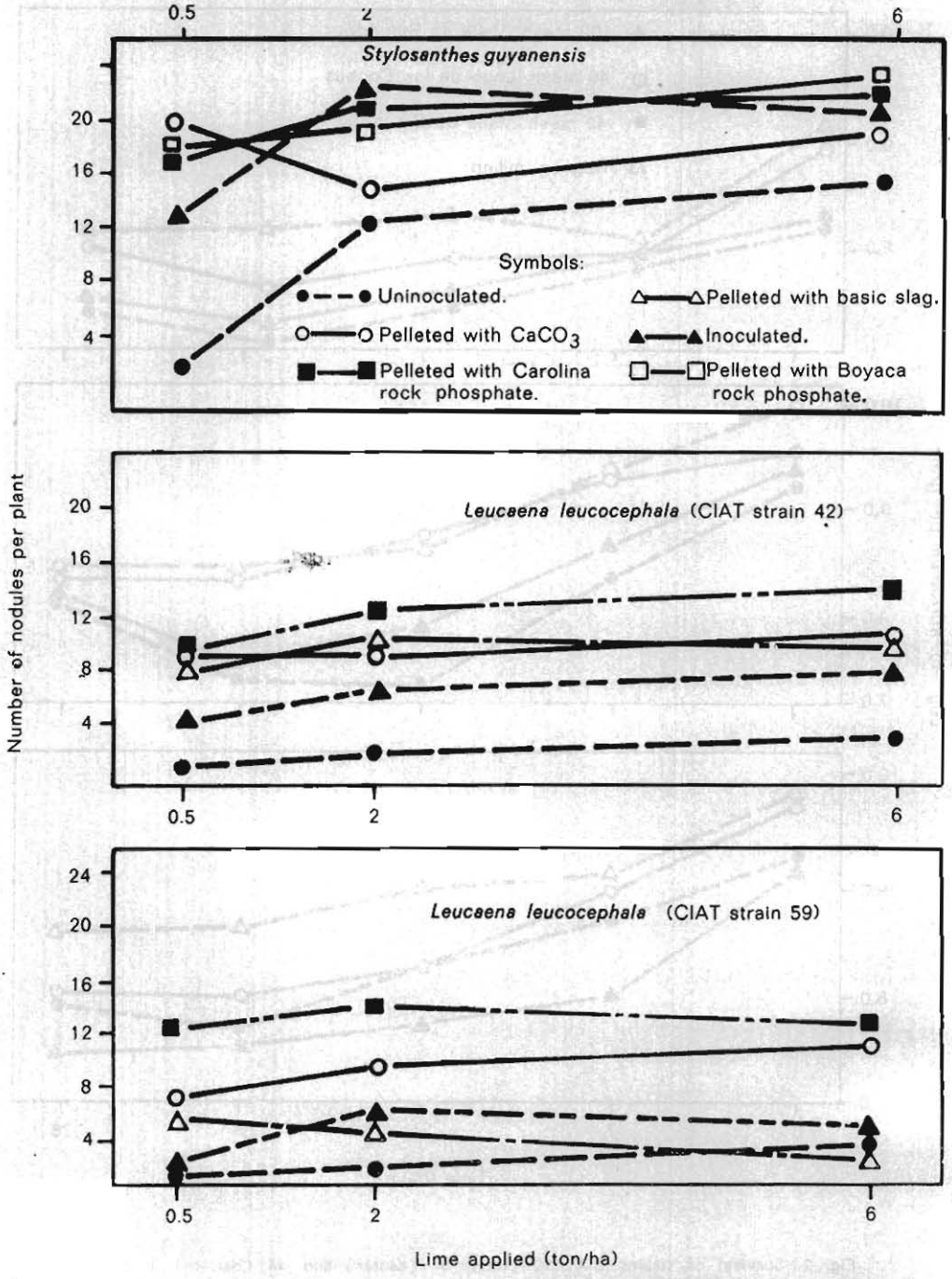


Fig. 3. The effect of inoculation and pelleting on nodulation of three tropical legumes.

The Elephant grass-type hybrid (Pennisetum typhoides **x** P. purpureum) **produces the low leafy plant (foreground) as contrasted with the erect plant of** P. typhoides **(background).**

reduced vigor compared to progenies from open-pollinated seed. Meiosis is regular with the 18 chromosomes associating as 9 bivalents. Estimates of pollen fertility average 90 percent.

Seed production

In order to increase the supply of seed of selected forage species, CIAT has seeded some 7.5 hectares to **Stylosanthes guyanensis,** variety La Libertad, (photo p. 22), and 6 hectares to **Paspalum plicatulum.** Smaller areas of **Desmodium distortum, Urochloa mosambicensis,** centro, kudzu, **Desmodium intortum** and several species of stylo are also being used for seed production.

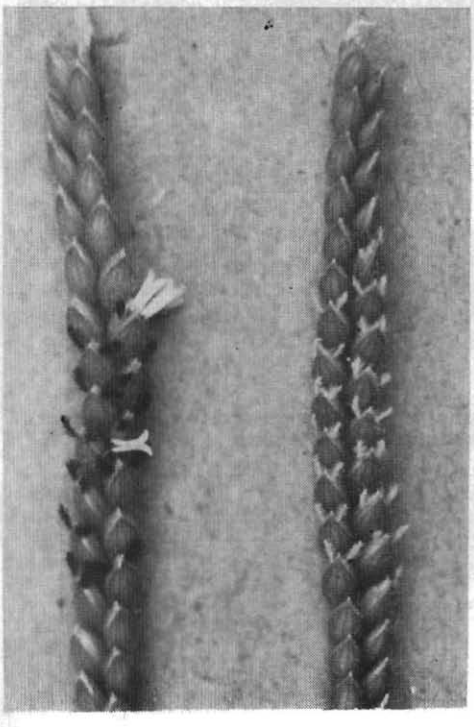
Pasture establishment

Studies relating to practical and economically feasible pasture establishment and range reseeding techniques have

The flowering head of Elephant grass (Pennisetum purpureum) **is used as a pollinator with pearl millet** (P. typhoides).

A crossing plot of Tift 23A male sterile pearl millet x Elephant grass.

Spaced plants of Brachiaria ruziziensis **are examined for seed set capacity.**



These phenotypes for stigma color are used in controlled pollination studies with the tropical grass Brachiaria ruziziensis. **The white anthrocyanin-free phenotype is at the right.**

been initiated at the Carimagua substation.

Five grass species, **Melinis minutiflora, Hyparrhenia rufa, Brachiaria decumbens, Paspalum plicatulum** and **Urochloa mosambicensis** Q.2447, have been seeded with four stylos (La Libertad, Cook, C.P.I.34,000 and **S. subsericea** C.P.I. 37274) to determine dry matter yields, seasonal production, grass-legume compatibility, and nutritive values of sown pasture components.

In another experiment at Carimagua, various methods of introducing stylo and **P. plicatulum** into existing native savannah with and without cultivation and fertilizer were investigated. The number of established grass and legume seedlings increased in proportion to improved cultural treatment used.

Two varieties of **Stylosanthes guyanensis** and **S. subsericea** were seeded into native pasture following light surface cultivation with an offset disc. Four levels of phosphorus (0,25, 50, 75 kg/ha P_2O_5) were applied. Satisfactory legume establishment was obtained in all treat-

Seed of the tropical legume variety, La Libertad (Stylosanthes guyanensis), **is being increased at CIAT for use in planting grazing trials.**

ments, and stylo, as well as native grasses, responded strongly to phosphorus application (Table 3).

Weed control

The greatest pasture weed control problems in the lowland tropics are on infertile rolling soils and on poorly drained soils in alluvial valleys. Pasture weed control programs are being developed in the Atlantic coast area and in the Llanos of Colombia, where these conditions are found.

TABLE 3. **Response of Stylosanthes to phosphorus when seeded into native savannah (Establishment yield three months after seeding).**

Stylosanthes variety or species	Level of P_2O_5 kg/ha			
	0	25	50	75
	Mean dry matter yield kg/ha			
S. guyanensis C.P.I.34,000	290	580	640	600
S. guyanensis La Libertad	310	440	675	775
S. subsericea C.P.I.33943	225	420	280	645

The problems are basically of three types: 1) undesirable grasses and sedges, 2) annual broadleaf herbaceous plants and 3) perennial brush species. Those weeds in the first and last groups are the most troublesome. CIAT's research has already shown that species from group 2, such as **Cassia tora, Hyptis** spp.,**Lantana camara, Vernonia patens, Verbesina turbacensis, Solanum hirsutissimum** and **Corchorus** sp., are easily controlled by foliar application of the common hormonal herbicides (2,4-D, 2,4,5-T, Dicamba and Picloram) and their combinations at 0.5 percent v/v of the commercial formulations.

The following perennial brush species are proving to be resistant to foliar applications of the above mentioned Products: **Heliconia bihai, Scheelea butyraceae, Chamaesfistula bacillaris, Piper marginatum, Chomelia spinosa, Smilax spinosa, Ahouai nitida** and others. Future work will be done on these species using various surfactants to aid foliar herbicide penetration and with a combination of herbicide and diesel fuel applied to the stems or trunks immediately after cutting the brush.

A number of species vary greatly in their response to foliar applied herbicides. For example, **Malachra acerifolia** is somewhat resistant to Picloram + 2,4-D and very susceptible to 2,4,5-T. **Steiractinia cornifolia** is, on the other hand, more susceptible to Picloram + 2,4-D than 2,4-D or 2,4,5-T alone or in combination. Another woody species, **Cordia coloccoca,** appears more susceptible to Dicamba + 2,4-D than to other treatments. Thus, the recommendation for a specific weed complex needs to be exact and may require the combination of several products.

Two pasture-grass weed problems were studied in the ICA research station, La Libertad, near Villavicencio, Meta. West Indian foxtail. (**Andropogon bicornis**) is a non-palatable, coarse bunch grass commonly found in the Llanos and jungle regions of many Latin American countries. It is resistant to burning and reproduces from the abundant number of wind-borne seeds it produces annually. "Guayacana" (**Imperata contracta**) is a shorter growing species that can also cause serious problems. It reproduces by both seeds and spreading rhizomes and because of the latter it appears in patches. Both species have upright leaves and any post-emergent herbicide must be highly toxic toward these species as the actual quantity of chemical absorbed will be much less than for flatter, wider-leaved plants.

The results show that the new post-emergence, translocated, non-selective herbicide Glyphosate, is the best product to control **A. bicornis.** One kilogram active ingredient per hectare is sufficient with a single application preferred over a split application. The normally effective grass herbicides, Dalapon, TCA, DSMA and MSMA, were essentially ineffective on this species and split applications were non-advantageous.

However, for **I. contracta,** Glyphosate gave poorer control. Dalapon demonstrated the best results; other grass herbicides were ineffective. Paraquat and Cacodylic acid caused initial burning of both species but these species later recovered. Diuron gave fair control of both weeds.

The weed control program has contributed significantly to the livestock production training program. Apart from the lectures and practical exercises given at CIAT's site at Palmira and in Turipana, a "mini-kit" herbicide trial was put together in order to give trainees research experience in brush control. Seven herbicides at two rates each were included in the kit and four kits were placed in each of the eight ranches where the trainees were located. Before the dry season arrived, a total of 24 kits were applied to a wide variety of weed complexes. Research students are now collecting data and will continue until the end of their stay on the ranches in early April, 1973. It is encouraging to

TABLE 4. **Weight gains of steers grazing on Pangola grass fertilized with nitrogen at Palmira, Colombia, in kg/day.**

Level of nitrogen kg/ha/year	Stocking rate, steers per hectare					
	4	5	6	7	8	9
200	0.406	0.400	0.332			
400		0.453	0.353	0.335		
600			0.443	0.356	0.328	
800				0.434	0.371	0.350

see the interest that veterinarians and animal scientists have in pasture-weed control, and surely they will develop into better cattle production specialists because of such involvement.

Effective weed control recommendations can be made to a rancher only after one knows the problem-causing weed species. This requires practical field guides for weed identification.

In cooperation with ICA and the National University in Medellin, a tropical pasture weed identification manual was prepared and is ready for publication. It contains 115 of the most frequent species in lowland tropical pastures. A black and white picture and a descriptive text of each one make identification easy.

Pasture and Forage Utilization

CIAT headquarters at Palmira

Two grazing trials were established in 1971 to measure the effect of nitrogen fertilization of pure grass pastures on the yield of beef obtained under intensive grazing (photo p. 26).

In one trial, Pangola grass was fertilized with four levels of nitrogen (urea). Each treatment was grazed at three stocking rates. Grazing was rotational over six paddocks for each treament. Irrigation was intended to be regularly applied according to soil moisture requirements. However, severe drought of more than six months decreased availability of irrigation water with the result that the pasture was irrigated on only three occasions of the ten needed. Tables 4 and 5 contain the weight gain data. Beef yields were below that expected. Deficiencies of boron, zinc and iron were suspected. However, addition of these did not increase dry matter yields. On the other hand, there has been marked improvement of the sward with time. It is possible that this change is due to improved drainage and the acidulating effect of nitrogen fertilizer used. Soil pH ranged as high as 8.2 in the experimental area.

Table 6 presents the results of a preliminary economic analysis. It can be observed that farmers will obtain about 8 percent profit on total investment which in this case includes 20 percent

TABLE 5. **Beef production of nitrogen fertilized Pangola grass at Palmira, Colombia, in kg/ha in a 308-day period.**

Level of nitrogen kg/ha/year	Stocking rate, steers per hectare						
	4	5	6	7	8	9	Average
200	500	616	613				576
400		697	652	722			690
600			818	767	808		797
800				936	912	981	943

TABLE 6. **Return to capital investment obtained in a beef fattening system on irrigated, nitrogen fertilized Pangola grass pasture.***

Level of nitrogen kg/ha/year	Stocking rate, steers/ha					
	4	5	6	7	8	9
	Percent return on investments					
200	6.0	13.0	9.6			
400		9.2	6.5	8.9		
600			9.1	6.6	10.0	
800				8.8	7.5	9.2

* Investment includes interest on all capital at the rates of 20 percent for cattle and land, and 15 percent for all other costs per year.

interest on cattle and land costs, and 15 percent on other fixed costs. Such rates are locally considered to be the opportunity investment rate. In the livestock business, 8 percent net profit, calculated in this way, is very encouraging.

In another trial, the response of Para grass (**Brachiaria mutica**) to nitrogen fertilization without irrigation was less than in the case of Pangola grass. Plots fertilized with 200, 400 and 600 kg of nitrogen (urea) per year were rotationally grazed using stocking rates of 4, 5 and 6 steers/ha. Table 7 shows the results obtained.

In the beef fattening systems using Pangola and Para, individual daily gains were not sufficient to allow maximum production per unit area. Maximum gains were from 350 to 400 g in both cases, while rates of 550 to 600 g/day are possible. Genetic potential has apparently been a limiting factor. This can be overcome by the use of higher quality animals such as F_1 crosses of Zebu and Criollo, or Zebu and a fast growing European breed. An indication of the possible level of improvement was obtained in the Pangola trial, in which two crossbred Charolais x Zebu were included in each treatment. Average weight gains over all treatments were: Charolais x Brahama, 472 g/day and grade Zebu, 353 g/day, an increase of 34 percent.

Turipana

A first attempt in establishing a mixed legume-Para grass pasture was made in late 1971. However, it was necessary to replant the area in May, 1972, because of the onset of a dry period soon after planting and lack of irrigation water. The pasture is now established. Carefully controlled grazing has begun and experimental grazing will begin in 1973. At the moment Kudzu (**Pueraria phaseoloides**) dominates, to the extent that it is smothering the other three legumes, **Centrosema plumierii, Desmodium intortum** and **Clitoria ternatea.**

Carimagua

The traditional system of beef cattle production in the Colombian Llanos has been based on the use of native grasses as the only source of feed. Lack of information on the native savannah prompted a study to determine its production capacity (photo p. 30). Feeder steers were used to compare three stocking rates and continuous vs. rotational grazing management. Stocking rates used were 0.18, 0.31 and 0.44 animals per hectare. Four paddocks were grazed ro-

TABLE 7. **Weight gains of steers grazing on unirrigated nitrogen fertilized Para grass** (Brachiaria mutica).

Level of nitrogen kg/ha/yr	Individual gain kg/steer/day	Gain per hectare kg/ha/336 days *
200	0.393	528
400	0.335	562
600	0.356	718

* Period: December 1971 - November 1972.

Steers representing a pasture treatment of a grazing trial are gathered monthly to obtain their body weights.

tationally for 28 days each and rested for 84 days. The first year results of this grazing study are summarized in Table 8.

Rotational grazing did not have any advantage over continuous grazing. Furthermore, the productivity of the savannah measured at all stocking rates is extremely low with a maximum output of less than 12 kg of weight gain/ha/year.

The botanical composition of the native savannah was followed in this grazing trial to see if stocking rate or grazing management has any effect on the distribution of species. Table 9 contains the average composition and total forage dry matter availability. Two species, **Trachypogon vestitus** and **Paspalum pectenatum** constitute 60 to 70 percent of the total forage available in this savannah; other minor contributors are **Leptocoryphium lanatum, Andropogon semiberbis, Panicum versicolor** and **Axonopus pulcher.** There were no drastic changes in species composition comparing 1971 and 1972 data. There is a general tendency towards a reduction of species density and percent basal coverage of the main forage species. This reduction tends to be accentuated with increasing stocking rate and continuous grazing.

Forage availability decreased as stocking rate increased. In spite of the fact that figures on forage availability indicate a sufficiently high amount of dry matter available for consumption by the animals, the weight gains are low at all times indicating low consumption of forage. Protein was recorded to be from 2 to 4 percent of the dry matter at all times.

Significant improvements in the productivity of latosols would appear to

TABLE 8. **Weight gains of steers grazing on the native savannah in the eastern plains of Colombia.**

Grazing management	Dry period Nov. 71–March 72			Rainy season March 72–Nov. 72			Year Nov. 71–Nov. 72		
	Stocking rate, animals/ha			Stocking rate, animals/ha			Stocking rate, animals/ha		
	0.18	0.31	0 44	0.18	0.31	0 44	0.18	0.31	0.44
	Gain per animal kg/day								
Continuous	–0.160	–0.191	–0.252	0.209	0.268	0.146	0.083	0.112	0.010
Rotational	–0.168	–0.267	–0.244	0.138	0.146	0.071	0.034	0.005	–0 036
	Gain per hectare kg/period								
Continuous	–3.2	–6.7	–12.4	8.0	18.2	13.8	4.8	11.5	1.5
Rotational	–3.3	–9.4	–12.0	5.3	9.9	6 8	2.0	0.5	–5.3

depend on the introduction of more productive species, capable of sustaining higher levels of animal production. Molasses grass (**Melinis minutiflora**) is used in many of the latosol areas of Brazil, Venezuela, and to a lesser extent in Colombia, because of its ability to produce under low soil fertility conditions. It is not among the more productive tropical pasture species, but when used to replace native savannah species results in greatly increased carrying capacity and is capable of maintaining good growth and reproductive performance even on the acid and infertile soils of the Llanos. Its introduction may often represent the first step in the evolution of efficient beef production systems.

A trial was initiated in October, 1971, to determine the effect of phosphate and potash fertilization at the time of

TABLE 9. **Composition of dominant grass species and forage availability of the native savannah in the eastern plains of Colombia.**

Species	Continuous grazing			Rotational grazing		
	0.18 animals /ha	0.31 animals /ha	0.44 animals /ha	0.18 animals /ha	0.31 animals /ha	0.44 animals /ha
	Percentage of total dry matter basis					
Trachypogon vestitus,	51	48	48	46	38	35
Paspalum pectenatum,	16	22	22	26	35	25
Other grasses and forbs,	33	30	30	28	27	40
	Dry matter available in kg/ha*					
	4800	4400	4000	5100	4200	4000

* Results are the average of two clippings, April, 72 and August, 72.

seeding on the beef production capacity of Molasses grass. Levels of fertilizer were: none, 75 kg P_2O_5/ha and 75 kg P_2O_5/ha plus 40 kg K/ha. Continuous grazing was used with three stocking rates: 0.44, 0.88 and 1.30 steers/ha. Table 10 presents a summary of the results obtained to date.

Fertilized pastures were ready for grazing several months before non-fertilized lots. However fertilization did not affect carrying capacity. Stocking rate of 1.3 head/ha is too high for year-round continuous grazing. Approximately 0.8 animals/ha would provide adequate forage and produce an expected weight gain per hectare per year of about 100 kg. A practical system in many instances would be to graze more heavily in the rainy season and less in the dry season.

There are large differences in productivity of the native savannah and Molasses grass pastures. While the savannah was not able to produce a gain of any more than 12 kg/ha/yr, gains on Molasses grass were seven to eight times greater. Cost of establishment of Molasses grass is relatively low since preparation of seedbed and purchase of seed are the major expenses. Fertilizer is not needed if one can wait 8-12 months for pasture establishment. Cost-benefit ratio is highly favorable, with establishment costs of US$ 23.00 and annual returns of US$ 26.00. A Molasses grass pasture would be depreciated in no less than 10 years and probably 15 years in accordance with experience obtained in the region.

Experience in other tropical regions indicates that establishment of legumes in grass pastures would often increase protein percentage of the consumed forage, and also improve soil nitrogen status through symbiotic nitrogen fixation, thus stimulating grass growth and total forage production. Past experience indicates that **Stylosanthes guyanensis** is one of the better adapted legume species. Of the grasses, Molasses grass, **Hyparrhenia rufa, Brachiaria decumbens** and **Paspalum plicatulum** are well adapted to the acid and infertile conditions characteristic of the area. A grazing trial is now being established comparing mixtures of each of these four grasses with **Stylosanthes guyanensis.** Each of the four mixtures will be grazed under three stocking rates. Grazing should start during the second half of 1973.

Three hundred and fifty pasture samples from Carimagua, representing more than 30 different species at several different stages of maturity, were analyzed for crude protein, calcium, phosphorus, sodium, potassium, magnesium, manganese and zinc content. This is part of a coordinated program to accumulate data to determine the nutritive value of forages as well as other feedstuffs available in the tropics.

Crude protein levels are low in most native grass species, ranging from 2 to 9 percent, with most samples containing approximately 4 to 5 percent. Improved grass species have somewhat higher crude protein levels, including Molasses grass with slightly higher protein content and **Paspalum plicatulum** which contains as much as 12 percent in the early stages of growth. Levels of protein below 7 to 8 percent are definitely inadequate, and optimum performance would generally be obtained at higher protein levels. In contrast, most tropical legumes generally contain from 15 to 18 percent protein, and some as much as 21 percent. Therefore, a practical method of correcting the protein deficiencies of many tropical grass species would be through over-seeding of tropical legumes in these grass pastures.

Similarly, most of these tropical grass species are deficient in certain minerals, particularly phosphorus. Most native grass species, as well as many improved grasses, generally contain less than 0.10 percent phosphorus, which is inadequate to support satisfactory growth and reproduction. High incidence of bone fractures is direct evidence of this deficiency. The tropical legumes have

TABLE 10. **Weight gains of steers grazing on Molasses grass in the eastern plains of Colombia.**

Period	No fertilizer			Phosphorus			Phosphorus + Potassium		
	Stocking rate, animal/ha			Stocking rate, animal/ha			Stocking rate, animal/ha		
	0.44	0.88	1.30	0.44	0.88	1.30	0.44	0.88	1.30
	Per animal kg/day								
Dry	0.156	0.102	0.227	0.016	0.117	0.016	0.024	0.016	0
Rainy	0.408	0.379	0.075[1]	0.498	0.421	0.245[1]	0.399	0.430	–0.043[1]
Year	0.316	0.239	0.162[2]	0.322	0.291	0.113[2]	0.262	0.239	–0.043[2]
	Per hectare kg/351 days								
Dry	8.8	11.4	37.6	0.9	13.1	2.6	1.3	1.8	0
Rainy	39.8	70.9	9.1[1]	48.6	78.8	29.8[1]	38.9	80.5	–5.2[1]
Year	48.6	82.3	46.7[2]	49.5	91.9	32.4[2]	40.2	82.3	–5.2[2]

1 = 94 days, 2 = 222 days.

higher phosphorus levels (0.10-0.20 percent) but still are considered deficient or marginal in meeting minimal requirements. Consequently, a standard recommendation is to provide a phosphorus supplement for cattle grazing pastures in these low fertility soil zones. Research is underway to test the validity of this recommendation.

Calcium content of the grass species ranged from 0.15 to 0.20 percent. However, higher values were encountered in some species during the early vegetative stage. Tropical legumes appear to provide adequate calcium as they contain 0.30 percent or more.

All of the species appear to contain adequate levels of sodium, potassium, magnesium, manganese and zinc. Analyses are currently underway to determine sulphur and trace mineral content.

Digestibility and intake studies

Tropical pasture species are of lower nutritive value than temperate species. In many instances, the low nutritive value appears to be a significant factor limiting animal production, because of low digestibility, low dry matter intake, and a combination of these two factors. Therefore, nutritive value should be taken into account in the selection of more productive tropical forages.

Two trials were conducted in 1972 with mature Para (**Brachiaria mutica**) hay supplemented with the legume **Desmodium distortum.** Because recently published work has demonstrated that varying opportunities for selection between leaves and stems can lead to different estimates of intake of unchaffed low protein forages by cattle, special attention was given to this aspect in these experiments.

In Experiment 1 two levels of chaffed Para grass, 68 and 136 g dry matter/kg body weight$^{.75}$ were offered to sheep, both in the presence and absence of 16 g of **Desmodium distortum.** In Experiment 2, three levels of Para hay were given, 65, 99 and 134 g dry matter/kg body weight$^{.75}$, all with 9 g **Desmodium.** The results of Experiment 1 showed that

Grazing trial on native pasture at Carimagua.

16 g supplementary **Desmodium** gave a significant increase in total feed intake, though the intake of Para hay decreased as a result of the supplement (see Table 11). The increase in total feed intake was accompanied by a rise in the crude protein content of the consumed ration from 6 to 9 percent. A significant increase in feed intake was also obtained as a result of increasing the amount of Para hay offered. This was because of an increase in the consumption of leaves, indicating a strong preference for this part of the forage. This preference is further demonstrated by the fact that the decrease in intake of Para, as a result of supplementary **Desmodium**, was mainly caused by a decrease in stem consumption. The results of Experiment 2 (Table 12) show that, as the level of feeding was increased, total consumption of hay and of leaves increased while the consumption of stems decreased. The combined results of the two experiments demonstrate clearly that sheep, even when offered chaffed forage, select sharply for leaves (Fig. 4) and that the measured level of forage intake may be affected by this. The tentative conclusion is that when total yields of mature Para and other forages are measured, the leaf/stem ratio must be taken into account to determine its value. Secondly, it appears that at all times the opportunity for selection must be taken into account while designing feeding trials to measure the intake characteristic of forages.

The combined results of the two experiments indicate that at both high levels and low levels of feeding of Para hay, 9 g/kg body weight$^{.75}$ supplementary **Desmodium** will be consumed without decreasing intake of Para hay but that at higher levels of supplementation the **Desmodium** will replace part of the Para.

During 1973, CIAT expects material from different species, ecotypes and ac-

cessions to become available in sufficient quantities for nutritive value determination with the use of animals. Nutritive value will be expresed in terms of voluntary intake, digestibility and nitrogen balance.

Cultivated forages

Beef production is generally associated with more extensive farming or ranching operations. However, there is also evidence that beef production may play an important role in intensive agricultural systems as well. This is especially true in the low, hot, humid tropics which probably have the world's greatest potential for forage production and consequently for beef production.

High-yielding forages such as Napier grass or Elephant grass (**Pennisetum purpureum**, Schum.), forage sugar cane, etc., may produce 40 tons or more of dry matter per hectare annually, with a potential animal production of 3,000 to 4,500 kg of beef per hectare. High producing dairy cattle would be even more competitive since they have a much higher production efficiency.

An experiment is in progress to determine: 1) the amount of protein and energy produced by one hectare of Napier grass per year, 2) the maximum amount of beef which can be produced by one hectare of this forage, and 3) the supplements which are necessary to obtain this maximum production.

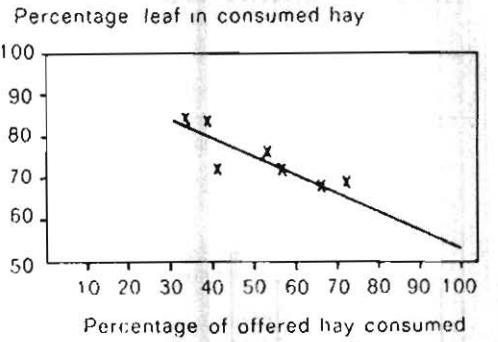


Fig. 4. Effect of proportion of hay which was consumed on percentage leaves in the consumed hay.

ANIMAL HEALTH

The Animal Health program of CIAT is designed to contribute to the eradication or control of the disease factors limiting the production of beef and pork in the tropical lowlands of South America. The aim is to devise specimen preventive medicine regimes which adapt to the varying conditions in these areas and which form part of the total tech-

TABLE 11. **Effect of supplementary** Desmodium **and level of feeding on the intake of Para hay (Experiment 1).**

Level of feeding Para hay Supplementary **Desmodium**	Low —	Low +	High —	High +	Significance of differences Due to level of feeding	 Due to **Desmod.**
Para hay offered	68	68	136	136		
Leaf offered	36	36	72	72		
Stem offered	32	32	64	64		
Total DM consumed	45	55	56	61	0.01	0.025
Desmodium consumed		16		16		
Total hay consumed	45	39	56	45	0.01	0.01
Leaf consumed	31	28	40	38	0.005	—
Stem consumed	14	11	16	7		0.05
% cp in consumed DM	6.1	9.4	6.1	9.1		

All data in DM/kg $W^{.75}$

TABLE 12. **Effect of level of feeding on intake of Para hay with a constant level of** Desmodium **(Experiment 2).**

Feeding systems	Low	Medium	High
Total hay offered	65	99	134
Leaf offered	35	53	72
Stem offered	30	46	62
Total DM consumed	56 [a]	61 [b]	62 [b]
Desmodium consumed	9	9	9
Total hay consumed	47 [a]	52 [b]	53 [b]
Leaf consumed	32 [a]	39 [b]	45 [b]
Stem consumed	15 [a]	13 [ab]	8 [b]

Different letters indicate that differences are significant at P = 0.05.

nology being collated and developed for these commodities.

Relative to beef this is interpreted as, first, determining the disease situation of cattle on traditionally low levels of management; second, identifying and monitoring changes in health status when beef management systems increase the density of cattle, and finally, initiation of research, when existing knowledge of the epidemiology of a disease is inadequate or where control measures are ill-defined or lacking. The program is, therefore, field oriented with the epidemiology and economic control of animal diseases as the prime considerations.

Out of the total program planned, work was started on breeding diseases and the involvement of wildlife in the epidemiology of diseases of cattle. Work continued in collaboration with Texas A&M University on hemoparasitic diseases and their vectors. All activities were carried out in collaboration with the Instituto Colombiano Agropecuario.

Breeding diseases

The necessity of providing cattle free of breeding diseases for the ICA/CIAT beef herd systems project at Carimagua in the Llanos stimulated work in this area. The 438 female stock, from which selection was to be made, were examined for brucellosis and leptospirosis. A small prevalence of brucellosis was detected but no leptospirosis. All 52 bulls on the station were examined for vibriosis and trichomoniasis, with negative results. The bulls to be used in the herd systems experiment will be examined a total of five times before breeding commences.

An additional 251 cattle were examined at a ranch further east of Carimagua where in 1971 and continuing into 1972 there had been serious infertility and abortion problems. Again, no vibriosis, trichomoniasis (0/51), or leptospirosis (0/251), was detected or any significant infection rate for brucellosis. In addition, 80 sera were checked for epidemic bovine abortion, again with negative results. Granular vaginitis was, however, clinically recognized in approximately 90 percent of the cattle in both locations.

Slaughterhouse studies at Villavicencio showed a similar high prevalence of granular vaginitis from three departments of the Llanos. The condition is unlikely to be economically important, but epidemiological studies will continue with the cattle under collaborative ex-

perimentation in Carimagua. Of the 303 cows examined **post mortem** at Villavicencio slaughterhouse, 158 were sampled for trichomoniasis and vibriosis, again with negative results.

The slaughterhouse studies revealed other interesting data. Eighty-eight percent of cattle being presented for slaughter were female and from the 303 female genital tracts examined, 69 percent were found pregnant. A parallel examination of the situation in Bogota revealed that slaughter cattle in the location derived from the Llanos were overwhelmingly male but the examination of 284 additional female genital tracts revealed an 85 percent pregnancy rate. Whatever the reason for the presentation of such a high percentage of pregnant animals for slaughter, infertility did not appear to be a general problem. However, abortions are commonly reported from the Llanos in epidemic form. One such condition associated with abortion is termed "vaca inflada."

Laboratory studies were carried out to determine whether viral agents were associated with abortions. Attempts were made to isolate virus from 169 vaginal or cervical mucous specimens of which 32 were from Carimagua and 137 from the Villavicencio slaughterhouse. Two cell culture systems were used and three isolations were made of apparently the same virus. Identification is pending. In addition, attempts were made to isolate virus from 55 specimens obtained from a total of 13 "vaca inflada" cases; material from 11 having been stored in liquid nitrogen since 1970. No isolations have been made thus far using both fertilized eggs and embryonic bovine kidney cell cultures.

Wildlife studies

A total of 180 animals was trapped at Carimagua, representing 5 mammalian orders and 16 species. All were examined for leptospirosis using two culture media with negative results. Sera have been collected and stored against further examinations, as have collections of their ectoparasites.

Hemoparasitic diseases

The main objective of the hemoparasite project conducted by the Texas A&M hemoparasite group is to develop and improve control measures for babesiosis (**Babesia bigemina, Babesia argentina**), anaplasmosis (**Anaplasma marginale**) and trypanosomiasis (**Trypanosoma vivax**). To accomplish this objective, more data on the immunology, diagnosis, chemoprophylaxis and epidemiology of each of these diseases is required.

Efforts to standardize methods of premunition for the control of babesiosis and anaplasmosis were continued. One field test was completed and two others initiated in which virulent stabilates of **B. bigemina, B. argentina** and **A. marginale** were used to premunize calves from a nonendemic area before transportation to an endemic area near the north coast of Colombia. Weight gains, mortality, complement-fixing antibody titers and other criteria were used to determine the economic benefits of premunization. For comparisons in these field studies, hemoparasites of similar groups of calves were controlled by either chemoprophylaxis or chemotherapy, and compared with a group with no control. In the completed trial, premunization and chemoprophylaxis were the superior methods.

Laboratory studies were continued on aspects of immunology relevant to the improvement or development of field immunization procedures. Attempts to harvest a **B. argentina** antigen from ticks were unsuccessful as were attempts to grow **B. bigemina** in tissue cultures of spleen and lymph node, but work is continuing. Antigenic variation was also studied by comparing four sources of a single strain of **B. bigemina** and comparing different strains of the same organism isolated from Carimagua (the Llanos) and Monteria (Atlantic coast).

Studies on **T. vivax** were related to immunological diagnosis using the indirect fluorescent antibody test (IFAT), serological surveys to identify problem

areas in Colombia, and adaptation of this organism to a rodent host. The IFAT proved to be reliable whether using serum collected by standard means or eluted from dried blood on filter paper. Efforts to adapt **T. vivax** to rodents were not successful.

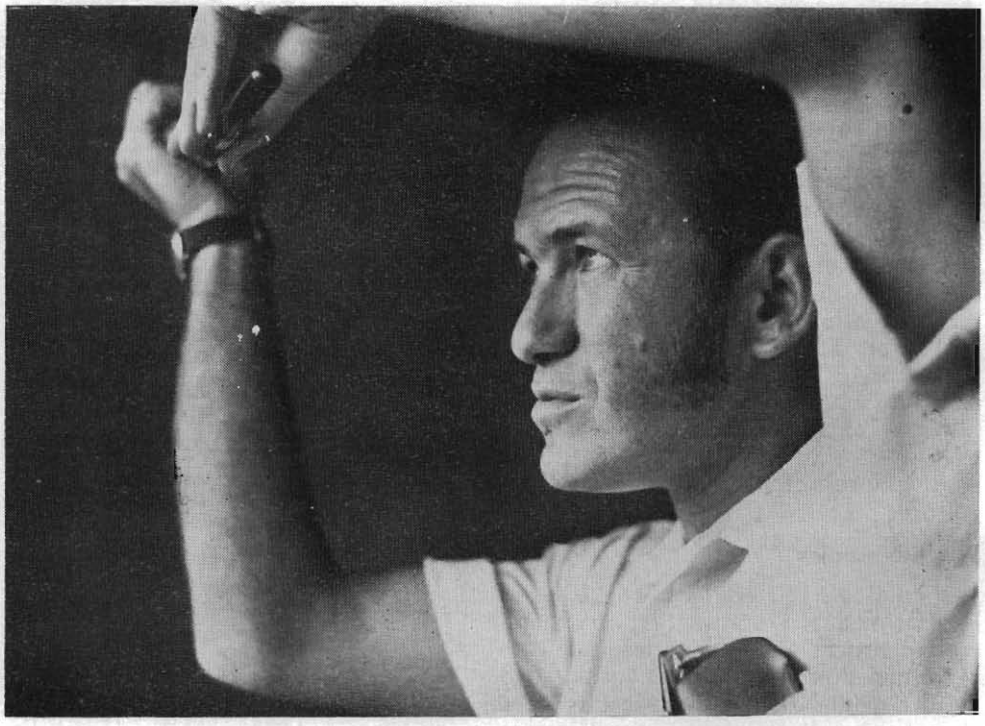
Examination of the cattle in the ICA/CIAT beef herd systems project at Carimagua using the complement fixation test revealed that approximately 80 percent were apparently susceptible to babesiosis and anaplasmosis. The cattle had been purchased from three sources in the Llanos. The presence of such a large number of susceptible animals indicates that a further sampling is required to determine whether epidemics of tick-borne diseases are a potential and serious danger in the development of the cattle industry in this part of Colombia.

Plans for 1973 include initiation of a field trial to compare premunization and chemoprophylaxis of young calves born in an endemic area for the control of babesiosis and anaplasmosis.

ECONOMICS

Major emphasis is placed on: 1) the economics of production inputs, practices and systems, and 2) the characterization of the beef cattle sector in the lowland tropics. Economic analyses of beef cattle experiments are reported under the respective experiments.

Preliminary results of a study of current beef cattle production systems along the north coast of Colombia were reported in the CIAT 1971 Annual Report. In the present report, a more complete summary of the major findings is pre-



An animal nutritionist studies a serum sample.

sented. The primary objective of the study was to make information available on the structure and performance of the beef cattle industry in a major beef cattle producing region of Colombia. CIAT expects similar studies to be carried out in other regions of Latin American lowland tropics. Hopefully, the information generated will be useful in establishing priorities for research and public policy on the production and marketing of beef cattle in Latin America.

Basic data were obtained from a survey carried out among 487 beef cattle producers in the north coast region of Colombia. The farms surveyed were stratified according to farm size with 58 percent of the farms being a size of less than 200 ha, 28 percent having between 200 and 500 ha and 14 percent containing an area of more than 500 ha. Cow-calf operations predominated with fattening alone on only a few farms. Eighty-eight percent of the area on the farms interviewed was in pasture, 6 percent in crops and 6 percent in non-usable lands. Nearly all cattle found on the farms were Zebu.

Table 13 summarizes the economic performance of the farms surveyed. As shown in this table, net returns and payment to occasional costs per ha of pasture were inversely correlated with farm size. A large portion of the revenues originated from milk sales, particularly among the smaller farms. About one-third of total revenues came from the sale of milk among the farms of less than 200 ha while only 13 percent of the revenues came from milk sales among the farms larger than 500 ha.

Table 14 summarizes certain technical coefficients estimated from the sample farms. While the average stocking rate did not vary greatly among size groups, considerable variation was found among regions. The lowest stocking rate (0.9) was found in the Atlantic coast region while the highest (2.4) was found among large farms in the Lower Sinu region. Variation among individual farms, of course, was found to be considerably higher. Interestingly, calving rate decreases as farm size increases.

In addition to the results discussed here, the study analyzes a large number of other factors related to cattle and pasture management, credit, technical assistance, etc. The study makes available a more accurate description and analysis of the beef cattle industry in the region studied than what was previously available and thereby provides the opportunity to support sound decision-making on research and public policy.

An in-depth study of a small number of ranches has been initiated in collaboration with the livestock production training program. A record-keeping system has been established and the trainees collect daily information from each ranch on a number of biological and economic factors. While this type of study is costly as well as lengthy, it is expected to supply valuable and reliable information.

PRODUCTION SYSTEMS

The practical value of a given technological input generally cannot be determined when tested singly, but only when measured within the context of a workable and practical production system that includes many components. Also farm size, availability of funds for recurring and fixed expenses and other factors will influence farm planning and the real value of a production practice or system.

Nonetheless, the basic components of a viable and profitable beef cattle production system are similar whether for the small family farm operation or for the larger more commercialized unit. In the small family farm unit, basic concerns include a subsistence and support base to provide food and shelter for the family. Also, sufficient cash income from beef cattle, other livestock and crops

TABLE 13. **Summary of economic performance of farms under survey (Col. pesos/6 months).**

	Size of farm		
	0-200 ha	200-500 ha	More than 500 ha
Total revenue per farm from sale of cattle	46 827	137,822	418,971
Total revenue per farm from sale of milk	23,472	57,882	62,340
Total revenue from cattle and milk	70,299	195,704	481,311
Total cost except drugs, temporary labor and other occasional expenses	40 661	111,331	292,349
Net returns and payment to occasional costs per ha in pasture	29,738	84,373	188,962
Net returns per ha in pasture	315	290	256

to cover living, educational and farm operational expenses are needed plus a residual cash surplus and/or increased farm inventory to allow further expansion of the farm business. The same basic considerations apply to larger units, i.e., providing an adequate subsistence and support base for ranch personnel and their families, and cash income to meet operational expenses and support expansion.

All CIAT beef cattle research is directed towards developing production techniques and systems that are broadly applicable throughout the lowland tropics in various sizes and types of beef cattle enterprises. Current comprehensive beef cattle production systems research is in progress in the Colombian Llanos at the ICA Carimagua station.

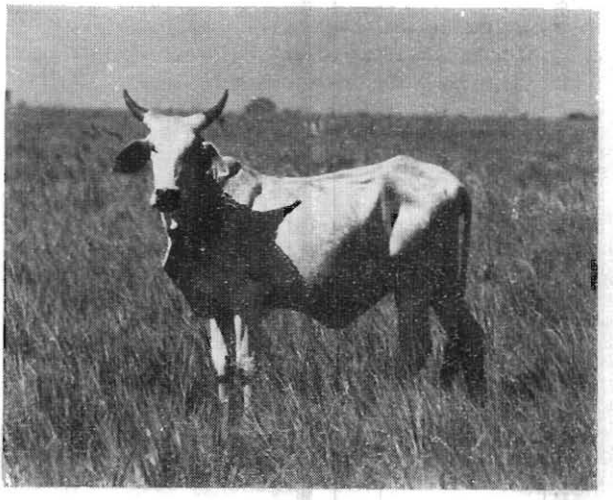
Family farm

Food production

Beans, cowpeas, cassava, rice and corn were screened for acid soil toler-

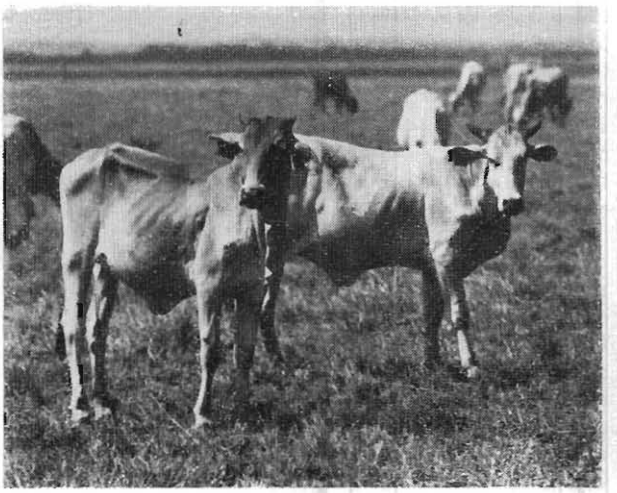
TABLE 14. **Selected technical coefficients estimated on the basis of data collected from sample farms.**

	Size of farm			
	0-200 ha	200-500 ha	More than 500 ha	Weighted average
Stocking rate (animals/ha)	1.5	1.3	1.5	1.5
Cows/ha in pasture	0.6	0.5	0.3	0.5
Liters of milk produced per ha/day	1.0	0.8	0.3	0.9
Annual calving (percentage)	65	58	39	63
Annual mortality rate (percentage)	4.6	4.4	3.4	4.5
Liters of milk produced per cow/day:				
Dry season	2.6	2.5	2.3	2.5
Rainy season	3.1	2.7	2.4	3.0



Herd systems heifer after 122 days of mineral supplementation on native range gained 80 grams daily or almost twice that of the heifers on native range without minerals during the rainy season.

Herd systems heifers after 112 days on Molasses grass pasture with minerals gained 350 grams daily or eight times as much as heifers on native range without minerals during the rainy season.



Herd systems heifers on native range without minerals gained only 45 grams per day over the first four-month period.

ance with promising results as reported in their respective chapters. Other food crops included in fertility or screening trials were peanuts, sorghum and "topocho" (plantain). Peanuts are generally well adapted to acid soils and yield well with reduced lime and fertilizer requirements. The first screening of a limited number of entries for acid soil tolerance is now in progress. The current peanut experiments were all planted for dry season harvest since pod rot is a problem in the rainy season. Peanuts are of interest for direct consumption, cash income, and as a source of high protein meal, a by-product of the edible oil extraction process. Protein is needed to complement the energy sources such as cassava or the cereals in poultry and swine diets.

Windmill and waterers

The "Carimagua windmill" was improved during 1972, and a number of units are now in use, supplying stock water on 2,600 hectares dedicated to grazing and herd management trials. The major change was the addition of a second pumping cylinder in the well and a double-acting bell crank in order to balance the load on the rotor throughout each cycle (rotation). With the single bell crank and one cylinder originally used, the rotor was loaded through only one-half of each cycle, resulting in a large moment of imbalance which induced serious vibration at high rotor speeds. The modified mill functions very smoothly and efficiently to rotor speeds of over 200 rpm.

The rotor and transmission (through the bell crank) are presently being manufactured locally at US$ 95.00 per unit. The cylinders and sucker rods are stock windmill parts. Two three-inch cylinders are being used in the Carimagua wells, set at nine to ten meters depth with adjustable stroke length from 2 to 8 centimeters depending on wind velocity and water depth.

Plaster tanks as described in the 1971 CIAT Annual Report are being successfully used for stock waterers in grazing trials and the herd systems experiment. These tanks are 4 meters in diameter by 0.60 meters in depth, and were built at a contract cost of US$ 90.00 per unit including all labor and materials.

Herd systems

To apply present technology and to simultaneously test new approaches, nine grade Zebu cattle herds were set up at the ICA Carimagua station to compare varying intensity production systems. Variables under investigation include: Molasses grass vs. native pasture; complete mineral supplementation vs. salt; crossbreeding with San Martinero vs. continual backcrossing to Zebu; protein supplementation before vs. during breeding; seasonal vs. continuous breeding; and early vs. normal weaning. Complete data are being taken on production, physiological and disease parameters, including those necessary for economic analysis.

In the first four months of trial, heifers on Molasses grass and minerals gained .35 kg/day which was almost nine times the gain of heifers on native pasture without minerals (.04 kg/day). Those on native pasture with minerals gained .08 kg/day (photos p. 37). Since young females must attain a minimum weight before reaching puberty, observed growth rates indicate that some groups will not reach puberty prior to the beginning of the breeding season in May.

Forage samples have been taken from native and Molasses grass pastures. Native grasses as well as Molasses grass appear to be deficient in phosphorus, and marginal in calcium. Protein content of native grasses appears to be deficient in all stages of growth except perhaps in the first new growth. Protein content of Molasses grass appears marginal.

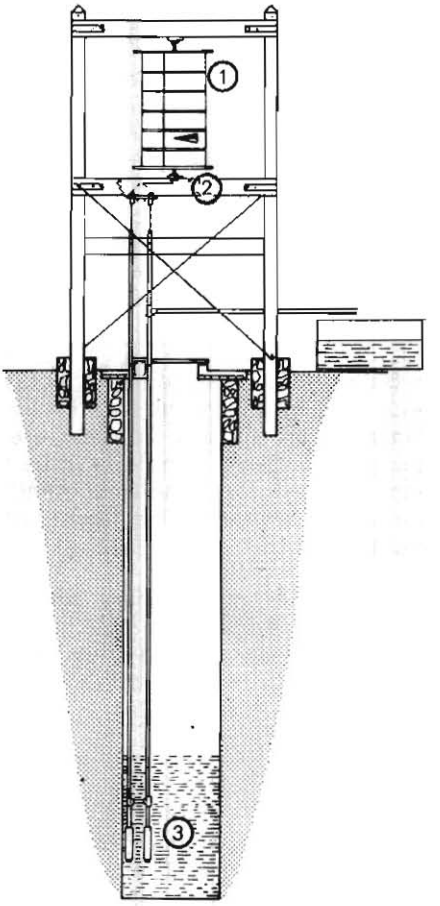
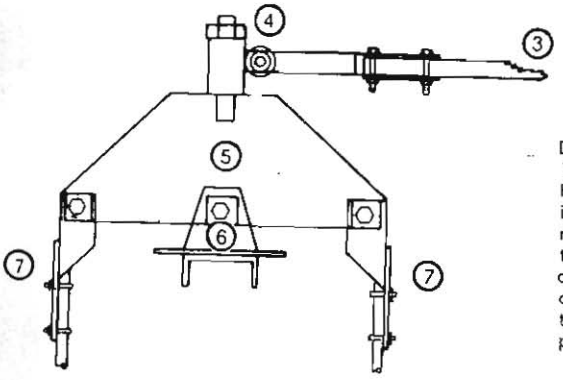


DIAGRAM 1. "Carimagua" windmill mounted on two-legged tower over dug well. Most units in Carimagua are mounted on tripod towers made of pole timbers resistant to rot and termite attack. 1) Savonius rotor made of two 55-gallon drums, split vertically. 2) Transmission mechanism shown in detail in Diagram 2 (below). 3) Standard windmill double check piston pumps mounted below water level on galvanized pipes.



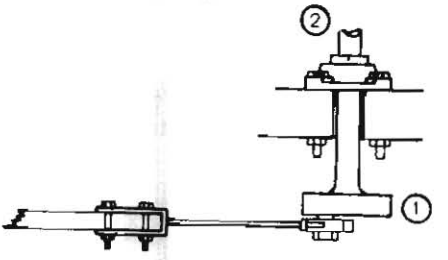


DIAGRAM 2. Detail of transmission mechanism. 1) Eccentric mounted on vertical rotor shaft. 2) Flange mounted, self-aligning ball bearing supporting the wind rotor. 3) Connecting rod (wooden member to facilitate linkage length adjustments in the field). 4) Double articulation attachment of connecting rod to bell crank. 5) Double acting bell crank for converting horizontal displacement to vertical displacement. 6) Mounting bracket (pivot point) for bell crank. 7) Sucker rod attachment brackets.

Blood samples were taken when the animals first arrived in February and again at the beginning of the experiment in July. Serum calcium level (8 mg percent) appears low, while serum phosphorus (> 4.5 mg percent) appears high. These are interesting observations since dietary phosphorus levels were markedly deficient. No phosphorus supplement was supplied during this period. However, similar analyses have been previously reported in the Amazon basin in Brazil.

Blood levels of sodium, potassium and magnesium were within normal ranges. Trace mineral analyses are now being done. Blood samples will be taken and analyzed for mineral content after animals have been on treatment for nine months.

All experimental heifers are free of brucellosis and leptospirosis, and bulls are free of vibriosis and trichomoniasis. The animals will be periodically checked for these diseases.

TRAINING

Ten persons completed training in the beef cattle program. These included five postgraduate interns who received instruction and practical experience in seed multiplication, pasture establishment and management, and pasture evaluation through grazing trials and laboratory analysis. While most of the training was at the CIAT headquarters, field trips were made to the Llanos and to the north coast of Colombia.

Two persons were trained in beef production and management, working closely with senior staff members in establishing the beef cattle systems project in the Llanos. Their training experiences included: the establishment and maintenance of brood cow herds under a controlled research environment, recognition of reproductive diseases, pregnancy diagnosis, establishment of routine herd health and disease prevention programs and development of pasture, water and animal handling facilities.

One intern in beef cattle nutrition was trained in the laboratory technique of nutrient analysis of plant and animal origin.

Two postgraduate interns completed training in the area of soils and microbiology as related to nutrient availability and inoculation of pasture legumes with **Rhizobia.**

One master's degree candidate completed his thesis under the supervision of the animal health staff. He investigated the virus disease Vesicular Stomatitis in cattle. He is presently working in the virology department at the Universidad del Valle, in Cali. Another master's degree candidate will soon complete his thesis research project in pastures and forages utilization.

One research fellow is presently working on a doctoral research project in breeding of pasture grasses. He will complete his doctoral program next year at Cornell University.

Two master's degree students and one doctoral candidate of Texas A&M University have completed research in tropical veterinary medicine related to hemoparasitic diseases in cattle. They have returned to Texas A&M University to complete the requirements for their degrees. A fourth student's program was extended from a master's to a doctoral project and he will continue his research for another year.

One student from Wageningen, the Netherlands, completed his practical training period and conducted a special project as related to chemical composition of native grasses at various stages of growth.

Activities of the Livestock Production Specialist Training Program, which concentrates on but is not limited to beef, are reported in the Training and Communication section of this report.

Learning how to control parasites is a first step in establishing an effective control program on the ranch.

OUTREACH

Outreach activities included visits to Latin American countries to identify trainees, to establish professional and institutional contacts and to collaborate in research and training projects.

Good progress has been made in the collaborative pastures and forages introduction and evaluation project involving pastures and forages programs from Bolivia, Brazil, Colombia, Ecuador, Peru, Venezuela, CIAT and IICA. CIAT maintains a germ plasm bank of promising materials and assumes a principal role in coordinating the evaluation and distribution of these species.

The CIAT beef cattle team provides technical assistance to the INIAP Beef Cattle Program, the Forage Legume Program of the University of the West Indies in the Caribbean area, and to other agencies as assistance is requested.

Papers were presented at meetings of the American Society of Agronomy, American Society of Animal Science, Latin American Association of Soil Science, Venezuelan Society for the Advancement of Science, Latin American Society of Rhizobiologists and at the Feed Processing Symposium held at the University of Florida. A member of the CIAT beef cattle team participated in a seminar on tropical soils.

Pastures and forages staff presented lectures in short courses sponsored by the Peruvian Society of Pastures and Forages, and at a Regional Meeting of Pastures and Forages Programs in the Andean zone.

The soils microbiology program sends monthly a listing of scientific papers on soil microbiology to Latin American soil microbiologists. **Rhizobium** cultures from the soil microbiology group are available for most legume species, and have been forwarded to teaching and research centers in many countries in South America and Asia.

Cassava Production Systems

IN 1972 the Cassava Program began to build up its full strength. At the same time multiplication of planting material went ahead rapidly so that new trials could be planted.

The germ plasm bank, consisting of some 2,000 collections, has now been freed of bacteria using a green shoot propagation method. This promises to give a simple system to rapidly propagate clean seed for release.

A new disease that causes superelongation was reported and is being investigated. It has been found in most areas of Colombia where cassava is grown extensively, but as yet has not been reported elsewhere.

Preliminary observations suggest that under dry conditions thrips may be a serious pest; however, there are lines that show a quite striking resistance to the insects.

On the experimental farm, acceptable yields in the region of 30 tons per hectare can be obtained in less than one year with little problem. The search for higher yielding types is intensifying.

The optimal plant spacings and fertilizer levels are being investigated. The optimal spacing on CIAT soils appears to be between 2 and 10 thousand plants per hectare. Above this level yield drops off rapidly. On relatively fertile soil we have gained no response to N, P, or K. However, on more impoverished soil fertilizer response will certainly occur.

Studies on the losses caused by weeds and ways of preventing these are underway. A large number of herbicides have been tested on a small scale. Some of these appear particularly promising

The development of simple on-the-farm techniques of fresh root storage is progressing rapidly and the possibilities of using a soil and straw storage unit appear good. Progress has also been made in the description of the drying characteristics of cassava so that simple solar driers can be designed in the future.

A study of world production figures suggests that cassava production is increasing at a rate equal to the population increase. Productivity per hectare has not, however, increased. Efforts are being made to study the alternative markets of cassava so that an excess, if produced, can be used.

The collection of cassava literature continues and work on a comprehensive bibliography is well advanced.

The Cassava Program has not been in a position to train many new people; however, as our knowledge and experience increases, we are taking more trainees from different countries so as to extend knowledge of this neglected but important crop.

PLANT PHYSIOLOGY

Growth cycle of the plant

CMC 84, a bitter variety, was planted in the ICA farm at Palmira at 1 x 1 m spacing, using 25 cm stem cuttings inclined to the horizontal. Missing plants were replaced by transplants one month after the original planting. At planting 100 kg/ha of N, P_2O_5 and K_2O were applied. A severe hailstorm 3½ months after planting severely defoliated the plants and damaged some of the apical buds.

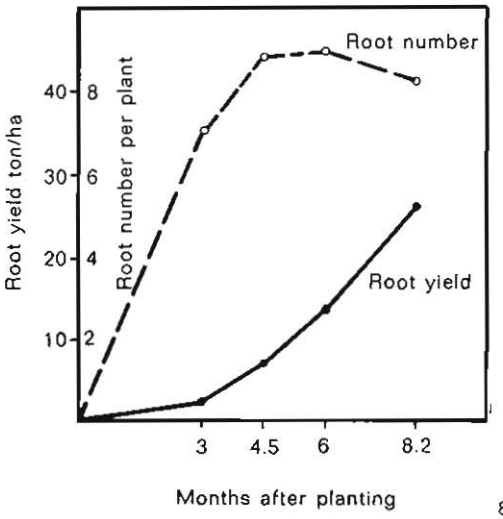


Fig. 1. Yield and root number of variety CMC 84.

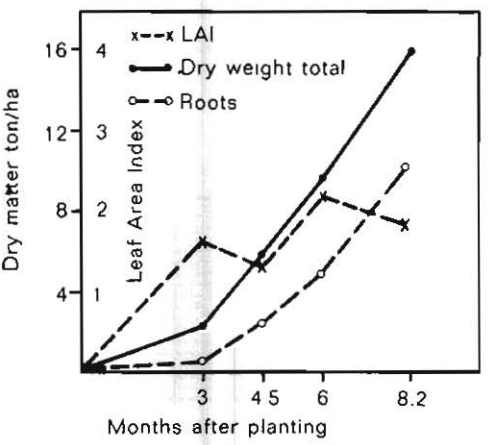


Fig 3. Dry matter production of whole plant and roots and Leaf Area Index (LAI) in variety CMC 84.

Fresh weight root yield after three months was less than 3 ton/ha but thereafter increased rapidly to 26 ton/ha after 8.2 months (Fig. 1). The percentage dry matter of the roots increased during the same period from 18 to 38 percent (Fig. 2). Consequently, the yield of root dry matter increased from less than 0.5 ton/ha to 10 ton/ha after 8.2 months (Fig. 3). This is equivalent to an annual production of more than 14 ton/ha of root dry matter.

The increase in yield from 3 to 8.2 months was not due to a large increase in the number of swollen roots but due to an increase in their size (Fig. 1).

The crop growth rate (CGR) during the first three months was extremely low (19 $g.m^{-2}$ wk^{-1}), while leaf area was being formed (Fig. 4). Later, the CGR stabilized at about 60 $g.m^{-2}wk^{-1}$ which is small compared with the crop growth rates achieved by many crops. The level

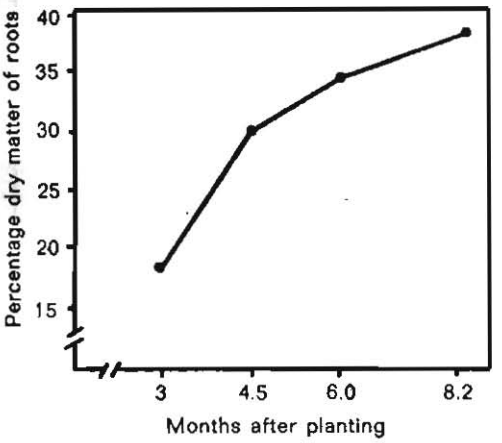


Fig. 2. Dry matter contents of roots of variety CMC 84.

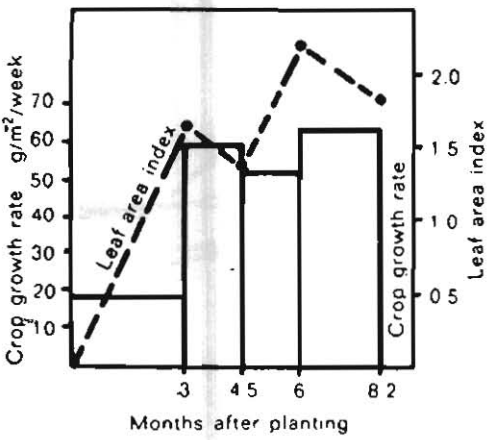


Fig. 4. Crop growth rate and leaf area index of variety CMC 84.

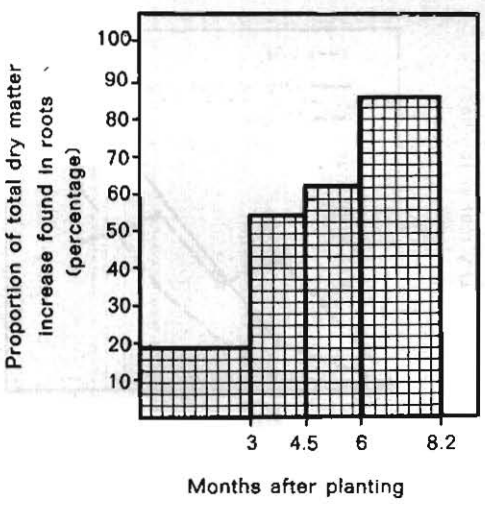


Fig 5. Distribution of dry matter in variety CMC 84.

of CGR may be low for two reasons, first, the low leaf area index (1.4-2.2) during the period and second, no attempt was made to assess the dry matter lost in the leaf fall, which might have been considerable.

Figure 5 shows the proportion of total dry matter that accumulated in the roots during the period between each harvest. During the final two months the plant diverted 86 percent of its dry matter production into the roots, demonstrating a remarkably efficient partition of dry matter.

The nitrogen content of the various plant parts is shown in Fig. 6. The nitrogen content of the leaves decreased from 4.7 percent at three months to about 3.5 percent at six months when apparently it became stable. The percentage of nitrogen in the roots decreased steadily from 0.95 to 0.40 percent at 8.2 months. The nitrogen content of the

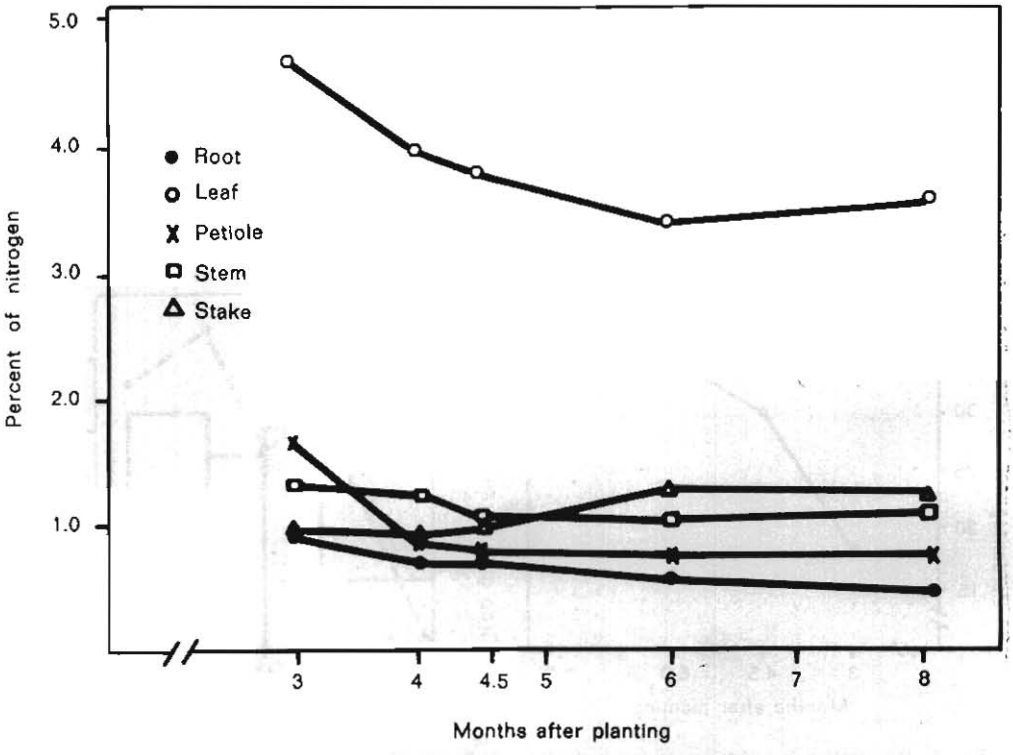


Fig. 6. Nitrogen content of various plant parts.

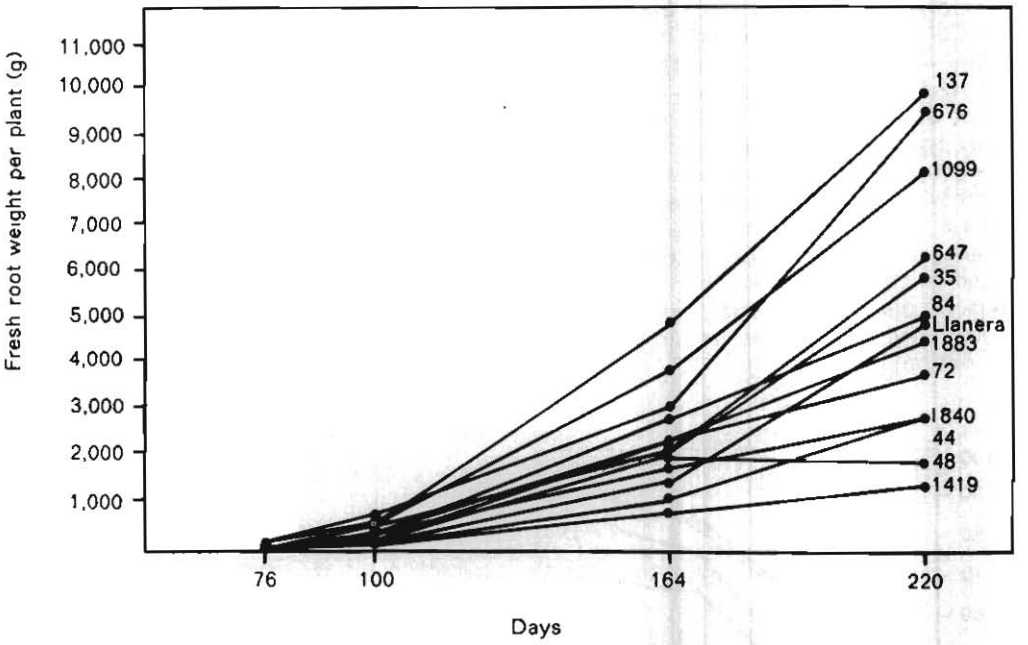


Fig. 7. Increase in fresh root weight of 13 cultivars of cassava grown as spaced plants (numbers refer to M Col material).

stems (without leaves and petioles) stayed almost constant at about 1 percent after 4.5 months.

Transplanted plants had thinner roots and yielded less than regular plants, suggesting that this method of replacing missing plants is not effective.

Precocity

In the germ plasm bank there are many varieties whose local name is "Tempranita" meaning early. Fifteen varieties* (ten of them called Tempranita) were planted as spaced plants (2 x 2 m) and havested at 76, 100, 164 and 220 days to investigate variation in the time the plant begins to store carbohydrates in the roots, a process called root bulking. By 76 days none of the varieties had produced a substantial root yield but by 100 days most of the varieties had started to produce root yield (Fig. 7). None of the varieties showed a delay in onset of root bulking followed by a rapid rate of bulking.

* Two collections were later lost because of severe bacterial infection.

These results suggest that there is little if any difference in the onset of root bulking; however, some varieties appear capable of producing acceptable yields after seven months' growth. Strain M Col 137 will be propagated and tested further.

Germination of cuttings under field conditions

Stem cuttings 15 cm long of CMC 71 and CMC 64 were planted vertically, inclined, horizontally and inverted (with the axillary buds pointing downward). Germination was assessed by counting the number of buds that broke the soil surface. The soil conditions were dry during the measurement period. The vertically planted cuttings emerged most rapidly in both varieties (Fig. 8), while those planted upside down emerged most slowly. In CMC 71 the final germination for all treatments was similar. In CMC 64 the inverted cuttings never reached the level of the other treatments. This experiment is being continued to give final yield figures.

Two-node cuttings of Llanera and M Col 375 were planted in the field. They were either treated with 4,000 ppm of NAA or IBA absorbed on talc or were kept as untreated controls. Germination was more than 90 percent in all treatments, and no improvement in germination was associated with the treatments. These results suggest that, under good management, two-node cuttings can be used in the field when there is a shortage of planting material, and that hormonal treatment does not improve germination.

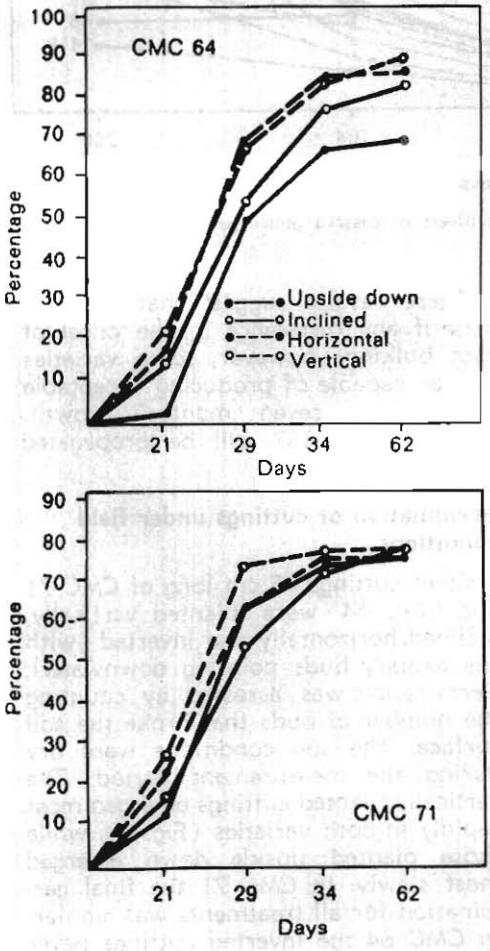


Fig. 8. Germination of stakes planted with four placements in varieties CMC 64 and CMC 71.

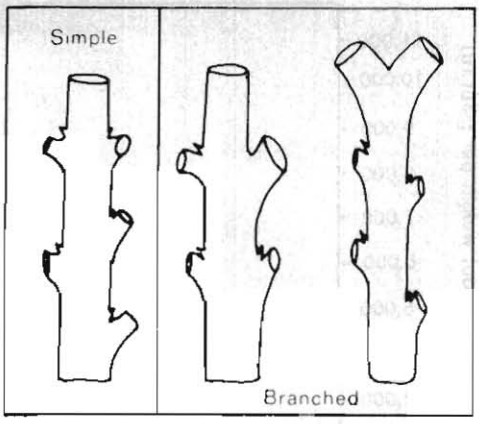


Fig. 9. Simple and branched stakes of cassava.

Farmers have frequently planted cuttings which previously bore side branches. Simple and branched cuttings of CMC 84, Llanera and M Col 1080 were cut to 25 cm. The branched cuttings were as shown in Fig. 9. Germination was slower in branched cuttings than in simple ones (Table 1). Hence, wherever possible, simple cuttings should be planted.

TABLE 1. **Germination of branched and unbranched stakes as percentage.**

Variety	Days after planting	Simple	Branched
M Col 1080	16	71	38
	21	97	86
	25	100	87
CMC 84	16	80	62
	21	97	92
	25	99	97
Llanera	16	47	16
	21	73	51
	25	83	61
Mean	16	66	39
	21	89	76
	25	94	87

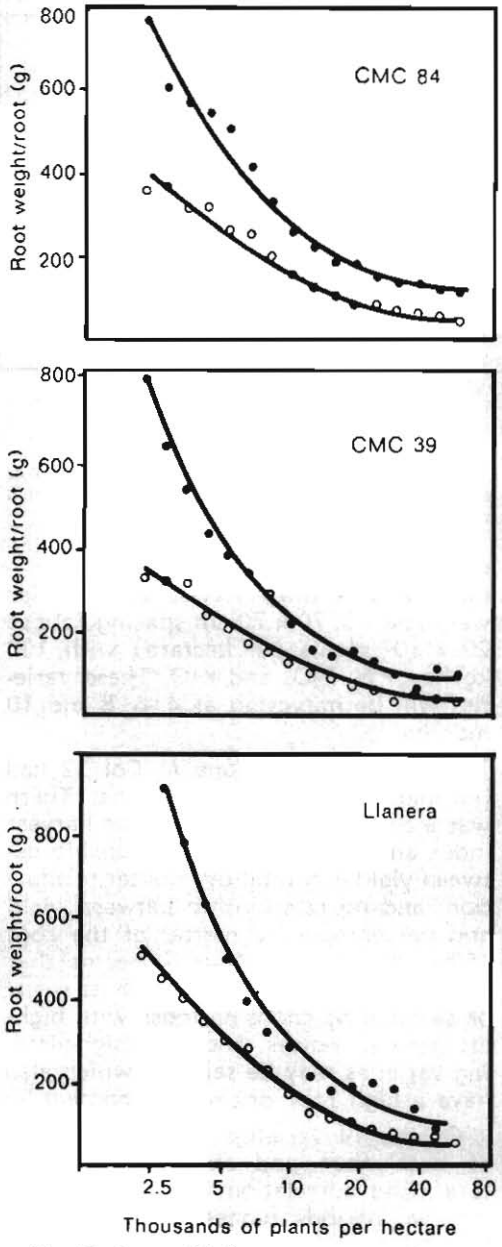


Fig. 15. Root weight/root at seven months (0-0) and five months (●-●).

the total dry matter found in the roots showed a marked decrease as plant population increased (Fig. 17).

The relationship between crop growth rate and leaf area index between 3-5 months was extremely variable unless an allowance was made for the weight of leaves and petioles lost through senescense. This was estimated by multiplying the mean leaf loss per week by the mean leaf weight from 3-7 months. In CMC 84, CGR increased with leaf area index (LAI) up to about four giving a CGR of about 150 $g/m^{-2}/wk^{-1}$ while in CMC 39 CGR increased with increasing LAI up to about three and reached a plateau value of about 110 $g/m^{-2}/wk^{-1}$ (Fig. 18).

These results are somewhat surprising in view of the light transmission data collected for these three varieties (Fig. 19). Light transmission was measured on a clear day at midday when the plants were approximately three months old. CMC 39 absorbed less light per unit LAI than CMC 84, suggesting greater light penetration. This should in turn lead to a greater critical LAI but does not. The reason is not clear but may be related to the leaf angle changes reported above.

Preliminary varietal observation

The work previously described suggests that growth rate of the cassava plant increases as plant population increases but that the proportion of this growth found in the roots decreases in some varieties as plant population increases. To select for high-yielding va-

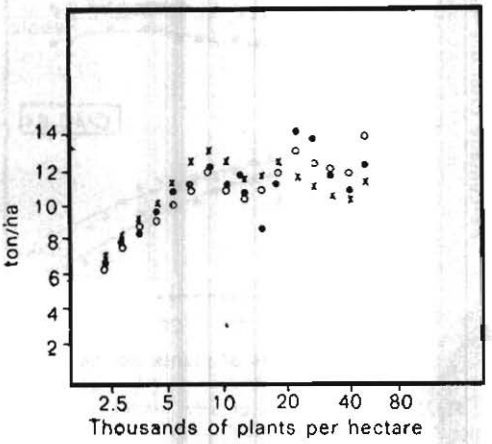


Fig. 16. Total dry matter production after five months of three varieties.

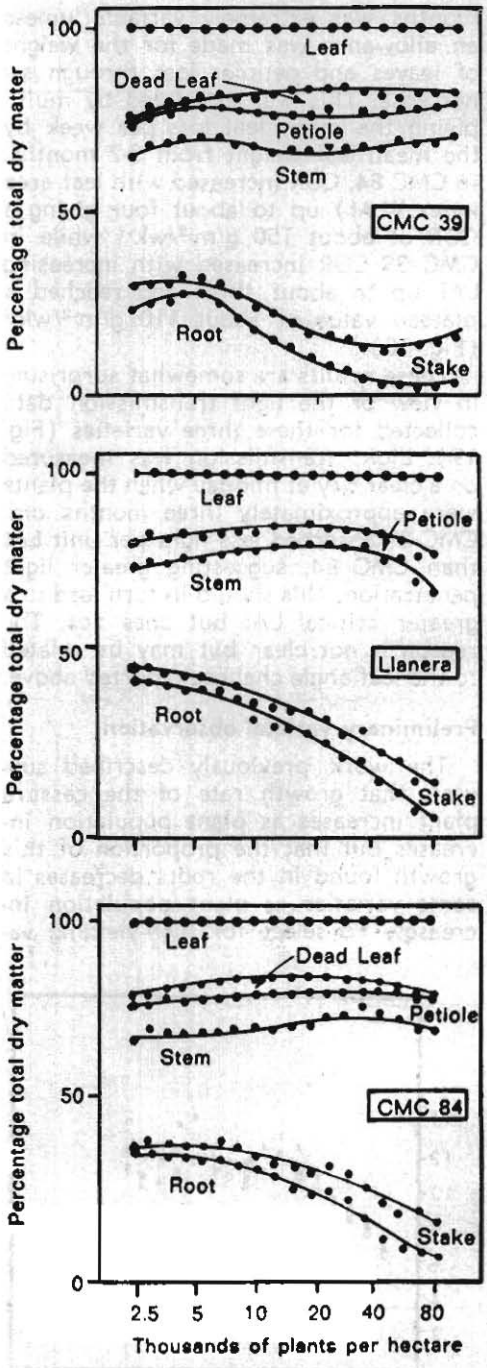


Fig. 17. Distribution of dry matter after five months at different plant populations (varieties CMC 84, CMC 39 and Llanera).

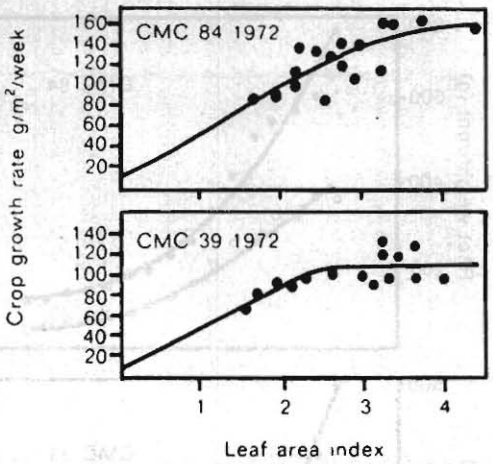


Fig. 18. Crop growth rate (three-five months) as a function of leaf area index making an estimation of dry weight loss due to leaf fall.

rieties that can withstand high populations and fertility levels, 28 varieties were sown at 70 x 70 cm spacing (about 20 x 10^3 plants per hectare) with 100 kg/ha of N, P_2O_5 and K_2O. These varieties will be harvested at 4, 6, 8 and 10 months.

After 120 days, clone M Col 22 had the highest yield, 12.4 ton/ha. There was a close relationship between harvest index and yield, a slight relationship between yield and total dry matter production, and no relationship between yield and percentage dry matter of the root (Figs. 20, 21, 22). Thus, it seems that higher yielding varieties may most easily be selected by choosing those with highest harvest indices, and that high-yielding varieties may be selected which also have a high root dry matter content.

Of the 14 varieties so far harvested at both four and six months, there is a close correlation between yield at the two periods suggesting that 1) the breeder can use young plants to select for final yield and 2) there is little difference in the time at which varieties start bulking (Fig. 23).

So far, there does not appear to be any obviously superior plant type. The three highest yielding varieties at four months of age were, respectively, short,

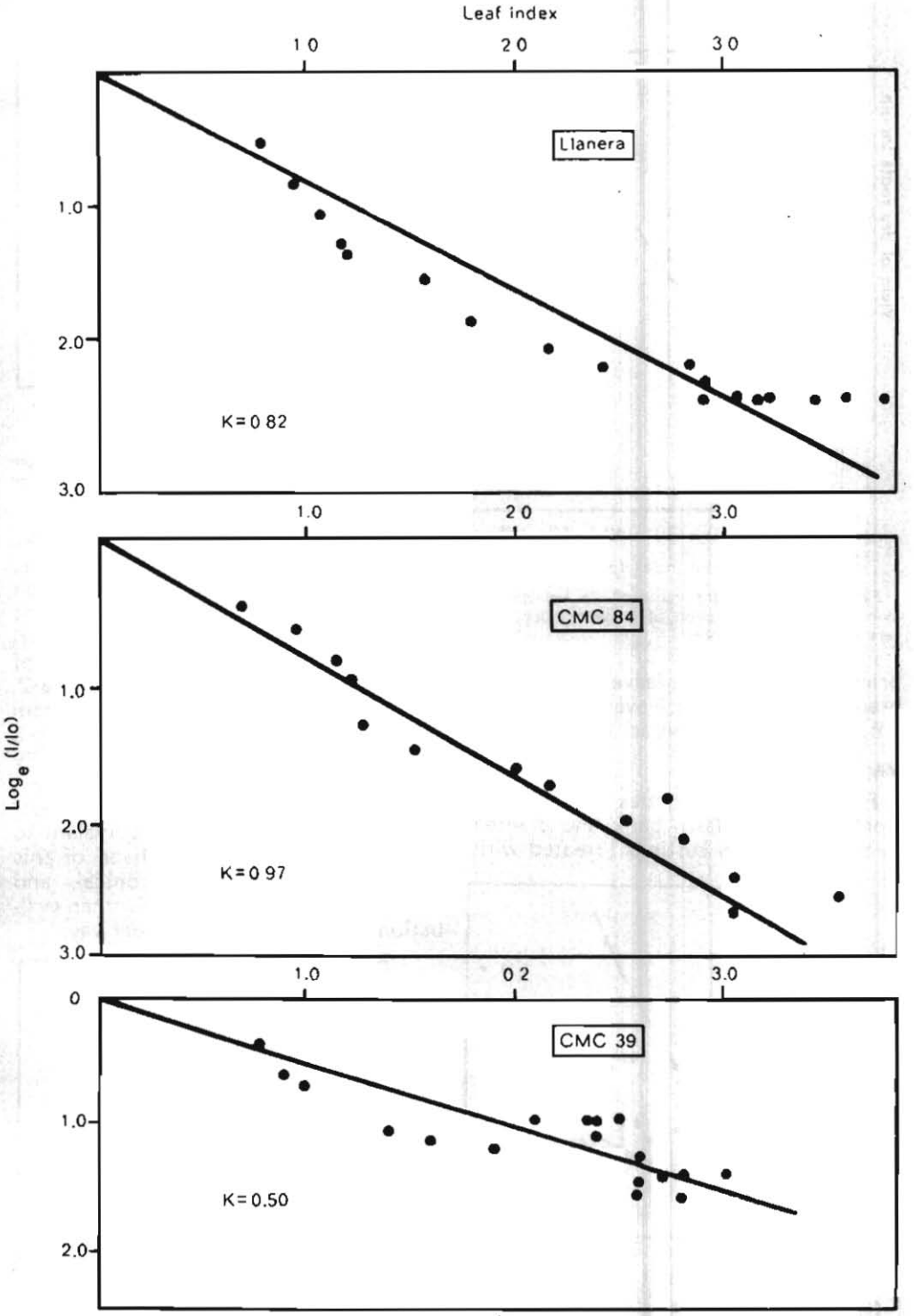


Fig. 19. Relation between radiation at the bottom of the canopy and leaf area index in CMC 84, CMC 39 and Llanera varieties.

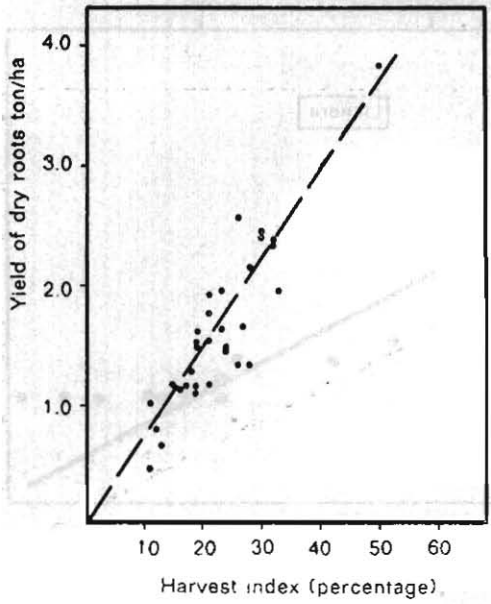


Fig. 20 Yield of dry roots of 28 varieties at four months as a function of harvest index (Llanera repeated four times).

branched with fine leaves; tall, unbranched with broad leaves; and medium, branched with broad leaves.

Varietal selection

Five promising varieties were chosen from the germ plasm bank and planted as two-node stem cuttings (treated with

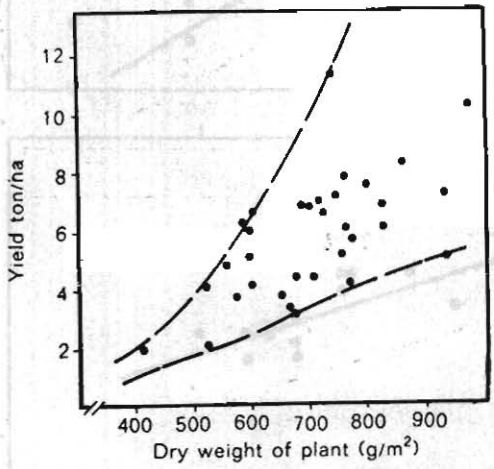


Fig. 21. Yield as related to dry matter production of 28 varieties at four months (Llanera repeated four times).

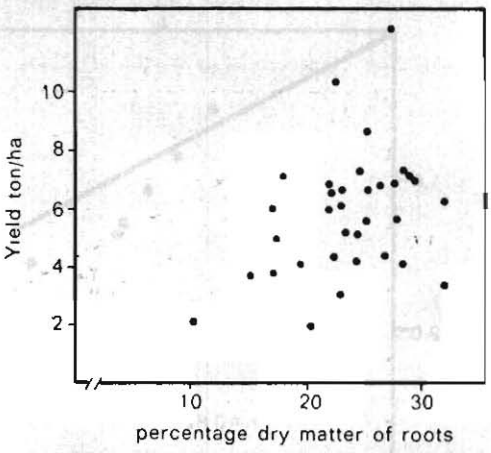


Fig. 22. Scatter diagram of yield and dry matter content of the root at four months of 28 varieties (Llanera repeated four times).

NAA) in red acid soil and three weeks later transplanted at 1 x 1 m spacing for planting material multiplication plots. Ten plants, all surrounded by at least two border rows, were harvested 7½ months after planting. Details of the yield data are presented in Table 2. Clone M Col 22, a short variety from the north coast of Colombia, showed a remarkable yield potential producing 29 ton/ha after 7 ½ months which is equivalent to 46.0 ton/ha/yr. The production of root dry matter is equivalent to 17.8 ton/ha/yr. The root shape of this variety is short, almost conical, and hence it is easy to harvest. Further evaluation of this variety is underway.

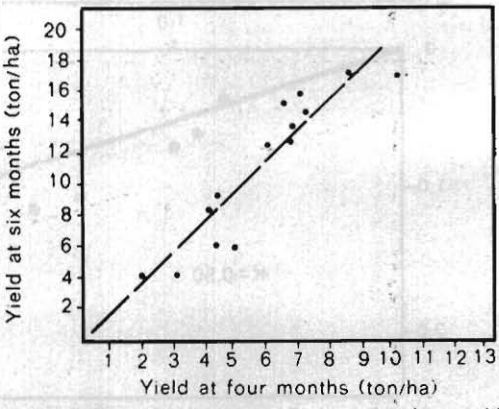


Fig. 23. Yield at six months as related to yield at four months of 14 varieties.

TABLE 2. **Yield and root characters of five varieties 7½ months after planting.**

Variety	Yield ton/ha (fresh material)	Yield ton/ha dry matter	Percent moisture in root	Root number per plant	Weight per root (kg)
M Panama 64	17	4.9	29	16	0.11
M Col 65	22	8.2	38	21	0.10
M Col 645	14	4.5	32	14	0.10
M Col 463	14	4.5	32	13	0.11
M Col 22	29	11.2	39	18	0.16
Mean	19	6.7	34	16.4	0.12

PROPAGATION

Techniques for propagation, storage of cuttings and the influence of agronomic practice on cutting production are being studied.*

Small size propagules

Cassava research is repeatedly slowed because of the lack of planting material; hence, rapid propagation methods are being studied. Although preliminary investigations demonstrated that cuttings with a single node from mature stems can be rooted under greenhouse conditions, poor results were obtained under field conditions. Two-node cuttings have given highly acceptable rates of emergence and establishment and are now used to plant in the field, where, because of a shortage of planting material, normal size stakes, i.e., 15-25 cm, are not available.

For success, two-node cuttings need to be of excellent quality and must be grown under intensive care during the rooting and establishment phase. Well-prepared soil is required as well as attention to both drainage and irrigation. Protection must be provided against pests which damage the buds and emerging shoots. Crickets, centipedes and cutworms are problems at CIAT but have been controlled by applying Aldrin powder to the soil surface, around the young shoots.

A bamboo lath house has facilitated experimental evaluation of rooting media, methods of planting and the effects of rooting hormones and fungicides on emergence and establishment of two-node cuttings.

Rooting media

Six locally available rooting media with pH's ranging from 4.9-7.3 and organic matter from 0.6-5.2 percent were prepared as raised beds. Soils were kept constantly at or near field capacity. The CIAT soil, probably because of its higher water retention properties, supported a more rapid rate of emergence of two-node cuttings. Differences in final establishment values were not statistically significant. Figure 24 shows the rates of emergence from the two most contrasting media. All the other treatments fell between the two curves.

Rooting method

Rate of emergence with two-node cassava cuttings was more rapid with inclined cuttings than with those horizontally placed. Vertically placed stakes produced intermediate results (Fig. 25). The initial advantage of inclined or vertical over horizontally placed cuttings is rapidly lost, and all planting methods yield similar establishment percentages after four weeks.

* These studies are being made by Mr. Douglas W. Wholey, a research fellow supported by CIAT for his doctoral thesis as well as a graduate student at the University of the West Indies.

Yield trials and multiplication plots.

Spraying of a yield trial field.

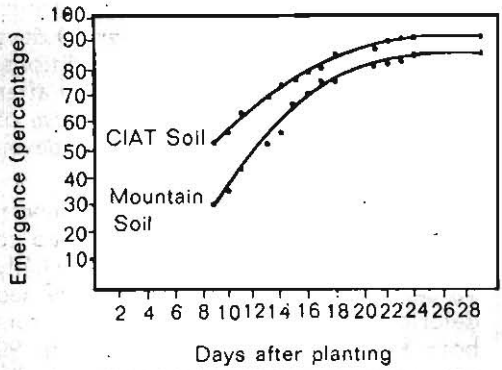


Fig. 24. Rate of emergence from two rooting media.

Rooting green cuttings

Two-node cuttings of Llanera were prepared from green stems with leaves still attached. An experiment to compare the rooting of this type of cutting with mature wood cuttings showed that more than 90 percent success can be achieved with both types of cuttings, but diseases result in the subsequent loss of a high proportion of these green stem cuttings.

Disease problems in propagation

Three weeks after planting, symptoms of "damping off" began to appear on the green stem cuttings. Diseased cuttings were examined by the pathologist and isolates of **Fusarium** sp., **Sclerotinium** sp., **Pythium** sp. and **Alternaria** sp.

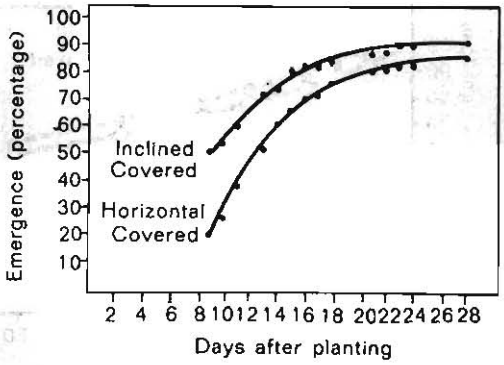


Fig. 25. Rate of emergence of horizontal and inclined cuttings.

obtained. However, while these fungi are known to be common soil-borne pathogens, the causal relationship between these fungi and the reported disease of cassava cuttings has not been established.

Dipping green cuttings in 1 percent Manzate D. fungicide increased the rate of establishment from 51 to 72 percent and may be recommended as a protective measure against soil-borne pathogens.

Rooting hormones

The application of naphthalene acetic acid (4,000 ppm absorbed on talc) to the base of each cutting increased rate of rooting in green cuttings (Fig. 26) and the number of roots produced from the callus at the basal cut in both types of cuttings.

Rapid propagation methods

Preliminary studies demonstrate that high humidity plays an important role in both shoot and root production. Mature stem cuttings rooted horizontally in vermiculite under high humidity produce shoots from a high proportion of the nodal buds. The excised shoots may be rooted allowing further shoot production from the same nodal growing point. Six mature stem cuttings (a total of 60 nodes) produced more than 180 shoots in 42 days using this technique, a threefold increase over single node propagation methods. The methods of maximizing production and rooting of these green shoot cuttings, using mist propagation are being studied further.

Tip cuttings

Green shoot cuttings produced under high humidity and shoot tips from young plants grown in the field can be sucessfully rooted. This technique has enabled the production of plants free from disease organisms harbored in the old cutting piece.

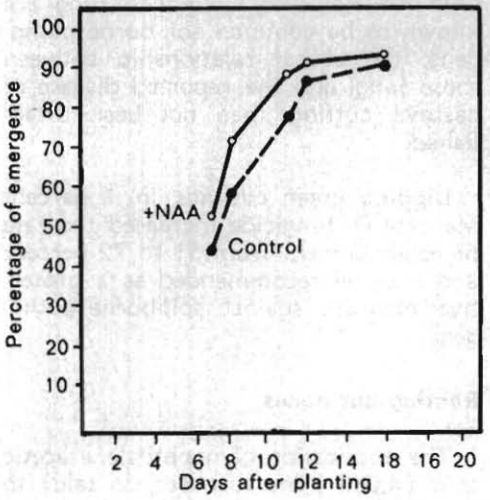


Fig. 26. The effect of NAA on rate of emergence of green stem cuttings.

A humidity chamber has been designed and constructed enabling large scale rooting of tip cuttings for pathological screening. Under constant mist it has been found that fine gravel provides a better rooting medium than a mixture of sand and gravel or sand alone.

Storage of cuttings

Long cuttings (i.e. greater than 1 m) have been kept for up to three months with the central portion viable; however, short cuttings (less than 25 cm) rapidly deteriorate.

Groups of cuttings with paraffin waxed ends were compared with non-waxed cuttings in an experiment to investigate moisture loss (Fig. 27). Waxing did not reduce loss of fresh weight at the 5 percent level of probability.

Storage position did not affect overall storage behavior; however, it was noted that bud breaking was delayed when cuttings were stored in the inverted position, and a larger proportion of nodal buds developed into shoots in horizontally stored cuttings than in either vertical or inverted cuttings.

The moisture content of the cuttings fell from 67 to 46 percent after 50 days storage in a room at ambient conditions. Waxed cuttings deteriorated rapidly after the twentieth day in storage because of a fungus (**Glomerella** sp.) which developed under the wax.

After 50 days 48 percent by length of the waxed planting material had to be discarded because of the fungus. Only 16 percent of the unwaxed material had deteriorated. Non-diseased cuttings from both treatments showed more than 90 percent germination, there being no differences between treatments. Waxing is not presently recommended as a stake storage method.

PATHOLOGY

Bacterial Blight

This disease has been associated with considerable losses in several Latin American countries and Africa. In Colombia, epidemics have been recorded in the most important cassava-growing areas, and the disease has been disseminated widely during the past few years.

Symptoms of the disease are characterized by spotting and blight of leaf tissues; wilting, die-back and exudation of gum on young shoots and vascular discoloration and necrosis in mature, old stem portions and roots of susceptible cultivars.

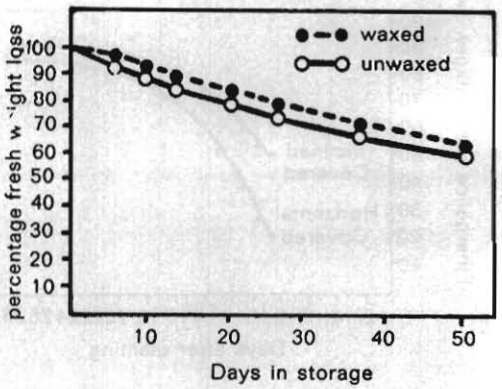


Fig. 27. Effect of waxing cuttings on fresh weight loss.

These symptoms are similar to those reportedly induced by **Xanthomonas manihotis** (Arthaud-Berthet) Starr, but studies of the morphology, physiology, serology, and phage susceptibility of the bacterium isolated in Colombia, Brazil, and Venezuela suggest that it is sufficiently different from **X. manihotis** to be considered a distinct strain or even species. The cassava blight bacterium (CBB) also differs from **X. manihotis** in pathogenicity. Using serological and phage-typing methods CBB can also be distinguished from species of **Erwinia, Pseudomonas** and **Xanthomonas.** A **Bdellovibrio** sp. causes lysis specifically on CBB and can be used to distinguish CBB from other plant pathogenic bacteria.

Isolates of CBB from distinct geographical areas could not be grouped on the basis of differences in virulence or biochemical characteristics. Using serological and physiological characteristics, different groups could be identified, but these differences could not be correlated with geographical origin.

Cassava leaves may be inoculated by spraying with aqueous suspensions of CBB cells and maintaining the plants under high moisture conditions for six hours after inoculation (Table 3). Addition of Tween 20 (0.01 percent) increased the effectiveness of this procedure (Table 4). Wounding epidermal tissues of leaves and stems with infested implements also proved an effective method of inoculation (Table 5).

CBB normally penetrates the host via stomatal openings and wounds and eventually invades the vascular tissues and results in extensive breakdown of parenchymatous tissue in leaves and young shoots. In mature, highly lignified old stems or roots, the bacteria remain restricted to the vascular tissue. CBB moves systematically into vascular strands of roots of susceptible cultivars; in susceptible cultivars, bacteria have been found in roots four months after leaf spray inoculations.

TABLE 3. **Effect of moist chamber exposure period on infection of cassava plants following inoculation with CBB at 10^9 cells/ml (isolate 5.27L).**

Moist chamber period (hr) incubation	Number of leaf spots/leaf[1] 25 days after inoculation
0	0.3
6	14.2
12	15.6
24	17.4
36	16.7
48	15.5

[1] The data are averages of three trials; each treatment consisted of 10 leaves from three plants.

Results of controlled inoculations in the field suggest that dissemination in cassava plantations is the result of rain splashing. A high correlation between total rainfall and the number of infected plants in successive 15-day periods has been recorded (Figs. 28 and 29). Studies on dissemination from an inoculum source to plants located at different distances from it revealed that spreading only occurred over 10 m during a 60-day period. No infection was observed on plants growing 15 m or more distance from the inoculum source (Table 6). During this 60-day period, the total rainfall was 207 mm and dissemination was observed to occur in the directions of the prevailing winds.

TABLE 4. **Effectiveness of various materials added to a bacterial suspension (3 x 10^9 cells/ml of CBB isolate 5.27L) used as inoculum sprayed on cassava plants.**

Bacterial suspension in distilled water plus:	Mean number of spots*
None	6.0
Carborundum (0.1 g/liter)	5.6
Agar (0.2%)	3.3
Gelatin (0.2%)	3.0
Dextrose (0.2%)	2.3
Tween 20 (0.01%)	10.0

* Number of spots on each lobe from each of six leaves from five plants. Averages of three replications. Readings were taken 25 days after inoculation.

LSD 0.5 percent = 1.8
LSD 0.1 percent = 2.6

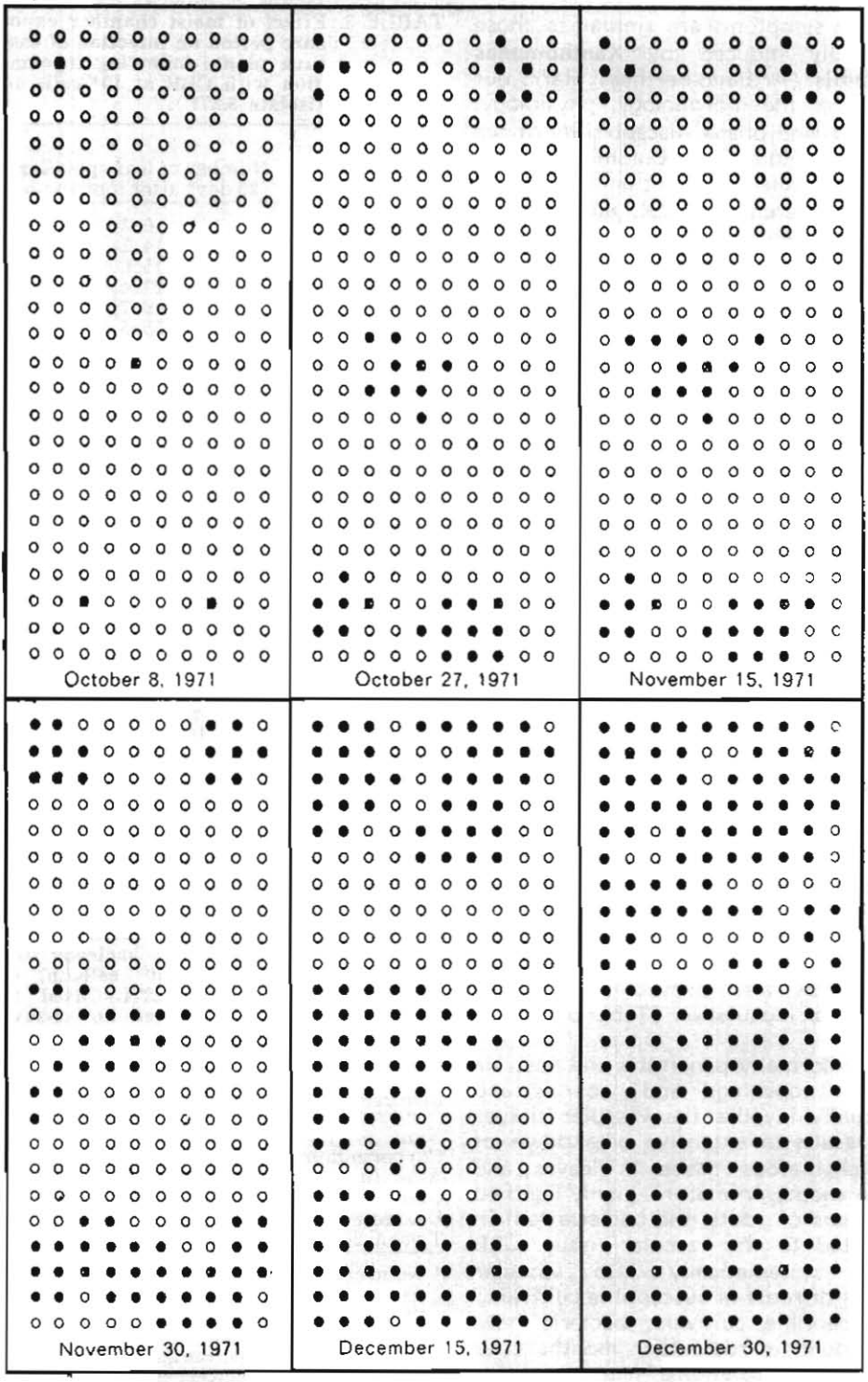


Fig. 28. Spread of CBB in the field from initial sources of infection in experiments conducted between September 15 and December 31, 1971. Results were recorded as number and position of plants infected at 15-day periods after inoculation.

TABLE 5. **Infection by CBB following wounding of epidermal tissues of leaves and stems of cassava cultivar M Col 1 with infested microneedles or infested knives.**

Tissue wounded	Number inoculated*	Number infested**	%
Leaves	56	54	97
Young stems	27	27	100
Mature stems	32	9	28
Old stems	82	9	11

* Average of three replications.

** Disease readings were recorded three months after inoculation as leaf spots (on leaves) or wilting (on stems). Control plants inoculated with distilled water showed no infection.

Dissemination from one area to another can occur by means of infected vegetative planting material (top photo p. 66). This method of dissemination is particularly important in Colombia because there is no restriction in the movement of vegetative cuttings throughout the country or any certification scheme for cassava.

Dissemination of CBB by means of infested tools is also probable. A high incidence of infection has been shown to result from cuts made with infested knives (machetes) (Table 6). This method of dissemination may be most important during harvesting when planting material stakes are obtained. These operations require extensive cutting in localized areas. Because wounds are portals of entry for CBB, dissemination may be caused by man, animals and insects, and may also occur during environmental conditions that lead to extensive wounding.

The following methods for controlling this disease have been investigated:

1) Field experiments in which infected plants were heavily pruned showed that only 6 percent of those pruned had symptoms on the young sprouts one month after pruning but after two months an additional 2-3 percent showed disease symptoms. Each of these infected plants was uprooted and destroyed, and by six months after pruning no additional diseased plants had appeared. The control unpruned plot was 100 percent infected.

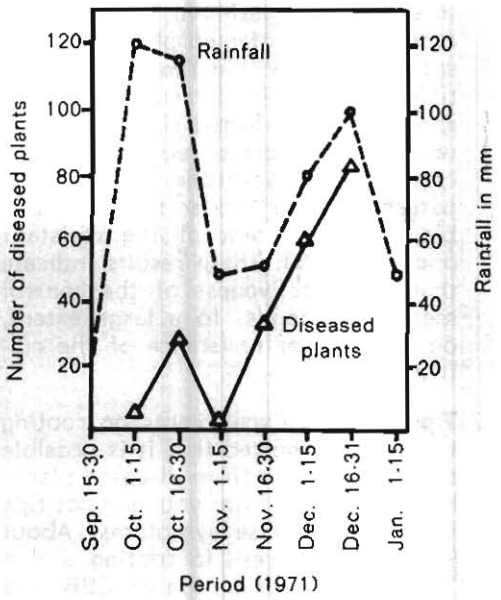


Fig. 29. Spread of CBB in the field from initial sources of infection in experiments conducted between September 15 and December 31, 1971. Relation of total rainfall (mm) and number of diseased plants in each 15-day period.

TABLE 6. **Dissemination of CBB on cassava plants located at different distances from the inoculum source.**

Distance (m) from inoculum source	Number of plants/plot	Number of infected plants per plot**	%
5	20*	12	60
10	20	5	25
15	20	0	0
20	20	0	0

* Number of plants in each of four plots, each plot located on one side of an inoculum source.

** Incidence of disease 60 days after planting.

In a further experiment, pruning was carried out in infected plots of different cultivars. Within the very susceptible cultivars, 76 percent of the new sprouts were infected six months after pruning as compared with 36 percent of the susceptible cultivars, 16 percent of the moderately susceptible, and 9 percent of the resistant ones (Fig. 30). These results indicate that the effectiveness of the control methods depends, to a large extent, on the level of resistance of the cultivar.

2) **Tip indexing.** Experiments on rooting tip cuttings showed that it is possible to eradicate CBB from diseased plants by propagating from young shoot tips free from disease symptoms. About 95 percent success in rooting and a 100 percent elimination of CBB was obtained when young cuttings were planted in fine gravel and in small waxed paper pots. Rooting cuttings were kept in a humidity chamber under mist produced from an electric humidifier at 25-33ºC. After 12 to 15 days rooted tip cuttings were transplanted into sterile soil and maintained in a greenhouse for two months before transplanting to the field.

To eradicate CBB from CIAT's cassava collection, about 80 percent (of the 2,200 clones) have been indexed by this method.

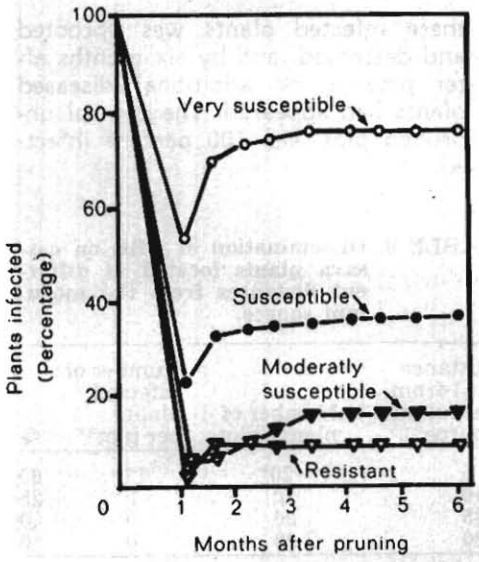


Fig 30. Effect of pruning infected cultivars having different levels of resistance to CBB. Plants were pruned six months after they were spray-inoculated with a bacterial suspension (10^9 cells/ml) of isolate 4.26L.

3) **Varietal resistance.** The response of 1,400 cassava cultivars to CBB has been determined using artificial inoculations with several isolates of the pathogen collected in Colombia. Disease indices of the 21 most resistant cultivars are presented in Table 7. Of these, M Col 647 and M Col 667 were the most resistant. Even those cultivars listed here as susceptible (M Col 282, M Col 707 and M Col 803) had few leaf spots per leaf as compared with the susceptible control cultivar Popayan.

Generally, the performance of cassava cultivars in the field appears to be well correlated with the resistance ranking calculated from die-back wilting, gum exudation and leaf spotting indices obtained following artificial inoculation. In general, leaf spotting alone appeared to be as good an index of resistance as all the other characteristics combined, but the resistant cultivars M Col 647 and M Col 667 had a relatively high number of leaf spots per leaf. These spots remained small, suggesting a hypersensitive response.

While other control methods based on knowledge of the epidemiology of the disease are being investigated, the use of clean planting material and resistant cultivars are the best known methods for practical control of bacterial blight.

Superelongation disease of cassava

A new disease of cassava has been found inducing epidemics in several cassava growing areas of Colombia. The

TABLE 7. **Disease severity indices of 21 cassava cultivars 30 days after spraying and stem inoculation with CBB isolate 4.26L (10^9 cell/ml).**

Cassava cultivar	Disease indices				Total index	Number of leaf spots/leaf	General evaluation*
	Die-back	Wilting	Gum exudation	Leaf spot			
M Col 282	15	15	15	20	65	4.0	SS
M Col 350	11	10	10	17	48	6.6	MS
M Col 353	8	8	10	15	41	10.1	MS
M Col 558	10	11	10	20	51	3.8	MS
M Col 642	0	6	0	15	21	3.1	RR
M Col 647	0	5	0	5	10	20.2	HR
M Col 667	5	5	0	5	15	11.0	HR
M Col 707	17	15	15	25	72	5.0	SS
M Col 800	10	13	10	20	53	5.2	MS
M Col 803	15	17	15	20	67	4.0	SS
M Col 808	0	7	5	15	27	4.4	RR
M Col 853	13	15	10	20	58	5.8	MS
M Col 866	11	10	15	20	56	8.5	MS
M Col 952	10	10	10	25	55	6.4	MS
M Col 1060	10	11	10	20	51	5.4	MS
M Col 1073	5	8	5	15	33	2.4	RR
M Col 1079	5	7	5	15	32	4.2	RR
M Col 1080	6	10	10	15	41	5.6	MS
M Col 1137	10	10	10	20	50	5.8	MS
M Col 1155	5	9	5	20	39	3.0	RR
M Col 1184	6	5	5	20	36	8.4	RR
Popayan (CK)	25	25	25	25	100	139.3	VS

* VS = Very susceptible, SS = susceptible, MS = moderately susceptible, HR = highly resistant, RR = resistant.

disease is characteristically recognized by an exaggerated elongation of the internodes of young stems of infected plants. As a consequence, the stems become thin and weak and are considerably taller than those of healthy plants. The youngest part of stems, petioles of young leaves and leaf midribs are frequently distorted, resulting in stem, petiole and leaf deformation. Frequently, leaflets are not completely developed and leaf lamina not fully expanded.

Portions of the epidermis of young stems show, on occasions, scratching damage which is characteristic of the damage known to be inflicted by thrips. However, the epidermis of infected stems commonly bear cankers of different sizes usually located on the youngest and the least lignified parts of the stem. Mature stem parts look normal, but they are generally brittle. These symptoms vary according to cultivar from mild to severe distortion, elongation and leaf deformation. These general symptoms have not previously been reported in the literature on cassava diseases.

A fungus has been found to be associated with the stem cankers usually observed on the infected plants. The relationship of this fungus to superelongation disease is being studied.

Dissemination of CBB by infected vegetative "seed." Left: healthy sprout from a healthy stem cutting. Right: diseased sprout from an infected stem cutting.

Plant affected by Cercospora leaf spot.

Cercospora leaf spot

Three **Cercospora** spp. (**C. caribea, C. henningsii,** and **Cercospora** sp.) have been found inducing leaf spots in most of the cassava-growing areas of Colombia. Their incidence and relative importance varied according to the environmental conditions prevailing in the areas as well as the susceptibility of the growing cultivars.

As a preliminary necessity to the screening of varieties for resistance to **Cercospora** spp., studies have been undertaken on methods of inducing artificial cultures to sporulate and on inoculation techniques.

The different **Cercospora** species differ in their growth rates on different media. None of the species sporulated well when incubated in the dark. Sporulation of **C. caribea** and **C. henningsii** was enhanced by periodic one-hour exposures to black-light or by continuous exposure to flourescent light.

A good infection (3-5 spots per leaf) has been obtained with spray inoculations of spore suspension of **C. henningsii.** Inoculated plants were kept in a moist chamber for 48 hours at 28°C following inoculation and disease symptoms appeared 10 to 12 days after inoculation.

Soft rot of cassava roots

A **Phytophtora** sp. has been isolated from roots with severe soft rot and also from seedlings showing severe damping-off symptoms. The soft rot disease was reported by the Federacion Nacional de Cafeteros, with losses up to 80 percent on certain plantations. Observations indicate that the disease is associated with wet soil conditions either in poorly drained areas or near drainage canals. A similar condition was experienced on the CIAT farm in mid-1971 when some areas under cassava cultivation became waterlogged because of excessive rainfall.

Present studies indicate that the isolated **Phytophthora** sp. is similar to the fungus (**P. drechsleri**) reported to cause a similar disease in Brazil. A **Fusarium** species was also isolated from a number of rooting roots. The role of this fungus in the epidemiology of this disease is also being investigated.

Phyllosticta leaf spotting

This disease has been found predominantly in high altitude areas of Colombia (more than 1,000 m). Infection results in severe leaf spotting, defoliation and die-back, with a subsequent decrease in yield. Spots are characterized by the presence of concentric rings on the necrosed areas and tiny brown dots which are the fruiting structures (Picnidia) of this fungus.

Successful isolation from diseased plant tissues is relatively simple, but spore production by the fungus in artificial culture is only induced by incubation under continuous flourescent light.

Powdery mildew leaf spot

This disease has been found to be present in most of the cassava-growing areas of Latin America. Its incidence is particularly important during the dry season when the pathogen attacks mature and fully expanded leaves, inducing yellowish spots but rarely necrosis.

Field observations and evaluations of about 2,200 cassava cultivars of CIAT's cassava collection have revealed a good source of varietal resistance. About 220 cultivars were rated as resistant and 1,350 as susceptible.

Gloeosporium disease

This pathogen appears only to attack young leaflets and shoots inducing blight and die-back. The occurrence and severity of this disease appear to be closely related to air moisture conditions. Artificial inoculation (by spraying aqueous spore suspension - 10^5 spores/ml) was only successful when plants were kept for 60 hours at 100 percent relative humidity.

Other diseases

An **Armillariella** sp. has been found to be associated with a stem-base and root rot of mature cassava plants.

Isolates of **Sclerotium** sp., **Sclerotinia** sp., **Pythium** sp., and **Fusarium** sp. have been obtained from young rooted cuttings which showed symptoms of damping-off during propagation experiments.

ENTOMOLOGY

Shoot fly

Nineteen varieties were screened for resistance to shoot fly (**Silba pendula**) at 20, 40 and 60 days after planting using natural populations in the field. Damage was estimated by counting the percentage of the total shoot number that had been attacked by the shoot fly. None of the varieties had a high level of resistance, but the level of damage after 60 days varied between 25-78 percent showing that there are differences in susceptibility. Young plants showed little damage, and it is suggested that plants should not be screened at less than 60 days.

Observations on more than 5,000 larvae of **Silba** spp. in different stages of development did not identify any parasites that could be used for control.

To screen varieties for resistance to **Silba** spp. under controlled conditions, it is necessary to breed flies artificially. Promising results have been obtained using a diet containing ground cassava roots, yeast, sorbic acid and ascorbic acid. Larvae collected in the field have been succesfully grown on this diet.

Thrips

Thirty varieties were planted in the field and were rated by eye for resistance to thrips. At the same time, the number of thrips per shoot was counted. There was no relationship between the two methods because some other insects (especially spider mites) can cause damage similar to that by thrips.

Several varieties had no thrips, suggesting that there is a high level of resistance to be exploited.

Horn Worm

Natural parasitism of the eggs of **Erynnis ello** by **Trichogramma** spp. produce good biological control under most conditions. When this control breaks down, applications of arsenic insecticides (5-6 lbs/ha of lead arsenate) give good control. These substances should not be used when the leaves are to be eaten by animals or humans.

Vatiga Manihotae (Hemiptera: Tingidae)

These lace bugs can produce symptoms similar to those produced by the spider mite. It oviposits in the leaf tissue itself and because of its feeding habits is considered to be a possible virus vector.

SOILS

Acid soil tolerance

One hundred and thirty eight cultivars from ICA were screened on plots having 0, 0.5, 2 and 6 ton/ha of lime. The effect of lime on the pH and aluminum levels is shown in Fig. 31. The soil is extremely infertile (Table 8).

TABLE 8. **Soil characteristics of a Carimagua soil used to compare ICA cultivars of cassava.**

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

* P.C. = permanent charge or CEC at native pH.

The entire field was seriously affected by superelongation and bacteriosis. However, in the first three months the plants were not seriously affected by diseases and the following observations were made:

Most varieties showed visual response to lime up to 2 ton ha.

Some cultivars appeared similar at 0, 0.5 and 2 ton ha of lime.

Many varieties were adversely affected by 6 ton/ha lime, probably because of induced micronutrient deficiences.

After eight months the plots were harvested. The yield figures are indications of varietal difference, not a measure of possible yields to be obtained on a large scale. Eight varieties yielded more than 1.2 kg/m^2 at 0, 0.5 and 2 ton/ha. The maximum yield was 2.6 kg/m^2 in CMC 172 at 0.5 ton/ha lime and was also among the highest yielding clones at 0 and 2 ton/ha lime. CMC 143 and 110 were among the best varieties in all treatments. These results suggest that many cultivars of cassava are extremely resistant to acid soils and potentially important in these areas.

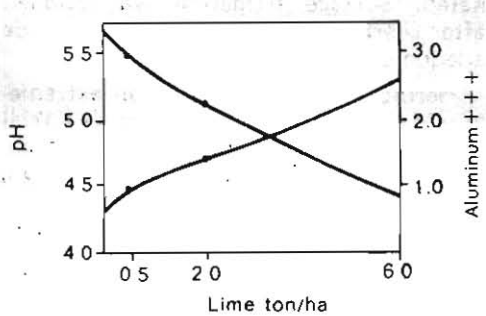


Fig. 31. Effects of lime on pH and aluminum levels in a Carimagua soil in which several ICA cassava cultivars were compared. Aluminum levels are in terms of Al+++ meq/100 gm.

In two other trials there was marked visual response to phosphorus, nitrogen and potassium.

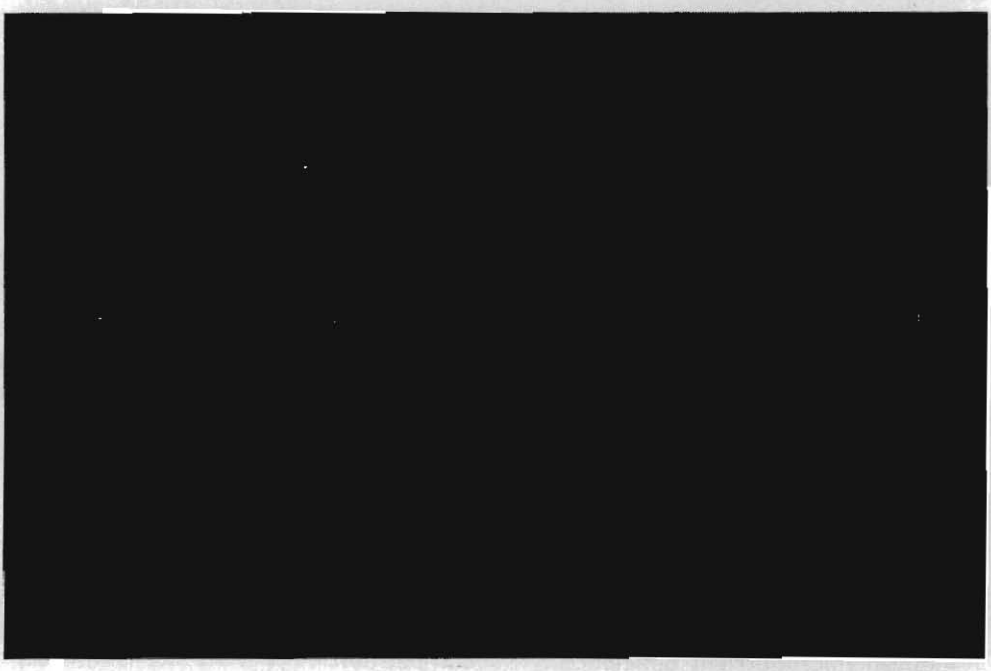
WEED CONTROL

Research objectives in weed control were to determine the safe compounds and recommended rates for cassava, and to determine the critical period of weed competition.

Selectivity of herbicides

A herbicide selectivity trial was done at CIAT where soils are relatively heavy. The results, consequently, are valid only for soils equally as heavy and cannot be transferred to lighter soil areas without an initial screening test. Three rates were used for the 27 herbicides tested: the recommended one for other crops on similar soils, twice that and quadruple the recommended rate. Thus, it was possible to determine not only which chemicals are selective but also what is their margin of selectivity.

Two special conditions exist for cassava planting which are not common in other crops and these also were taken into consideration. Normally, a pre-emergence herbicide is applied to the soil after the crop has been planted. Sometimes cassava is planted leaving a portion of the seed piece exposed and a herbicide application would bring the product into direct contact with the seed piece. On the other hand, if the herbicide is applied before planting, the seed



Ways of controlling weeds in cassava with herbicides are being studied in experimental plots at CIAT and under typical farm conditions.

piece is pushed through treated soil, also bringing it into direct herbicide contact. To determine which system caused the least toxicity, half of each plot was planted before the herbicide application (leaving part of the seed piece exposed), and the other half of the plot planted after application.

The practice of ridging before planting also presents a problem. Several excellent herbicides are only effective if soil-incorporated after being applied. If ridges are formed after such chemicals have been incorporated, the product is accumulated within the ridge and the furrows are left with little or no product. Applying and incorporating after the ridges have been made is impossible without damaging the ridges. Thus, if such chemicals are to be used, ridging may have to be eliminated.

To study the possible interaction between ridging and herbicide toxicity, half of each plot was ridged after application while the other half was planted directly in non-ridged soil. The variety used in these tests was CMC 64 and it was planted in rows 66 cm wide with 50 cm between plants. Observations were made at 30, 45, 60, 90 and 110 days, after which time the trial was terminated. Surface irrigation was applied after herbicide application to provide adequate soil moisture.

Herbicides which showed an extremely wide range of selectivity in this trial were (Tables 9, 10, 11): Linuron, Norea, Fluometuron, Chlorbromuron, Diuron, Fluorodifen, Nitrofen, Pronamide and Nitralin. Even at four times the recommended rate, only slight or initial injury was observed for a few of these products, the majority being completely selective.

Those herbicides which were selective only at the recommended rates were: Ametryne, Prometryne, Terbutryne and

TABLE 9. **Injury ratings in cassava at 30, 45, 60, 90 and 110 days for the pre-plant incorporated herbicides.**

	Herbicide	Rate kg a.i./ha	Injury rating*				
			30	45	60	90	110 days
1.	Butylate	3.0	2.0	1.2	2.2	0.5	0.0
2.	Butylate	6.0	3.0	2.8	4.5	4.8	4.0
3.	Butylate	12.0	3.5	2.8	6.0	6.5	5.0
4.	Vernolate	3.0	2.5	1.2	3.0	3.5	3.0
5.	Vernolate	6.0	4.5	2.0	5.5	4.2	3.8
6.	Vernolate	12.0	7.8	9.0	9.0	7.2	7.5
7.	EPTC	3.0	3.0	1.0	3.5	2.5	3.0
8.	EPTC	6.0	3.2	2.2	4.0	4.2	4.0
9.	EPTC	12.0	6.2	8.2	7.8	6.8	5.0
10.	Trifluralin	1.5	2.2	0.8	1.0	0.0	0.0
11.	Trifluralin	3.0	4.5	0.8	2.0	0.0	0.0
12.	Trifluralin	6.0	6.0	2.0	3.0	0.8	0.0
13.	Nitralin	1.5	1.2	0.8	0.2	0.0	0.0
14.	Nitralin	3.0	0.2	0.8	0.8	0.0	0.0
15.	Nitralin	6.0	1.0	0.8	1.8	0.0	0.0
16.	Control	—	1.0	0.5	1.5	0.0	0.0

* 0 = No injury; 10 = complete kill.

Butylate, and the ones which were phytotoxic at the recommended rate were: Atrazine, Bromacil, Karbutilate, Vernolate and EPTC. In general, the herbicides of the triazine, carbamate and uracil families presented the greatest injury to the cassava plant. No differences were found between planting either before or after pre-emergence herbicide application or between ridging and non-ridging for the pre-plant incorporated herbicides (Table 10). It appears that the pre-emergence application can be made either before or after planting and that there is no increased injury when ridges are made after applying preplant incorporated chemicals.

Critical competition period

Because of cassava's slow initial growth and traditionally wide plant spacing, it is thought to be susceptible to early weed competition. Once the foliage has "closed," that is, formed a complete ground cover, weed control

TABLE 10. **Plant injury at 90 days and percent reduction in germination at 30 and 90 days, when planting either before or after pre-emergence herbicide application, and when planting with or without ridges for the pre-plant incorporated products (average for all treatments).**

	Planting method	Injury rating* at 90 days	Germination reduction** (percentage)	
			30 days	90 days
1.	**Pre-emergence**			
	a. Before applying	2.7	6.0	12.3
	b. After applying	3.0	5.0	14.5
2.	**Pre-plant incorporated**			
	a. With ridges	2.8	22.2	7.9
	b. Without ridges	2.4	24.6	13.0

* 0 = No injury; 10 = complete kill
** With respect to the control

TABLE 11. **Injury ratings in cassava at 30, 45, 60, 90 and 110 days for pre-emergence herbicides.**

	Herbicide	Rate kg a.i./ha	Injury rating*				
			30	45	60	90	110 days
1.	Linuron	1.5	1.0	1.0	1.5	0.0	0.0
2.	Linuron	3.0	1.0	1.0	2.5	0.0	0.0
3.	Linuron	6.0	1.2	1.0	3.5	1.8	2.5
4.	Norea	2.5	1.2	0.2	0.0	0.0	0.5
5.	Norea	5.0	1.2	0.8	0.8	0.0	0.5
6.	Norea	10.0	1.5	1.2	2.8	2.5	0.0
7.	Fluorodifen	3.0	1.2	0.5	1.8	0.0	0.0
8.	Fluorodifen	6.0	1.5	0.8	1.8	0.0	0.0
9.	Fluorodifen	12.0	2.8	0.2	1.0	1.0	1.5
10.	DNBP	1.5	1.0	0.2	0.2	0.0	0.0
11.	DNBP	3.0	2.0	0.2	0.5	0.0	0.0
12.	DNBP	6.0	1.5	0.8	1.5	0.0	0.0
13.	Pronamide	1.5	1.0	1.2	1.5	0.0	0.0
14.	Pronamide	3.0	1.5	0.8	1.2	0.0	0.0
15.	Pronamide	6.0	2.5	1.5	2.2	1.0	0.0
16.	Methazole	2.0	1.8	1.5	1.8	0.0	0.0
17.	Methazole	4.0	1.0	1.0	1.0	0.0	0.0
18.	Methazole	8.0	1.5	1.2	2.0	1.0	0.0
19.	Nitrofen	3.0	1.0	0.8	1.0	0.0	0.0
20.	Nitrofen	6.0	1.8	1.2	1.5	0.0	0.0
21.	Nitrofen	12.0	1.0	1.0	1.8	0.0	1.0
22.	Butachlor	2.0	1.8	1.0	2.0	0.0	0.0
23.	Butachlor	4.0	1.5	1.2	1.5	0.0	0.0
24.	Butachlor	8.0	1.8	0.8	0.5	0.0	0.0
25.	Atrazine	2.0	1.8	1.5	4.2	2.5	1.5
26.	Atrazine	4.0	3.0	2.5	8.5	7.8	8.0
27.	Atrazine	8.0	1.8	3.2	8.8	5.0	10.0
28.	Alachlor	2.0	1.5	1.0	1.0	0.0	0.0
29.	Alachlor	4.0	1.8	1.0	1.5	0.0	0.0
30.	Alachlor	8.0	3.0	1.2	3.5	1.0	0.0
31.	Fluometuron	2.0	1.8	1.0	2.8	2.5	0.0
32.	Fluometuron	4.0	1.0	0.5	1.2	0.0	0.0
33.	Fluometuron	8.0	1.8	1.5	1.8	0.0	0.0
34.	Chlorbromuron	1.5	1.0	1.0	2.5	0.0	0.0
35.	Chlorbromuron	3.0	1.0	1.2	3.0	0.0	1.0
36.	Chlorbromuron	6.0	1.5	2.2	2.5	3.0	0.0
37.	Bromacil	0.5	1.0	1.0	1.5	0.0	0.0
38.	Bromacil	1.0	2.5	1.5	3.5	2.0	0.0
39.	Bromacil	2.0	2.0	2.0	5.5	6.8	5.0
40.	Chloramben	2.0	1.5	1.0	2.5	0.0	0.0
41.	Chloramben	4.0	1.0	0.8	0.8	1.0	1.0
42.	Chloramben	8.0	1.0	0.2	1.5	2.5	2.0
43.	Norea + Diuron	1.11 + 0.5	1.0	1.5	2.8	0.5	0.0
44.	Norea + Diuron	2.22 + 1	1.0	1.5	3.5	2.0	1.5
45.	Norea + Diuron	4.44 + 2	1.0	1.8	4.5	2.5	2.0
46.	Ametryne	2.0	1.5	1.5	2.5	0.0	0.0
47.	Ametryne	4.0	2.0	1.2	2.0	0.0	0.5
48.	Ametryne	8.0	0.8	1.5	4.2	5.0	4.0
49.	Cyanazine	2.0	3.2	1.5	1.8	0.0	0.0
50.	Cyanazine	4.0	1.5	1.5	2.0	0.0	0.0
51.	Cyanazine	8.0	1.8	1.0	3.0	0.0	0.8
52.	Bentriocarb	3.0	2.0	0.8	2.0	0.0	0.0
53.	Bentriocarb	6.0	2.5	1.5	3.0	0.0	0.0
54.	Bentriocarb	12.0	3.8	1.5	3.5	0.0	0.0
55.	Karbutilate	2.0	1.5	2.2	7.2	6.8	6.0
56.	Karbutilate	4.0	1.8	2.5	8.0	9.0	8.0
57.	Karbutilate	8.0	2.0	3.8	9.0	10.0	9.8

* 0 = No injury, 10 = complete kill.

TABLE 11. **Injury ratings in cassava at 30, 45, 60, 90 and 110 days for the pre-emergence herbicides.** (continued)

	Herbicide	Rate kg a.i./ha	Injury rating*				
			30	45	60	90	110 days
58.	Terbutryne	1.0	1.0	0.8	3.2	0.0	0.0
59.	Terbutryne	2.0	1.2	1.2	3.8	4.0	1.8
60.	Terbutryne	4.0	1.5	2.2	4.8	4.5	0.5
61.	Prometryne	2.0	1.0	1.8	3.5	1.8	0.5
62.	Prometryne	4.0	1.5	2.0	4.0	2.0	0.5
63.	Prometryne	8.0	1.8	2.8	5.5	5.5	4.8
64.	Diuron	1.5	1.2	1.0	1.0	0.0	0.0
65.	Diuron	3.0	1.8	0.8	1.5	0.0	0.0
66.	Diuron	6.0	1.5	1.5	3.5	2.5	0.0
67.	Control	—	1.0	0.8	1.8	0.0	0.0
68.	Control	—	1.0	0.5	0.5	0.0	0.0

* 0 = No injury; 10 = complete kill.

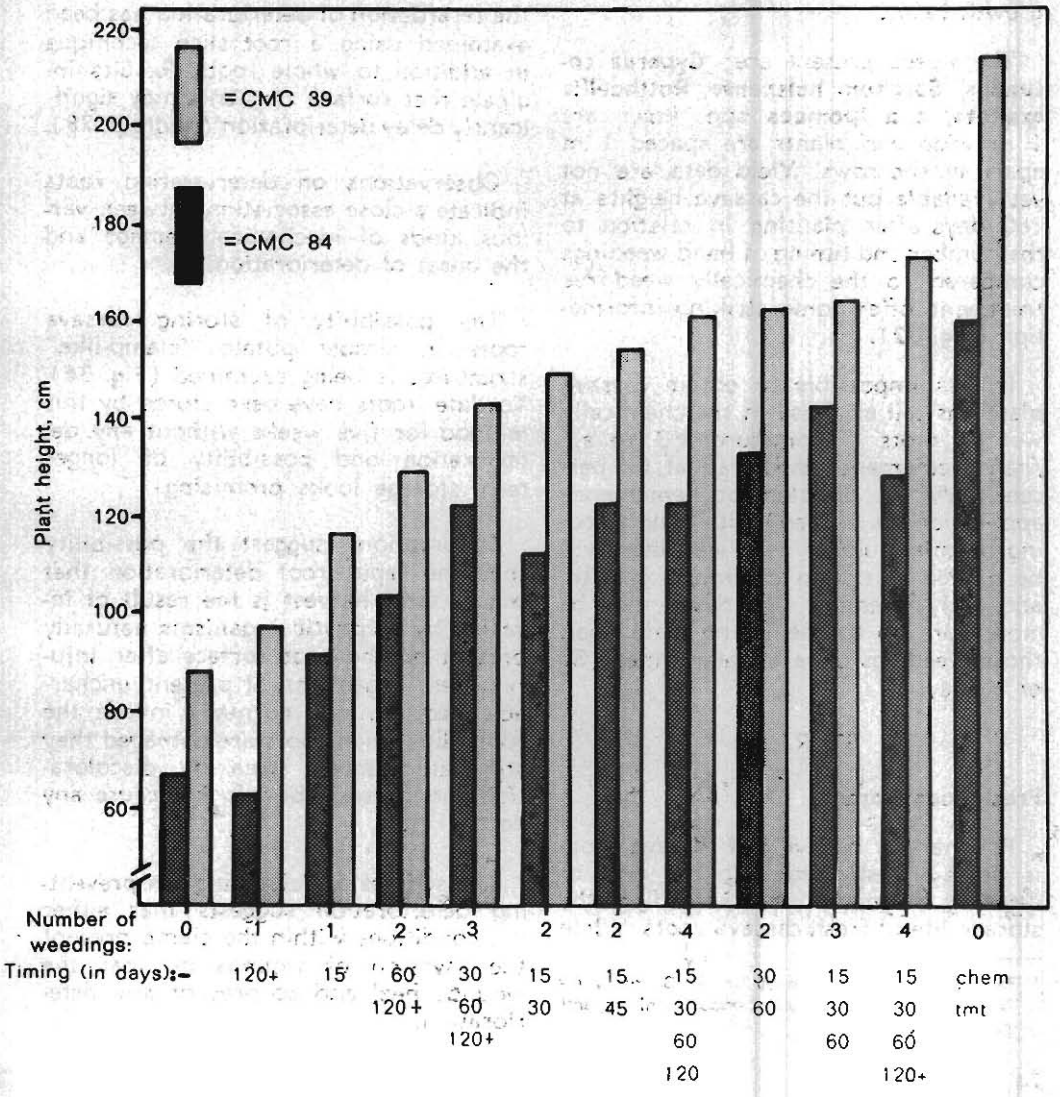


Fig. 32. Effect of number and timing of hand weedings on cassava height 160 days after planting the varieties CMC 39 and CMC 84 as compared to chemical weeding (the + indicates weedings were continued until harvest time).

practices are normally not needed. However, most varieties delay three to four months in closing and thus may be affected by weed competition over relatively long periods.

To determine the exact period that weed competition is most serious, a series of hand weeding treatments is being carried out with two cassava varieties, CMC 84, a short growing plant and CMC 39, a more vigorous and taller one. It is logical to expect that there will be different critical weed-free periods for each variety to produce the maximum yield in relation to its particular vigor and growth habits.

The weeds present are: **Cyperus rotundus, Sorghum halepense, Rottboellia exaltata, and Ipomoea** spp. Rows are 1 m wide and plants are spaced 1 m apart in the rows. Yield data are not yet available but the cassava heights at 160 days after planting in relation to the number and timing of hand weedings compared to the chemically weed-free treatment offer some striking information (Fig. 32).

It was impossible to obtain cassava plants as tall as those in the chemically weeded plots (Fluometuron, 3 kg a.i. /ha pre-emergence and Paraquat, 0.5 percent, v/v, in directed post-emergence applications as needed) with hand weeding. A minimum of two weedings will be needed to obtain maximum growth, and early weedings (15 days) may be more harmful to the young plant than those weedings done at later times (30 or 60 days).

STORAGE

Fresh root storage*

Post-harvest behavior of cassava roots is being investigated with the goal of devising techniques for extending the storage life of fresh cassava roots. While it is realized that such techniques as refrigeration and waxing can satisfactorily extend the storage life of fresh roots, the present investigation is directed at finding simple, inexpensive, on-the-farm methods.

A detailed study was made of the nature, occurrence, symptoms, and progress of the post-harvest deterioration that occurs in fresh cassava roots. Resulting from th s investigation a key for the assessment of deterioration has been prepared (Fig. 33).

The effect of various chemicals on the retardation of deterioration has been examined using a root slice technique in addition to whole roots. Results indicate that surface sterilants may significantly delay deterioration (photo p. 78).

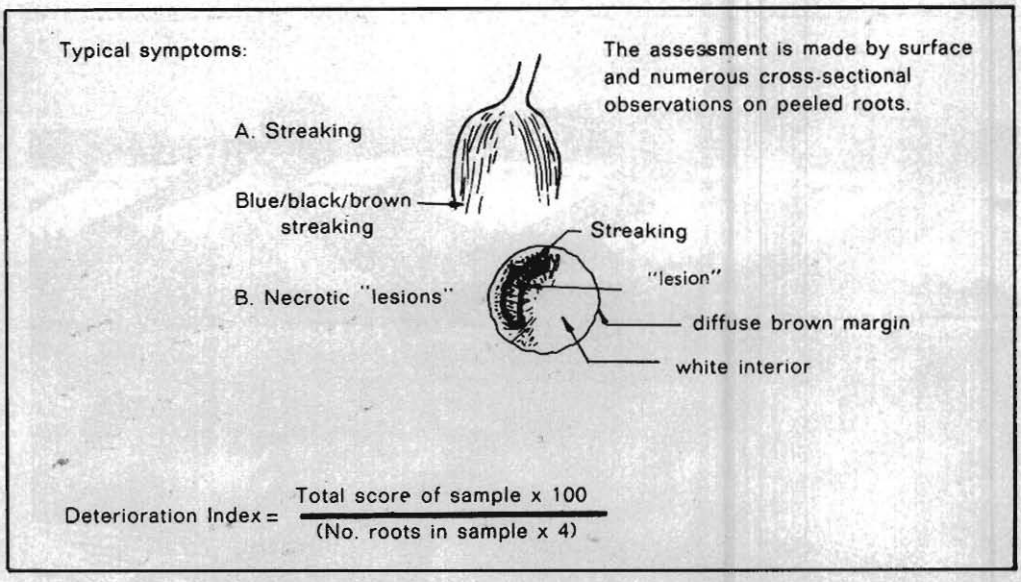
Observations on deteriorating roots indicate a close association between various kinds of mechanical damage and the onset of deterioration.

The possibility of storing cassava roots in simple potato "clamp-like" structures is being examined (Fig. 34). To date, roots have been stored by this method for five weeks without any deterioration and possibility of longer term storage looks promising.

Observations suggest the possibility that the rapid root deterioration that occurs after harvest is the result of invasion by epiphytic organisms naturally present on the root surface after injury. These organisms, at present uncharacterized, do not normally invade the roots, but when roots are damaged they stimulate vascular streaking, discoloration and necrosis but do not cause any decay.

The success of "clamping" in preventing deterioration suggests that either the conditions within the clamp prevent the invasion of wounds or that the wounds heal and so prevent any deterioration.

* This work is being done by Dr. R. Booth of the Tropical Products Institute, London, while spending a year at CIAT.



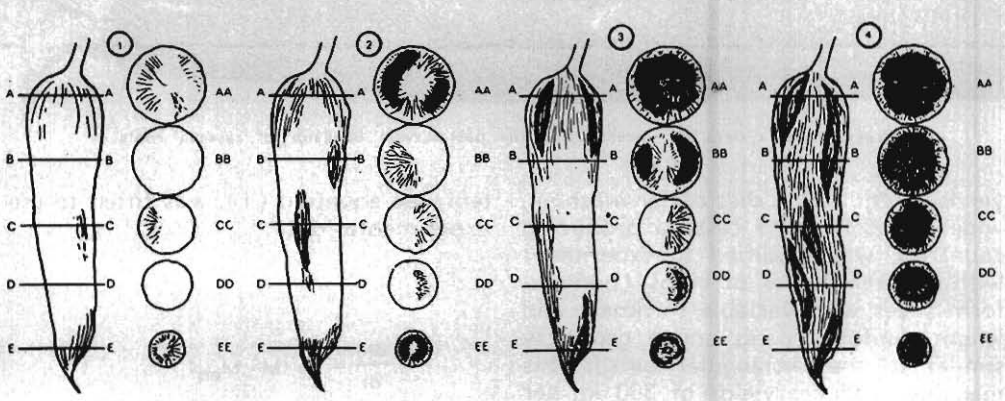


Fig. 33 Key for the assessment of deterioration in whole cassava roots. Symptoms of advancement of deterioration are shown in four consecutive stages (from 1, slight, to 4, severe).

Should the use of "clamps" be repeatedly found to control deterioration, this technique would provide a simple, inexpensive method of on-the-farm storage of fresh cassava roots.

Natural drying*

Research was conducted to estimate quantitatively the basic physical mechanisms that control the drying of cassava particles with emphasis on drying under natural ambient conditions. Existing theoretical principles of drying of biological products were successfully applied to design the experiments and to explain mathematically the influence of the independent variables in the desorption characteristics of cassava particles.

A manual cutting press was built to produce rectangular bars of one square centimeter of section and variable length. The device cut about 30 kg per hour but could be modified to obtain higher

* This work forms part of the Ph. D. thesis of Gonzalo Roa, at Michigan State University.

Experimental system for investigating the post-harvest behavior of cassava roots.

yields if required. A disc cutter machine, widely used in some cassava producing countries, was modified to experiment with different types of chips (non-uniform slices with variable thickness and length, uniform slices and a geometry similar to the rectangular bars). This machine produces yields of 300 kg per hour when operated by a man using a bicycle pedal mechanism or 600 kg per hour operated by the power take-off of a tractor or by a gasoline motor.

The field tests consisted of drying cassava particles in horizontal wire trays elevated from the floor during drying experiments. Two types of solar driers were tested, and a preliminary bin drying of cassava chips with unheated forced air was perfomed.

A simple thin layer equation which expresses the drying rates (changes in moisture content per unit time) proportional to the removable moisture content, see equation (1), was fitted to the experimental data:

$$\frac{dM}{dt} = -K\,(M - M_{eq}) \qquad (1)$$

Where:

- M, moisture content, dry basis
- t, time, hours
- K, proportional constant
- M_{eq}, equilibrium moisture content, dry basis

A multiple linear regression indicated that drying of cassava is sensitive mainly to changes in air temperatures (dry bulb) and, to a lesser extent, wind. Solar radiation does not influence natural drying of cassava directly because of its highly reflectant surface. Absolute humidity had small influence because of

Cassava roots remain in good condition after eight weeks of storage in straw-soil piles.

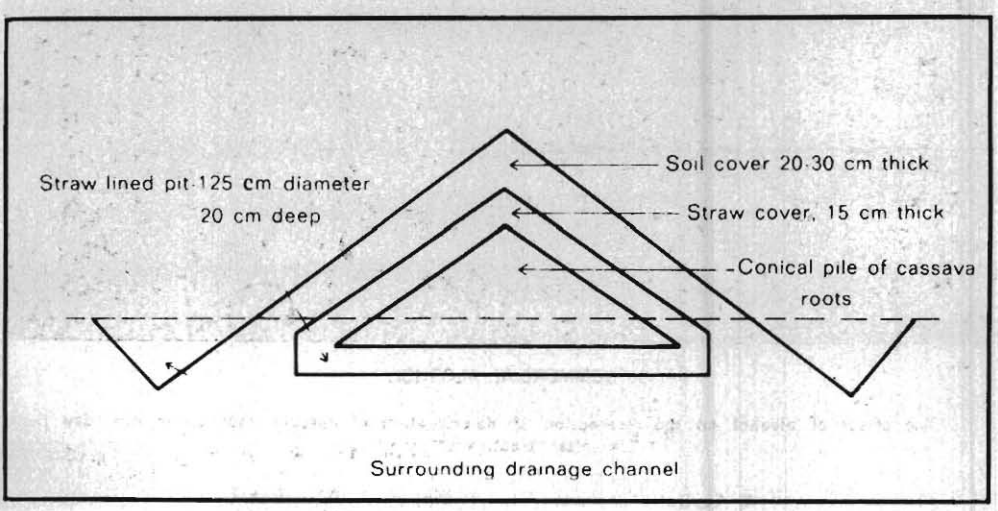


Fig. 34. Section through cassava "clamp."

the relatively low air free movement of the air between the particles in natural drying (under the experimental conditions, absolute air water content varied from 0.012 to 0.019 g/g and this, in more humid areas, may be significant). The results of regression are summarized in the equation:

This equation allows calculation of values of moisture content of 1 x 1 x 5 cm unselected rectangular bars when the average independent variables are known or can be predicted.

When the moisture content is expressed in the form of equation (2), the

$$\frac{M - M_{eq}}{M_i - M_{eq}} = e^{-Kt} \quad (2)$$

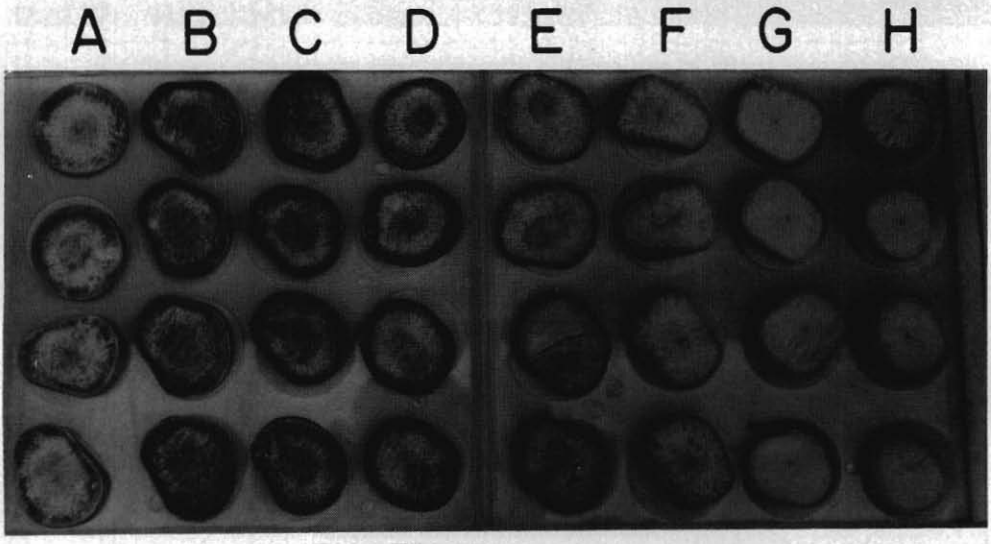
$$K = 0.01\,[-48.8 + 1.51\,D + (4.07 - 3.38 \times 10^{7} D^{-8})\,W + 6.54\,D^{-0.654}\,T] \quad (3)$$

M_i, initial moisture content, dry basis

D, fresh cassava weight per unit area, kg/m^2

W, average wind velocity, m/sec

T, average air dry bulb temperature, ^{o}C



The effect of alcohol on the retardation of deterioration of cassava root slices one day after treatment.

A. Control
B. Dipped in water
C. Dipped in 1% alcohol
D. Dipped in 5% alcohol
E. Dipped in 10% alcohol
F. Dipped in 20% alcohol
G. Dipped in 40% alcohol
H. Dipped in 60% alcohol

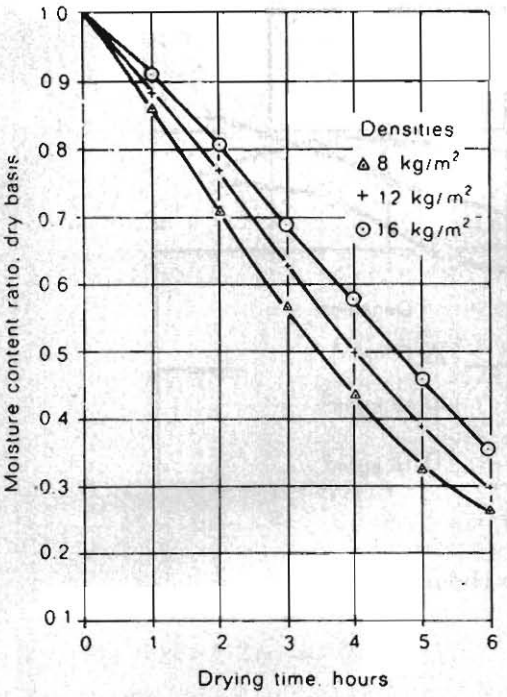


Fig 35. Desorption curves of natural cassava drying.

desorption equation and curves are not affected by the initial moisture content (Fig. 35) when the moisture contact is above 20 percent wet basis. This fact was particularly useful during the desorption curve analysis where differences of initial moisture content were in the order of ten percent, wet basis, because of differences in cassava age, variety and position of the particle along the root.

The influence of ambient conditions in the drying rates are shown in Fig. 36. The bottom section shows the recorded ambient variables. The experimental K value, calculated using equation (1) in its finite form are indicated in the upper section.

The experimental K values and those calculated using the expression (3) are compared in Fig. 37. The standard deviation of the differences is 0.03 and the mean K value is 0.20. The estimated error in the experimental K value due to field measurements is 0.02. These figures allow moisture content, wet basis, after eight hours of natural drying to be estimated to within $\pm$ 4 percent.

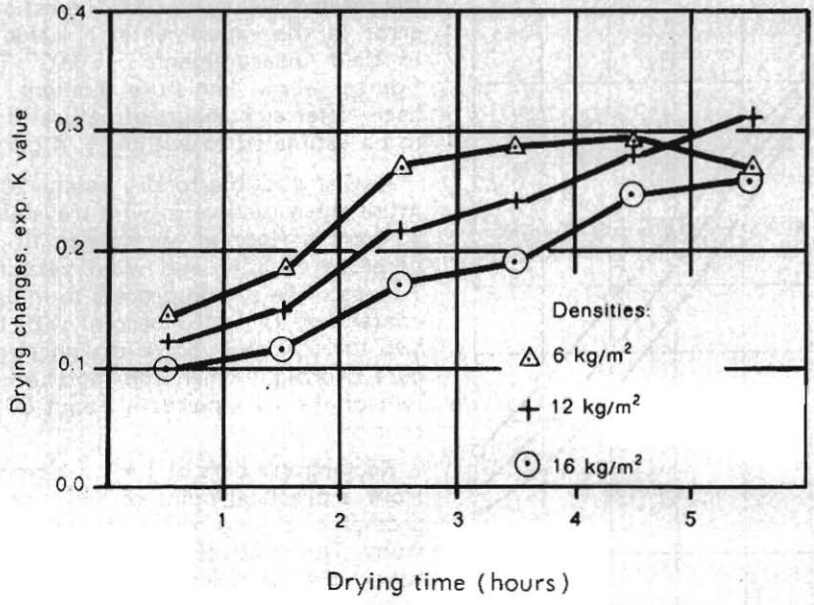
It was possible to dry safely 20 kg/m² of fresh cassava in wire trays elevated from a floor at an average air temperature of 30°C and wind velocity of 1 m/sec. The drying process to moisture content of 15 to 13 percent w.b. takes two to four days. Some drying also occurs overnight when the moisture content of the root pieces is about 20 percent or higher.

Rectangular bars of 1 x 1 x 5 cm were from a practical point of view the best geometry among those tested in the study. The relatively high void space between the particles, about 55 percent, allows the natural air to circulate removing the saturated air. Also, the dry bars do not break easily producing the undesirable fines. Other geometries tested were: small chips (non-uniform slices, 1 to 12 cm long and 0.1 to 0.70 cm thick); big chips (non-uniform slices 1 to 12 cm long and 0.2 to 1.2 cm thick) and slices (uniform 0.3 cm slices).

Hourly stirring of the product does not accelerate the drying of cassava particles significantly if appropriate natural drying conditions exist. The reason for this is the high solar reflectivity value of the white cassava surface.

The tested solar driers are not recommended to dry cassava because they have advantages over natural drying only when the radiation intensity is very high.

Drying of cassava particles in bins, with forced ventilation is a difficult process if low air flows are used because of big differences in static pressures caused by the non-uniformity of the product and by the shrinkage (about 30 percent of the initial volume) that occurs when drying cassava from 65 to 14 percent w.b. This results in non-uniform drying and rotting of the product.



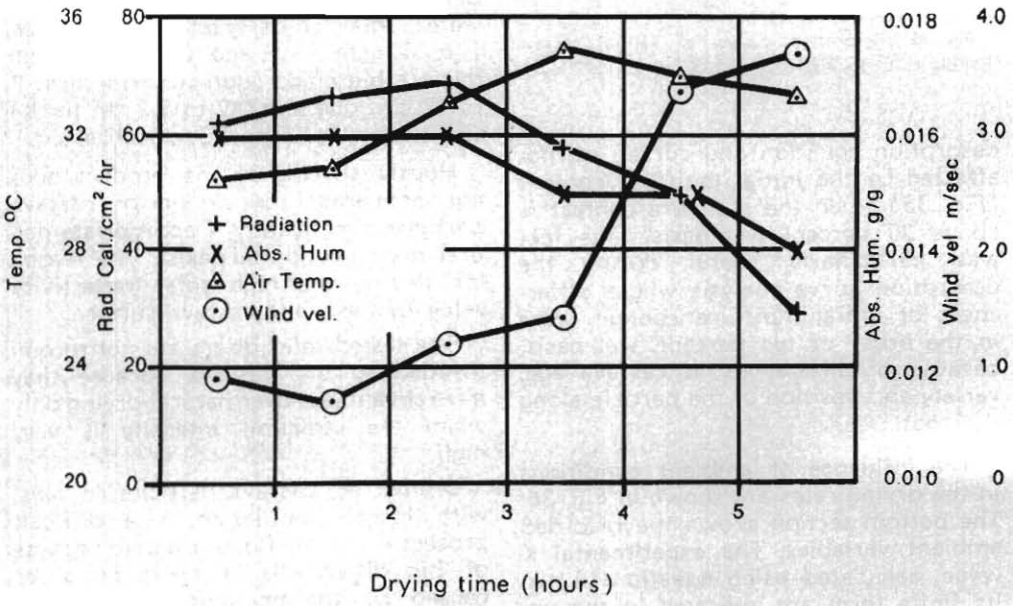


Fig. 36. Influence of ambient conditions on natural cassava drying.

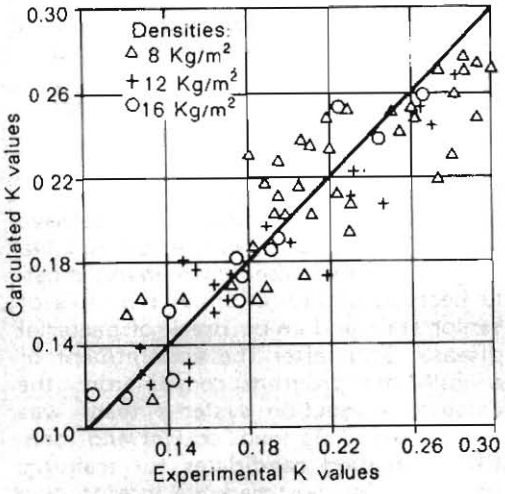


Fig. 37. Comparison of experimental and calculated K values.

AGRICULTURAL ECONOMICS

The work carried out during 1972 focused on: 1) a description of existing cassava production systems in Colombia and the cost of production under these systems, and 2) the economics of utilization of cassava.

Description of production systems

A farm survey was carried out among 330 cassava producers in various regions of Colombia. A stratified sampling procedure was used in an attempt to obtain information expected to be representative of the various Colombian production systems. The objectives of the survey were to describe present production systems and to estimate costs of production and labor use by production activity for the various production systems. Although the analysis of the data has not been completed, some preliminary results may be reported.

Almost one-half of the cassava producers included in the survey had less than two hectares of cassava, while only 13 percent had more than 10 hectares. Slightly more than one-half of the farmers grew cassava mixed with other crops. Maize was the crop most frequently found together with cassava, followed by plantains, yams, coffee and beans. A large proportion of the farms (22 percent) grew cassava together with more than one other crop.

A large variation was found in plant population per hectare. The majority of the farmers producing cassava on flat lands outside the north coast region maintained a population of 10,000-15,000 plants per hectare, while the farmers in the north coast region maintained a much lower plant population (4,000-12,000) and the farmers producing on sloping lands were found to maintain a plant population of 6,000-12,000 in most cases. The length of the crop cycle varied from one region to another. The most common crop cycle was found to be 12-14 months.

The use of purchased inputs was low. Only 5 percent of the farmers interviewed used fertilizers and 31 percent used insecticides. About two-thirds of the farmers used only manual labor for land preparation, 6 percent used animal traction and 27 percent used a more mechanized form for land preparation. On all farms the planting and harvesting was done exclusively by manual labor. None of the farmers used chemical weed control. Most of the farmers weeded the cassava field three times during the crop cycle.

The data are presently being analyzed with respect to labor utilization and production costs by production activity and farm size. It appears that present production costs run from 400 to 700 Colombian pesos/ton of cassava. These figures are tentative, however, and subject to revision.

Cassava utilization

The potential demand for cassava for direct human consumption, industrial starch and animal feed is presently being analyzed jointly by the University of Guelph (Canada) and CIAT.

Tentative results from an analysis of the economic feasibility of partial sub-

stitution of wheat in bread in Colombia suggest that such substitution would not be economically sound given present prices of wheat and cassava. If the wheat price remains constant, the price of cassava flour would have to drop by approximately 50 percent to make the substitution economically sound for the bread producer. If the present costs of marketing and processing per ton cannot be reduced, the price of fresh cassava would have to fall from the present Col. $1,700/ton to around $ 190/ton. It is likely, however, that the cost of processing will be reduced if the quantity of cassava flour increases. The extent to which processing costs can be reduced is not clear at present; however, they are a major portion of the total cost.

Given the large outflow of foreign exchange associated with wheat import, a partial substitution of wheat in bread might considerably influence the foreign exchange balance. The economic feasibility of partial replacement of wheat imports by other Latin American countries and the implications of such replacement on foreign exchange, farm sector revenues and domestic employment are presently being analyzed.

The economic feasibility of using cassava as an energy source for swine is being studied. Tentative results are reported under Swine Production Systems.

Recent trends in cassava production and yields

An analysis of the world cassava production and yield trends during the period 1960-68 was carried out on the basis of secondary data. The analysis suggests an increasing production trend of about two million tons annually during the period. The increasing production was because of an increase in cassava acreage of about 200,000 hectares annually. Average world yields of approximately 9 ton/ha show no significant change during the period.

The largest production increases took place in Africa and South America. The increase in total world production of cassava just kept pace with population increase in the cassava producing countries leaving **per capita** cassava consumption in these countries constant.

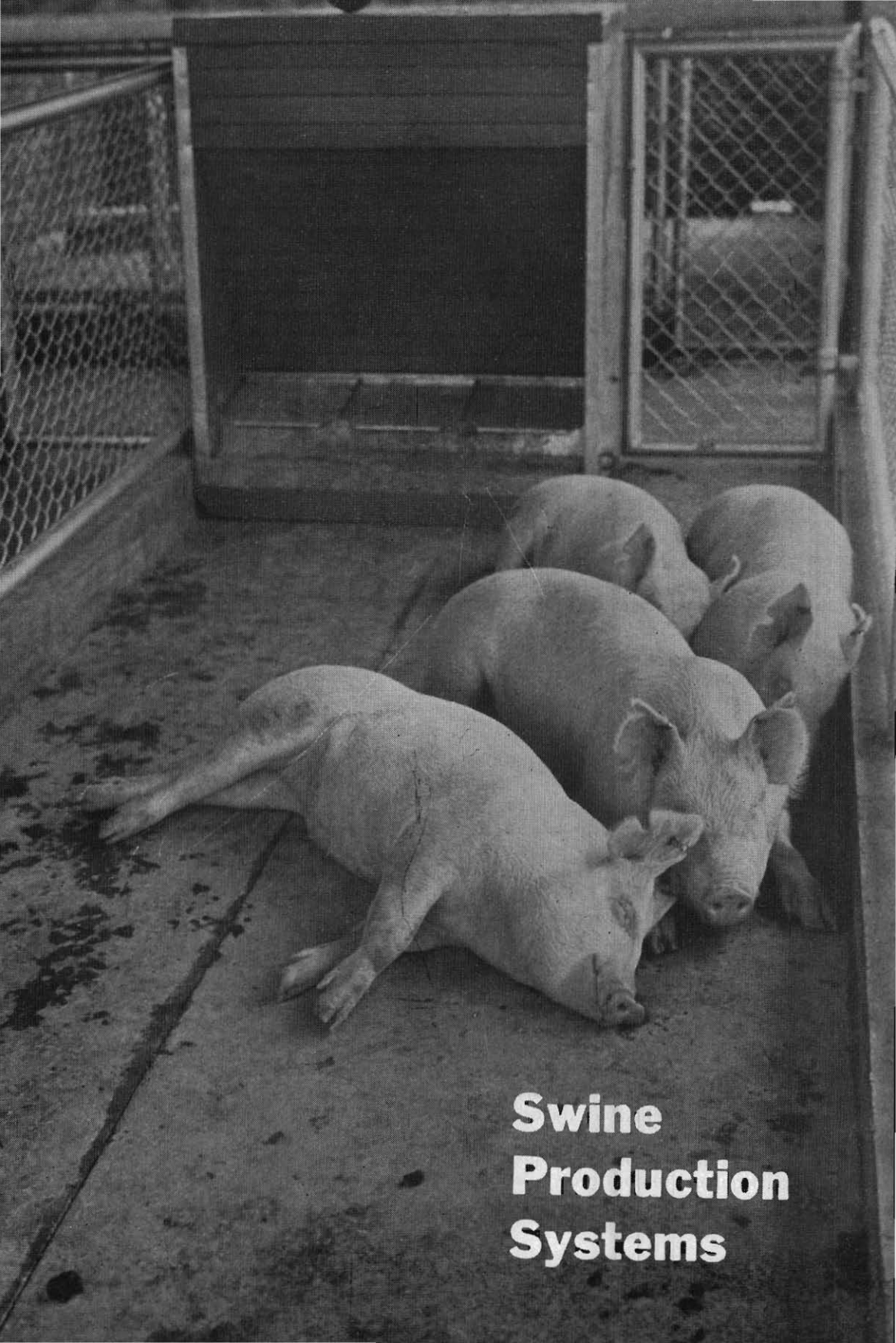
TRAINING

Before 1972, training in the cassava program had been available to few (two interns and two research fellows) mostly because of limitation in numbers of senior staff and an outbreak of bacterial disease. Soon after the appointment of a full-time program coordinator, the cassava production systems team was established. This team sought and identified qualified candidates for training. In 1972, nine postgraduate interns, two doctoral candidates and two special trainess were appointed or continued training.

In addition, three trainees in plant protection dealt with cassava as part of their training. Colombia, Peru, the United States and the United Kingdom have been so far represented in the above groups. Additional professionals have already been selected from Ecuador and Venezuela for training in early 1973.

CONFERENCES

In cooperation with the Canadian International Development Agency and the International Development Research Centre of Canada, CIAT invited some 40 scientists from 15 countries to Cali for a Cassava Program Review Conference in early January. These participants helped CIAT to define its cassava program and also discussed ways to stimulate interest among other institutions in cooperative efforts. Each participant presented a short working document and each discussed the state of cassava research in his own area. Countries represented included Brazil, Canada, Colombia, England, France, India, Madagascar, Mexico, the Netherlands, Puerto Rico, Scotland, Sierra Leone, Trinidad, and the United States.



Swine Production Systems

THE Swine Program has become an integrated commodity program emphasizing improved production on small subsistence farms, evaluation of protein sources that can be grown and used on tropical farms, economic evaluation of both commercial and backyard swine enterprises, and the development of national swine programs.

SMALL FARM PRODUCTION SYSTEMS

Studies were initiated in 1971 to determine, through field survey, the existing level and efficiency of production, husbandry practices, feeding systems, health problems and marketing systems related to swine production on small farms. On the basis of this survey, efforts were made to introduce production systems developed for local conditions in Cacaotal, a small village on the north coast of Colombia. The village is located at an altitude of 25 m above sea level and receives an average of 1,115 mm of precipitation annually during a seven-month rainy season. The mean environmental temperature is 32°C. The village has some 90 families who live basically on the crops produced and on income received from limited part-time work.

Farmers traditionally grow three crops. Corn is seeded and when it sprouts, a seed-piece from a yam tuber is planted adjacent to the corn, the stalk supporting the yam vine. Shortly after, farmers plant cassava stakes in the spaces that remain. They have a few plantains and occasionally grow rice. Food legumes, seldom grown, are not a part of the farming system.

Traditionally, pigs are maintained on the farm as a ready source of cash. The pigs roam freely within the fields and village, scavenging food, including pasture, garbage, worms, fallen fruit and both human and livestock feces. When available, pigs eat common corn, unsalable cassava and plantains, and occasionally, a small amount of whey from home-cheese production.

Sows are bred at random by freely roaming boars. Inbreeding is common, and village animals evidence little improved breeding. At farrowing time, to prevent the sow from giving birth to the young far from home in a sheltered or wooded area, the farmer ties her close to the house.

With a poor diet during gestation and a low level of nutrition during lactation, the sow produces little milk after 14 to 21 days. Both the sow and her young are soon in poor physical condition. When the sow's milk production ceases, baby pigs obtain food where and if available. Of the more than 300 pigs studied in one year, few weighed more than 20 kg at 6 months and 60 kg at 12 to 18 months.

During the 15 months since the initiation of the project, the difficulties of transferring available technology into practical, acceptable production systems for the subsistence farmers have been readily apparent. Level of education, available capital, availability of supplemental vitamins, minerals and proteins, and established traditions all present stumbling blocks to application of existing knowledge and to rapid improvements in swine production.

Package programs were provided and demonstrated, but generally the farmers accepted and put into practice only parts of the package. This fact stressed the need for a stepwise introduction of proved practices, each as an aid to improved production. For example, confinement rearing and treatment with drugs were introduced to control internal parasites; also, vitamins, minerals and supplemental protein were provided to overcome nutritional deficiencies.

The demonstration clearly indicated that local pigs fed under traditional systems gained an average of only 4 kg each in 56 days and required 9.4 kg of corn with a value of Col. $ 18.80 to produce a kilogram of live-weight gain worth $ 8.50 to $ 9.50. Those fed under the improved system gained an average of 26 kg during the same period and required 2.6 kg of improved diet with a cost of Col. $ 7.48 to produce a kilogram of gain worth $ 8.50 to $ 9.50.

Although this improved system does not produce a large income over feed cost, it demonstrates the magnitude of improvement (650 percent) that can be realized with minimum inputs and changes in management and feeding. These production changes must be accompanied by changes in marketing systems and practices in order to obtain better prices for market animals.

Increased profits can be obtained by using locally available feedstuffs such as cottonseed meal, fresh-water fish, blood and meat meal and rice by-products which are available at lower prices during part of the year. However, the introduction and utilization of these products will require the development of local sales agents or cooperatives to distribute the products, the availability of credit for purchase of these ingredients and the training of farmers in diet preparation.

To increase the protein sources available within the village, a demonstration plot of 42 different varieties of five species of legumes was planted. This demonstration included soybeans, beans, mung beans, cowpeas and pigeon peas. Of the legumes seeded, only the cowpeas and the pigeon peas produced seed, with the cowpea production exceeding the pigeon pea production both in earliness and in total seed.

Since these improved management and feeding and legume seeding demonstrations were conducted, many farmers have adopted confinement feeding and have planted substantial quantities of cowpeas, some with seed "gleaned" from the demonstration plots. The increased seeding of cowpeas should have a positive effect on protein availability within the village; however, adoption of confinement rearing to reduce losses caused by parasites without the simultaneous adoption of improved feeding practices could detrimentally affect production by excluding, from the pigs' diet, garbage, pasture, feces, worms and other substances that they are able to scavenge and that significantly contribute to their total nutrition.

High cost of feeds and inefficient production practices combine to make small farm swine production a marginal venture at best, but 80 to 90 percent of Latin America's 100 million head of swine are produced under these conditions. A 650 percent improvement in production and a 260 percent reduction in feed required per kilogram of gain would have a significant impact on pork available and feed saved.

FEEDS AND SWINE FEEDING SYSTEMS

High feed cost and local unavailability of adequate protein sources continue to reduce the economic potential of swine production in many areas of Latin America's lowland tropics. Emphasis is continually given to the efficient utilization of available feedstuffs and to the evaluation of new sources.

Bananas

Detailed studies have been completed to identify the factors limiting the utilization of green bananas by swine, to determine the digestibility of the component parts and to measure the digestible and metabolizable energy values of ripe and green bananas, both as the fresh fruit and as dried meal. It was shown that the reduced performance of pigs fed green bananas was because of poor palatability of the green fruit and because of reduced protein digestibility, both resulting from the presence of active tannins. Digestible and metabolizable energy values did not differ for either the ripe or the green fruit. Drying of the green bananas had little effect on the digestibility of the various fractions; however, the level of heat required to dry ripe bananas caused carmelization to occur (browning reaction) and the reduction of the digestibility of all fractions. Both ripe and green bananas had a digestible energy value of 3,100 to 3,200 kcal/kg of dry matter. With these data, it is confirmed that fresh bananas should be fed ripe and banana meal be prepared from green bananas for maximum utilization of bananas by swine.

Cassava

Studies continued to evaluate cassava as an energy source for swine and to determine the true value of the protein it contains, as well as to determine the effect that hydrocyanic acid (HCN) has on nutrition and animal health.

Digestibility of the components of cassava and the digestible and metabolizable energy values of cassava meal were determined. Results indicate that the energy fraction was highly digestible (3,758 kcal/kg of dry matter) but that the nitrogen fraction represented as crude protein was only 40 percent digestible.

Biological studies with rats have shown that the crude protein has a value equal to 52 to 59 percent of that of casein (the milk protein) used for comparison. Gains, feed efficiency and efficiency of protein utilization are significantly improved by the addition of methionine which is deficient in cassava protein.

These biological studies correspond closely to chemical analyses which indicate that approximately 40 to 60 percent of the nitrogen in cassava roots is present as true protein. More detailed analyses indicate that nitrogen present as nitrates, nitrites and hydrocyanic acid represent less than 1 percent of the total nitrogen in the root, leaving 25 to 30 percent as other nitrogen compounds not yet identified.

Studies confirmed previous theories that the level of supplemented methionine required to obtain maximum responses from cassava are only partially required to correct the methionine deficiency of the diet. The level of methionine needed increases as the level of cyanide increases in the diet. Methionine is used to supply the sulphur required in the detoxification mechanism which converts cyanide (^{-}CN) to thiocyanate (^{-}SCN) which is excreted in the urine. These factors are significant in both human and animal nutrition and health.

The cyanide is fatal to animals if it is ingested in toxic quantities. If not detoxified, it can cause nerve degeneration and may affect the offspring when consumed by gestating females. The detoxification product, thiocyanate, is a goitrogenic substance that prevents the normal intake of iodine by the thyroid and thus causes goiter. Both conditions have been reported to occur in the African population that consumes large quantities of cassava.

The condition is most commonly reported under conditions of low or marginal nutrition. Under conditions of adequate nutrition and especially adequate quantities of iodine and protein containing adequate levels of the sulphur amino acids, the problem is less or nonexistent. High levels of cassava consump-

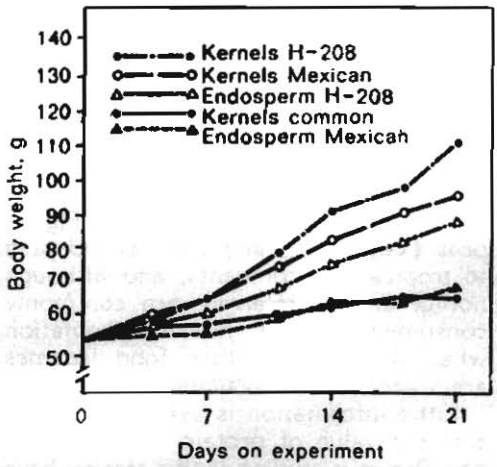


Fig. 1. Performance of rats fed diets based on whole kernels or endosperms of H-208 or Mexican vitreous maize.

tion containing medium to high levels of cyanide increase the requirement for both iodine and methionine and reduce the utilization of these nutrients for normal body functions.

Maize

It is assumed that opaque-2 maize plays an important role in animal agriculture and human nutrition. Because of the improved level and balance of essential amino acids, its use reduces supplemental protein requirements. Swine production systems based on opaque-2 maize have been developed that require only approximately 25 percent as much supplemental protein as that required by systems based on normal maize. However, because of the softness of the kernels, storage is difficult because corn weevils attack the grain. A hard crystalline or vitreous endosperm is needed to increase grain density and to reduce weevil damage. In collaboration with the maize programs of CIAT and CIMMYT, the modified opaque-2 maize produced from their breeding programs has been evaluated. Figure 1 summarizes the results obtained when the modified vitreous grain from Mexico is compared to H-208 opaque-2 and when the endosperm fractions are compared. The vitreous kernels produced gains and feed utilization similar but slightly lower than those of the whole kernels of H-208 opaque-2. However, the value of the separated endosperms of the vitreous kernels was much inferior to the endosperm of the opaque-2 kernels.

Additional studies (Table 1) indicated that the whole kernel of the Mexican vitreous produced in Colombia has a nutritive value only slightly less than the H-208 opaque-2. When the kernels of the Mexican vitreous were separated into intermediate hard (semi-crystalline) and hard (crystalline) and fed to rats, the intermediate supported greater weight gains and improved feed conversion, but similar protein efficiency ratio (PER) when compared to the hard. Both were only slightly inferior when compared to the H-208 opaque-2 kernels. A cross between the H-208 and Mexican vitreous supported performance similar to that obtained by the other maize treatments.

TABLE 1. **Performance of rats fed H-208 opaque-2 maize compared with selections of Mexican vitreous opaque-2 maize.**

Diets	Average daily gain, g	Feed/gain ratio	PER
1. Control - casein	4.24	3.31	3.30
2. H-208 opaque-2	3.08	4.43	2.53
3. Mexican intermediate	3.05	4.74	2.37
4. Mexican vitreous	2.73	5.08	2.34
5. Mexican x H-208	2.87	4.70	2.47

Cottonseed

In certain areas of the lowland tropics, such as in Bolivia, large supplies of cottonseed are wasted or used as fertilizer because of the difficulty of transporting these seeds to distant crushing plants. Published information is not available to indicate how these whole seeds can be used for swine feeding. As they offer a readily available and cheap source of protein, studies were initiated to determine the minimum processing and/or supplementation required for efficient utilization of these seeds for swine.

Results of chemical analyses and of both pig and rat trials indicate that it is a poor source of protein because of the high level of gossypol in the unprocessed seed. Heating for 24 hours at 80 to 90°C after first soaking for 12-24 hours in water did not significantly improve the raw seed. When either raw or soaked-toasted seed were included in growing swine rations at levels to supply 33, 66 or 100 percent of the supplemental soybean meal, poor results were obtained, even when ferrous sulfate was added to complex part of the free gossypol.

Exploratory trials with the same cottonseed were carried out using rats. In addition to soaking and toasting, liquid calcium hydroxide and crystalline ferrous sulfate were added alone or in combination in an attempt to reduce the free gossypol toxicity. Both compounds were partially effective in reducing toxicity and improving rat performance and in the utilization of the cottonseed which served as the only source of supplemental protein. Although rat performance was improved, the level of performance of rats receiving the cottonseed treatments, even with calcium hydroxide and ferrous sulfate supplementation, was inferior to the soybean meal treatment utilized as the control.

Studies are continuing with both rats and swine to develop a processing and supplementation procedure that will aid swine producers to make economic use of cottonseed as a protein source.

Pigeon Peas

As swine feeds, especially protein sources, are costly and in short supply particularly for small subsistence farmers in remote areas, efforts are being made to stimulate the production of proteinaceous foods that can be used for human food and animal feed. Pigeon peas (**Cajanus cajan**) are well adapted to tropical environments, and although not generally preferred, are commonly consumed by the human population when supplies of other food legumes are scarce or not available.

Little information is available to indicate the value of protein in the pigeon pea. Previous studies at this station have shown that raw pigeon peas are highly toxic to rats and must be cooked to be of any value. Available published data indicate that the amino acid, tryptophan, is most limiting in the pigeon pea followed by methionine.

Trials with rats (Fig. 2) confirmed previous results showing that pigeon peas must be cooked to be efficiently utilized. These studies (Fig. 3), however, failed to confirm previously published results which indicate that the pigeon pea protein is first limiting in the amino acid, tryptophan, and second limiting in methionine. The reverse was found in

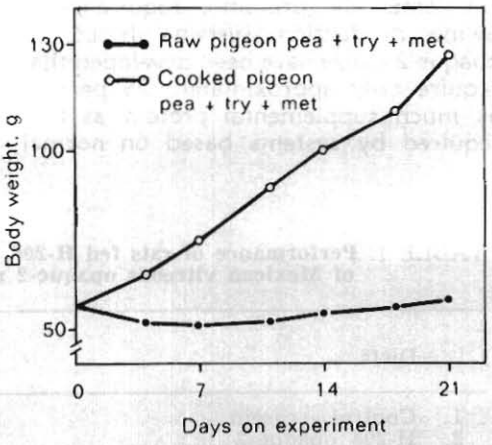


Fig 2. Effect of cooking pigeon peas on the performance of rats fed diets based on pigeon peas supplemented with tryptophan and methionine.

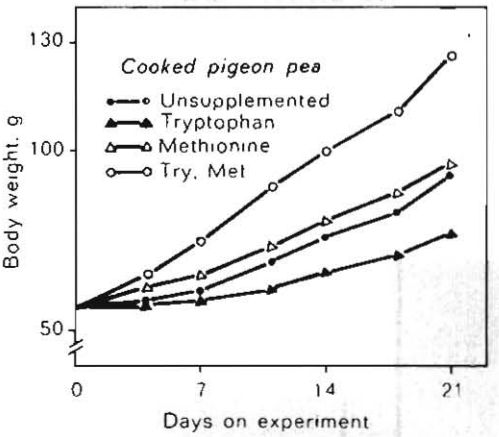


Fig. 3. Effect of tryptophan and methionine supplementation on the performance of rats fed cooked pigeon pea diets.

these trials. When the pigeon pea diets were supplemented with tryptophan alone, rat perfomance was reduced; however, methionine alone improved performance when fed as the only supplement and was most effective when it was added along with tryptophan. This indicates that both are deficient in the protein, but for the rat, the methionine is more limiting.

Cowpeas (Vigna sinensis)

Cowpeas are commonly grown and consumed in lowland trópical areas where the bean (**P. vulgaris**) and other food legumes are not adapted and fail to produce seed. Although the cowpea contains less total protein than the soybean, the protein content is of fairly good quality as indicated by results previously reported by CIAT and elsewhere.

With most other grain legumes, the cowpea contains antidigestive and antimetabolic factors that must be destroyed to allow the protein to be efficiently utilized. Cooking in boiling water for 15 minutes has shown effective elimination of these toxic factors. Research has been in progress to develop other, simpler methods for processing.

Previously reported studies have indicated that germination would reduce these toxic factors to a level sufficiently low to allow the protein of the cowpea to be efficiently utilized. Results have shown extreme variation between trials.

Length and degree of germination or sprouting was considered as a principal cause of this variation, and a study measured the effect of sprouting time and degree of sprouting on the nutritional value of the protein as affected by antimetabolic reduction. Carefully prepared samples of cowpeas sprouted for one day; sprouts allowed to develop to one and two inches in length were obtained. These samples were incorporated into diets for growing rats and compared with diets prepared from raw and cooked samples of cowpeas and with casein.

The performance of rats fed the germinated cowpea diets was poor even when supplemented with methionine. In each case the rate of growth (Fig. 4) and the efficiency of feed conversion was lower than that observed when raw cowpeas were used in the diet. A proved explanation for the difference in these and previous results is not available; however, it is postulated that early positive results with germinated cowpeas may have occurred because of fermentation and/or fungal or bacterial growth on the wetted-germinating peas. Studies are continuing to characterize the reasons for the differences in response.

Other studies with germinated cowpeas have demonstrated the value of this legume as a supplement to maize and other carbohydrate sources available in the tropics. Data in Table 2 clearly demonstrate that germinated cowpeas can effectively supplement opaque-2 maize if small quantities of methionine are added. In this trial, the opaque-2 maize-germinated cowpea diet supplemented with only 0.05 percent methionine supported rat performance not differently from that obtained from soybean meal supplemented with opaque-2 maize. Even without methionine supplementation, the cowpea effectively improved the all opaque-2 maize diet by 30 to 40 percent. Data in Table 3 demonstrate the

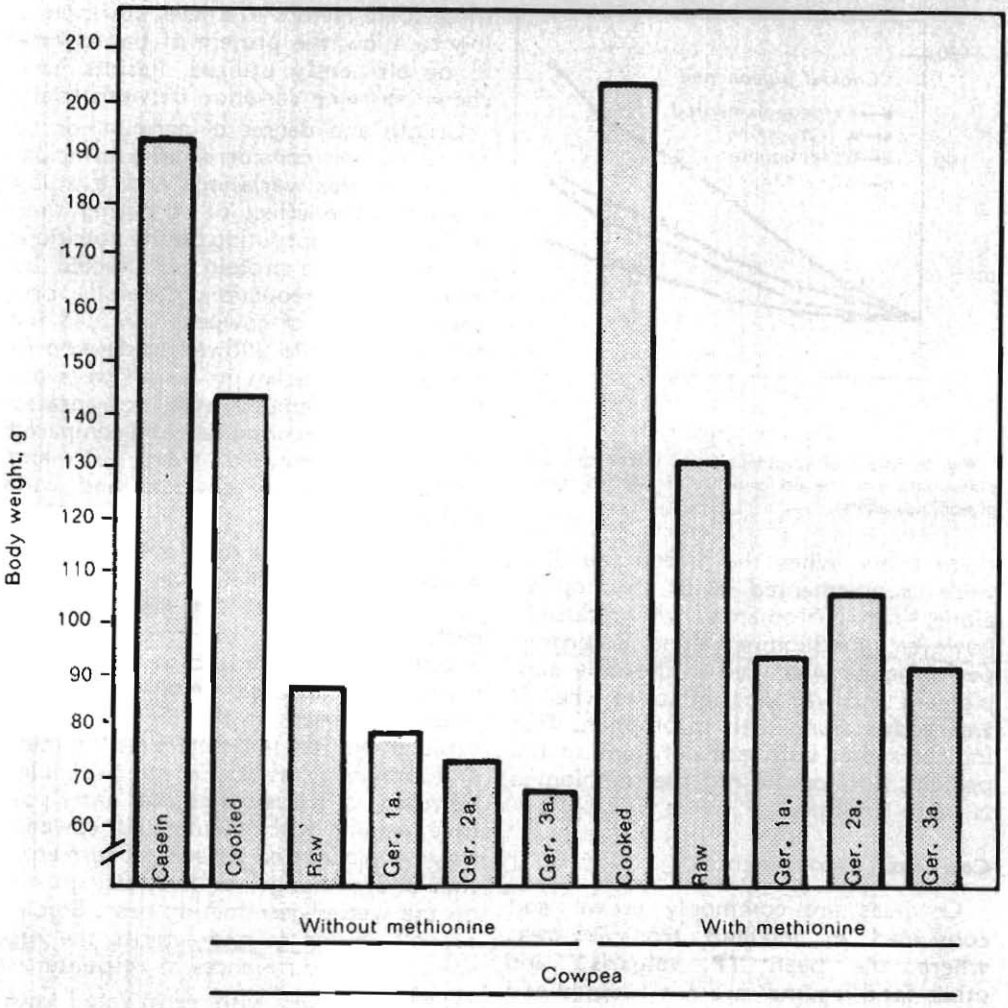


Fig. 4. Effect of processing method and methionine supplementation on the performance of rats fed cowpeas.

TABLE 2. **Germinated cowpeas as protein supplement to opaque-2 maize for growing rats.**

	Diet	Average daily gain g	Feed/ gain
1.	Opaque-2 maize	3.35	3.42
2.	Opaque-2 + cowpeas	4.54	2.89
3.	Opaque-2 + cowpeas + 0.05% methionine	5.24	2.55
4.	Opaque-2 + cowpeas + 0.10% methionine	4.57	2.72
5.	Opaque-2 + soybean meal	5.06	2.67

TABLE 3. **Value of cowpeas as a protein supplement to some tropical carbohydrate sources.***

Carbohydrate source	Without methionine suppl.		With methionine suppl.	
	Av. daily gain, g	Feed/ gain	Av. daily gain, g	Feed/ gain
Cassava dried	3.24	3.71	3.86	3.16
Cassava cooked	2.90	4.09	3.07	3.67
Plantain-green	3.26	4.25	3.83	3.74
Banana-green	2.78	4.19	2.77	4.35
Opaque-2 corn	4.61	2.83	5.04	2.70
Common corn	4.20	3.14	4.01	3.14
Average	3.50	3.70	3.76	3.46

* Five rats per treatment, 18 days, 12 percent protein diets.

value of cowpeas with and without methionine addition as a supplement to common maize, opaque-2 maize, dried green plantains, and cooked and raw cassava. Additional studies will evaluate these combinations.

AGRICULTURAL ECONOMICS

The economics activities focused on an evaluation of tropical swine feeds and economic analysis of swine production in selected regions of Colombia. An economic evaluation of cassava for swine is in process. A linear programming model is presently being tested on a number of feeds. Results of these analyses will be available soon.

An economic analysis of the swine production activities in the village of Cacaotal was made as an integral part of the overall project. The productivity of current swine production in the region was found to be low, and negative if the inputs used were valued at their opportunity cost. Improving the swine diets and other management practices was found to improve productivity significantly. Under improved management, however, the price relationships between available feeds and the swine produced were found to be unfavorable to the producer.

Analyses of the swine marketing system indicated that a greater participation by the farmer in the marketing process might significantly increase the price received for his swine.

Alternative sources of feeds were identified and analyzed. Unless subsidized, it did not appear economically sound to use purchased concentrates.

Based on available feeds and other inputs, a credit plan for swine production was developed. Unless management and selling practices are greatly improved and unless the majority of the feeds are to be produced on the farm, obtaining a reasonable level of net returns is doubtful.

Study of the farms included in the project continues to improve the understanding of such factors as costs, returns, risk and objective function and their relationship with biological and social factors in the environment of small marginal farmers.

Finally, an analysis is presently being carried out on the economics of commercial swine production in the Cauca Valley of Colombia.

ANIMAL HEALTH

Studies to determine those swine diseases of economic importance in Latin America were started in 1972 with additional staff being appointed to the Animal Health group and the completion of minimal laboratory accommodations at Palmira.

Two investigation areas were chosen in Colombia, these representing differ-

First swine in the new CIAT facilities were specific-pathogen-free Yorkshire pigs air-lifted from the United States.

ent levels of husbandry. They were anticipated to reveal different spectra of diseases and parasitisms. The first area was the village project at Cacaotal, and the second was a group of commercial swine operations in the Cauca Valley. Laboratory services were provided by the ICA laboratory at Turipana (Laboratorio de Investigaciones Medicas Veterinarias Tropicales) and the CIAT Animal Health Laboratory, Palmira.

The graduate student in the swine program at Cacaotal collected data on the conditions he observed in the course of his study; most importantly, he discovered a high incidence of brucellosis (80 positive from 170 samples examined) but found little evidence of abortion being a basic problem. The blood samples taken for brucella testing were also examined for hemoparasites. None were found. Tick species found infesting pigs were **Amblyomma cayennense** and **Anocentor nitens.**

The appointment of a helminthologist enabled work on the identification of endoparasites. Fecal samples were examined from Cacaotal, intestines were collected from slaughtered pigs and viscera were examined in the Monteria slaughterhouse. The following parasites were identified:

Ascaris suum	"roundworm"
Oesophagastomum spp.	"nodular worm"
Macracanthorhynchus hirudinaceus	"thorny headed worm"
Hyostrongylus rubidus	"red stomach worm"
Ascarops strongylina	"thick stomach worm"
Physocephalus sexalatus	also with common name "thick stomach worm"
Metastrongylus spp.	"lungworm"
Cysticercus cellulosae	larval stage of the tapeworm **Taenia solium**
Stephanurus dentatus	"kidney worm"
Trichuris suis	"whipworm"

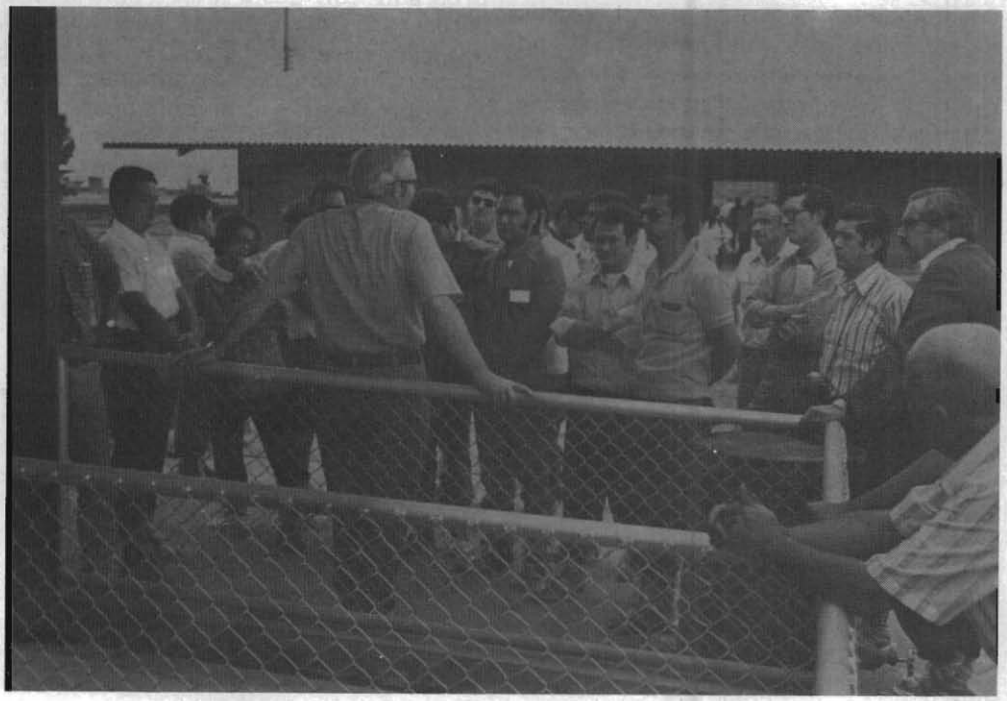
The data were inadequate, but the common observation on the importance of lungworms was not confirmed, and livers showed surprisingly few "milk spots" (**Ascaris** scars).

Investigations in the Cauca Valley included 16 farms and 12,600 swine. In six months, samples were processed from 363 animals, 24 of which were necropsies. The principal problems which emerged were diarrhea and pneumonia in suckling pigs, pneumonia and otitis in immature animals, and abscesses, mastitis and abortion in adults. On one farm an epidemic of abortion was associated with brucellosis. Five strains of **Brucella suis** were isolated and 85 of 200 serum samples were positive. On another farm, **Leptospira** sp. was believed to be a cause of epidemic abortion.

A doctoral thesis was completed by a staff member on the histological characterization of foot and mouth disease in pigs. The intra-muscular route of inoculation was considered the most satisfactory for these studies. A hypothesis raised was that the distribution of lesions was related to the degree of challenge. A small infective dose appeared least likely to produce the more serious skeletal and cardiac muscle involvement. If correct, this could lead to methods of modifying field outbreaks of the disease in the current absence of any satisfactory immunization procedure.

TRAINING

In 1972, four animal scientists completed postgraduate intern training in swine. Two Ecuadorians completed training programs in swine nutrition and research and returned to Ecuador to work in the national agricultural research organization, INIAP.



Participants of the Seminar on Swine Production in Latin America are briefed on CIAT's new swine facilities.

One Colombian completed his postgraduate intern training in swine nutrition and production by mid-year and was employed by the Swine Program to be responsible for the routine management of the CIAT swine herd.

One postgraduate intern from Mexico completed his research training and returned to Mexico to teach swine production at the Escuela de Agricultura y Ganadería (ITESM), Monterrey, Mexico.

One research fellow from the University of Illinois completed data collection in November on "The problems of the small farmer on the north coast of Colombia" which he will use in his dissertation as partial fulfillment of his requirements for a Ph.D. degree in International Animal Science at the University of Illinois.

Two postgraduate interns were accepted early in the year, one Bolivian and one Colombian, who are presently receiving training in swine production and research. Both men are being trained to return to universities in their respective countries to assume teaching and research responsibilities.

One research scholar from Costa Rica joined the CIAT swine staff in April for research in swine nutrition as partial fulfillment of his Master of Science degree at the University of Florida. Upon completion of his graduate program, he will work in the national swine improvement program of Costa Rica.

Lectures were presented to the livestock production specialist trainees on swine nutrition, swine production and laboratory exercises in swine management. Two of the swine trainees attended the first two months of the Livestock Production Specialist Training Program before undertaking major training activities in the swine program. In the future, more swine trainees will attend the two-month intensive portion of the livestock production specialist course as a part of their overall training in swine production and research.

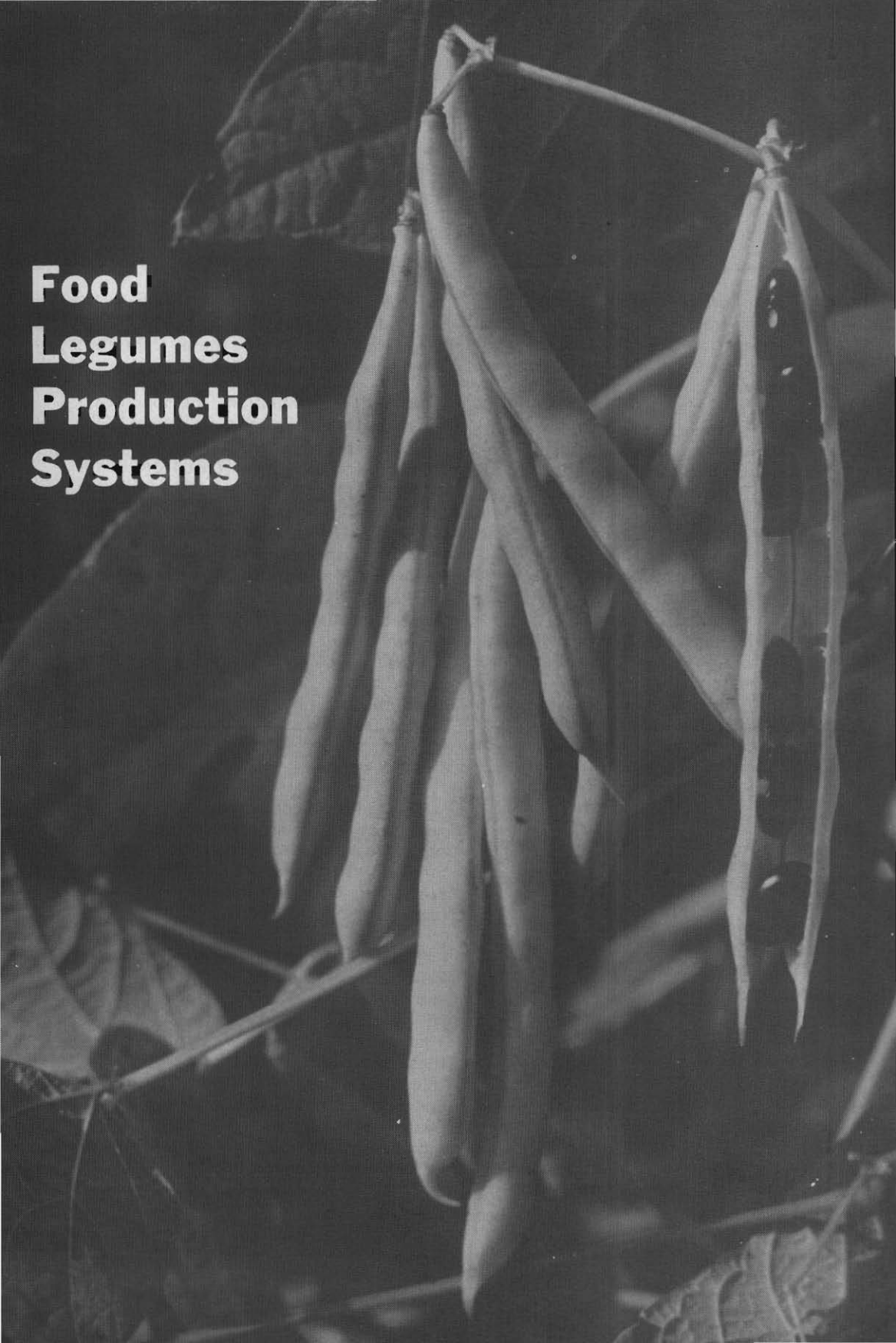
OUTREACH

The programs of CIAT are greatly amplified and strengthened by collaborating national programs. These help solve local production problems, train national personnel and aid farmers in improving their production efficiency. In Latin America, many countries do not have active swine programs. Emphasis is being given by the Swine Program to developing these national centers and to obtaining financial support to aid in their development and operation.

Progress was made in helping plan programs for Costa Rica, Bolivia and Nicaragua. International and national agencies were approached for financial support. If support is obtained, these three programs will become operational and greatly extend CIAT's network and efforts to improve swine production in Latin America.

During May, a seminar on swine production held in San Jose, Costa Rica, was attended by 135 swine teaching, research and extension personnel.

A Seminar on Swine Production Systems in Latin America was held in Cali, Colombia, in September. More than 85 leading scientists in the field of swine production, teaching and research, discussed the swine industry in Latin America and participated in sessions dedicated to economics and swine feeding in the lowland tropics. Numerous linkages were established between CIAT and national programs.


Food
Legumes
Production
Systems

Many Latin Americans eat beans, which frequently are their principal source of protein. Consumer prices of beans, however, have reached levels that cannot compete with the lower prices at which the high-yielding varieties of cereals are available. One of the main reasons for the high price of beans is the limited offer in relation to the demand. The limiting factor on supply is the low yield obtained even with improved varieties. The national average in Latin America is approximately 500 kg/ha as compared with 1,400 kg/ha in the United States. Even this higher yield is low when compared with those of high-yielding cereals. Therefore, efforts to increase bean yields are essential, but the reasons for the low yields are not clear. Through concentrated, multidisciplinary research, it should be possible to determine why yields are low and to find ways to increase them.

In May, 1972, the Board of Trustees approved a program intended to work primarily on beans (**Phaseolus vulgaris** L.) at the regional level in Latin America and the Caribbean. In October, a Bean Production Systems program was established, which included such disciplines as: plant breeding, plant pathology, entomology, plant physiology, soil microbiology, agronomy, and agricultural economics.

Because of earlier exploratory work begun at CIAT on other species, the reported activities in 1972 also included work on other food legumes.

BREEDING

USDA/ARS Bean Collection. Since 1970, from a total of 3,780 collections that have been evaluated, 1,097 have been selected as resistant to rust, 355 to the leaf bacterial complex, and 214 to the virus complex. From these, 500 have been selected for future studies.

Germ plasm evaluation. The population being studied at Palmira (altitude 1,000 m, 24°C, and rainfall 930 mm) includes 3,054 collections. These come from Costa Rica (966), Guatemala (201), Mexico (488), the United States (1,089), and Venezuela (310). From these, 3,010 belong to the species **P. vulgaris,** and 44 to **P. lunatus, P. acutifolius, P. calcaratus, P. angularis, P. aconitifolius, P. coccineus, Vigna sinensis,** and **Cajanus cajan.**

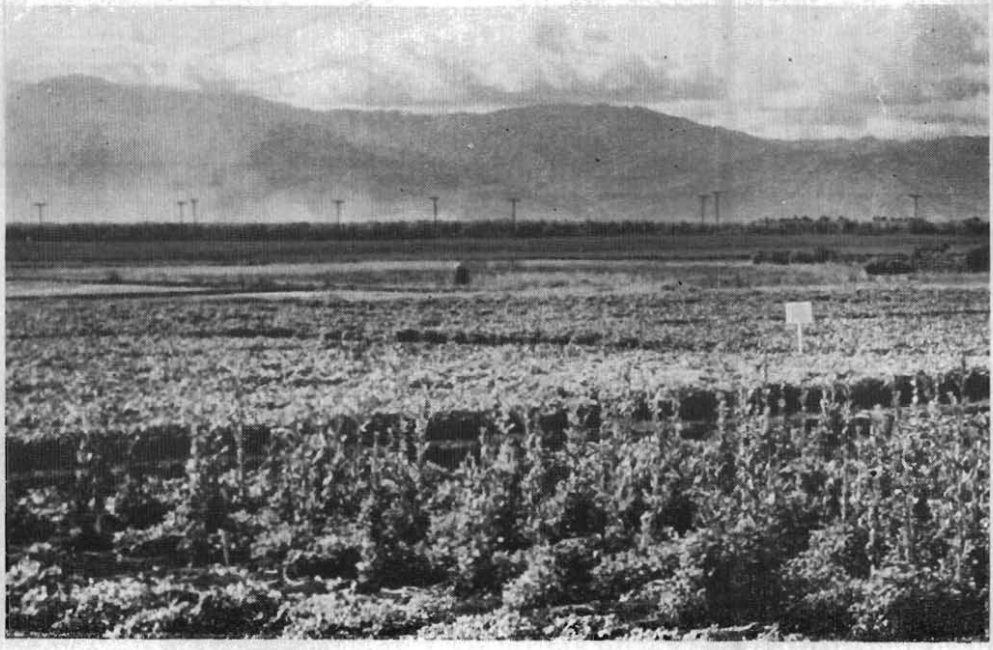
P. vulgaris* collections are being observed for 23 characteristics. One hundred and forty selections have been made taking into consideration the fruiting ability and plant structure, clusters per plant, and pods per cluster.

The same collections will be evaluated next year in different environments to separate genotypes with high yield potential, with resistance to diseases and pests, and with adaptation to the high tropical temperatures.

The 108 selections previously made in Palmira were planted at the ICA Experiment Station at "Turipana" (altitude 40 m, 27°C, and rainfall 1,500 mm). Heavy rains destroyed 90 percent of these selections, but 10 percent (eight selections) survived the highly humid conditions. From the eight selections, four showed good fruit formation at high temperatures. These selections will be closely evaluated in the future.

* Throughout this report, **P. vulgaris** refers to **Phaseolus vulgaris** L.

Seed increase plot of Phaseolus vulgaris.



Several thousand varieties of field beans (Phaseolus vulgaris) **are being screened at CIAT. Evaluations include behavior of beans when interplanted with maize, a common practice in Latin America.**

AGRONOMY

Tolerance to soil acidity. Trials show a wide range of varietal tolerance to soil acidity among the food legumes as well as other species, as discussed in the Soils chapter (page 163 of this report). Interesting varietal differences are found among the **Phaseolus vulgaris** (Fig. 1). The black beans included in the trials (5 entries) are much better adapted to acid soil than the non-black beans (7 entries). Cowpeas (**Vigna sinensis**), uniquely adapted to acid soils, respond mainly to the first increment of lime, while the field beans respond to lime across the entire range with no yield at the 0 and ½ ton/ha levels in the case of the non-black beans. These results point to the potential importance of **Vigna sinensis** and **Phaseolus vulgaris**, especially the black varieties, in acid soil regions as a prime source of protein.

Micronutrient studies. Micronutrient trials with soybeans and beans were conducted at CIAT. Preliminary results indicate that zinc and boron are the principal limiting factors (Fig. 2). Soybeans appear to have varietal differences in response to micronutrients. Pelican shows more tolerance to conditions of micronutrient deficiencies than do Hill or Mandarin.

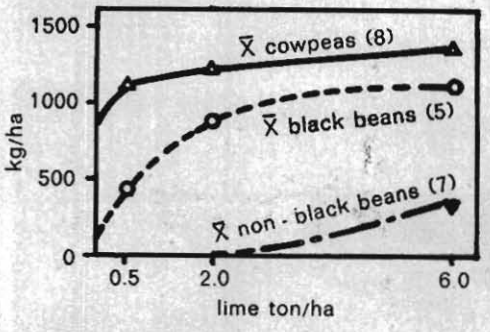


Fig 1. Effect of lime on yields of **Phaseolus vulgaris** (black and non-black varieties) and cowpeas. Data from Carimagua acid soil tolerance screening, 1971.

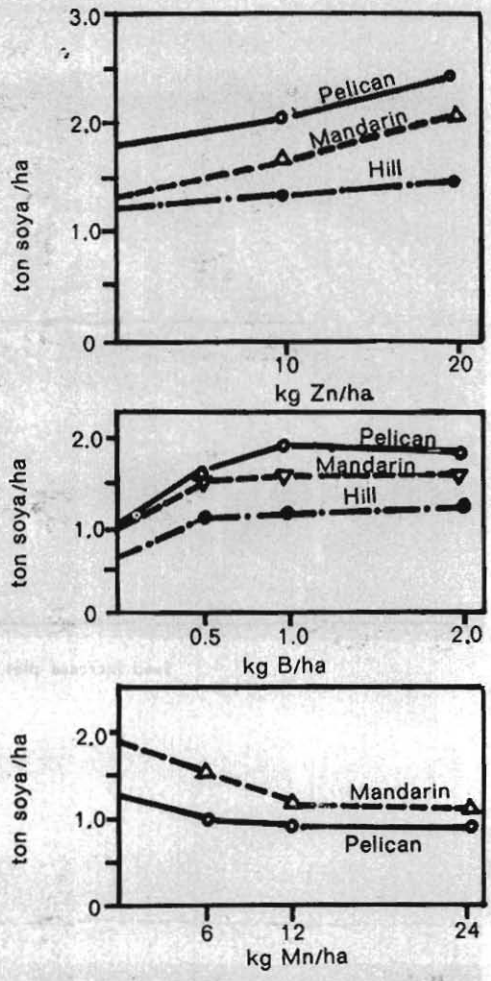


Fig 2. Response of soybean varieties to applications of zinc, boron, and manganese.

PLANT PATHOLOGY

Diseases are one of the major limiting factors in bean production. Many diseases affect beans. The literature reports 252 pathogens on beans in the tropics as compared with 52 in the temperate zone. It will be important to establish priorities in pathology research, to seek resistance to several pathogens and to incorporate the resistance into desirable plant materials.

Disease survey. A survey of bean diseases has been started by exchange of correspondence with bean workers in

Latin America and through visits by the CIAT pathologist to the bean producing areas.

Most bean researchers agree that rust (**Uromyces phaseoli** var. **typica**), common bacterial blight (**Xanthomonas phaseoli**), golden yellow mosaic, the virus complex and the root-rot complex are the most important diseases. Other diseases, either locally or regionally important, include web blight (**Thanatephorus cucumeris**), anthracnose (**Colletotrichum lindemuthianum**), and angular leaf spot (**Isariopsis griseola**). Observations in Costa Rica, Guatemala, Nicaragua, El Salvador, and Colombia agree in general with the above conclusion plus the addition of web blight and round spot (**Chaetoseptoria wellmanii**).

Epiphytological studies. Distance between rows and among plants plays an important part in epiphytotics of beans. Initial observation from a "parallel rows" experiment still in the field, shows that oidium (**Erysiphe poligoni**) affects the plants on all experimental distances, but there are considerable varietal differences in regard to incidence of rust, angular leaf spot, and common bacterial blight.

Varietal screening. The most economical and efficient way of controlling diseases is by the development of partially resistant varieties (horizontal resistance). Therefore, we have taken advantage of the germ plasm planted in the field in order to make field observations on rust and oidium incidence. From the 1,754 populations planted at CIAT, in which an epiphytotic of oidium was present, 241 showed resistance, and from the 1,320 collections at ICA where rust was prevalent, 396 showed resistance to the local races of the pathogen.

From these locally resistant collections, international nurseries will be formed for testing in different countries and under various environmental conditions.

Common bacterial blight nursery. In collaboration with the USDA and Michigan State University, a nursery of 200 varieties was planted assuring good infection of **Xanthomonas phaseoli.** From these varieties, 58 were resistant to the common bacterial blight.

ENTOMOLOGY

A review of available literature about insects and related pests indicates that some 208 species attack beans in Latin America. A CIAT study of cutworms (**Spodoptera frugiperda**) in beans showed that cutworm damage increased as the rainfall rate increased and decreased with dry weather.

WEED CONTROL

Some work has been done already in chemical weed control in food legumes. Routine testing of herbicides has not been part of CIAT's weed control activities. The evaluation of the feasibility of certain herbicide combinations and the determination of yield losses because of weeds received primary attention.

Herbicide combinations in dry beans. Two of the recommended bean herbicides, Trifluralin and Vernolate, satisfactorily control a wide range of narrow-leaf weeds. Both products are somewhat weak on several of the broadleaf species, and thus the use of a herbicide combination would give ample and efficient weed control. Both Trifluralin and Vernolate must be incorporated into the soil before planting. Thus, the benefit of a tank mix (the combination of the two products mixed within the tank and applied simultaneously) is limited as frequently the second herbicide in the combination is simply surface-applied after planting. The convenience of applying a pre-plant herbicide before planting, and the pre-emergence application of a second herbicide was evaluated with both Trifluralin and Vernolate, in a split-plot design trial.

Another herbicide, Fluorodifen, with a wide margin of selectivity and which controls many weeds, was tried. Although it is not widely used by farmers because of its relatively high cost, in combination with other less expensive herbicides this product might be practical as the mixture would have a lower overall cost and provide an effective, economical treatment in a given planting.

The results indicated that the combinations tested effectively control weeds. Yields were not reduced by any treatment because of herbicide injury (Table 1). No injury symptoms were observed at any time.

The worst controls were those where only half the normal rate of Trifluralin, Vernolate and Fluorodifen were applied with the purpose of making a valid comparison among combinations. In general, Fluorodiphen and Prometryne in combination with nearly any of the other products gave the best control. The harvestability was always lowest when Methazole was present in the mixture because **Ipomoea** sp. is resistant to it. This species can cause serious harvesting problems because of its climbing and twining growth habits.

The overall weed population was low throughout the season, and there was no significant yield reduction in the check plot. The method of planting dry beans in alternating row spacings of 30 and 60 cm is effective in obtaining full foliage coverage early in the life-cycle of the crop. This observation is important to keep in mind as an effective cultural weed control method.

SOIL MICROBIOLOGY

In Colombia, as in most other countries on the western coast of Latin America, the inoculation of leguminous plants to promote nitrogen fixation is seldom done. A major reason for this is the low quality of locally produced inoculants and the death of imported cultures during transit and storage. A typical result is presented in Table 2, where all but two of imported soybean inoculants have failed to enhance nodulation. Therefore, the early experimental program has aimed at producing locally, high quality effective inoculants, able to withstand transit conditions of a tropical or semi-tropical nature. We have emphasized the collection of strains and their testing for nitrogen fixing ability in symbiosis, the development of the organic carrier media needed to ensure **Rhizobium** viability during transit and storage, and have investigated obvious problem areas in the use of these inoculants.

Strain selection and testing. During 1972, some 400 isolations were made from nodules of both native and commercially grown legumes. The **Rhizobia** obtained have been characterized and preserved by lyophilisation. The collection includes more than 100 isolates from **Phaseolus vulgaris,** as well as strains from **Alysicarpus, Bauhinia, Centrosema, Crotalaria, Desmodium, Glycine, Leucaena, Mimosa,** assorted **Phaseolus** species, **Pisum, Rhynchosia, Sesbania, Stizolobium, Stylosanthes** and **Trifolium.**

Testing of isolates from **P. vulgaris** using small pot and Leonard jar assemblies is not yet completed, but in early testings inoculation has influenced grain yields as much as 100 percent.

Organic carrier media for inoculants. To be suitable as inoculant carriers, substances must maintain high viability of **Rhizobium** for periods up to three months, be neutral or neutralizable in pH, and have high water holding capacity. Materials high in organic matter generally best protect the **Rhizobia,** with peat being the most common inoculant carrier. During 1972 we located, and are now comparing, six different substances possibly suitable as inoculant carriers. The characteristics of two of these substances are shown in Table 3. Inoculants produced during 1972 were shipped in the Sibundoy peat, in bagasse, or in

TABLE 1. **Total weed control, harvestability ratings and yield of dry beans with herbicide combinations and mechanical weedings.**

	Herbicides	Rate kg a.i./ha	Time [1]	Total control[2] 30 days	60 days	Har [3]	Yield [4] kg/ha
1.	Trifluralin	.75	PPI	6.7	4.0	3.7	1,455
2.	Trifluralin + Linuron	.75 + 1.5	PPI PRE	7.5	6.5	4.5	1,855
3.	Trifluralin + Prometryne	.75 + 1.5	PPI PRE	8.5	8.7	3.7	1,577
4.	Trifluralin + Methazole	.75 + 2.0	PPI PRE	7.2	7.5	3.2	1,433
5.	Trifluralin + Fluorodifen	.75 + 2.0	PPI PRE	8.5	9.2	3.7	1,866
6.	Trifluralin + Benthiocarb	.75 + 2.25	PPI PRE	8.0	8.2	3.7	1,600
7.	Trifluralin + DNBP	.75 + 2.0	PPI PRE	5.5	2.5	3.5	1,577
8.	Vernolate	2.0	PPI	4.0	7.0	4.2	1,688
9.	Vernolate + Linuron	2.0 + 1.5	PPI PRE	7.0	7.7	4.5	1,744
10.	Vernolate + Prometryne	2.0 + 1.5	PPI PRE	9.0	10.0	5.0	1,633
11.	Vernolate + Methazole	2.0 + 2.0	PPI PRE	7.0	7.7	3.2	1,566
12.	Vernolate + Fluorodifen	2.0 + 2.0	PPI PRE	8.5	9.0	3.5	1,700
13.	Vernolate + Benthiocarb	2.0 + 2.25	PPI PRE	8.0	8.5	4.2	1,888
14.	Vernolate + DNBP	2.0 + 2.0	PPI PRE	7.2	7.5	4.5	1,755
15.	Fluorodifen	2.0	PRE	0.0	4.5	3.5	1,800
16.	Fluorodifen + Linuron	2.0 + 1.5	PRE PRE	7.7	8.7	4.2	1,744
17.	Fluorodifen + Prometryne	2.0 + 1.5	PRE PRE	8.5	9.2	4.5	1,133
18.	Fluorodifen + Methazole	2.0 + 2.0	PRE PRE	3.7	2.5	3.2	1,422
19.	Fluorodifen + Fluorodifen	4.0	PRE	9.2	9.2	4.7	1,466
20.	Fluorodifen + Benthiocarb	2.0 + 2.25	PRE PRE	7.0	8.5	3.7	1,555
21.	Fluorodifen + DNBP	2.0 + 2.0	PRE PRE	8.7	8.7	4.5	1,611
22.	Weeded check 20-40 days	—	—	8.7	9.5	5.0	1,922
23.	Weeded check 30-60 days	—	—	10.0	10.0	5.0	1,800
24.	Control	—	—	1.7	0.0	3.2	1,688

[1] PPI = Pre-plant incorporated.
PRE = Pre-emergence.

[2] 0 = No control; 10 complete control.

[3] Harvestability: 0 = Non-harvestable; 5 = Completely harvestable.

[4] Yield at 13% moisture.

TABLE 2. **Average nodule number per soybean plant found at time of flowering in two stations in Ecuador[1], 1970[2].**

Inoculant	Boliche	Porto Viejo
Nitragin	31.00	23.25
E.Z.	22.80	26.00
Urbana	12.50	12 80
Legume AID	1.00	5.20
Noctin	1.20	0.20
Dormal	0.50	0 50
No inoculation	3.00	0.00
100 kg/ha N	0.00	0.20

1 In CIAT fields, the average nodule number per plant has been 45 using CIAT inoculant.
2 INIAP data.

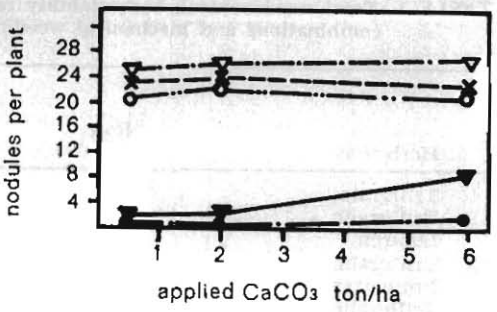
mixtures of the two. (See Fig. 2, Beef section, page 17).

Pelleting of seeds to improve nodulation under acid conditions. Acid soil as experienced in the eastern Llanos of Colombia can adversely influence strain survival in soil and result in nodulation failure. Because of this, we have examined the need for inoculation and/or pelleting under acid soil conditions using **Phaseolus vulgaris, Vigna sinensis, Stylosanthes gracilis, Leucaena leucocephala** and **Centrosema pubescens** as test plants.

The results for **Phaseolus vulgaris** and **Vigna sinensis** as shown in Figs. 3 and 4, indicate that:

TABLE 3. **Characteristics of representative peats from the Sibundoy and Rionegro districts of Colombia.**

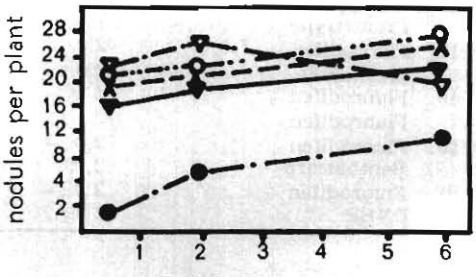
	Sibundoy peat	Rionegro peat
pH	3.9	5.1
Grams $CaCO_3$/kilo peat to raise pH to 6.5	330	100
Al (mequiv/100 g peat)	12.0	9.5
C.E.C. (mequiv/100 g peat)	74.6	92.6
Fe (ppm)	2.37	39.2
Mn (ppm)	212.0	1.4



species: ***Phaseolus vulgaris***
F (inoculation) = 256.84***
F (lime application) = 7.53*

symbols:
pelleted with $CaCO_3$
pelleted with Carolina rock phosphate
pelleted with Boyaca rock phosphate
inoculated
uninoculated

Fig. 3. Influence of inoculation method and lime application on nodule number per plant in Carimagua soil (**Phaseolus vulgaris** var. ICA-Tui).



species: ***Vigna sinensis***
F (inoculation) = 31.44***
F (lime application) = 5.43*
symbols: same as in Figure 3

Fig. 4. Influence of the inoculation method and lime application on nodule number per plant in Carimagua soil (**Vigna sinensis**).

a) All plants tested needed inoculation to obtain adequate nodulation.

b) Seed pelleting with either ground limestone or rock phosphate as the pelleting agent resulted in good nodulation of all species, even at low soil calcium levels.

c) The material known as Escorias Thomas was unsatisfactory as a pelleting agent (Table 4).

Nodulation characteristics of Phaseolus vulgaris. Of the different species of root-nodule bacteria, the least studied to date has been **R. phaseoli.** Because of its importance to the agriculture of Latin America, we have begun an in-depth study of the interaction of **R. phaseoli** with different bean varieties. In the first stage in this study, we examined the nodulation characteristics of four varieties of **Phaseolus vulgaris** when inoculated by four different strains of **R. phaseoli.** Features examined included time to first nodule formation, nodule number, weight and disposition with time, commencement and duration of fixation, and plant dry weight changes. Noteworthy points in these results are:

a) Satisfactory nodulation was obtained in all treatments when sand was used but nodulation was poor under Palmira soil conditions. This was probably because of the high NO_3^- in these soils (47.3 ppm N as NO_3^-).

b) There was considerable **Rhizobium**-host interaction. Even when there were no obvious differences in plant development resulting from the inoculant strain used, as for example in the varieties Guali and Calima, there were significant differences in the number of nodules found per plant and in the dry weight per nodule. Results for the variety Calima are shown in Figs. 5 and 6.

For the variety 20574 (M3) 13 (M2), the strain CIAT 57 was

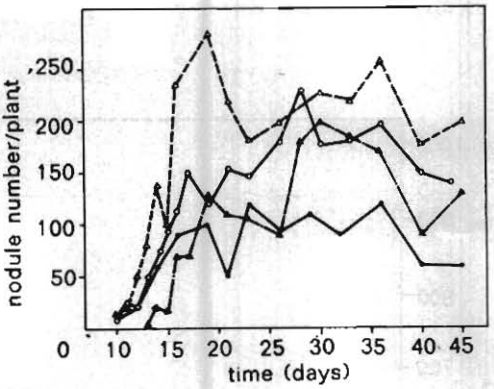


Fig 5. Average nodule number per plant (variety ICA-Calima) with time, as influenced by four different inoculant strains.

TABLE 4. **Influence of the inoculation method and lime application on the number of nodules per plant of** Phaseolus vulgaris **var. Calima in the Carimagua soils[1].**

Treatment	Added $CaCO_3$ (ton/ha)		
	0.5	2.0	6.0
Inoculated	1.00	1.50	2.50
	1.00	2.00	2.75
	1.50	10.00	4.50
Inoculated and covered with $CaCO_3$	10.75	44.25	29.75
	25.75	23.75	20.00
	32.00	51.25	15.00
Inoculated and covered with Escorias (Basic slag)	2.00	5.75	2.00
	0.75	2.25	2.00
	1.50	1.75	3.75

[1] Each figure is the average of four plants per pot.

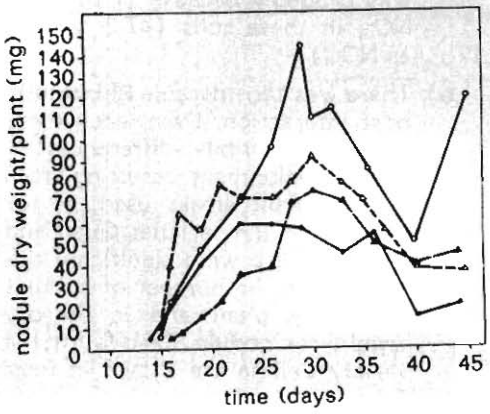


Fig. 6. Average nodule dry weight per plant (variety ICA-Calima) with time, as influenced by four different inoculant strains.

clearly superior, producing appreciably more dry matter and nodule dry weight per plant than the other strains (Figs. 7 and 8).

c) Differences in time to first nodule formation were noted, an important feature where the growing cycle is short.

d) Assuming equal seedling rates and proportions of active nodule tissue, the red seeded varieties tested would fix more nitrogen per hectare than the beans of the caraota (black) type.

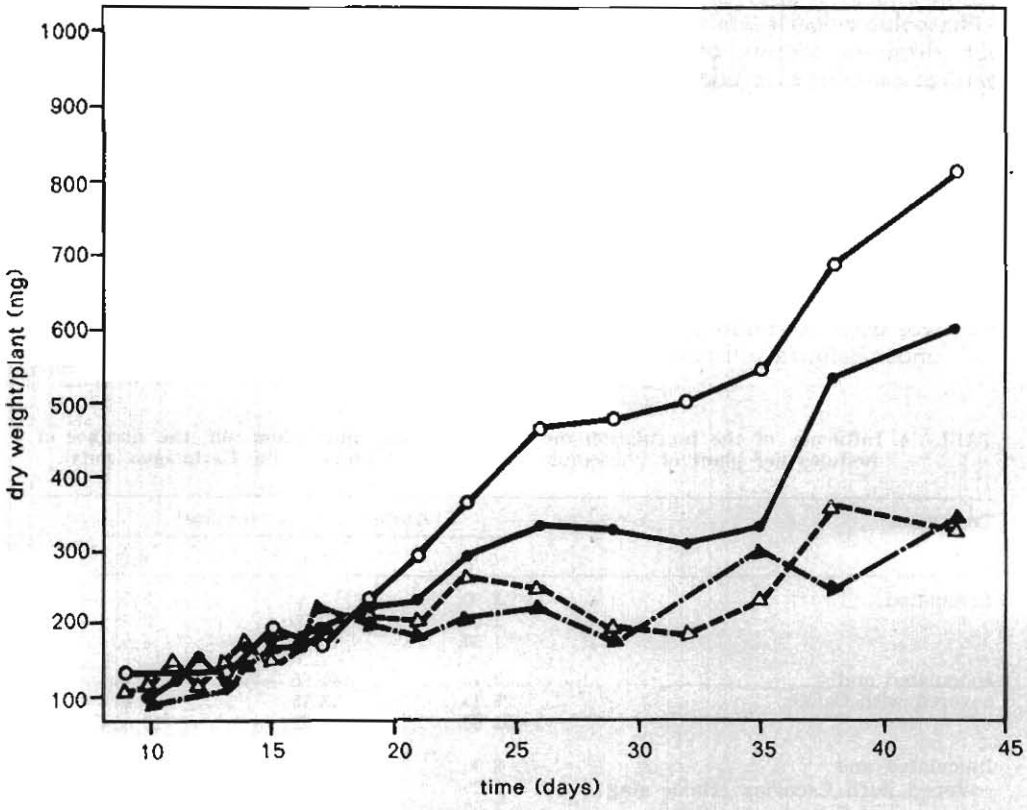


Fig. 7. Increase in dry weight per plant, with time, variety 20574 (M3) 13 (M2), as influenced by four different inoculant strains.

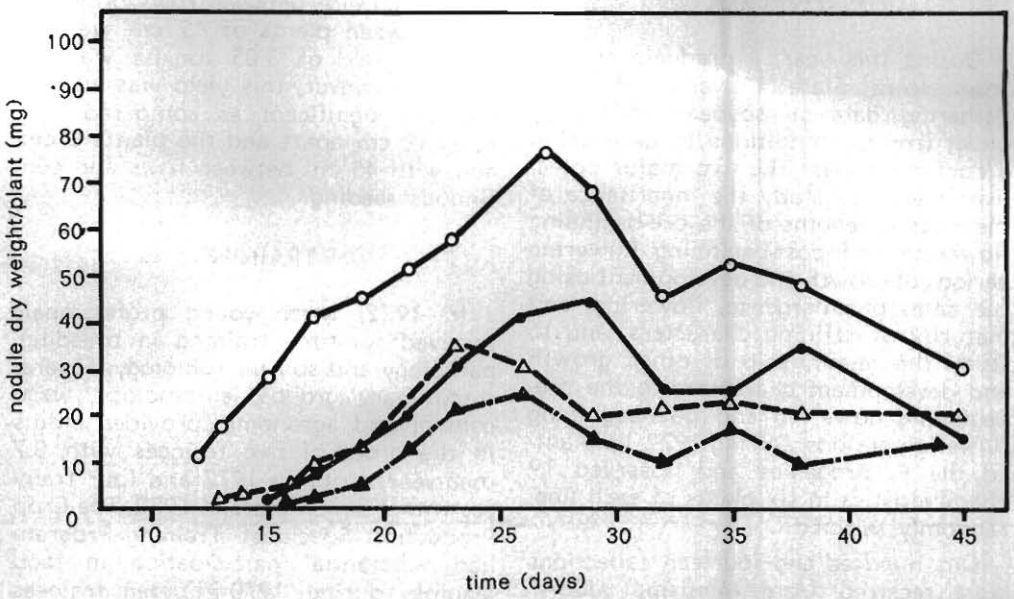


Fig. 8. Average nodule dry weight per plant, with time, variety 20574 (M3) 13 (M2), as influenced by four different inoculant strains.

Research workers plant field beans in six-meter rows

SOYBEANS

During this year, a graduate student from Iowa State University finished gathering data on soybean physiology under tropical conditions to be used in a doctoral thesis. The two major objectives were: to study the inheritance of the relative lengths of the pre-beginning flowering and post-beginning flowering periods of growth and development using the dates of emergence, flowering, and maturity as defining characters, and to study the relationship of other growth and development characters to the pre-beginning flowering and post-beginning flowering periods. During 1972, he planted the F_4 progenies and observed 19 characteristics in six plants of each line, randomly selected.

One hundred and fourteen collections were received from Missisippi USDA/ARS. From these, 14 individual selections were made based on apparent high-yielding capacity and resistance to diseases.

A study of different populations per unit area with the variety Davis indicated that a distance between rows of 12 cm and between plants of 12 cm was the best. A yield of 3.05 ton/ha was obtained. However, this yield was not statistically significant as compared with rows 18 cm apart and the plants 8 cm, and with 45 cm between rows and continuous seeding.

TRAINING

In 1972, three young professionals received full-time training in breeding, pathology and soil microbiology. Several disciplinary groups, entomology, weed control and agronomy, provided inputs in the order of five trainees with 0.7 man-years prior to 1972 and four trainees with 1.3 man-years in 1972. The Crop Production Specialist Training Program had substantial participation in food legumes during 1970-71; ten trainees participated, representing 3.0 man-years. In 1972, 14 trainees, amounting to 4.6 man-years of training, acquired experience in the fields with field beans, soybeans, and cowpeas plus related components of the production systems.

Maize Production Systems

Maize is primarily a subsistence crop in Latin America with the exception of small pockets of technology - Cauca Valley of Colombia, Coast of Peru, State of Portuguesa in Venezuela, among other areas - the crop is grown for direct family consumption as green corn or dry grain, and in plots generally less than five hectares in size, even on large farms. Research, development, and training efforts are being directed at this scale of agriculture, to complement the work of national programs in the zone to increase yields and improve the quality of farm family diets.

Principal technical factors which currently limit maize production and quality in the Andean zone are: 1) excessive plant height and low production efficiency, 2) narrow adaptation of commercial materials, 3) low protein quality, compared to improved genetic mutants now available, 4) insect attacks by **Spodoptera** spp. (soil cutworm and whorl worm) and **Diatraea** spp. (stalk borer) which reduce plant populations and yields, 5) special problems such as the acid soils of the interior plains of Venezuela, Colombia and Brazil, and 6) absence of an integrated production package to offer the farmer.

The CIAT Maize Program is one part of the international maize research and development program coordinated by the Centro International de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico. On the farm in Palmira and with collaborating institutions, CIAT tests new CIMMYT selections which are promising for the Andean zone. International and regional trials from CIMMYT and other regions are also distributed through CIAT. In summary, CIAT represents CIMMYT in the Andean zone, and coordinates various improvement efforts with the national programs.

BREEDING

The improvement program, in collaboration with ICA (Colombia), and INIAP (Ecuador), concentrates on reducing plant height (thus improving crop efficiency and the ability of the plant to remain upright) and widening the adaptation of potentially useful maize populations. The objective is to improve the population for distribution to national programs and commercial companies. Protein quality improvement is reported under maize nutrition.

Basic material for reducing plant height was introduced primarily from CIMMYT in Mexico, with brachytic progeny and short plant selections, and from other programs in the Andean zone, Central America and Asia. These selections are planted in the Cauca Valley at 1000 m elevation in progeny yield trials, and crosses made between individual plants in selected families. Criteria for selecting individuals and families before making crosses are seedling vigor, early vegetative growth, apparent resistance to insect and pathogen attacks to the foliage, ample pollen production, and prolificacy. Further selection is made at harvest, based on yield, lodging resistance, and evidence of resistance to borers. The full-sib progenies are then planted in four locations in the next season to observe the yield of each cross under a wide range of climatic conditions: La Selva

Pollen from a selected male plant falls onto the silk of a selected female, a critical moment in the maize crossing sequence.

(Rionegro, Antioquia, Colombia), 2,100 m; Palmira (Valle, Colombia), 1,000 m; Turipana (Monteria, Cordoba, Colombia), 40 m; and Boliche (Guayaquil, Ecuador), 20 m.

In the next step, there are several alternatives. To obtain a population specifically adapted to a particular test location, the entire trial may be harvested as an open-pollinated mixture of desirable germ plasm. An alternative is to construct a balanced composite of open-pollinated ears from the highest yielding or otherwise desirable families. A more controlled composite may be derived from a mixture of remnant seed from the best progeny, based on the yield data of the progeny trial. Immediate production of a hybrid specific to each test location may be achieved by increasing remnant seed of specific parents and combining these into a commercial single cross. These schemes are all location specific.

To widen the range of adaptation of this population, progenies are being evaluated in yield trials in several locations. The several best progeny across all locations may be recombined into a new population which has a wider potential range of application. As in the previous specific scheme, a progeny which performs well across the zone can be reconstructed from the remnant seed of

Progeny selections in maize are based on yields and agronomic characteristics at several testing locations.

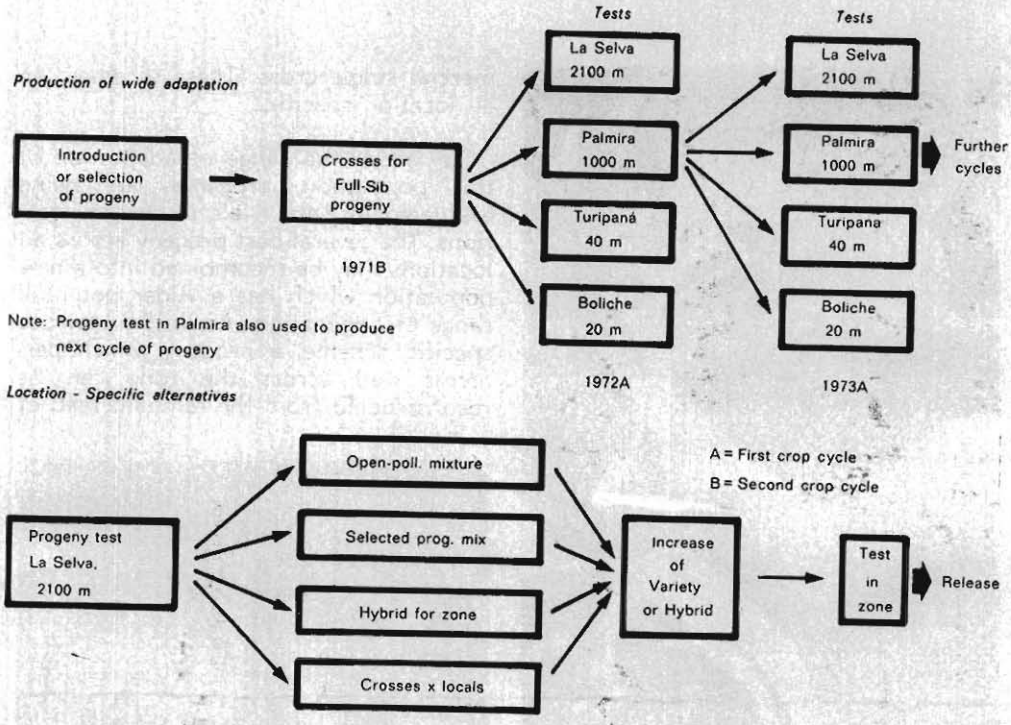


Fig. 1. Full-sib family selections for wide adaptation of brachytic and short-plant selections.

the lines and the hybrid produced after increasing the seed. To further increase the yield potential of the population across the zone, the highest yielding families based on data from all locations are planted and another cycle of full-sib progeny produced from this elite material.

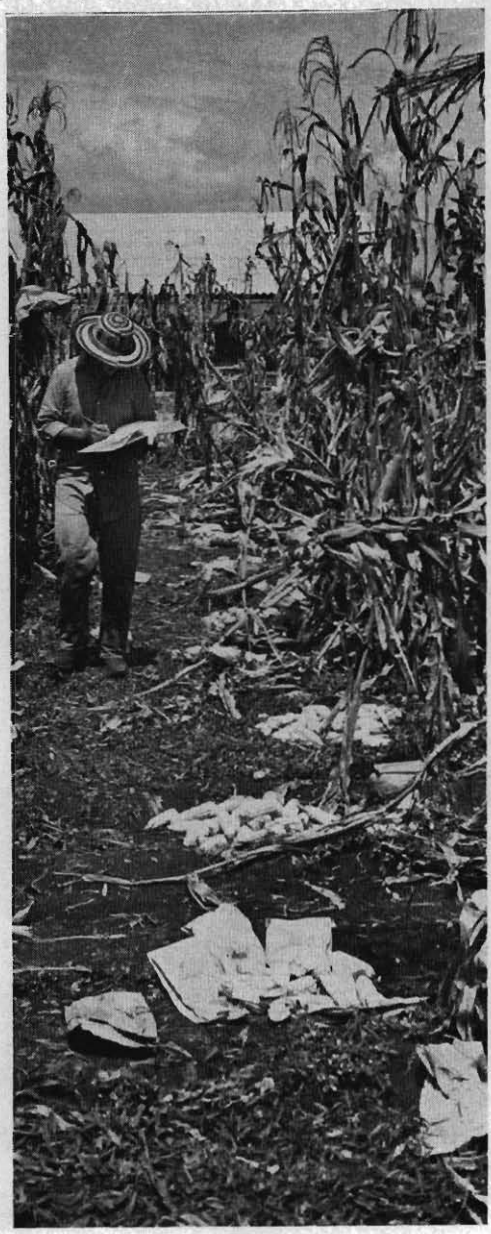
This improvement program based on full-sib families started two seasons ago, and the first cycle in several zones is now complete. Results show an exceptional range of altitude adaptation under which certain progeny performed relatively well (Table 1). On this basis, decisions are reached about which

TABLE 1. **Individual progeny yields from Trial E-72-28, short plant crosses planted in four locations in Colombia and Ecuador, 1972.**

Progeny	Yield (kg/ha)			
	Rionegro (2100 m)	Palmira (1000 m)	Monteria (40 m)	Guayaquil (20 m)
1	686	7,543*	3,676	2,652
2	4,343*	6,629*	5 044*	3,994*
5	3,200	5,257	4,959*	4,876*
17	3 657*	6,400*	6,498*	5,213*
19	7,724*	5,943*	3,847	2,860
23	914	5,600	5,814*	4 137*
36	3,657*	8,115*	4,018	4,134*
37	4 800*	3,086	4,018	5,306*
43	2,514	5,486	5,812*	3,732*
50	8,229*	5,943*	2 223	3,633
Average for trial	3,417	5 632	4,110	3,204

* Progeny yield above mean for that location.

progeny to use in a specific zone. A potentially valuable approach is to reproduce a hybrid from remnant seed which is specific to a zone: for example, progeny Nº 36 in Palmira, Nº 50 or 19 in Rionegro, Nº 17 or 43 in Monteria, and Nº 37 or 17 in Guayaquil. For population improvement over the entire range of climates, to widen the potential value of the population to breeding programs, the progeny to be recombined are those with best performance across locations: for example, numbers 2 and 17.



The maize selection process includes taking notes on harvested plots in the field; these opaque-2 trials were evaluated for ear rots as well as yield and adaptability.

An agronomist supervises pollination of full-sib families in the maize research program.

PHYSIOLOGY

Research interest continues to focus on the adaptation of maize and development of populations which will yield well and provide basic genetic material to other programs over a range in altitudes and latitudes. Factors influencing adaptation, such as photoperiod and temperature are studied in detail, while

Field workers indicate crosses between selected plants within selected families at harvest time, and afterwards, prepare the seed for planting the next cycle.

insects and diseases are considered in our breeding and progeny testing program across altitudes. Results from the past field cycles provide a relatively clear preliminary picture of photoperiod sensitivity in maize.

Screening for insensitivity

Artificial extension of day length in the field using incandescent bulbs has enabled us to screen for sensitivity and identify lines relatively insensitive to drastic changes in photoperiod. Results from two field cycles in Table 2 show the difference between three tropical sensitive maize genotypes and three subtropical or temperate insensitive types. These results are repeatable over cycles, and give a source of insensitivity for further development of populations which may be moved over a range of latitudes.

Critical light intensity

There are sharp cut-off points in the sensitivity reaction in rows of maize exposed to a gradient in light intensity in the field. To identify more precisely the critical light intensity for this reaction, dissections were made at one me-

TABLE 2. **Days to differentiation in maize grown under long days (17 hr) and natural short days (12.5 hr).**

	First test		Second test	
	Long days	Short days	Long days	Short days
Sensitive group				
ICA H.207	37	14	31	17
D.V.351	36	14	36	18
D.H.253	35	15	37	18
Insensitive group				
USA 342	20	13	17	16
Longear	18	13	17	16
Trojan O_2	13	12	17	13

ter intervals along the row of several sensitive varieties. A pronounced delay occurs near the lights. Within one meter in the row, there was a delay in differentiation of up to three weeks in the most sensitive variety, ICA V.503. There was variation in the critical distance, and thus the critical intensity, from six meters (six ft.c)* to nine meters (four ft.c) in the genotypes tested. The major delay in tassel differentiation is thus defined as about five ft.c, with some genetic variation in the response.

There was another characteristic delay in certain sensitive lines between the distances of 15 and 23 m from the lights. This corresponded to a light intensity of about one to two ft.c and again there was genetic variation among the lines tested, from no sensitivity at all to a one week delay at intensities specific to each genotype. These two distinct thresholds and delays in differentiation are both active in some genotypes such as ICA V.503. In others there is delay at the higher intensity but none at the lower level. This suggests a separate genetic control of each type of delay in floral initiation.

Critical day length

Past research has indicated a critical day length for maize between 13 and 15 hours. In a special study with three sensitive and two insensitive genotypes of maize grown under three photoperiods: 16.5 hr, 14.5 hr, and 12.5 hr (natural) days, there was no delay in the first two genotypes (insensitive). In the three sensitive types, there was a pronounced difference between the artificial 16.5 hr and 14.5 hr days. This suggests a critical day length for maize between 14.5 and 15 hours, considering these experimental results and the past work in this field.

Growth rate

In the same field tests, growth rates were measured in terms of leaf number and plant height. There was no difference among the several distances measured from the light source, from 2 m out to 30 m. Observations in several cycles confirm that there is no effect of extended photoperiod on growth rate up to the time of differentiation, and also that the growth or elongation of the stem is independent of differentiation of the tassel and ear.

Inheritance of photoperiod sensitivity

Sensitivity to photoperiod changes appears to be governed by a relatively simple inheritance system. Crosses of insensitive by insensitive lines give insensitive progeny. Crosses of insensitive by sensitive lines are either sensitive or insensitive, but rarely intermediate. Crosses of two sensitive lines are usually

* ft.c = foot candle.

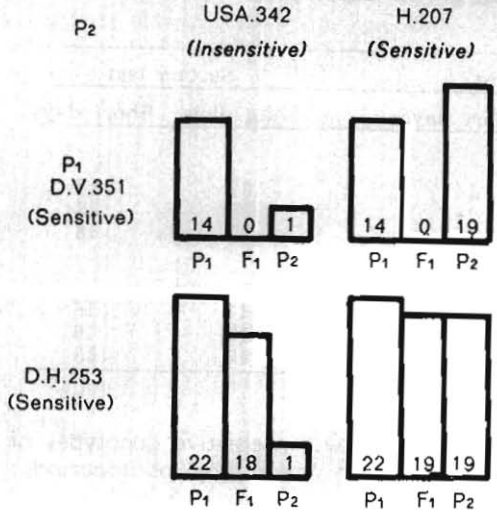


Fig. 2. Sensitivity to photoperiod changes in F_1 crosses. (Numbers are "sensitivity differences" in days between long and short day treatments).

sensitive, although an exception may occur. The lack of intermediate types indicates a simple inheritance system (Fig. 2). A new diallel set of crosses will test this inheritance pattern and produce advanced F_2 and F_3 generations for confirmation.

Interaction of photoperiod with temperature

To study the effects of temperature, and to test the interaction of temperature with photoperiod in influencing growth and development of maize, it was necessary to organize two additional testing locations. Currently, trials in collaboration with ICA include Turipana, near Monteria (40 m, 28ºC); Palmira, (1,000 m, 23ºC); and Tibaitata, near Bogota, (2,600 m, 13ºC). In the first cycle in three locations, there was apparently less sensitivity in the low elevation (high temperature) site on the coast. The opposite response was found in the high altitude location, where the low temperature apparently allowed a greater expression of sensitivity. These tests are being repeated. An adaptation study in collaboration with Purdue University and CIMMYT is also testing these location and climatic effects on growth, development, and grain protein quality.

Cold tolerance study

The international test of tolerance to cold and frost has been planted in the Andean zone in Colombia (San Jorge, 2,900 m and 3,100 m); Ecuador, (Santa Catalina, 2,700 m and 3,000 m); and Peru (Huancayo, 3,300 m).

Observations at San Jorge showed a striking difference between maize planted at 2,900 m, which grew relatively well and produced seed, and maize in the "paramo" or tundra zone at 3,100 m which barely germinated and did not grow more than 25 cm tall. Data from these trials in the Andean zone will be reunited with data from other locations in Asia, Africa and North America to obtain a new population based on performance across all testing sites. Resulting genetic materials should provide a germ plasm source for breeding programs which serve the high-elevation or high-latitude regions of the world.

PROTEIN QUALITY

Maize nutritional work has emphasized selection and testing of hard endosperm versions of opaque-2. First reported by Pradilla, Harpstead, and others in 1968, these maize selections maintain the quality of opaque-2, with an endosperm which is crystalline and acceptable to the consumer in lowland regions for the traditional types of food preparation. Results from the genetic conversions and work in human nutrition are reported here, while data from trials with rats and swine are presented under Swine Production Systems. A visiting scientist, Dr. Alberto Pradilla of the Universidad del Valle, is with CIAT on sabbatical leave in 1972-73 and is undertaking additional nutrition studies.

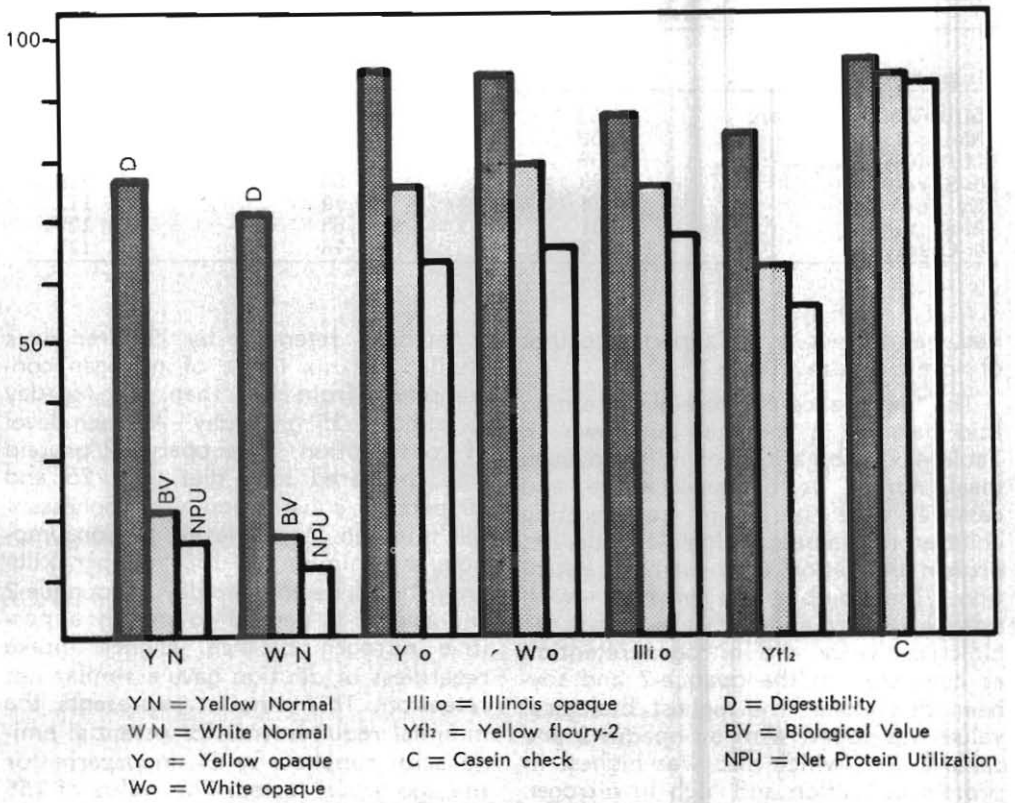


Fig. 3. Nutritional value of six maize genotypes, casein = 100.

Traditional opaque-2 hybrids

The nutritional value of the soft-endosperm opaque-2 hybrids has been confirmed in recent tests with children in the metabolic unit of the Universidad del Valle hospital. Such factors as digestibility, biological value, net protein utilization and nitrogen retention of two normal hybrids (H.207 and H.253), two Colombian opaque-2 hybrids (H. 208 and H.255), an Illinois opaque-2 hybrid (Illi o), and a floury-2 hybrid (Yfl_2) were compared in an experiment with a casein check. Digestibility and biological value are highest in the opaque-2 hybrids, while N retention and net protein utilization in all the modi-

TABLE 3. **Comparison of six maize types with casein check in children.**

	Digestibility	Biological value	Net protein utilization	Nitrogen retention
H.207	77	21	16	30
H.253	66	17	11	20
H.208	95	76	62	140
H.255	95	80	86	120
Illi o	88	76	67	170
Yfl_2	85	62	54	130
Casein	98	85	83	130

TABLE 4. **Comparison of utilization efficiency of seven test diets based on maize, soybeans, cassava and milk.**

Ingredients	Biological value	Net protein utilization	Nitrogen retention
Milk-Maize-Soybeans	68	61	115
Maize-Soybeans	59	51	102
Milk-O_2-Soybeans	59	50	97
O_2-Soybeans	63	53	114
Ev. milk	74	59	111
Mod. milk	81	65	127
O_2-Cassava	84	76	121

fied maize types is far superior to that of normal maize (Table 3).

The importance of protein and amino acid balance in the diet is shown in Table 4. Combinations of milk, soybean meal, normal vs. opaque-2 maize, and cassava were tested in recuperating children to evaluate biological value, net protein utilization, and nitrogen retention. The combination of milk with opaque-2 maize and soybeans lowers the biological value and nitrogen retention as compared to the opaque-2 and soybean diet alone. The highest biological value was found with an opaque-2 and cassava diet, which also was highest in protein utilization and high in nitrogen retention.

Nitrogen retention by children was studied for six levels of nitrogen consumption, from less than .2 g/kg/day to almost .35 g/kg/day. At each level of consumption, pure opaque-2 protein was compared to a diet with 25 and 50 percent substitution with nonessential nitrogen. At all levels of consumption, a minimum of 155 mg per kilogram body weight per day of opaque-2 endosperm is needed to obtain a positive nitrogen balance. Higher intake regardless of dilution gave a similar net retention. This amount represents the minimal requirements for essential amino acids supplied by O_2 endosperm for the age group tested. This value of 155 mg opaque-2 nitrogen may be compared

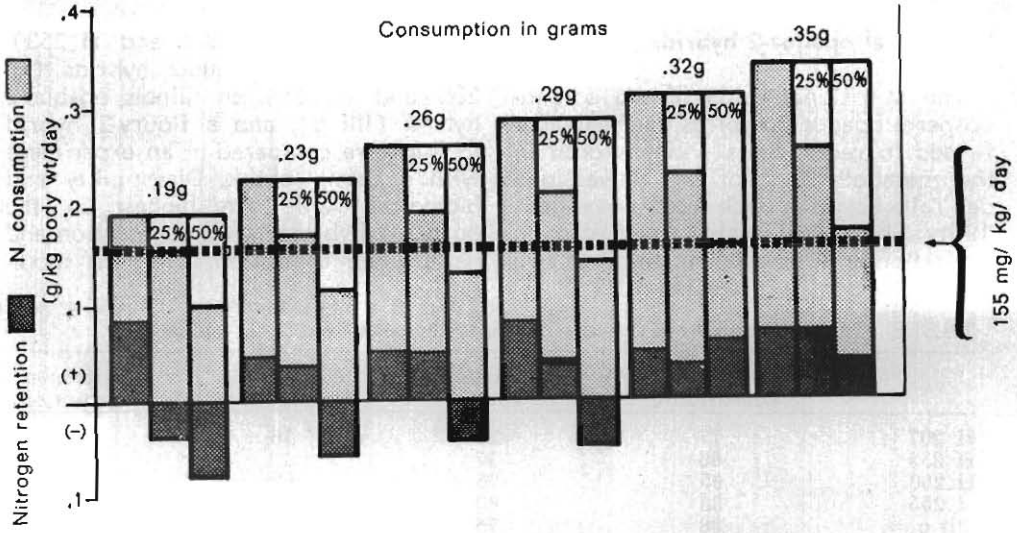


Fig. 4. Nitrogen retention by children when non-essential nitrogen is used to dilute opaque-2 protein; 25 percent and 50 percent substitutions are compared with non-diluted opaque-2 at six levels of consumption.

TABLE 5. **Level of maize consumption necessary to satisfy the total protein requirement of humans (achieve positive nitrogen balance).**

Body weight	Maize type	Grams/day
Child 10 kg (12 months)	Opaque-2	91
	Normal	225
Child 20 kg (40 months)	Opaque-2	181
	Normal	450
Young adult 50 kg	Opaque-2	454
	Normal	1125
Adult 70 kg	Opaque-2	635
	Normal	1575

to the amount of normal maize nitrogen, 360 mg/kg body weight/day, which is needed to maintain a positive balance. Table 5 shows the amounts of normal and of opaque-2 maize needed in the diet to satisfy the complete protein requirement, or at least to create a positive nitrogen balance. While it is unrealistic to think that anyone would consume only maize, the comparison between normal and opaque is impressive. In certain countries, such as Guatemala, where maize consumption averages 350 g/person/day, the farm family could satisfy a large portion of its protein requirement if maize production were shifted entirely to opaque-2 types.

Figure 5 demonstrates the recovery of children on an opaque-2 diet during six months in the metabolic unit of the Universidad del Valle hospital. The upper curve (N) shows the normal growth of children up to age six years. In the lower part of the figure are shown growth curves which divide the zones of first (I), second (II), and third (III) degree malnutrition. The "x" marks represent starting weights of individual children who entered the unit in a state of third degree malnutrition, and the straight lines show the recovery growth during their six-month period on the opaque-2 maize diet. This impressive recovery rate demonstrates the potential of the current opaque-2 maize hybrids in improving the nutritional health of children. However, there are still acceptability problems to be solved with this unfamiliar soft-endosperm maize.

Data from yield trials with farmers and acceptance surveys conducted in Colombia over two seasons to assess the potential use of opaque-2 maize in the middle and lowland regions of the country reveal some striking contrasts.

Yields were highly variable, particularly from farm to farm. No significant differences were found between the two growing seasons, among the six regions of the country, or between opaque-2 and the best normal-endosperm hybrids. There was a significant (25 percent) increase in yields when traditional farmer technology was replaced with a package of cultural practices which in-

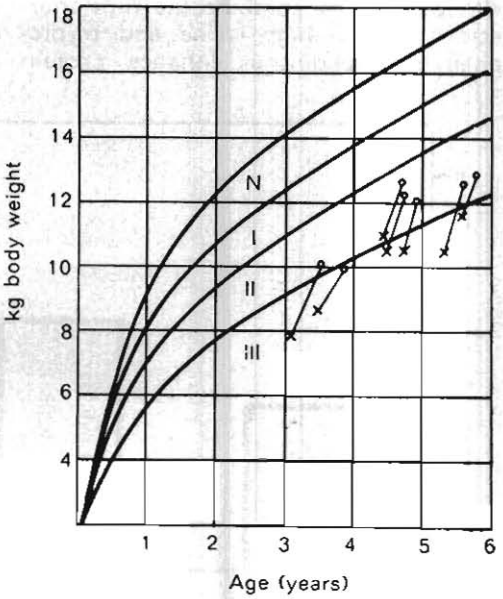


Fig. 5. Recovery growth on diets of opaque-2 protein.

cluded adequate fertility, insect control, and weed control. Opaque-2 hybrids substantially improved the yield potential over the farmer's traditional varieties, whether he used his existing technology (46 percent increase) or the package of improved practices (32 percent increase). These data are summarized in Fig. 6.

Comparing normal hybrids with their opaque-2 counterparts, there was a nonsignificant advantage for the normals, both in the yellow and the white versions. In 21 of the 75 trials harvested, an opaque hybrid was the highest yielding entry. These results indicate a significant potential for opaque-2 maize in the tropics.

Modifield crystalline types

To overcome problems of farmer and consumer acceptability, a strong research thrust is directed toward providing a maize more similar to the flint types currently grown and consumed in the lowlands. The first separation of crystalline, hard-endosperm types revealed that it was possible to combine the flint characteristic with high lysine and tryptophan levels and thus enhance protein quality. Two further selection cycles were completed in 1972 with both white and yellow endosperm maize, and these selections are now ready for recombination into useful source populations.

The first promising modified-endosperm opaque-2 population from CIMMYT, (Ver. 181 x Ant. Gpo. 2) x Ven. 1 opaque-2, has been increased in CIAT and tested with rats, in children and in a pilot plant study. Protein quality appears to be good, and commercial companies report no unusual problems with processing. This will be a valuable advantage over the current soft-endosperm types.

A whole grain ground sample received from CIMMYT, an endosperm sample from maize grown in CIAT and a casein control were compared in nutrition trials with children. Four levels of protein intake were studied. The net protein utilization and biological value of the two test diets were essentially equal to the casein check. This further confirms the quality of the new crystalline selection. Data on trials with rats and swine are reported under Swine Production Systems.

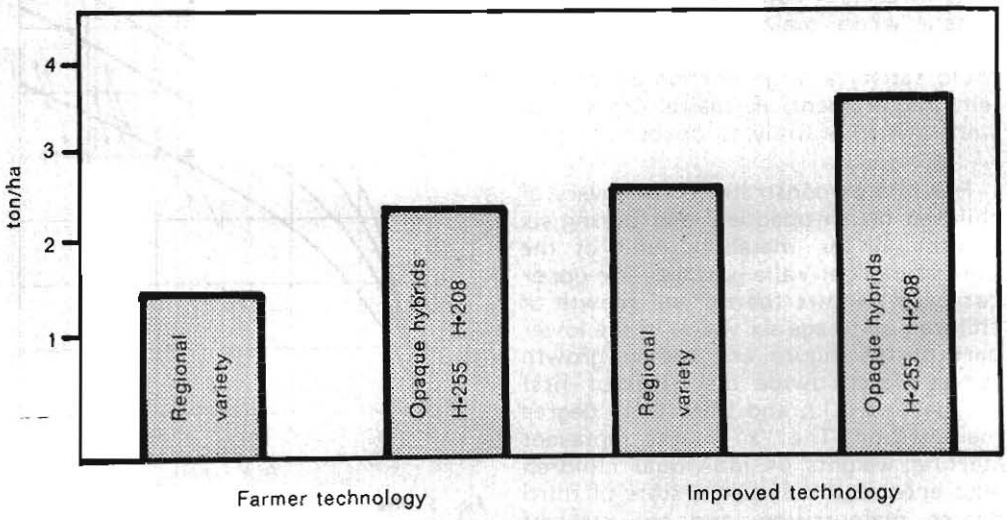


Fig. 6. Yields of opaque-2 hybrids (H-255 and H-208) compared to regional varieties under two levels of technology (yields in ton/ha).

Further nutrition work with maize

Techniques for simple selection of high quality individual kernels of either hard- or soft-endosperm maize are being perfected for use in the early steps of selection. These depend on thin sections of endosperm which are stained and observed with a microscope.

A new method for biological evaluation of extremely small quantities of maize endosperm is being tested in the Universidad del Valle hospital. In this test, human volunteers ingest a sample of the test maize prepared as an "arepa," a traditional corn bread in Colombia. Two hours later, a small sample of blood is drawn from each participant, and the level of free essential amino acids in this sample indicates with relatively accurate precision the amino acid content and total biological quality of the test sample.

AGRONOMY AND SOILS

The Agronomy/Soils group has been active in research and training on the alluvial soils at CIAT headquarters near Palmira and on the oxisols at Carimagua. At the first site, maize is of interest both as a cash crop and as a farm food crop. At Carimagua, the main interest is in maize as a food crop for people involved in the livestock industry. In Turipana on the north coast of Colombia, a graduate student and an agricultural engineer have worked with the heavy, poorly drained soils of this region. The weed control specialist has studied the interactions of weed competition with nitrogen fertilization.

CIAT site at Palmira

Reclamation of alkaline soils

Maize was used to measure the effects of gypsum, sulfur, manure and fertilizer applications on an alkaline soil where earlier crops of sorghum and soybeans were essentially total failures. The soil pH varies around 8.0 and Ca: Mg ratio approaches 1. High Mg appears to have a dispersing effect similar to that of Na. The soil amendment treatments were followed by almost a year of leaching by natural rainfall and irrigation. It appears that the principal response is to NPK application and that, in the absence of added fertilizer, the effects of gypsum and sulfur are negative (Fig. 7).

Uniformity trial

Maize was used to determine soil uniformity after land forming in a field not previously planted to row crops. Yields and "barrenness" indices (due to boron deficiency) were determined at harvest in 1,215 experimental units of two rows 30 meters in length. This proved useful in determining the most efficient use of the field for a number of replicated small plot experiments related to factors of soil fertility, especially boron and zinc deficiency, and soil management. Bean,

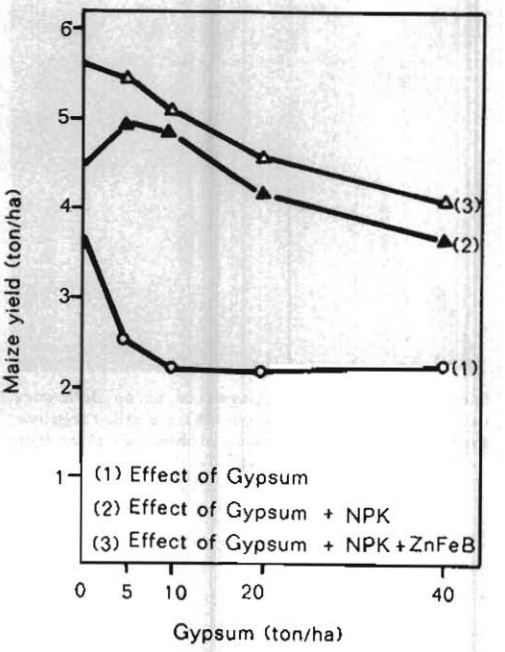


Fig. 7. Effects of gypsum, NPK, and ZnFeB on the recuperation of an alkaline soil.

Ear showing typical symptoms of boron deficiency, i.e., lack of pollination when silks are still receptive; such a deficiency is a serious problem on some tropical soils.

maize and sorghum varieties are being screened for tolerance to low levels of available boron, following preliminary information from previous seasons with sorghum and soybeans.

The uniformity trial was planted with a minimum tillage method of seedbed preparation, including disking and bed forming with an ordinary lister. A fixed traffic pattern was established which limited all wheel traffic to alternate middles.

The trafficked middles (furrows) served for drainage and irrigation with the corn planted on top of the beds. Soil physical conditions on non-compacted beds improved markedly during the season, leading to the design of a series of management experiments based on reduced and zero tillage methods. In addition, a two-hectare plot was seeded commercially with no tillage and all residue left on the surface. A standard planter was used with rolling coulters mounted in front of planter units to cut through the mass of residue and crowns from the previous crop, with the new crop planted on top of the old ridge. Planting was accomplished with no problems and stands were excellent.

Nitrogen application and weed competition

Effective weed control recommendations are already available for maize growers in the tropics, but there are insufficient weed competition data to establish the economic loss associated with weeds. A factorial experiment was established to study the possible interaction between nitrogen fertility and the type of weed control practiced on the degree of weed competition.

The results show obvious interactions, the most notable being the lack of response to N by maize in the weedy check plots. It was not profitable to apply N unless it were combined with some type of weed control. In general, the maize yield associated with any weeding method without N was only slightly above that of the weedy check. The greatest yield increase was obtained by integrating an effective weed control method (either manual or chemical) with the use of N, and the maximum yield response was produced at the high N rate.

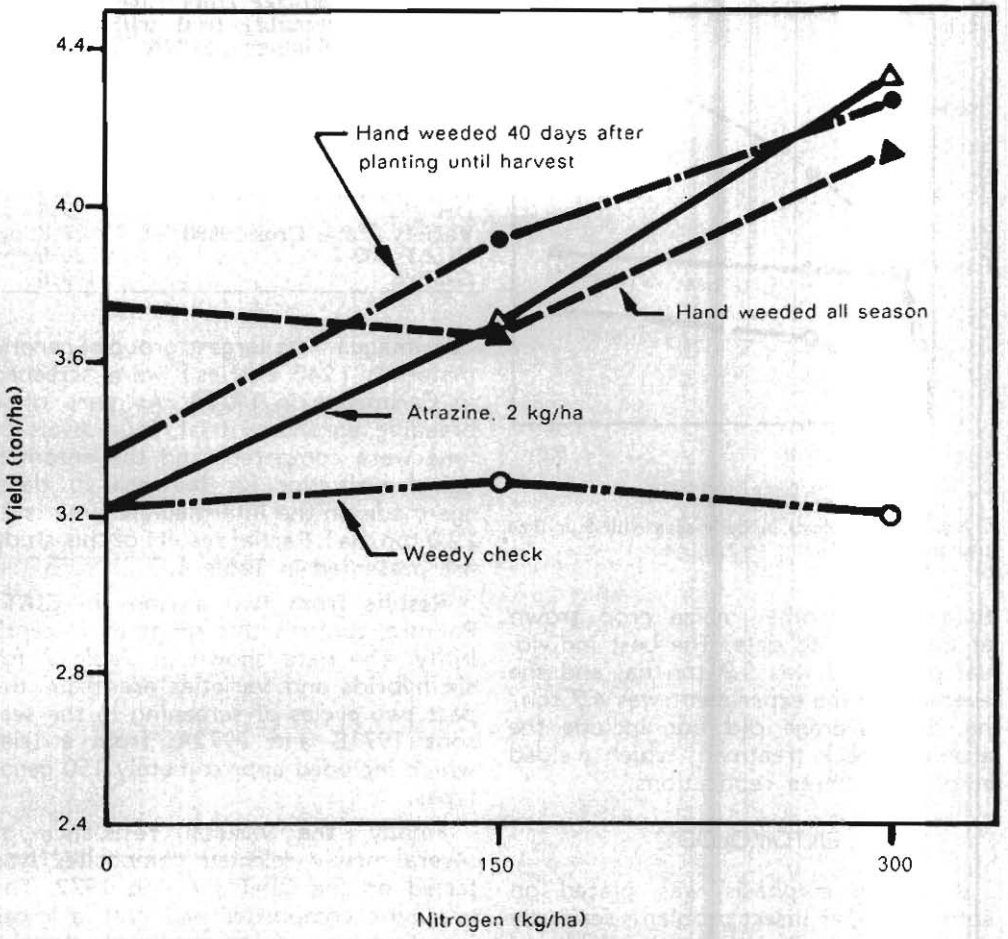


Fig. 8. Effects of nitrogen and method of weed control on maize yields in the field.

ICA-CIAT at Carimagua

Acid soil tolerance

In 1971, 20 corn entries were screened as described on page 105 (1971 Annual Report). Two hundred and forty entries were screened in 1972A, and the best of these are in further yield tests. The first steps in seed multiplication have also been taken, with the goal of providing agronomic material suitable for off-station testing in the second season of 1973.

We have found a surprisingly wide range of tolerance to soil acidity. Figure 9 shows the average response of 240 entries to lime and in contrast, the results for the six best entries with which the major response is to the first increment (0.5 ton/ha) of lime.

Micronutrient response

Corn was grown in a micronutrient trial under irrigation during the 1972 dry season with no significant response to applied elements. Yields were better

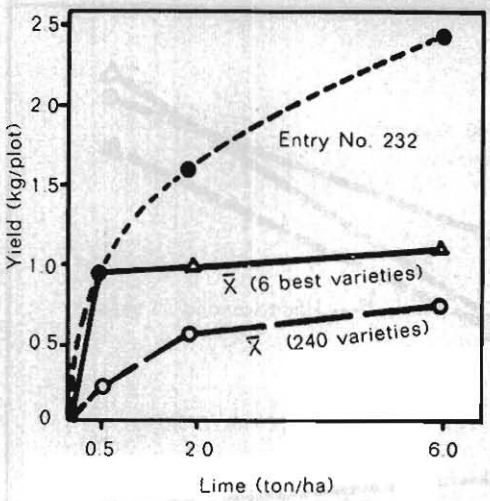


Fig. 9. Maize yields in Carimagua with four lime treatments (1972A).

than for any other maize crop grown at Carimagua to date. The best individual plot yield was 5.9 ton/ha, and the average for the experiment was 4.7 ton/ha. This average did not include the absolute check treatment which yielded zero in all three replications.

ENTOMOLOGY

A strong emphasis was placed on entomology, as insect problems seriously limit plant populations in the field and reduce yields throughout the Andean zone. This work has included varietal resistance, chemical and microbiological control (**Spodoptera frugiperda**), and biological control (**Diatraea saccharalis**). Integrated control is practiced in the commercial and experimental fields in CIAT, and more importance will be placed on the economics of integrated control as we move into cropping systems which include longer term minimum tillage and multiple crop combinations.

Varietal resistance

Trials of screening of varietal resistance continued in three locations: CIAT-Palmira, ICA-Nataima and ICA/CIAT - Carimagua. The largest group of genetic materials (240 entries) were screened in Carimagua in 1972A. As part of a breeding agronomy trial, four levels of lime were compared, and the entomological evaluation for **Diatraea** sp. damage made on the intermediate lime level (2.0 ton/ha). Partial results of this study are presented in Table 6.

TABLE 6. **Damage from** Diatraea **sp. in screening trial with maize in Carimagua, 1972A.**

Genotype	Damaged internodes (percentage)
ICA H.255	18.4
Tropical flint	22.4
DH.253	25.9
Variety - Line Cross 9098	27.8
INIAP 509-2	30.0
G-5757	100.0

Results from two seasons in CIAT-Palmira, confirm this range in susceptibility. The data shown in Table 7 for six hybrids and varieties are from the past two cycles of screening in the seasons 1971B and 1972A, from a trial which included approximately 150 genotypes.

Finally, the varietal resistance of several newly selected composites was tested on the CIAT farm in 1972. The brachytic composites had both a lower insect count and less internode damage from **Diatraea** sp. than the normal selections. However, brachytic plants with the same level of stalk damage as normal plants were much more resistant to lodging, probably because of their short stature and thick stalks.

TABLE 7. **Damage from** Diatraea **sp. in two seasons of screening in CIAT-Palmira, 1971-1972.**

Genotype	Damaged internodes (percentage) 1971B	1972A	X̄
XB-101	21.9	23.2	22.6
X-304	19.9	39.2	29.6
624 P_1 Br_2	27.4	32.8	30.1
XB-101A	24.6	37.5	31.0
Kysan Syn 70	27.5	43.9	35.7
Blanco Comun	47.3	53.5	50.4

TABLE 8. **Control of** Spodoptera **sp. and** Diatraea **sp. in maize with several granular insecticides and one microbial agent, CIAT - Palmira, 1972A.**

Treatment	Dosage (a.i./ha)	Percent effectiveness compared to control		Damaged internodes (percentage)
		48 hours	7 days	
Hoe-2960	400 g	99.0	99.5	25.8
Cytrolane 2%	750 g	97.0	96.5	30.1
MC-2188 5%	200 g	94.0	84.4	35.2
Trichlorofon 3%	1500 g	86.3	88.9	32.7
Thiodan Standar 3%	750 g	77.3	69.5	34.1
Cebicid 4.5%	1125 g	73.2	70.8	27.2
Thiodan (L+R)	750 g	66.8	61.1	36.2
Furadan (L+R)	750 g	65.0	39.0	8.3
Metarrhizium Anisopliae	*	23.5	32.7	38.1
Check plots		0	0	42.6

* Spores per cc were not determined.

Chemical and microbiological control of Spodoptera **sp.**

The whorl worm damages the growing point in tropical maize. This results in dwarfed plants which produce no ears. With concern for preserving beneficial predators and natural control, the effectiveness of control by eight granular insecticides and one fungus was tested. Dosage of each product and results of the test are shown in Table 8. The first six products listed were effective, with Hoe-2960 and Cytrolane showing the best control.

At harvest, the damage from stalk borers (**Diatraea** sp.) was evaluated to test the residual effect of the treatments and possible translocation of the product. Results are shown in the last column of Table 8. The effectiveness of Furadan for this control of **Diatraea** sp. is apparent. The observations in this trial suggest that an ideal product for maize in this zone to control both pests should combine the characteristics of Hoe-2960 and Furadan (L+R), giving an acceptable control with a single application.

Biological control

The trials for resistance have identified some varieties with a tolerance to damage by the maize stalk borer (**Diatraea** sp.). The use of insecticides may not be economical, since this approach requires several applications and an understanding of population fluctuations of **Diatraea** sp. to reach optimum control.

Exploratory studies have been initiated with the liberation of several **Diatraea** sp. parasites in different valleys in Colombia. These include **Apanteles flavipes** from India, **Metagonistylum mineansis** from the Amazon region, **Paratheresia claripalpis** from Peru, **Lixophaga diatraea** from Cuba, and **Jaynesleskia jaynesi** from Colombia. Multiplication of these parasites can be accomplished in the laboratory, using host larvae of **Diatreaea** sp. To collect sufficient larvae in the field is a difficult and time-consuming operation. To avoid this step, several artificial diets were tried to propagate **Diatraea** sp. in the laboratory in order to have sufficient biological material for the several laboratory and field studies in progress.

The entire cost of this rearing procedure on artificial media is one dollar (U.S.) 500 larvae.

Although this boiled bean diet gave excellent results for a series of **Lepidopterous** larvae, it did not provide normal growth of **Spodoptera frugiperda.** For the **Spodoptera** sp. a similar diet is prepared without boiling the beans. This new diet produces a larva which weighs more than three times that in the original diet, a heavier pupa, five days less time per larval period, and no larval mortality.

Larvae of Diatraea saccharalis **feeding on an artificial pinto-bean base diet.**

A detailed description of these diets and their applications has been published by CIAT and is available on request.

Field populations of Spodoptera **sp.**

The fluctuation of field populations of **Spodoptera frugiperda** in maize was studied in a field with plantings each 15 days. Data collected in 1972 indicate that the greatest population in the maize whorl occurs during the first rains, with high temperatures. The most serious attacks of cutworms occur in the dry periods or when rain is sporadic. This information will help in control procedures, in maize and other crops which are attacked by **S. frugiperda.**

ECONOMICS

Agricultural economics research during 1972 was aimed at determining the factors associated with low maize yields, understanding the adoption process with respect to improved seeds, estimating the change in cost of production and labor utilization due to adoption of new technologies, and estimating the economic feasibility of utilizing maize to partially replace wheat in bread.

While none of the above mentioned work has yet been completed, preliminary results indicate that with current prices in Colombia it would be economically sound to use maize as a partial replacement of wheat in bread. This replacement is presently considered to be technically feasible up to the level of 27 percent substitution of total flour. This replacement assumes an availability of maize in Colombia at the current price, and thus depends on an increase in production which can offset the current scarcity of maize.

TRAINING

It is essential that each research specialist must first be a capable production agronomist who knows the crop and how to grow it well. With this in mind, a new concept for in-service trainees was initiated in the second season of 1972 with a group of six Colombian agronomists working in maize breeding, agronomy and physiology. The plan includes both practical production and research activities, on both commercial and subsistence-scale farms. Trainees' time is divided among four activities: commercial-scale production experience on the CIAT farm (30 percent); applied research trials with small farmers (10 percent); research experience with the maize team (40 percent); and special research or development project (20 percent).

The production training on CIAT's farm is planned and supervised by the coordinator of plant science training. Practical field work in growing maize, soybeans, rice, field beans, cassava, sorghum, and vegetables is provided. The production experience will better prepare research specialists to plant and care for their maize crop so it produces meaningful data. The production experience at CIAT and the adaptive trials with small farmers help the trainee to understand the crop and its culture, focus his attention toward the most important factors limiting farm production, and put the research work in perspective as an immediate effort to solve these critical problems.

The research work with the maize production systems team includes direct participation in the projects of several disciplines - breeding, physiology, agronomy, entomology, nutrition and economics. Trainees work with senior scientists and experienced assistants in the field and the laboratory to learn the practical techniques which are essential to research progress. Special research projects which are an integral part of the total program are assigned to each trainee. In this project he is responsible for outlining the objectives, organizing and executing the field planting, collecting relevant data during the crop cycle, analyzing and interpreting all information from the crop, and preparing a summary of the experiment. The results of this trial become one section of the trainee's final report and evaluation of his experience in CIAT.

Examples of special research projects of individual trainees include international trials, conversion of opaque-2 maize to a hard-endosperm type, minimum tillage, systems of planting, land preparation schemes, and photoperiod-temperature work.

One trainee from Ecuador and a research fellow from Haiti each completed a year of general research training, with special projects in maize efficiency and sorghum. A special course in field and laboratory aspects of protein quality improvement has been organized for two trainees from Ecuador and Nepal. In August, the maize trainees joined several young agronomists from ICA for the second intensive course on maize improvement.

INTERNATIONAL ACTIVITIES

The quarterly newsletter, "El Maicero," was introduced to the Andean zone in 1972. The first three issues have been sent to some 300 persons in Latin America, either directly involved with or interested in maize research and development. Contributions from cooperating programs in the zone, include preliminary research results and news items from national programs, commercial organizations, and other interested groups.

Seed for regional trials in the Andean zone, ENZAT (tropical locations) and ENZAS (highland areas) were sent from CIAT in August, 1972. The ENZAT, with 35 entries, was sent to 23 locations, while the highland trial with 18 entries went to 15 locations. Results from this first cycle will be summarized and presented at the next regional workshop.

TABLE 9. **Results of international trials planted in CIAT during the seasons 1970B and 1971B.**

Trial	Name	Nº var.	Nº rep.	Yield (kg/ha)	Best entry	Yield (kg/ha)	Origin
E70B-20	IMAN	50	2	1,816	Comp. Nte. Am.	5,445	Peru
E71B-20	IMAN	50	2	6,106	ICA H.154	9,828	Colombia
E71B-21	IACP	21	4	6,597	HS-209	8,116	Colombia
E71B-22	IACP	9	2	6,756	Cuba 40 x Cuba	7,945	Thailand
E71B-23	PCCMCA(ME)	27	4	7,248	Desarrural Exp.	9,671	Honduras
E71B-24	PCCMCA(BA)	30	4	7,199	Desarrural HB-105	9 029	Honduras
E71B-25	PCCMCA(OP)	9	4	4 852	Comp. B1. Car.0₂	6,214	CIMMYT
E71B-26	PCCMCA(Br)	9	4	6,481	J-6309 x 6309	9,114	Poey Seed Co.

This conference is scheduled for March, 1973 at Cochabamba, Bolivia. Another workshop is scheduled for February, 1973, on practical aspects of insect and disease control and genetic resistance.

The international and regional trials planted in CIAT during the past two years are summarized in Table 9. Yields in these trials were acceptable during 1971, with the best trials producing more than 7 ton/ha. The highest yielding hybrids in several trials were more than 9 ton/ha, including one brachytic single cross. The trials for 1972 are in the field, and will be harvested in early 1973. In addition to these trials of commercial and promising maize, a large number of progeny trials from CIMMYT have been planted and evaluated, and this germ plasm forms the basis of our current effort in reducing plant height in promising populations of maize.

Coordination of research projects and other cooperative programs requires frequent travel in Colombia and the Andean zone. Senior scientists working with maize have traveled to Ecuador, Peru, Bolivia, Venezuela, Brazil, Central America and Mexico during the past year. In addition, they have attended meetings in the United States (California, New York, Florida, Illinois, North Carolina), Egypt, Kenya, and Thailand, and have presented research results from the maize projects detailed above. Research assistants and trainees have worked at the ICA research stations at Carimagua, Turipana, Tibaitata, La Selva and Nataima as part of their research and training activities. These cooperative research projects and travel are the core of CIAT's international work, and provide an avenue for moving germ plasm and sharing ideas throughout the Andean zone and the tropics.

Rice Production Systems

NEW VARIETIES

CICA 4 and IR22

The new rice varieties recommended by CIAT during 1971 are now being tested or grown on a commercial scale in a number of countries. CICA 4 is being distributed under that name in Colombia, Venezuela, Brazil, Panama, Costa Rica, Jamaica, Honduras, and Guatemala; as INIAP 6 in Ecuador, and as Avance 72 in the Dominican Republic. IR22 is being distributed under that name in Colombia, Venezuela, Panama, and Guatemala; as INIAP 2 in Ecuador, and as Navolato A 71 in México.

BREEDING

Crosses

A total of 61 new crosses was made in 1972, bringing the total since 1967 to 642. The crossing program concentrates on searching for resistance to blast. Most of the crosses made in 1972 involved the varieties Colombia 1 and Tetep, which are suspected to have generalized resistance to rice blast (**Pyricularia oryzae**). Fifteen of the new crosses were the results of intercrossing several F_5 lines that seem to have the same resistances as Colombia 1. Other crosses, 37 in all, involving dwarf x (dwarf x F_1

Promising genetic lines of rice are transplanted for observation and evaluation of agronomic characteristics and yield potential.

Col. 1 x dwarf), were made to combine the high yield and excellent grain and quality of the more promising lines with the resistance to **Pyricularia** present in some selected F_5 lines. Tetep was crossed with six of the best lines in yield trial experiments. ICA 10, which is resistant to hoja blanca disease, was backcrossed to both CICA 4 and Line 13 (IR665-23-3-1-1B) to combine resistance to mechanical damage by **Sogatodes orizicola,** the insect vector for hoja blanca, with the good plant type and high-yielding ability of both CICA 4 and Line 13.

Nurseries

Breeding materials were planted at the ICA experiment station in Palmira in March, April, June, July, August, September and December. These included over 22,086 pedigree rows F_2 to F_6 that were evaluated thoroughly for cooking and milling quality, plant type, vigor, resistance to blast, and mechanical damage by **Sogatodes** and hoja blanca.

The F_2 populations of several three-way crosses were grown and evaluated in 1,152 F_2 families having about 200 plants each. These crosses, F_1 (dwarf x dwarf) x a tall resistant parent to blast, (Tetep, Dissi Hatif, C46-15 and Mamoriaka were included) segregated 3:1 tall plants to dwarf ones. The percentage of segregates having good grain and plant type was low. F_2 populations involving Mamoriaka were discarded because of poor plant type and lodging. In March, 1,075 F_2 families of about 200 plants each were grown and evaluated. These families came from backcrosses between excellent dwarf lines (but susceptible to blast) and different sources of resistance. Before planting these backcrosses in the field, they were evaluated for resistance to blast at Corinto, Valle and La Libertad, Meta. About 50 percent of the families were susceptible to blast and were discarded. The remaining 1,075 F_2 families were segregated for blast and produced approximately 4,000 plant selections having good plant type and long grain. This material is now being evaluated in F_3 pedigree rows and about half of it carries blast resistance.

Plant selections are being made in 150 F_2 families of about 200 plants each that were planted in August. These families came from backcrosses between F_1 selections, resistant to blast, and IR305 lines. These backcrosses were made in an attempt at combining blast resistance with the high-yield potential of IR-305. Other sources of blast resistance studied were F_3 selections from single crosses between dwarfs and Tetep, and C46-15 and Dissi Hatif. These selections are now in F_4 pedigree rows. Approximately 6,000 F_4 lines from backcrosses between dwarf lines and Colombia 1, a local variety that has maintained its blast resistance in hundreds of tests, were evaluated in April. Although most of these lines were resistant to blast, they were unsatisfactory in other agronomic traits; so only a few selections, which are now in F_5 pedigree rows, were made.

A number of F_5 lines from crosses of IR841, IR579 and IR930 selections combine most of the desired traits except blast resistance. A few F_5 lines, crosses of Colombia 1 and CICA 4, IR506, IR634, IR661, IR662 and IR665 selections, still carry blast resistance. About 360 plant selections were made from the F_5 lines for further testing as both F_6 rows and observational plots in 1973. This material needs to be rigorously observed for a few more generations before firm conclusions may be drawn.

Observations indicate that single crosses and three-way crosses between tall and dwarf parents have not resulted in useful F_3 lines. Therefore, crosses involving blast resistance or any crosses involving tall and dwarf parents will require some modification in the breeding program.

In summary, nearly all material in the breeding program is dwarf, has excellent milling and cooking quality, early maturity, and resistance to mechanical damage by **Sogatodes orizicola.**

TABLE 1. **Yield of 15 promising lines and some rice varieties at four places in Colombia.**

Line Nº	Cross	Pedigree	CIAT	ICA	La Libertad	Turipana		General average
						Lowland	Upland	
3626	IR930-2xIR532-E208	P726-239-1-2	7232	7504	2042	4222	3333	4867
3630	IR930-2xIR532-E208	P726-287-2-1	9614	7890	1083	4111	3667	5273
3640	IR930-80xIR822-432	P753-40-3-1	8998	7227	3330	6822	4444	6164
3641	IR930-2xIR822-432	P723-6-3-1	8354	7644	3575	4400	3333	5461
3649	IR930-36xIR532-E208	P733-88-3-2	9814	7145	2250	5333	4733	5855
3656	IR930-53xIRIR579-160	P738-97-3-1	10676	8250	2958	8400	4800	7096
3657	IR930-53xIR579-160	P738-137-3-1	11070	8250	2958	8400	4800	7096
3658	IR930-53xIR579-160	P738-137-4-1	10802	7483	2958	7288	4511	6608
3669	IR579-16-1xIR532-1-33	P757-12-3-3	8592	8190	2333	5667	2033	5363
3671	IR579-16-1xIR532-E208	P758-30-2-1	8879	7433	1833	5355	2444	5189
3689	IR577-38-2-2xIR532-E208	P761-86-1-3	8020	8114	1583	5400	3622	5348
3703	IR930-2xIR662-1-108-5	P773-44-3-1	9230	7945	3666	6667	5622	6626
3713	IR930-80xIR532-E208	P780-55-1-1	10494	8616	1375	6755	3688	6185
3714	IR930-2xIR532-1-33	P725-10-2-2	9087	9235	2333	5611	4355	6124
3717	IR930-2xIR665-31-6-5	P792-47-2-2	9255	9058	2167	5155	3500	5827
Line 13			10175*	6442*	—	8222	5577	7604
Bbt. 50			6570	6352	—	4111	2556	4897
IR8			9102	—	—	4333	3178	5538
CICA 4			9258**	8982**	3281	6135**	4943**	6522
IR22			8257	5933	2875	6244	4266	5515

* Average of 7 plots.
** Average of 14 plots.

TABLE 2. **Milling quality and shattering data of 15 selected lines in comparison with some check varieties.**

Line Nº	Cross	Pedigree	Grain lenght	White center	Head rice %	Total rice %	Amylose %	Shattering*
3626	IR930-2xIR532-E208	P726-239-1-2	7.2	0.0	53.0	59.3	29.7	MS
3630	IR930-2xIR532-E208	P726-287-2-1	6.8	0.0	56.0	60.5	29.6	MS
3640	IR930-80xIR822-432	P753-40-3-1	7.0	0.0	37.5	45.0	30.6	MS
3641	IR930-2xIR822-432	P723-6-3-1	7.0	1.0	49.6	67.8	30.9	R
3649	IR930-36xIR532-E208	P733-88-3-2	7.0	0.2	50.2	55.9	29.0	MR
3656	IR930-53xIR579-160	P738-97-3-1	7.0	0.0	51.0	61.5	30.9	MR
3657	IR930-53xIR579-160	P738-137-3-1	7.0	0.2	52.5	63.0	30.6	MS
3658	IR930-53xIR579-160	P738-137-4-1	7.0	0.6	54.2	64.4	30.7	MR
3669	IR579-16-1xIR532-1-33	P757-12-3-3	7.2	0.0	34.0	52.5	30.6	MR
3671	IR579-16-1xIR532-E208	P758-30-2-1	7.2	0.0	56.0	58.7	30.5	MR
3689	IR577-38-2-2xIR532-E208	P761-86-1-3	7.0	0.8	61.6	65.1	30.4	MS
3703	IR930-2xIR662-1-108-5	P773-44-3-1	7.0	0.8	65.0	69.0	30.6	MR
3713	IR930-80xIR532-E208	P780-55-1-1	7.0	0.4	49.5	59.0	29.0	R
3714	IR930-2xIR532-1-33	P725-10-2-2	7.0	0.4	48.0	57.0	29.2	MR
3717	IR930-2xIR665-31-6-5	P792-47-2-2	7.0	0.4	54.0	60.5	28.2	S
CICA 4			6.8	0.6	36.5	47.0	25.8	S
IR22			6.8	0.0	—	—	29.0	MS
Bbt. 50			7.2	0.0	56.3	60.0	26.8	MS
IR8			6.5	1.0	32.0	41.0	30.2	R

*/R = Resistant; MR = Moderately resistant; MS = Moderately susceptible; S = Susceptible.

Blast resistance is now the major objective of the program and continues to be a difficult breeding problem.

Observational plots

A total of 390 entries were planted in 4-row unreplicated plots. The average yield of CICA 4 was 8.2 tons/ha while local check varieties produced 3.7 to 5.0 ton/ha. Many lines yielded from 8 to 10 ton/ha, but the majority had undesirable grain and/or weak stems. Ninety-three lines were selected for yield trials.

Yield trials

Yield trials of the 93 promising lines were planted at CIAT and at the research center of ICA in Palmira, Turipana and La Libertad in unreplicated plots. A planting was also made at Carimagua to observe the tolerance of these lines to acid soil conditions. In Turipana, one replication was under irrigated conditions and another under upland conditions. CICA 4, IR22, IR8, and Line 13, as well as other locally grown varieties, were included as check plots. Attacks of blast on the leaves and necks of the panicles of many lines occurred at La Libertad and Turipana, while moderate attacks of neck blast were observed on some lines at Palmira. The sheath blight disease (**Corticium** sp.) affected many lines in La Libertad, Turipana and Palmira. There was moderate incidence of **Helminthosporium** and **Cercospora** in Turipana. Lodging was also present in Turipana and Palmira plots. Anaranjamiento (a form of iron toxicity) was an important factor at La Libertad.

In order to have an idea of the milling recovery, 1 kg of seed from each of the best 50 plots in the field were milled in an experimental mill; amylose content was determined and cooking tests were made to complement the gelatinization temperature data.

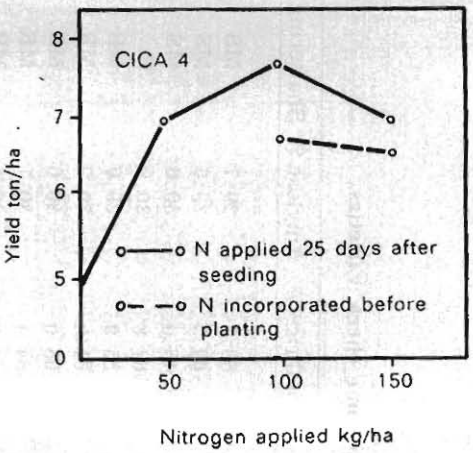


Fig. 1. Response of CICA 4 to nitrogen applications.

Fifteen lines were selected for further testing in 1973. Yields and some characteristics of these lines appear in Tables 1 and 2. Some lines have the yielding ability of CICA 4. Many out-yielded IR8, or IR22 and Bluebonnet 50 by more than 15 and 30 percent, respectively. Some lines, such as 3640, 3641, 3656 and 3703, did relatively well under severe attacks of neck blast in La Libertad, while others such as 3656 and 3703, appeared promising for upland conditions. Lines 3640 and 3641 seemed resistant to the races of the blast fungus present in La Libertad and Turipana; about 10 percent of their panicles were affected by neck blast, while some other lines had more than 60 percent. CICA 4 had 35 percent of its panicles affected by neck blast.

Most of the lines have long, slender and translucent grains that cook dry and loose. Head rice and total rice percentages in some lines are similar or better than those of Bluebonnet 50. Most of the lines are less subject to shattering than CICA 4 (Table 2).

In summary, the majority of the lines are susceptible to blast and sheath blight disease, but they are superior to CICA 4 in grain and milling quality and shattering. More extensive testing is needed.

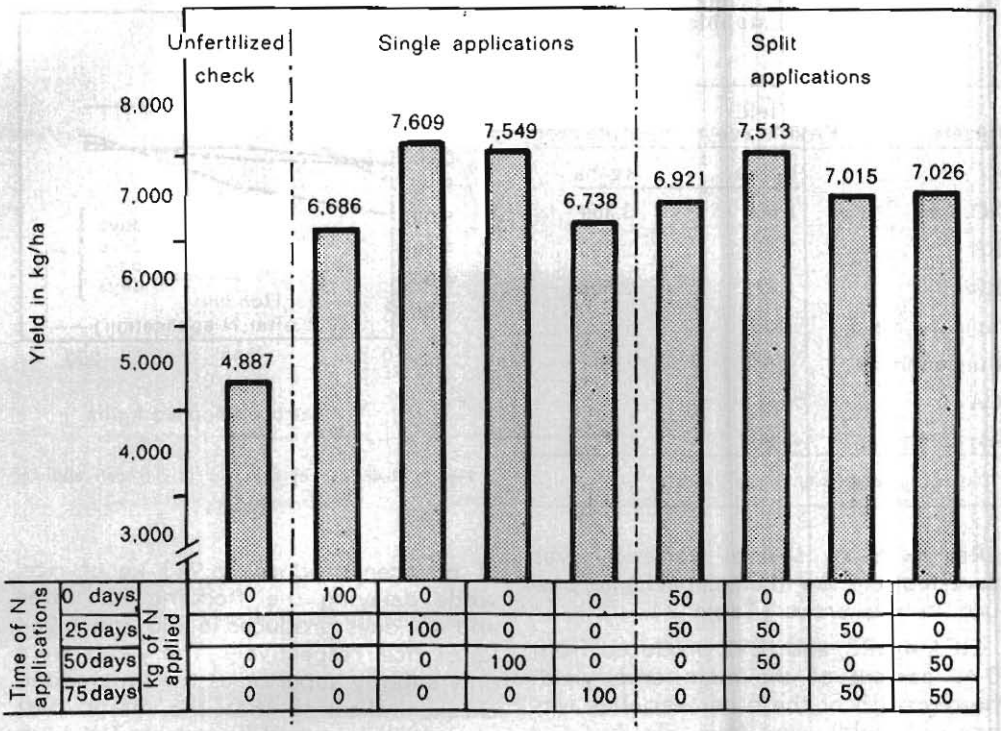


Fig. 2. Effect of time of nitrogen applications on yield of CICA 4.

AGRONOMY

The improvement of nitrogen efficiency was a major objective in 1972, the problem being studied through rate and time of nitrogen application experiments and through a study of water management and fertilization practices.

Rate and timing of nitrogen applications

Experiments were conducted with CICA 4. The results of the experiment with CICA 4 are shown in Figs. 1 and 2. The highest yield, 7,609 ton/ha, was produced from 100 kg/ha of N applied 25 days after planting. This time of application was superior to incorporation of the nitrogen in the soil immediately before planting. Fig. 2 compares the effects of single vs. split nitrogen applications. The best single applications were at either 25 or 50 days after planting while the best split application was 50 kg N at 25 days, followed by another 50 kg N at 50 days. There appeared to be no advantages in making more than one application.

Milling data on these treatments showed that the highest yields of whole grain rice corresponded with the highest field yields and best fertilizer treatments.

Production of stubble crops

Farmers in several countries habitually harvest a main crop and then permit regrowth of the stubble to produce a second harvest. Before adopting a new rice variety, they want to know what yields can be expected from the stubble crop.

TABLE 3. **Yields of some varieties in main and stubble crops in Colombia.**

Variety	Yield First harvest	Stubble crop
	kg/ha	kg/ha
CICA 4	8,000	3,304
IR8	7,775	2,395
IR22	5,818	2 503
Tapuripa	5,007	*
Bluebonnet 50	2,653	*
ICA 10	6,066	*
Starbonnet	3,984	*

* Did not produce significant yields.

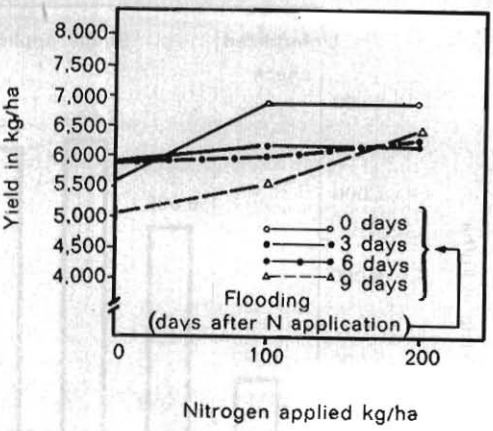


Fig. 3. Response of Line 13 to nitrogen applications.

Regrowth of several varieties was harvested to show their capacity to produce stubble crops (Table 3).

CICA 4, IR8, and IR22 produced from 30-40 percent of the main crop yield. The regrowth of the other varieties was poor and yields were low.

In another area, after a harvest of 7,500 kg/ha of CICA 4, a fertilizer and height of cutting experiment was located on the stubble. The stubble was cut to 15 cm and 1 cm and each height received 0, 25, 50 and 75 kg N/ha.

The 15 cm cutting height and 25 kg N proved to be the best combinations. This treatment produced 4,168 kg/ha of rice in 85 days after the date of the first harvest. The rice cut at a 1 cm height required 14 days more to mature.

Effect of water management practices on nitrogen efficiency

Two experiments were carried out in 1972 involving time of irrigation and time of drainage after nitrogen applications. In one experiment, 0, 100 and 200 kg of N were applied with various irrigation treatments.

The results in Fig. 3 show that immediate flooding after applying 100 kg of nitrogen produced 6,923 kg of rice, while delaying the flooding for three and six days produced 6,200 and 6,064 kg of rice, respectively. The yields were only slightly superior to the unfertilized check, indicating that the major part of the nitrogen had been lost. The poor yield of the treatment in which flooding was delayed nine days is probably the result of not only the loss of nitrogen, but also a deficit of water, resulting in fewer tillers.

In another experiment, the time of drainage of the irrigation water after nitrogen application of 0, 100 and 200 kg/ha was studied. Because of soil variations, the data are not conclusive. Indications are that continuous flooding after fertilization is the best practice and that draining at 7 and 14 days was the least productive. When the draining was delayed for 21 days, the response to the applied nitrogen was superior to the earlier drainage treatments. However, it still appears to be inferior to the no-drainage treatment.

Seed multiplication

If direct-seeded lowland rice is planted under good conditions, with from 80 to 100 kg/ha of seed, it can be expected to produce from 8 - 9 ton/ha.

TABLE 4. **Multiplication of small quantities of seed through multiple transplanting.**

Line	Amount of seed g	Rice produced kg	Multiplication factor
1	10	239	23,900
2	10	452	45,200
3	10	289	28,900
4	10	261	26,100
5	10	84	8,400

This is a ratio of 80 - 90 kg of rice produced per kilogram of seed. The multiplication of seed from some promising lines must often begin with seed from only one plant or one panicle, but to produce sufficient seed for use in widespread variety trials or commercial testing may require several years.

In an attempt to reduce this time and to advance the research program, ten grams of seed from five deep-water rice varieties were subjected to multiple transplanting treatments (Table 4). The yields were produced from three transplantings and matured in about six months.

The data indicate that the use of this method can greatly accelerate seed production providing that the vegetative cycle of the variety is sufficiently long and that it is a high tillering variety.

Lowland Rice Production on Oxisols in the Llanos Orientales

Work on the problems of flooded rice in the eastern Llanos was continued with major emphasis on the causes and possible solutions of the problem of anaranjamiento or orange-leaf disease.

Anaranjamiento

Flooded rice cultivation in the Llanos has been hampered by severe disease problems, infertility of the soil, and a physiological disease called anaranjamiento. The latter problem is characterized by yellowing or oranging of the rice leaves which starts at the lower leaves and moves toward the top of the plant. The disease was studied in pot experiments in Palmira, using soils from the Llanos.

Chemical characteristics of four soils from the Llanos and one from the ICA center at Palmira are listed in Table 5. The high savannah soil (Nº 1) from Carimagua is representative of most of the oxisols in the Llanos, south of the Meta river. The low savannah soil (Nº 2) is a soil which is naturally flooded during the rainy season (8 months of the year), but is dry in the dry season. This soil is probably representative of many Llanos soils north of the Meta. The La Libertad soil (Nº 3) came from the ICA experiment station La Libertad,

TABLE 5. **Chemical characteristics of four soils from the Llanos Orientales and one Palmira soil.**

Soil	Nº	Active Fe %	pH	O.M. %	Bray I ppm P	Al	Ca	Mg	K	CEC
							meq/100 gm			
Carimagua- high savannah	(1)	1.81	4.0	4.14	2.0	3.1	0.60	0.10	0.09	14.0
Carimagua- low savannah	(2)	0.31	4.9	24.3	2.7	3.1	0.38	0.17	0.25	39.4
La Libertad	(3)	1.54	3.8	2.45	5.6	3.9	0.58	0.04	0.09	10.2
Orisol	(4)	0.62	4.1	1.78	6.1	2.7	0.36	0.06	0.06	7.2
Palmira	(5)	0.77	6.8	4.72	151.2	0	11.6	5.2	0.69	18.6

in the piedmont of the Llanos, where anaranjamiento is extremely serious. The Orisol soil (Nº 4) is also from the piedmont, but from a "good" rice farm where anaranjamiento is not a problem. Table 5 indicates that these Llanos soils are extremely acid, high in exchangeable Al, high in Fe, and low in Ca, Mg, K and P. The low savannah soil is high in organic matter and consequently, has a high pH-dependent cation exchange capacity. The Palmira soil (Nº 5) is neutral and has no problems with anaranjamiento.

Figure 4 shows the change in pH, Eh, and Fe concentration in the soil solution after flooding. Soils 1 and 4 showed similar changes in pH and Eh. The pH increased from 4.2 to 6.2, while the Eh decreased from +550 mV to about +100 mV. Soil 3 reduced much slower, resulting in low pH and high Eh values. Soil 2 showed practically no change in pH, Eh, and Fe concentration, while soil 5 showed no change in pH, but a rapid decrease in Eh. Fig. 1C shows that the Fe concentration in soils 1 and 4 started to increase rapidly after three weeks, reaching peak Fe concentrations of 260 and 150 ppm, respectively. Soil 3 showed a very slow increase in Fe concentration, while soils 2 and 5 maintained low and nearly constant Fe levels in solution.

In general, plant growth was good until Fe concentrations in solution started to increase. Plants on soil 1 developed typical bronzing symptoms, indicative of direct Fe toxicity. Plants on soil 3 grew well initially, but developed very

Soils directly influence growth of rice plants, as illustrated here with three soils from the Colombian Llanos. From left to right: note the differences in depression in plant growth, with the one on the left being seriously depressed, the one in the middle intermediately depressed, and no depression or symptoms of anaranjamiento in the plant on the right.

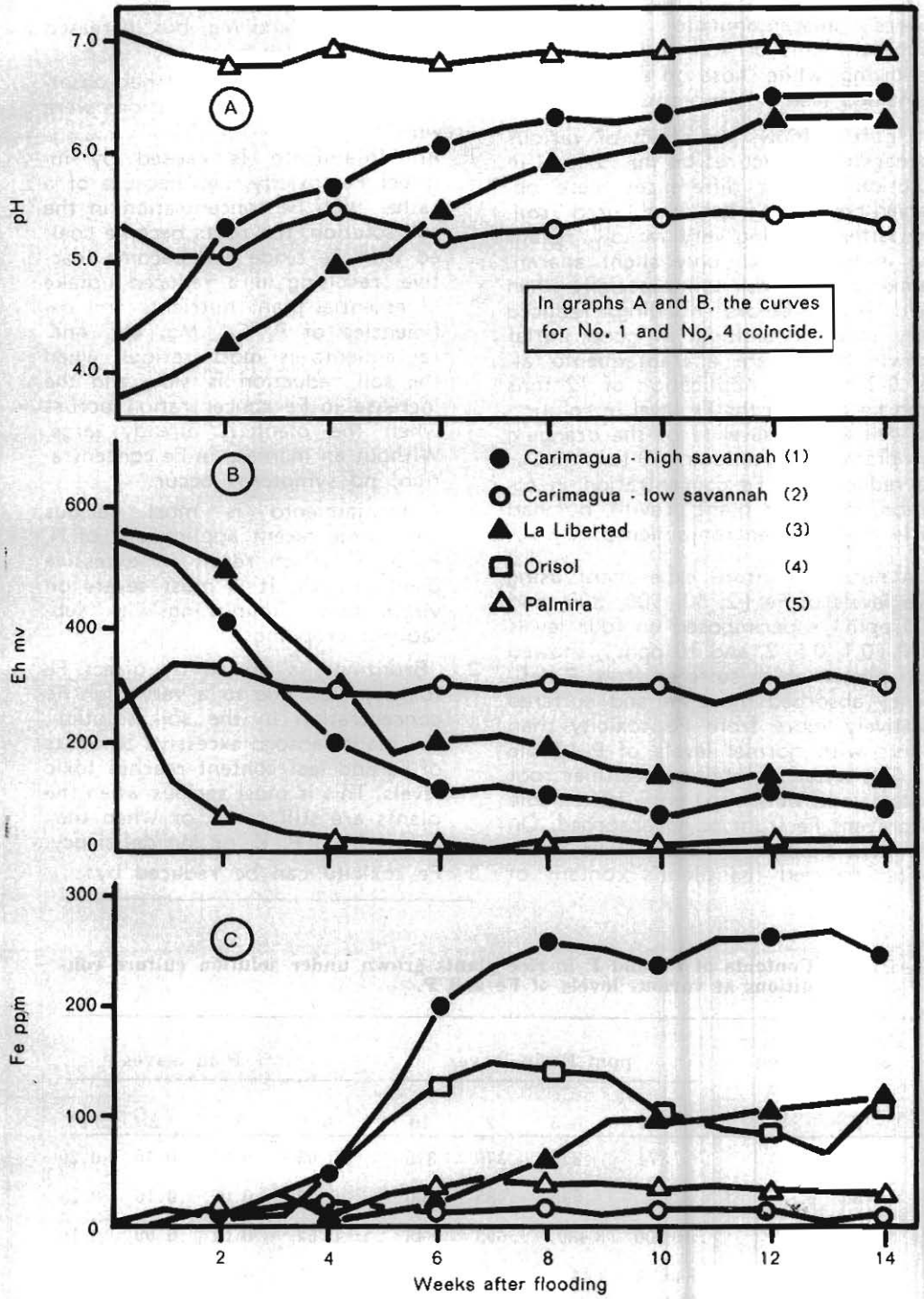


Fig. 4. Change in pH, Eh, and Fe concentration in the soil solution after flooding of various soils from the Llanos Orientales and from Palmira

severe anaranjamiento after two months. Plants on soil 4 showed slight yellowing, while those on soils 2 and 5 remained free of symptoms.

Figure 5 shows the effect of various management practices on the Fe level in solution. Largest differences were observed between "fresh" and "used" soil, the latter reducing very rapidly, resulting in plants with only slight anaranjamiento. The fresh soil, especially when field moist before flooding, reduced very slowly, resulting in good initial growth but severe anaranjamiento after 2-3 months. Application of 12 tons lime/ha reduced the Fe level in solution as well as the severity of the oranging symptoms. Application of 10 tons MnO_2/ha reduced the Fe concentration in solution, improved plant growth, but had little effect on anaranjamiento.

A nutrient culture experiment using five levels of Fe (2, 50, 100, 300, and 800 ppm) superimposed on four levels of P (0.1, 0.5, 2, and 10 ppm), showed that plants which suffered from P deficiency absorbed more Fe and suffered relatively more from Fe toxicity than plants with normal levels of P (Table 6). The latter maintained healthier root systems and were apparently better able to prevent Fe from being absorbed. On the other hand, high levels of Fe in solution reduced the plant's content of P as well as Ca and Mg, but increased its content of K.

From these studies and other observations, the following conclusions were drawn:

1. Anaranjamiento is caused by indirect Fe toxicity, i.e., because of a rather high Fe concentration in the soil solution, the roots become coated with Fe oxide and become inactive, resulting in a reduced uptake of essential plant nutrients and deficiencies of P, Ca, Mg, etc. Anaranjamiento is most serious when the soil reduction is slow and the increase in Fe concentration occurs when the plant is already large. Without an increase in Fe concentration, no symptoms occur.

   Anaranjamiento is most serious with large recent applications of N, P, or K which result in excessive plant growth. It is most severe on virgin soils, diminishing with subsequent croppings.
2. "Bronzing" is caused by direct Fe toxicity, i.e., due to a very high Fe concentration in the soil solution, the plants absorb excessive amounts of Fe and leaf content reaches toxic levels. This is most serious when the plants are still small, or when they suffer from P, K, or Mg deficiency.
3. Fe toxicity can be reduced by:

TABLE 6. **Contents of Fe and P in rice plants grown under solution culture conditions at various levels of Fe and P.**

Concentration in solution ppm		ppm Fe in leaves				% P in leaves			
↓ Fe	P →	0.1	0.5	2	10	0.1	0.5	2	10
2		374	853	370	318	0.03	0.03	0.10	0.20
50		3,320	695	485	500	0.02	0.03	0.10	0.23
100		10 200	3,480	693	643	0.02	0.01	0.09	0.16
300		54,650	3,440	950	1,350	0.01	0.03	0.08	0.11
800		+	18,750	1,715	1,523	+	0.03	0.11	0.15

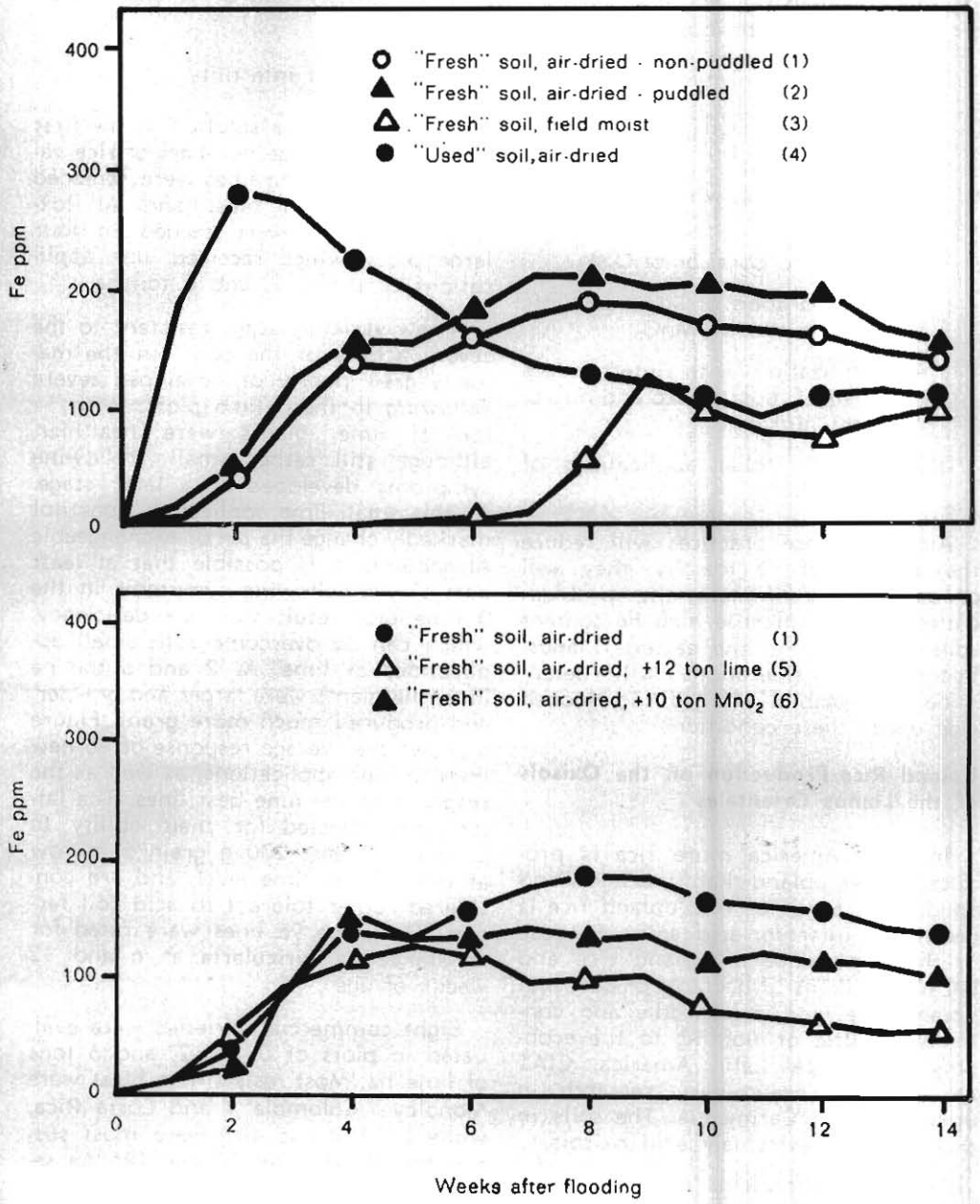


Fig. 5. Change in Fe concentration in the soil solution after flooding Carimagua soil and with various treatments.

a) Alternate flooding and drying.
b) Flooding with internal drainage.
c) Accelerating the rate of soil reduction by:
   (i) use of soil previously fertilized.
   (ii) flooding when soil is very dry.
   (iii) incorporation of O.M.
d) Incorporation of large amounts of lime and/or MnO_2.
e) Fertilization with intermediate levels of most macro and micro-plant nutrients.
f) Biweekly foliar applications of P and K.

Although these practices will reduce the severity of Fe toxicity, they will probably not eliminate the problem entirely in the infertile high Fe content soils like those in the eastern Llanos. Economic considerations will determine the feasibility of growing flooded rice under these conditions.

Upland Rice Production on the Oxisols of the Llanos Orientales

In Latin America more rice is produced under upland than under lowland conditions. Much of this upland rice is grown on infertile, acid soils. Because of the importance of upland rice and because millions of hectares of potential upland rice land is now idle and contributing little or nothing to the economy in tropical Latin America, CIAT has initiated preliminary research in upland rice at Carimagua. The soils in this area are extremely acid oxisols.

The major problems of upland rice production in the Llanos are:

1. Fungus diseases, principally **Pyricularia oryzae** (blast) and **Helminthosporium oryzae** (brown spot).
2. Extreme soil acidity, resulting in yellowing symptoms of aluminum (Al) toxicity and/or calcium (Ca) deficiency.
3. Extreme soil infertility.

In a search for a solution to the first two problems, large numbers of rice varieties and breeding lines were screened for resistance to blast and Al toxicity. The lines were seeded in four large plots, which received lime applications of 0, ½, 2, and 6 ton/ha.

A few varieties seem resistant to the severe acidity of the soil, but the majority grew poorly or developed severe yellowing in the 0 lime plots. With ½ ton of lime, plants were healthier, although still rather small. Yellowing symptoms developed at a later stage. As this small lime application does not markedly change the pH or exchangeable Al content, it is possible that at least part of the yellowing symptoms in the 0 lime plot result from Ca deficiency, which can be overcome with small applications of lime. At 2 and 6 ton/ha lime, the plants were larger and greener, and produced much more grain. Figure 6 shows the average response of 96 new lines to lime applications, as well as the response of the nine best lines. The latter were selected for their ability to produce at least 200 g grain/5 m row at the 0.5 ton lime level, and are considered rather tolerant to acid soil factors. The same 96 lines were rated for resistance to **Pyricularia** at 6 and 12 weeks of age.

Eight commercial varieties were evaluated in plots of 0, ½, 2, and 6 tons of lime/ha. Most resistant to blast were Monolaya, Colombia 1 and Costa Rica, while CICA 4 and IR8 were most susceptible. Bluebonnet 50 and IR5 (a selection from La Libertad) were intermediately susceptible. Monolaya and Colombia 1 were most resistant to soil acidity. Although yields were generally low, the most promising commercial varieties for upland rice in the Llanos seem to be Bluebonnet 50, Colombia 1, IR5, and Monolaya. Of these, only IR5

The differences in the rice plant growth demonstrated here are due to anaranjamiento in "fresh" and "used" Carimagua soil that was either air-dried or field moist before flooding. The center plant is severely affected; the one on the left, intermediately, and on the right, slightly.

Potted plants illustrating the response of rice grown on flooded soil from Carimagua to applications of 1 and 12 tons of lime and 10 tons of MnO_2 per hectare.

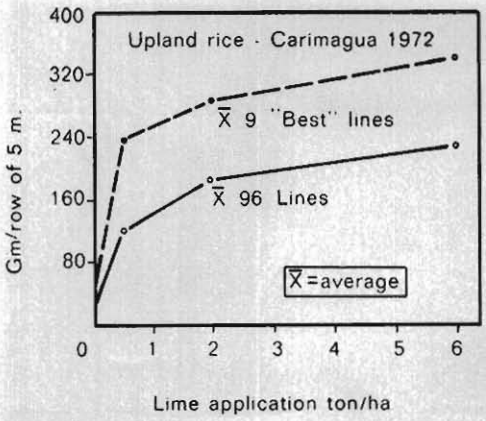


Fig. 6. Response of 96 rice varieties and lines to lime applications under upland conditions in Carimagua. Top curve indicates the response of the best nine lines.

is a dwarf variety. The others are tall, lodge at high population and yield levels, and suffer much bird damage. Because of their resistance to blast, they generally yield more than most of the dwarfs.

Twelve promising breeding lines were compared with IR8, CICA 4 and Monolaya at levels of 75 and 150 kg N/ha with a constant application of 4 tons of lime, 100 kg P_2O_5 and 100 kg K_2O/ha. The lines were also evaluated for blast resistance. Lines 3609-3612 showed most resistance to blast and produced highest yields of 1.95-2.32 ton/ha. Yields were generally low because of severe infection of brown spot and about 20-25 percent bird damage. Most new lines produced more than IR8 or CICA 4 because of better resistance to blast.

The P x lime experiment reported in 1971 with CICA 4, was repeated this year using four varieties: IR8, CICA 4, Bluebonnet 50, and Monolaya. The latter is a tall "local" variety that is well adapt-

Rice varieties are grown under upland conditions and without lime in the acid soils of Carimagua to determine their adaptability to such conditions.

ed to the soil and climatic conditions of the Llanos but has a poor plant type and low yield potential. While CICA 4 and IR8 were almost completely destroyed by blast, Monolaya was not affected, and Bluebonnet 50 only slightly. Similarly, CICA 4 and IR8, died completely with 0 lime, suffered from soil acidity with 0.4 ton of lime, while Bluebonnet 50 and especially Monolaya were only slightly affected. The latter varieties showed little growth response to lime applications, and only Bluebonnet 50 responded to P applications.

Fig. 7 shows the yield response to lime applications, averaged for the 0, 50 and 100 kg P_2O_5/ha applied before seeding. Monolaya showed no lime response up to 8 tons, with a slight negative response at 16 tons. Bluebonnet

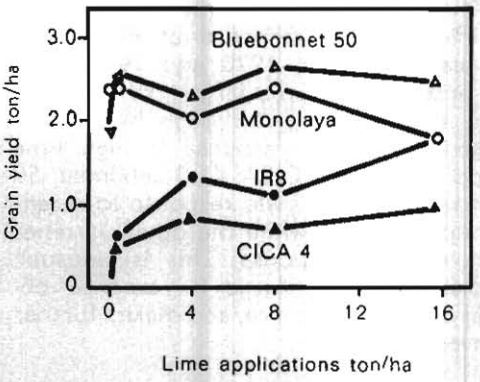


Fig 7. Response of four rice varieties to lime applications under upland conditions in Carimagua. (Averages for P applications of 0, 50, and 100 kg P_2O_5/ha).

Rice varieties differ greatly when grown under upland conditions at Carimagua; from left to right, Bluebonnet 50, IR8 and Monolaya.

50 responded to the first increment of lime, with no response at higher applications. As in 1970 and 1971 CICA 4 and IR8 showed a large lime response up to 16 ton/ha, although blast damage masked the response to high lime applications in CICA 4. Bluebonnet 50 showed a small yield response to recent P applications, while the other varieties showed no response. This is unusual, considering the large P response observed in flooded rice, and merits further investigation.

INVESTIGATIONS WITH ZINC

Studies on zinc deficiency were continued in 1972. A complex of problems such as high soil pH, presence of free calcium carbonates in the soil profile, poor superficial and internal drainage, narrow Ca:Mg ratios, and soil movement by land leveling appear to be associated with the problem.

Zinc requirements

Zinc sulfate ($ZnSO_4 \cdot 7H_2O$) was applied to two CIAT fields at 0, 5, 10, 20, 40 and 80 kg Zn/ha. The material was incorporated into the soil before seeding. Two applications of 100 kg N/ha each, were applied at 28 and 56 days after planting. The results are shown in Fig. 8.

Neither of the two experiments showed the severe zinc deficiency symptoms observed in 1971. Growth and development of the check plots appeared to be normal, with yields of more than 8 ton/ha. However, these plants apparently had been affected by zinc deficiency since both areas responded to the 5 kg application of zinc and produced 500 to 700 kg more rice.

The cost per kilogram of Zn from zinc sulfate is about 66 Colombian pesos (U.S.$ 2.93) and the price paid for 1 kg of rice is two pesos (U.S. $0.09). The use of 5 kg Zn/ha appears to be economical but the use of 10 kg Zn under these conditions would probably not be justified on the basis of the increased production.

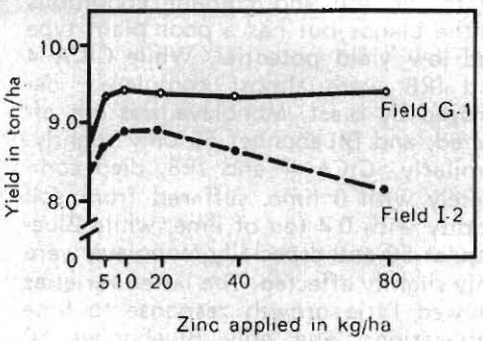


Fig 8. Response of rice to different levels of zinc in two CIAT fields.

Time of application of zinc

Three times of application, 0, 28 and 56 days after planting, and three rates of application were studied. Two hundred kg N/ha from urea was applied in two applications which corresponded to the 28 and 56 day zinc applications. The soil pH was 7.9 and the zinc content of the 0 - 10 cm depth was 2.68 ppm Zn (EDTA extraction) and 1.46 ppm Zn (HCL + H_2SO_4 extraction). Results indicate that the best time of application was immediately before planting. Ten kg/ha of zinc produced the highest yields (Fig. 9).

Methods of applying zinc

Zinc applied before planting to the soil was compared to zinc applied as

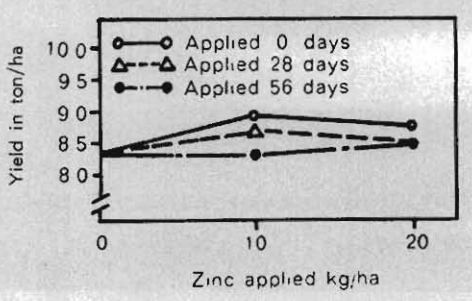
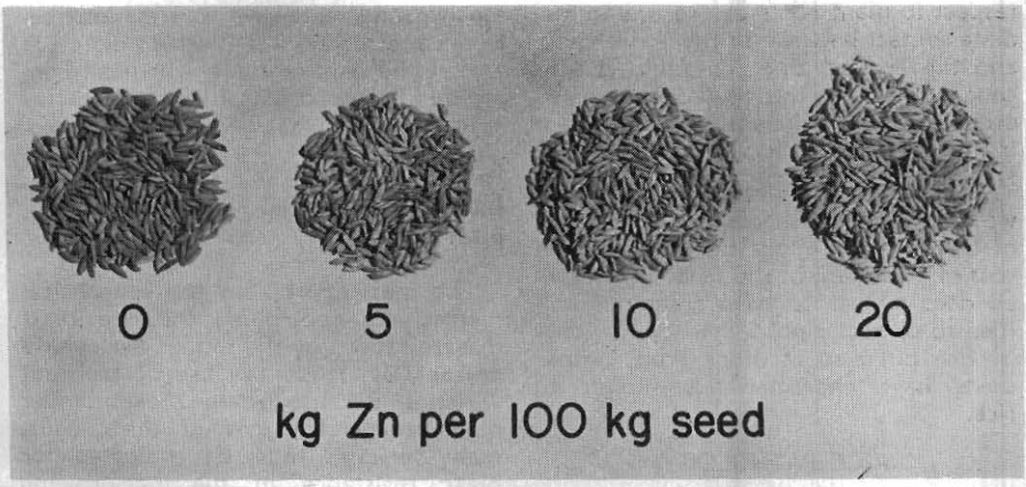


Fig 9. Effect of time of application on level of zinc in CICA 4 variety.



Sowing rice seed coated with zinc oxide represents a new approach to correct zinc deficiences in rice soils.

a coating on rice seed. Zinc oxide was used as it is a proved source of zinc. It is practically insoluble in water and does not present a problem for germination of the rice seed.

Some zinc oxide powder will adhere readily to moistened rice seed. As each seed would be in contact with moist soil and water, gum arabic was used to increase the adhesiveness of the powder to the rice seed. It was found that a ratio of three volumes water to one volume gum arabic was satisfactory, and increased considerably the adherence of the zinc oxide.

The seeds were immersed in the water-gum arabic suspension for about 30 seconds, then removed and the excess liquid allowed to drain. Zinc oxide was then dusted over the sticky seeds until they were completely covered by the material after which they were sun-dried.

Some of the dried seeds were lightly stuck together as a result of the treatment but these were easily separated prior to planting. With this procedure it was possible to obtain different amounts of zinc adhering to the seed. Germination tests were made 100 days after treatment and showed no effect.

The zinc treatments used were 0, 5, 10 and 20 kg Zn/ha incorporated in the soil before planting and rice seed coated with zinc to give the same equivalent rates of application, when seeded at 100 kg/ha. The results are shown in Fig. 10.

Results indicate that zinc oxide applied as a seed coating was equal or superior to soil applications under conditions of slight zinc deficiency. The superiority of the method may be explained by more uniform distribution and perhaps a better placement with

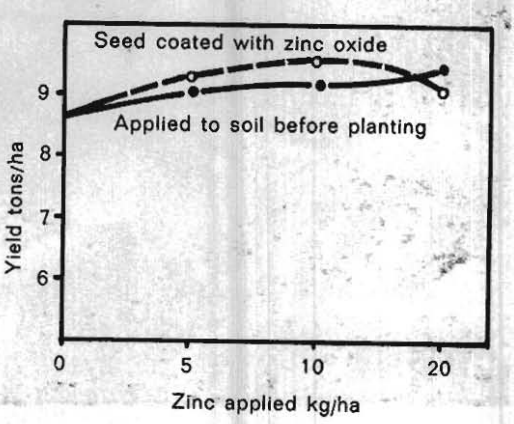


Fig 10. Comparison of two methods of zinc application.

respect to plant roots as there is immediate contact between primary rice roots and the applied zinc. The zinc is also concentrated in the root zone and is probably more efficiently utilized than in the case of broadcast applications.

Applications of zinc in this manner would eliminate the cost of application of the zinc but might be offset by the cost of treatment of the seed. This method does appear to have great possibilities to correct zinc deficiency not only in rice but also in other crops whose seeds have characteristics similar to rice.

RICE PATHOLOGY

During 1972, the pathologists continued to look for varieties with partial (horizontal) resistance to the rice blast disease caused by the fungus **Pyricularia oryzae** Cav. Likewise, they developed avenues for screening varieties under dry weather conditions, and studied intensive and extensive correlation between the reaction at the seedling stage and at the panicle stage. Chemical control of the pathogen, although in minor scale, was also included in the pathological activities.

International partial resistance blast nursery

The most appropiate and economical method for controlling the rice blast disease caused by the fungus **Pyricularia oryzae** Cav. is by the use of resistant varieties. Because of the great number of physiological races of the fungus, many varieties must be evaluated for blast resistance in the rice-growing regions of the world and also, at different locations within the same region. The selection of varieties with broad spectrum of resistance to the different races of the fungus is of primary importance in the development of new rice varieties.

Latin American rice technicians observe a CIAT plant pathologist inspect plants in a rice blast nursery.

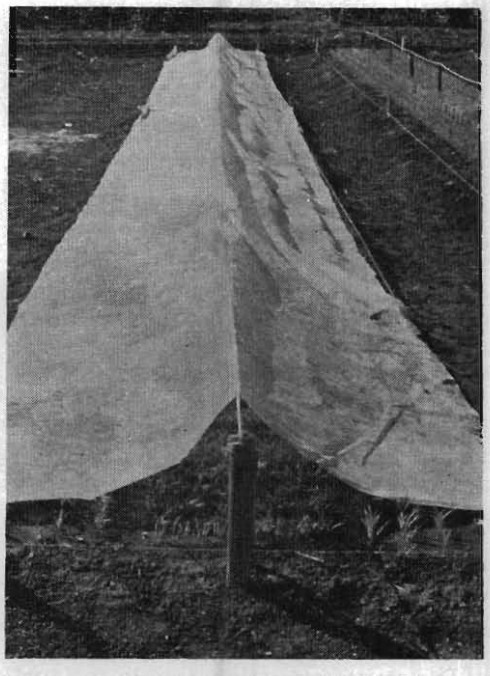
The International Partial Resistance Blast Nursery (IPRBN) during 1972 included 225 varieties. The reduction from the initial 1,190 varieties (1969) and some few additions comprise the IPRBN nursery in 1972.

After 18 evaluations during the year in Colombia, Brazil and Guyana, 47 of these varieties were eliminated. Tetep, Carreon, C46-15, Milagrosa, Mamoriaka, Ram Tulasi (Sel.), and Molagolukula maintained their broad spectrum of resistance to all of the races present in the mentioned areas.

New method for obtaining high infection of Pyricularia oryzae **Cav.**

A new method to obtain high infection of **Pyricularia oryzae** Cav. in areas of low relative humidity was developed to evaluate varietal resistance of rice to this pathogen in such areas.

In the CIAT and ICA farms where the mean temperature and relative humidity are 23.70°C and 71 percent, re-



A plastic hood helps to maintain a humid environment in beds planted to rice seedlings inoculated with the rice blast disease organism.

Rice blast infection produced under a plastic hood. The variety at left and in the foreground is susceptible and the plants have been killed by the fungus; the variety at right is resistant.

spectively, it has been possible to obtain excellent infections of the fungus when the relative humidity was maintained at 100 percent during the night by use of moistened seed beds. The beds were sprinkler irrigated at 5 p.m. and then covered with a plastic daily, starting as soon as the seedlings emerged. Likewise, pieces of infected tissue were spread throughout the bed at the beginning as inoculum. Using this method, seedlings of the variety Fanny died after 15 days and the susceptible test lines in 35 days. This method will make it possible to obtain a uniform infection but, most important, it will enable plant breeders to test lines effectively in low humidity areas.

Correlation between leaf blast in the vegetative stage and neck blast of the panicle

The resistance rating used in the evaluation of rice varieties to the blast disease is based on the reaction of 35-day-old rice plants to the pathogen. This system assumes that a good correlation exists between the severity of the attacks to the leaves of young rice and the severity of the neck infection. The following field study was carried out to determine if this assumption is correct.

Eighteen varieties were used in the study, 14 of which showed a high degree of resistance in the vegetative stage. Two varieties were rated as moderately susceptible and two were highly susceptible to leaf blast. All varieties were planted in Corinto and in Los Llanos, Colombia, under conditions favorable for the development of the disease.

In general, the results indicated that a correlation does exist between leaf blast infection and neck blast infections. The resistant varieties, Tetep, Tadukan, Carreon, Barawee, Uvar Vellai, IR782-53, IR224-20-1-2-2-1B, CPSLO x Dawn, and Milagrosa, showed the best correlation. However, ICA 10 and Bluebonnet 50, which were moderately susceptible to leaf blast, showed neck blast infections of 100 and 53 percent, respectively. However, these two varieties in some tests have been killed at the seedling stage. CICA 4 and Fanny were highly susceptible in both growth stages.

Chemical control of rice blast

The drastic environmental conditions of tropical zones limit the effectiveness of chemical control of rice blast. The use of chemical fungicides for the control of the fungus is a common practice in rice growing areas and it is possible to observe significant differences in the effectiveness of the control depending on the product used, the time of application and the conditions under which it was used.

Seed treatment at different time periods before planting

Seed of CICA 4 was treated with Benlate, NF.44, NF.35, Demosan, Hoe 2989, Duter and Brestan, at 1.0 kg and Piomy at 0.08 kg active ingredient per 100 kg of seed. The rating of incidence of the disease on the rice plants was made between 35 and 75 days after the planting of the fungicide treated seed. The results suggest that chemical seed treatment can be effective with fungicides of systemic action if the treatment is made 48 hours before planting. Some of them protected the plants for about 45 days after planting. Benlate appeared to give the best results.

Soil treatments

Benlate, NF.44, NF.35, Duter, and Brestan at rates of 20 and 40 kg a.i./ha were applied to the soil and CICA 4 was planted. Readings were continued until 93 days after planting. Treatment of the soil with Benlate and NF.44 gave the best control. With these products, the incidence of the disease was less than 5 percent dead leaf area at 20 kg/ha (active ingredient).

Foliar application of fungicides

Seed of CICA 4 was treated with Benlate (0.5 kg a.i./100 kg seed) and planted in plots of 32 square meters for the purpose of checking the effect of the chemical therapeutics in controlling rice blast. Each plot was replicated and was sprayed with the following products:

Product	Active ingredient kg/ha
Kasumin	30 ml
NF.44	250 g
Dithane M-45	4,800 g
Bla-s	30 ml
Benlate	125 g
Hinosan	750 ml
Brestan	1,000 g
Kitazin	7,650 g
Benlate + Kasumin	65 g + 20 ml
Benlate + Brestan	65 g + 500 g
Benlate + D.thane M-45	65 g + 2,400 g
Benlate + NF.44	65 g + 150 g
Benlate + Hinosan	65 g + 500 ml
Kasumin + Dithane M-45	20 ml + 2,400 g

The results of this experiment showed that Hinosan or Benlate plus Hinosan were the best products in controlling rice blast. However, in other experiments, Benlate or Kasumin alone, or in mixture have also given good results. Plots treated with these two compounds had a neck blast infection of 23 and 13 percent, respectively, as compared with the untreated check which had an infection of 46 percent. The increase in production because of the use of those products was 1,024 and 1,019 kg/ha more rice than was produced by the checks plots.

Varietal resistance to sheath blight

Sheath blight (**Corticium sasakii** (Shirai) Matsumoto) is becoming an important problem of rice and has caused losses of 70 percent in the variety, Tapuripa. Because of the increase in the seriousness of this disease in some countries, it was considered necessary to develop a simple system for evaluating varietal resistance to this disease.

To determine the resistance of some rice varieties in the adult stage and under naturally ocurring field conditions, 148 varieties were planted. The susceptibility or resistance was evaluated by means of a conventional scale which expressed the percentage of tillers affected per planted row. The scale used was:

Percent tillers affected	Classification
0 – 25 percent	Resistant
26 – 50 percent	Moderately susceptible
51 – 100 percent	Susceptible

Sixty-three percent of the varieties were rated as resistant, 20 percent as moderately susceptible and 17 percent as susceptible.

Tetep, Kataktara DA-2, Milagrosa, Pusur, C46-15, Mamoriaka, Ram Tulasi (Sel.), Zenith, Molagolukula and Pah Leuad 111, that have good resistance to blast also, showed excellent resistance to sheath blight. Dawn and Nahng Mon S-4 that have high resistance to blast showed a marked susceptibility to sheath blight. Other varieties, such as CICA 4, IR532-1-33 and IR8 also were susceptible to sheath blight.

ENTOMOLOGY

Sogata

Nine Ecuatorian rice varieties were tested to determine susceptibility to mechanical damage of **Sogatodes oryzicola** Muir. Four of these varieties were resistant to the direct damage. These varieties are also being tested to evaluate their resistance to hoja blanca virus. Similar tests will be done in Ecuador in event that the insect does develop the capability to attack formerly resistant varieties.

Stem Borers

Eighteen rice varieties and lines were screened under field conditions to evaluate resistance to the stem borers (**Diatrea** spp. and **Rupela albinella**). The

TABLE 7. **Resistance of different rice varieties to natural infestation of stem borers.**

Variety	Stems* damaged (percentage)	Yield kg/ha
1. IR22	2.16	5.531
2. CICA 4	5.26	7.575
3. IR8-41-63-5 (L9)	5.50	8.030
4. IR8	7.84	8.129
5. Starbonnet	9.15	4.341
6. L-13	10.76	7.233
7. ICA-10	11.31	8.674
8. Tapuripa	14.00	5.305
9. LM-1	14.73	4.890
10. Bluebonnet 50	19.00	3.924
11. Milfor	19.83	3.567

* Damaged by both **Diatrea** sp. and **Rupela albinella**.

degree of resistance was based on the percentage of dead hearts and white heads and expressed as percentage of stem damage. IR22 was the most resistant as compared with Milfor which was highly susceptible to stem borer damage (Table 7). In general, the dwarf varieties checked were more resistant than tall varieties.

CICA 4 and Line 13 were treated with the granular insecticide, Carbofuran (Furadan) 3 percent. Reduced damage by stem borers and other sucking insects in rice took place. The timing of the application appears to be important and can reduce the number of applications required.

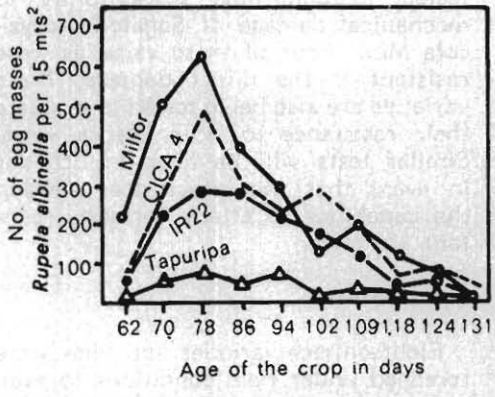
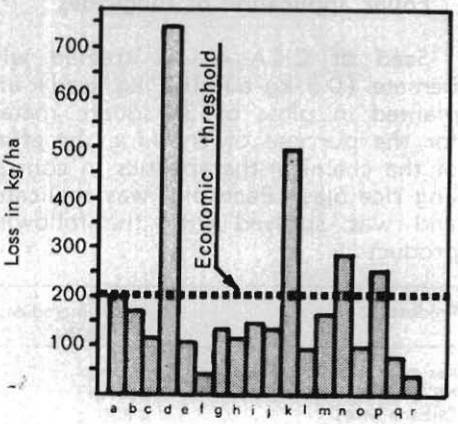


Fig 11. Preference for oviposition by **Rupela albinella** C. in four rice varieties.



a Milfor
b L9-22
c L9-21
d LM-1
e L9-16
f CICA 4
g L9-30
h IR8
i L9-17
j L9-20
k ICA-10
l Bluebonnet
m L9-33
n IR-841-67-1-2
o Starbonnet
p L-13
q IR22
r Tapuripa

Fig 12. Estimated yield loss by **Rupela albinella** C. in 18 rice varieties.

Rupela albinella Cramer is a stem borer that is mostly found in rice in Latin America. Its abundance in rice fields has caused concern among farmers, and the use of insecticides has been recommended.

In order to observe its preference of **Rupela** sp. to oviposit, 18 varieties of rice were tested and the total number of egg masses per variety were counted at 60 to 130 days after planting. **Rupela** did show a varietal preference for oviposture and the peak period for oviposture occurred when the plant was 78 days old. Milfor was the most preferred variety and Tapuripa the least preferred for oviposition (Fig. 11).

Comparatively less larvae were found in Milfor, LM-1, ICA-10, L9-20 and CICA 4 and more larvae were found in Tapuripa, IR22, L9-17, Starbonnet, and Line 13. This indicated that a non-preference behavior of the insect to oviposit in

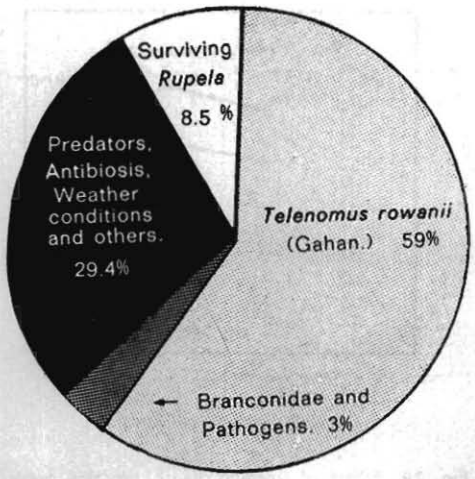


Fig. 13. Natural factors that affect the population of **Rupela albinella** C.

some varieties exists but also that an antibiosis effect may play a role in resistance (Fig. 12).

It was determined that a level of four dead hearts per square meter is the economic limit of damage that could be supported, and that insecticides should be applied if the damage exceeds this amount.

For the commercial varieties tested in this experiment, it was concluded that no recommendation of insecticide was necessary for control of **Rupela** sp. Furthermore, the excellent natural control primarily influenced by **Telonomus** sp. and other factors greatly reduced initial or hatched population of **Rupela** sp. and that only 8.5 percent of the population lived to reach the stem of the plant in order to produce the damage (Fig. 13).

WEED CONTROL

Rice weed control investigations during 1972 consisted of herbicide testing, studies of seeding methods and competitive ability of young rice, and the solution of special problems.

Herbicide testing

When establishing rice from pre-germinated seed, an immediate question arises about the effects of herbicides, especially those applied pre-emergence to the weeds, on the pre-germinated seed. As the seeds lie on the soil surface and the radicle is emerging, reduced herbicide tolerance results, as the chemical directly touches the seed and perhaps both growing points.

Herbicide selectivity was evaluated in four trials with direct-seeded rice and by seeding pre-germinated seed. Products causing serious injury in the first growing season were discontinued and new herbicides were added in the second. The weeds present were **Echinochloa colonum, Eleusine indica, Elipta alba, Heteranthera reniformis** and **Cyperus** sp. Only in the 1972-A direct-seeded trial, was a high population of weeds present. The soil puddling operations greatly reduced weed stands, and the pre-germinated seed gave the rice a definite early height advantage over any weeds that germinated.

The following products were phytotoxic to pre-germinated rice when applied in pre-emergence: Methazole, Pronamide, Butachlor, Oxadiazone, Benthiocarb, and Linuron. By applying Butachlor in late pre-emergence, selectivity was improved but injury was not eliminated. Chlorbromuron was much more selective than Linuron even though chemically they are nearly identical. The only pre-emergence compound with sufficient selectivity toward pre-germinated seed was Fluorodifen. All the post-emergence treatments proved to be selective and thus can be applied just as safely to rice from pre-germinated seed as to that directly seeded. No injury was observed by any treatment in the direct-seeded rice.

The yield data reflect the serious injury caused by some of the pre-emergence products. Yet, averaging the yields for all treatments, the average rice production from pre-germinated seed is 31

percent above that from direct-seeded rice (5,841 vs. 7,643 kg/ha). This reflects the inherent yield advantage of pre-germinated rice.

Weed control, in general, was good to excellent. The most promising new product is Oxadiazone applied in pre-emergence in direct-seeded rice. Butachlor and Benthiocarb gave similar results, the notable difference between them being that the latter is much weaker on composite weeds such as **Eclipta alba.**

Many combinations with Propanil were tested in post-emergence applications. The second product used was nearly always one with soil residual activity to prolong the control, as Propanil is strictly a contact herbicide. Such treatments are promising for weed control in upland rice, and combinations of Propanil and Butachlor, Benthiocarb, Fluorodifen, or DNBP should be tested in upland conditions.

Seeding methods and competitive ability of young rice

One of the observed advantages of planting pre-germinated rice seed is the rapid early rice growth, giving the crop a definite height advantage over weeds which germinate later. No actual data are available on this in Latin America.

A screenhouse trial compared the seedling vigor of rice grown from dry, pre-soaked, and pre-germinated seed. The first two seed types were also sown at depths of 1, 2 and 3 cm to observe the effects of planting depth on seedling vigor. The pre-germinated seed was always sown on the surface of puddled soil (Fig. 14).

Seed of **Echinochloa colonum, Eclipta alba, Amaranthus dubius, Jussiaea** sp. and **Leptochloa filiformis** were mixed uniformly in the first 3 cm of soil. Sixty seeds of the appropriately prepared rice seed (variety CICA 4) were sown at the desired depth.

Pre-germinated seed and pre-soaked seed planted at 1 and 2 cm produced

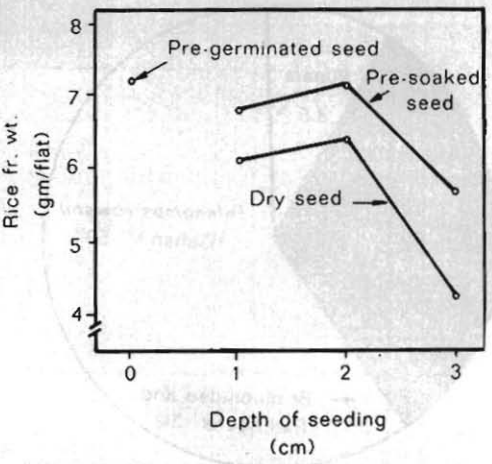


Fig. 14. Effect of seeding depth on rice fresh weight 14 days after planting greenhouse flats (averages of three trials).

the most rice. Seeding at 3 cm was detrimental for both the dry and pre-soaked seed and the dry seed rice growth was always inferior to that of the other two types, regardless of planting depth.

The early vigor of pre-germinated rice is reflected in the average plant height at seven days. There was a definite negative correlation between planting depth and seedling height for the dry and pre-soaked seed. Thus, the seeding method which gives rice its greatest competitive advantage over the weeds is that using pre-germinated seed. Pre-soaked seed is better than dry seed in this regard and shallow planting depths are better than deeper ones (Fig. 15).

These conclusions are supported strongly by comparing the rice and weed fresh weights at 14 days after planting for the three planting methods, averaged for all planting depths (Fig. 16). There is a great reduction of weeds because of the soil puddling process employed with pre-germinated seed. This, coupled with the increased competitive capacity of pre-germinated seed, makes this system the most advantageous in terms of obtaining good weed control through cultural means. The next best seeding method is with pre-soaked seed as it too reduced the weed growth as compared to seeding dry seed.

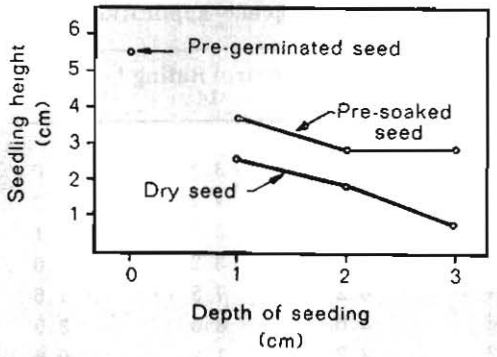


Fig. 15. Effect of planting depth on seedling height seven days after planting (averages of three trials).

Special weed problems

Two troublesome weeds were studied individually. **Heteranthera reniformis** (mudplantain), an aquatic broadleaf, invades canals and rice fields and is resistant to currently available post-emergence rice herbicides. It is a late invader and thus pre-emergence treatments are often weak. **Paspalum distichum** (knotgrass) often starts by infesting the rice levees and canal banks and encroaches into the flooded field. It propagates by both seeds and aggressive stolons, the latter making control difficult (Tables 8 and 9).

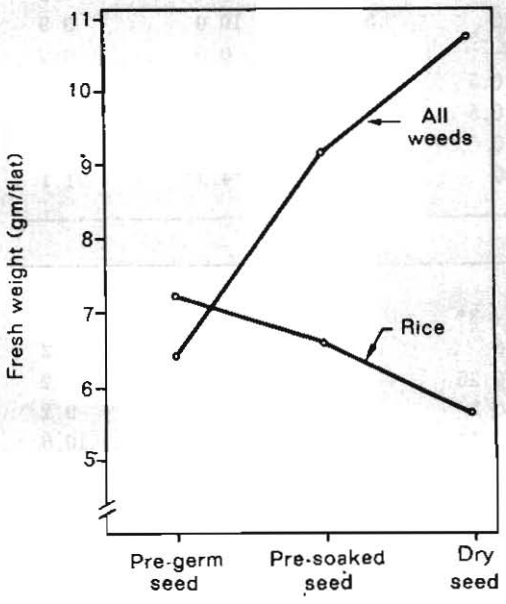


Fig 16. Effect of rice planting method on rice and weed fresh weights averaged for three seeding depths 14 days after planting (averages of three trials).

Previous experience had demonstrated that control of both species is difficult in rice. Therefore, various post-emergence herbicides were tested in the absence of rice to try and destroy the weeds before establishing rice.

Knotgrass was controlled by Glyphosate (a new post-emergent, non-selective chemical), MSMA, and Dalapon in split applications. MSMA proved more effective than DSMA, and there was obvious antagonism between Dalapon and Glyphosate. Cacodilic acid and Paraquat gave good initial control but the knotgrass later recovered.

Fewer chemicals were tested against mudplantain, and only Glyphosate gave excellent control. Only 0.5 kg a.i./ha was needed to completely kill it. One week after applying the combination of Glyphosate and 2, 4, 5-T, an obvious antagonism was observed, demonstrating again that Glyphosate is more efficient by itself than in mixtures with other products.

AGRICULTURAL ENGINEERING

The most productive rice lands in tropical Asia are located in the naturally flooded, poorly drained lowlands. These same areas are among the least productive areas of tropical America as most presently are in swamps and dry season pastures. CIAT is in an unique position to develop rice production systems suited to these tropical American lowlands by blending the most adapted Asian wet land practices with Western industrial scheduling. Continuous production of rice throughout the year was discussed in 1971 as a means of reducing unemployment and increasing income. It was implemented in 1972 on the CIAT

TABLE 8. **Control of** Paspalum distichum **with post-emergence applications.**

Trial I. treatment	Rate kg a.i./ha	Control Rating [1] 7	14	30 days
1. MSMA	2	4.8	3.5	0.0
2. MSMA	4	7.7	4.7	0.3
3. MSMA	6	8.0	5.5	1.1
4. Cacodilic acid	2	6.8	3.2	0.0
5. Cacodilic acid	4	8.2	7.5	1.6
6. Cacodilic acid	6	8.6	8.5	3.0
7. DSMA	2	3.2	1.2	0.0
8. DSMA	4	4.3	1.7	0.0
9. DSMA	6	4.7	1.7	0.0
10. DSMA	1 +1*	1.5	2.8	0.0
11. DSMA	2 +2*	3.3	2.8	0.6
12. DSMA	3 +3*	4.8	4.5	1.3
13. Dalapon	4	2.2	2.8	4.0
14. Dalapon	8	4.3	5.0	5.3
15. Dalapon + Paraquat	4+ 0.5*	2.2	8.5	**
16. Dalapon + Glyphosate	4+ 0.5*	2.2	4.0	6.5
17. Glyphosate	0.5	2.5	7.7	9.0
18. Glyphosate	1	4.5	10.0	9.8
19. Glyphosate	2	5.2	10.0	9.9
20. Control	—	0.0	0.0	0.0
21. Paraquat	0.5	5.8	2.0	0.0
22. Diquat	0.5	4.0	0.7	0.0
23. TCA	10	2.2	0.7	0.0
24. TCA	20	3.3	4.3	1.1
Trial II				
1. MSMA	3 + 3*	—	8.6	9.2
2. MSMA	6	—	8.6	8.2
3. Glyphosate	0.25	—	1.3	8.2
4. Glyphosate	0.5	—	5.1	9.2
5. Dalapon	4 + 4*	—	5.1	10.0
6. Dalapon	8	—	2.0	5.5
7. Cacodilic acid	6	—	6.8	4.5
8. Paraquat	0.5	—	0.8	1.5

[1] Ratings were based on the scale of: 0 = no control, and 10 = complete kill.

* The second herbicide was applied seven days after the first.

** Missing data.

TABLE 9. **Control ratings for the post-emergence applications in** Heteranthera reniformis **8, 16 and 60 days after application.**

Treatment	Rate kg a.i /ha	Control rating [1]		
		8	16	60 days
1. 2. 4-D	1.0	4.0	3.8	0.0
2. 2, 4 5-T	1.0	4.5	5.3	0.6
3. Glyphosate	0.5	10.0	10.0	3.1
4. Glyphosate	0.75	10.0	10.0	4.6
5. Glyphosate	1.0	10.0	10.0	6.0
6. Glyphosate + 2, 4-D	0.5 + 0.5	9.7	9.8	1.8
7. Glyphosate + 2, 4 5-T	0.5 + 0.5	6.7	9.7	1.5
8. Control	—	0.0	0.0	0.0

[1] Based on the scale of: 0 = no control, and 10 = perfect control.

farm and will be extended to other tropical lowland areas as results and interest are generated.

The original plan was to use 5 and 10-horsepower tillers to prepare about ½ hectare per work-day. As the areas used had not been developed for rice previously, soil movement requirements, the uneven surface, and vegetation made the use of these small tillers impractical. Larger 70-horsepower tractors with large rice and cane tires were used to level and prepare the fields. Some trials during 1973 will use the small tillers on the developed area as the land has now been leveled and the soils have settled, forming a more stable surface and soil profile during 1972.

Land preparation has been the only operation where a power unit is used. Seeds and fertilizers were broadcast by hand. Insecticides and herbicides were applied by a knapsack sprayer (if liquid), and by hand broadcast, if in a granular form.

Intensive, continuous and well paid use of labor has been set as a desirable goal. Time studies of labor required with scheduling for continuous land preparation, planting, harvesting, and contract payment per unit of work have given data on labor requirements; these data will permit comparative costing and scheduling with other methods. Table 10 shows labor, machine and material requirements and costs based on the CIAT 1972 data.

Table 11 shows dates of planting, harvesting, area yields, etc. The fields were harvested 120 to 140 days after sowing. These fields could have been immediately prepared and reseeded, if adequate water and power had been available. The requirements of other CIAT programs with experimental plots had priority for water and power over the production systems field.

Hand harvesting was expected to be the major problem. As combines are normally used in Colombia, most laborers had no experience with hand harvesting and no special threshers were available. Rice-plot harvests during 1971 had been successfully threshed on a 55-gallon drum. The CICA 4 rice variety was easily threshed on the drum with a high apparent output per man-hour. A time and motion study (Table 12) indicated that the output averaged 79 kg per man-hour which compares favorably with 70 to 84 kilograms per man-hour reported for a small engine-powered thresher especially developed to replace hand threshing.

TABLE 10. **Average labor, equipment, and materials required for producing rice in CIAT production fields in 1972 (Costs shown in US dollars).**

Operation		Man days/ha	Labor cost	Machine and material cost
1. Land preparation* with 70 rated horsepower tractor, rototiller and harrow		0.5-1.0	2.00	25.00 to 50.00
2. Construction** or repair of 640 meters/ha of levees with 50 cm top, 75 cm base and 25 cm high		8.0	16.00	—
3. Clean levees during crop season-640 meters		4.0	8.00	—
4. Broadcast pre-germinated seed-100 kg/ha		1.0	2.00	15.00
5. Broadcast fertilizer-200 kg/ha of urea (2 applications of 100 kg)		2.0	4.00	22.00
6. Application of insecticide broadcast granules (20 kg of 3 percent active ingredient Furadan)		1.0	2.00	20.00
7. Weed Control				
a) Handweed one time 30% of area		5.0	10.00	—
b) Knapsack sprayer application of Propanil 2.6 kg in 100 lts of water		1.0	2.00	20.00
8. Irrigation-maintenance of canals, dikes, and keep flooded 100 days by pumping		10.0	20.00	25.00
9. A - Hand harvest 6,000 kg/ha (cut, carry, stack, hand thresh on a 55-gallon drum, clean, bag 100 bags and carry 100 m to road)		30.0	90.00	—
B - Hand harvest 6 000 kg/ha (cut, thresh on portable thresher, clean, bag 100 bags and carry 100 m to road)		25.0	75.00	—
C - Combine with medium size combine 100 sacks and carry 100 m to road, 3 man crew and combine for 1/3 day		1.0	6.00	60.00
Summary based on harvest method				
	A	62.5	$ 156.00	$ 127.00 to $ 152.00
	B	57.5	$ 141.00	$ 127.00 to $ 152.00
	C	33.5	$ 72.00	$ 187.00 to $ 212.00

Value of threshed rice at 25 percent moisture content and five percent impurities was about $85 per ton at the farm roadside where the buyer furnished bags and transportation during 1972. The 6,000 kg/ha average was sold for $510 per hectare. Returns to land and management would be about $200 per crop of 135 days.

* Developmental land leveling and land preparation requires 1.0 man-day and tractor-day
** Construction requires 16 man-days.

The most important information in Table 12 is that the major effort is not in threshing but in cutting and carrying which require 62 percent of the effort. This led to the development of a CIAT man-powered portable combine. The contract laborers immediately expressed a preference for the portable unit. As it required less effort, they harvested more per day and received more pay. Two laborers cut, threshed, cleaned, bagged, and carried to the roadside eight to ten bags of 60 kilograms each per day. The CIAT contract labor was paid 21 pesos or about US$ 0.93 per bag which gave an earned income of $ 3.73 to $ 4.65 per man-day. Custom-combine charges in Colombia are 15 pesos or $ 0.67 per bag. The contract labor could earn $ 2.68 to $ 3.33 per day even if paid combine charges of $ 0.67 per bag. Since normal wages are $ 1.00 to $ 1.50 per day, hand harvesting is an attractive job.

Unit data collected in 1972 in Tables 10, 11 and 12 permit the development of various systems either labor intensive or machine intensive depending upon labor wages, labor availability and objectives. A rice production system to provide productive employment of laborers and land could be developed for areas that are near major rivers, roads, ports, and cities such as Barranquilla, Cartagena and Cali in Colombia, and for other areas near major cities in other countries such as Guayaquil, Ecuador; and Belem, Brazil. Continuous rice production systems can be planned using the following data (in US dollars):

1) Land and water are available in blocks of up to 10,000 hectares at rental rates less than $ 50 per hectare per year and less than $ 50 per hectare irrigation charges per year.
2) Laborers are available in excess of 10,000 in the area around the major city of 200,000 population with average wage rates of urban and rural laborer less than $ 2 per day and average work rates as given in Table 10.

TABLE 11. **Centro Internacional de Agricultura Tropical, station operations production of CICA 4 in 1972.**

Lot Nº	Date of		Days	Area	Production		
	Seeding	Harvest		ha.	Total tons	Tons/ha	Kgs/ha
I_2S	6-XII-71	18-IV-72	134	3.75	19.4	5.17	39
H_2S	15-XII-71	26-IV-72	133	4.20	21.8	5.19	39
J_1S	12-I-72	24-V-72	133	1.80	9.2	5.11	38
K_1S	14-I-72	26-V-72	133	1.80	12.2	6.77	51
G_2S	11-II-72	12-VI-72	122	3.50	25.1	7.17	59
H_1N,I_1N	12-II-72	26-VI-72	135	7.45	50.0	6.71	50
	18-II-72	6-VII-72	139				48
G_2N	1-III-72	18-VII-72	139	4.00	19.5	4.88	35
H_2N	11-III-72	24-VII-72	135	4.00	17.7	4.42	33
I_2N	29-III-72	2-VIII-72	126	2.54	15.3	6.02	48
H_1S I_1S	28-IV-72	31-VIII-72	125	3.00	20.3	6.77	54
H_2S I_2S	12-V-72	22-IX-72	133	7.00	36.0	5.14	39
F_1	23-V-72	28-IX-72	128	8.80	50.5	5.74	45
D_1	26-V-72	4-X-72	131	8.80	66.8	7.59	58
Total				60.64	363.8		
Average			132			6.00	45

TABLE 12. **Average values to hand harvest - cut, carry, stack, thresh on 55-gallon drum, clean, and sack a total of 48.4 tons paddy at 25 percent moisture content from a 9.6 hectare area.**

Operation	Total man-hours	Man-hours per ton	Man-hours per hectare	Percentage
Cut & lay	1059	22	110	44
Carry and stack	430	9	45	18
Thresh	611	13	64	36
Clean and bag	296	6	31	12
Total	2396	50	250	100

3) Custom-hire 70-horsepower tractors and equipment are available at $ 50 per tractor day including operator fuel and all costs. Smaller tillers are not yet widely used but could be obtained.
4) Hand application or custom airplane and helicopter services are available at one man-day at $ 1.50 to $ 4 per application of seed, fertilizer, and pesticides.
5) Hand havest or custom-combine services are available at $ 0.67 to $ 0.93 per bag of 62 kilograms.

A portable, man-powered rice combine, designed at CIAT, increases labor efficiency.

6) Trucks for transportation are available at $ 0.05 per ton-kilometer.
7) Productivity of paddy at harvest ranges from 30 to 60 kg/ha/day with an average of 45 kg/ha/day (Table 11).
8) Paddy sales price at farm with 25 percent moisture content and 5 percent impurities is $ 85 per ton, with sacks supplied by the purchaser.
9) Temperatures, irrigation, rainfall, and other conditions permit continuous planting and harvesting during the entire year.
10) Consumption of rice is expanding to replace cassava, plantains, corn, potatoes, and wheat in the local diet.

It should be mentioned that the rice yields used in these tables were produced on land undergoing reclamation for salinity and alkalinity and were therefore probably lower than would have been the case on normal well-prepared soils.

With the conditions as given, then, a mixture of labor, land, machinery and materials must be developed to operate a production system. If one major condition is to provide productive employment and about 60 man-days are required per hectare, distributed as in Table 10, then it is possible to plan for continuous stable employment and production with 120 man-days of work during a 140 calendar-day crop cycle.

Using these tables, the CIAT staff has developed a number of possible rice production systems at various levels of magnitude and labor intensity on a year-round basis, harvesting 0.2 hectares every 14 days, to a commercial 120 hectare operation, mechanized and employing 32 laborers steadily, havesting 6 hectares weekly. Details of these theoretical projections and the underlying assumptions may be obtained by writing CIAT.

The production systems described illustrate the potential production and employment opportunities for management, machine operators, and laborers working together daily, each performing his part and each sharing in an income from continuous utilization of the available resources. No one method is universally good; however, the availabillty of land, water, favorable temperatures, and labor supply that are under utilization could lead to rice production systems in some tropical areas which will set patterns for the future. The other implication is that there are obviously potential advantages in sizing units to reduce the equipment and managerial costs per hectare.

AGRICULTURAL ECONOMICS

During 1972, major emphasis was placed on identifying and analyzing alternative markets for the expected increase in rice production in Latin America because of the adoption of new high-yielding rice varieties (HYV). Furthermore, attempts were made to estimate the rate of adoption of these new varieties and the expected production increases. Finally, work was initiated to analyze the adoption process and to estimate the change in cost of production and labor use caused by the adoption of the HYV.

The ministries of agriculture and other national entities in the Latin American countries supplied basic information on current rice utilization and spread of HYV. It was found that industrial uses of rice were limited primarily to broken grains, while the use of whole grains for industrial purposes was not common. The data are presently being analyzed to determine the economic feasibility of utilizing whole grain as livestock feed and for various industrial purposes. Preliminary results suggest that it would be economically sound to utilize rice to partially replace wheat in bread in Colombia if the price of rice flour drops approximately 10 percent. The analyses for other Latin American countries has not yet been completed.

TABLE 13. **Estimated area grown with HYV in 1971 and expected area for 1972-1973.**

Country	Percent of total rice area in Latin America									
	Estimated 1971-72					Estimated 1972-73				
	IR8	IR22	CICA 4	Other	Total	IR8	IR22	CICA 4	Other	Total
Argentina	—	—	—	—	—	—	—	—	—	—
Brazil	—	—	—	—	—	—	—	—	—	—
Bolivia	—	—	—	—	—	—	—	—	—	—
Colombia	27.2	—	—	—	27.2	17.4	—	22.4	—	39.8
Chile	—	—	—	—	—	—	—	—	—	—
Cuba	35.0	—	—	63.0	98.0	35.0	—	—	63.0	98.0
Costa Rica	55.8	—	—	—	55.8	23.3	22.8	10.2	10.0	66.3
Ecuador	13.0	—	—	—	13.0	6.0	3.0[1]	12.0[2]	—	21.0
El Salvador	—	—	—	—	—	—	—	—	—	—
Honduras	—	—	—	—	—	—	4.0	—	9.0	13.0
Mexico	9.0	—	—	21.0	30.0	9.0	4.3[3]	—	21.0	34.3
Nicaragua	n.a.	n.a.	n.a.	n.a.	39.0	n.a.	n.a.	n.a.	n.a.	39.0
Paraguay	—	—	—	—	—	—	—	—	—	—
Peru	18.0	—	—	—	18.0	2.3	—	—	20.0	22.3
Dom. Rep.	—	—	—	—	—	—	—	—	15.0	15.0
Uruguay	—	—	—	—	—	—	—	—	—	—

n.a. = information not available.
– very small or none.

1 INIAP 2.
2 INIAP 6.
3 Navolato A 71.

Table 13 shows preliminary data on the estimated adoption of HYV in Latin America during the period 1971-72 and expected adoption during 1972-73. The area in IR8 is expected to decrease while the CICA 4 and IR22 become more important. Other varieties expected to be of considerable importance include Sinaloa A-68 (Mexico and Costa Rica) and Naylamp in Peru.

The overall rate of adoption is high in Cuba, Costa Rica, Colombia, and Nicaragua. The data on the rate of adoption of HYV should be interpreted with some care, as the accuracy of such data is difficult to verify. Furthermore, unforeseen market developments, such as price discrimination because of grain quality of the HYV, may reduce the adoption severely and rapidly.

TRAINING

The importance and interest in rice in the Latin American tropics have been reflected in the requests for training. The rice production system team, recognizing the importance of a network of trained people to further develop, test and introduce new varieties and practices, actively screened and selected candidates from national programs. Between 1969 and 1971, 14 professionals were trained in rice. Including the partial involvement of trainees in disciplinary groups, such as plant protection and in the Crop Production Specialist Training Program, a total of 11.2 man-years of training were provided. In 1972, 16 trainees participated in the rice program full-time and 20 others from disciplinary groups and production training, participated part time, for a total of 10.7 man-years of training.

A trainee from Ecuador prepares land with a small tractor.

Brazilian rice agronomists, while in training at CIAT, organized a rice production field day.

As a result of a joint effort of the Rio Grande Rice Institute (IRGA) and CIAT, 22 research and extension agronomists from Rio Grande do Sul, Brazil, came to CIAT in late July for a one-month short course on rice production.

The staff of the rice program and the crop production training program joined efforts to organize and conduct this course, with 26 other scientists of CIAT and Colombian institutions contributing. The course stressed field practice and covered all operations from planting to harvest on rice production with new high-yielding varieties under irrigation.

In addition, subject matter in crop technology production, economics and communication was covered in a series of conference-discussion sessions. Trainees also conducted a field day.

An evaluation of the changes in diagnostic skills and knowledge of cultural practices showed substantial progress indicated by a mean change from 5.15 to 7.3 in a 1 to 10 scale.

The organization of a network of specialists with common interests in a particular commodity, such as rice, is a catalytic function of CIAT, which provides opportunities for these specialists to exchange ideas and information, hear refresher presentations and discuss strategies for future work. Forty-nine rice research and production specialists, 12 of them trained at CIAT in the past, came to CIAT for a one-week conference of Latin American Rice Research Workers, in June.

SOILS

The old, well-drained soils of the humid lowland tropics are generally acid and infertile. They are readily modified by applications of fertilizer and lime and can be made quite productive for any climatically adapted crop. None the less, little lime and fertilizers are used in the area and agricultural production continues at a low level.

There are undoubtedly many cultural, social and economic factors involved but the principal one is basically economic. On-the-farm prices for fertilizer and lime are high and crop prices are low because of distance to market and general lack of adequate transportation arteries.

The cost of inputs will remain high until the market infrastructures are developed. In the meantime, rural tropical families need more and better food and increasing urban populations create an ever expanding demand for low-cost quality sources of energy and protein.

Acid soil tolerance

One approach to this problem of low soil productivity in the absence of added fertilizers and lime is the selection of species which are better adapted to the native soil environment and require a minimum of high-cost inputs. Many species are well adapted to extremely acid soil conditions and are often-times also very efficient at absorbing native soil phosphorus. Mangos, citrus, cashew nuts, brazil nuts, and rubber are among the more acid tolerant tree crops. There are many acid tolerant forage grasses and legumes and a number of long season, starchy food crops such as cassava, tropical yams and certain plantains. (See CIAT Annual Report 1971, p. 118). Tropical farmers have made use of these species for centuries both for subsistence and commercial production. There is however, a general shortage of cereal grains and food legumes as a basis for adequate diets.

In recent years a number of annuals including cereals and legumes have been shown to vary markedly between varieties and cultivars in regard to acid soil tolerance. However, no systematic effort has been made to screen tropically adapted species for this character in a search for agronomically acceptable material or sources of germ plasm for crop improvement programs. There is no other region in the world where such varietal and species differences could be more important than in the humid tropics of the Americas.

A cooperative ICA-CIAT screening program was initiated in 1971 at Carimagua as reported in the 1971 Annual Report. The trials, including cassava, field beans, corn, rice, sorghum, cowpeas, and peanuts, are being conducted on an oxisol with the characteristics shown in Table 1.

Large plots were established with lime levels of 0, 0.5, 2 and 6 ton/ha. The 0.5 ton level is sufficient to supply calcium and magnesium as nutrients but does not greatly alter pH nor exchange-

TABLE 1. **Some important properties of a typical Carimagua soil, from the high, smooth, well-drained savannahs.**

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

* P.C. = permanent charge or CEC at native pH.

able Al+++ levels. The 6 ton level is sufficient to neutralize most of the Al+++ and raise the pH to approximately 5.5. The intermediate level neutralizes 30-40 percent of the Al+++, while raising the pH to 5.0 as shown in Fig. 31, page 69 of cassava.

Cowpeas appear to be the most tolerant food legume. Corn and black beans are intermediate while the non-black beans (both are **Phaseolus vulgaris**) are the poorest. Between species there is considerable genetic variability regarding acid soil tolerance as can be seen in Fig. 1. Corn presents a wide range of tolerance (Fig. 9, page 122). In the case of upland rice, there are traditional varieties such as Monolaya that barely respond to the first increment of lime while the majority of the new semidwarf varieties respond strikingly to lime and produce practically nothing in its absence under upland conditions. (Figs. 6 and 7, pages 142 and 143, respectively).

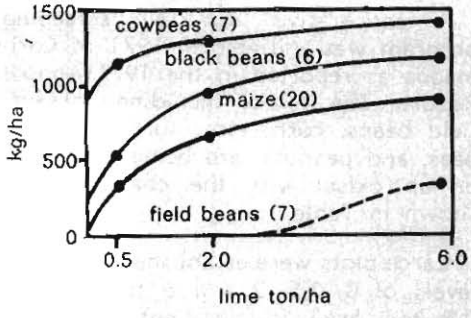


Fig 1. Crop response to lime, Carimagua, 1971.

Soil management

Little soil management research has been conducted in tropical Latin America. In many of the better agricultural areas of the region, tillage methods are very much like traditional temperate zone methods practiced in Europe or North America. In less favored areas (less favored because of topography, climate, soil, or combinations of these factors), agricultural systems tend to be more primitive or, at least, less mechanized. Tillage ranges from "zero" (i.e., stick or punch planting in many cases on steep slopes or in shifting cultivation) to animal drawn plows and harrows. In general, cultivation is rather shallow which is usually fortuitous especially for the steep mountain soils. There are exceptional cases where tillage is entirely manual and also rather deep (e.g., Rionegro region in Antioquia, Colombia). Andean farmers still use the "foot plow" in Peru and Bolivia to turn sod after long wild fallow periods, prior to planting potatoes. Much tillage is done in the process of controlling weeds and hilling crops (especially potatoes and corn), with heavy, often short handled hoes.

The main problems with traditional tropical soil management practices are: a) inadequate control of weeds; b) the amount of man-power required to carry out the necessary tillage and consequently the limited capacity of a man in terms of area under cultivation and his relatively low return for labor input; c) shallow cultivation on some soils means shallow root penetration and crops which are too subject to drought stress.

Conventional temperate zone tillage practices are often disastrous on rolling to steep tropical lands because of the obvious erosion hazards. The major problem with such practices on the better lands, especially those areas with irrigation for year-round agriculture or rainfall adequate for two or more crops per year, is the time lost between harvest and seeding of the subsequent crop. This is not too critical or often not critical at all in a temperate, one crop per year agricultural system. Time is required to: a) incorporate and/or decompose the crop residues; b) perform several tillage operations to "fit" the land for planting; c) wait for adequate moisture (may be either too much or too little in non-irrigated areas); d) permit heavy soils to condition themselves, i.e., for large aggregates or clods to slake and break up after plowing to a desirable stage for adequate seed-soil contact at planting.

An analysis of the soil management problems which confront farmers in the tropics indicated the need for the testing of practices other than those presently in use. Several soil management trials were initiated in 1972 to study different methods of tillage, planting and residue management. A primary objective is to devise crop production systems in which little or no time is lost between crops and which require less energy input or substitute forms of energy more easily accessible to the small farmer for machine and human inputs, to increase the productivity of farmers and the land.

First year experience confirms that "zero" tillage contributes to a dramatic reduction in the time required between crops, and in the cost of production assuming other means of weed control are accessible and not too costly (cost of herbicides and/or hand labor to control weeds are factors to consider). We have also observed that soil physical conditions are much better under "zero" tillage management than with conventional or reduced tillage. Soil moisture is also retained much longer during periods of drought with "zero" tillage and a mulch cover. The advantages of reduced or "zero" tillage on soil susceptible to erosion, either wind or water, are obvious.

The use of "zero" tillage should reduce weed problems in the long run if effective chemical weed control is achieved since the soil is not stirred to bring buried weed seeds to the surface and fresh seeds are not incorporated. Chemical weed control is potentially more accessible to the small farmer than mechanized weed control because of capital requirements and (often) topographic limitations to mechanization. Heavy residues (corn, sorghum stubble) left on the surface greatly suppress weed growth.

TABLE 2. **Grain and stalk yields, residue management trial - CIAT, Palmira, 1972-B.**

Treatment	Grain, ton/ha (15% H_2O)	Stalk, ton/ha (dry matter)
Residue Removed	3.94	12.2
Residue Burned[1]	3.90	13.8
Residue Chopped[2]	3.83	14.0
Residue Intact[3]	3.71	13.6
Average	3.85	13.4

1 Stalks from two rows are placed in one middle for burning.

2 Standing stalks are chopped with a rotary mower immediately after harvest.

3 Stalks from two rows are placed in one middle and left intact, leaving every other middle free of residues for drainage or irrigation.

In the first and only experiment harvested to date, four methods of corn residue management are compared with results as shown in Table 2. All treatments were superimposed on a "zero" tillage system, in which the crop was bed-planted. There were no significant yield differences between treatments. This experiment has just been successfully planted to corn for the third time with no tillage since the initial preparation one year ago. The first crop was part of a uniformity trial.

It appears very likely that the selective use of technology (e.g. herbicides) could aid the small farmer to overcome some of his inherent disadvantages and increase his capacity to produce and thus his returns for labor. The reduction of time lost and labor required for seed bed preparation between crops could be a critical factor in determining total annual productivity of tropical soils and costs of production for small and large farmers alike.

Micronutrient deficiencies

Applications of four kg of elemental boron per hectare have greatly improved corn and sorghum production. The dramatic effects of boron deficiency in corn are shown in the photo on page 120. Zinc deficiency severely limited rice production on many CIAT fields (CIAT Annual Report 1971, p. 52). Continued cropping and zinc applications of 10-20 kg/ha have largely eliminated the problem. Further information is presented in the maize, rice and bean chapters.

AGRICULTURAL SYSTEMS

Staff activity during 1972 reviewed the work previously undertaken and reported, as well as that currently underway with respect to its relevance to the proposed Agricultural Systems Program. As a result, reports on production systems research, as presented in previous annual reports, are incorporated this year in the relevant commodity sections. For instance, the family operated ranches in the Colombian Llanos are discussed in the Beef Production Systems section.

Conferences within the CIAT staff, with outside consultants, and with present and prospective donors helped to formulate, for review by the Board of Trustees at its next meeting, a proposed Agricultural Systems Program.

This review recognized the basic diversity of agriculture in the tropics of Latin America, CIAT's principal area of operation. This fact, among others, earlier led the Board of Trustees to conclude that CIAT could not achieve its objectives unless it concerned itself with farming as an integrated system in which a number of enterprises compete with and complement one another.

Agriculture varies greatly throughout the region and clearly is deeply influenced by the social and cultural traditions of the rural people. Within quite small areas, the cultural and social environment is sometimes extremely varied, more varied even than the agricultural pattern itself. European and African cultural patterns, as well as indigenous ones, are clearly discernable. Because of this diversity, the research worker may be largely out of touch with the farmer both as to what he does and why he does it.

In authorizing the Agricultural Systems Program, the Board basically said that CIAT should concern itself with farming in tropical America in all its complexity. This decision is so basic that it is difficult to plan a course of action without at the same time planning the whole strategy of CIAT. To do this in the present planning exercises would be not only presumptious, but would divert attention from concrete proposals for system program activities **per se.** These proposals presume that CIAT will concentrate most of its research and training efforts on a few key commodities and that it will draw heavily on the other international centers for technology basic to other commodities. It is also implicit that CIAT will rely heavily on national agencies to develop much of the technology and for most of its implementation. CIAT will have as one of its underlying principles the development and strengthening of national institutions.

Within this context, what kind of an Agricultural Systems research team is required and how should it function? These questions have been debated and discussed among the CIAT staff and with advisors and consultants who have helped clarify the goal for such a program.

Yams are often interplanted with cassava, maize and other crops, representing a valuable source of human foodstuffs for families of small farmers.

On all farms, big and small, transporting farm produce to market is a continual problem and a factor directly influencing what the farmer grows.

The long term goal for the Agricultural Systems Program is **to develop a process for the identification and analysis of existing farming systems and for the utilization of new agricultural technology in the development of rural areas.**

It is necessary to distinguish clearly between developing specific systems and developing a process. The agriculture of Latin America is so diverse that no one system or no half-dozen systems would serve the region adequately. No one commodity is of such paramount importance that a "miracle" within it would create an agricultural revolution.

The International Rice Research Institute, working with a crop of over-riding importance, was able to effect significantly a green revolution in Asia. It did so, whether it ever stated it this way or not, by making basic improvements in the rice production system of the small Asian farmer. Fortunately, the type of technology to do the job was largely scale neutral and the changes which were necessary in traditional practice were relatively simple for the farmer to learn. The socio-cultural-economic environment with respect to rice was likewise similar.

CIAT's individual teams expect to develop specific technology to improve the production and profitability of that commodity. That is, for the major commodity programs, beef and cassava, CIAT in collaboration with national agencies **does** aim to do a job similar to that of IRRI. The Agricultural Systems team will assist them in reaching these commodity production systems objectives.

Just as there is no paramount farming system in Latin America, likewise there is no major system that clearly needs to be drastically altered or curtailed. In West Africa, the International

Where and how the family lives are important aspects of a farming system.

Institute for Tropical Agriculture has set as one of its major goals the development of systems to replace shifting agriculture. This primitive system is so widely used there and falls so short of meeting the needs of the region that the development of a more productive system or systems is a major goal in itself. In Latin America many existing systems need to be modified in several ways, both small and large. Most of these changes, adjustments and modifications must be done by the national agencies. CIAT must be ready to help in this effort by channeling information from its own commodity programs and from those of other international centers to the national agencies.

But, how does one go about adjusting and modifying traditional systems? What are the key and essential elements to success? Is there a general process which could be applied to a given set of conditions with a good chance of

First-hand experience with, and study of diverse cropping systems and patterns are involved in developing an understanding of agricultural production systems.

success? These are some of the questions that the CIAT Agricultural Systems team will investigate.

Among CIAT's stated goals are the improvement in quantity and quality of food both for people on the land and people in the city and the improvement in general living standards for rural people through the introduction of improved technology and through the use of more efficient agricultural practices.

Many successful development projects have also involved the fortuitous presence of one or more individuals in key positions who have had the broad vision to identify not only the technological elements of the system, but also their interaction with social and economic factors.

But good fortune in matching new technology to traditional practice or in providing the breadth of knowledge or insight is not good enough. CIAT proposes to reduce the element of chance by forming a team that includes specialists in key fields who will analyze the existing situation, identify limiting factors and who will use every available tool to reduce costly trial and error. Their methodology should help to guide the research effort itself as well as to guide those who extend the research results into farm practice.

This, subject to the approval of the Board of Trustees, will be the basis of the Agricultural Systems Program of CIAT. Much of the needed personnel can be provided from the present scientific staff or by employing appropiate persons in posts already authorized and funded.

TRAINING AND COMMUNICATION

The Centro Internacional de Agricultura Tropical (CIAT) continues to provide an unique opportunity for the development and interaction of behavioral science-oriented approaches to training and communication with the multi-disciplinary agricultural research and development programs of the organization.

Acceptance and integration of the professional and sub-professional personnel associated with Training and Communication into multi-disciplinary commodity teams of CIAT assures continual attention to the "people" aspects of the problems, objectives, activities, and end results.

As a consequence, with the assistance of a training coordinator, when requested, individual scientists write behavioral or performance objectives in the process of requesting the appointment of a postgraduate intern, research scholar, or research fellow. The value of preparing and using such objectives had been demonstrated earlier with the production specialist courses in crops and livestock.

Planning of conferences and symposia now begins with specific concern for the objectives to be achieved and how these are to be accomplished through those being invited to attend. This process frequently results in a revision of the intended participant list as well as direct concern for the topics to be presented, who will present them, how, and the opportunities for discussion, commitment and decision which must be built into the schedules. Also, evaluation plans are developed and carried out, as well as indicated follow-up activities.

Similar concerns are stressed in the planning, writing, and design of publications, and in the conduct of the internal seminars.

Along with the overall growth of CIAT, the size of the Training and Communication staff increased slightly, and the volume of traffic in trainees and conference participants considerably. During the year, 118 trainees were at CIAT for all or part of the year. Nearly 200 persons participated in the three major conferences (cassava, rice, and swine), while another 180 attended the International Symposium of Basic Biology, an event in which CIAT assisted in cooperation with the Universidad del Valle.

Short course attendance included 22 rice research and extension workers from Rio Grande do Sul, Brazil, for one month, and 23 community health workers from Panama for a week.

CIAT continued to put major training emphasis in 1972 in three areas: postgraduate production-oriented internship experiences for young scientists from national programs, production-oriented research opportunities for a limited number of persons working on master's and doctoral programs, and intensive one-year training programs to prepare specialists to work in national livestock or crop production programs.

TABLE 1. **CIAT trainees appointed and/or completed training***
(January 1, 1972 to December 31, 1972)

Specialization	Training Category					
	In-service trainees	Production specialists	Research fellows	Research scholars	Special trainees	Total
Livestock production	—	17	—	—	4	21
Pastures & Forages	5	—	1	—	1	7
Beef	—	—	—	—	1	1
Swine	6	—	1	1	1	9
Rice	12	—	1	—	1	14
Cassava	8	—	1	—	1	10
Animal health	2	—	—	1	—	3
Maize	8	—	1	—	1	10
Food legumes	1	—	—	—	—	1
Crop production	—	14	—	1	—	15
Ag. economics	1	—	—	1	1	3
Ag. engineering	1	—	1	2	1	5
Soils	3	—	—	—	1	4
Plant pathology	1	—	—	—	—	1
Entomology	4	—	—	1	—	5
Weed control	3	—	—	1	1	5
Communication	—	—	1	—	1	2
Social sciences	1	—	—	—	1	2
Total	56	31	7	8	16	118

* This table includes only trainees appointed for three months or longer.

These production specialist training programs, for which the Interamerican Development Bank provides a number of scholarships, were established with the following objectives:

1) To train plant and animal scientists in the modern technology and skills necessary to produce crops and animals efficiently within the biological, economic and social environment of agricultural systems, and to transfer effectively this knowledge and skill to producers of crops and animals.

2) To explore, develop, test and demonstrate effective methodology for training in an integrated system involving agricultural and social sciences.

3) To prepare teams of well-trained production specialists who would organize and conduct in-country training so as to multiply their knowledge and

TABLE 2. **Trainees processed by CIAT (classified by field of specialization).**
(January 1, 1972 to December 31, 1972)

Trainee Category	Field of Specialization					
	Animal Sciences	Plant Sciences	Agricultural Economics	Agricultural Engineering	Communication Social Sciences	Total
In-service trainees	13	40	1	1	1	56
Production specialists	17	14	—	—	—	31
Research fellows	2	3	—	1	1	7
Research scholars	2	3	1	2	—	8
Special trainees	7	5	1	1	2	16
Total	41	65	3	5	4	118

TABLE 3. **Trainees processed by CIAT (classified by country of origin).**

(January 1, 1972 to December 31, 1972)

Country	Training Category					Total
	In-service trainees	Production specialists	Research fellows	Research scholars	Special trainees	
Australia	—		1	—	—	1
Bolivia	2	1	—	—	—	3
Brazil	8	—	—	1	1	10
Colombia	33	11	1	5	4	54
Costa Rica	2	2	—	1	—	5
Dominican Republic	—	4	—	—	—	4
Ecuador	7	5	—	—	—	12
England	—	—	2	—	—	2
Germany	—	—	1	—	—	1
Haiti	—	—	1	—	—	1
Holland	—	—	—	—	2	2
Honduras	—	2	—	—	—	2
Italy	1	—	—	—	—	1
Jamaica	1	—	—	—	—	1
Mexico	1	2	—	—	—	3
Panama	—	2	—	—	—	2
Paraguay	—	2	—	—	—	2
Peru	1	—	—	1	—	2
USA	—	—	1	—	4	5
Venezuela	—	—	—	—	5	5
Total	56	31	7	8	16	118

skills with the goal of contributing significantly toward agricultural development.

The approaches used in the production courses are highly pragmatic. "Learning by doing" is emphasized in developing five basic competencies necessary in production specialists. These competencies are technical, scientific, economic, farming, and communication.

Major personnel changes during the year included the appointment of five Latin Americans at the junior professional level for responsible positions in Training and Communication: Mr. Carlos Lascano, as leader of the Livestock Production Specialist Training Program; Mr. David Evans, as administrative associate to coordinate and provide logistic support for conferences and symposia; Mr. Alvaro Rojas, as associate editor to

TABLE 4. **Trainees in training during 1972, completed training in 1972, and continuing in 1973.**

Classification	In training during 1972	Completed in 1972	Continuing in 1973
In-service trainees	56	35	21
Production specialists	31	14	17
Research scholars	8	1	7
Research fellows	7	2	5
Special trainees	16	12	4
	118	64	54

handle the Spanish language publications and to maintain liaison between CIAT and its contract printers; and Mr. Eugenio Tascon, as a training associate and Mr. Carlos Dominguez as a training assistant, respectively, in plant science.

The resignation during the year of Mr. Barry Donath, associate editor for English publications, and Miss Patricia Chain, editorial assistant for English publications, created problems in Information Services which have not yet been fully resolved.

Mr. Nestor Guzman, appointed in mid-1971 to coordinate development of the new housing and food facilities for CIAT, worked closely with the architects, engineers and suppliers. In addition, he helped supervise operation of the temporary food facilities on the farm and represented CIAT in arrangements for use of local hotel facilities for conferences, symposia and meetings.

Financial support for the training and communication activities derives from many sources, beginning with a substantial contribution each year by the W. K. Kellogg Foundation to the core program of CIAT (for Training and Communication) plus additional funds to assist with conferences and symposia. In addition, most of the postgraduate interns are funded from the overall core budget (as provided by several foundations and governments), while a few are enrolled under specific auspices of a government or agency.

The Interamerican Development Bank, through a contract with CIAT, provides about half of the scholarships for trainees in the livestock and production specialist training programs, with the others being funded by national agencies and other organizations.

Additional support for specific conferences and symposia may come from interested organizations, such as the International Development Research Centre of Canada which contributed US$ 20,000 toward the support of the Cassava Program Review Conference and financed the Seminar on Swine Production Systems in Latin America.

Basically, the funding pattern in training and communication is to provide, through continuing core support, for the staff, facilities and equipment necessary to carry out the various activities. Then, in the case of specific events, funding organizations are invited to help share in the costs of assuring participation, such as for the travel and support of trainees or conference participants.

CONFERENCES AND SYMPOSIA

One of CIAT's major operational goals is to make knowledge available to scientists and national decision-makers and to provide opportunity for them to exchange information and experience. Through knowledge and interaction, it is expected that decisions will be reached and actions taken toward solving the problems important to the agricultural and economic development of their countries.

Although the new facilities for conferences and symposia were not yet available, CIAT carried out an active conference program during the year. The events were held in Cali hotels, although participants in each affair spent at least a half-day on the CIAT farm. Details of the various conferences (cassava, rice, swine) are reported in the respective commodity sections.

Over the past two years, CIAT assisted the Universidad del Valle in Cali in planning and organizing the XII International Symposium of Basic Biology which was sponsored by the University, the Colombian National University, the Colombian Agricultural Institute, Cornell University, the National Academy of Sciences (US), the Oak Ridge National Laboratory, the Pan American Association of Biochemical Societies, and the Colombian Association of Biological Sciences. The symposium, held in November, was attended by 180 participants from all over the world.

In September, the series of internal seminars was renewed, with members of the senior staff and occasional guests leading discussions on relevant subjects. These seminars, presented through simultaneous interpretation, are attended by the professional staff and trainees.

Work on the conference facilities progressed rapidly. By the latter part of 1973 there will be six conference rooms, of varying sizes, four of them with complete simultaneous interpretation systems and recording and playback equipment. Total capacity for fully equipped seminars and/or symposia will be 250 participants at one time, plus 280 in the amphitheatre.

SOCIAL SCIENCES

CIAT's small staff concerned with the social sciences, other than agricultural economics, actively participated in a wide range of projects, within and outside of CIAT. These are reviewed under four general categories: training, evaluation, research and consultation.

Training. With the cooperation of personnel from the staff in agricultural economics, the group designed, prepared materials for, and organized the instruction for the teaching of communication, economics and other social sciences to agricultural production specialists. This program, involving some 70 hours of classroom instruction, plus additional time in field exercises, was introduced in the Livestock Production Specialist Training Program, beginning in June.

Briefly, the integrated approach used draws upon systems concepts to help trainees recognize, understand and develop abilities to work with the factors affecting decision-making at various levels — individual, farm, community, organization and society.

A paper describing and analyzing this approach to teaching social sciences to agriculturalists was read at a meeting of Latin American rural sociologists in Sao Paulo, Brazil, in November. Earlier, a paper analyzing the role of credibility and competence as factors key to the success of agricultural production and extension specialists was presented to The Third World Congress for Rural Sociology in Baton Rouge, Louisiana.

Evaluation. Planning of conferences and symposia at CIAT includes personnel from the social sciences, one of their principal roles being to help the agricultural scientists concerned with the events under discussion to express their objectives in behavioral change terms. Once this is accomplished, personnel of the unit work both to help those developing the program select topics and methods most likely to achieve the objectives, and, at the same time, they determine how the event will be evaluated. This frequently gets them involved in working out with the scientists various pre-symposia involvement activities for the invited participants.

The following paragraphs report briefly on evaluation activities completed or underway.

This continuing involvement of evaluation personnel in the process of planning future events provides an effective link by which CIAT accumulates experience, develops expertise, and effectively employs this in the planning and conduct of future events.

In September, 1972, 83 scientists from 17 Latin American countries, Switzerland, the United States, and CIAT participated in a four-day seminar on Swine Production Systems in Latin America.

This seminar is being evaluated in two stages. The first stage, already completed, investigated the immediate impact of the seminar by means of questionnaires administered to participants on the first and last days of the seminar. A third questionnaire will be sent to participants in March, 1973, to assess the longer term impact.

On the first day of the seminar, effective communication and cooperation among the participants was extremely low (only 2.3 percent of the total of possible interactions). As a result of the seminar, this figure increased to 12 percent.

The participants indicated that in the seminar they had obtained valuable information on the use and value of locally available products such as cassava, maize, bananas, yams and molasses as pig feeds.

Of a total of 30 factors which the participants listed as limiting swine production in Latin America, those factors relating to the traditional behavior of producers, the high cost of balanced feeds, lack of production credit, and high interest rates were most frequently mentioned.

Among ways of strengthening research in swine production systems in Latin America, the participants suggested establishment of a regular system of information dissemination, more frequent meetings, establishment of a professional association, and the continued assistance of CIAT in providing training for professionals and technicians.

In June, 1972, a four-day conference for Latin American rice research workers was attended by 49 participants from 14 countries. In the end-of-the-conference evaluations, participants indicated that the information presented on plant improvement, disease and pest control, and the new varieties and their necessary complementary input packages was most valuable to them.

A one-month short course in rice production was conducted in July and August, 1972, for 22 rice workers from the Instituto Riograndense de Arroz (IRGA), Brazil. The post-course evaluation showed that the trainess considered the course extremely useful because of its orientation to practical problems of rice cultivation.

Finally, a follow-up evaluation of the Seminar on Rice Policies in Latin America held in October, 1971, was initiated. In the immediate post-session evaluation, participants had indicated that the conference had clarified ideas about new high-yielding rice varieties, their adoption and diffusion and possible "second generation" problems. In addition, participants had discussed the appropiate policies to take full advantage of the production potential of these varieties and to avoid, if possible, any negative effects.

A recent enquiry, conducted by interviewing seminar participants one year later in six Latin American countries, suggests that the visible effects of this seminar have been limited to the participants' observations as described above. None of these countries appear to have developed policies as yet, with respect to the new rice varieties, that have well-defined and implemented objectives that distribute costs and benefits among producers, processors and consumers.

Opinions of seminar participants in recent interviews were consistent with the view that adoption of the new varieties has not had a significant impact on rice production in Latin America as a whole. A major negative factor for these new varieties is that the millers appear to pay lower prices for these than for traditional varieties.

For the most part, the interviewed participants attributed these results to the fact that, for the new rice varieties to attain their production potential, well-leveled soils, good water supplies and high amounts of nitrogen are required. These conditions are met only in relatively limited areas of lowland rice production and by producers who encounter little or no budget restrictions.

On the other hand, a large part of the Latin American areas that meet the conditions mentioned above, are located in the temperate zone, and the new rice varieties presently available are not adapted to these conditions.

Research. A project was initiated in 1972 in cooperation with the Agricultural Economics program to examine the process of adoption and diffusion of new rice and corn varieties within regional agricultural systems. The overall aim of the project is to develop quantitatively described systems simulation models to analyze the introduction of new agricultural inputs into regions.

Adoption of new technology by farmers is a decision-making or learning process which takes place within the framework of a regional socio-economic environment or system. Rural institutions in the public and private sectors develop new inputs and attempt to create conditions conducive to their rapid acceptance by all potential adopters.

The specific objectives of the study are thus twofold: 1) to examine the impact, both direct and indirect, of rural institution strategies on intra-regional variations in adoption rates for new varieties, and 2) to determine the reasons for adoption or non-adoption of specific new varieties by farmers operating within the decision-making environment created by rural institutions within the socio-economic and ecological environments of the study zones.

Two extensive studies are being undertaken in Colombia in conjunction with this project. The first examines the adoption and diffusion of the high-yielding rices, IR8, IR22 and CICA 4 within the southern part of the Department of Tolima, and a second study will examine the adoption of hybrid and improved varieties of maize in the northern part of the Department of Valle del Cauca.

By the end of the year, an initial formulation of the model, based on unstructured interviews with farmers and representatives of relevant rural institutions had been completed. Construction of the sample frames for both the rice and corn studies was in progress.

Late in the year, with the cooperation of the Library, work was initiated to identify and bring together research literature relevant to the issue of food habits, diet patterns, and programs around the world which have attempted to influence these. These subjects are highly relevant to CIAT and the countries in the developing world. Whenever a new variety is developed, for instance, it runs the risk of being rejected by farmers, the market agencies, or consumers if it differs from the traditional product in color, texture, size, shape, smell, or processing characteristics.

Socio-economic studies in Colombia three years ago revealed strong resistances in all sectors to the opaque-2 corn then available. These findings have led the corn breeders to seek ways of introducing the high lysine genes into more traditional types of flint corn.

With the launching of a regional improvement program with field beans, it was obvious that with the already existing variations of beans within one species, **Phaseolus vulgaris,** bean breeders would need to take already established specific habits into account.

Through the literature search, CIAT hopes to gain a greater understanding of the issue and of the various factors that help establish and maintain food preferences and taboos. At the same time, various efforts aimed at changing food practices will be studied for the suggestions these may have for appropriate action programs in the future.

Consultation. Rapid spread of rural development projects in Colombia, these being adapted from the Puebla Project approach of Mexico, has created a demand within national agencies for social science assistance in these projects. As time permits, personnel of the unit meet with ICA and other agencies on project plans and developments, attend specific conferences on these programs, and assist in other ways as requested. In return, CIAT has found in these projects new opportunities for providing those enrolled in production specialist training programs with useful learning experiences in how to work with small farm operators.

Within CIAT, personnel have been directly involved with others in developing the concepts and possible approaches for the Agricultural Systems Program.

One research associate regularly teaches a course in linear programming at the nearby School of Agriculture, of the National University.

TRAINING IN ANIMAL SCIENCE

During the first six months, the animal science training staff cooperated with three Colombian universities (Universidad de Antioquia, Universidad Nacional at Medellin and Universidad de Caldas) to help establish field-oriented training programs in the undergraduate curriculum. Programs were outlined for each of the universities as part of the fifth year curriculum activities.

As courses were designed to fit the particular needs and schedule of each university, they varied in content and organization. In general, they provided instruction in farm management and animal production as well as practical professional work on livestock farms.

This type of assistance was well received by both the administration and students of the respective universities. One university continued the field part of the program after CIAT personnel left. This university had a trainee in

Regular observation of animals and record-keeping of animal treatment and performance are practices which the staff members of CIAT encourage trainees to adopt.

CIAT's first Livestock Production Specialist Training Program (LPSTP). This points out the value of having previously trained personnel on the institution staff before introducing this type of a program. Another problem is that universities sometimes report difficulties in financing the technical support needed for a practical training course.

The first LPSTP group of 11 (all Colombians) was graduated in December, 1970. These professionals are presently working in such Colombian organizations as ICA, Federacion Nacional de Cafeteros, Caja Agraria, and various universities.

In 1971, the training staff evaluated the course completed in 1970, continued to collect data on the collaborating ranches on the north coast of Colombia, and developed systems by which similar training programs could be incorporated into university degree programs.

In April, as part of the continuing follow-up, the 11 graduates of the first LPSTP met for two days with the CIAT staff.

On the basis of their 18 months' experience after finishing the course, the graduates recommended that future programs give additional attention to: economics and accounting at the ranch level, sociological aspects of community development, elementary statistics and experimental design, and sanitation on the ranch and in the community.

Other aspects rated as important included thorough orientation of project leaders to the people and problems of the area, providing more direct specialist assistance to trainees in the field, establishing daily animal management practice during the theoretical training period, including an agronomist to help on weed control, and closer collaboration throughout with other CIAT programs.

An animal scientist was employed in April as leader of the Livestock Production Specialist Training Program. He is stationed in Monteria and is responsible for the day-to-day operation of the training program on the coast.

Details of the postgraduate internship program with respect to beef and swine are reported in those sections.

Livestock Production Specialist Training Program

Plans for the second LPSTP began in early 1972 with CIAT staff members interviewing prospective candidates in eight countries. By June, 17 trainees had been selected and enrolled from Bolivia (1), Colombia (7), Dominican Republic (2), Ecuador (2), Honduras (1), Mexico (2), and Paraguay (2). Of these, 14 were funded through support provided by the Interamerican Development Bank.

In April, the base of operations for the field portion of the course was moved from Sincelejo to the ICA Research Center (Turipana) near Monteria. The new location provides well-equipped offices with a conference room and is adjacent to the ICA research and diagnostic laboratory.

This move necessitated identifying new ranch collaborators in the Monteria area.

During the first ten weeks of the course at CIAT, the trainees received approximately 440 hours of instruction in communication, economics, animal nutrition (ruminant and monogastric), animal health, soils, animal husbandry, animal breeding, agronomy, engineering and farm machinery, weed control, pastures and forages, human health and first aid, and statistics. This ten-week period is designed to focus the trainee's attention and competence on the important factors in production and to demonstrate how many disciplines are involved in developing and applying a production package.

Approximately 70 percent of the staff-student contact time was in the class-

room, the remaining time being spent in such field activities as animal restraint, minor surgery, semen evaluation and pregnancy diagnosis, necropsy, forage evaluation and weed control.

In mid-August trainees moved to Monteria, which is located in a livestock producing area. They and the training staff spent three weeks studying ranches as possible training grounds for the field activities. They selected ranches on the basis of accessibility, feasibility of introducing new as well as basic technology, living conditions, and attitude of the ranch owner in relation to the system on the ranch.

Of 15 ranches evaluated, 8 were selected and trainees were assigned to them. Five ranches each received two trainees (one veterinarian and one agronomist). They work together to present a broad base plan of improvement for the ranch. In addition, they learn from each other. Three trainees serve generally coordinating and supervising work on all ranches on animal reproduction, animal management and weed control. One trainee with special interest in swine was assigned to the CIAT small swine farm project.

Each trainee has essentially two assignments during his eight months on the ranch. He establishes base-line data for the ranch in terms of land utilization, labor utilization, livestock numbers, health and disease situation, and nutrition, as well as other factors, which contribute to production and productivity of the ranch. He also designs and implements (as time permits) a plan for improving the production of the ranch with emphasis on increasing conception rate, reducing the calving interval and reducing baby calf death loss. This includes establishing such practices as a record-keeping system, improving pasture management, animal selection and culling, an organized breeding program, supplying vitamins and minerals, construction of maternity pastures, and reducing animal health and disease problems through improved management and nutrition.

Every trainee sees a training supervisor at least once and usually twice a week. In addition, all trainees meet twice monthly at the training headquarters to report progress, to discuss plans, and to participate in seminars lead by staff members of CIAT or other organizations.

Every trainee conducts a research project in the ranch where he lives. Such trials include: evaluation of different pasture weed control methods, comparison of different methods of castration, vitamin supplementation in steers, hormone implants for fattening steers, and mineral supplementations. These trials provide data useful in future courses and provide experience in designing and running a field experiment.

The field program will continue until April 15, 1973. The trainees will then return to CIAT headquarters for approximately one month when they will each prepare and present (as a seminar) a report on their field experience. Round-table discussions with staff members will inform the staff on the production problems that exist on the ranches and also give the staff opportunity to evaluate the trainees' progress.

TRAINING IN PLANT SCIENCES

Immediate training objectives in the plant sciences are: 1) to train research and production scientists from various countries so as to help strengthen national institutions and to provide ways by which these personnel can multiply their training in their countries, 2) to develop a network of research and production scientists around a common interest for the future testing and introduction of promising research results, and 3) to identify and further qualify young scientists to staff programs of CIAT and other organizations.

Crop production trainees study the cropping systems and practices on small farms as a first step toward considering ways to bring about improvements.

With the growth in numbers of the senior staff, the sharper definition of objectives and the advances in the commodity programs, there has been an increase in the number of persons trained, in countries served, and the quality of training provided.

Several changes in the training staff in plant sciences occurred in 1972. One training associate received a CIAT scholarship to continue studies at the University of Guelph. One training assistant accepted a position in the ICA's North of Cauca Rural Development Project, while another left to work in a private crop-production business. Two agronomists with long experience in crop production joined CIAT as training associate and assistant, respectively.

During the period between the end of the second and beginning of the third crop production specialist training programs, the training coordinator and his staff were engaged in several activities aimed at developing and extending CIAT's training effects.

They prepared instructional and training materials, field tested agronomic practices, explored training grounds and identified cooperating farmers for the succeeding courses and in-country training back-up.

In May, they conducted a one-week short course in practical vegetable crop production for 23 rural community supervisors of the Ministry of Health, Panama.

Crop production trainees study ways of producing vegetables on the farm as an integral part of agricultural systems for large and small operations. They concentrate on identifying adapted varieties and in testing appropriate cultural practices.

An exploratory experience was started in September, 1972, this combining in-field training on diversified crop production with training for research in maize. This first attempt to equip young scientists with crop production skills was aimed at qualifying the participants: a) to identify field problems restricting production, b) to achieve the maximum effectiveness from their research efforts through management of the crop under study, c) to plan their research and evaluate results in the light of the economic factors and relationships affecting commercial production, d) to make effective use of field diagnostic skills, and e) to consider the technological and socio-economic relationships between the crop being investigated and other crops and components of a production system.

In the future, greater participation of research postgraduate interns in production training will be encouraged. Specific training activities in the various commodity programs are described in the respective commodity sections.

Crop Production Specialist Training Program

Since its beginning in July, 1970, the Crop Production Specialist Training Program has presented two 12-month courses. The first one, exploratory in nature, involved ten young Colombians in field and classroom training activities. In the second course, more international in scope, 14 trainees participated, these coming from the Dominican Republic (2), Honduras (1), Costa Rica (2), Panama (2), Colombia (4) and Ecuador (3).

Activities of the course, initiated in March, 1971, continued to completion in February, 1972. During the last two months, heavy emphasis was placed on the practice of communication as related to the transfer of technology and community development.

After the previous two months of intensive training, this involving theory instruction and practical experiences in crop technology, field experimentation, farm management and communication, the 14 participants spent most of their time working closely with a number of small farmers in the community of El Bolo. They studied the production system in which the farmer operates, including the various components such as the family, ecology, crop technology, community infrastructure, education, transportation, marketing, availability of inputs, labor and machinery. They prepared detailed reports, these serving as the basis for a series of round-table discussions, with the scientists and administrators of CIAT and other institutions in Colombia.

Other activities at the end of the course included:

1) Analysis of data and preparation of reports of experiments carried on during the last semester, both at CIAT as well as on farmers' fields with the objective of practicing "validation of technology."

2) A four-day trip to visit ICA's Rural Development Project at Rionegro, Antioquia. This included interviews with small farmers in their fields and meetings with project leaders to discuss strategy and results.

3) A review of the economics of crop production on the trainee-managed farms, with emphasis on cost-benefit relationships.

4) Examinations and course evaluation.

Upon completion of the course, participants returned to their places of origin. Without exception, they immediately started working in their institutions. Follow-up with the former trainees and officials of their institutions have indicated that, in all cases, they are making effective use of their training. These activities range from extension to direct field operations of an agrarian reform project.

The impact of the training of these professionals on the communities or on country programs is difficult to measure. First-hand information from institution officials and farmers in the areas where the trainees are operating indicates that these trainees are effectively transferring technology to farmers and are helping to bring about increases in real income and improved family welfare.

But the ultimate goal of the CPSTP, that is, the in-country multiplication of training, has not yet been achieved. Follow-up action has identified obstacles, as follows:

1) The value of guided practical training to provide considerable experience in a short time so as to energize professionals into action has not yet been fully recognized by national institutions. They are oriented to and more likely to take advantage of the frequent opportunities their professionals have to obtain advanced training in traditional theory courses.

2) Trained personnel are scarce, and there are constant pressures to launch national action programs. Thus the national officials tend to assign newly trained personnel to work directly in existing or new field programs rather than in the training of others, an activity which they consider belongs in the universities.

3) Faculties of agronomy in the national universities cling to their traditional forms of education and lack the leadership and financial resources to introduce practical training programs (which they associate with vocational education) into their undergraduate and graduate curricula.

4) The limited number of production-oriented professionals capable of training others has not yet reached a "critical mass" in any country in order to demonstrate to decision-makers the value of in-country production training programs.

Consequently, the Training and Communication program in 1972 adopted a more aggressive approach in preparatory and recruiting actions for the next crop production specialist course. These activities have included obtaining commitment from the national institutions to make, in advance, definite plans for in-country multiplication of the training CIAT offers, and training simultaneously a "critical mass number of professionals" to form a "training team" for a given country.

Members of CIAT's training staff travelled extensively in 1972 to ten countries promoting this idea and identified two, Ecuador and the Dominican Republic, where conditions seemed to be most appropriate for a concentrated effort. As a result, eight Dominicans and seven Ecuadorians have been selected to participate in the third CPSTP along with lesser numbers from other countries including Mexico, El Salvador, and Colombia, for a total of 25 participants in a Crop Production Specialist Training Program to begin March 1, 1973.

INFORMATION SERVICES

Information service activities continued to increase at a rapid rate in 1972, commensurate with the growth in the CIAT professional staff and mounting commodity program demands and outputs. One of the continuing problems has been a way to obtain satisfactory translation of technical material for publication in English and Spanish. Another has been that of staffing the editorial ranks with some personnel whose native language is English.

Publications completed during the year included the annual report, a technical bulletin on photoperiod sensitivity in maize, a reference bulletin on world production and utilization of cassava, the proceedings of the rice policies seminar, and a directory of Latin American plant pathologists.

Support to the various CIAT activities included printed materials for conferences, symposia and training programs, design of visual aids, and photographs.

In cooperation with the Library, the mailing list was reviewed and expanded, with materials now being circulated to individuals and institutions in more than 90 countries. Similarly, a list of some 500 newspapers, magazines and journals was established for the mailing of occasional press releases or reports.

LIBRARY

Up to 1971, the main task of the Library was to build a specialized collection to serve the scientific staff. The beginning of 1972, however, marked a change in policy as the rapid growth of the collection has made it possible to develop and provide services to a broader clientele.

Following CIAT's specific fields of interests, the Library stands now at approximately 6,000 book titles catalogued and 850 journal titles being received regularly. In addition to library activities, two special services were started this year to make the information at the Library more readily available to its users; one was the distribution of photocopies of tables of contents of specifically selected journals, and the other was the Cassava Document Analysis Center.

Tables of Contents. Scientists selected individually those journals they wished to review regularly. The tables of contents of these journals are copied and distributed selectively to them every month. They mark the articles of interest and these are photocopied for them. In this manner, each department at CIAT is gradually building up a specialized file of reprints being continually used both by scientists and trainees. A useful by-product is the compilation of specialized bibliographies which some departments have initiated for distribution among their colleagues in Latin America.

In May, a request to extend it to the personnel at the ICA Research Center in Palmira was received, and a month later, the ICA-LIMV in Bogota and Monteria (Turipana) also requested to be included. At present, more than 140 scientists receive this personalized service and some 5,000 tables of contents have been copied and distributed during the year. More than 2,500 articles were photocopied to meet requests made.

Cassava Document Analysis Center. The Cassava Document Analysis Center is an experimental project designed to identify and collect available research literature on cassava and to disseminate this information selectively on the basis of individual interest profiles. It started to operate in March and, by December, it had identified and purchased 2,939 cassava documents out of the estimated 3,500 - 4,000 existing in the world. Of these, 1,260 documents had arrived at CIAT.

Discussions with the International Development Research Centre of Canada culminated in an agreement whereby a variety of activities will either be continued or initiated in 1973.

The Center uses a mechanized interior-punched card system for retrieval. Documents are numbered consecutively and abstract cards are produced both in English and Spanish. Keywords are

used for specific searches requested and for distributing cards regularly according to users' interest profiles.

Other areas of CIAT's concern will be included in this type of service in the future.

Library Holdings in Agricultural Economics. A survey of library holdings of six major graduate programs in Agricultural Economics in Latin American universities was undertaken in cooperation with the Ford Foundation. This work was carried out to provide data which might be used to assess the adequacy of these libraries in relation to a graduate training program in Agricultural Economics, as well as to study the feasibility of an international program in this area.

The data were obtained through personal interviews with personnel of the Library as well as with agricultural economists of each institution involved. Besides a list of questions which served as a guide for interviewing, a "master list" prepared by Dr. Jorge Lopera, Agricultural Economist of ICA, and scored by the agricultural economics staff at CIAT, served as criteria for qualitative evaluation of the collections.

Results of this study were reported at the 1972 Ford Foundation Seminar of Program Advisors in Agriculture held in Mexico City, November 6-10, 1972. Policy implications and action programs suggested in this study are presently being studied for possible implementation during 1973.

ACKNOWLEDGEMENT: Research and training activities reported for the calendar year 1972 were financed by grants from a number of donors, principally the United States Agency for International Development, the Ford Foundation, the Rockefeller Foundation, the Canadian International Development Agency, the W.K. Kellogg Foundation, and the Government of the Netherlands. In addition, special project funds were supplied by the International Development Research Centre of Canada and the Interamerican Development Bank. Information and conclusions reported herein do not necessarily reflect the position of any of the agencies, foundations, or governments involved.

FINANCE

PRICE WATERHOUSE & CO.

APARTADO AEREO 180
CALI-COLOMBIA

April 2, 1973

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, 1972 and the related operating statement 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 operating costs of commitments for future expenditures amounting to $155,783 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, 1972 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 individual grants and earned income for the year ended December 31, 1972, 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 1)

ASSETS (Note 2)	December 31 1972	1971	1970
CURRENT ASSETS:			
Cash	272	450	959
Accounts receivable:			
Donors (Note 3)	499	471	446
Employees	73	29	16
Others	287	334	86
	859	834	548
Inventories	54	7	
Prepaid expenses	17		
Total current assets	1,202	1,291	1,507
FIXED ASSETS (Note 4):			
Revolving fund (Note 5)	64	51	44
Operating equipment	313	295	224
Research equipment	329	255	171
Vehicles	314	257	249
Furniture, fixtures and office equipment	369	236	145
Buildings and construction in progress	2 359	1 276	474
Land		4	3
Others	116	64	42
Total fixed assets	3 864	2,438	1,352
Total assets	5,066	3,729	2 859
LIABILITIES, CAPITAL AND UNEXPENDED FUNDS			
CURRENT LIABILITIES:			
Bank overdrafts	7		
Accounts payable	181	423	74
Payable to donors	25	25	25
Others	100		
Total current liabilities	313	448	99
CAPITAL AND UNEXPENDED FUNDS:			
Capital (Note 6)	4 755	3,141	2,829
Unexpended funds (deficit):			
Core	(12)	77	(69)
Special projects			
I.D.R.C.	35	63	
Other	(25)		
	(2)	140	(69)
Total capital and unexpended funds	4,753	3,281	2,760
Total liabilities, capital and unexpended funds	5,066	3,729	2 859

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

OPERATING STATEMENT

(Expressed in thousands of U.S. dollars - Note 1)

	Year ended December 31		
	1972	1971	1970
SOURCES OF FUNDS:			
Core Operation grants:			
Unrestricted	2,286	2 144	924
Restricted	433	352	165
Total core	2,719	2,496	1,089
Special projects - grants	98	191	145
Earned income	98	8	34
Total operating funds	2.915	2 695	1 268
APPLICATION OF FUNDS:			
By Core Programs			
Research:			
Beef	417		
Swine	177		
Cassava	309		
Field beans	114	(1)	(1)
Rice	240		
Maize	150		
Agricultural production systems	110		
Total direct research	1,517	1,338	754
Training and Communication	371	300	143
Library, documentation and information services	77	88	62
Station operations	343	115	
Biometrics	4	2	
Administration	314	230	238
General expenses	265	285	237
Total core program costs	2,891	2 358	1,434
By Special Projects	166	128	145
Total operating costs	3,057	2,486	1,579
Unexpended balances (deficit):			
Net operating result for year	(142)	209	(311)
Balances at beginning of year	140	(69)	242
Balances at end of year	(2)	140	(69)

(1) Comparative figures for 1971 and 1970 are not available.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

NOTES TO FINANCIAL STATEMENTS

DECEMBER 31, 1972

NOTE 1:

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	22.79	Approximate year-end exchange rate
Peso income and peso disbursements for fixed assets and expenses	22.09	Average monthly rate of exchange applicable to sales of dollars

NOTE 2:

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 3:

Accounts receivable from donors as at December 31, 1972, comprised the following:

	$ 000
Agency for International Development — balance of 1972 grant which was received in 1973	362
The Rockefeller Foundation:	
Allocations for purchases and expenses which expire on December 31, 1973	76
Balance of 1971 grant	24
	100
Interamerican Development Bank — balance of 1972 scholarship expenses	37
	499

NOTE 4:

In conformity with generally accepted accounting principles applicable to non-profit organizations, CIAT does not record depreciation of its property and equipment.

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, 1972 was as follows:

	$ 000
Inventory of livestock — December 31, 1971	51
Purchases during the year	56
Sales during the year	43
Inventory of livestock — December 31, 1972	64

NOTE 6:

The movement on the capital account for the year ended December 31, 1972 was as follows:

	$ 000
Balance at beginning of year	3,141
Capital grants	1,557
Gain on sale of fixed assets	31
Gain on sale of livestock	11
Interest earned on capital grants	15
Balance at end of year	4,755

The unexpended balance of the above capital grants at December 31, 1972 amounted to $ 131,000.

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
SUPPLEMENTARY INFORMATION

SCHEDULE OF INDIVIDUAL GRANTS FOR THE YEAR ENDED DECEMBER 31, 1972

(Expressed in thousands of U. S. dollars)

	$ 000
Unrestricted core:	
Agency for International Development, Washington, D. C.	721
The Ford Foundation, New York	720
The Rockefeller Foundation, New York	720
The Government of the Netherlands The Hague	125
	2 286
Restricted core:	
International Development Research Centre, Ottawa	278
The W. K. Kellogg Foundation, Battle Creek	155
	433
Total core	2,719
Special projects:	
Interamerican Development Bank, Washington, D. C.	50
The W. K. Kellogg Foundation, Battle Creek	30
International Development Research Centre Ottawa	10
Others	8
Total special projects	98
Capital grants:	
The Rockefeller Foundation, New York	807
The Kresge Foundation, New York	750
Total capital grants	1,557

SCHEDULE OF EARNED INCOME FOR THE YEAR ENDED DECEMBER 31, 1972

(Expressed in thousands of U.S. dollars)

	$000
Sources of earned income:	
Interest on deposits	26
Sale of farm produce	67
Use of CIAT facilities	5
	98
Application of earned income:	
Core operations	82
Special projects	16
	98