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Cassava Program

Working Document No. 58, 1985

CIAT Centro Internacional de Agricultura Tropical

El CIAT, Centro Internacional de Agricultura Tropical, es una institución de investigación y capacitación agrícolas, sin ánimo de lucro, dedicada a incrementar la producción de alimentos en las regiones tropicales en desarrollo. El CIAT es uno de los 13 centros internacionales de investigación agrícola bajo los auspicios del Grupo Consultivo para la Investigación Agrícola Internacional (GCIAI).

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La información y las conclusiones contenidas en esta publicación no reflejan, necesariamente, el punto de vista de las entidades mencionadas anteriormente

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CASSAVA PROGRAM ANNUAL REVIEW
1985

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INTRODUCTION

The much publicized food crisis in Africa has highlighted the importance of securing the food supply over time. Cassava, due to its special inherent attributes, has a particularly important role to play in the elimination of periodic famine. While CIAT does not work directly in Africa, it continues to support the efforts of its sister center, IITA (International Institute for Tropical Agriculture), to ensure a more stable food supply on that continent.

In Asia the CIAT regional cassava program is now firmly established and provides increasing back up for the national programs in the area. As Asian countries improve their rice production they are increasingly turning their attention in research and develpment to upland crops such as cassava.

In Latin America, the economic situation continues to favor cassava development and there has been a remarkable surge of interest in the crop. In the Caribbean, the national program research directors have made root crops, including cassava, a priority area.

INTERNATIONAL COOPERATION

Latin America and the Caribbean

Experience in Latin America and the Caribbean in the last few years has shown that increased cassava production in the area is unlikely to occur spontaneously as a result solely of improved production technology. However we have also observed that when alternative markets are created for cassava or cassava products then farmers are quick to request new production technology. In recognition of this situation the CIAT cassava program, in close collaboration with national agencies in the region, has embarked on a major study to determine the future and present demand potential for cassava.

The demand studies will cover all of Latin America and the Caribbean in general terms. It is obviously not possible to cover all regions and countries in detail and hence case studies will be done for each of the major uses in representative countries or areas. The use of fresh cassava, with the new storage technology, is being analysed in Bucaramanga (Colombia) and Lima (Peru). Cassava as animal feed on the farm is being evaluated in southern Brazil, while its use as a component of balanced diets is being studied in Mexico, Panama, Colombia and Ecuador. The demand for traditional dry cassava products will be estimated in Brazil and Haiti. The use of dried cassava as a substitute for wheat flour is under review in Brazil and Colombia where a pilot project is underway. The studies are made at three different levels. Initially, the demand is estimated at current production levels with current policies. If it is found that cassava is not competitive under these conditions then the effect of policy changes, such as removing subsidies on competing products, are evaluated. Finally the effects of new production technology are determined. The results of these studies will be made available to the appropriate national agencies for planning purposes.

Country Reports

In this report it is not our intention to fully describe all activities related to cassava development in the region, but rather to describe a few of those programs very closely linked to the CIAT Cassava Program that have made great strides in the last year.

Colombia

Colombia is the host country of CIAT and due to its diverse uses of cassava and varied climatic conditions it provides an excellent testing ground for new technology. At present two main end uses of cassava are being studied; the efforts on fresh cassava are reported elsewhere (see fresh cassava storage pilot project) while those on dried cassava for animal feed are reported below. In previous CIAT Cassava Program Annual Reports (1983, 1984) we have described the methodology for the development of integrated cassava projects. The proving ground for the testing of this methodology has been the DRI (Desarrollo Rural Integrado) cassava drying project on the Colombian North Coast.

The project, which has focused on the establishment of small agroindustrial businesses based on the organization of cassava farmers'

TABLE 1. Costs of producing dry cassava. Average values for the 20 plants during the 1984/85 drying season. Col.$/ton dry product.

	Partial cost		
	Col.$	%	Total cost
Variable costs			17,800
Raw material	13,890	66.8	
Fuel, labor and other costs[a]	2,040	9.8	
Transport	1,870	9.0	
Fixed costs			2,980
Management[b]	780	3.8	
Depreciation	1,160	5.6	
Interest[c]	1,040	5.0	
Total			20,780
Selling price			23,190
Profit			2,410

[a] Other costs include bank charges, etc.

[b] Management includes maintenance and administration.

[c] Interest on investment and working capital.

associations, has passed through three distinct phases: an experimental phase, a demonstration phase and a replication phase. During the experimental phase, which was undertaken in 1981, a pilot plant was constructed and operated in collaboration with a group of 15 farmers to collect data on drying performance under the conditions prevailing on the Atlantic Coast and to ascertain the acceptability of the product by the animal feed industry. Subsequently, in 1982, the pilot plant was operated on a semi-commercial basis and accurate price and cost data was obtained with which it was possible to demonstrate the economic feasibility of replicating the plants in other localities. Since 1983, 19 additional plants have been established throughout the Atlantic Coast region (6 in 1983, 13 in 1984). The ultimate goal is to establish 400 drying plants with a capacity to produce 100,000 tons of dry cassava chips per year.

Throughout 1985, CIAT maintained its close links with the project. For the 1984/85 drying season (December-April) 13 new plants were established, 10 by DRI and 3 by INCORA (Instituto Colombiano de la Reforma Agraria). This increased the total number of plants located on the Atlantic Coast to 20. During the season these 20 plants processed 7,158 tons of fresh cassava and produced 3,006 tons of dry cassava chips. This represents a 217% increase in production over the previous drying season (1983/84).

Of the 20 plants, 14 made average profits of Col.$4,020 per ton of dry cassava. Six new plants made losses of Col.$1,229 per ton. All of these started drying late because of delays in the construction of the plants. This substantially reduced the period during which they could operate before the onset of the rainy season and consequently reduced their production of dry cassava. It is expected that these plants will operate profitably next season.

The profitability of some of the recently established plants has also been affected by the fact that the groups formed to manage them have been made up of farmers with little or no capacity to produce cassava. This means that the plants depend on a supply of cassava from non-members and there is no guarantee that this supply can be maintained. In future it will be important to assure that the farmers' associations or cooperatives are made up of members with an adequate capacity to produce and supply cassava to the drying plant.

The raw material cost represents 67% of the total cost of producing dry cassava chips (Table 1) and therefore the price paid by the plants for fresh cassava is the principal factor that determines the economic attractiveness of the drying process. Among the range of improved agronomic practices, whose adoption could increase crop productivity and thereby reduce raw material production costs, the use of good quality seed is perhaps the most important. In the first semester of 1985, the DRI program initiated an improved "seed" project which contemplates the production of clean planting material by farmers and the multiplication of improved varieties at the ICA experimental stations, for subsequent distribution to members of the drying plant cooperatives. CIAT assisted in a special "seed" production course established by DRI.

Technical assistance to the drying plants is provided in each department by teams made up of personnel from the different government institutions that make up the DRI program. The rapid and successful expansion of the project will depend largely on the efficiency of these teams and their capacity to respond to the problems faced by the drying cooperatives. The teams must therefore receive adequate preparation and updating on aspects relating to the establishment and operation of the plants.

Table 2 summarizes the performance of the plants, differentiating between the old plants and those established recently. The results illustrate the better overall performance of the those plants that are operating for the second or third year. It is also worth noting that the new plants established this year by INCORA operated as efficiently as the older DRI-established plants and a greater proportion of the cassava processed by these plants was supplied by members. It appears that two fundamental aspects, land availability and cassava production credit. are not limiting factors for these beneficiaries of the Colombian Land Reform Program, whereas this is not the case for those farmers organized through the DRI program.

A number of new buyers have entered the market for dry cassava chips and the product is now being used in all the principal animal feed concentrate manufacturing centers (Table 3). The need to despatch and transport large quantities of dry cassava over long distances has posed problems for the drying cooperatives and initiatives will have to be taken to improve the organization of this area of the marketing operation.

Cooperation among the members of the 20 cooperatives has increased the most important being the joint negotiation, by an elected committee of representatives from each department, to fix quotas and prices for the sale of the dry cassava produced during the year. On the June 2, 1985, the Colombian Government officially recognized the formation of a Cassava Growers' Federation whose aim is to further and to protect the interests of the farmers involved in the processing of cassava for animal feed.

The DRI program is maintaining its support for the cassava drying project and a further 14 plants are under construction. INCORA is financing the establishment of two new plants. Outside the Atlantic Coast region there are four cassava natural drying plants in the Department of Santander del Sur and two are projected to be built in the Department of Antioquia.

A mailed questionaire that was completed by the end of 1984 established that the demand for dried cassava in Colombia is excellent. The animal feed industry has been growing at an annual rate of 8%, but the demand for specific animal feed, raw materials, such as sorghum, for which cassava is a substitute, grew at about double this rate. This is because the animal feed industry initially could supply itself largely with by-products of other agro-industrial processes. By 1984 the Colombian animal feed industry consumed some 750,000 tons per year of sorghum valued at 190 million US dollars. Sorghum has almost always

TABLE 2. Overall results of the operation of the cassava natural drying plants 1984/85.

Drying plant type	Number of plants	Total drying area m^2	Dry cassava production t	Conversion[a]	Plant utilization[b] %	Cassava supplied by cooperative members %
DRI, established 1983	7	8,860	1,762	2.38	66	32
DRI, established 1984	10	6,378	634	2.46	34	12
INCORA, established 1984	3	3,000	610	2.31	65	47
Overall	20	18,238	3,006	2.38	55	31

[a] Conversion: tonnes fresh cassava required to produce 1 tonne dry cassava chips.

[b] Plant capacity based on 3 batches per week during 20 weeks using fresh cassava chip loading rates of 12 kg/m^2.

TABLE 3. Destination of dry cassava produced during the 1984/85 season on the Atlantic Coast of Colombia, and distances to animal feed concentrate manufacturing centers.

Department	Number of drying plants	Dry cassava production t	Cartagena[a] (80-250 km)	Barranquilla[b] (60-150 km)	Medellin[c] (500 km)	B/manga[a] (500 km)	Buga[a] (1000 km)	Palmira[d] (1000 km)	Others
Cordoba	4	442.3	20	-	19	-	31	26	4
Sucre	7	1,617.0	43	-	16	-	33	7	-
Bolivar	2	75.0	100	-	-	-	-	-	-
Atlantico	3	190.7	42	58	-	-	-	-	-
Magdalena	3	635.8	29	63	-	8	-	-	-
Cesar	1	45.2	-	-	-	100	-	-	-
Total	20	3,006.0	38	16	12	3	23	8	1

[a] Purina Colombiana, S. A.

[b] Acondesa and Nutridíaz

[c] Solla, S. A. and Fedegan

[d] Villa Lismori.

been in short supply over the last decade and imports have risen to an average volume of 60 to 100,000 tons per year.

Increased availability of cassava raw material would further stimulate development of the industry and consequently the industry's interest in dried cassava as a calorie source is considerable. At 78% of the price of sorghum (which more or less reflects the nutritive value of dried cassava versus sorghum) a yearly demand of some 140,000 tons was estimated. This demand is very price sensitive. For every one percent price change, the demand would change by more than four percent in the opposite direction. As can be appreciated in Table 4, demand is proportionally greatest for elaboration of pig and cattle compound feeds. These are the high growth products of the animal feed industry at present. It can be concluded that the dried cassava demand will grow at a higher percentage rate than that of the animal feed industry. This is even more true if we consider that many Colombian animal feed producers are not familiar with dried cassava at present. Inclusion rates in the mixtures are presently below 20%, while in Europe's compound feed industry, 30% is a normal value. When familiarized with the product, Colombian animal feed producers could start including higher percentages of dried cassava.

By 1990, an aggregate dried cassava demand of at least 200,000 tons is estimated. This would need additional fresh cassava production of about 500,000 tons or, at present yield levels, 50,000 to 60,000 hectares. This implies that the use of cassava as an animal feed will increase total demand for cassava by more than 30% in five years.

The increased demand for cassava has lead to requests for new technology to improve production technology by the "campesinos" (small farmers) who previously only requested assistance in marketing and price stabilization. This new demand for technology has lead to a strengthening of the national research program on cassava of ICA, which is now concentrating its efforts on the Colombian North Coast. CIAT is assisting this renewed research effort through training and the setting up of a series of joint trials on technology validation in the region.

Ecuador

During the decade of the 70's there was close collaboration between CIAT and INIAP (Instituto Nacional de Investigaciones Agropecuarias) on testing of cassava varieties and agronomic practices. In 1981, INIAP commissioned a study by CIAT on the future needs for cassava research in Ecuador. In the subsequent report it was stated that "In the absence of a plan for integrated production, processing and marketing there will not be sufficient stimulus to the farmer and as a consequence the production of cassava as an alternative source of energy will progress little or remain static" and furthermore "In order to reach the goal of an integrated industry, cooperation is required between various groups of the public sector, associations, private companies and farmers".

In the interim between 1981 and 1985 conditions for increasing cassava production were not, in economic terms, particularly favorable. However, the recent change of policies resulting in reduced subsidies to competing products has made the increased use of cassava an attractive

proposition. The moment appeared propitious to utilize experience gained in Colombia in mounting a cassava drying industry in Ecuador.

The CIAT Cassava Program and Colombia's integrated Rural Development (DRI) office have promoted solar drying of cassava on the North Coast of Colombia since 1980. Each plant is operated by an association or cooperative of small-scale farmers (campesinos), and so far none have failed. Production last year reached 3,000 tons of dry cassava with complete market acceptance.

The Colombian experience shows that promoting the technology through an integrated rural development (DRI) project and an international center is costly. A cassava chipper costs only US$800, and a complete cassava-drying plant bears a mere US$10,000 turnkey price, a real bargain for rural development planners given its impact. However, the hardware is surrounded by technical assistance, agricultural credit, management, economic research, and other peripherals. Because of these services and overhead, the total cost of promoting the plants is much greater.

Cost reductions will require new methods of supporting and promoting the plants. For its part, CIAT is interested in reducing the amount of support needed to replicate the Colombian success. The issue is not just institutional economy; benefiting a larger number of small farmers will also require new institutional arrangements.

The CIAT-DRI experience in Colombia and the institutional need for new successes suggested a trial in Ecuador: (1) to see if inexpensive direct involvement would stimulate technology diffusion to another country; (2) to see if costs could be reduced; and (3) to see if large numbers of small-scale producers could again be benefitted by cassava-drying plants.

Preparation started with short visits to Ecuador beginning in April, 1985, to contact institutions that might play a role in technology transfer, to screen potential production zones on Ecuador's dry coast, and to gather data. The Colombian experience suggested the types of institutions that would be needed (i.e. for coordination and promotion, credit, organization of associations, socio-economic studies, extension, technical assistance, and purchases). There was no prior commitment to any area or institution; rather, the technology went in search of comfortable, cheap lodging. The criteria for selecting areas were: (1) dry weather; (2) smallholder cassava production; (3) cassava marketing problems; and (4) high small farmer population. The criteria for choosing institutions varied according to their potential role: interest in cassava research, prior contact with small-scale producers, money for farmer associations, etc. The head of the CIAT Cassava Program visited Ecuador to advance the institutional aspects of the activity. Using ground transportation between Cali and Quito and taking advantage of trips to other parts of Latin America, the incremental costs for the initial visits were very modest.

Once Manabi province was chosen for the trial on the basis of the initial visits, CIAT and INIAP conducted a "sondeo" or rapid

reconnaissance of the province. This served to identify the cassava growing areas and to confirm the initial data on the province. The sondeo report will be published by INIAP, IICA (Inter-American Institute for Cooperation on Agriculture), and CIAT. While still in the field, several factors (the raw data of the survey, the extraordinary participation of institutions, and the enthusiastic response of small farmers to the idea of processing) warranted a decision to begin the trial immediately after the Portoviejo cassava course scheduled for early to mid-October.

That course was one of several training sessions (courses, lectures, field days) in which CIAT staff participated. These were opportunities to organize activities, to mobilize institutional support, and to fulfill requests from organizations that would reciprocate. The sessions included the MAG (Ministerio de Agricultura y Ganaderia) and IICA course in Quito in July, the presentation of a minicourse in Manabi in July, leadership in the full October course in Portoviejo, a lecture at a MAG course in Guayas Province concerning post-harvest technology, and a lecture at USAID (United States Agency for International Development) in Quito to AID (Agency for International Development), Peace Corps, and the F Foundation.

The Portoviejo course, which was delayed until October 28 to 30, emphasized lectures by local functionaries, regional functionaries, and a potential buyer on cassava production and demand.

CIAT brought in two cassava chippers to give a demonstration, and four CIAT professionals were invited to give talks. INIAP hosted the course, and MAG (Portoviejo and Guayaquil) coordinated it, with assistance from CIAT and IICA. The course did not end with formation of a provincial or regional cassava committee because of divergent interests within the audience, but it legitimized actions concerning cassava and so facilitated later work.

While the Portoviejo course was in progress, CIAT and MAG organized two small farmer groups in MAG/FODERUMA project areas that CIAT had visited briefly during prior trips. The two companies (Jaboncillo and Bijahual) unite 25 and 15 farmers respectively. The motive for farmers to join the groups was economic incentive (cassava marketing problems), but a prior relation with a functionary was essential to forming the group, given initial scepticism. The companies, as associations, are independent of the MAG/FODERUMA projects from which they sprang.

After several more meetings, each group agreed to rent a drying floor, borrow equipment, and use a CIAT chipper to produce 10 tons of dry cassava. Both were able to secure short-term loans from the local committees of their MAG/FODERUMA projects. The members also agreed to put up some of the money for working capital, as well as to provide some cassava on consignment. The two groups immediately applied to USAID (U.S. bilateral assistance) for a loan. AID, which had been kept informed of progress, was expecting such applications. They responded almost instantaneously with US$5000, thus assuring that the groups would be adequately financed.

Inter-institutional coordination has been an aim of the trial. One of the lessons from Colombia was that inter-institutional bureaucratic committees can be effective. In Manabi province, the working group comprises mid-level staff from MAG-central, MAG-projects, INIAP, and CIAT, with hopes of wider participation. The group began to meet when the plants started production and it met almost every week until production ceased. An evaluation meeting is scheduled, and then a recess until the construction of new drying plants.

The MAG office of Portoviejo assigned a staff member to coordinate the cassava trial. He deals directly with the producers' associations, as well as with other functionaries and buyers

To teach the groups how to dry cassava, CIAT hired a farmer (the son of the manager of the first Colombian plant) to come to Ecuador for a month; at the same time, CIAT cancelled a drying course for functionaries. This case of small farmer-to small farmer technology transfer was extremely successful, judged both by the performance of the plants and the testimonial dinners offered by the associations.

Various forms of dried cassava have been on the market in limited quantities in the past few years. These products ranged from the dried waste from starch plants and grated and dried cassava produced when starch prices were low, to the hand-peeled and dried product used for shrimp feeding. The waste by-product is of inherently low feed value, the grated cassava normally of poor quality due to its slow rate of drying and the hand peeled product allows little profit margin. However, knowledge of the fact that unpeeled dry cassava is an acceptable animal feed ingredient is crucial to opening up new perspectives for cassava marketing.

Marketing the cassava was handled by a committee from the plants, assisted by MAG-Guayaquil and CIAT. So far, all the cassava (50 t) has been sold in Guayaquil, though one goal was to sell in Manabi and Quito as well.

The social structure of the marketing situation is similar to that of Colombia. Upper level bureaucrats, often of higher social status than lower level bureaucrats, have contacts with large-volume buyers. They use these to promote initial sales and to solve problems, even while the project promotes direct contact between associations and buyers for more ordinary transactions. Lower-level bureaucrats have working relations with small farmers (or, in the Ecuadorian case, with local intermediaries). Direct links between small farmers and upper-level bureaucrats are only occasional, to solve a problem or for ceremonial ends. This structure is found in both Colombia and Ecuador.

Even though in the first phase of technology transfer institutional costs are likely to exceed benefits to farmers, several factors have kept costs to a minimum. The steps taken were: (1) choosing sites where the technology will be spontaneously adopted; (2) working with pre-formed groups or self-formed groups; (3) allowing small farmers rather than professionals to train new groups; (4) looking for in-place or underutilized functionaries or others to diffuse the technology; (5)

seeking ways to reduce capital costs (in this case, by using rented floors and equipment); (6) promoting independent diffusion of technology (through the courses and the trial) while still skewing it to small-scale producers; and (7) making studies more efficient by conducting minimal studies aimed at monitoring or at specific decisions (where to locate plants, how much to pay for cassava, etc.) and by integrating investigation and extension.

The trial could not be considered a success if the companies and their members did not make money. The final accounting has not been done, but in the first three weeks of the trial each plant turned a profit of US$300 to US$500 after paying for equipment. In that period, the two bought over US$3000 worth of cassava, most of which would otherwise have been lost. The final tally of beneficiaries will not be ready for some months, but it will show substantial benefits to small farmers.

Bureaucrats among others also benefited from the trial. Almost all of the institutions involved published reports about the cassava course and the trial. The functionaries in direct contact with farmers have validated their roles, and the government has found a means of making small farmers more productive. Researchers have published findings that are usually left in archives, and they have seen the research benefit the farmers. CIAT has concluded an activity in accordance with its mandate and the buyers have reaped some financial reward for dealing with the associations.

It is true that the production trial could have been carried out with less social networking. But future promotion of cassava drying, particularly if it is to benefit small-scale producers, will require a wide variety of actors. Therefore, uniting functionaries and others, and planning for their legitimate benefits, are part of the trial.

Paraguay

Paraguay has the highest per capita production of cassava in Latin America. There is a long tradition of producing and eating cassava, however, over the years research and development agencies have tended to take the crop for granted. Recently the Secretaría de Extensión Agrícola (SEAG) of the Ministry of Agriculture agreed to collaborate with CIAT in the development of a joint cassava project. The project proposal was prepared by staff of SEAG and CIAT, presented to IDRC (International Development Research Center) from Canada and later approved.

The objective of the project is to improve the available technology for cassava production in Paraguay through a series of trials done in collaboration with farmers.

The project is divided into four phases: identification of limiting factors; design of improved technology; field testing; and finally massive diffusion of the technology. The first phase is already underway and a preliminary characterization of production zones and systems was made by SEAG/CIAT.

Panama

IDIAP (Instituto de Investigaciones Agropecuarias de Panama) and CIAT have an agreement for technical cooperation and work closely with each other. Much of the work is financed by USAID. The overall objective of the project is to improve the welfare of the farmers dedicated to cassava through increased production and productivity, and better utilization. In order to do this research is being directed toward field trials which include factors such as new varieties, management practices, production systems and processing.

Although there is no overall plan for cassava development in the country, IDIAP, with the tacit approval of the government, is moving towards increased use of cassava in animal feed. IDIAP has concentrated initial efforts in the plains of Ocu. This area is an important root producing region where cassava is grown grown with rice, maize, yam, taro, chickpea, cowpea and even sugarcane. Cassava occupies about one quarter of the cultivated land which in turn is 27% of total area. The uncultivated area is dedicated to extensive pasture (approx. 0.5 animal units/ha). About thirty per cent of the land is suitable for cropping. The soils are generally of low pH (i.e. approx. 4.5) with only 30-40% base saturation. Fertility levels are medium to low and farmers maintain fertility by rotation with fallow.

A survey of the area shows that 95% of the farmers sell 100% of what they produce in cassava. In other words cassava is a cash crop for them. On the other hand, rice, maize and cowpea are grown for home consumption. About 75% of the cassava is grown as a monocrop and the remainder with various intercropping systems. The cassava, maize, yam system is very similar to that used in the Colombian North Coast and appears to have been taken from Colombia to Panama by migrants who went in search of land to plant rubber.

Land is normally prepared mechanically; planting material is selected but not treated; the principle planting season is in May but some farmers plant in August-October so as to harvest when prices are highest. Only about 30% of the farmers use fertilizers for cassava; those that do fertilize apply 50-150 kg/ha immediately after the first weeding. Most farmers weed at 30-45 and 75 days after planting with a final weeding just before harvest to prevent weeds from seeding. Forty percent of the farmers used gramoxone as a weedkiller before fertilizing.

Harvest is generally after 12 months, however if the price is high farmers will harvest as early as 8 months. Yields in monoculture range from 9-13.5 t/ha of roots of which about 1.8 t are not of commercial size.

Production costs are estimated at 360 US$/ha. The breakdown is as follows: US$ 95 land preparation; US$ 137 labor for planting, weed control etc.; US$ 92 for labour costs of harvesting and US$ 36 for inputs such as fertilizers, and herbicides. This gives production costs of the order of US$ 30 - 40/t. Allowing for a conversion ratio of 2.6:1 fresh to dry cassava and US$ 30/t for cassava processing and transport this gives a final cost of about US$ 110 - 134 per dry ton. As sorghum

produced locally is selling at US$ 225/t. There is ample margin for dried casssava to enter the market at less than 80% of the sorghum price or US$ 180/t. (The value of 80% allows for the lower protein content of cassava).

The possibility of establishing a small scale cassava drying industry was further explored by building a small (500 m^2) drying patio with the necessary chipper, store and other equipment. In 1984, fourteen tons of dried cassava were produced from 36 t of fresh giving the very favorable ratio of 2.42:1. In 1985 a total of 65 t dried cassava was produced with ratios of 2.26 - 2.52:1. These ratios are very favourable and suggest that the economic analysis made above on the assumption of 2.6:1 is on the conservative side.

In the IDIAP/CIAT project attention is being paid to the development of improved technology. In the early stages of the project the local clone Brazilera (which appears identical to M Pan 51 Sabanera, the most widely grown clone in Mexico) was selected and multiplied from virus-free stock obtained from tissue culture. Propagation facilities have been established and materials introduced have been multiplied and entered into regional trials. One of the lines introduced from CIAT is named Dayana and consistently outyields Brasilera.

Various agronomic trials have also been established in farmers fields. Preliminary results confirm that together Karmex and Lazo is an excellent herbicide mixture.

Mexico

Since its inception in 1977, the Mexican cassava program has taken great strides forward, however, the development of a new small scale agroindustry is still suffering from teething problems. Most of these problems are related to marketing and post-harvest handling. There are now approximately 2,500 ha of cassava grown in Mexico with the clone M Pan 51 which was introduced from CIAT and selected by the Mexican research program. Although this variety has good adaptation and tolerance to the savannah conditions, it has only moderate yield potential, and excessively long roots which make mechanical harvesting nearly impossible. Over the past few years there has been very close collaboration between the INIA (Instituto Nacional de Investigaciones Agricolas) and the CIAT program in the search for improved clones to replace M Pan 51 or Sabanera as it is named locally. Two new clones (CGM1314-1 and SGM714-5) were selected by the Mexican researchers as extremely promising and have done very well in advanced yield trials and regional trials (e.g. Table 4). Both of these clones were introduced to Mexico as sexual seed and the results obtained indicate that the strategy of seed rather than in vitro introduction is effective. If yields hold up next year, these clones will be good candidates for verification trials on farmers' fields and possibly for release soon after. The advantage of their having been derived from seed introductions is that they have already been selected in trials over three years, and thus have an edge over in vitro introduced material passed directly to advanced yield trials.

TABLE 4. Results of yield trials in Tabasco, Mexico, 1985.

Clone	Mean root yield (t/ha)
CGM 1314-1	29
SGM 726-2	25
SGM 714-5	25
CMM 4183-3	24
CGM 1312-3	23
Sabanera (M Pan 51)	15
Trial mean	18

Source: J. Acosta, INIA

The overall management of farmers fields in Mexico is good; however, problems have consistently occured with control of the hornworm (*Erinnys ello*). The entomologist of the Mexican program has recently returned to Mexico, after a year's research experience at CIAT, to implement a biological control program.

The 1986 harvest is expected to be 35-40,000 t of cassava. The total number of drying plants has been increased from 10 to 17 and in addition seven new silos for silage production are being constructed. Official Mexican agencies are, however, still worried about their ability to effectively handle the cassava produced and have requested help from CIAT in improving the technical and organizational aspects of the post-harvest handling operation.

Peru

This year Peru has shown renewed interest in cassava. The potential exists to revolutionize the marketing of cassava produced in the Selva and transported to the major urban center of Lima. Activities aimed to this goal are described below.

FRESH CASSAVA STORAGE PILOT PROJECT, BUCARAMANGA, COLOMBIA

Background

In the rapidly urbanising countries of Latin America, per capita cassava consumption is higher in rural than in urban areas. Cassava has not made the transition from being a rural staple to an urban convenience food. Recent studies show that the primary reason why cassava is at a disadvantage in urban markets is the rapid postharvest deterioration of the roots. This makes the purchase of cassava a risky procedure, inflates marketing margins through the high level of losses incurred, and results in an expensive, inconvenient foodstuff of variable quality for urban consumers. The greater postharvest stability of potatoes, rice and other starchy staples thus makes them a more attractive and convenient foodstuff. A simple low-cost storage technology increases the postharvest life from 2 or 3 days to two or more weeks. This consists of a postharvest fungicidal treatment to prevent microbial rotting, followed by packing roots into polyethylene bags. Many questions as to the consumer acceptability of stored cassava, the behaviour of the roots under commercial marketing conditions and the optimal strategy for achieving commercialization still remain to be answered. These issues can only be resolved through the execution of a pilot project. In such a project the success of cassava storage technology in: (a) eliminating urban consumers' adverse reactions to cassava; (b) reducing the marketing margins and hence consumer price of cassava; and, as a consequence, (c) ultimately increasing demand for cassava can be tested.

Bucaramanga (pop. 1985: 700,000), which has small farmer-dominated cassava production zones supplying a population with a tradition of cassava consumption, was chosen for a pilot project. Figure 1 shows the location of Bucaramanga and the main production zones in the Department of Santander.

The pilot project was designed to: (a) demonstrate the viability of the new cassava storage technology under commercial conditions; (b) to evaluate and monitor consumer acceptance of stored cassava; and (c) to describe quantitatively the impact of the new storage technology on total demand for fresh cassava, on farm-level and consumer prices and on the structure of the fresh cassava market.

The project is divided into four phases: production, marketing and consumption surveys; a series of on-farm storage trials designed to familiarize farmers with and test the technology under local conditions with local varieties; commercial marketing of stored cassava; and measurement of the impact of the new cassava technology on prices, demand and market structure.

The project is being implemented by the CIAT Cassava Program and the Integrated Rural Development (DRI) Program of the Colombian Ministry of Agriculture.

Production, Marketing and Consumption Surveys-Bucaramanga.

A survey of cassava producers was carried out in four of the five major municipios serving the Bucaramanga market. (San Vicente de Chucuri, Barrancabermeja, Rio Negro, and El Playon). The other municipio (Saravena) could not be included because of guerrilla activity in the area. The areas vary from relatively high production zones of around 1300 m on steep slopes to flat or rolling terrain in the Magdalena river valley. Median farm size is relatively large, as a high percentage of farms tend to group in the 10 to 50 ha. strata (Table 1). Cassava production and consumption in Santander Department is a relatively closed system, as little cassava is imported or exported and the market for cassava is dominated by fresh urban consumption in Bucaramanga and the smaller towns of Socorro and San Gil.

Because of the terrain and poor soils in the region and the relatively large farm size, farms are extensively managed. Production is geared toward cattle and cassava (Table 2). The major portion of farm land is devoted to pasture and fallow, with the relatively small area that is cultivated being devoted to cassava production systems. There is some variation in area planted to cassava between the four municipios. The two farthest from Bucaramanga (Barrancabermeja and El Playon) sow smaller areas of less than 3 ha in cassava while the farmers in the municipio closest to the city plant a significantly larger area to casssava, on average over 9 ha. In terms of land the potential for expanding cassava production is significant.

Cassava production systems in turn are relatively extensive (Table 3). Land is prepared manually, primarily because of the sloping terrain. Only in Barrancabermeja is there any land preparation with tractors. Nevertheless, labor utilization in cassava production is low, rarely averaging over 80 mandays per hectare. Cassava is either sown in monoculture or in association with maize. No purchased inputs are used. Poor soils together with relatively extensive production systems result in low yields.

On-farm consumption is high, as cassava is the dominant subsistence crop in Santander. In the municipios farthest from Bucaramanga, i.e. El Playon and Barrancabermeja, cassava is grown principally for on-farm consumption. In these areas only a quarter to a third of the cassava is marketed. On the other hand, in the other two municipios which are closer to the city, cassava is grown principally for sale, as about three-quarters of the crop is marketed. Marketed cassava goes either to Bucaramanga or the local town. The small towns tend to draw cassava only from the production area of their own municipalities.

Farmer marketing is based on bagged cassava. Few farmers sell cassava unharvested in the lot. This, in part, reflects the proximity of the market and the ready supply of cassava. Sales are characterized by relatively small lot size (Table 4) and these vary by market access. Where the municipality is farthest from the major market (El Playon and Barrancabermeja) farmers attempt to arrange the sales before harvesting. Farmers in these zones have few options and they reduce the risk inherent in restricted market access through prior arrangement with assembly agents. El Playon has probably the most severe marketing

problems as reflected in low volumes sold and low prices. Holding distance to market constant (Table 5), those farmers who can arrange a sale prior to harvest usually sell more and at a higher price, as is especially obvious in Barrancabermeja. Finally, where there is very good market access, such as in Rio Negro, farmers market the cassava themselves, even in Bucaramanga.

Where cassava farmers have good market access, they tend to take over more marketing functions, thereby reducing the number of middlemen. The introduction of cassava storage technology should reduce marketing risk and improve market access, farmers in El Playon are most in need of such a technology. However, if introduction of the technology requires farmers to assume more marketing functions, even up to wholesaling functions, then farmers in Rio Negro are in a better position to do so. Wholesaling of bagged cassava by farmers, will require a continuous supply and this is limited by current planting and harvest patterns (Figure 2). However, there are no major restrictions on planting and harvesting cassava year round, apart from labor shortages during coffee harvest, and no restrictions on land availability. As the project moves to the commercial phase, decisions will have to be made on area selection, whether farmers assume wholesaling functions, and what changes are required in cassava production systems.

The marketing and consumption of cassava was compared with that of potatoes in Bucaramanga. However there were a number of differences between the two products, which can be at least partly explained by the better storing quality of the potato. (Figure 3 shows the structure of the general marketing system for both crops in Bucaramanga). All cassava arrives at one wholesale market (San Francisco). Each wholesaler buys an average of 235 sacks (1 sack = 62 kg) each week. Potatoes arrive at a different marketplace, and each wholesaler buys 450 bultos/week. The links between the wholesalers and their clients are much stronger for potatoes than for cassava; potato wholesalers give credit, arrange sales in advance and, if a sack turns out to be of bad quality, will replace it. This never happens with cassava.

Retailers exist in the four large municipal markets, the ten smaller, local neighbourhood markets and in numerous neighbourhood shops. Potato retailers in the municipal markets are specialized, often selling no other produce, whereas cassava is often found among vegetables: this explains the higher potato volumes traded per retailer (Table 6). Cassava volumes sold in local shops are very small, perhaps because of the risk involved in selling this perishable crop. The retailers in the municipal markets buy cassava and potatoes everyday, many receiving credit. In the neighbourhood markets and in shops, however, retailers almost never receive credit but most supply it to their clients. These retailers buy cassava daily, and potatoes only once or twice a week.

The 86 consumers (and their families) interviewed in this survey, consumed 46 kg of cassava and 79 kg of potato per capita per year. Consumers buy both potato and cassava on average four times a week, but eat potatoes everyday and cassava only five days a week, because of the

rapid cassava deterioration which prohibits storage at home from one day to the next.

Consumer attitudes to cassava clearly show the effects of deterioration (Table 7). Cassava is seen as being a risky, variable quality product which cannot be stored. However, it is liked, considered necessary in meals and is easy to prepare. The disadvantages compared with potatoes (those related to storage, combined with a less favored nutritional quality) account for the lower cassava consumption. Factor analysis (CIAT Cassava Annual Report, 1984) showed that a solution to the deterioration and storage problems of cassava would result in at least a 15-25% increase in cassava consumption in Bucaramanga.

The purchase of storable cassava in polyethylene bags has several possible advantages for consumers, including lower risk of deterioration loss, improved root quality and a lower price. Present shopping habits will influence consumer acceptance of this new technology, the necessity for frequent purchases being removed. Compared with other Colombian cities, Bucaramanga has a large number of markets. Even in the remotest neighborhoods 60% of people shop regularly at a market. But there are differences between neighborhoods in the percentage of market shoppers and also in the frequency of visits to markets. Those living far away will only visit a market once a week; those living closer may go daily. This is related to the frequency of cassava purchase, since 78% of people buy cassava at markets (19% in neighborhood shops; 3% in supermarkets).* In general, consumers will not change their shopping frequency just for cassava, and those who visit daily may not need the advantages of storable cassava. Potatoes, storable at home for 1 week or more, were nevertheless purchased daily by 40% of the people questioned. One additional reason behind this is that many people do not have enough money to buy food for a week at a time: in the five poorest neighborhoods sampled, 45-60% of people named this as the major reason for frequent shopping. Such consumers may, however, buy storable cassava if the price is lower, and the quality is more reliable.

Regression analysis demonstrated that the differences in consumption between neighborhoods (Table 8) can largely be explained by the ease or difficulty of market access, by whether the household owns a refrigerator and by whether the person who does the shopping in each household is employed (Table 9). Poor market access decreases cassava consumption by 18 kg/capita/year. This is directly related to the difficutly of at-home storage of cassava, since people from neighborhoods with poor market access shop less frequently than those with good access. Ownership of a refrigerator increases consumption by 7.8 kg/capita/year, obviously due to the better storage possibilities. Where the principal shopper of a family also works, consumption is decreased by 6.8 kg/capita/year, again reflecting the effects of cassava deterioration on people who shop less frequently. None of these factors were significant in the case of potatoes. Income level did not affect consumption level of either crop.

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* Survey data based on 400 questionaires equally divided between 10 neighbourhoods.

Half (48%) of consumers reported that the cassava they buy sometimes deteriorates before they prepare it. This is especially true for people who buy cassava from local neighbourhood shops, where quality is poorer (roots are less fresh). These consumers will directly benefit from storable cassava.

Although 80% of households interviewed own a refrigerator, many do not use it for storing cassava (Table 10) because of the large quantities involved or because of adverse root quality changes, especially related to texture, during storage of peeled root sections in the freezer. This latter method is the only one which serves for more than 1 week: outside a refrigerator, storage times are limited to 3 days. Although cassava in bags can be stored for two weeks, consumers may not require a longer period than one week, since this is the minimum shopping frequency encountered.

Consumers were asked for their opinion on this new, storable cassava (although without having seen or experienced it). 54% thought it was a good idea; 19% had no opinion yet and 27% responded unfavourably for a variety of reasons (e.g. possible taste changes, prefer to select roots individually or a negative reaction to the chemical nature of the root treatment involved in storage). These factors were all taken into account when designing the consumer taste panels for stored cassava. Members of this panel were selected from interested respondents to this survey. Some 85% of the 400 people interviewed were willing to test stored cassava.

Storage Experiments in Santander

A series of storage experiments was set up in San Vicente, the main cassava producing region of the Santander Department using cassava roots obtained from small farmers. Three experiments were completed in this zone, each one using a different local variety.

The results of the on-farm storage were positive (Table 11) with losses on the 100-point evaluation scale for total deterioration (physiological plus microbial) being below 12, 19 and 6 after two weeks in experiments 1, 2 and 3 respectively. Only in experiment 1 was any physiological deterioration present, and this never exceeded 3.5%. 5 kg bags tended to have higher microbial deterioration ratings than 1 kg bags. Some varietal differences were apparent, with the local variety used in experiment 3 (Venezolana), having less mechanically damaged roots than the other two varieties (because of root shape) and thus, having lower losses due to microbial rotting. Roots were cooked and evaluated by farmers after storage. They were uniformly accepted, even in the second week of storage, and substantial farmer interest in the storage technology was shown.

Due to an overnight stop at Socorro where low temperatures disrupted the root curing process, cassava transported directly to San Gil showed higher losses on the total deterioration evaluation scale. (Table 12). Losses after 5 and 9 days of storage were higher than those normally found because internal rotting had developed from the uncured damaged areas: Mertect, being a superficial treatment, does not offer protection against internal rotting. Losses of 30 and 27 on the total

deterioration scale in experiments 1 and 2, respectively after nine days storage were thus too high to be commercially acceptable. Nevertheless, the cassava in good condition was cooked and consumed and rated as being of high quality with no sweet taste discernable (see Utilization Section).

The quality analyses performed on samples sent by air to CIAT showed (Table 13) that during the two week storage period there were no noticeable changes in root dry matter content, regardless of the method of analysis, but that starch content decreased between weeks 1 and 2 and that both reducing and total sugar contents increased. However, these changes were not, apparently, enough to affect the organoleptic quality of the roots as consumed by the farmers.

A further series of storage trials was carried out in August 1985, with the aim of field-testing the aspersion method of Mertect application, and of obtaining some details of the extra labor requirements and costs involved in the storage operations. Of the three experiments reported, two were carried out in the vicinity of Barrancabermeja and one in El Playon (Table 14). There were large differences in the amount of cassava harvested and treated per person in each of these trials, due to the relative ease or difficulty of harvesting (soil characteristics, etc.) and productivity differences of the harvesters. For this reason, it is difficult to conclude from this data whether immersion or aspersion treatments were most labor or cost efficient: the relative novelty of the treatment operations would also have reduced productivity. As these trials progress, an increase in productivity of the treatment operations will, therefore, be expected. With the fungicide cost at Col.$4,000 Pesos per litre and the polyethylene bags at Col.$1.21 Pesos/kg roots (purchased locally), the aspersion treatment was the cheaper alternative, because of the lower fungicide costs: an average of Col $ 2.9 Pesos (US$0.018) per kg of roots for treatment, labor and polyethylene bags, compared with Col.$4.3 Pesos (US$0.029) per kg for the immersion method. In these three trials an average of 77% of roots harvested were suitable for storage, a further 14% were not of a commercial size, and the remainder (9%), consisted of roots of commercial size but unsuitable for storage either because of excessive mechanical damage or their large size.

In two of the experiments, the results were excellent, with minimal losses due to either physiological or microbial deterioration, although some external microbial growth was evident. In the third experiment however, losses were higher than usual, due to substantial microbial deterioration. This was a consequence of two factors: storage in an enclosed room where temperatures exceeded 40°C within the microclimate of the bags, and the presence of rats which opened and contaminated several bags.

Consumer panel testing of stored cassava in Bucaramanga

A consumer taste panel was set up in Bucaramanga to (a) determine consumer quality preferences for cassava in Bucaramanga; (b) to evaluate quality changes occurring during storage; (c) to evaluate the relative importance of the various advantages and disadvantages of the cassava storage technology; and (d) to estimate possible consumption changes

which could occur following the commercial introduction of storage technology.

Table 15 shows the basic characteristics of the five neighborhoods included in the panel.

Consumers had to discard some of the fresh root sample only in La Joya, due mainly to "viruela" disease (pre-harvest root rot) (Table 16). After one week, losses were below 10% in all barrios, and after two weeks were acceptably low in all but one barrio (El Bosque/Campestre) where, again, internal pre-harvest root rots caused losses. These losses are probably higher than would be experienced in practice, since consumers could only open bags after 1 and 2 weeks of storage: in normal use, roots would be consumed more frequently and if problems with rots arose, the cassava would be eaten more quickly instead of left to waste. In general this cassava cured well with damaged areas of the roots not producing either internal physiological or microbial deterioration.

The appearance of whole fresh and stored roots was judged as good on a four-point evaluation scale and cooking times were slightly better for stored than fresh roots (Table 17). During storage some callus or even rootlets may develop on the root exterior, but this was not seen as being disadvantageous in general, so long as internal root quality was maintained.

Detailed taste and texture evaluations of the fresh roots showed that they were of good quality, with a floury, soft texture and no bitter, sweet or deteriorated ("off") taste. A few roots were glassy in texture (hard, uneatable) but this variation in root quality is commonly found in fresh roots. Roots were similarly evaluated after 1 and 2 weeks of storage, as having a floury, soft texture. A slightly greater number of "glassy" roots were found, but this could be due more to sample variation than any quality changes on storage. Most encouragingly, no changes in root flavor occurred. The eating quality of both fresh and stored roots was thus assessed as good by these consumers: there were no significant differences between fresh and stored roots.

Housewives were asked after experiencing both one and two week-stored cassava, if they would buy cassava in bags if they were available in the market place (Table 18). After one week, 68% replied positively. After two weeks, 93% were positive if the cassava in bags were sold at the same price as normal, fresh cassava; a similar percentage if cassava in bags was Col.$5 Pesos per pound cheaper; and 87% if cassava in bags was Col.$5 Pesos per pound more expensive than normal cassava. This demonstrates that consumers were definately impressed by the results of cassava storage. Questions were asked on the relative importance of several advantages and disadvantages of storage (Figures 4 and 5). The most important advantages were: (i) that cassava can be stored for two weeks: (ii) that purchases can be less frequent and (iii) that the cassava is selected. This last point is very important, since a disadvantage of selling cassava in bags is that consumers cannot select each root individually as at present. They, therefore, have to be assured that only high-quality cassava is packed into the bags. The two

disadvantages of selling cassava in bags which were most important were: (i) that cassava quality could not be examined, and: (ii) that roots were treated with a chemical. Neither of these were rated as being much more than of little importance by consumers. The necessity of removing consumer doubts about the safety of the thiabendazole treatment is clear.

Consumers were asked how much more cassava they would eat if it were available for purchase in bags (Table 19). In general, consumption would increase by 15%, 27% and 8% if cassava in bags were the same price, Col.$5 Pesos per pound cheaper or Col.$5 Pesos per pound more expensive than normal loose cassava, respectively. Differences between nieghborhoods were large, however: the two neighbohoods having the largest increases (38%, 50%) were those of the lowest socio-economic stratum and with poor market access. This demonstrates that cassava storage could directly benefit the most needy urban poor. The lowest consumption increases were found in Concordia and La Joya barrios. Concordia has a municipal market within the neighborhood, making daily cassava purchase easy; and La Joya lies on a bus route to the cheapest, central market place. Nevertheless, in both these neighborhoods, the majority of consumers (84 and 95%, respectively) would prefer to purchase cassava in bags. Regression analysis showed that the factors of market access, ownership of refrigerator and employment of the household shopper were no longer significant in these consumption figures i.e. storage of cassava removes the constraints on consumption operating at present.

In three of these neighborhoods (La Joya, Miraflores, Villa Rosa) a sample of cassava in bags was also given to a total of 20 small shop keepers, and in Concordia to five market stall holders selling cassava. Total storage losses were 4% after one week. Both root appearance and eating quality were rated as good (2.2. and 2.0 after one week's storage, on 0-3 scale). Some 21 of these 25 retailers were interested in selling cassava in bags, 3 did not know and 1 replied negatively (he does not sell cassava now either). The five retailers who do not presently sell cassava said the main reason for this was lack of time to visit the market place everyday to buy the product: four of them would sell cassava in bags.

If the consumer panel studies finish with positive results, as expected, this project will proceed to trial commercial marketing of stored cassava in 1986.

TABLE 1. Department of Santander, Colombia: farm size distribution by municipio, 1971.

Strata (ha)	San Vicente de Chucuri		Rio Negro - El Playon		Barrancabermeja	
	No. farms	%	No. farms	%	No. farms	%
0 - 0.9	129	3.8	60	2.0	226	23.0
1.0 - 2.9	291	8.8	386	12.0	202	20.0
3.0 - 4.9	300	9.1	336	10.0	76	8.0
5.0 - 9.9	521	15.7	534	16.0	72	7.0
10.0 - 49.9	1417	42.8	1307	40.0	200	20.0
50.0 - 99.9	396	11.9	373	11.0	102	10.0
100.0 - 499.9	231	7.0	270	8.0	88	9.0
500.0 - 999.9	19	0.6	28	0.9	15	2.0
More than 1000	10	0.3	4	0.1	12	1.0

Source: DANE (Departamento Administrativo Nacional de Estadistica), Censo Agropecuario, 1971.

TABLE 2. Department of Santander, Colombia: characteristics of farms producing cassava, 1985.

Characteristic	San Vicente de Chucuri	Barrancabermeja	El Playon	Rio Negro
Land use (ha):				
Area in cassava	3.1	1.7	2.7	9.5
Area in other crops	0	0.1	0.5	0.8
Area in pasture	18.5	12.2	3.2	12.1
Area in fallow	16.3	4.6	17.3	23.0
Area not utilizable	4.3	2.4	0.2	6.0
Total farm size	42.2	21.0	23.9	51.4
Livestock:				
% farms having cattle	60	83	60	68
Cattle per producing farm	17	21	6	17
% Farms having pigs	73	94	58	55
Pigs per producing farm	5	7	2	3
Land tenure:				
% Farms with secure tenure	76	89	78	78
% Farms with insecure tenure	24	11	22	22
N	120	54	60	62

TABLE 3. Department of Santander, Colombia: Characteristics of cassava production systems and on-farm consumption, 1985.

Characteristic	San Vicente de Chucuri	Barrancabermeja	El Playon	Rio Negro
Cassava yield (t/ha)	6.9	5.1	3.4	3.9
Method of land preparation:				
Manual (% of farms)	100	87	100	100
Tractor (% of farms)	-	13		
Labor input in cassava (m.d./ha)	65.7	54.8	81.6	79.7
Daily wage (Col$/m.d.)	423	390	370	395
Cassava varieties cultivated:	Moradilla Torrana Mona Blanca	Moradilla Criolla Mona Blanca	Varita Moradilla Botona	Coralita Criolla Moradilla
On-farm subsistance consumption (kg/day):				
Per capita	1.6	1.0	1.6	1.8
Total	9.6	7.7	9.6	14.6
On-farm animal feeding (kg/day)	5.1	9.5	6.6	12.0
N	120	54	60	62

Table 4. Department of Santander, Colombia: Farmer marketing of cassava, 1985.

Characteristic	San Vicente de Chucuri	Barrancabermeja	Playon	Rio Negro
% of production that is marketed	75	27	35	73
Average volume per sale (kg)	875	1155	190	500
Average price at last sale (Col $/kg)	11.6	8.3	5.8	11.4
Market destination (%):				
Bucaramanga	47	46	75	81
Municipal	37	50	25	19
Other	16	4	-	-
Root selection criteria (% farmers):				
Skin color	0	2	100	60
Starch content	0	23	100	5
Root size	100	98	100	92
Variety	34	42	100	5
Arrange sale prior to harvest (%)	2	49	100	0
N	120	54	60	62

TABLE 5. Department of Santander, Colombia: Sales volume and price, by place and prior arrangement of harvest, 1985.

Place of sale	San Vicente de Chucuri		Barrancabermeja		El Playon		Rio Negro	
	Prior arrangement	No prior arrangement	prior arrangement	No prior arrangement	prior arrangement	No prior arrangement	prior arrangement	No prior arrangement
Volume sold per sale (kg)								
Farm	-	815	1145	665	190	-	-	-
Roadside	2190	830	1250	990	200	-	-	-
Local market	-	-	-	-	-	-	-	530
City market	-	-	1500	520	-	-	-	525
Price received (Col $/kg)								
Farm	-	13.6	10.2	6.8	7.2	-	-	-
Roadside	12.4	11.6	9.2	5.6	5.7	-	-	-
Local market	-	-	-	-	-	-	-	8.2
City market	-	-	9.3	8.2	-	-	-	12.1

TABLE 6. Quantity (kg) of cassava and potato sold per week by retailers in Bucaramanga.

	Cassava	Potatoes
Municipal market	644	1,744
Neighbourhood market	250	256
Shops	162	256

TABLE 7. Consumer attitudes to cassava and other starchy foodstuffs in Bucaramanga (% of respondants agreeing with statement).

Statement	Cassava	Potato	Rice	Plantain
This product cannot be stored well	88	35	2	19
The quality of this product is very variable	92	84	38	56
Purchasing this product is always risky because of its quality	90	69	1	8
This product is easy to prepare	100	100	99	99
This product is necessary in our meals	80	93	93	91
This product is very tasty	78	91	87	93
This product is purchased the day of consumption	59	51	48	50

TABLE 8. Differences in cassava consumption per neighborhood in Bucaramanga.

Socio-economic stratum	Access to market	Number of neighborhoods	Cassava purchase frequency (times/week)	Average cassava consumption (kg/capita/year)
low	good	1	5.3	57
low	bad	1	3.1	39
low-middle	bad	3	3.1	36
middle	good	3	3.8	41
middle-high	fair[a]	2	1.4	27

[a] Far from market, but own cars.

TABLE 9. Factors affecting cassava consumption in Bucaramanga (regression analysis).

Factor	Consumption change due to factor (kg/capita/year)
Market access bad (no nearby market)	- 18 **
Market access fair (market in nearby neighborhood)	- 10 *
Market access good (small market in neighborhood)	- 6
Market access excellent (large, central market in neighborhood)	0
Ownership of refrigerator	+ 8 *
Shopper of household employed	- 7 *

Significance of results: ** = 1% ; * = 5%.

TABLE 10. Cassava storage methods currently used by consumers in Bucaramanga.

Refrigerator	33%
Freezer	15%
Under water	8%
Buried	1%
Do not store roots	43%

Table 11. Results of threee cassava storage experiments carried out in the region of San Vicente-Barrancabermeja, Sandander. Results are expressed on the standard deterioration evaluation (0-100) scale (CIAT Cassava Program Annual Report, 1983).

Experiment	Storage time (weeks)	Bag size (kg)	External microbial growth (A)	Internal microbial rotting (B)	Internal physiological deterioration (C)	Total deterioration (B+C)
1	1	5	8.6	7.9	0.8	8.7
1	1	1	0.6	2.1	1.5	3.6
1	2	5	16.5	9.6	2.5	12.1
1	2	1	4.7	0.4	3.5	3.9
2	1	5	9.2	8.7	0.0	8.7
2	1	1	2.0	9.6	0.0	9.6
2	2	5	20.3	18.6	0.0	18.6
2	2	1	2.5	8.4	0.0	8.4
3	1	5	0.9	0.9	0.0	0.9
3	1	1	0.5	0.0	0.0	0.0
3	2	5	3.3	5.9	0.0	5.9
3	2	1	1.3	0.4	0.0	0.4

TABLE 12. Results of cassava root storage experiments, after transport through a cold climate region to San Gil for subsequent storage. Results are expressed on the standard deterioration evaluation scale (0-100) (CIAT Cassava Program Annual Report, 1983)

Experiment	Storage time (days)	External microbial growth (A)	Internal microbial deterioration (B)	Internal physiological deterioration (C)	Total deterioration (B+C)
1	3	1.0	2.2	4.2	6.4
1	5	10.5	23.2	14.5	37.7
1	9	22.5	16.4	13.8	30.2
2	3	0.9	7.2	1.5	8.7
2	5	11.1	19.9	0.5	20.4
2	9	20.8	26.0	1.0	27.0

TABLE 13. Results of quality analyses of cassava roots from the three storage experiments in San Vicente, Department of Santander.

	Dry matter by specific gravity (whole root)	Dry matter by oven drying (parenchyma)	Starch (DM basis)	Reducing sugars (DM basis)	Total sugars (DM basis)
Initial sample					
Expt.1	39.8	43.4	84	0.40	1.31
Expt.2	33.6	36.5	87	0.45	2.27
Expt.3	30.5	37.8	87	0.77	2.91
One week storage					
Expt.1	38.3	42.3	87	2.73	5.51
Expt.2	32.0	36.0	88	1.36	4.96
Expt.3	33.6	35.0	86	1.99	3.94
Two week storage					
Expt.1	38.3	42.4	81	5.67	8.64
Expt.2	32.0	37.2	81	6.20	8.07
Expt.3	32.0	37.1	81	6.74	9.63

TABLE 14. Cassava storage experiments in the Department Santander, August 1985: Evaluation at two weeks of storage, with treatment costs.

Experiment:	1	2	3
site:	Barrancabermeja		El Playón
Treatment method	Aspersion	Immersion	Aspersion
kg roots harvested/man/h	22.6	36.2	125.3
kg roots treated/man/h	48.0	57.3	71.9
cost harvest/kg roots (Col.$)	2.7	1.7	0.5
cost treatment (labor)/kg roots (Col.$)	1.3	1.1	0.9
cost treatment (Mertect)/kg roots (Col.$)	0.4	2.0	0.4
cost polyethylene bag (Col.$/ kg roots)	1.2	1.2	1.2
cost materials + labor(Col.$/ kg roots)	2.9	4.3	2.5
% roots stored	80	79	71
% rejected: broken	5	11	11
% rejected: non-commercial	15	9	18
Storage Evaluation after two weeks in 5 kg-sized bags			
Microbial growth	11.3	14.8	32.3
Microbial deterioration	1.0	0.0	38.3
Physiological deterioration	0.0	0.0	0.4
Total deterioration	1.0	0.0	38.7

TABLE 15. The characteristics of the five neighborhoods of Bucaramanga included in the consumer test panel for stored cassava.

Code	Name	Socio-economic stratum	Access to markets	Cassava consumption (kg/capita/y)
1	La Joya	low/middle	fair	45
2	Villa Rosa	low	poor	32
3	Miraflores	low	poor	39
4	Concordia	low/middle	good	50
5	El Bosque/ Campestre	middle/high	fair	25

TABLE 16. Consumer testing of stored cassava: storage losses (%).

Neighborhood	Fresh	1 week storage	2 weeks storage
La Joya	7.8	5.5	5.8
Villa Rosa	0.5	2.3	9.4
Miraflores	2.0	7.9	9.2
Concordia	0.5	2.3	16.0
El Bosque/Campestre	0.0	9.8	33.0

TABLE 17. Consumer quality evaluation of stored and fresh cassava.

Quality parameter	Fresh	1 week stored	2 weeks stored
General appearance[a]	2.32[a*]	2.23[ab]	2.07[b]
Cooking time (% normal or less)	67%	82%	80%
Texture evaluations:			
floury[b]	1.87[a]	1.68[b]	1.71[b]
glassy[b]	0.19	0.40	0.33
fibrous[b]	0.15	0.09	0.03
soft[b]	1.72	1.56	1.51
hard[b]	0.13	0.43	0.37
Taste evaluations			
bitter[b]	0.13[a]	0.11[a]	0.09[a]
sweet[b]	0.05[a]	0.03[a]	0.01[a]
"deteriorated"[b]	0.03[a]	0.12[ab]	0.17[b]
Eating quality			
general[a]	2.25[a]	2.23[a]	2.14[a]

[a] Evaluation scale: 0 = bad, 1 = fair, 2 = good, 3 = excellent.

[*] Values with different letter superscripts are significantly different (P = 0.05) according to Duncan's Multiple Range Test.

[b] Evaluation scale: 0 none (not present)
1 little (present to limited degree)
2 yes (present)
3 much (present, pronounced)

floury, soft = too much (present, to excess).

TABLE 18. Consumer testing of stored cassava: percentage of consumers preferring to purchase cassava in bags (A) rather than cassava sold loose as usual (B)

Barrio	After storing cassava for 1 week	After storing cassava for 2 weeks		
		A same price B	A $5/pound cheaper than B[a]	A $5/pound more expensive than B
La Joya	75	95	95	90
Villa Rosa	75	100	100	100
Miraflores	58	95	95	90
Concordia	70	84	84	68
El Bosque/Campestre	60	89	89	84
Mean	68	93	93	86

[a] Prices refer to Colombian pesos, November 1985 (Col.$ 160 = US$ 1).

Cassava retail price was Col.$ 20-25 per pound (0.5kg).

TABLE 19. Consumer testing of stored cassava: estimated possible consumption changes due to commercialization of storeable cassava, according to consumers questioned after storing cassava at home for two weeks.

Neighborhood	Present consumption (kg/household/week)	Estimated consumption change (%) when: A = B[a]	A $5/pound B	A $5/pound B
La Joya	4.88	+ 7.2	+ 9.5	+ 2.1
Villa Rosa	3.07	+ 27.7	+ 50.8	+ 13.0
Miraflores	2.61	+ 16.9	+ 38.3	+ 5.8
Concordia	4.30	+ 7.6	+ 15.1	- 4.7
El Bosque	2.40	+ 15.0	+ 20.0	+ 15.0
mean	3.42	+ 14.9	+ 26.7	+ 8.1

[a] A = Cassava sold in bags.

B = Cassava sold loose, as at present.

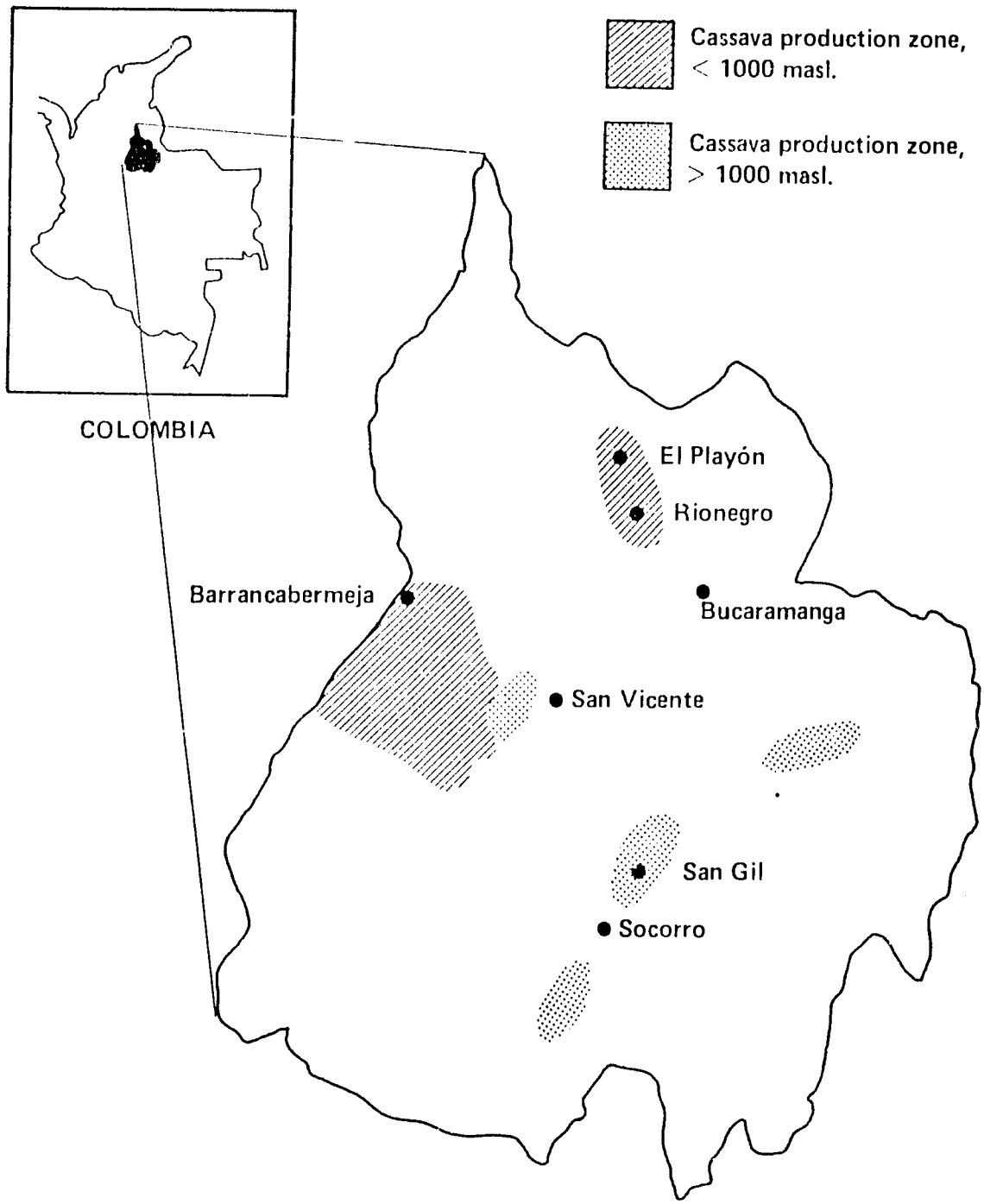
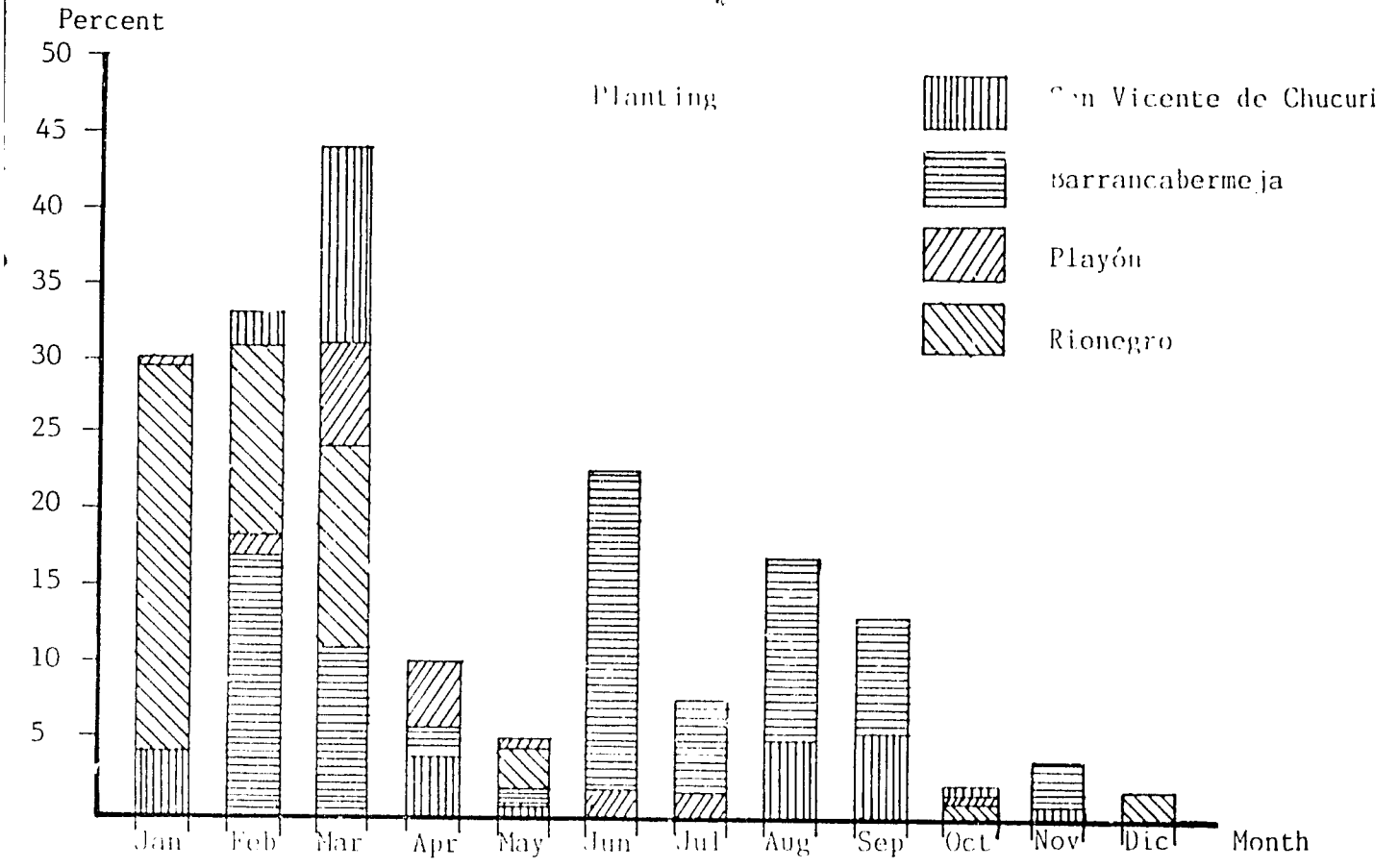


Figure 1. Outline map of Santander Department, Colombia, showing major cassava production regions and urban center mentioned in text.



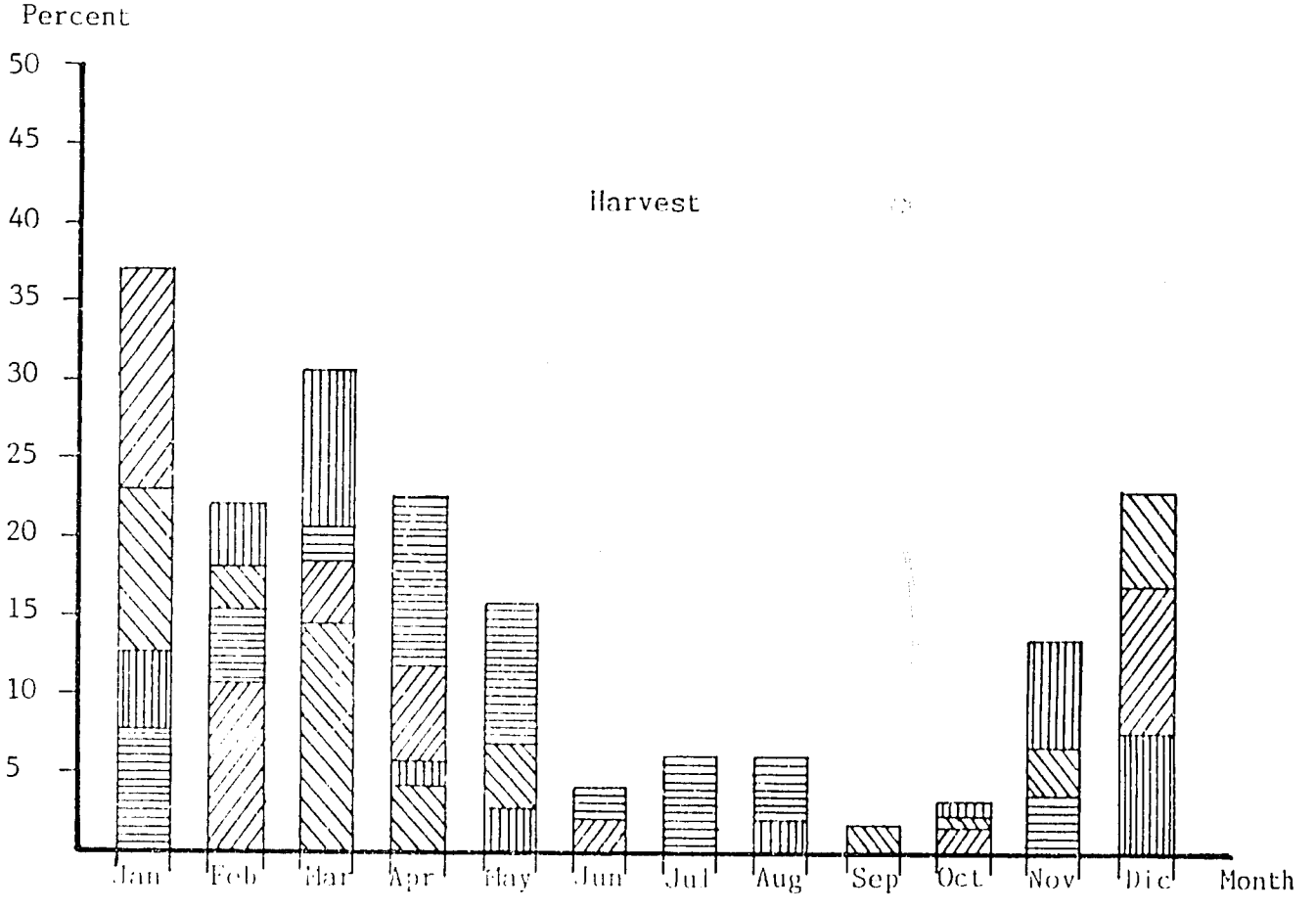


Figure 2. Percentage planted and harvested by month in the major producing areas serving Bucaramanga.

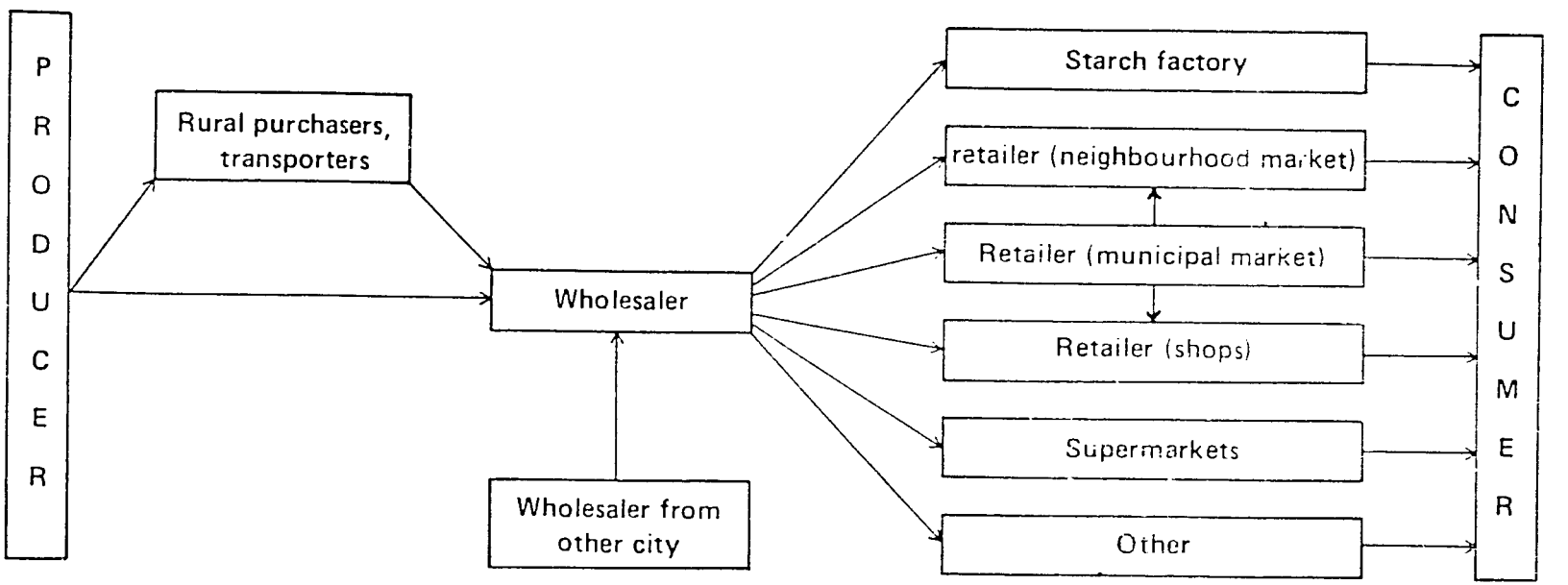


Figure 3. The structure of the marketing system for cassava and potatoes in Bucaramanga.

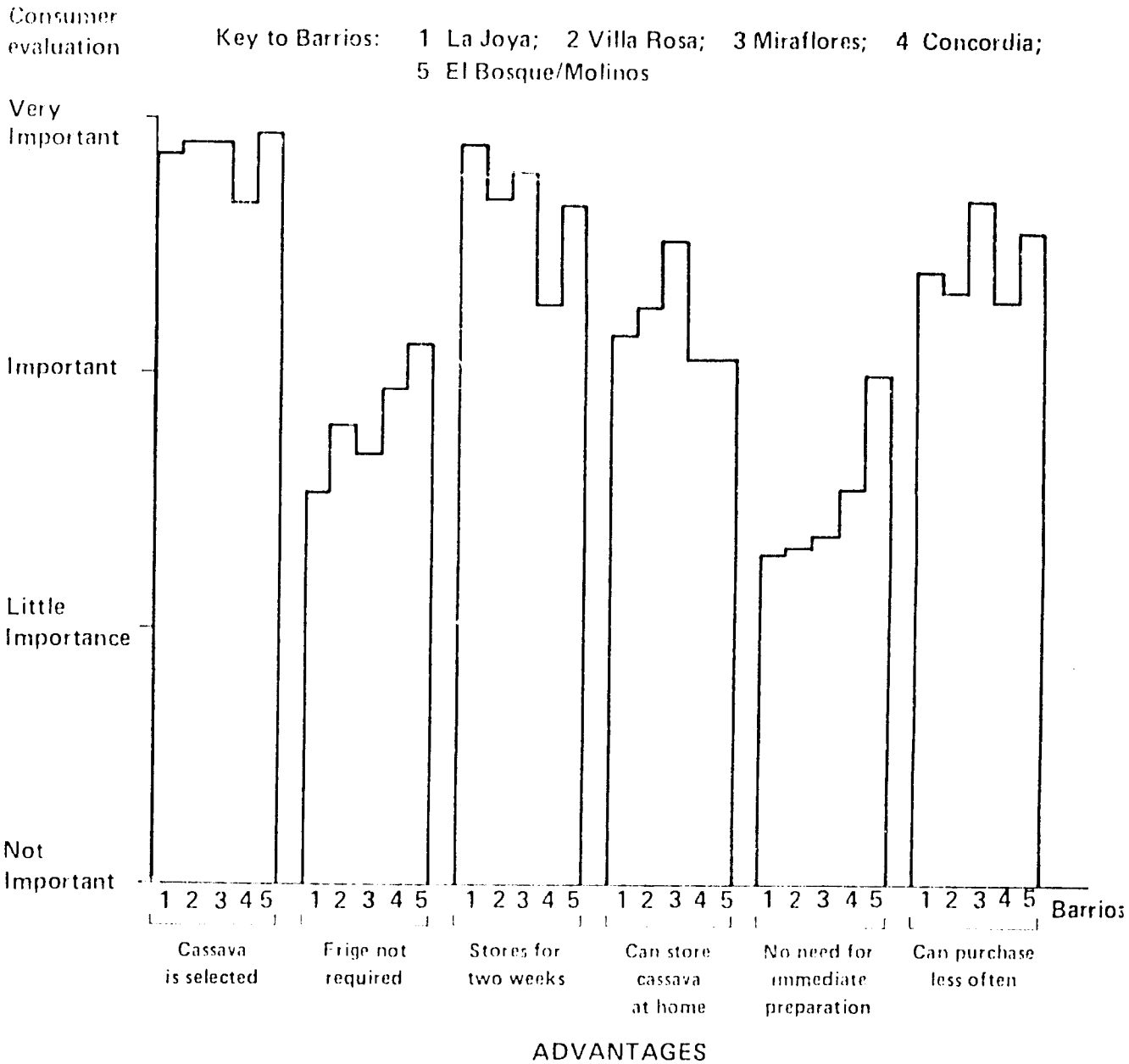


Figure 4. Consumer testing of stored cassava: evaluation of the importance of several advantages of cassava storage by 20 consumers in each of 5 barrios of Bucaramanga.

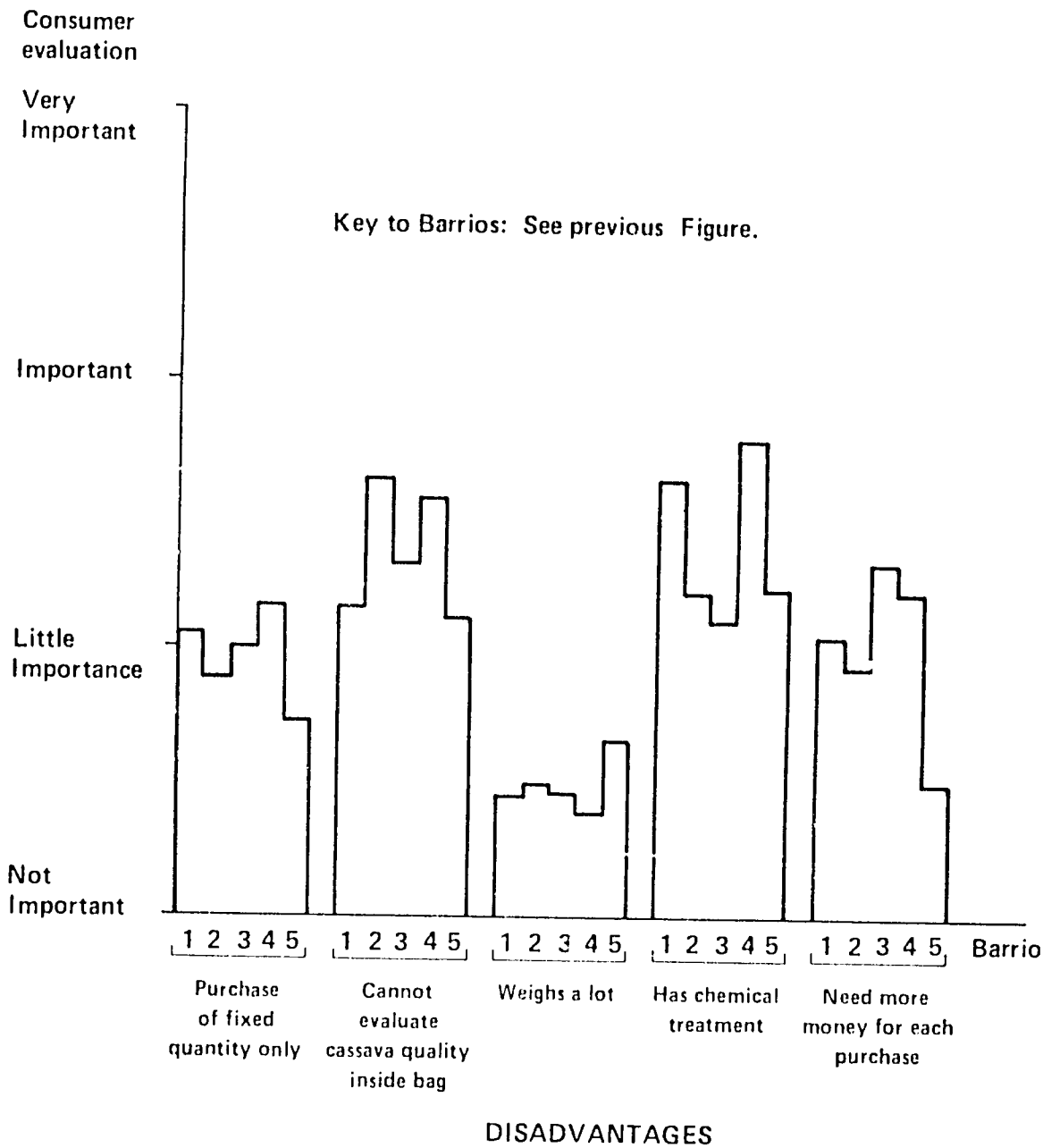


Figure 5. Consumer testing of stored cassava: evaluation of the importance of several disadvantages of cassava storage by 20 consumers in each of 5 barrios of Bucaramanga.

CASSAVA VARIETAL IMPROVEMENT IN ASIA

During the first 10 years of the Cassava Program (1973-1982), CIAT had offered cassava germplasm and training/communication opportunities to Asian cassava researchers. These contributed to the establishment and improvement of national cassava research programs in many Asian countries. Since the CIAT Cassava Program Regional Office was opered in Bangkok, Thailand in 1983, our cooperation with Asian national program has been strengthened.

Germplasm Distribution

Sexual seeds have been the major means of germplasm transfer, occasionally supplemented by meristem culture. In the past, approximately 125,000 hybrid seeds from some 2,000 crosses were distributed to cassava breeding programs in Asia (Table 1). The strategy evolved from sending any Latin American germplasm to any interested program in the early years to provinding seed populations of better defined parents for the specific needs and capacity of each national program later on, particularly after 1982.

It should be noted that the capacity to handle sexual seeds at the national program level has increased enormously in the last few years. In many national programs, these seed populations are regarded as sources for inmediate varietal selection while programs such as that in Thailand, have also selected cross parents from the seed populations to be used in their hybridization program. These materials are being processed through evaluation steps in each national program.

Thailand

The Cassava Research Program, with headquartes at the Rayong Field Crop Research Center, Field Crop Research Institute, Department of Agriculture, had developed a highly comprehensive varietal improvement program, which has incorporated massive germplasm introductions from CIAT (Table 2) into its evaluation scheme (Table 3). From the first CIAT seed introduction in 1975, a clone selected from CM 407 cross (M Mex 55 x M Ven 307, crossed at CIAT in 1973) were released as Rayong 3, a high starch cultivar and Rayong 2, a cultivar for snack food, respectively. Several clones have been selected from the seed populations to be used as parents in hybridizations and the resulting hybrid seeds from Thai x locally selected CIAT clones and locally selected CIAT x CIAT clones now constitute the mainstream of breeding materials. Extra quantity of promising hybrid seeds are produced to be distributed to other national cassava pr rams in Asia.

Rayong 3 seems to be popular among advanced farmers and is estimated to be planted in more than 300 ha. Rayong 2, just released, attracted a few snack food companies and is being multiplied for planting stakes to be used by contract farmers.

Some clones continued to show their yielding ability to be higher than that of the venerable local cultivar Rayong 1 in on-farm trials (Table 4). CMC 76 x V43)21-1 is high yielding and has very high starch content, thus, it seems to be better than Rayong 3 nearly in every

aspect, however, the plant type is as bad or even worse than that of Rayong 3 . (VI x R/21-8 is high yielding and of excellent plant type and root shape but is starch content is not higher than Rayong 1. These clones are selections from crosses made before 1980.

In regional trials with clones selected mainly from 1979/80 crosses, CMR 23 crosses were evaluated; some clones outyielded Rayong 1 on the average in all locations but the difference was not very large (Table 5).

A similar result was obtained from advanced trials in which clones were selected from 1980/81 crosses (CMR 24 crosses), (Table 6). Some clones such as CMR 24-14-266, a selection from Rayong 3 x Rayong 1 cross, showed a favorable combination of high yield with good plant type and root shape, and reasonable high root dry matter content.

More promising materials have come from preliminary trials in which clones from 1981/82 crosses (CMR 25 or OMR25) or 1981/82 seed introduction from CIAT were evaluated (Table 7). Many clones outyielded Rayong 1 and the average yield of the top five entries was 48% higher than that of Rayong 1. Clones such as CM 3292-18 or CMR 25-32-5020 seem to combine high yield with high root dry matter content and good plant type and root shape.

Planting cassava at the beginning of wet season (April/May) has been the standard practice in Thailand but recently more and more farmers are shifting their plantings toward the end of wet season (September to November). Clonal evaluation was started for late season planting in 1983 and now comprehensive set of genotype evaluations are in progress covering F2 seedling selection to advanced trials fro late season planting are in progress. In all the trials for later season planting so far obtained, selected clones have shown extremely promising results. In one such trial, the average yield of the five best entries exceeded that of Rayong 1 by 70% (Table 8).

Philippines

In the early years of cassava research program establishment in the Philippines, an introduction of 12 clones from CIAT was made through the CIAT/SEARCA/IDRC project. After multiplication cycles, these clones were handed to IPB (Institute of Plant Breeding), UPLB (University of Philippines at Los Banos) and PRCRTC (Philippine Root Crops Research and Training Center), VISCA (Visayan State College of Agriculture), and were later evaluated in regional trials (Philippines Seed Board trials). After some years of trials, CM 323-52 is being considered for official release together with G 50-3, a high yielding selection from the IPB root crop breeding project based on local germplasm. Several selected clones found their way into the hybridization scheme of PRCRTC as cross parents (Table 9). Some clones were unofficially released for large planters in Mindanao and Visayas during 1980 and 1981 (Table 10). They are reportedly planted in hundreds of hectares in these areas now.

Introductions of CIAT cassava hybrid seeds have been made almost continuously since 1982 to the cassava breeding program of PRCRTC (Table

10), while their capacity of systematically evaluating large quantity of genotypes has been greatly enhanced through cooperation with CIAT in recent years (Table 11). In many trials selected CIAT clones showed highly promising results. In one such trial (in which the experimental plot did not receive any fertilizer application, irrigation or chemical pests control), a group of selected CIAT clones which had shown great yielding ability in highly fertilized plots of the previous year trial, also demonstrated great yield superiority over local control (Table 12).

Such clones as CM 323-52, M Col 1684 amd CMC 40 have been actively crossed with local germplasm and the resulting hybrids have now advanced to the single-row trial. Recent selections from seed introductions are also entering the hybridization scheme now.

Additionally, CIAT has been contributing hybrid seed populations since 1975 to the cassava varietal improvement section of IPB and UPLB, (Table 13). With the improvement in evaluation materials of later introductions are being evaluated more systematically (Table 14). Many promising selections have resulted from the cross number above CM 3000.

Indonesia

CIAT's contribution of cassava hybrid seeds to the cassava varietal improvement section of CRIFC (Central Research Institute for Food Crops, Bogor) started as early as in 1975. The capacity of CRIFC cassava program was limited due mainly to the very restricted resource allocated to cassava, thus germplasm transfer from CIAT to CRIFC has been sporadic (Table 15) and the resulting clones could not be evaluated systematically (Table 16).

However, the recent development of CRIFC cassava program to carry out, a major part of its varietal development work at P.T. Umas Jaya Farm, Lampung, Southern Sumatra, using resources of PTUJF, made it possible to evaluate a large CIAT seed population in an organized fashion (Table 16). The majority of selected clones from the single-row trial at PTUJF gave a higher root fresh yield than that of the leading local cultivar, Kretek (Figure 1). Root dry matter content and harvest index of the selected clones were much higher than those of Kretek. The best selection from the earlier CRIFC breeding work based on local germplasm, M-31, also showed highly promising results.

Malaysia

Cassava seed introduction to the cassava varietal improvement section of MARDI (Malaysian Agricultural Research and Development Institute started in 1975 and was continued until 1982 (Table 17). It was discontinued thereafter because of the MARDI's decision that they had introduced sufficient germplasm variability for the limited importance of cassava in their national economy. Though small in size, the cassava varietal improvement program of MARDI is well organized and highly functional, thus, the introduced germplasm has been evaluated in a well organized fashion (Table 18).

Selected CIAT clones occasionally showed yield superiority over the traditional local cultivar, Black Twigg, however, the difference was not large (Table 19) and in many other trials, selected CIAT clones could

not demonstrate significantly higher yield levels. Cassava is a minor crop in Malaysia, thus, new clones must demonstrate a spectacular yield superiority over the currently available cultivar to be introduced. Although promising genotypes are being developed, the results so far obtained were not highly convincing.

In 1980, several CIAT clones were introduced through meristem culture transfer. The recent result of advance trials for these clones was disappointing; none of these directly introduced clones yielded nearly as well as Black Twigg or another local control C5 (Table 20). The result suggests that the possibility of finding truely adapted genotype(s) from a small number of clonal introductions is very low.

China

Our contact with the cassava research team at SCATC (South China Academy of Tropical Crops), Hainan started in 1982 and CIAT has contributed hybrid seeds on several occasions (Table 21). With CIAT's cooperation their varietal evaluaton scheme is rapidly building up and materials are being evaluated in an organized manner (Table 22).

Overview of CIAT cassava breeding materials in Asia

Summarizing the results of numerous yield trials in the past, the average root dry yield of the top five CIAT selections were compared with those of the local cultivar(s) in each trial to appraise the superiority (or inferiority) of selected CIAT clones relative to leading local cultivars). An average score of 150% suggests an excellent opportunity for selecting new high yielding cultivar(s); 100-120% suggests some but not vry convincing opportunity; and less than 100 % means almost no hope.

In Thailand, the analyses suggest that we are still struggling for convincingly higher yielding clones for early season planting but promising late season planting selections exist (Table 23). In the Philippines, CIAT genotypes seem to offer magnificent selection opportunities (Table 24). In Indonesia, though the number of trials is far too small to draw a general conclusion, selected CIAT genotypes are far superior to the current local cultivar(s) (Table 25). In Malaysia, however, CIAT genotypes so far selected are not offer a convincing selection opportunity (Table 26). The apparent superiority of CIAT clones over local cultivars in the Philippines and Indonesia may be because local cultivars in these countries are adapted to traditional plantings of a few plants in backyard farming to human consumption and not to new ways of planting on larger scale for processing.

Our experiences indicate that Latin American germplasm in general, and CIAT hybrid seed populatons in particular, are rich sources of genetic variability not only for yield but also, for disease and pest resistance or root characteristics. CIAT's germplasm offers high yielding capacity for immediate varietal selection as well as other desirable characteristics to be utilized in the long term breeding endeavors of the Asian national programs.

Table 1. CIAT cassava F_1 hybrid seeds distributed to Asian program.

Year/Country	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Thailand	900		6170	7720		3050	1400	7450	7900	8000	9300	51890
Indonesia	900			700					4600		6000	12200
Philippines	900			950			5100	4700	5500	2350	5000	24500
China								2300	6100		3500	11900
Malaysia	900		1500			2050	1250	4050				9750
India	900			850					1050	7900		10700
Vietnam									1900			1900
Rep. China (Taiwan)	500							1200				1700
Total	5000		7610	10220		5100	7750	19700	27050	18250	23800	124540

Table 2. CIAT cassava hybrid seeds supplied to the cassava varietal improvement program, Dept. Agriculture, Thailand.

Year	No. Seeds	No. Crosses	Principal cross No.	Principal parents
1975	800	16	CM 305 CM 407	M Col 22 M Col 113 M Mex 55
1977	5300	120	Crosses made by Charn T. at CIAT	M Col 1684 M Mex 17 M Ven 218
1978	5400	95	Crosses made by Somsak at CIAT	M Col 1684 M Ven 218 CM 309-41
1980	3050	42	CM 1442 - CM 2516	M Ven 62 CM 430-51 CM 516-6
1981	1400	28	CM 2450 - CM 3305	CM 520-5 CM 523-7 CM 727-14
1982	7450	128	CM 3515 - CM 4234	M Bra 12 CM 517-1 CM 523-7 CM 1103-7
1983	7900	153	CM 2784 - CM 4284	M Pan 51 CM 342-170 CM 681-2 CM 849-1 CM 1015-19
1984	6650	133	CM 3965 - CM 5124 SM 302 - SM 493 Some CG and SG	M Col 1823 M Col 2207 CM 681-2 CM 922-2 CM 1559-5
1985	6150	123	CM 3322 - CM 5834 SM 315 - SM 615 SG 563 - SG 831	M Bra 12 M Cub 31 CM 1983-2 CM 847-11

Table 3. Utilization of CIAT seed introduction by the cassava varietal improvement program, Department of Agriculture, Thailand during the past ten years. - Schematic presentation by number of genotypes.

	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Seed introduction No. seeds (No. crosses)	800 (16)		5300 (120)	5400 (95)		3050 (42)	1400 (28)	7450 (128)	7900 (158)	6650 (133)	6150 (123)
Seedling selection									5816	5377	3642
Single-row trial									419	1237	568
Preliminary trial									22	62	69
Advanced trial											16
Regional trial									6		
On-farm trial									2	2	
On farm test										2	
Multiplication									1		
Varietal recommendation									1 (Rayong 3)	1 (Rayong 2)	

Table 4. Some results of on-farm trials in Thailand, 1984/85.

	Root dry yield (t/ha) at					Root dry matter content	Plant type	Root shape
	Rayong	Huai Pong	Sattahip	Klang	Average			
(CMC 76xV43)21-1	8.9	10.6	6.7	7.1	8.33	5	2	3
(V1 x R) 21-8	9.7	10.0	4.8	8.8	8.33	3	5	4
Rayong 1	7.7	7.8	5.7	6.3	6.88	3	5	4
Rayong 3	9.9	8.3	4.2	6.1	7.13	5	2	2

Table 5. Result of Regional Trials in Thailand, 1984/85.

Clone	Parents	Root dry matter yield (t/ha) at						Plant type	Root shape	Root dry matter content
		Rayong	Khon Kaen	karasin	Mahasa-rakarm	Sriracha	Average			
CMR 23-128-141	CM 407-9 x CM 309-211	8.2	10.1	13.0	17.4	10.1	11.8	2	4	3
CMR 23-29-15	CM 407-14	8.5	7.0	13.1	17.9	10.8	11.5	3	2	3
Rayong 3	M Mex 55 x M Ven 307	8.2	8.2	15.9	16.9	8.0	11.4	2	2	5
Rayong 1		7.6	6.8	14.1	17.7	10.3	11.3	5	4	3
CMR 23-149-128	CM 407-24 x M Col 1684	8.4	8.7	15.6	15.2	7.7	11.1	4	5	1
CMR 23-126-122	CM 407-9 x M Col 1684	8.4	8.3	14.6	15.9	7.2	10.9	4	2	3
CMR 23-17-251	Kaset x M Col 1684	7.9	6.8	7.3	15.8	8.3	9.2	5	4	3
CMR 23-08-8	Hanatee x CM 407-24	5.8	4.9	8.2	10.5	7.7	7.4	4	4	2

Table 6. Results of an advanced trial in Thailand, 1984/85[a]

Clone	Parents	Root dry yield (t/ha) at				Plant type	Root shape	Root dry matter content
		Rayong	Banmai	Khon Kaen	Average			
CMk 24-23-4	CM 309-211 x R1		12.5	12.9	12.7	3	5	3
CMR 24-14-266	R3 x R1	12.3	15.0	9.1	12.1	4	4	3
CMR 24-89-65	R1 x M Col 1684	12.4	12.9	9.6	11.6	4	4	3
OMR 24-07-12	CM 305-15	12.2	12.7	9.6	11.5	4	5	3
Rayong 1		9.7	11.3	11.1	10.7	5	4	3
CMR 24-14-532	R3 x R1	11.2	10.3	9.5	10.3	3	3	4
CMR 24-14-1038	R3 x R1	9.7	11.6	9.2	10.2	3	3	4
Rayong 3	M Mex 55 x M Ven 307	8.5	9.2	8.5	8.7	2	2	5

[a] Entries eliminated at this trial are not shown.

Table 7. Results of a preliminary yield trial at Rayong, Thailand. 1984/85[a]

Clone	Parents	Root dry yield (t/ha)	Root dry matter contents (%)	Plant type	Root shape
CM 3281-11	M Bra 12 x M Col 22	14.6	28	5	5
MKU 2-151	M Col 113 x M Col 22	14.6	24	5	4
CM 3292-18	CM 825-3 x CM 681-2	14.0	39	3	4
CMR 25-32-502Q	(V1 x R) 20-15 x R3	13.1	39	4	3
CMR 25-33-157Q	R3 x R1	12.5	41	5	3
MKU 2-162	M Col 113 x M Col 22	12.3	31	2	4
CMR 25-33-134Q	R3 R1	12.0	36	3	4
CMR 25-32-365Q	(V1 x R) 20-15 x R3	11.9	35	4	3
CMR 25-34-112	R3 x M Col 1684	10.9	34	4	2
OMR 25-05-05	Kaset	10.8	32	5	4
CMR 25-34-159	R3 x M Col 1684	10.6	32	3	4
Rayong 3	M Mex 55 x M Ven 307	10.6	35	2	2
CM 3299-15	CM 849-1 x M Col 22	10.4	32	5	5
CM 3299-14	CM 849-1 x M Col 22	10.3	31	5	5
CM 2502-35	M Ven 142 x M Col 1684	10.1	28	5	4
CMR 25-34-93	R3 x M Col 1684	10.0	35	3	3
CMR 25-34-242	R3 x M Col 1684	9.8	38	3	3
CM 2493-37	M Col 1515 x M Col 1684	9.5	29	4	3
Rayong 1		9.3	32	5	4
CM 3299-22	CM 849-1 x M Col 22	9.3	32	4	4
CM 3281-15	M Bra 12 x M Col 22	8.4	33	3	3
CM 3292-14	CM 825-3 x CM 681-2	8.1	25	5	5

[a] Entries eliminated at this trial are not shown.

Table 8. Result of Preliminary Trial at Rayong, Thailand. Second season, 1984/85.

Clone	Parents	Root dry yield (t/ha)	Root dry matter contents (%)	Plant type	Root shape	Harvest index
CMR 25-82-88	CM 309-211 x CM 305-13	20.0	39	4	4	.64
CMR 25-93-52	CM 367-34 x M Col 1684	18.7	31	4	4	.64
CM 2504-2	M Ven 142 x M Col 1684	18.4	35	4	3	.66
Rayong 3	M Mex 55 x M Ven 307	17.5	38	2	3	.63
CMR 23-105-47	27-77-10 x R3	17.1	37	2	2	.53
CMR 25-105-112	27-77-10 x R3	16.9	37	5	4	.64
CMR 25-106-26	M Col 22 x M Col 1684	16.9	37	5	3	.64
CMR 25-46-1	CM 305-13 x R1	16.3	29	4	5	.69
CMR 25-106-60	M Col 22 x M Col 1684	16.1	31	5	3	.58
CMR 25-35-18	R3 x CM 305-13	15.5	37	4	3	.63
CMR 25-50-8	CM 305-13 x R3	15.5	34	3	3	.63
CMR 25-33.105	R3 x R1	15.4	37	4	4	.53
CMR 25-106-56	M Col 22 x M Col 1684	15.2	33	3	3	.41
CMR 25-11-25	Kaset x M Col 22	14.9	29	4	4	.52
CMR 25-29-622	(V1 x R) 20-15x CM 305-13	14.4	35	5	3	.53
CMR 25-35-78	R3 x CM 305-13	13.2	36	4	4	.72
CMR 25-56-23	R1 x CM 305-15	12.5	34	4	2	.51
CMR 25-35-248	R3 x CM 305-13	12.4	35	2	3	.55
CMR 25-11-37	Kaset x M Col 22	12.2	35	1	3	.50
CMR 25-31-47	(VI x R) 20-15 x M Col 1684	12.2	32	5	3	.46
CMR 25-52-85	CM 305-15 x M Col 1684	11.9	33	1	3	.42
Rayong 1	CM 305-15 x M Col 1684	10.7	35	5	4	.40

Table 9. Utilization of CIAT clonal introductions by various institutions in the Philippines.

Year / Utilization step	1978/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Clonal introduction	12 (SEARCA/CIAT)							
Multiplication		12 (SEARCA/CIAT)	12 (SEARCA/CIAT)					CM 323-52 (PRCRTC)
Regional trial				10 (UPLB)	10 (UPLB)	5 (Philippines Seed Board)	5 (PSB)	5 (PSB)
Hybridization						6 (PRCRTC)	4 (PRCRTC)	4 (PRCRTC)
Release			Unofficial CMC 40 CMC 84 HMC 4	Unofficial M Col 1684 CM 305-38 CM 308-197 CM 323-52				

Table 10. CIAT cassava hybrid seeds supplied to PRCRTC, VISCA Philippines.

Date	No. Seeds	No. Crosses	Principal cross no.	Principal parents
Aug 1976	250	5	CM 585 CM 690	M Mex 55 M Col 638
Jan 1982	2200	43	CM 2450 CM 3320 CM 3504 CM 3816	M Col 22 CM 342-170 CM 523-7 CM 586-1
Nov 1982	5550	100	CM 3341 CM 4011 CM 4049 CM 4234	CM 681-2 CM 849-1 CM 922-2 CM 1015-19
Jan 1985	2800	56	CM 4397 CM 5371 SM 306 SM 418	M Bra 12 CM 942-14 CM 1335-4 CM 1523-19
Oct 1985	3000	60	SM 457 - SM 598	M Bra 35 CM 681-2 CM 2452-5 M Tai 1

Table 11. Utilization of CIAT seed introduction by the Cassava Varietal Improvement program, PRCRTC, VISCA, Philippines. - Schematic presentation by number of genotypes.

Year Evaluation step	1976/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Seed introduction No. seeds No. crosses	250 (5)					2200 (43)	5500 (100)		2800 (56)	3000 (60)
Seedling selection		?							2105	
Single-row trial							418	819		294
Preliminary trial								119	147	29
Advanced trial									24	8
Regional trial										

Table 12. Result of an advanced trial at PRCRTC, VISCA, Philippines 1984-1985[a]

Clone	Parents	Root dry yield (t/ha)	Root dry matter content (%)	Plant type	Root shape
Selected					
CM 3380-30	CM 586-1 x CM 523-7	6.9	33	5	4
CM 3590-1	CM 859-12 x M Col 22	6.8	34	5	4
CM 3504-9	CM 728-2 x CM 523-7	6.1	30	3	4
CM 3816-4	CM 1191-9 x CM 523-7	5.6	35	3	3
CM 3340-3	CM 342-170 x CM 586-1	5.5	32	2	3
CM 3422-3	CM 630-122 x CM 728-2	5.4	33	2	3
CM 3341-4	CM 342-170 x CM 523-7	5.1	33	3	4
CM 3320-11	M Bra 12 x CM 523-7	4.6	33	4	2
CM 3504-8	CM 728-2 x CM 523-7	4.3	36	4	4
Control					
CM 323-52	M Col 22 x M Mex 59	3.4	32	4	4
M Col 1684		3.3	29	3	3
CMC 40		3.0	30	2	4
Golden Yellow (local)		1.9	31	5	1

[a] Entries eliminated at this trial are not presented.

Table 13. CIAT cassava hybrid seeds supplied to IPB, UPLB, root crop breeding program, Philippines.

Date	No. seeds	No. crosses	Principal cross No.	Principal parents
Feb. 1975	900	18	CM 305 CM 378 SM 61	M Col 22 M Col 113 M Mex 1
May 1977	950	19	CM 692 CM 791 CM 825	M Col 638 M Col 1684
Jan 1981	1400	28	CM 2098 - CM 3248	M Col 1515 M Col 1684 M Ven 77
Jun 1981	1050	21	CM 2450 - CM 3304	CM 520-5 CM 523-7 CM 727-14
Mar 1982	2500	50	CM 2527 - CM 3906	M Ven 77 M Bra 12 CM 342-170 CM 523-7
Sept 1984	2350	38	CM 3433 - CM 4238	CM 681-2 CM 849-1 CM 922-2 CM 1015
Oct 1985	2000	40	SM 425 - SM 520	M Bra 5 CM 507-37 CM 681-2 CM 2088-1

Table 14. Utilization of CIAT seed introductions by the Cassava Varietal Improvement Program, Institute of Plant Breeding, UPLB, Philippines. - Schematic presentation by number of genotypes.

Year Evaluation step	1976/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Seed introduction No. seeds No. crosses	900 (18)		950 (19)		1400 (28)	1050 (21)	2500 (50)		2350 (38)	2000 (40)
Seedling selection									1208	
Single-row trial		?	-?	?	?	?	?			155
Preliminary trial									53	45
Advanced trial								20	14	8
Regional trial										

Table 15. CIAT cassava hybrid seeds supplied to CRIFC, Bogor, Indonesia.

Date	No.seeds	No.crosses	Principal cross no.	Principal parents
Feb 1975	850	17	CM 305	M Col 22
			CM 407	M Col 113
			CM 690	M Col 638
May 1978	700	14	CM 1006	M Col 1684
			CM 1305	CM 323-142
			CM 1371	CM 462-1
			CM 1405	CM 499-49
Jun 1983	4600	80	CM 3341	CM 523-7
			CM 3993	CM 681-2
			CM 4031	CM 849-1
			CM 4049	CM 922-2
			CM 4063	CM 1015-19
Oct 1985	3500	20	SM 446 - SM 598	M Bra 35
				CM 682-2
				CM 2174-7
				M Tai 1
Feb 1986	2000	50	SM 443	CM 955-2
	(from CIAT)		CM 521	CM 996-6
	2950	73	CMR 28-97	(CM776 x V43)21-1
	(from Thai/CIAT)		OMR 28-45	CMR 23-149-128

Table 16. Utilization of CIAT seed introductions by the Cassava Varietal Improvement Program of CRIFC/P.T. Umas Jaya Farm, Indonesia.

- Schematic presentation by number of genotypes -

Evaluation step \ Year	1975/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Seed introduction No. seeds (No. crosses)	850 (17)			700 (14)				4600 (80)			3000 (20)
Seedling selection		?							2600 (PTUJ)		
Single-row trial					?					574 (PTUJ)	
Preliminary trial						?	20				97 (PTUJ)
Advanced trial								2	2		
Regional trial									2 ?	2 ?	

Table 17. CIAT cassava hybrid seeds supplied to MARDI breeding program, Malaysia.

Date	No. seeds	No. crosses	Principal cross no.	Principal parents
1. Feb 1975	850	17	CM 305 CM 378 CM 429 SM 61	M Col 22 M Col 113 M Mex 1
2. May 1977	550	11	CM 621 CM 845 CM 942	M Col 628 M Col 1684 M Ven 270 CM 309-37
3. Sept. 1980	2050	40	CM 1442 CM 1794-CM-2525	M Col 1684 M Ven 77 CM 430-51 CM 516-6 CM 516-7 CM 517-1 CM 533-15
4. July 1981	1250	25	CM 2674-CM 3303	CM 507-37 CM 523-7 CM 727-14 CM 825-3 CM 849-1
5. March 1982	4050	80	CM 2778-CM 3906	M Col 22 M Bra 12 CM 342-170 CM 523-7 CM 586-1 CM 621-167 CM 728-2 CM 849-1

Table 18. Ten years of cassava varietal improvement work at MARDI, Malaysia.
- Schematic presentation by number of genotypes -

	1975/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Seed introduction No. seeds (No. of crosses)	CIAT 1 850 (17)		CIAT 2 550 (11)			CIAT 3 2050 (40)	CIAT 4 1250 (25)	CIAT 5 4050 (80)			
Seedling selection									2511		
Single-row trial									336	854	
Preliminary trial									66	64	159
Advanced trial										66	64
Regional Trial								12 13	12 13	10	4
Multiplication/ release											3 ? 1 ?

Table 19. Result of Preliminary Yield Trial (CIAT 4, Gp. 1) at MARDI, Serdang, Malaysia. 1984/85.

Clone	Parents	Starch yield (t/ha)	Fresh yield (t/ha)	Starch content (%)	H.I.
CM 3275	CM 978-28 x CM 523-7	12.5	46.2	26.8	.59
CM 3275-38	CM 978-28 x CM 523-7	12.5	49.1	25.4	.62
CM 3275-6	CM 978-28 x CM 523-7	11.5	50.3	22.9	.67
CM 3263-10	CM 621-214 c CM 523-7	11.2	37.5	29.9	.56
CM 3275-32	CM 978-28 x CM 523-7	11.2	41.9	26.7	.55
C 5 (Control)		10.7	43.4	24.5	.49
CM 3280-25	CM 1252-12 x CM 91-3	9.9	39.8	24.8	.68
CM 3275-8	CM 978-28 x CM 523-7	9.8	38.4	25.6	.64
CM-3275-36	CM 978-28 x CM 523-7	9.8	38.8	25.2	.54
CM 3263-5	CM 621-214 x CM 523-7	9.4	37.3	25.3	.49
CM 3263-8	CM 621-214 x CM 523-7	9.2	32.2	28.7	.47
Black Twig (Control)		9.0	32.7	27.6	.45
CM 3275-12	CM 978-28 x CM 523-7	8.8	32.6	27.0	.50
CM 3275-34	CM 978-28 x CM 523-7	8.3	40.0	20.9	.51
CM 2459-8	CM 727-15 x CM 520-5	8.1	33.7	24.2	.51
CM 2778-20	CM 727-14 x CM 523-7	7.9	29.3	27.0	.52
CM 2450.25	CM 727-14 x CM 520-5	7.8	29.2	26.6	.44
CM 3275-16	CM 978-28 x CM 523-7	7.7	30.1	25.5	.72
CM 3275-18	CM 978-28 x CM 523-7	7.3	27.9	26.2	.52
CM 2459-36	CM 727-15 x CM 520-5	7.2	28.9	25.4	.56
LSD (5%)		4.9	19.2	1.6	0.14

Data source: Tan Swee Lian, MARDI.

Table 20. Result of advanced yield trials for meristem-culture introduction from CIAT at MARDI, Jalan Kebun (on peat soil), Malaysia, 1984/85

Clone	Parents	Starch yield (t/ha)	Fresh yield (t/ha)	Starch content (%)	H.I.
Black Twig (control)		8.3	32.3	25.9	.57
C 5 (Control)		7.4	27.1	28.0	.58
CM 342-55	M Col 22 x M Col 468	6.2	26.7	23.3	.62
CM 462-6	Llanera x M Ven 270	5.9	24.0	24.8	.66
CM 507-34	Llanera x M Col 1684	5.0	21.0	23.9	.45
CM 458-2 A	Llanera x M Col 22	4.5	18.1	25.2	.72
CM 458-2 B	Llanera x M Col 22	4.3	18.4	23.2	.71
CM 321-188 A	M Col 22 x M Ven 270	4.0	16.7	23.6	.64
CM 321-188 B	M Col 22 x M Ven 270	3.7	16.1	24.9	.65
LSD		2.2	8.9	6.2	.07

Data source: Tan Swee Lian, MARDI

Table 21. CIAT cassava hybrid seeds supplied to SCATC, Hainan, China.

D.	No. seeds	No. crosses	Principal cross	Principal parents
June 1982	2300	38	CM 3281 - CM 4081	M Col 22 M Bra 12 CM 523-7 CM 849-1
Nov 1982	6100	100	CM 3009 - CM 4238 SG 504 - SG 709	CM 523-7 CM 681-2 CM 922-2 CM 1015-19
Oct 1985	2500	50	SM 465 - SM 616	M Bra 35 M Cub 65 CM 430-37 CM 2452-5

Table 22. Utilization of CIAT seed introduction by the Cassava Varietal Improvement program, SCATC, Hainan, China. - Schematic presentation by number of genotypes -

Year Evaluation step	1981/82	82/83	83/84	84/85	85/86	86/87
Seed introduction No. seeds (No. crosses)	2300 (38)	6100 (100)			2500 (50)	
Seedling selection				2300		
Single-row trial				30	232	
Preliminary trial					12	
Advanced trial						

Table 23. Performance of top five selections in yield trials relative to local cultivar in Thailand [a].

Year	No. trial	% local cultivar		
		Fresh yield	Dry yield	Root dry matter content
1981/82	2	109	114	109
1982/83	12	117	108	101
1983/84-I	14	119	121	102
1983/84-II	1	151	151	102
1984/85-I	15	115	115	104
1984/85-II	5	145	147	99

[a] Local cultivar: Rayong 1

Table 24. Performance of top five selections in yield trials relative to local cultivar in Philippines[a].

Year	No. trial	% local cultivar		
		Fresh yield	Dry yield	Root dry matter content
1982/83	4	143		
1983/84	2	142	145	108
1984/85	5	163	177	122

[a] Local cultivar: Golden Yellow and Kadabao.

Table 25. Performance of top five selections in yield trials relative to local cultivar in Indonesia[a].

Year	No. trial	% local cultivar		
		Fresh yield	Dry yield	Root dry matter content
1982/83	1	145		
1983/84	1	153	199	130

[a] Local cultivar: Kretek

Table 26. Performance of top five selections in yield trials relative to local cultivar at MARDI, Malaysia[a].

Year	No. trial	% local cultivar		
		Fresh yield	Dry yield	Root dry matter content
1982/83	3	96	96	100
1983/84	10	114	104	96
1984/85	9	115	105	98
Meristem culture introduction	1	66	63	95

[a] Local cultivar: Black Twig and C5

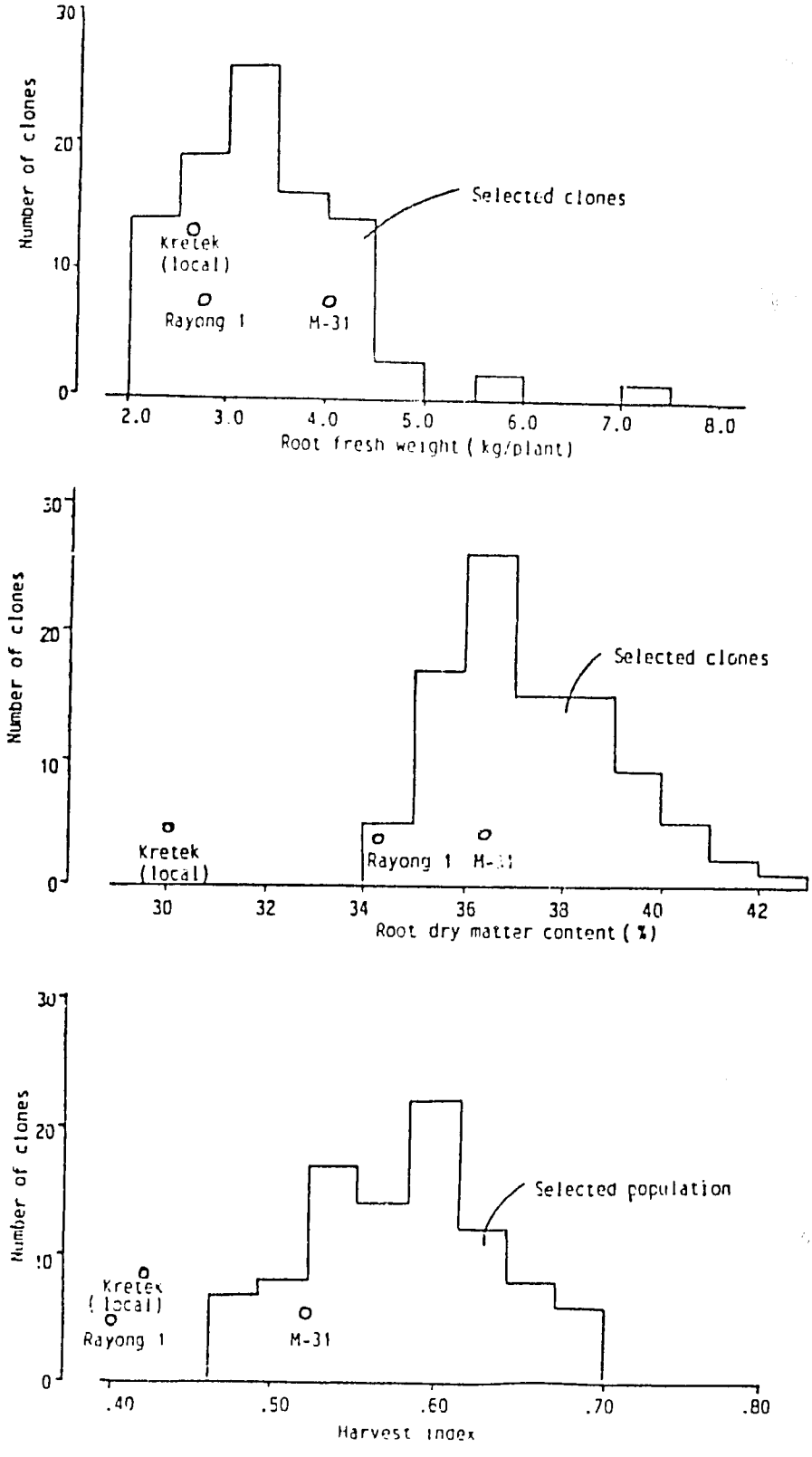


Figure 1. Frequency distribution in yield characters of selected clones in a single-row trial at P.T. Umas Jaya Farm, Lampung, Southern Sumatra,1984/85.

ECONOMICS SECTION

Impact Assessment

Impact studies represented the first real involvement of the social sciences in the evaluation of IARC-generated technology. Most were independent observers and framed their research as critique. Studies dealt with marketing problems, quality deficiencies, and adoption constraints but the principal focus was on the distribution of benefits. These studies represented the professional concerns of the period and in the end formed an advocacy for the incorporation of social scientists in the process of technology generation at the centers. In hindsight, the findings of these early studies were premature but the legacy remains: how social scientists can link the process of technology generation and evaluation to the socio-economic objectives that were largely defined by those first impact studies.

Impact studies examine the past and essentially ask what can be learned about technology characteristics from adoption patterns and performance under farmer management and about benefit distribution from the additional effect on market prices. Thus impact studies so viewed presuppose technology diffusion and in a sense are an afterthought to the process of technology design and generation. However, if social science is to hold technology design (and its creators) responsible for its eventual socioeconomic impact, then a means is needed for assessing impact within the actual process of technology generation prior to its diffusion. Moreover, since social scientists have been integrated into the centers, this responsibility to a very significant degree falls on their shoulders. At the IARC's then impact assessment should be a continuous process.

The economics section has attempted to adopt such an integrative approach to impact assessment within the Caassava Program. The following dicussion will utilize particular studies to demonstrate how impact assessment is a continuous and evolving element of the section's activities and how it is incorporated in the technology generation process.

Objectives and Strategy

The issue is how to direct the impact of improved technologies without sacrificing optimal potential production and efficiency. The process starts with well defined objectives, that necessarily include expected impact of technology on socio-economic goals, and a strategy whereby those objectives might be obtained. The Cassava Program's objectives have been defined as follows: "The overall goals of the cassava network are to increase small farmers' food supplies and income, as well as to improve food availability for the overall population." The analysis of existing cassava production and consumption patterns that have been carried out helped to define and in turn justify these objectives. However, a research strategy whereby new technology can begin to impact on these objectives requires that cassava be analyzed in more of a development context. Considered in this section are studies that have helped to define and/or confirm a cassava research and development strategy.

A central focus in the development of a research strategy is the effect that traditional markets have on the demand for improved production technology. In Latin America, markets for cassava, and therefore the sources of income for cassava producers, are dependent on food markets, and with the exception of Brazil, these are essentially markets for the fresh root. The perishability and bulkiness of fresh roots lead to several hypotheses about the marketing and consumption of cassava. These were intensively evaluated on the Atlantic Coast of Colombia, the principal cassava producing region of the country.

The difference in consumption patterns based on rural-urban residence between cassava and the other starchy staples is striking (Table 1). Cassava consumption declines precipituously from the point of production, so that consumption in the large cities is less than 20% of that of cassava producers. Neither plantain or rice show such differences, and potato, an imported commodity in the region, exhibits the opposite pattern. These differences in cassava consumption based on residence are not due to any signficant difference in the manner of utilization in the home (Table 2). Cassava to a reasonable extent is eaten at the same meals and prepared in the same manner. The differences arise from the number of meals per week at which cassava is served and the size of the portion per serving. The primary factors resulting in these differences in consumption of cassava are price and convenience. Cassava is over five times more expensive in metropolitan areas than the opportunity cost to cassava producers. Moreover, implicit costs in buying cassava daily in urban areas makes cassava far less of a convenient food than for example, rice.

The price difference between cassava producer and metropolitan consumer reflects the very signficant marketing margin for the crop. These margins derive from a marketing structure which must move a bulky and perishable crop from many small-scale producers to consumers who buy their cassava in small amounts at convenient locations (Table 3). The basic structure of this marketing system is presented in Table 4 and portrays a process which includes assembly in small packages of 800 kg. from small-scale producers, breakdown at the wholesale level into very small lots of 100 kg, and retail distribution. Assembly agents and wholesalers trade in about the same volumes and have similar margins. Retailers must recuperate costs with very small volumes and thus have very high margins. An analysis of costs (Table 5) suggests that the margins are not excessive, especially when viewed in terms of net profit.

The average time required from harvest to move cassava to consumers is 32 hours (Table 6). Such efficiency requires significant coordination and this is achieved principally by arranging sales prior to harvest (Tables 6 and 7). Seasonal price variation is relatively low in cassava due to supply management by storage in the field. However, interyear price fluctuations are relatively high. The latter is in part due to a demand price elasticity of 0.8 and significant weather variability. Price variation, quite stringent quality requirements, and an inherent rationing of market access, in which the farmer very often cannot arrange a sale, all result in making cassava a very risky crop to market. A market structure resulting in small volume transactions and significant marketing risk gives small farmers a comparative advantage but results in

farmers limiting this risk by planting a limited area in cassava in relation to farm size (Table 8).

The demand for improved technology under such market conditions is limited. The physical root characteristics of varieties, such as skin color, are a proxy for other, established quality factors. Since new varieties are a risky marketing venture, quality characteristics for introduced varieties are stringent and result in a low probability of adoption. Moreover, farmers already limit production because of marketing constraints (Table 7) and would be resistant to risking higher cash costs to expand yields. However, the most important aspect is that not only is there little effective demand for improved production technology but such technology would not achieve the objectives as originally outlined. Because of the high marketing margin, any reduction in production costs would have little impact on retail prices and therefore cassava consumption. Moreover, any signficant yield response could easily saturate what are very limited markets - given the price elasticity and the limited arbitrage possibilities because of time and transport constraints - and because of the price decline and/or lack of market access could result in an actual decrease in farmer incomes.

A cassava research strategy whose eventual goal is impact on farmer incomes can not be based on the hypothesis that improved production technology is sufficient for that end. The strategy necessarily has to include processing and/or storage technology and the development of alternative markets. The hypotheses underlying a consistent strategy then are: that (1) development of an alternative market based on processed cassava increases the size of the market, in most cases has more growth potential, and can result in a stable price floor under traditional markets; (2) a more expansive market with a stable price floor would provide incentives for the adoption of improved production technology; (3) small-scale processing technology is most compatible with small-farmer production systems; and (4) wherever possible small-scale cassava producers themselves should do the processing in order to maximize the benefits of new market development. The linkage of research objectives to research strategy thus depends on a clear understanding of the commodity system with a view to eventual impact.

Market Development

A fundamental knowledge of the commodity system honed the research strategy, and in most cases in Latin America the initial intervention would be through utilization technology and market development. A basic operational assumption in such intervention is that cassava is already competitive with substitutes in many of these markets, especially the animal feed concentrate market. That is, there are constraints on the operation of Adam Smith's hidden hand that have prevented development of these markets based on just price signals. In the first place a cassava market based on just fresh, food consumption is very fractured, consisting of small, independent local markets often with individual supply areas. Prices are subject to local supply and demand and therefore differ between markets. Moreover, there is a difference between the sales price and the implicit price at which farmers would supply roots for industrial uses. This difference on the Colombian Atlantic Coast is based on the 13% of roots that must be discarded at harvest because of size or breakage, the

transport costs to rural markets, and the cost of unsold roots (Table 7). Correcting the farmers' price for these factors results in a 24% reduction compared to an equivalent price where all roots can be used (Table 7). That is, price incentives for development of alternative markets are masked where market structure is based on urban fresh root markets. Project site selection to avoid local markets with particularly high prices and a firm understanding of the farmers' supply price are crucial to development of alternative markets.

A second operational principle is that the introduction of processing capacity and opening of new marketing channels should not require in the initial stages major adjustments in cassava production systems and supply. That is, development should be evolutionary - i.e. develop along a classic logistic curve -, to accomodate the learning process associated with management of the processing technology and the need for potential adjustments in output and input markets. The small-scale nature of the processing technology and appropriate design of the diffusion process would provide the best assurances of this least risky growth path.

The final principle is that market development is a means to increasing small farmer income. The governing assumption is that the source of income generation would be the potential to put underutilized land and labor resources within the farm into cassava production and so increase cassava yields. The cassava drying plants, the processing technology chosen for the particular case of the Atlantic Coast, provide access to market and only need to operate on a cost basis if farmer-managed. This led to the conception that a drying plant could be supplied by 15 to 20 small-scale producers. Both to share the risk of the investment costs and to supply labor for plant management and cassava for plant operation, these farmers were organized in units, called farmer associations. The conception then was that these farmer associations would be self-contained units for production, processing, and sales.

Such a strategy needs testing and the testing bridges research to development. These principles were tested within the framework of the Colombian Integrated Rural Development Program (DRI). In the three years of the project, the number of plants has grown from 1 to 7 to 20. An impact assessment of the 20 plants was undertaken in the 1984-85 production-processing season. Economic viability was already an established fact since over three thousand tons of dried cassava were produced in that season. Principal issues in the assessment were the mechanisms determining income distribution and whether the original assumptions underlying the strategy held true. The former issue will be covered in some detail in the next and last sections; the point to be highlighted here is the value of early impact assessment in the modification of assumptions and strategy.

The notion of the farmer association as a self-contained unit was overturned by events which had far more utility as a model for income generation and equitable distribution. First, the potential of the plants themselves as a source of income generation was underestimated. Each plant on average paid out over three thousand dollars in wages and almost four thousand dollars in net profits to its members. The oldest plant earned over 16 thousand dollars in net profits. Moreover, this does not

consider the equity accumulation in the plant. Second, on average slightly less than a third of processed roots were derived from members own production. In none of the plants was this figure over 50%. The plants were drawing on a larger supply area than just those farmers in the association. Third, and most importantly, the associations, especially those formed in the third year, were drawing in members with little, if any, land resources. Of almost 400 farmers in the associations by 1985, only 1% had farms over 20 ha. and 42% did not have secure tenancy in land at all. Mean "farm" size was 4.1 ha.

The multiple sources of income generation served all its members, with the land owners having a strong interest in cassava sales and members with little or no land, a vested interest in employment and profit redistribution. Although there was some element of conflict here, the associations were bound together by the increasing equity - through amortization of loans and plant expansion. Moreover, the plant provided an outlet for cassava production of non-members, which served to increase the number of beneficiaries even more (see last paragraph). Incorporation of appropriate technology and operational hypotheses, arising from an understanding of the cassava commodity system, into an actual field-level project provided a fine tuning of the strategy and confirmation that cassava could be a means of generating income for even the most marginal producers in a relatively marginal agricultural area. The principal conclusion, however, is that equitable impact, even as preliminary as in this case followed from the initial focus on distribution.

Market Development and Farmer Response

Cassava utilization technology associated with market development can have a direct impact on incomes in a region but it is the secondary impact on production response that deepens the income generation potential. The hypothesis is that the alternative market, in most cases closely linked to more stable grain prices, will provide a price floor under cassava and because of the reduced price risk, farmers will increase their production of cassava. In the longer term, as processing capacity becomes more generalized, a response due to more secure market access would also be expected.

As in the case of market development, the approach to production impact is hypothesis development, modeling or testing of the hypothesis and verification within a project framework. The effect of market development on farmer response was modeled in a programming framework based on farms typical of many parts of Cordoba and Sucre Departments. The impact of the price floor was introduced by truncating the lower tail of the price distribution, i.e. expected prices would rise and price variance would decline. Evaluation of the impact of risk reduction led to the adoption of a quadratic programming farm model. Without going into detail, the structure of the model included credit availability and the role of cattle in financing the capital requirements for crops, subsistence needs, cash flow requirements, and rotational patterns as well as income and risk objectives.

The model results (Tables 9 and 10) demonstrate the effect of both production and market risk on cropping pattern and average income. The establishment of a price floor, provided in this case by the support price

for sorghum (discounted for protein differentials), results in a significant increase in cassava sales, caused both by some expansion in cassava area and a shift in cassava production system away from yams in the cropping pattern. The result is a significant increase in farm income and even a slight reduction in income variance.

All farms in the relevant range (up to 15 hectares) respond to the establishment of the price floor (Table 11). However, large farms tend to have a greater response, essentially because of the more abundant land resources available to them. Small-scale farmers of three hectares are limited as well by the need to maintain cattle as a stock of capital. Assured credit could increase farmer responsiveness in the case of the very small-scale producer.

Verification started in the third year of the project in 1985 when two-thirds of the plants had only been operating one season. Some 73% of plant members were sampled for cassava plantings in 1984 and 1985. Between the two seasons, area planted increased by 17%. Practically all farm size groups planted an increased area in cassava in 1985. However, distinct differences in response were apparent between tenancy types (Table 12). What was unexpected was the very large response of renters. Farmers with very few resources were very responsive to the establishment of the plants. This raises questions about the impact of the expansion of the drying industry on the land rental market, especially if more marginal groups continue to be brought into the farmer associations. For farmers with more secure access to land, there was something of a dichotomy. Land reform beneficiaries significantly increased their cassava area, while planting by traditional landowners actually declined. What is influencing these differences and whether they will continue over time remains to be defined.

One insight into farmer response comes from relative changes in average area sown (Figure 1). Most of the area increase has come from farmers whose cassava area was well below the optimum as predicted by the model. There is yet to be much adjustment in planted area larger than three hectares. Constraints on adjustment and the period of adjustment are questions that need to be answered, since production response time will start to become a critical issue as processing capacity continues to expand.

Impact monitoring is critical to a process where major technological and economic change is introduced into a quite stable small farm economy. Insights into the structure and dynamics of technical change have expanded the potential of the project, at least in terms of its income distribution consequences. In this case, the impact of the drying plants on non-member producers, the expanded role of farmers with insecure tenancy, and whether larger farmers will provide the bulk of the production response are issues that will be more fully researched as the project progresses. Such early impact assessment thus allows potential for maximizing objectives.

Production Technology and Yield Improvement

The hypothesis has been that market development will create a signficant demand for improved production technology, which in turn will fuel the rate of development of alternative markets. Market development

is thus a precondition to the field level definition and testing of new technology and the monitoring of farmer adoption and technology response. The Cassava Program is presently launching a major effort in this area, so there is no actual impact to discuss. However, as has been stressed throughout this report, the process starts before adoption is ever underway.

Impact assessment of improved production technology is at its most elementary level yield evaluation, especially identification of factors that are influencing yields. In this respect cassava and cassava production systems are very different from the cereal and legume grains or even potatoes. This difference arises from the fact that there is usually little, if any, input use in cassava in Latin America. Nevertheless, there is a very wide range in cassava yields at the farm-level due, it is hypothesized, to differences in agro-climatic conditions, pests and diseases, and management practices. Labor input itself is, on the one hand, a very poor proxy for these management practices and, on the other hand, largely determined by yield, since there is a direct correlation between yield and harvest labor per hectare. This leads to the very difficult question of how the impact of improved technology, which itself consists principally of improved varieties and management practices and not inputs, is to be evaluated; that is, in any cross-sectional analysis many of the factors now influencing yields will have to be identified and controlled to measure the yield benefit of the technology itself.

The one previous attempt to identify limiting factors and evaluate their influence on yield (Pinstrup-Andersen and Diaz, 1977) failed. This was relatively early in the research program and yield-limiting factors were not well defined. The exercise was repeated in 1983-84 on the Atlantic Coast of Colombia. Production systems and their variation in the region were already fairly well described and climatic conditions were relatively homogenous. To ensure a signficiant yield variance, production zones of known high and low productivity were chosen - the survey was not randomized - and 104 farmers in 12 towns in four departments were selected and visited five to six times during the production year. To simplify an already complex process any plots with noticeable disease or pest problems were eliminated early on from the sample.

The sampling achieved its objective of getting a wide yield range (Figure 2), as yield varied from 3 to 22 t/ha with half the farmers producing yields over 9 t/ha. The major yield determining factors which were measured and included in the model (Table 13) were cropping system, method of soil preparation, number of and time of weeding, time of planting and time of harvest, soil fertility, rotation, and irrigation. No purchased inputs were applied in the sample. The soil fertility variables were based on critical response levels (CIAT Cassava Program Annual Report, 1982); the time of planting and harvest were based on the known rainfall distribution and yield response from previous experimental trials in the area; and weeding was related to timing. The resulting equation (Table 14) largely failed to define yield-limiting factors. The only variables that were statistically signficant and of correct sign (in accordance with experimental data) were the yield depressing effect of yam in the cropping system, and the yield augmenting influence of irrigation

in the one region where it was used - this area had an advantageous marketing position in Barranquilla, the largest urban market.

More refined specification and measurement of management practices and yields moves the process to some form of on-farm trial. The experience of the cassava economics section in such trials for any particular region has been that treatment response across farms is often variable, yield variation between farms is usually greater than that between treatments, and any attempts to begin to explain these differences is usually constrained by the limited degrees of freedom. The two methods taken together would seem to imply that standardized on-farm trials be carried out across a large number of sites. These are costly, often limited by seed availability where a new variety is a component, and beset by problems of how much farmer participation to allow in relation to the ability to measure non-treatment variables. However, future resolution of this issue will be critical to defining where and if new technology has had an impact.

Measurement of Benefits

Research output at the IARC's in general, and within the CIAT Cassava Program in particular, is measured by its eventual impact on production and income generation. Very few agricultural research programs are evaluated by such stringent criteria; in most, research productivity is measured by more intermediate outputs. That research should be so clearly focused on eventual impact builds in certain biases in how scarce resources are allocated: that applied research will be preferred over more basic research, that projects with shorter-term pay-off with be preferred over those with longer-term pay-off, and that research will attempt to integrate extension and/or development activities within its strategy. Correctives can be built in through long-term planning, but the primary Gordian knot remains that, if the research program is to be held accountable for impact, agricultural research necessarily must take a more activist role in development.

Impact assessment in this context thus becomes a monitoring device to ensure that research is appropriately targeted on the development objectives that have been defined. The role of monitoring is particularly exigent where income distribution is built into program objectives. Figures 3 and 4 summarize the impact of the drying plants on benefit distribution for members of the farmers associations in the 1984-85 drying season. The major portion of the benefits were distributed to the population with few land resources, principally because of the make-up of the associations. On an individual basis benefits increased with farm size, as income sources shifted away from wages and distributed profits to cassava sales. Thus, the income generation potential of the project still depends critically on access to land resources. However, the significant innovation is that the farmer associations could be a vehicle for bringing the most marginal economic population into the growth process. The key organizational insight here is that these farmer organizations are closed, they generate multiple income sources within the plant operation, and each member maintains a significant economic stake in the shared equity capital.

The plants, however, did not depend on only members' cassava production but rather supplies from non-members. For every member there were five non-member vendors of cassava. Moreover, these sellers were concentrated in the more marginal economic population on the coast; for example, a third were renters (Table 15). The plants signficantly expanded the number of beneficiaries far beyond that originally conceived. Although the per capita benefits were not large, the benefits were not insignificant for this rather marginal population, since either the cassava was of low quality and, therefore, of low opportunity cost, or the plants provided a sales outlet when capital was required. However, the principal finding was that this sales pattern was dependent on close physical (Figure 5) and social (Table 16) distance to the plant. Those few plants where large landowners or intermediaries were important were those relatively distant or isolated from cassava production zones. Plant location thus became a primary determinant of benefit distribution. Plant location in the beginning phases of the project was determined by the criteria of institutions within the project, but in the future the plant location effect on income distribution could be maintained though screening of credit applications for plant investment, especially where, as in this case, credit is already rationed.

The conclusion here is that the impact achieved in this case was dependent as much on institutional or organizational innovations as it was on new utilization or production techniques. More to the point, impact depended on the integration of both types of innovations, with each influencing the other. Nor can it be clearly demarcated where research ended and development began, since certainly in the case of organization innovations, the laboratory is provided by actual field-level projects.

Development of an alternative market can introduce quite radical changes in the local agricultural economy. What these changes will be can only be forseen by modelling of the commodity system. As a further tool for directing impact, a simulation model of the cassava economy on the Colombian Atlantic coast was constructed. The model incorporates significant detail on cassava production, marketing and consumption and estimates equilibrium, market-clearing prices in a significant number of inter-dependent markets. The model has a stochastic element to simulate weather and can incorporate various assumptions concerning yield response, sorghum prices, and the rate of investment in drying plants. The model runs for a ten-year period and can estimate the discounted economic benefits of the development of a cassava drying industry.

The first outcome of the model is that the cassava economy without the development of a dry cassava industry essentially stagnates at current production and consumption levels over the next ten years, since rural-urban migration and the "convenience" factor counter the effect of increasing population (Tables 17 and 18). Such an effect describes what has already happened in a country such as Venezuela. However, the development of a drying industry significantly changes that prognosis. In this case cassava production increases at the very respectable rate of 3.7% per annum, primarily on farms of less than 20 hectares.

The development of a dried cassava industry has the expected effect on reducing variation in producer prices and in consumer prices. Both

area planted and yields increase, due essentially to improved price stability. The differential yield response by farm size due to reduced market risk comes out of the quadratic programming model and reflects the stronger shift to monoculture systems on the part of large farmers. The difference in area response reflects the degree of land constraint faced by the different sized farmers. What was not included in the model was non-producing farmers coming into production, especially renters. This requires modelling of the land market and remains a future research activity.

Varying yield and investment response assumptions provide useful insights into the development of the cassava economy. An important conclusion is that the development of the cassava industry and overall production response is quite sensitive to cassava yields. Improved production technology can provide an important stimulus to the growth of the dried cassava industry. On the other hand, increasing the rate of investment in drying plants is also a stimulus to increased cassava production, partially through the further reduction in price variation.

The expected benefits in the development of a dried cassava industry over the 10-year period are significant (Table 19). Benefits are captured by producers but with the important consideration that there is little negative impact on consumer welfare. Producer benefits are expected to be distributed more or less proportionally according to farm size. Employment in the cassava sector is expected to increase at about 2.7% per annum, due in part to increased labor utilization in the drying plants but principally to intensification of farm production. This is about the rate of population growth and although significant is not expected to put pressure on wages in the region. Finally, the production of dried cassava will be replacing imported sorghum, resulting in a reduction in foreign exchange outflows.

Models reflect the current understanding of the cassava commodity system and the expected adjustments in the development of an alternative market. In one respect, they represent a standard against which progress within the project can be measured. On the other hand, when the model results are compared to actual adjustment patterns and benefit streams, the interplay provides a basis for improving understanding of that process. Understanding change in a rural economy thus becomes an interactive process between model formulation and verification. It is this mechanism which provides the means, particularly through organizational and institutional changes, of directing impact toward the defined objectives.

Conclusions

Impact assessment serves a valuable role within the international centers but only if it is an integral part of an on-going research program. Ex-post-facto impact evaluation, in and of itself, makes interesting history but is of little use to decision-making within a research program, especially where one of the objectives is income distribution. An interesting question is the effect that the innumerable impact studies of improved rice and wheat varieties has had on research at the International Rice Research Institute (IRRI) and the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). Impact assessment

can play a more active role in a research program but that role must begin before actual impact is even detectable.

Such a role for impact assessment, however, presupposes that there are alternatives in research design and in their consequent impact. The focus of the CGIAR system's objectives on increased food production by the small farmer and increased food consumption by the poor consumer, suggests that there are such alternatives. The argument, however, can be made that these objectives are reflected only in terms of the commodity choice and the country priorities. Actual decisions within the commodity research program can then be isolated from such concerns about impact, and in fact, the recent bandwagon among social scientists for the scale neutrality of improved varieties represents an apparent acceptance of this point of view.

However, commodity research programs cannot have it both ways. Either, research is defined by purely technical criteria and the priorities set within the particular disciplines and the respective literature, in which case potential impact becomes essentially unknown, or research is married to development objectives and research alternatives are assessed accordingly. The point is not just a case of "truth in advertising" but fundamentally affects how the research program is organized and how closely it is linked to what are seemingly development activities. In particular, if the program's objectives include income distributional goals, then research activities necessarily must be integrated with field-level, development projects.

The success of the dwarf rice and wheat varieties in Asia has tended to narrow the conception of the types of innovations that IARC's produce to essentially varieties. The far greater misconception, however, is that improved varieties alone are sufficient for impact. While this may be true for some commodity programs, the argument for the case of cassava in Latin America is that varieties by themselves will have little potential for increasing production and utilization. This has moved the Cassava Program to search for innovations not only in production techniques but also in post-harvest and utilization technology and even organizational[b] and institutional innovations. Ruttan (1984) has recently argued that the latter is a primary output of social science research. In the case of cassava, it is difficult to divine which type of innovation will have the greater impact and, therefore, which should be the principal concern of the research program. By extension, restricting an IARC's mandate to just germplasm can in some cases be unproductive.

The case of cassava exemplifies a commodity approach to income generation and development. The role of commodity "booms" in agricultural development is often underplayed but such examples as coffee, and later soybeans, in Brazil, or rubber and later oil palm in Malaysia, highlight the commodity as a growth source. A commodity approach to research is a

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b The Colombian Integrated Rural Development Program (DRI) should be given primary credit for the innovations inherent in the farmer associations.

logical solution to the difficulties in focus and problem identification in applied research. However, a commodity focus also has a potential role in development and it can be easily linked to agricultural research, on the one hand, and to agricultural policy on the other. A commodity approach to identifying the key interventions that lead to income growth and equitable distribution thus has certain merits. Such an approach slices the world in a different way than, say, farming systems research. Whereas the latter adopts a regional, production, and often farm strata focus in order to delimit the system universe, a commodity system is defined across a variety of system levels, including farm, marketing and consumption systems. The recent search for holisum in agricultural research thus need not in all cases sacrifice a commodity focus. The question to be evaluated is which is the most efficient means to impact ?

Finally, cassava is not necessarily a paradigm for the organization of research in other commodity programs, just as wheat and rice are unique cases as well. What is apparent, however, is that the focus and structure of the research program follows from a clear specification of potential impact. That IARC's should be measured by their impact thus has obvious benefits but in many cases this moves commodity research programs away from a singular focus on breeding and forces links with development activities. That IARC's serve only national research organizations thus becomes too limiting and instead there is a natural tendency to collaborate with that institution or complex of institutions which best assures impact. Nevertheless, since crop development creates demand for improved production technology, this process in the end strengthens national commodity research programs. Impact through research, thus, has its own organizationl logic: either IARC's are made responsible for it or they are not, each with its resultant implications.

Table 1. Atlantic Coast, Colombia: average consumption (kg/capita/year) of some starchy food crops by rural-urban residence, 1983.

	Rice	Potato	Cassava	Plantain	Yam	Number of observations
Metropolitan urban area	69.4	36.6	30.5	64.4	30.5	80
Intermediate urban areas	71.4	35.0	53.5	76.6	30.8	80
Rural areas	66.9	24.2	82.9	67.8	41.9	160
Cassava producers	68.7	8.9	170.4	79.0	85.7	160

Source: Cassava consumption surveys among purchasers and producers, 1983.

Table 2. Atlantic Coast, Colombia: distribution of cassava consumption over the different meals, by rural-urban residence, 1983.

	Metropolitan urban areas	Intermediate urban areas	Rural areas	Producers
% of cassava consumed at breakfast	30.0	53.5	50.2	42.3
Most important form of preparation	boiled	boiled	boiled	boiled
% of cassava consumed at lunch	69.0	43.6	39.7	49.1
Most important form of preparation	in soup	in soup	in soup	in soup
% of cassava consumed at dinner	1.0	3.0	10.0	8.6
Most important form of preparation	boiled/ fried	boiled/ fried	boiled/ fried	boiled/ fried
Number of meals per week with cassava	4.9	6.3	8.3	11.0
Average portion of cassava served per person (grams)	118	158	191	313
Price (US-$/kg)	0.45	0.27	0.26	0.08
Number of observations	80	80	160	160

Source: Cassava consumption survey among purchasers and producers, 1983, CIAT.

Table 3. Atlantic Coast, Colombia: purchasing habits of fresh cassava and other starchy staples, 1983.

	Metropolitan urban areas	Intermediate urban areas	Rural areas
Quantity purchased (kg):			
Cassava	0.86	1.85	1.74
Potato	2.01	2.41	1.57
Plantain	3.2	5.43	4.3
Yam	1.49	3.76	6.29
Rice	5.92	9.11	5.59
Location of cassava purchase (%):			
Market place	12.3	27.5	21.3
Neighbourhood shop	43.2	36.3	20.6
Street	19.7	26.3	36.2
Supermarket	19.7	2.5	-
Other (among with farms)	5.1	7.4	21.9
Reason for buying cassava in a certain outlet (%):			
Close	60	48	59
Buy everything there	17	17	12
Inexpensive	-	-	14
Type of cassava purchased determined by (%):			
Availability	73	40	52
Quality	26	49	35
More important cassava quality characteristics mentioned (%):			
- High starch content	24	38	42
- Slowly deteriorating	48	35	52
- Taste	48	34	30
Estimation of % cassava deterioration before consumption	15	5	5
Sample size	80	80	160

Source: Cassava consumption surveys, 1983, CIAT.

Table 4. Atlantic Coast, Colombia: characteristics of the market structure for fresh cassava, 1983.

	Rural assembly agents	Wholesalers/ distributors	Retailers[a]
Number of middlemen per municipality			
Rural	7-20	1-8	1 retailer per 200-400 inhabitants
Urban	-	15-40	1 retailer per 200-300 inhabitants
Purchasing price (US-$/kg)	0.098	0.129	0.182
Sales price (US-$/kg)	0.139	0.180	0.309
Sales price as % of farm gate price	141	183	315
Size of purchasing transactions (kg)	800	750	68
Size of sales transaction (kg)	750	100	1.55
Volume traded per week (kg) of cassava	9600	7340	320
Turn-over in cassava/year (US-dollars)	55600	64120	4320
Number of suppliers per day	3.7	1.77	1.0
Number of purchasers per day	3.9	13.4	36.6
Capital goods available:	Warehouse - 25% truck - 11%	Warehouse - 30% truck - 12%	Shop: 40% -
% with income from outside trading	42	18	23
Average number of months per year selling cassava	9.1	11.0	10.3
Information means:	Visiting farmers, personal contacts with wholesalers	Telephone, contacts with retailers and assembly agents	Contacts with wholesalers
Socio-economic class	Low/middle low	Low/middle low	Low/middle low
Average years in business	8.6	n.a	n.a
Sample size	136	83	252

[a] Supermarkets are excluded.

Source: Market agents survey, 1983.

Table 5. Atlantic Coast, Colombia: fresh cassava marketing costs, 1983.

	Rural assembly agents	Wholesalers/ distributors	Retailers	Costs as a % of total margin
Marketing margin (US $ cents/kg)	4.10	5.10	12.70	
Estimated handling costs (US $ cents/kg)	3.65	4.65	9.78	83
of which:				
Labor	0.97	1.16	5.60	35
Transport	1.51	0.60	1.25	15
Deterioration	0.20	1.03	1.82	14
Packing material	0.12	-	-	1
Equipment	0.25	0.60	0.60	7
Working capital	0.22	0.38	0.26	4
Government fees	0.38	0.88	0.25	7
Estimated net profit per year (US-$)	1804	1866	439	

Source: Market agents survey, 1983, CIAT.

Table 6. Atlantic Coast, Colombia: characteristics of fresh cassava market conduct , 1983.

	Rural assembly agents	Wholesalers distributors	Retailers[a]
% that determines traded volume according to:			
- Prior arrangements	39	18	-
- Available supply	-	62	31
- Available working capital	-	13	-
- Time of the year/day of the week	61	-	69
% that determines sales price according to:			
- Prior arrangements	21	2	-
- Available supply	52	75	72
- Fixed margins	26	21	28
Moment of purchase payment			
- Advanced	30	15	26
- Cash	56	42	56
- Delayed	4	37	15
% that arranges purchases in advance	100	45	19
% that sells cassava at day of purchasing	19	76	75
Post-harvest age of cassava at moment of sale (hours)	19	25	32
% that has frequent problems with deterioration	31	70	66
Use of deteriorated cassava:			
- Animal feed or processing	59	60	51
- Waste	41	28	49
Important aspects in quality control	Size, skin colour	Size, freshness	Size, freshness
Purchasing price (US-$/kg)	0.098	0.129	0.182
Sales price (US-$/kg)	0.139	0.180	0.309
Sales price as % of farm gate price	141	183	315
Sample size	136	83	252

[a] Supermarkets are excluded.
Source: Markets Agents Survey, 1983, CIAT.

Table 7. Atlantic Coast, Colombia: Marketing characteristics of cassava producers by department, 1983.

	Atlantico	Bolivar	Cordoba	Sucre
% farmers that arrange sales before harvesting	81	62	79	64
% farmers who wanted to sell but could not find a buyer	60	42	61	64
% farmers that retailed cassava	-	-	7	7
Major sales period	October to December	March to June	June to September	October to January
% farmers that sell cassava:				
In the farm	35	33	54	58
In rural market	43	39	19	28
In regional market	22	28	27	14
Average transaction size (kg)	700	579	1712	342
Reasons why farmers do not plant more cassava (% of farmers):				
Lack of land	43	31	41	35
Lack of credit	15	8	11	9
Lack of labor	6	15	-	-
Difficult to sell	-	36	13	40
Low prices	23	10	33	14
Other reasons	17	-	2	-
Average percentage of unmarketable roots:	20.0	17.8	10.0	5.4
Producer price (US-$/kg):				
Actual price received	0.092	0.093	0.089	0.069
Farm gate price corrected for losses and transport costs	0.070	0.071	0.068	0.065
Sample Size	40	38	74	57

Source: Production and farm marketing survey, 1983, CIAT

Table 8. Atlantic Coast, Colombia: land utilization by cassava producers by department, 1983.

	Atlantico	Bolivar	Cordoba	Sucre
Farm size (ha)	6.1	11.2	9.7	7.4
% farms with crop land	100	100	100	100
Land under crops (ha)	2.7	3.3	3.3	2.8
Area under crops in cassava (ha)	2.0	1.7	2.1	1.5
Area under crops in maize (ha)	2.6	3.1	3.1	2.5
% farms with pasture land	50	42.4	74.8	66.4
Area in pastures (ha)	2.2	3.7	4.5	3.9
Number of cows	1.5	1.6	4.2	3.4
Liters of milk/day	5.9	4.8	10.9	9.0
% farms with land in fallow	46	58	58	31
Area in fallow (ha)	1.2	4.1	1.8	0.7
Sample size	60	65	153	134

Source: Production and farm marketing survey, 1983, CIAT.

Table 9. Sucre, Colombia: Optimal farm plan in different market risk situations for a three hectare farm, 1985.

	Farm plan without considering risk	Present farm plan	Farm plan with stabilized prices	Farm plan when drying industry would support prices
Area planted in (ha):				
Cassava/maize/yam	1.76	1.76	1.53	0.91
Cassava/maize	-	-	0.19	1.02
Cassava	-	-	0.08	-
Maize	-	-	-	-
Pastures	1.24	1.24	1.20	1.07
Cattle stock (no.)	2.13	2.13	2.08	1.88
Credit needed (US-$)	250[a]	250[a]	250[a]	250[a]
Dual value of credit	2.14	0.27	0.80	0.74
Family employment (mandays)	181	181	177	178
Contracted labor (mandays)	39	39	39	36
Total employment (mandays)	220	220	216	214
Cassava sales (kg)	11314	11314	12180	14353
Maize sales (kg)	1020	1020	1026	1410
Yam sales (kg)	6445	6445	5504	3025
Dual value of rented land (US-$)	436	229	284	281
Farm income (US-$)	2217	2217	2187	2321
Coefficient of variation of income	0.330	0.330	0.276	0.288

[a] Maximum value.

Source: Quadratic Programming Models.

Table 10. Sucre, Colombia: optimal farm plan in different market risk situations for eight hectare farm, 1985.

	Farm plan without considering risk	Present farm plan	Farm plan with stabilized cassava prices	Farm plan when drying industry would support prices
Area planted in (ha):				
Cassava/maize/yam	0.25	2.77	2.08	1.25
Cassava/maize	4.46	0.07	0.20	1.68
Cassava	1.29	-	2.38	1.06
Maize	-	-	-	
Pastures	2	5.16	3.33	4.01
Cattle stock (no.)	3.6	8.65	5.73	6.8
Credit needed (US-$)	875[a]	354	665	328
Family employment (mandays)	373	360	343	355
Contracted labor (mandays)	184	92	154	114
Total employment (mandays)	557	452	497	469
Cassava sales (kg)	54739	19189	41375	34428
Maize sales (kg)	4663	1975	1525	2450
Yam sales (kg)	385	10476	7745	4406
Dual value of rented land (US-$/ha)	226	145	173	177
Farm income (US-$)	5126	3942	4920	4746
Coefficient of variation of income	0.440	0.312	0.303	0.305

[a] Maximum value.

Source: Quadratic Programming Models.

Table 11. Atlantic Coast, Colombia: model results of farmer response to the development of a dried cassava industry, 1985.

	Present situation	Situation with price sustained by drying industry	Difference	Explained by price increase	Explained by risk decrease	Estimated supply price elasticity (area or production)
Small farm (3 ha)						
Area planted (ha)	1.76	1.93	10%	4%	6%	0.28
Expected supply (kg)	11314	14353	27%	12%	15%	0.65
Middle- sized farm (8 ha)						
Area planted (ha)	2.84	3.97	40%	11%	20%	1.03
Expected supply (kg)	19189	34428	79%	22%	57%	2.05
Large farm (15 ha):						
Area planted (ha)	3.08	4.25	38%	12%	26%	1.12
Expected supply (kg)	22353	42459	90%	35%	65%	3.27

Source: Market risk questionaire, quadratic programming models, CIAT.

Table 12. Atlantic Coast, Colombia: actual increase in area planted to cassava by farmer association members, 1984-85.

Land tenancy	Number of members	Cassava planted in 1984 (ha)	Cassava planted in 1985 (ha)
Land reform	53	131	177
Land owner	69	93	77
Communal plot	20	32	31
Renter	58	48	71
Share cropper	6	7	9
Pasture improvement	11	23	26
Land invasion	1	2	2
Kin's plot	48	68	78
No data	20	-	-
Total	286	404	471

Table 13. Atlantic Coast, Colombia: characterization of yield-limiting or yield augmenting factors in cassava production systems, 1983-84.

Yield-limiting factor	Variable specification
Cropping System	
Monoculture	Dummy = 0
Cassava-maize	Dummy = 1
Cassava-yam-other crops	Dummy = 1
Land preparation	
Manual	Dummy = 0
Mechanized	Dummy = 1
Weeding	
First weeding	No. of months after planting.
Second weeding	No. of months after first weeding.
Third weeding	Dummy = 1 if done.
Irrigation	Number of irrigations.
Time of planting and harvest	
Plant March-April; Harvest 8 months (wet season)	Dummy = 1
Plant March-April; Harvest 8 months (dry season)	Dummy = 0
Plant May-June; Harvest 7 months (wet season)	Dummy = 1
Plant May-June; 7 months Harvest 12 months (dry season)	Dummy = 1
Plant May-June; Harvest 12 months (wet season)	Dummy = 1
Plant July-Oct.	Dummy = 1
Soil Factors	
Phosphorus 6.0 ppm., Bray II	Dummy = 1 if this level.
Potassium 0.15 meq.	Dummy = 1 if this level.
Interaction, P 6.0 ppm. and K 0.15 meq.	Dummy = 1 if this level.
Organic Matter, Percentage	Level
Years plot planted continously to cassava	No. of years.

Table 14. Atlantic Coast, Colombia: effect on cassava yields of management and soil factors, 1983-84.

Yield limiting factor	Estimated yield increment[b]
Intercept	4513 *
Cropping System	
Cassava-maize over monoculture	1010 ns
Cassava-yam over monoculture	- 2395 ***
Land Preparation	
Mechanized over manual	- 172 ns
Weeding	
Loss per month delay in first weeding	- 16 ns
Loss per month delay in second weeding	411 ns
Effect of third weeding	- 986 ns
Irrigation	
Effect per irrigation	1992 ***
Time of Planting and Harvest[a]	
Plant Mar-Apr; early harvest	2877 *
Plant May-June; early harvest	1108 ns
Plant May-June; harvest in dry season	2089 ns
Plant May-June; late harvest	1253 ns
Late planting	2939 **
Soil factors	
Insufficient phosphorus	1348 ns
Insufficient potassium	2301 **
P x K Interaction	- 270 ns
Response per % of organic matter	291 ns
Effect per year of previous cassava planting	275 ns

a Yield advantage over planting at beginning of the rains and harvest after eight months.

b R - square of the equation was 0.39; significance levels are as follows: ***P 0.01; ** P 0.05; * P 0.10.

Table 15. Atlantic Coast, Colombia: number of vendors and quantity sold by Non-members of farmers associations by tenancy, 1984-85.

Tenancy	Number of vendors	Percent of all vendors (%)	Cassava sold (tons)	Percent of all cassava (%)	Average sold (kg/capita)
Land reform	93	6	223.3	7	2411
Land reform-small plot	86	5	378.5	11	4401
Land owner-small scale	303	19	783.6	23	2590
Communal plot	128	8	405.4	12	3162
Renter	546	35	887.1	26	1625
Share cropper	151	9	80.1	2	533
Land invasion	3	0.2	2.3	0.1	682
Kin's plot	214	13	223.0	7	1044
Landowner-large scale	34	2	157.3	5	4639
Intermediary	25	2	233.4	7	9190
Total	1582		3374.0		2132

Table 16. Atlantic Coast, Colombia: cassava sold by non-members of the farmer associations by social relation.

Social relationship	Number of vendors	Percent of all vendors (%)	Cassava sold (tons)	Percent of all cassava sold (%)	Average sold (kg/capita)
Kin	439	24	589.9	17	1344
Friend	710	38	1322.1	38	1863
Known Acquaintance	415	22	1048.5	30	2528
Unknown Person	275	15	494.8	14	1797
No data	12	1	1.2	1	101
Total	1851		3456.5		1868

Table 17. Atlantic Coast, Colombia: simulation of production characteristics of the cassava economy, 1994.

	Situation in 1985	A[a]	B[a]	B1[a]	B2[a]	B3[a]
Yields (t/ha):						
Small farms	6.81	6.98	7.73	8.50	7.40	7.89
Medium farms	6.83	7.10	8.29	8.51	7.34	8.49
Large farms	6.83	7.23	8.52	8.50	7.18	8.69
Area (ha):						
Small farms	22502	22344	23699	23583	24059	23983
Medium farms	21142	20916	24708	24472	25426	25433
Large farms	26801	26398	32496	32078	33768	33710
Production:						
Total(t)	480878	496001	666137	682471	607713	698738
C.V.	0.13	0.13	0.13	0.14	0.12	0.12
Producers' price:						
US-$/t	84.7	75.9	82.3	80.7	87.4	84.5
C.V.	0.27	0.29	0.17	0.19	0.12	0.10

[a]
A = Present situation develops as expected without a growing drying industry or fresh cassava storage.
B = Drying industry develops.

B 1 = Establishment of drying industry increases yields uniformly over the farm types by 25%.
B 2 = Establishment of drying industry does not increase yield levels at all.
B 3 = Drying industry grows at double the estimated rate.

Table 18. Atlantic Coast, Colombia: simulation of consumption characteristics of cassava economy, 1994.

	Situation in 1985	A[a]	B[a]	B1[a]	B2[a]	B3[a]
Fresh cassava consumption: (kg/head)						
Metropolitan area	29.9	21.6	21.1	21.2	20.7	21.0
Intermediate urban area	53.5	46.5	45.0	45.4	43.9	44.5
Rural area	80.6	63.7	62.2	62.6	61.0	61.7
Producers	164.0	158.5	152.4	153.9	152.5	150.2
Fresh cassava prices: (US-$/ton)						
Metropolitan area	404	387	399	396	409	404
C.V. cassava price in metropolitan area	0.11	0.11	0.07	0.07	0.05	0.04
Intermediate urban area	252	236	247	244	256	251
Rural area	243	228	239	236	248	243
Dried cassava:						
Total consumption (t)	4089	4681	80108	84880	62667	95797
Price (US-$/t)	221	199	215	211	228	220
C.V. of total consumption	0.46	0.25	0.29	0.29	0.33	0.26
% utilization of drying capacity	0.82	0.94	0.74	0.75	0.67	0.64

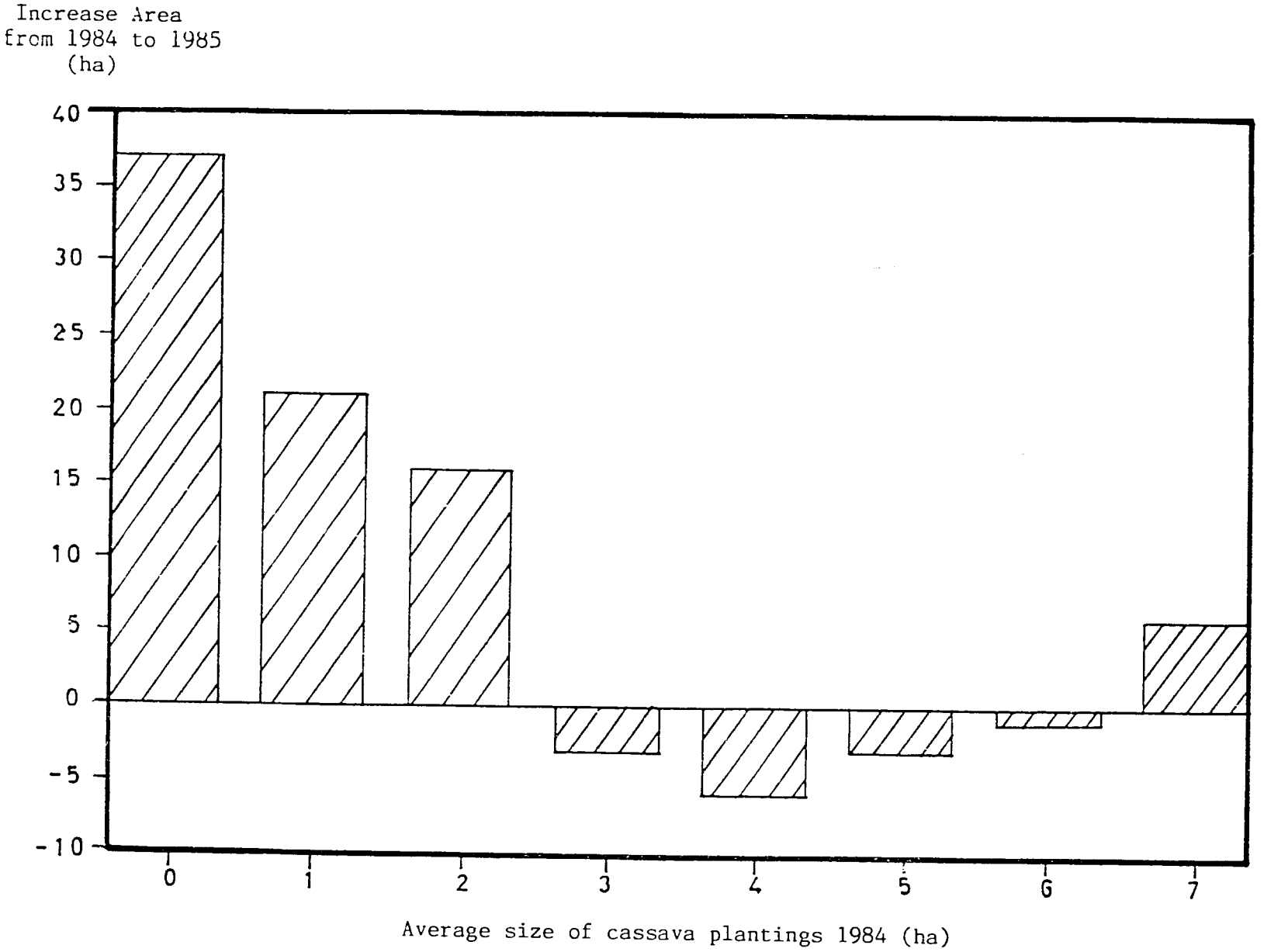
[a] For explanatory notes on the different simulations reported, see Table 17.

Table 19. Atlantic Coast, Colombia: simulation of social benefits to the development of a dried cassava industry.

	Situation in 1985	A[a]	B[a]	B1[a]	B2[a]	B3[a]
Employment in 1994: (man-years)						
Rural employment	21608	21541	27422	27530	26936	28597
Urban employment	4404	4365	4363	4366	4348	4363
Foreign exchange saved in 1994:						
Millions US-$	0.56	0.65	11.05	11.71	8.65	13.22
Increase in producers surplus: (million US-$)						
Small farms	n.a.	-	8.4	9.8	10.9	12.8
Medium farms	n.a.	-	11.8	11.3	12.4	18.1
Large farms	n.a.	-	17.1	15.2	16.1	26.1
Increase in consumers surplus: (million US-$)						
Metropolitan consumers	n.a.	-	-1.1	-0.9	-2.0	-1.7
Intermediate urban consumers	n.a.	-	-0.9	-0.7	-1.6	-1.3
Rural consumers	n.a.	-	-3.5	-2.7	-6.2	-5.2
Animal feed industry	n.a.	-	8.6	9.7	5.4	10.3
Increase in total benefits: (million US-$)						
Producers	n.a.	-	33.3	33.1	32.3	50.8
Consumers	n.a.	-	-5.7	-4.3	-9.9	-8.3
Industry	n.a.	-	7.2	8.5	3.1	8.1
Total	n.a.	-	34.8	37.4	25.5	50.6

[a] For explanatory notes on the different simulations reported, see Table 17.

Figure 1. Atlantic Cost, Colombia: increase in cassava area planted in 1985 over 1984 according to average cassava area planted in 1984.



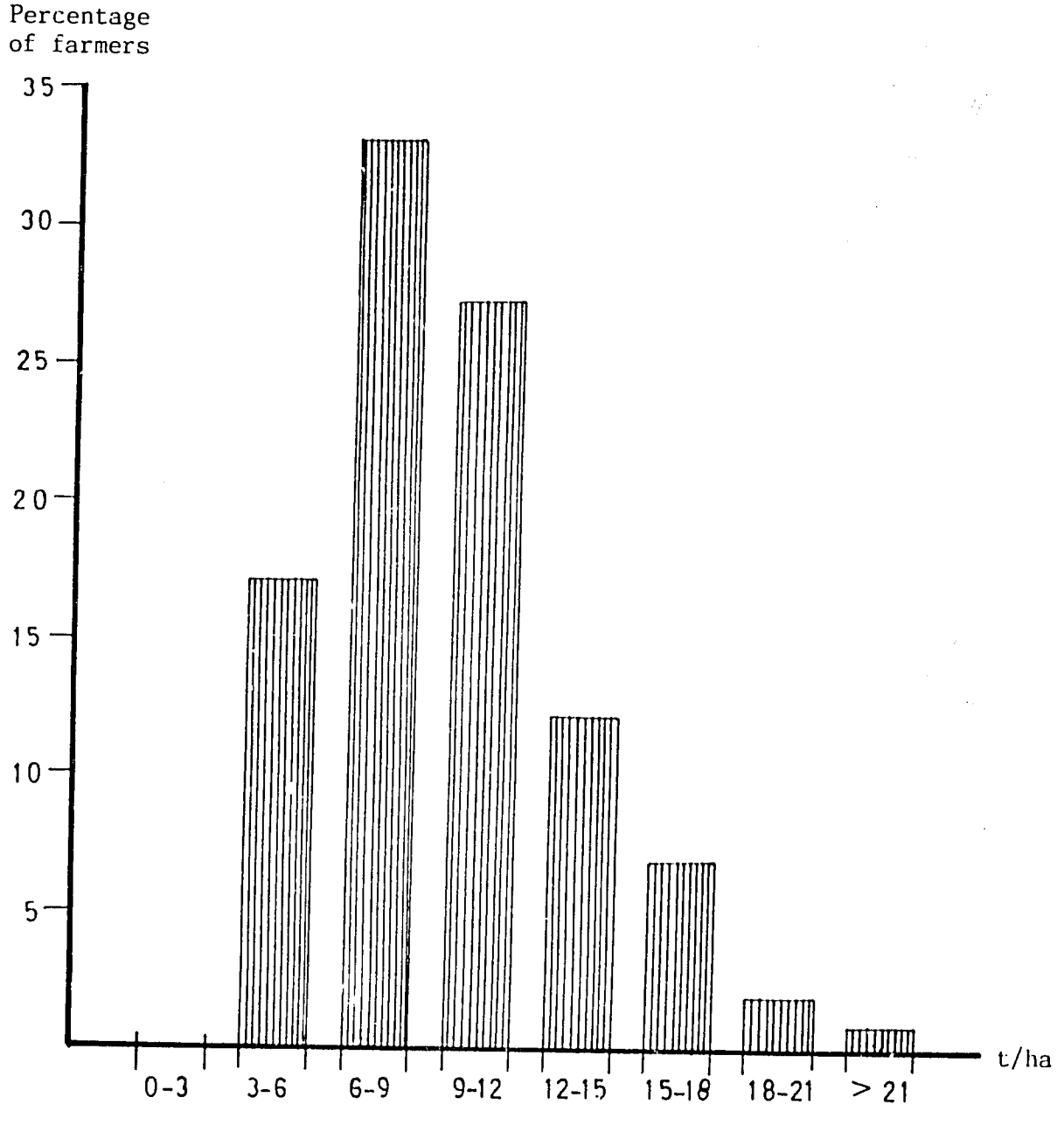


Figure 2. Atlantic Coast, Colombia: yield distribution of cassava for sample of producers, 1983-84.

Figure 3. Atlantic Coast, Colombia: total benefits received by members of farmer associations by farm size, 1984-85.

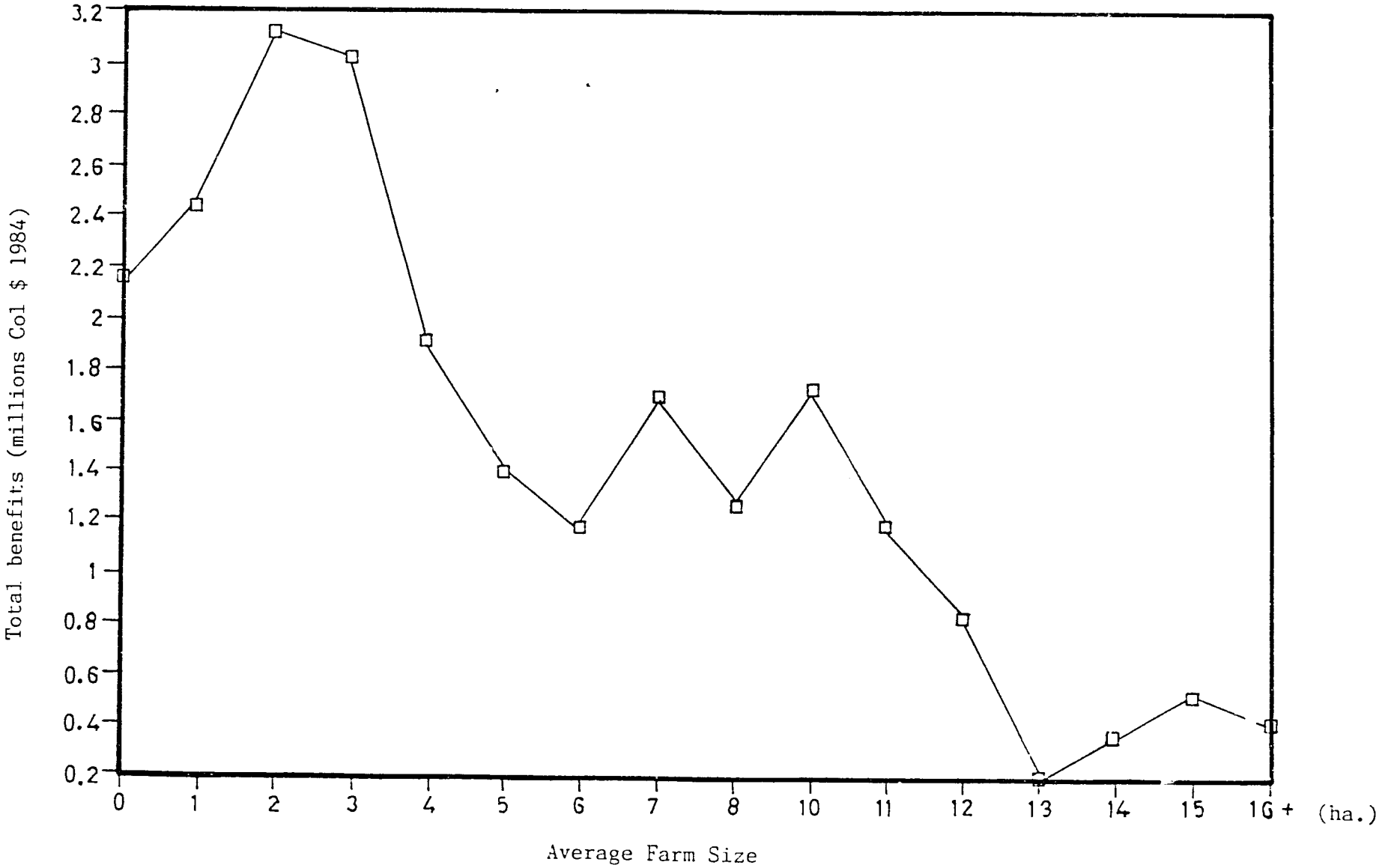
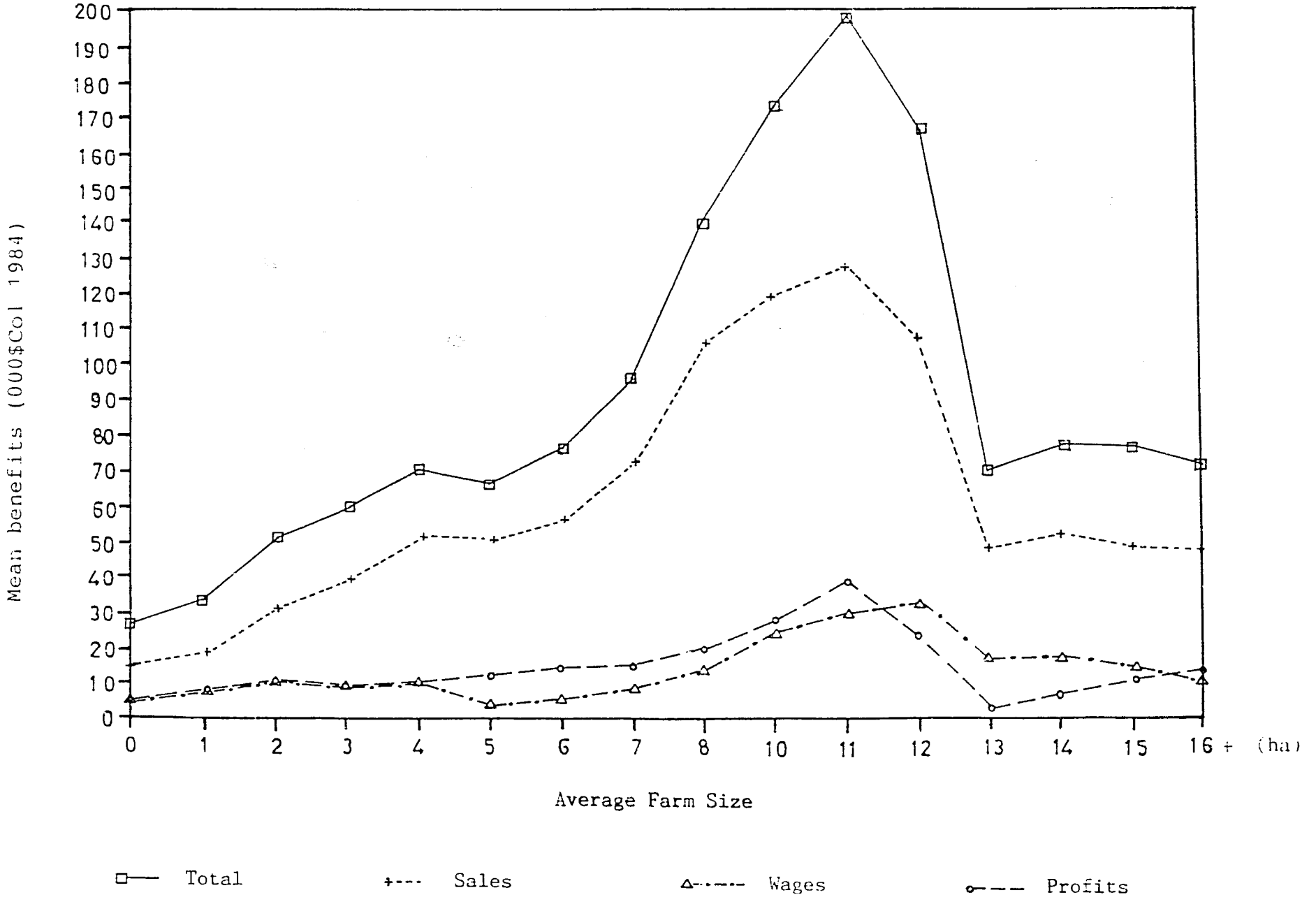


Figure 4. Atlantic Coast, Colombia: benefits received per member of farmer associatios by farm size, 1984-85.



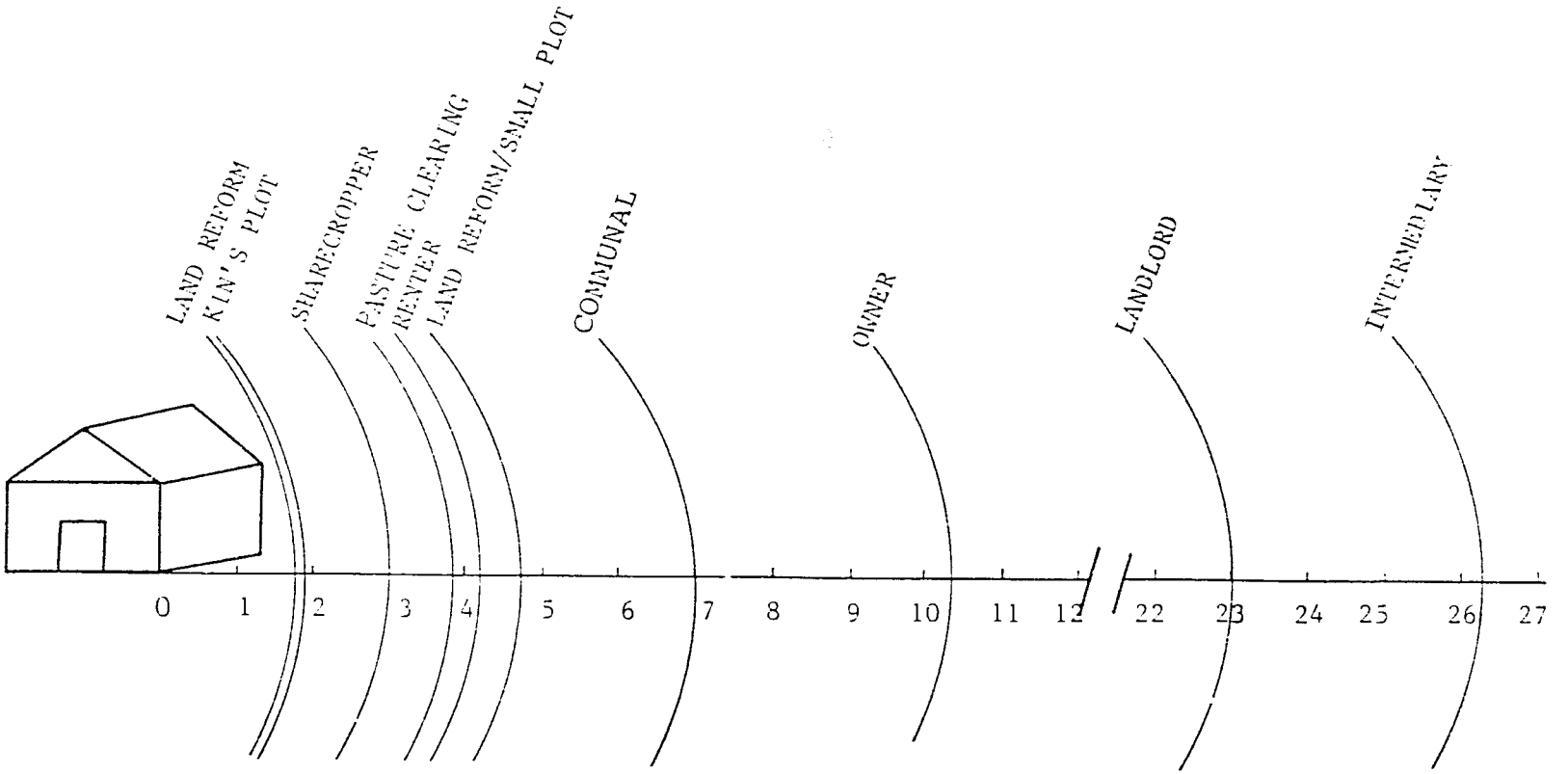


FIGURE 5. FARM-TO-PROCESSING PLANT DISTANCE FOR NON-MEMBER SELLERS

CASSAVA UTILIZATION

Fresh Cassava for Human Consumption

The simple storage system for fresh cassava roots developed and tested in previous years (CIAT Cassava Annual Reports, 1983, 1984) formed the basis for this year's work. The system has been further refined to reduce costs, and testing in different edaphoclimatic zones continued with a series of trials in Peru and around Bucaramanga, Colombia.

Refinement of storage system

The simple cassava root storage system consists of (a) root treatment with a thiabendazole-based fungicide to control microbial rotting and (b) subsequent packing of treated roots into polyethylene bags which are then sealed to obtain the high temperature and humidity necessary to achieve rapid wound healing (curing), which prevents the onset of post-harvest physiological deterioration. The cassava roots are treated with the thiabendazole by immersion (five minute dip in a 0.4% solution of Mertect, Ciba-Geigy, Colombia). An alternative method of treatment, namely by spraying the fungicide solution onto roots already placed inside the polyethylene bag, was tested as a means of reducing the quantity of fungicide required, and hence of reducing costs.

The root curing process requires temperatures in excess of 30°C inside the polyethylene bag. In some of the colder zones of cassava cultivation, these temperatures are not reached, and curing is incomplete. Losses can, therefore, be high under these conditions (Cassava Anual Report, 1984). The same problem was also observed this year, where cassava treated and packed in a tropical zone and transported immediately to a cool climate urban centre for storage. Therefore, experiments were conducted to determine how many days of storage in tropical conditions were required to complete curing before transport to and storage in cooler climates.

Thiabendazole treatment: aspersion tested against immersion. The two different treatment methods were compared. The standard immersion (dipping) method required a 5 minute dip followed by a 15-30 minute wait before packing roots into the bags, to allow for excess moisture removal. The aspersion treatment consisted of placing roots immediately after harvest into the bags, and spraying using a backpack sprayer with the nozzle inside the bag. Roots were evenly sprayed with the 0.4% solution of thiabendazole, and any excess was drained off before sealing the bags.

Table 1 gives the raw results for experiment 1 with M Col 22 and CMC40 in which both treatments gave good control of external microbial growth and internal rotting, although the aspersion treatment gave rather high losses after two weeks in M Col 22. However, statistical analysis showed that there was no significant difference between the two treatments (Table 3). In experiment 2 with M Col 22, both treatments also gave good control of rotting and microbial growth (Table 2), but

statistical analysis showed that aspersion was significantly better than immersion in preventing microbial rotting. From these two experiments, either thiabendazole treatment method seems to provide good control of postharvest losses in the two cultivars tested. Table 4 shows that the aspersion treatment method allows maintenance of root quality at a significantly better level than the immersion treatment. The loss of starch and consequent build up of both total and reducing sugars is slower in the roots treated by spraying than in roots treated by dipping in both cultivars tested over the two week storage period.

The implications of these results are that the aspersion method is preferable to the former method of treatment by immersion, because although the control of postharvest losses is equivalent in both methods, aspersion is much easier, faster and simpler to carry out, uses less water (a limiting factor in some areas) and less fungicide. Semi-commercial trials of the method have shown that treatment costs can be reduced from 1.2 cents US$/kg roots by immersion to at most 0.4 cents US$/kg roots by aspersion, simply because less fungicide is used per kilo of roots treated. An extra advantage is that when spraying roots a clean solution is always used, whereas constant dipping gradually contaminates the fungicide solution, slowly reducing its effectiveness. The procedures to be followed for the two different methods are shown below: the greater simplicity of the aspersion method can be readily appreciated, since only one packing operation is now required. The aspersion method has now been adopted as standard in all storage trials as of mid-1985.

MERTECT TREATMENT PROCEDURES

1. IMMERSION	2. ASPERSION
HARVEST	HARVEST
SELECTION	SELECTION
PACK INTO SISAL SACK	PACK INTO PLASTIC BAGS
TRANSPORT TO TREATMENT SITE	TREAT WITH MERTECT: SPRAY
TREAT WITH MERTECT: IMMERSION (5 min)	REMOVE EXCESS LIQUID
SPREAD OUT TO DRY (15-30 min)	SEAL AND STORE
PACK INTO PLASTIC BAGS	
SEAL AND STORE	

Determination of time needed for root curing before transport to climatic regions. In order to determine the length of time required by cassava roots to complete the curing process in warm, tropical climates before transport to cooler climates can be safely recommended, the following experiment was conducted. Roots of CMC40

were harvested and packed at CIAT-Palmira (1,000 masl, 24°C) using the aspersion method of thiabendazole application. Roots were packed into five kg sized bags, which were divided into five treatment groups. The first group of five bags was transported to a site 50 km distant at an altitude of 1950 masl. with a mean temperature of 17°C. At this site, called Km 18, the bags were stored for two weeks before evaluation. On each of the succeeding five days, a further group of bags was transferred to the cool climate site, thus providing cassava with storage time from zero to six days in conditions where curing can proceed rapidly. The remainder of the two week period was thus spent in the cooler conditions of Km 18. A control group of bags was stored for the entire two week period at CIAT.

The results showed the importance of curing to the successful outcome of cassava root storage: roots which were stored from the outset at Km 18 had losses of 12.8 and 17.8% from microbial and physiological deterioration respectively. Roots stored at CIAT for two weeks suffered only 4.0 and 4.2% losses respectively (Figure 1). Thus a period in conditions in which curing can rapidly develop is essential for the successful storage of cassava. The incidence of both forms of deterioration decreased with increasing time at CIAT before transport to Km 18. Only treatments with zero and one day's storage at CIAT were significantly higher than the CIAT-stored control treatment as regards total deterioration after two weeks, suggesting that only one day of curing is required before transport. Looking at each deterioration component separately, however, a one or two day storage period at CIAT was required for control of physiological deterioration and microbial deterioration when considered separately (Table 5). This variation in significance depending on the whether each type of deterioration is considered separately or together, suggests that the longer of the two times, i.e. two days, is the safest option. The excellent results obtained from the treatments with four and five days of storage at CIAT before transport to the cool climate storage site suggests that as long as curing is completed before transportation, storage times of two weeks or more are readily achievable in these conditions.

Cassava Storage Trials in Peru (Partially Financed by USAID, Lima)

Cassava is widely grown in the jungle or "selva" region of Peru, where it is a staple foodstuff. The majority of the population, however, inhabits the coastal region, separated from the selva by the Andes. Lima has a rapidly growing population (6,000,000, 1985) and a problem of providing a sufficient food supply from the neighboring desert coastal or high mountain agricultural regions. Consumption of cassava by Lima's inhabitants is low (3 kg/capita/year) because the majority of the population has a tradition of potato consumption and partly because of the problems encountered in transporting the crop across the Andes from the main production regions in the selva. Supplying Lima with cassava from the Selva currently presents several problems:

(1) The cold, low humidity climate during the journey (see Figure 2) encourages the development of physiological deterioration, through the loss of root moisture, and can lead to root chilling damage.

(2) The poor road communications, especially during the rainy season(s), can produce journey times of 24-72 hrs (if landslides occur) in a normal 8-12 hr journey. This can, and frequently does, lead to the loss of an entire truckload of cassava en route to Lima.

3) The two factors above combine to reduce the quality of the cassava arriving at the wholesale market in Lima. Cassava is sold at two prices depending on the freshness/quality of the roots: this discount can very adversely affect the farmers/traders.

Through the use of the CIAT and the Tropical Developmnet Research Institute (TDRI), developed simple storage technology, the above problems could be resolved: transport of cassava treated with thiabendazole and packed into polyethylene bags would prevent deterioration developing during the journey to Lima, and should provide protection against chilling damage and low humidity environments. The following advantages would be apparent in Lima:

(1) The quality (freshness) of cassava should dramatically improve.

(2) The wholesale and retail margins should decrease, as losses are greatly reduced.

(3) The consumer price should decrease as a consequence of 2, while demand may increase as the quality improves (and risk of purchasing bad cassava decreases).

Storage trials. Three trials were carried out in different farms of the San Ramon, Satipo region of the central selva district of Peru. at 800-500 masl in this area. The cassava was harvested by the farmers themselves, and was all of good quality for human consumption. Between 80 and 95% of harvested roots were suitable for storage. Roots were treated with thiabendazole using the immersion method, and then packed into 5 kg-sized polyethylene bags. These were stored in San Ramon before being transported on to Lima. The three trials were set up on successive days, to provide differing lengths of storage time in the warm climate of San Ramon for root curing to develop, before being transported together through the cold climate Andean regions to Lima. Table 6 gives the details of each experiment, and Figure 2 shows in profile the route taken from San Ramon to Lima. Roots were all transported to Lima in an open truck on 18 May, taking 10 hours to make the journey. The highest point on route was snow-covered.

Each experiment was evaluated 2, 6 and 10 days after transportation. The length of the storage time varied between experiments, since they were set up on different days.

The results (Table 7) show that the mean total deterioration evaluations of treated roots were of 7, 18 and 17 on a 0-100 scale for evaluations 1, 2 and 3, respectively. Losses due to external growth of fungi were much lower. Untreated roots suffered substantially higher losses (13, 45 and 65 in each evaluation, respectively). The thiabendazole treatment thus served to limit losses from microbial

deterioration. However, the losses were higher than those experienced in Colombia, suggesting that curing was not completed before roots were transported through the cold climate regions to Lima. This could be because ambient temperatures at San Ramon, where roots were stored prior to transport, were not adequate, especially at night, to allow curing to proceed rapidly. A storage site closer to the cassava production area itself might have produced better results. Nevertheless, the great majority of roots did store successfully in Lima. The quality of the stored roots, evaluated informally by a group of housewives, was rated as excellent, and the superiority of these roots over those available in the market was widely remarked. Chilling damage, which did not occur in roots packed in bags, seems to make cassava difficult to cook, producing a hard texture on boiling. This adverse quality characteristic was not encountered in these stored roots.

Economic feasability. The cost of the fungicide and polyethylene bags amounted to 250 Soles (US$0.025) per kg of cassava roots treated in May 1985. Figure 3 shows the prevailing on-farm, wholesale and retail prices at this time. Although the cost of treatment is equal to the actual on-farm price of cassava, it represents only 16% of the final consumer price: 66% of this price is due to the large margins of both wholesaler and retailer. These margins should be reduced by the introduction of storage technology, since post-harvest losses, and the risk of such losses, will be greatly decreased. If margins are reduced by 50%, the introduction of storage technology would result in a fall of 16% in the final price (or an increase in the on-farm price). Given an improvement in root quality, an increase in demand should also occur. In Peru, the farmer frequently takes the cassava to Lima himself, rather than relying on a rural transporter as in Colombia. Thus, he directly experiences the adverse consequences of deterioration losses so that obtaining farmer cooperation in storage trials should be facilitated. The existence in the Lima wholesale market of a price discount for low quality cassava (i.e. deteriorating roots) is another economic incentive for the adoption of this technology.

Studies on Fresh Cassava Root Quality[a]

In last year's CIAT Cassava Annual Report, experiments were reported in which correlations between various root quality parameters, both chemical, physical and subjective, were found. Specifically, a series of correlations between the various chemical parameters (starch, sugar, HCN, fibre contents) were significant, and these were related to changes in root hardness. as measured by a penetrometer. A further experiment this year, using 4 clones (CMC40, HMC1, M Col 22 and M Ven 218) harvested at monthly intervals from 7 to 12 months of age was carried out to study the variation in these parameters, and obtain more information on the relationships between the various quality factors. Some parameters showed a marked variation with the different harvest ages in all 4 clones (e.g. deterioration %; cooking time, which tended to increase with plant age, and starch content) , other parameters were more stable (e.g. penetration and dry matter content, Table 8).

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[a] Carried out in cooperation with the Tropical Development Research Institute, London.

Regression analysis produced no consistently significant correlations between these quality factors across all clones. For example, in contrast to previous results, deterioration did not correlate with DM or starch content; penetration readings did not correlate with DM, starch, sugars, cooking time or taste/texture evaluations. These rather unhelpful results could be due to the sampling procedure employed, since in this experiment for the first time, large amounts of roots from each experimental plot were pooled before each sub-sample was removed. If the variation in root quality was large within a given plot, the lack of correlations between the quality characteristics found here would be explained.

With this in mind, an experiment was designed to examine in detail the variation in root quality within a particultur field plot of one clone. Additionally, the best method of sampling for the penetration measurement was examined, since accurate and valid data on this parameter could aid selection of good quality cassava roots if reliable correlation with other parameters exist. Specifically, it was hoped that through taking penetration readings at different points along the root, an improved sampling methodology could be devised. Advantage was taken of one field plot in which CMC40 plants 8 m of age had been planted at the same time and given the same management. Nevertheless there were substantial differences in plant habit, especially as regards plant height. Ten plants of greater than average height and ten of less than average height were selected for inclusion in the experiment, in the hope that this would facilitate the expression of different root quality characteristics. Table 9 shows the general characteristics of these plants. The taller plants, besides having a greater mean height, also weighed more both as regards the stem and foliage and total root weight. Three- medium sized commercial roots were sampled from each plant: thus, roots selected from the smaller plants were not of an obviously poorer quality, and in fact had a slightly higher mean weight per root. Each root was individually labelled, peeled and sampled as in Figure 4.

A section of the root was removed from the distal and the proximal ends, and a series of penetrometer readings taken from each section. Four readings were taken from each of the outer (A), intermediate (B) and inner (C) zones of the root, as shown above. The remainder of the peeled root was divided into two equal parts. One was diced, freeze dried and later analysed for starch and sugar contents; the other half was boiled and evaluated for various organoleptic characteristics (taste, texture, fibre and glassyness). Special importance was placed on this last evaluation, since one of the objectives of the experiment was to determine if it were possible to predict the occurence of this phenomenon (a glassy or crystalline texture when boiled) in the uncooked roots through the use of penetration readings.

The results of the organoleptic evaluations (Table 10) showed that roots from tall and short plants were very different, despite superficially being of the same size, weight etc. Only one of the thirty roots from tall plants showed any sign of bad organoleptic quality, whereas the 28 of the 30 roots from short plants were rated with one or more negative factors. Interestingly, not one of the roots from tall plants had any trace of glassyness, but 19 of the 30 roots from the shorter

did. The starch and sugar analyses also produced differences (Table 11). Tall plants had roots with significantly higher starch and lower total sugar contents, although there was no difference in reducing sugar content. Thus, both chemical and organoleptic quality of cassava roots from taller, unstressed plants was higher than from shorter, stressed plants, even though roots were selected to be of approximately the same weight in both groups.

Although root quality can be assessed through the chemical analyses, a simpler and more rapid alternative is required if the large number of samples produced through a breeding program, for example, are to be analysed. The penetrometer offers just such a possibility. Since the previous experiment did not produce any consistent correlations between penetration readings and other root characteristics, the detailed sampling method for penetration readings in this experiment, was designed to find the optimum procedure for using this instrument for rapidly predicting root quality from the uncooked root.

The mean readings (penetration in mm in a 20 second time interval) showed significant differences between roots from tall and short plants, as did all the individual values for each root section and zone (Table 12). The proximal and distal means were also significantly different, as were the readings from the three different zones (outer, A; intermediate B; and inner C). The penetration values increased from the outer to the inner root zones (i.e. root hardness decreased), and the distal section had higher readings than the proximal. The shorter plants consistently had higher values than the taller plant roots, suggesting a good fit with the starch content results, since roots with a higher starch content would be expected to have a firmer texture (or less penetration) than low starch content roots. The fact that all the penetration readings from each root section and zone produced significant differences between tall and short plants, suggests that this evaluation has great potential for distinguishing certain root quality characteristics.

The penetration values themselves correlated well with each other: all 15 correlations in the correlation matrix of these parameters were significant, 13 of them at $P = 0.001$. Several significant correlations between the different penetration readings and the starch and sugar analyses were also found (Table 13). The correlations between the penetration values and starch content were consistently negative, suggesting that ease of penetration increases as starch content falls. The converse was true of total sugar content, which changed inversely with starch content.

Correlations were found more consistently with the penetration readings from zones B and C of the root, suggesting that the changes in starch content which cause changes in root texture occur first in the central area of the root. This seems reasonable from a physiological standpoint, since mobilization or deposition of starch reserves may be most rapid closer to the central vascular bundles (zone C). This suggests that penetration readings should be concentrated in zone C to detect changes in starch content. This may explain why previous attempts to use penetration values to show changes in root starch

content have not always been successful, since readings were taken equally from zones A, B and C, and then averaged.

This experiment also attempted to determine to what extent the penetration values could be used to predict the quality of the cassava when cooked. Since 29 of the 30 roots studied from the tall plants were of good eating quality, with no negative scores for taste, texture, fibre or glassyness, and 28 of the 30 roots from the short plants did have at least one negative score for these factors, these results can be used to test the suitability of the penetration measurement for predicting root quality. Table 14 presents the mean, maximum and minimum values for each of the different penetration readings (by root section and zone) for tall and short plants separately. Generally, the differences in maximum, minimum and mean values between tall and short plants were greater in the distal than in the proximal sections, and were greater in the zones in the order inner, intermediate, outer i.e. the greatest differences were found in the distal root section in the inner (C) zone where almost no overlap occured between the short and tall plant root values (Figure 5 shows this as a frequency diagram). Thus, the penetration readings taken from this particular region showed an excellent relationship with root quality. Specifically, all roots from tall plants had penetration readings below 3.1 mm and 29 of the 30 roots from short plants had readings above 3-4 mm. This separation also applies to root quality: only four of the 60 roots evaluated for quality do not fit this same pattern. Use of penetration readings from this root zone would thus enable a prediction of root quality with a 93% success rate in this experiment. The distal, inner part of the cassava root appears to be the most sensitive to plant stresses which affect root quality (starch reserves from this area are probably the first to be mobilized), thus it is the most accurate site for the measurement of root hardness through the penetrometer. Further experiments are obviously necessary in order to test the results and conclusions of this experiment.

One further experiment on root quality was carried out in 1985.* The study was directed at the glassyness phenomenon mentioned earlier. It attempted to determine which of the other chemical and physical characteristics of the cassava root could be correlated with glassyness with the aim of finding a rapid evaluation method in the uncooked root. Advantage was taken of the fact that on pruning the aerial parts of the cassava plant, the glassyness phenomenon develops with a time of two-three weeks as a result of plant stress (CIAT Cassava Annual Report, 1982). Plants of three clones CM 523-7, CM 681-2, HMC1 were pruned and harvested on six dates of a four week period, to obtain roots in various stages of glassyness. Roots were sampled in the three different root zones separately (inner, intermediate, outer) for a range of chemical analyses (DM, starch, sugar). Samples were also cooked and evaluated subjectively for taste, texture (and glassyness) sweetness and bitterness.

Roots of all clones gradually developed the glassy phenomenon on cooking after the third harvest, with the final two harvests having very

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* Leo van Zanten, 1985. (CIAT Cassava Annual Report, 1982).

poor quality roots. Alongside this change in quality, the starch and DM contents decreased significantly, and the sugar content increased (Table 15). This was as expected from previous results. (CIAT Cassava Program Annual Report, 1982). The penetration readings also increased significantly, further demonstrating the ability of this measurement to reflect changes in root chemical composition. Considering each root zone separately (Table 16), the penetration readings were significantly higher in the inner and outermost zones than the intermediate. The starch and sugar contents were correspondingly lower in these two zones. The correlation matrix for all these evaluations and analyses (Figure 6) reveals that glassyness correlates with almost every other parameter: positively with sweetness, flavor, texture, sugar content, cooking time and penetration; negatively with DM and starch. These results suggest that, since the onset of glassyness is associated with significant changes in almost all the the root quality characteristics, the possibility of developing a rapid evaluation method is good, perhaps using the penetration readings as a basis.

A short study was made of the possibility of using a microwave oven to shorten cooking times, and hence increase the number of samples evaluated per day. Cooking by boiling takes from 20-40 minutes per sample, and a maximum of 6 samples can be screened at a time. By heating root pieces, contained in a small plastic bag, inside a microwave oven for 4 minutes, a considerable increase in output can be obtained. Roots from 20 clones were cooked using both methods, and the results compared. The overall agreement between the two methods was 65%; sufficient for screening a large number of lines early in a selection program, but not enough to be able to replace the "household" boiling method in more advanced stages. The agreement between methods was better for sweetness and bitterness than for texture/glassyness evaluations.

CASSAVA DRYING

Research on drying during 1985 has been orientated towards backstopping the Atlantic Coast and Cassava Flour projects and has concentrated on three areas:

(1) The comparison of three types of cassava chipping machines.

(2) The pilot plant evaluation of a through circulation bin dryer coupled to a flat plate solar air heater.

(3) The comparison of three fuel sources for the artificial drying of cassava chips.

Comparison of cassava chipping machines

For small to medium scale cassava drying enterprises, there exist three types of cassava chipping machines: Thai, Malaysian and Brazilian, named after their country of origin. With the objective of determining which type of machine is the most appropriate for use either in natural or artificial drying plants, studies were undertaken to evaluate both the mechanical performance of the machines and the drying characteristics of the chips they produce.

The Thai type chipping machine consists of a frame that supports a feed hopper and a cutting disc. The frame is constructed of welded angle iron and covered with sheet steel. The feed hopper is joined to the structure at an angle of between 40° and 45° which allows the cassava roots to fall by gravity towards the cutting disc. The 910 mm diameter cutting disc is constructed from sheet steel and strengthened by an external ring and lateral veins. On the disc, six rows of cutting elements are formed by heating and expanding the metal using a specially designed tool. Power is transmitted through V belt and pulley mounted on the same axel as the cutting disc to give a speed of 500 rpm.

The Malasian type chipping machine is similar to the Thai type, differing only in the design of the cutting disc which is constructed of 10 mm steel plate with four radial rectangular openings to which four interchangeable corrugated steel blades are bolted.

The Brazilian type chipping machine consists of a 430 mm diameter drum, open at the front to allow the feeding of the roots, with an internal rotating disc to which three radial paddles are attached. The paddles propel the roots against one 202 mm wide horizontal stationary blade and then against a set of 17 vertical, serrated, circular, rotating blades separated 10 mm one from the other which terminate the cut and eject the chips from the machine. The whole assembly is supported by a welded, angle iron frame. Power is transmitted through hexagonal belts and pulleys to give a drum speed of 500 rpm.

Capacity and power consumption

The capacity and power consumption of the three models are shown in Table 17. Per unit of power consumed, the Malaysian model has the greatest capacity, followed by the Thai and Brazilian machines.

Chip form, geometry and size distribution

Table 18 shows the form and geometry of the chips that ideally should be produced from each machine, together with the distribution between whole chips, broken and thin chips and fine particles that are actually produced. None of the machines produces more than 50% of whole chips due to factors such as variability in the feed rate and size of the fresh roots and deficiencies in the adjustment of the individual machines. The size distribution of the chips produced by the Thai and Brazilian machines is similar, whereas the Malaysian machine produces fewer whole chips and a greater percentage of fine chips.

Chip drying characteristics

The drying characteristics of the three types of chip were compared using three different drying methods: concrete floors, inclined mesh bottomed trays and a through circulation bin drier.

Figure 7 compares the net drying times of the chips at varying loading densities (kg of fresh chips per unit area of drying surface) dried on the concrete floor and in inclined trays. Comparing the two drying methods employed, at each loading density, all three types of chips dried faster in trays than on the concrete floor. On the concrete floor, the Malaysian chips dried faster than the Brazilian and Thai chips respectively, although the results are not significantly different

(P = 0.01). In trays there was no significant difference between Malaysian and Brazilian chips, however the Thai chips dried considerably slower at all loading densities.

Using the artificial through circulation bin dryer, no significant difference (P = 0.01) was found in drying time between the different types of chip, although the Thai chip tended to take longer to dry at all loading densities (Figure 8). At the higher loading densities (150 and 250 kg/m^3) compacting of the bed was observed when using the Malaysian chip, and this probably accounts for the longer drying times compared with the Brazilian chips at these densities.

Cyanide elimination

Figure 9 presents the final total cyanide content of Thai and Brazilian type whole root chips as a function of drying time. The graph indicates that the longer the drying time the greater the elimination of cyanide. However, for a given drying time, while cyanide elimination is greater on concrete floors than on inclined trays it appears to be independent of chip type. For varieties with an intermediate cyanide content, such as CM 976-15 used in this experiment, drying on inclined trays produces a product with levels of cyanide greater than 100 ppm which is the quality standard set for animal feed.

Construction, maintenance and costs

The Thai and Malaysian models require 240 man hours construction time and can be made in a workshop with basic facilities. The Brazilian model requires 480 man hours construction time, skilled labour and a workshop with machine tools. The cost of the Brazilian model is therefore approximately double the cost of the other two models.

At present the Thai cutting disc is produced without difficulty in Colombian workshops. However, a number of problems have been experienced in reproducing the Malaysian type interchangeable cutting blades and they are not commercially available. Given adequate workshop facilities, the blades for the Brazilian model present no production problems and are considerably more durable, requiring less maintenance than the blades of the other two models.

Overall assessment

In terms of chip characteristics (size distribution and drying performance), the Brazilian model is marginally superior to both the Thai and Malaysian models. However, the advantages of the Thai and Malaysian models, with respect to ease of construction and maintenance and lower cost, appear to outweigh the improved performance of the Brazilian model. Other factors, such as dry chip bulk density, milling and handling characteristics are being evaluated.

Pilot plant evaluation of a through circulation dryer

Last year the results of the evaluation of a through circulation bin dryer coupled to a flat plate solar air heater were reported. The principal conclusion of the work was that this type of drying system does not offer any advantage in terms of cost, product quality and operating period (months) compared with natural drying on concrete floors. However, the operation of the bin dryer and solar air heater combined

with the drying floor showed that it is possible to increase the capacity of both systems and, at the same time, introduce a certain degree of flexibility into the operation of a drying plant. The trials that have been undertaken this year have concentrated on trying to reduce the costs (both capital and operating) of the combined drying system.

The combined drying system

The infrastructure of the combined drying system consists of a drying floor and the bin dryer (described in the CIAT Cassava Annual Report, 1984). In order to reduce operating (fuel and maintenance) costs, the 3hp gasoline motor used last year was replaced by a 1hp electric motor. In addition, the height of the walls of the solar air heater were reduced from 60 cm to 20 cm thus making a considerable saving in material costs.

The quantity of cassava roots required for each trial was chipped at around 06:00 hours and the chips spread on the concrete floor at a loading rate of 12 kg/m^2. At 18:00 hours the chips were collected and loaded into the drying bin. The following day at 06:00 hours drying in the bin was started and continued until the product was dry. During the process the chips were turned every two hours on the concrete floor and every four hours in the drying bin.

Two groups of trials were carried out. The first group was aimed at determining the maximum capacity of the drying system that would give a total drying time of two days (or 24 hours net drying time) using the solar air heater in its original configuration, i.e. galvanized iron sheets painted mat black and covered by polyethylene sheet. The second group of trials was aimed at determining the maximum capacity of the drying system using the solar air heater in a modified form, i.e. with the polyethylene sheet removed and the galvanized iron sheets placed on top of the walls of the solar heater. This configuration simulates the collection of solar radiation from roof tops.

Solar collector performance and dryer capacity

Table 19 shows the air temperature increases and efficiency of the solar air heater with and without the polyethylene cover. The removal of the polyethylene reduced the thermal efficiency from 55 to 51%. The lower temperature increment (4.0°C versus 4.8°C) observed using the solar air heater without the polythene over is caused only in part by the reduced efficiency since a lower solar radiation value was recorded for the period under study (0.67 versus 0.76 cal/cm^2.min). The cost of the solar air heater is reduced by about 40% by the elimination of the polyethylene cover.

Despite the reduced drying air temperature achieved on removing the polyethylene cover, there was no appreciable difference in drier capacity (Table 20). In both configurations the maximum capacity for the combined system was 1,800 kg of fresh cassava chips per day (greater quantities did not dry within the two day period). During the first day's drying on the concrete floor the moisture content of the fresh chips was reduced from 60% to 38%. The resulting 1,200 kg of partially dried chips that were then loaded into the bin took approximately 11 hours during the second day to complete the drying process.

Operating and investment costs

The labour requirement for the combined drying system is 8.2 man hours per ton of fresh cassava which is higher than that required for concrete floor drying (7.4 man hours). The energy consumption of the electric motor averaged 12.4 kwh per ton of fresh cassava which represents a cost of Col.$152 per ton of dry cassava chips. Last year an average of Col.$1,600 per ton of dry chips was spent on fuel and maintenance of the gasoline motor.

Table 21 compares the construction cost of a natural concrete floor drying plant with that of a combined concrete floor/bin dryer-solar air heater drying plant. The calculations have been made on the basis of a processing capacity of 3,600 kg fresh cassava every two days (the actual capacity of the pilot plant described here).

The natural drying plant consists of 300 m^2 of concrete floor, and costs $186,000 Col.Pesos. The combined plant, consists of 150 m^2 of concrete floor, 30 m^2 of solar air heater, 6 m^2 of drying bin and a fan and motor at a total cost of Col.$ 341,190 or 1.8 times the cost of the natural drying plant. The cost of the solar air heater represents 17% of the total investment and, although the removal of the polyethylene cover reduces the cost of this item by 40%, the reduction in cost of the system overall is only 6%. By far the most costly item of the system is the fan and motor. Due to the relatively low air drying temperature (± 35°C) large volumes of air are required to assure a reasonable dryer capacity.

Conclusions on the use of solar drying systems for cassava

Having operated the bin dryer/solar collector system at the pilot plant level during two drying seasons the following conclusions have been reached:

1) Deep bed drying of cassava chips in bins with solar heated air is technically feasible but results in higher capital and operating costs compared with natural drying on concrete floors.

2) Pre-drying of cassava chips on concrete floors followed by drying in bins with solar heated air, increases the capacity of both the natural and solar assisted systems. However, the capital and operating costs per ton of dry product processed remain higher than those for natural drying alone.

3) Bin drying of cassava chips with solar heated air is characterized by a low drying air temperature and high airflow rate. This results in high investment and operating costs of the air moving equipment.

4) To achieve continuous production of dry cassava throughout the year it will be necessary to heat the drying air by artificial means to temperatures between 50-60°C. At these temperatures airflow requirements are reduced and the drying system becomes totally independent of the climatic conditions.

5) Fuel costs of fully artificial drying systems could be reduced by pre-heating the air in a solar air heater. It is estimated that the savings would be in the order of 15-20%.

6) The use of polyethylene covers on solar air heaters that operate with high airflow rates and low air temperature increments is not justified in terms of increased collector efficiency. This type of heater could therefore be incorporated into the roofs of the drying plant, thereby substantially reducing construction costs.

Cost comparison of three fuel sources for the artificial drying of cassava chips in bins

Although it is possible to estimate fuel consumption costs with a fair degree of precision by estimating the efficiency of heat and mass transfer in the total drying system and by knowing the calorific value of the specific fuels, when evaluating or promoting relatively novel fuel sources, (such as coal in Colombia), and burner designs, it is as well to have reliable cost comparisons with more conventional fuel sources (such as oil and propane gas). For this reason, three fuel-fired air heaters were evaluated for drying cassava chips in a thick bed through circulation drier (Table 22). The results of this evaluation (Table 23) clearly show the cost advantage, in the Colombian situation, of using coal compared with oil and propane gas fired systems. Although this advantage is reduced when applying higher airflow rates (for shorter drying times), reflecting the lower efficiency of the coal fired air heater, the margin is still substantial.

Joint CIAT/IIT/Univalle Wheat-cassava Composite Flour Project

The objective of this project is to determine the technical and economic conditions required for the development of a rural cassava flour industry in Colombia. The methodological framework and principal activities that are to be carried out during the life of the project were described in the CIAT Cassava Annual Report, 1984. These are summarized in Figure 10. In the following sections a brief presentation is given of the results that have been obtained during the first year of the project.

Economic Studies

Consumption and demand for wheat-based food products: bread and pasta

In 1981, a national consumer budget survey of 9000 households was carried out by DANE/DRI-PAN (Departamento Administrativo Nacional de Estadistica/Programa de Desarrollo Rural Integrado-Plan de Alimentacion y Nutricion). The data tape was made available to CIAT for analysis which has allowed a very exact analysis of consumption patterns for bread and pasta.

Consumption patterns for bread in Colombia are significantly different from those for pasta (Table 24). Average annual consumption of bread is 11.9 kg/capita compared to 6.2 kg for pastas. Bread consumption is highly concentrated, with urban consumption being three times higher than rural consumption, and consumption in the highest income quintile being three times higher than the lowest income quintile.

Bread consumption is highest in Bogota, Cali and the urban areas of the eastern region. By contrast, pasta consumption is more evenly distributed throughout the country and, in particular, is more important than bread in the rural areas.

Wheat products are important but do not dominate in the national diet. Bread contributes on average 111 calories and 3.0 grams of protein or about 4.0% total calorie intake and 4.4% of total protein. Pastas contribute 60 calories (2.2%) and 1.8 grams of protein (2.7%). In terms of average calorie intake, cassava and bread make equal contributions, though the distribution of consumption is almost exactly reversed. Cassava is more important in rural areas, in the Atlantic Coast region and in the lower income strata. Bread and pasta make the largest contribution to the diet in Bogota. There bread contributes an average of 7.3% of daily protein intake with a maximum of 8.7% in the lowest income strata. It is only in Bogota where the impact of the inclusion of cassava flour on the protein content of bread becomes a nutritional issue. In all other regions, bread makes up less than 4% of average daily protein intake. However, since the maximum substitution rate of cassava flour is 15% (see section on Baking Trials), the potential decrease in daily protein intake is 1.3% for the lowest income quintile in the highest bread consuming region (Table 25). In all other areas the impact on daily protein intake is negligable for the low income quintile.

However, the other area in which composite flour can potentially have an impact on nutrition is by lowering the cost of the product and thereby increasing consumption. This impact, however, will depend, among other things, on how responsive consumers are to price change. The impact of price changes on consumption behavior is measured through a price elasticity, and these were estimated for bread and pastas by income strata (Table 26). All the price elasticity estimates are significant, of appropriate sign, and within a reasonable range. In general, bread is more price elastic than pastas, except in the lowest income quintile, where consumers would consume slightly more pasta with a percentage reduction in price. Of course, the other two factors that would determine the impact on nutrition would be the level of price decline - where pasta would have the edge because of the higher possible admixture rates, and the absolute importance of the product in total consumption where pasta would have the advantage in rural areas and bread in urban areas. Moreover, the principal benefits from a reduction in bread prices will be garnered by the high income strata in urban areas.

On-farm trials

The development of a new market for cassava based on composite flour may require marked changes in the production technology and cassava production systems. In the first place yield increasing and cost-decreasing technology may be necessary in order to make the whole enterprise economically viable. Raw material makes up by far the major portion of production costs of cassava flour and in the end cassava flour must be cheaper than wheat flour. Root production costs are thus critical to the overall economic viability of a composite flour program. Second, cassava flour will probably have to be produced year round,

since continuous supplies are necessary to motivate investments within the flour milling industry. Continuous root supplies, in many cases, will require changes in the temporal organization of cassava production systems.

The above issues motivated first an evaluation of the current farming system (see below) and second the establishment of on-farm trials to evaluate changes in both the production system and in technology. The trials involving changes in production systems focused on an evaluation of changes in planting and harvest dates to assure a continuous supply of roots and an analysis of stake storage to evaluate adequate supplies of planting material. The trials involving improved technology focused on the introduction of new varieties, intensification of the intercropping system, and an evaluation of fertilizer and crop rotation systems in the maintenance of soil fertility.

Continuous Production Systems: Cassava production on the Atlantic Coast of Colombia is seasonal, especially in particular production zones. The seasonality is partly due to the rainfall distribution (a single rainy period of varying intensity lasting from April to November and a dry season from December to April), and partly to the demands of the intercropping system widely practiced in the western part of the coast. Most of the cassava is planted at the beginning of the rains in April to June. Certain regions also plant cassava towards the end of the rains in September and October but this practice is limited in many areas by varietal response and by the desire to plant cassava in an intercropping system with yam and maize which must be planted at the beginning of the rains.

To evaluate the viability of a continuous production system, different varieties, the local and an introduction, were planted on four different farms in April, to be harvested in December (210 days), February (280 days) and April (360 days), and the same varieties were planted again in August to be harvested in June (300 days), September (375 days) and November (430 days). Such a system would provide a relatively continuous production of roots. The results, as presented in Table 27, demonstrate that a major constraint on planting in the second season is the significantly lower yields of the local variety Venezolana. However, as the trials indicate, M Ven 25 offers significant scope for planting in the second season without significant reductions in yield, even though in the first season there is no yield advantage with the introduced variety over the local variety.

Motivating expansion of planting in the second semester will require, at least in the initial periods, availability of sufficient seed material. One alternative is to store the stakes from the harvest period to the next planting period. Different lengths of storage were evaluated to gauge how long stakes could be stored. The results (Table 28) suggest that up to 3 months has little impact on germination and yield. However, five months results in significant reductions in both germination and yield.

Intensification of the Cassava-Maize Intercropping System: Small-scale farmers commonly utilize multiple cropping as a means of

reducing production risk, insuring a more continuous cash flow and maximizing income per hectare. On the Atlantic Coast of Colombia, maize is the most common intercrop in cassava cropping systems. Moreover, recent research on cassava cropping systems has suggested the possibility of increasing the total yield of traditional cassava/maize systems through changes in the spatial arrangement of the cassava and increases in the plant population of the maize. To evaluate whether these results remain valid under different production conditions, cassava/maize intercropping trials were established in different departments on the Atlantic Coast.

The objective was to evaluate the potential for intensifying the farmer's intercropping system. The trials were mounted in the Departments of Cordoba, Sucre, Atlantico, and Magdalena. In Cordoba and Sucre, the farmer's system consisted of planting cassava in a 1.40 x 1.40 meter arrangement (5,100 plants/ha) and the maize in a 2.80 x 2.80 meter pattern with four plants per hill (10,200 plants/ha). In Atlantico and Magdalena, the farmer's system consisted of a 1 x 1 meter cassava arrangement (10,000 plants/ha) and a 2 x 1 meter maize pattern with four plants per hill (20,000 plants/ha). The farmer's system was then compared with a more intensive system where the cassava was planted at a distance of 1.6 x 0.6 meters (10,200 plants/ha) and the maize at 1.6 x 0.3 meters with two plants per hill (41,667 plants/ha). In effect, the only changes were in spatial arrangement and planting density.

The results were somewhat variable (Table 29). In all cases there was an increase in maize yields. In Betulia and Momil, maize yields more than doubled, while in Pivijay and Sabanalarga they only increased by a third. However, this came at a trade-off in cassava yields. Where maize yields increased most dramatically, cassava yields declined most markedly, especially in Betulia. In Carranzo, Pivijay and Sabanalarga there was little, if any, decline in cassava yields, supporting the conclusions of the original research done at CIAT. However, in the Cordoba and Sucre area, there was also a significant decline in average root size to the point that a high percentage of roots were not saleabe for the fresh market, although they would be suitable for the drying plants.

Changes in spatial arrangement and plant population are not a means of increasing productivity of cassava intercropping systems under all circumstances. The optimum system will depend on relative prices between maize and cassava, quality characteristics in the principal markets, and agro-climatic conditions. Plant type may also play a role since a late branching type such as CM 922-2 showed least variance in yield between the two systems. Adaptive research is required in each micro-region to define the most profitable system.

Soil Fertility and Crop Rotation: Farmer demand for new technology and, therefore, higher yield levels, depends critically on assured access to markets. With the creation of a more expansive market such as that for composite flour, the expectation is that farmers will begin to intensify their production of cassava. A primary concern in such a process is the maintenance of soil fertility. To understand the changes in the cropping system that might be required both to increase cassava yields and to maintain soil fertility, on-farm trials were planted to

evaluate the relative role of fertilizer and crop rotation with cereal and legume crops on cassava yield. The trials will require three years to complete and are only in their second year. Preliminary results are thus left until the next report.

Design and Development of Processing Equipment

In Colombia, cassava is predominantly grown on small to medium sized farms. It is a highly perishable crop and due to its bulkiness transport costs to urban centres are high. Taking into account these factors, the development of processing plants and equipment is being based on a batch or semi-batch modular design, with each module having a capacity to produce approximately one ton of cassava flour per day. At this scale, the processing technology should be suitable for operation by farmer cooperatives and/or small to medium agro-entrepreneurs, with the processing plants being located as close to the areas of cassava production as possible. For the establishment of the industry it is proposed to closely follow the steps taken in the successful development of the production of dry cassava for animal feed in the Atlantic Coast region of Colombia (see International Cooperation, Colombia).

The operations involved in processing cassava roots to flour are shown in the flow diagram, Figure 11. Research and equipment development work has been centred on: (1) the design and testing of a continuous washing/peeling machine; (2) the evaluation of three types of chipping machine; (3) the development of natural and artificial drying systems; (4) the selection and testing of milling equipment; (5) the selection of packing materials and storage conditions. The advances in each of these areas are summarized below.

Washing and peeling. The original aim was to develop a machine that would both wash and peel the cassava roots. After a careful study of the equipment available, it was decided to adapt a design by Odigboh[a].

The machine consists of a rotating cylinder whose surface is constructed in expanded mesh. Internal deflecting paddles insure that the residence time in the machine is sufficient for peeling to take place. A water spray is provided through a mounting axle that passes concentrically through the cylinder. Prototype testing of this machine showed that it was possible to remove approximately 75% of the cassava bark however the losses of parenchima tissue was unacceptably high at around 20-40%. Also the expanded mesh surface rapidly rusted and lost its abrasive properties. The machine is now being modified to act solely as a washing machine by replacing the expanded mesh with a perforated steel sheet. Recent advances in research into roller milling of dry cassava chips have shown that it is possible to separate both bark and fibrous matter from the flour, thus obviating the need to achieve a peeled root.

Chipping. The work that has been carried out in evaluating three types of cassava chipping machine is described in Section B on Cassava Drying.

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[a] Odigboh, E.U. 1978.

Drying. The development of suitable drying systems has concentrated on collecting cost information for natural drying on inclined mesh bottomed trays (see CIAT Cassava Program Annual Report, 1976) and the development of a thick bed through circulation bin dryer (see CIAT Cassava Program Annual Report, 1984 and Section B). Preliminary trials are now underway to evaluate semibatch drying in trays in both a vertical flow cabinet dryer and a crosscurrent flow tunnel dryer.

Milling. A preliminary evaluation of hammer, plate and knife type mills was undertaken. The results indicated that of these three mills the hammer mill appeared to be the most appropriate in terms of capital cost, local availability, throughput and flour yield and therefore a more thorough examination of this type of mill was undertaken. Using a small industrial mill with a capacity to process between 900 and 1,300 kg/h of cereal grains, performance characteristics were determined at 4 peripheral hammer speeds, 5 screen sizes and 2 types of dry cassava chip (with and without peel). The highest yield (58%) of cassava flour (fraction less than 200 micras) was obtained by milling unpeeled chips at the highest peripheral hammer speed (66.0 m/s) and using the smallest screen size (3.47 mm). However, the greatest milling efficiency (53%), measured in terms of the quantity of flour produced per kilowatt-hour consumed, was obtained by milling peeled chips at the lowest peripheral hammer speed (37.7 m/s) and using the largest screen size (12.70 mm). Further studies are being carried out to try and increase the yield of cassava flour, which, at a level of 58%, is low and could negatively affect the economic feasibility of the process as a whole. Designs of suitable screening methods for the milled cassava are being studied.

Exploratory milling trials have also been carried out using roller mills similar to the ones employed in the wheat milling industry. The initial results are very promising; no technical problems have been encountered and yields of cassava flour of between 80 and 90% have been obtained. An important discovery is that cassava bark and fibrous tissue pass through the mill without being disintegrated and may be removed by screening. The ramifications of these findings are two-fold: (a) milling of dry cassava chips can be carried out at the wheat mill, obviating the need to install milling and screening equipment at the cassava drying plant; and (b) there appears to be no need to peel the cassava before chipping and drying, thus eliminating a step that is technically problematical and which consumes large quantities of water.

Packing and storage. Trials are underway to observe the effect of storage conditions and packing material on the quality of both dry cassava chips and cassava flour. Experiments are also planned to determine whether segregation of wheat/cassava flour mixtures is likely to occur.

Baking trials

The baking trials that have been undertaken during the first year of the project have been orientated towards determining whether cassava variety and plant age have an effect on bread characteristics. Flours were prepared from four cassava varieties, M Col 22, CM 976-15, M Col

1684 and M Ven 25, at each of four harvest dates, 8, 10, 12 and 14 months. The proximal analysis and cyanide content of the flours are presented in Table 30. The bread making formula used was 85% wheat flour, 12% cassava flour and 3% soya flour. No additives were incorporated and the composite flour was compared against a 100% wheat flour control using the standard A.A.C.C. method No. 1010.

In trials carried out using flours of the four varieties harvested at 12 months, the bread that gave the highest specific volume was that containing M Col 22 flour (Table 31). This bread was also marginally superior in terms of bread score compared with the other breads prepared from composite flours, but inferior to the bread score of the 100% wheat flour control. Subsequently, trials using M Col 22 flour prepared at the four harvest dates showed that both specific volume and bread score improve with increasing plant age (Table 32).

Preliminary economic analysis of the wheat/cassava composite flour system, indicated that the need to incorporate soya flour substantially reduces the margin that might be obtained by the substitution of 15% wheat flour in bread. In addition, the incorporation of soya flour appears to negatively affect the specific volume and bread score in wheat/cassava/soya flour mixtures compared with wheat/cassava flour mixtures (Table 33). Given that the nutritional effects of replacing 15% wheat flour by cassava flour on the total protein consumption of the Colombian population is minimal, it was decided to eliminate the use of soya flour in the composite flour mixtures.

Complementary baking trials, using the variety that had given the best results in the previous experiments and the variety M Ven 25 which in agronomic trials on the Atlantic Coast has outperformed the best local variety, confirmed the superiority of M Col 22 flour (Table 34). However, loaf quality deteriorated markedly on using the flours of both varieties harvested at 14 months. This result is the reverse of what was found when soya flour was incorporated in the breadmaking formula. Further research will have to be carried out to investigate these apparent changes in cassava flour quality, both between varieties and different plant ages.

TABLE 1. Experiment 1. A comparison of storage losses using two different cassava root thiabendazole treatment methods and two cultivars over a two week storage time. Storage losses for each parameter are evaluated on a 0-100 scale.

Variety	M Col 22		CMC-40	
Storage time (weeks)	1	2	1	2
External microbial growth				
Control	19.6	38.4	21.8	41.4
Immersion	0.0	2.0	0.4	2.0
Aspersion	0.2	2.0	0.0	2.4
Internal microbial rotting				
Control	22.8	40.4	26.4	58.6
Immersion	2.6	1.8	1.8	2.6
Aspersion	7.0	13.6	0.2	1.4
Internal physiological deterioration				
Control	0.0	5.6	0.0	0.0
Immersion	0.4	0.2	1.4	0.0
Aspersion	3.4	0.0	0.8	0.0

TABLE 2. Experiment 2. A comparison of storage losses using two different cassava (M Col 22) root thiabendazole treatment methods on M Col 22 over a two week storage period. Storage losses for each parameter are evaluated on a 0-100 scale

	External microbial growth		Internal microbial rotting		Internal physiological deterioration	
Storage time (weeks)	1	2	1	2	1	2
Control	22.0	39.4	19.8	21.6	2.8	4.4
Immersion	0.6	8.2	4.6	14.0	0.2	1.6
Aspersion	1.0	7.6	1.2	0.8	0.8	1.8

TABLE 3. Statistical analysis of treatment means of Experiments 1 and 2, comparing different cassava root thiabendazole treatment methods.

Thiabendazole treatment method	Losses due to external microbial growth	Losses due to internal microbial rotting	Losses due to internal physiological deterioration
Experiment 1			
Control	31.0[a*]	37.1[a]	1.4[a]
Immersion	1.1[b]	2.2[b]	0.5[a]
Aspersion	1.2[b]	5.5[b]	0.5[a]
Experiment 2			
Control	30.7[a]	20.7[a]	3.6[a]
Immersion	4.4[b]	9.3[b]	0.9[a]
Aspersion	4.3[b]	1.0[c]	1.3[a]

* Values with different letters are significantly different (P = 0.05) according to Duncan's Multiple Range Test.

TABLE 4. Differences in cassava root characteristics between the different thiabendazole root treatment methods from Experiment 1 (Table 1) over a two week storage period. The data refer to treatment means

	Dry mater content (oven drying)	Starch content (% dry matter basis)	Sugar content (% dry matter basis)	
			Reducing	Total
Control	36.54[a*]	82.05[a]	1.61[a]	5.09[a]
Immersion	36.64[a]	86.15[b]	1.06[b]	4.90[a]
Aspersion	37.72[a]	89.75[c]	0.56[c]	3.82[b]

* Values with different letters are significantly different (P = 0.05) according to Duncan's Multiple Range Test.

TABLE 5. Significant differences between storage treatment for each deterioration component (number of days at each storage site) obtained using Duncan's Multiple Range Test (P = 0.05). Treatments with different letters are significantly different.

Time at each storage site (days)		Microbial	Physiological	Total
CIAT	Km 18	deterioration	deterioration	deterioration
0	14	A	A	A
1	13	BA	B	A
2	12	BC	BC	B
3	11	C	DC	B
4	10	C	DC	B
5	9	C	D	B
14	0	C	DC	B

TABLE 6. Experimental design of the cassava storage trials carried out in Peru.

	Experiment 1	Experiment 2	Experiment 3
Starting date	May 14	May 15	May 16
Harvest site	Kirinaki	Huaro	Santa Ana
Plant age (months)	10	12	8-10
Time between harvest and packing (h)	1.5-3	2-3	1-2
Number of days cassava keeps (according to farmer)	4	2-3	1-2
Number of days stored at San Ramón	4	3	2
Number of 5 kg bags packed: treated	18	20	20
untreated	3	3	3

TABLE 7. Results of storage experiments in Lima, for each of three trials at three evaluation dates. Results are expressed as losses on the standard evaluation scale (0-100) for physiological deterioration (PD); microbial deterioration (MD) and external microbial growth (MG). Total Deterioration (TD) is the sum of PD and MD

	Evaluation 1		Evaluation 2		Evaluation 3	
	20 May		24 May		28 May	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
Experiment 1 (harvested, 14 May)						
MG	2.4	17.0	5.6	40.0	11.4	46.6
MD	3.6	14.6	20.0	55.0	16.0	90.0
PD	6.4	2.2	2.2	2.6	0.4	0.0
TD	10.0	16.8	22.2	57.6	16.4	90.0
Experiment 2 (harvested, 15 May)						
MG	0.5	12.2	1.4	18.0	7.4	34.0
MD	0.5	11.1	14.8	33.0	13.6	24.0
PD	6.3	0.0	1.8	0.0	0.0	0.0
TD	6.8	11.1	16.6	33.0	13.6	24.0
Experiment 3 (harvested, 16 May)						
MG	0.0	12.0	0 6	20.0	4.2	80.0
MD	0.3	8.0	14.8	40.0	17.6	80.0
PD	4.1	2.0	1.4	3.4	3.8	0.0
TD	4.4	10.0	16.2	43.4	21.4	80.0
Mean ID	7.1	12.6	18.3	44.7	17.1	64.7

Note: Control roots, untreated and stored at ambient conditions (i.e. not packed into bags, were totally deteriorated at the first evaluation date.

TABLE 8. Results of cassava root quality evaluations of four clones harvested at six different plant ages at CIAT.

	Plant age at harvest (months)					
	7	8	9	10	11	12
CMC-40						
Starch (% DM)	71	91	87	85	79	84
Total sugar (% DM)	2.1	2.4	2.2	1.8	2.0	2.3
DM	39	42	43	41	41	41
Penetration (mm)	1.8	1.8	1.9	1.8	1.8	1.9
Det. %	33	40	64	18	24	17
Cooking time (min)	15	17	21	26	25	20
Taste/texture	0	0	0.5	1	0.25	0
M Col 22						
Starch (% DM)	70	86	91	84	83	92
Total sugar (% DM)	1.3	2.1	2.1	2.0	1.3	1.4
DM	40	44	46	44	43	44
Penetration (mm)	1.7	1.8	1.6	1.5	1.6	1.7
Det. %	80	89	90	46	46	43
Cooking time (min)	18	19	25	25	24	22
Taste/texture	0	0	0	0	0.25	1
M Ven 18						
Starch (% DM)	87	83	90	87	87	88
Total sugar (% DM)	1.8	1.9	2.3	2.6	1.4	1.3
DM	43	45	45	42	42	43
Penetration (mm)	1.8	1.7	1.8	1.6	1.7	1.8
Det. %	69	74	49	11	30	39
Cooking time (min)	23	17	25	22	23	21
Taste/texture	0.25	0.5	2	0.05	0.75	1.5
HMC-1						
Starch (% DM)	78	88	83			
Total sugar (% DM)	2.3	1.7	1.7	1.4	1.5	1.4
DM	41	43	42	41	43	42
Penetration (mm)	1.7	1.7	1.8	1.7	1.8	1.7
Det. %	60	61	54	35	44	39
Cooking time (min)	16	17	26	21	25	27
Taste/texture	0	0	1	0.5	1.25	1.25

Note: The taste-texture evaluations are presented on a 0-3 scale. 0 = excellent; 3 = bad.

TABLE 9. General characteristics of the plants of CMC40 harvested for later quality evaluations from one experimental plot.

Character	Plant Type	
	Tall	Short
Plant height (m)	3.16	1.46
Weight of aerial plant parts (kg)	5.19	1.15
Total root weight/plant (kg)	4.79	2.27
Mean weight of sampled roots (g)	382	461

TABLE 10. Taste and texture quality comparison between roots of "tall" and "short" plants. 30 roots evaluated per plant type. Values represent number of roots with each quality score

	Tall plants				Short plants			
Quality evaluation	0 [a]	1	2	3	0	1	2	3
Taste	29	1			6	22	2	
Texture	29	1			4	25	1	
Glassyness[b]	30				11	18	1	
Fibre	30				13	14	3	

[a] Roots evaluated on a four point scale, 0 = excellent, 3 = bad for each characteristic.

[b] Glassyness is a hard texture phenomenon encountered on boiling roots, when texture becomes crystaline or 'glassy'. See CIAT Cassava Annual Report, 1984.

TABLE 11. Results of starch and sugar analyses (on a dry matter ıs) for roots from tall and short plants of CMC40 in one experimental plot.

	Plant type		
	Tall		Short
Starch (%)	82.73	***	77.97
Reducing sugars (%)	0.41	ns	0.57
Total sugars (%)	1.84	***	2.64

*** Means significantly different at P = 0.001.

TABLE 12. The results of penetrometer evaluations (in mm penetration) of root sections taken from tall and short plants of CMC40. Significant differences between tall and short plants are shown at P = 0.001 (***). Significant differences between mean values, shown by different letter superscripts (Duncan's multiple range P = 0.05)

Root section	Root zone	Plant type			
		Tall		Short	Mean
Proximal	A	1.93	***	2.20	
Proximal	B	1.82	***	2.42	
Proximal	C	2.02	***	2.90	
Distal	A	2.18	***	2.65	
Distal	B	2.22	***	3.23	
Distal	C	2.68	***	3.74	
Mean	A	2.06	***	2.43	2.24^{a}
Mean	B	2.02	***	2.83	2.42^{b}
Mean	C	2.35	***	3.32	2.84^{c}
Proximal	Mean	1.92	***	2.50	2.21^{a}
Distal	Mean	2.36	***	3.21	2.79^{b}
Mean	Mean	2.14	***	2.85	

TABLE 13. Coefficient of correlations, and their significance, between penetration readings and root starch and total sugar contents.

Penetration value		Starch	Total sugars
Section	Zone	(DM basis)	(DM basis)
Proximal	A	NS	NS
Proximal	B	-0.28 * [a]	0.21 *
Proximal	C	0.35 **	NS
Distal	A	NS	0.29 *
Distal	B	-0.30 *	0.36 **
Distal	C	-0.27 *	0.31 *

[a] Significance of correlations: P = 0.05, *; P = 0.01, **; not significant, NS.

NOTE: No significant correlations found with reducing sugar content, hence results not included in Table. For each corelation, n = 60

TABLE 14. Maximum, minimum and mean penetration values for each root zone (A, B, C) and region (proximal, distal) for roots from tall and short plants

Root Section	Proximal			Distal		
Root zone	A	B	C	A	B	C
Roots from tall plants (29 roots no negative score; 1 root with negative score)						
Maximum	2.3	2.4	2.6	2.5	2.9	3.1
Minimum	1.4	1.5	1.5	1.7	1.7	2.0
Mean	1.9	1.8	2.0	2.1	2.2	2.7
Roots from short plants (2 roots no negative score, 28 roots with negative score)						
Maximum	2.7	3.6	4.2	3.5	4.2	4.5
Minimum	1.9	1.8	1.8	1.9	2.2	2.8
Mean	2.2	2.4	2.9	2.7	3.2	3.7

TABLE 15. Results of root quality analyses and evaluations of an experiment to induce glassyness in roots through pre-harvest pruning

Time between pruning and harvest (days)	Root quality evaluation				
	Dry matter	Starch % (DM basis)	Total sugars % (DM basis)	Penetration (mm)	Glassyness
0	37.4[a]	87.3[a]	2.53[b]	2.53[b]	1
3	35.9[ab]	86.4[a]	1.82[a]	1.82[a]	0
8	35.9[ab]	86.8[a]	2.72[b]	2.72[b]	0
16	34.4[b]	85.9[b]	3.62[c]	3.62[c]	1.3
23	33.2[c]	82.3[b]	5.13[d]	5.13[d]	2
30	33.4[c]	79.7[b]	4.97[d]	4.97[d]	2.3

[a] Glassyness evaluated on a 0-3 subjective scale, 0 = no glassyness 3 = completely glassy.

TABLE 16. Results of root quality evaluations and analyses, of the different root zones (A, B, C)

Quality parameter	Inner(A)	Intermediate(B)	Outer(C)
Dry matter, %	31.5^{a*}	37.5^{c}	36.0^{b}
Starch %, DM basis	83.6^{a}	86.5^{b}	84.0^{a}
Total sugars %, DM basis	3.82^{a}	3.03^{b}	3.54^{a}
Penetration (mm)	2.28^{a}	1.84^{b}	1.92^{b}

* Significant (P = 0.05) differences shown by different letter superscripts, after analysis with Duncan's Multiple Range test.

TABLE 17. Capacity and power consumption of three types of cassava chipping machines.

Model	Capacity t/h	Power consumption hp	Ratio capacity/ Power consumption
Thai	4.8	3.1	1.6
Malaysian	5.0	2.8	1.8
Brazilian	3.9	3.3	1.2

TABLE 18. Geometry, dimensions and size distribution of three types of cassava chips.

Machine	Geometry and dimensions of chip	Size distribution, %		
		Whole chips	Thin or broken chips	Fine particles
Thai	Slices 7 x 30 x 80 mm	42	34	24
Malaysian	Strips 6 x 6 x 80 mm	35	29	36
Brazilian	Rectangular bars 5 x 10 x 70 mm	45	35	20

TABLE 19. Solar collector performance,[a] with and without polyethylene cover

Solar collector configuration	Ambient air conditions			Air flow rate	Air temperature increase	Solar collector efficiency
	T °C	RH %	Rad. Solar cal/cm^2.min	m^3/min	°C	%
Galvanized iron sheets with polyethylene cover	31	61	0.76	110	4.8	55
Galvanized iron sheets without polyethylene cover	31	61	0.67	110	4.0	51

[a] 26 daily observations for each collector configuration from 07:00 to 17:30.

TABLE 20. Evaluation of a combined concrete floor - through circulation bin dryer/solar air heater system

Solar collector configuration	Concrete floor drying [a]					Bin drying			Total net drying time h
	Fresh chips			Partially dry chips					
	Floor area m^2	Initial loading[b] kg	Moisture content %	Weight kg	Moisture content %	Bin loading kg/m^2	Airflow rate[c] m^3/min.t	Drying time h	
Galvanized iron sheets with polyethylene cover	150	1,800	59.0	1,190	38	198	82	10.8	22.8
Galvanized iron sheets without polyethylene cover	150	1,800	61.0	1,130	38	188	82	10.7	22.7

[a] Net drying time on concrete floor 12 hours.

[b] Loading density on concrete floor 12 kg/m^2.

[c] Airflow rate in m^3/min per ton of fresh cassava.

TABLE 21. Comparison of investment costs of natural concrete floor and combined concrete floor/solar-assisted bin drying systems with a capacity to process 3,600 kg fresh cassava chips in two days

Drying system		Components	Component cost Col.$ [a]	System cost Col.$
A. Natural drying	1)	300 m^2 Concrete floor	186,000	186,000
B. Combined natural and solar assisted bin drying	1)	150 m^2 Concrete floor	93,000	
	2)	30 m^2 Solar air heater	57,000	
	3)	6 m^2 Drying bin	65,590	
	4)	100 m^3/min Fan	125,600	341,190

[a] US$1.00 = Col.$140.

TABLE 22. Technical details of three fuel-fired air heaters used to dry cassava chips

Fuel source	Type of heater	Type of heat exchanger	Make and model	Heat output Btu/h	Air heater efficiency, %
Coal	Indirect	Single finned tube	CIAT designed [a]	78,500	50-60
Oil	Indirect	Multiple tube	Benson EM60	205,000	80
Propane	Direct	-	Farm Fans DH16	215,000	95

[a] See CIAT Cassava Annual Report, 1984 for a full description of this air heater.

TABLE 23. Consumption and cost of three fuels used in through circulation bin drying of cassava chips at 50°C

Airflow rate	Drying time	Consumption and cost per ton of dry product					
		Coal[a]		Oil[b]		Propane gas[c]	
m^3/min.t[d]	h	kg	Col.$	gl	Col.$	kg	Col.$
130	10	250	1,120	52	4,940	104	2,500
190	8	380	1,730	55	5,230	123	2,950

[a] Cost of coal: 4,500 Col.$/t.

[b] Cost of oil : 95 Col.$/gl.

[c] Cost of propane gas : 24 Col.$/kg.

[d] Cubic meters per minute per ton of fresh cassava.

TABLE 24. Annual per capita consumption of bread and pasta by income strata and rural urban residence, 1981

Region	Residence	Bread						Pasta					
		I	II	III	IV	V	Average	I	II	III	IV	V	Average
		kg/capita/year											
Atlantic	Urban	3.7	7.1	9.5	12.8	17.1	8.0	3.6	3.2	5.4	6.2	5.5	5.0
	Rural	0.9	2.7	3.1	5.6	7.1		2.6	3.4	5.0	7.4	11.7	
Eastern	Urban	12.8	17.5	24.0	28.6	29.6	16.0	7.2	7.1	10.6	10.4	10.9	9.6
	Rural	4.3	10.2	11.9	18.7	12.7		5.4	9.3	14.0	13.3	10.1	
Bogota	Urban	11.8	14.3	19.1	23.0	24.0	20.4	5.1	6.4	8.1	9.3	8.5	8.0
Central	Urban	2.7	5.8	7.4	10.4	9.1	5.4	2.5	3.6	3.3	5.0	4.0	3.8
	Rural	1.2	2.1	1.7	3.1	3.4		2.8	3.8	3.9	5.4	5.2	
Pacific	Urban	11.6	11.9	19.9	24.5	26.9	15.0	4.2	4.7	6.2	7.4	7.0	6.2
	Rural	2.8	5.7	6.1	8.1	7.3		4.1	6.2	8.8	7.7	7.4	
Total	Urban	7.3	10.4	14.9	18.8	20.1	11.9	4.1	4.8	6.4	7.4	6.7	6.2
	Rural	2.5	5.2	5.7	9.2	7.6		3.8	5.9	7.8	8.6	3.5	

TABLE 25. Impact of the use of a 85% wheat 15% cassava composite flour in breadmaking on the protein intake of the population

Region	Protein consumption with 100% wheat flour bread							Protein consumption with 85:15 composite wheat: cassava flour bread						
	Quintile	I	II	III	IV	V	Average	Quintile	I	II	III	IV	V	Average
				grams/day							grams/day			
Atlantic	Bread	0.51	1.19	1.70	2.81	3.88	2.04	Bread	0.43	1.01	1.45	2.39	3.30	1.73
	Total	41.05	63.04	77.89	84.70	91.19	72.28	Total	40.97	62.86	77.64	84.28	90.61	71.97
	Percentage	1.24%	1.89%	2.18%	3.32	4.25%	2.82%	Reduction in the total	-0.19%	-0.28%	-0.33%	-0.50%	-0.64%	-0.42%
Eastern	Bread	1.76	3.28	4.59	6.19	5.79	4.02	Bread	1.50	2.79	3.90	5.26	4.92	3.42
	Total	44.77	63.96	79.09	86.00	84.87	68.25	Total	44.51	63.47	78.40	85.07	85.07	67.65
	Percentage	3.93%	5.13%	5.80%	7.20%	6.82%	5.89%	Reduction in the total	-0.59%	-0.77%	-0.87	-1.08%	-1.02%	-0.88%
Bogota	Bread	2.97	3.58	4.81	5.78	5.99	5.10	Bread	2.52	3.04	4.09	4.91	5.09	4.34
	Total	34.00	49.34	65.06	75.62	86.59	69.73	Total	33.55	48.80	64.30	74.75	85.69	68.97
	Percentage	8.74%	7.26%	7.40%	7.64%	6.92%	7.31%	Reduction in the total	-1.31%	-1.09%	-1.11%	-1.15%	-1.04%	-1.10%
Central	Bread	0.53	1.04	1.37	2.14	2.10	1.39	Bread	0.45	0.88	1.16	1.82	1.79	1.18
	Total	38.97	60.40	72.10	83.02	73.16	64.57	Total	38.89	60.24	71.89	82.70	72.85	64.36
	Percentage	1.36%	1.72%	1.90%	2.58%	2.87%	2.15%	Reduction in the total	-0.20%	-0.26%	-0.29%	-0.39%	-0 43%	-0.32%
Pacific	Bread	1.48	2.20	3.65	5.43	6.80	3.90	Bread	1.26	1.87	3.10	4.62	5.78	3.32
	Total	39.69	59.37	75.49	84.33	83.26	70.28	Total	39.38	59.04	74.94	83.52	92.24	69.70
	Percentage	3.74%	3.71%	4.84%	6.44%	7.29%	5.55%	Reduction in the total	-0.56%	-0.56%	-0.73%	-0.97%	-1.05%	-0.32%

TABLE 26. Price and income elasticity for bread and pastas in Colombia

Quintile		Bread		Pastas	
		Price	Income	Price	Income
1	Coefficient	-0.76	-0.06	-0.79	0.97
	P 0.01	1%	90%	1%	2%
	R^2	0.67	0.66	0.55	0.54
2	Coefficient	-0.83	0.15	-0.77	0.32
	P 0.01	1%	80%	1%	38%
	R^2	0.54	0.52	0.78	0.78
3	Coefficient	1.08	0.43	-0.84	-0.25
	P 0.01	1%	51%	1%	54%
	R^2	0.40	0.38	0.38	0.37
4	Coefficient	-0.86	0.73	-0.79	0.29
	P 0.01	1%	17%	1%	29%
	R^2	0.56	0.54	0.31	0.30
5	Coefficient	-0.84	0.47	-0.78	0.14
	P 0.01	1%	4%	1%	40%
	R^2	0.79	0.79	0.63	0.62

TABLE 27. Evaluation of the potential for producing cassava during all the year

Variety	First harvest		Second harvest		Third harvest	
	Yield t/ha	D.M. %	Yield t/ha	D.M. %	Yield t/ha	D.M. %
1st Semester sowing [a]						
M Ven 25	16.6	36.0	18.0	36.3	17.1	33.8
Venezolana	16.1	37.9	17.0	36.4	20.2	34.6
2nd Semester sowing [a]						
M Ven 25	11.1	33.0	15.2	34.9	17.3	37.8
Venezolana	6.8	35.8	9.1	37.0	7.5	38.3

[a] Average values for trials sown in 4 different locations.

TABLE 28. Evaluation of the effect of stake storage on subsequent crop yield

Storage period Days	Variety	Fertilized			Unfertilized		
		Plants lost %	Yield t/ha	Dry matter %	Plants lost %	Yield t/ha	Dry matter %
149	M Ven 25	71	6.4	36.0	68	6.5	36.4
	Venezolana	54	6.9	37.9	55	7.0	38.2
85	M Ven 25	11	11.8	37.5	11	12.3	37.4
	Venezolana	8	12.8	38.0	4	11.7	37.9
20	M Ven 25	7	8.1	37.2	7	9.7	37.4
	Venezolana	3	11.6	38.0	3	11.9	37.5

TABLE 29. A comparison of cassava and maize yields in farmer's intercropping system and intensive system.

System	Cassava variety	Cassava yield t/ha	Cassava yield %D.M.	Maize yield t/ha	Cassava yield t/ha	Cassava yield %D.M.	Maize yield t/ha	Cassava yield t/ha	Cassava yield %D.M.	Maize yield t/ha
		Albania, Sucre			Betulia, Sucre			Carranzo, Cordoba		
Farmer's system	Venezolana	9.9	37.3	0.46	11.9	36.3	0.97	7.2	35.1	0.56
	CM-681-2	10.4	35.5	0.46	11.1	35.3	0.81	3.3	33.2	0.40
	CM-922-2	8.6	35.8	0.33	10.8	36.1	0.86	3.1	35.9	0.51
	Average	9.6	36.2	0.42	11.3	35.9	0.88	4.5	34.7	0.49
Intensive system	Venezolana	9.0	37.0	0.76	6.1	35.2	2.38	5.1	37.0	0.94
	CM-681-2	8.7	34.3	0.78	6.0	36.1	2.43	4.7	34.7	0.78
	CM-922-2	7.2	35.7	0.97	8.4	34.1	2.22	3.9	34.8	0.97
	Average	8.3	35.7	0.84	6.8	35.1	2.34	4.6	35.5	0.90
		Momil, Cordoba			Pivijay, Magdalena			Sabanalarga, Atlantico		
Farmer's system	Venezolana	9.8	35.7	0.45	15.9	28.9	1.0	8.4	32.0	1.3
	Various[a]	7.4	32.0	0.46	12.0	30.7	1.3	18.9	28.4	1.0
	Various[b]	10.6	35.2	0.50	11.9	29.8	1.3	13.7	29.4	1.3
	Average	9.3	34.3	0.48	13.3	29.8	1.2	11.5	29.9	1.2
Intensive system	Venezolana	7.7	35.2	0.90	13.6	32.9	1.5	8.6	29.4	1.5
	Various[a]	6.9	35.1	1.31	16.1	28.9	1.8	15.3	27.3	1.5
	Various[b]	9.1	34.8	1.59	9.9	29.9	1.6	15.7	32.3	2.1
	Average	7.9	35.0	1.27	13.2	30.5	1.6	12.3	29.8	1.6

[a] Momil, CM-681-2; Pivijay, CM-981-8; Sabanalarga, M. Col. 22.

[b] Momil, CM-922-2; Pivijay, M. Col. 2216; Sabanalarga, M. Ven. 25.

TABLE 30. Chemical composition of cassava flour [a] of 4 varieties as affected by plant age [b]

Variety	Plant age months	DM %	Starch %	Total sugars %	Reducing sugars %	Protein %	Ether extract %	Crude fibre %	Ash %	Total cyanide mg/kg	Free cyanide mg/kg
M Col 22	8		97	1.85	0.45	5.64	0.57	1.47	1.57	59	7
	10		90	1.54	0.23	5.71	0.65	1.66	1.74	39	6
	12		94	1.47	0.45	5.08	0.64	1.58	1.77	34	7
	14		95	2.42	0.37	5.15	0.93	1.51	1.88	48	9
	Mean		94	1.82	0.37	5.39	0.70	1.55	1.74	45	7
CM 976-15	8		95	1.71	0.35	4.33	0.51	1.98	2.38	92	6
	10		86	2.17	0.54	4.67	0.51	2.05	2.16	96	7
	12		91	2.01	0.62	3.61	1.02	1.39	2.03	97	3
	14		87	1.99	0.45	3.70	0.81	1.76	2.15	145	6
	Mean		90	1.97	0.49	4.08	0.71	1.79	2.18	107	6
M Col 1684	8		87	1.19	0.26	4.43	0.70	2.85	2.80	276	17
	10		80	4.19	0.76	4.77	0.85	2.40	2.64	378	14
	12		89	2.51	0.66	4.43	0.83	2.27	2.82	358	10
	14		90	3.29	0.55	4.14	1.03	1.89	2.32	323	7
	Mean		86	2.80	0.56	4.44	0.85	2.35	2.64	334	12
M Ven 25	8		90	2.04	0.52	5.47	0.88	2.73	1.86	906	37
	10		86	3.36	0.96	5.15	0.88	1.68	1.79	1110	9
	12		87	2.59	0.65	4.98	0.78	2.03	1.73	967	16
	14		85	1.94	0.50	4.69	0.97	2.07	1.73	719	12
	Mean		87	2.48	0.65	5.07	0.88	2.13	1.78	925	18

[a] Peeled, chipped roots dried at 60°C.
[b] Each monthly value is the average of six replications. All values on a dry matter basis.

TABLE 31. Effect of cassava variety on loaf characteristics [a]

Variety	Specific volume cm^3/g	Bread score max.100
M Col 22	4.36	84.0
CM 976-15	4.27	83.0
M Col 1684	4.21	76.8
M Ven 25	4.24	82.4
Control	4.26	92.0

[a] Bread formula: 85% wheat flour, 12% cassava flour, 3% soya flour. All varieties harvested at 12 months.

TABLE 32. Effect of plant age on loaf characteristics [a]

Plant age	Specific volume cm^3/g	Bread score max.100
8	3.84	75.0
10	3.87	76.0
12	4.21	82.0
14	4.38	81.0
Control	4.37	92.5

[a] Bread formula: 85% wheat flour, 12% cassava flour, 3% soya flour. Cassava flour prepared from the variety M Col 22.

TABLE 33. Effect of the level of addition of cassava and soya flour on loaf characteristics [a]

Breadmaking formula			Specific Volume	Bread Score
Wheat flour %	Cassava flour %	Soya flour %	cm^3/g	max.100
85	12	3	4.20	84.0
80	18	2	4.29	71.0
85	15	-	4.72	86.5
100	-	-	4.68	92.5

[a] Variety M Col 22 harvested at 12 months plant age.

TABLE 34. Effect of plant age and cassava variety on loaf characteristics[a]

Plant age months	Variety			
	M Col 22		M Ven 25	
	Specific volume[b] cm^3/g	Bread score[b] max.100	Specific volume[b] cm^3/g	Bread score[b] max.100
8	4.39[c]	84.5[b]	3.99[c]	73.7[b]
10	4.48[b]	89.0[b]	4.00[c]	73.5[b]
12	4.72[a]	86.5[b]	4.21[b]	72.7[b]
14	4.12[d]	66.2[c]	4.05[c]	59.7[c]
Control	4.68[a]	92.5[a]	4.68[a]	92.5[a]
DMS	0.07	5.9	0.07	5.9

[a] Breadmaking formula: 85% wheat flour, 15% cassava flour.

[b] Values with the same letter are not significantly different at the 99% confidence level.

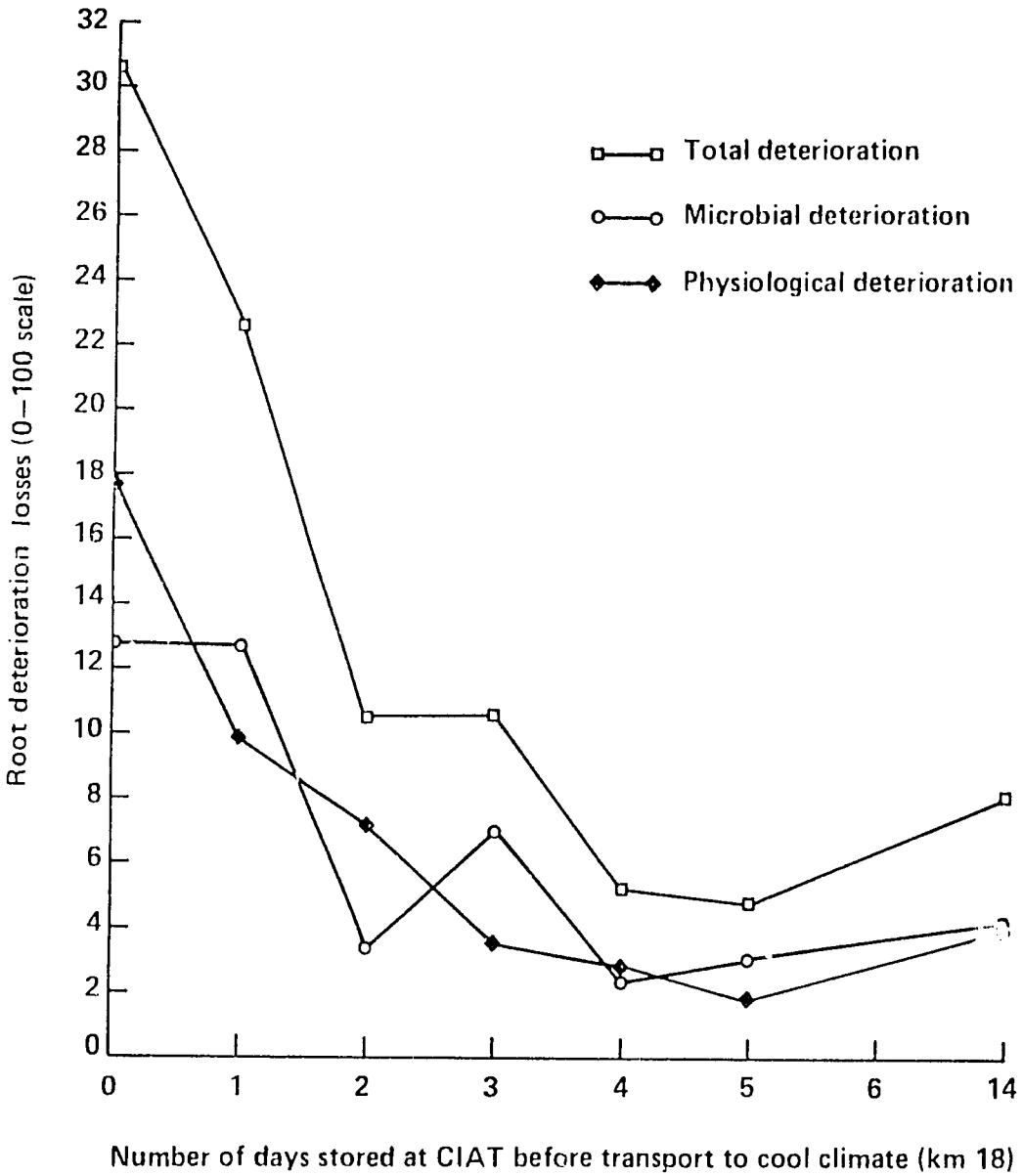


Figure 1. Results of an experiment to determine the number of days storage in tropical conditions required before roots can be transported to cool climates.

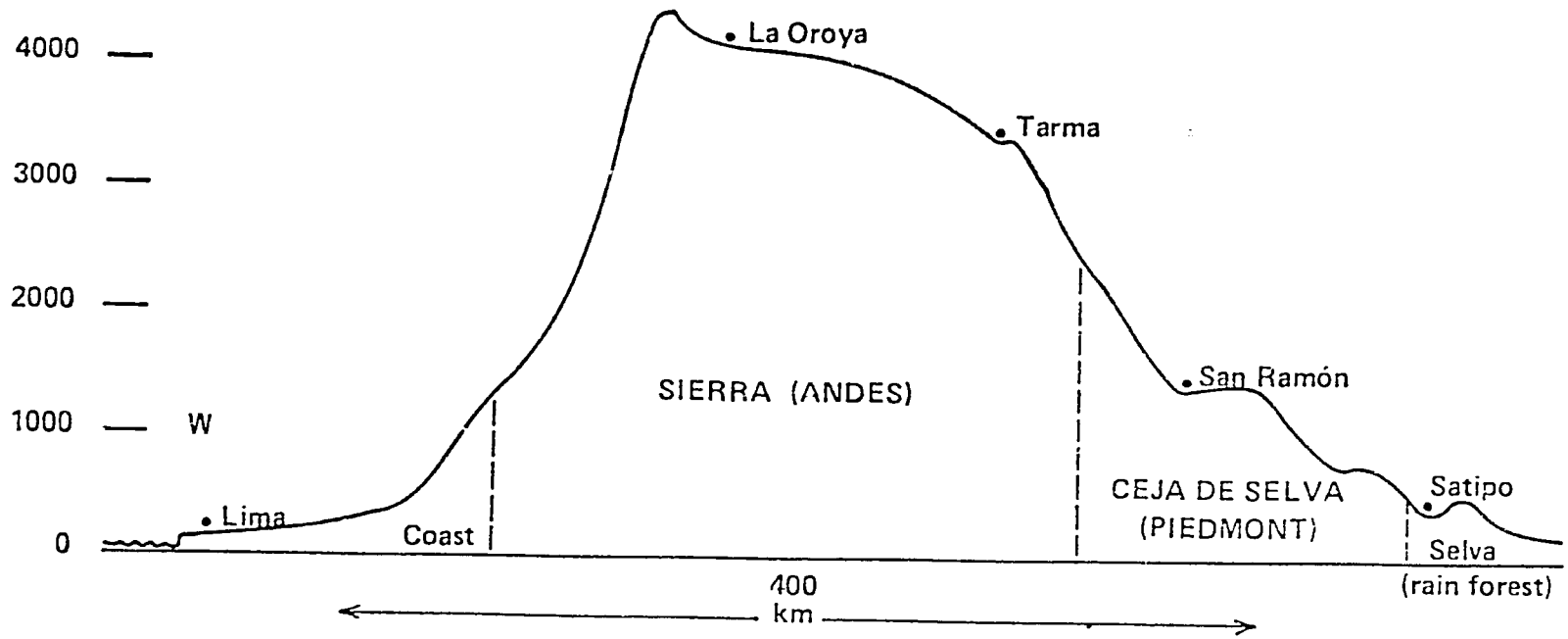


Figure 2. Profile of the land route traveled by cassava transported from Satipo to Lima, Perú.

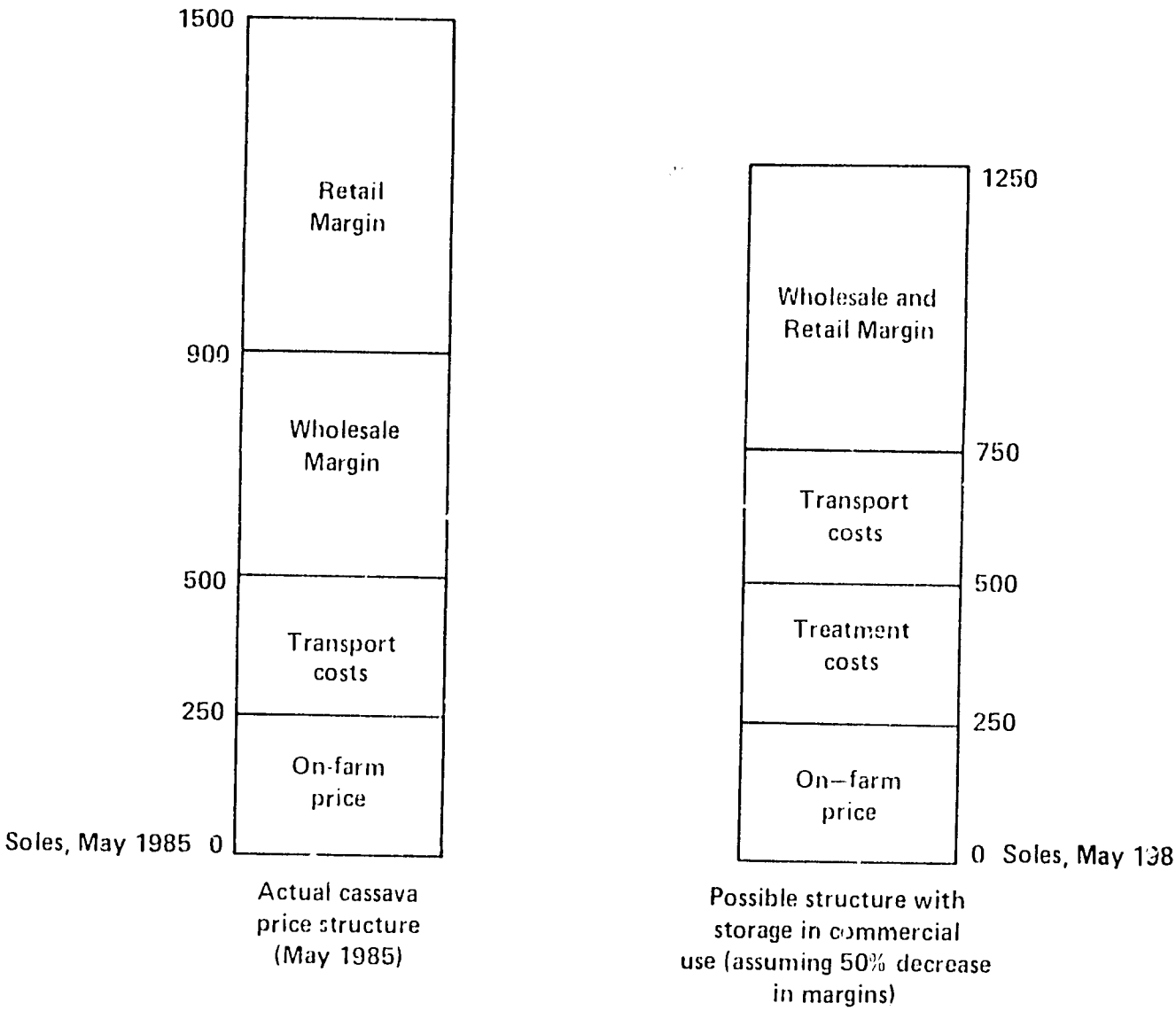


Figure 3. Actual and possible price structure of cassava in the Lima market.

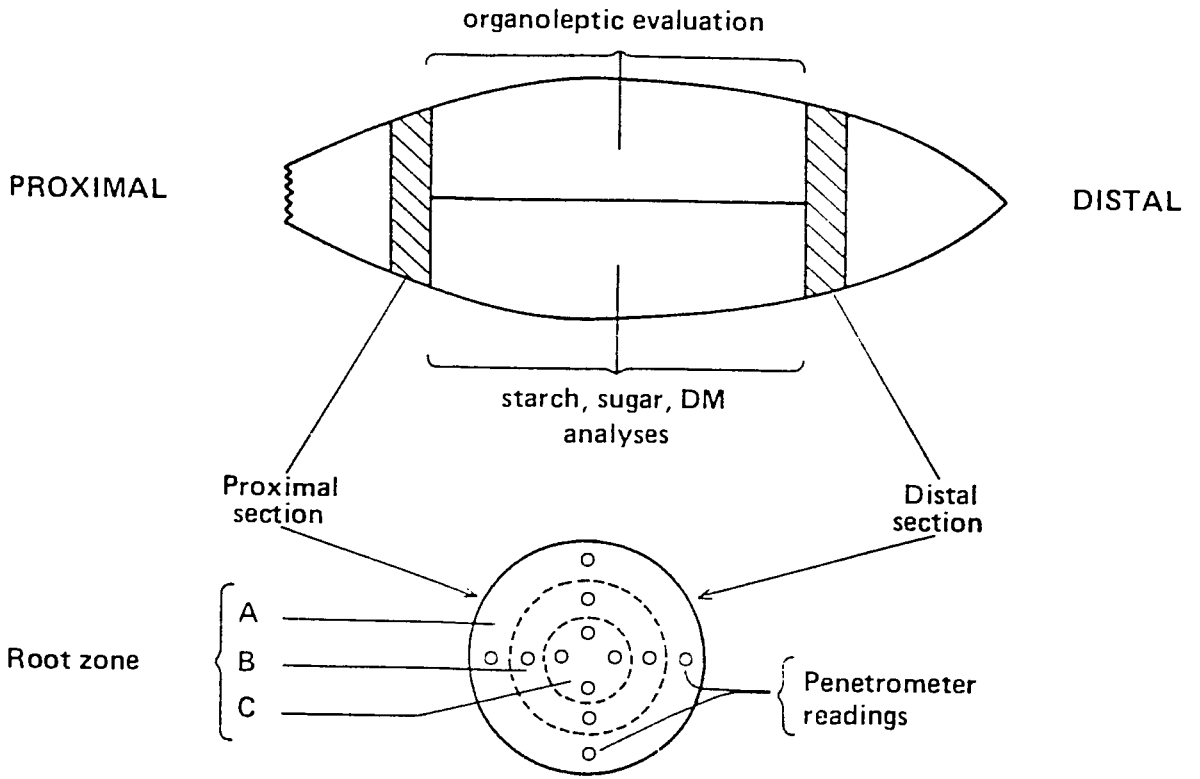


Figure 4. Sampling scheme for individual root quality evaluations (Peeled roots).

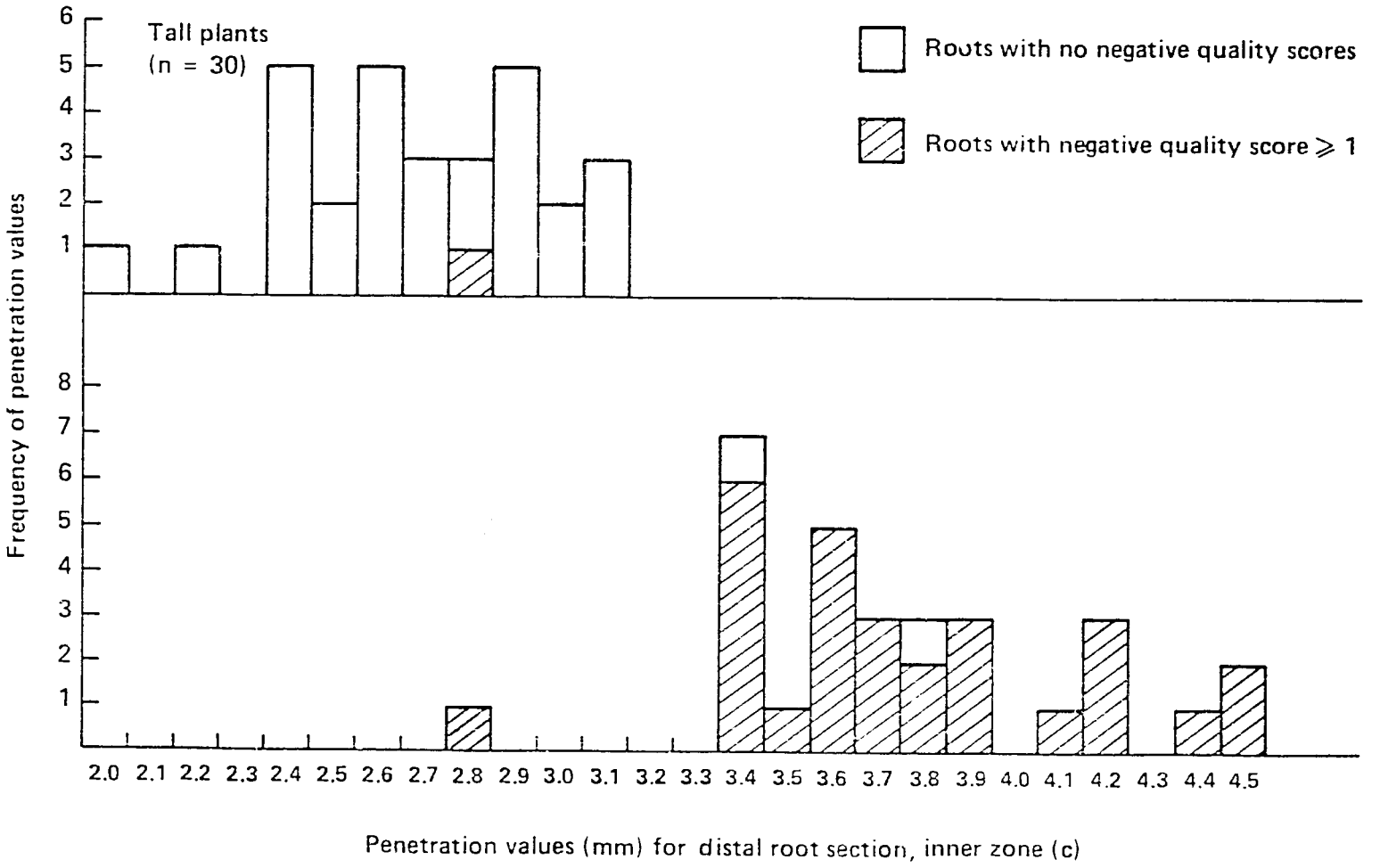


Figure 5. Frequency diagram of penetration results from the distal root section, inner (c) zone comparing roots from tall and short plants of CMC 40, and of good and poor quality.

Figure 6. Correlation matrix of root quality analyses and evaluations.

	Glassyness	Fibrousness	Dry Matter	Cooking time	Flavour	Texture	Starch (A)	Starch (B)	Sweetness	Sugar content	Penetration	Bitterness	Fiber content
Glassyness	+	+	-	+	+	+	-	-	+	+	+		-
Fibrousness		+	-		+			-	+	+			-
Dry Matter			+		-		+						
Cooking time				+		+							-
Flavour					+	+		-					-
Texture						+	-		+				-
Starch (A)							+	+		-	-		
Starch (B)								+					+
Sweetness									+	+			-
Sugar content										+			-
Penetration											+		
Bitterness												+	+
Fiber content													+

NOTE: + = Positive and - = negative corelations (P = 0.05)

A = Specific gravity method; B = direct determination of starch content.

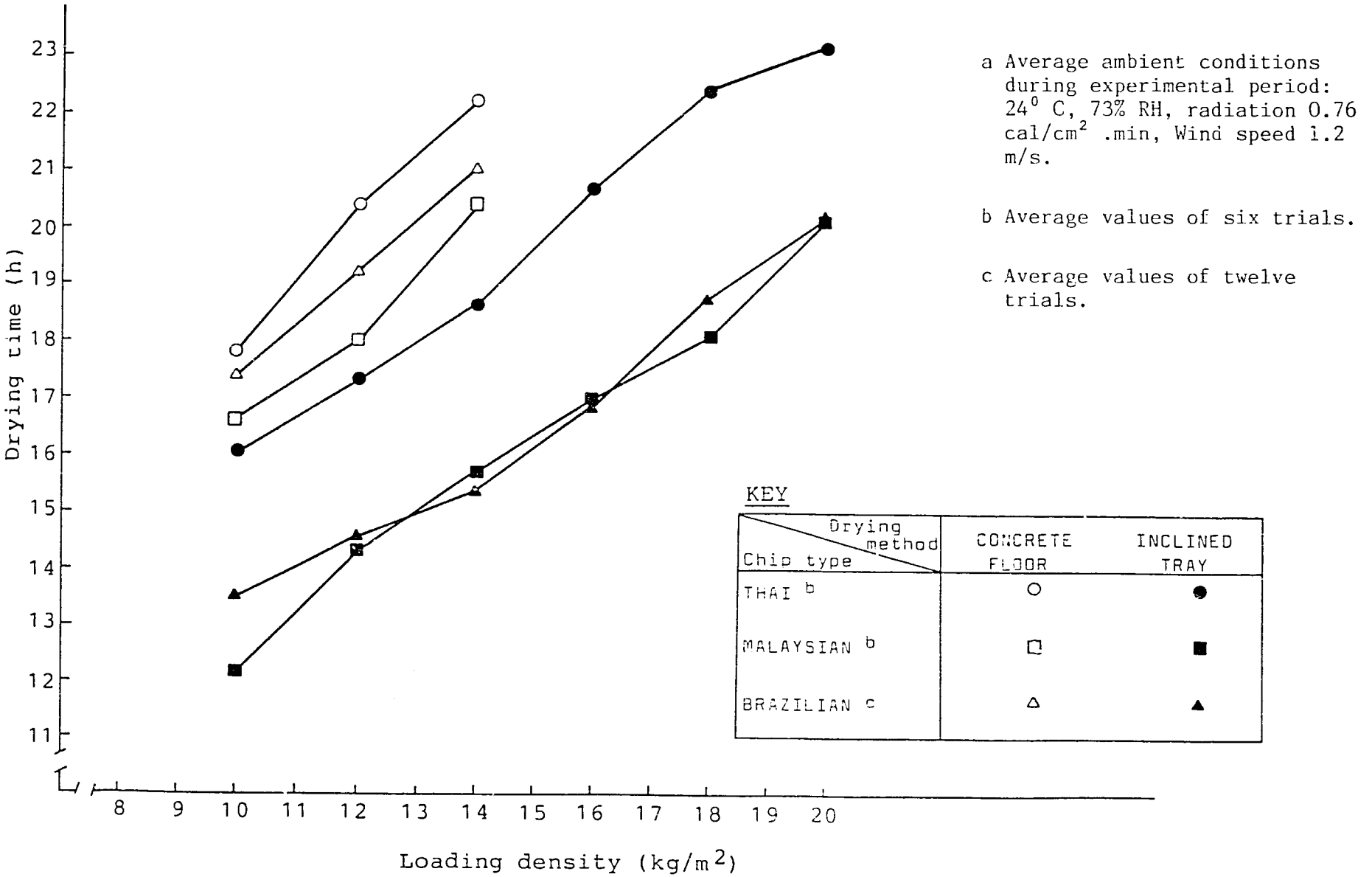


Figure 7. Drying times of Thai, Malaysian and Brazilian type cassava chips at different loading densities on concrete floor and inclined trays a/

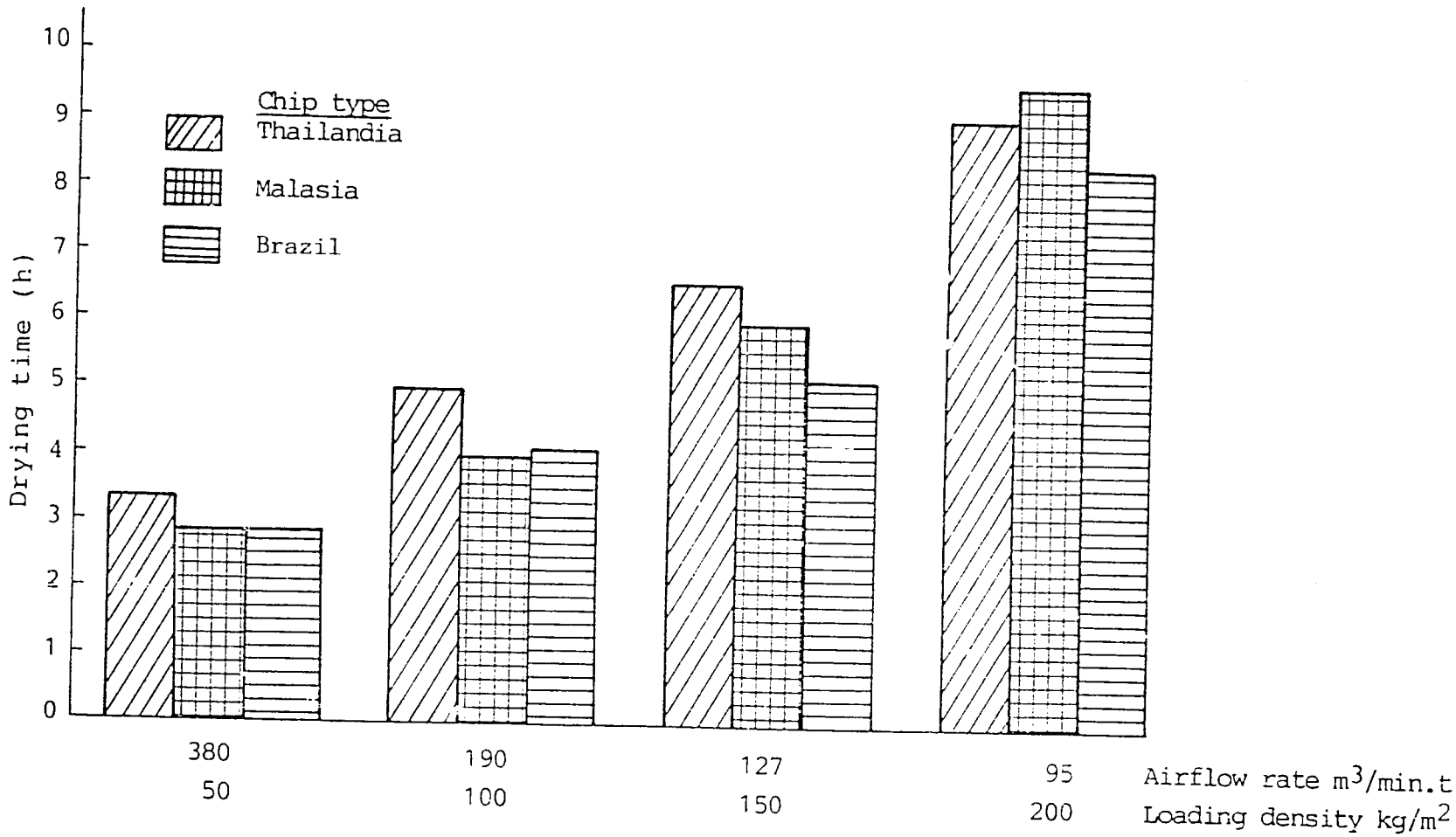
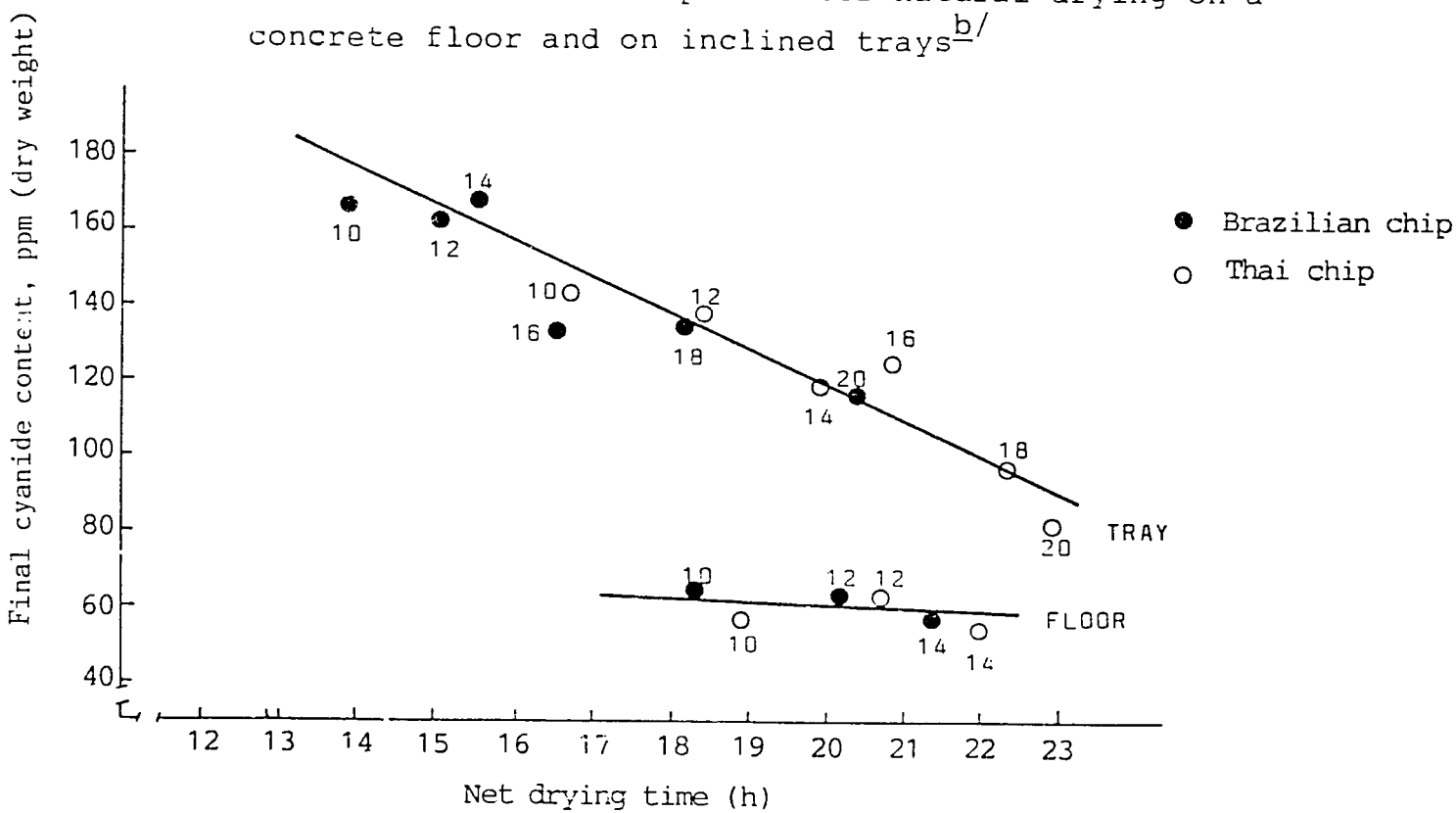


Figure 8. Drying times of Thai, Malaysian and Brazilian-type cassava chips in a through circulation bin dryer at 60°C.

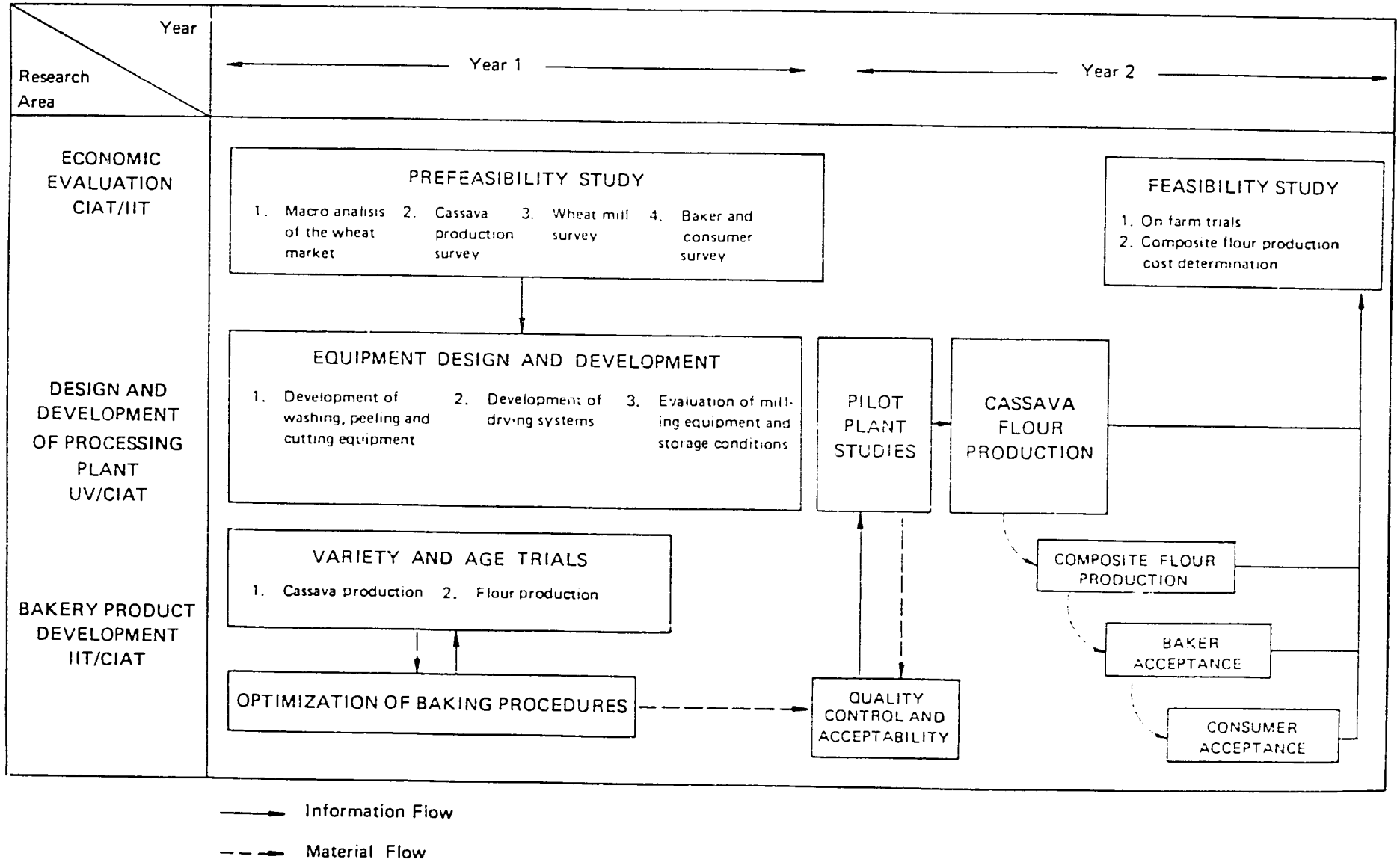
Figure 9. The final total cyanide content of Thai and Brazilian type cassava whole root chips[a] after natural drying on a concrete floor and on inclined trays[b]



[a]Variety CM 976-15, 17 months, initial total cyanide content 516 ppm (dry weight)

[b]Numbers above data points denote loading density in kg/m^2

FIGURE 10. PRINCIPAL ACTIVITIES IN THE CASSAVA BAKING FLOUR PROJECT



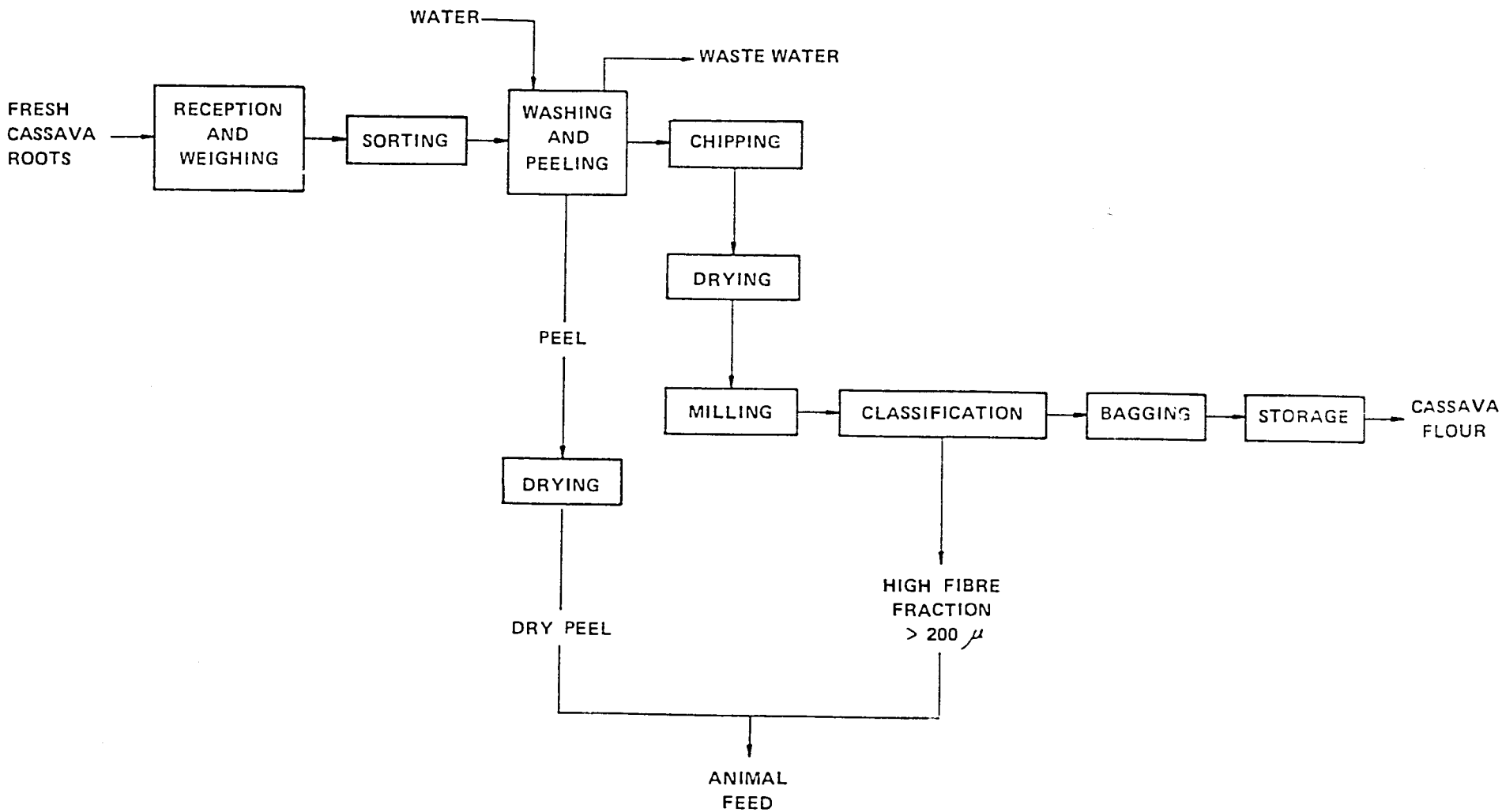


FIGURE 11. FLOW DIAGRAM OF CASSAVA FLOUR PROCESSING PLANT

SOIL MANAGEMENT AND PLANT NUTRITION

During 1985 research on cassava soil management and plant nutrition focused on the following aspects:

1) Screening of germplasm for adaptation to low P and acid soil.
2) The effect of alternating wet and dry seasons on cassava growth, nutrient absorption and mycorrhizal infection.
3) Long term effect of cassava on soil fertility.
4) Use of green manures.
5) Fertilizer response of cassava on sandy soils of the Colombian North Coast.
6) Erosion control for cassava grown on steep slopes.
7) Plant population and varieties for cassava forage production.
8) Effect of mycorrhiza.

Screening of Cassava Germplasm for Adaptation to Low P and Acid Soils.

As in previous years, a large number of varieties from the germplasm bank and breeding lines were evaluated in CIAT- Quilichao and Mondomo for adaptation to low-P soil, and in Carimagua for adaptation to low-P and high levels of soil acidity. In Quilichao, 677 materials were planted in single rows in large plots with either no P or 75 kg P/ha applied as banded diammonium phosphate (DAP). All plants received 100 kg N and 150 kg K/ha, band applied as DAP or urea and KCl, respectively. The high and low P plots had Bray II extractable P levels of 17.5 and 3.4 ppm at the time of planting. After 12 months the average yields were 39.2 and 31.2 t/ha in the plots with and without P applications. Table 1 shows the yield and low-P adaptation indices for the 20 most tolerant varieties. These varieties will be further tested for their low-P tolerance in replicated yield trials.

In one of the latter trials, 77 of the most well adapted varieties selected from single row trials were planted in subplots of 30 plants with two replications in large plots with either zero or 75 kg P/ha, band applied as DAP as described above; at the onset of the trial (the fourth planting in the same location) these plots contained 11.9 and 4.6 ppm Bray II P, respectively. Eventhough the months of June, July and September were unusually dry this year, the yields were very high, even without P application. Average yields in the same field have been increasing with each consecutive cassava planting as follows:

	Bray II-P (ppm)		Cassava yield (t/ha)	
	oP	75P	oP	75P
1981	1.4	-	16.7	27.2
1982	2.2	8.7	16.2	27.7
1983	4.8	22.0	24.9	31.1
1984	4.6	11.9	34.0	36.6
1985	1.8	4.0	-	-

This increase in yield, with or without applied P, is probably due to an increased mycorrhizal population, stimulated by a gradually improved soil fertility and abundant cassava root growth. Table 2 shows the yield and low-P adaptation indices of the 13 most adapted varieties compared with two standard check varieties. It is clear that some varieties are very well adapted to acid low-P soils, producing about 50 t/ha of fresh roots in a soil with pH 4.0 and only 4.6 ppm Bray II extractable P. Thus, in areas where diseases and pest problems are minimal, adequate soil management and maintenance of soil fertility can not only maintain but actually increase yields of consecutively grown cassava crops. In the same acid "infertile" soil of CIAT-Quilichao a yield trial of eight local varieties from the Mondomo area produced yields between 30 and 84 t/ha in only 11 months. These cold climate varieties, adapted to extremely infertile soils, are not only early but also very productive under warmer and more favorable soil conditions.

Another set of varieties and breeding lines adapted to the high altitude tropics (Edapho-climatic zone V) was screened for low-P tolerance in Mondomo. The varieties were planted in subplots in two main plots with 0 and 100 kg P/ha band applied as TSP. Table 3 shows the yields obtained and the low-P adaptation indices. There was an extreme response to P in all varieties, increasing yields on the average from 2.9 to 16.1 t/ha, in a soil with 1.8 ppm Bray II-P. Most adapted were two local varieties, Regional Amarilla and Negrita and two germplasm accessions, M Col 113 and M Col 2019. Some breeding lines selected in Popayan were also well adapted, while some warm-climate varieties like CMC 40 succumbed to severe anthracnose problems.

As in previous years, a group of 60 varieties and breeding lines were evaluated for tolerance to low P and high acidity in Carimagua by planting each in three large plots that received either no P, no lime, or both lime and P. Table 4 shows the root yield and adaptation indices of the most adapted varieties as well as those of four standard varieties. Average yields without P were only 2.3 t/ha, while those without lime were 10.9 t/ha and with both lime and P 9.4 t/ha. Thus, yields were actually higher without lime, eventhough these plots had 82 percent Al saturation, indicating the extreme tolerance to soil acidity of these materials. Of the five Brasilian accessions included, all were highly adapted to acid low-P soils, probably due to similar conditions in their region of origin. On the other hand, the local variety, Llanera, was completely unadapted and succumbed under the present high disease and pest pressure in Carimagua.

Effect of wet and dry seasons on cassava growth, nutrient absorption and mycorrhizal infection.

To determine the effect of the dry season on cassava growth and nutrient absorption a trial was established in Carimagua in October 1984, towards the end of the rainy season. The variety M Ven 77 was planted in large plots of 169 plants, either with or without fertilization, and with four replications. The fertilized plots received 1 t/ha of dolomitic lime, 1 t/ha 10-20-20, 10 kg Zn/ha as ZnO, 1 kg B/ha as Borax and 10 kg S/ha as elemental sulphur, all broadcast and incorporated before planting.

Figure 1 shows that, compared with the 11-year average, this year the dry season was unusually long and dry, while rainfall during the wet season was unusually high, with a maximum of 463 mm during May. During the long dry season plants defoliated almost completely, while full foliage was reestablished with the first rains of April. These drastic changes between extreme dry and extreme wet had a profound effect on plant growth, nutrient concentrations in the plant, and in the soil, as well as the mycorrhizal populations.

Figure 2 shows the total and root dry matter production for fertilized and unfertilized plants during the 11-month growth cycle. Due to the long dry season (from November 15 to April 15 it rained only 86 mm) crop growth was very reduced during the first six months, but increased rapidly with the onset of rains in April and May. In the fertilized plants total dry matter (D.M.) increased until harvest at 11 months, while in unfertilized plants total dry matter production was less and actually decreased slightly during the last two months. Root growth was slow during the first six months, but increased rapidly in the second half of the growth cycle. At 11 months, fresh root yield was 11.0 t/ha for unfertilized and 22.8 t/ha for fertilized plants. Figure 3 shows the dynamics of dry matter distribution between roots, stem, leaves and fallen leaves for fertilized plants. Initially, leaf growth predominated; however, during the dry season most of the leaves fell. At the onset of rains there was a very rapid regrowth of leaves, reaching a maximum of 238 gm/plant in one month, followed by rapid growth of roots and stem.

Figure 4 shows the change in nutrient concentration in youngest fully expanded leaf (YFEL) blades. Concentrations of N, P and K decreased during the dry season and increased markedly at the onset of rains, reaching a maximum at the sixth month. During the seventh month nutrient absorption rates still increased but the sudden increase in growth (especially leaves) resulted in a decrease in nutrient concentrations in YFEL-blades. It is clear that due to these drastic changes in nutrient concentrations, for diagnostic purposes leaves should not be sampled during the dry season, nor during the first two months of rain, but rather at reinitiation of leaf fall,at about the eighth month, or three months after the start of the rainy season. Even at this time, leaf analysis in this trial did not give a good indication of nutrient deficiency (Figure. 2).

Figure 5 shows the effect of dry and wet season on total root length, on Vesicular arbuscular mycorrhiza, VAM-infection and spore numbers. Root length in the top 20 cm of soil decreased during the dry season, while the % VAM infection initially increased up to the third month and then decreased due to drought. Spore numbers, on the other hand, increased markedly during the dry season. During the first two months of rain, root length in the top 20 cms increased from 1.2 to 37 meters/plant, after which it decreased markedly again. At the same time, the percentage of root infection increased from 5 to nearly 25%. Thus, at the end of May plants had on the average about 7.5 meters of VAM infected roots. This increase in root infection was accompanied by a marked decrease in spore numbers as spores germinated in response to

increased root activity. Following this flush of top and root growth at the beginning of the rainy season, root growth and VAM infection decreased, while spore numbers again increased. Towards the end of the rainy season root length stabilized while percentage of infection again increased.

Figure 6 shows the changes in soil nutrient contents. Available P concentrations nearly doubled during the dry season both in fertilized and unfertilized plots. Fertilization with 1 t/ha of 10-20-20 resulted in an available P content of 38 ppm compared with 8 ppm without fertilization. Similarly, K contents increased during the dry season, while inorganic N initially decreased and then increased markedly towards the end of the dry season due to a build up of both NO_3 and NH_4-N. At the onset of rains at the end of April, N, P and K contents in the soil decreased rapidly due to leaching and increased plant growth and nutrient absorption.

After the flush of top and root growth, nutrient absorption leveled off or decreased. Nutrient levels in the soil more or less stabilized around the seventh to eighth month. Fertilized plots had consistently higher levels of P and K, while the effect on inorganic N had essentially disappeared after the sixth month. In unfertilized plots there was essentially no net change in available P, there was a slight build up of inorganic N and a considerable decline in exchangeable K during the course of one crop cycle. Only with the application of 167 kg K/ha did K contents in the soil return to their original level of 0.11 me/100 gm. At the time of harvest there was a total K absorption of 122 kg/ha, of which 66 kg were removed in the roots.

Long-term effect of cassava on soil fertility

A long term fertility trial, initiated in 1977 in CIAT-Quilichao, completed its seventh consecutive cassava crop. Main plots had a total of 35 treatments, three levels of N, P and K applied only in 1977 in all possible combinations and eight additional treatments which were applied annually with each crop. As of the sixth crop each plot was divided in two, with one half refertilized annually and the other half without further applications. Figure 7 shows the average response of CMC 40 to application of N, P, and K, either the residual effect of fertilizers applied in 1977 or after reapplication in the 6th and 7th year. During seven years of continuous cassava cropping the initial fertilizer application had completely lost its residual effect. The yield of the absolute check was 17 t/ha, down from 31 t/ha in the second crop. Reapplication of fertilizers in the 6th and 7th crop resulted in a small response to N and P, and a very significant response to K. Potassium application with the last two crops increased yields from 23.0 to 43.7 t/ha. There was a good relation between the K content of YFEL-blades at 4 months and final root yield, maximum yields being obtained with more than 1.5% K in YFEL-blades.

Figure 8 shows that the reapplication of fertilizers in the 6th and 7th year completely restored the productivity of the soil, exhausted of K after 5 consecutive cassava crops with only one fertilizer application in 1977. On the other hand, the lack of fertilizers in the 6th and 7th year after five annual applications resulted in a drastic yield decline,

especially at the intermediate level of application. Thus, to maintain high cassava yields in soils low in K-supplying minerals, it is essential to reapply K with every planting, since a root yield of 40-45 t/ha extracts at least 150 kg K in the root harvest. On the other hand, once the P content of the soil is brought up above the critical level of 4-6 ppm, this element is not depleted to a great extent by leaching or plant uptake and future applications can be greatly reduced while maintaining productivity.

Similar results were obtained in two N, P, K, trials, located side by side in CIAT-Quilichao, one in an annually fertilized soil and one in a soil exhausted by four consecutive regional trials without fertilization. Figure 9A shows that in the exhausted soil there was a small but non-significant response to application of N and P, and a highly significant response to K, which increased yields from 15.7 to 36.4 t/ha. With the second year application of 100 kg K/ha, the productivity was almost as high as in the continuously fertilized soil (Figure 9B), which produced yields of about 40 t/ha. On the other hand, the lack of K application in these fertilized plots reduced yields to 36 t/ha in the first year and to 27 t/ha in the second year. Thus, again K is the critical element for cassava grown continuously on acid infertile soils with low K supplying power.

Cassava farmers traditionally try to maintain soil fertility by leaving plots in fallow for 5-10 years after 1-2 crops of cassava, after which they cut and burn the vegetation to plant another 1-2 crops of cassava without fertilizer application. Thus, they rotate cassava plots continuously, clearing and burning new plots every year, often cut of necessity, on very steep slopes, causing severe erosion.

The Cassava Economics section has studied the effect of fallowing by planting three consecutive cassava crops, with various levels of fertilization in seven different farms in the Mondomo area on plots that had 1-2, 4-5, 7-10 or more than 15 years of fallow before the first cassava crop. Figure 10 shows that the length of fallow had no significant effect on yield in any of the three plantings. In fact, in the first two plantings the shortest fallow period produced the highest yield of unfertilized cassava. Thus, it appears that on these extremely infertile and eroded soils the regrowth of weeds and bushes does not accumulate sufficient nutrients to have a significant effect on the following cassava crop. Application of P, especially as triple superphosphate (TSP), markedly increased yields, but these yield increases were even more pronounced in combination with an annual application of 100 kg/ha of N and K. Figure 11 shows the average yield response to P in the seven locations during the three consecutive plantings (in presence of N and K). Maximum yields were obtained with the application of 50 kg P/ha as TSP, but in the third year there was only a significant response up to 25 kg P/ha. Huila rock phosphate was much less effective than TSP in the first two years, but its effectiveness approached that of TSP in the third year. Also, with adequate fertilization (100 kg N, 25 kg P, 100 kg K/ha) cassava yields increased year after year due to improved soil fertility and probably a better mycorrhizal population. Thus, it is clear that in these highly infertile soils the traditional fallow system cannot maintain soil fertility and sustain high yields, while annual

fertilizer applications improve soil fertility and increase yields when cassava is grown for several years in the same plots. By intensification of crop management, especially fertilization, cassava can be grown almost continuously on the most productive and flattest fields, leaving steep slopes in permanent pasture or forest vegetation. Under these conditions yields as high as 60 t/ha have been obtained in the fourth year of continuous cropping with fertilization in Mondomo, compared with 5-8 t/ha that farmers obtain with the traditional cassava-fallow rotations.

Use of Green Manures

An alternative to the cassava-fallow rotation would be to plant a green manure crop for one semester and incorporate the vegetative material into the soil before planting cassava. Unfortunately, many traditional green manure crops are susceptible to Al-toxicity in acid soils, requiring large lime inputs for optimum growth, while cassava requires no lime or only small applications. To test the tolerance of several green manure species to soil acidity 40 different accessions were grown in single rows at lime levels of 0, 0.5, 2 and 6 t/ha in CIAT-Quilichao.

The highest level of application increased pH from 4.1 to 4.4, while decreasing the Al saturation from 79 to 41 per cent. Figure 12 shows the lime response of 10 selected species. Crotalaria juncea, a highly productive green manure on slightly acid and neutral soils, was the most susceptible to soil acidity, responding markedly to lime application. Other Crotalaria species, such as C. spectabilis, C. mucronata, and several unidentified species were highly acid-soil tolerant as well as much more productive than C. juncea. Other highly tolerant materials include some Mucuna (formerly Styzolium) species, Cajanus cajan and Desmodium distortum, while Canavalia ensiformis and cowpea were very acid soil tolerant but not very productive. The most promising materials are being re-evaluated in larger plots in Quilichao and will also be tested in a cooler climate in Mondomo to evaluate their potential for improving soil fertility to replace the traditional fallow system of natural regrowth.

In the very sandy soils of Media Luna on the Colombian North Coast the response of cassava to fertilization have often been erratic and not very marked. To determine whether incorporation of green manures can replace or complement the effect of chemical fertilizers, a trial was planted with eight green manures in a soil with 82% sand, 16% clay and 2% silt, pH 5.3 and 0.5% organic matter, 6.5 ppm P and 0.06 me K/100 gm. After 2, 3, or 4 months the above ground vegetative material was chopped up and incorporated. Cassava was planted four months after the green manures, either without chemical fertilizers, with 500 kg/ha 15-15-15 band applied at planting, or with foliar application of Nitrofoska at 60, 90 and 120 days after planting.

Table 5 shows the production of dry matter by the various green manures and the effect on soil chemical characteristics two months after incorporation of the green manures. Indigophera and peanut were most productive, followed by the native weeds, consisting of tall grasses and many creeping legumes. The latter had a marked effect on the inorganic N content of the soil, while also slightly improving the exchangeable K content. Canavalia ensiformis (sword bean) was intermediately productive

but had the greatest effect on the level of inorganic N, P and K, as well as Ca and Mg. The check plots, from which weeds were removed before planting, had the lowest levels of NO_3 - N, K, Ca and Mg.

Figure 13 shows the effect of the green manures on cassava yield in combination with the three fertilizer treatments. In both cassava varieties, but especially in the highly productive variety M Ven 25, there was a significant response to the green manure treatments in the absence of soil applied fertilizers. When fertilizers were applied yields increased from 19.5 to 34.3 t/ha without any further increase due to green manures. Foliar NPK applications (Nitrofoska) slightly increased yields to 22.9 t/ha but some green manures increased these yields up to 34.1 t/ha. In the absence of any chemical fertilizers, the incorporation of native weeds, or some green manures such as Canavalia, peanut and velvet bean increased yields from 19.5 to as much as 34.4 t/ha. Thus, on this sandy low O.M. soil the incorporation of the local weeds or some green manures can markedly increase yields to the same levels as those obtained with chemical fertilizers applied to the soil; foliar applications were not very effective. Of the green manures, Canavalia ensiformis had the greatest effect on soil fertility and cassava yield, while Crotalaria juncea was least productive and least effective.

Effect of Chemical Fertilizers in Media Luna

On the same sandy soil described above, another trial was planted with the same two varieties to evaluate several alternatives of chemical fertilizers. Figure 14 shows the response to several levels of 15-15-15, band applied at planting, as well as some other alternative sources and methods of fertilizer application. Again M Ven 25, planted with stakes from CIAT, produced much higher yields than M Col 2215, planted with locally produced stakes. There was a significant response up to 750 kg/ha of 15-15-15 with a negative response to higher applications in the case of M Ven 25. Highest yields, however, were obtained with a combination of 500 kg/ha soil applied 15-15-15 and three foliar applications of urea at 60, 90 and 120 days. There was a good response to application of 75 kg N/ha to the soil as urea, but no response to application of P and only a minor response to K. Foliar application by itself with either urea, KNO_3 or Nitrofoska had no significant effect on yield. Thus, on the sandy soils of Media Luna high cassava yields can be obtained using good planting material of high-yielding varieties and an intermediate application of urea or 15-15-15 to the soil, possibly in addition to foliar applications with urea.

Soil Management for Erosion Control in Cassava

When cassava is grown on steep slopes special precautions should be taken to prevent soil erosion. Due to its wide planting distance and slow establishment, a large percentage of the soil surface remains exposed after planting, which often results in severe soil losses due to water erosion.

In two previous trials (see CIAT Cassava Program, Annual Reports 1982, 1983) maximum soil losses of 105 and 36 t/ha were reported, while

erosion was markedly reduced by the application of mulch, by minimum or zero tillage, by fertilization and the planting of live barriers.

This year a third trial compared in more detail the effect of land preparation, methods of weed control, intercrops or live barriers, and the use of fertilizers on erosion and cassava yield. The methodology was essentially the same as that described in 1982 and 1983.

Table 6 shows the effect of treatments on soil loss and yield. While the trial was planted on a steep slope of 40% and rainfall was abundant throughout the year (2421 mm in 14 months) soil erosion was minimal, reaching a maximum of 3.71 t/ha in 13 months. This is due to a rather stable soil (a silt loam with 11% O.M.), and minimum soil preparation of one pass with an oxen-drawn plow, which left a rough blocky surface. When soil preparation was even further reduced, such as hand preparation of 1 meter wide strips, alternated with unprepared strips, or by planting without any preparation, soil losses declined even more. These treatments had a slight negative effect on yield. Yields in general were very low because of severe weed competition, as weeds were controlled only by machete (eight cuts).

When weeds were controlled with herbicides or by hoeing (4 weedings), increased slightly but yields improved markedly. Thus, in cassava, adequate weed control, generally with herbicides and hoe, is extremely important. Live barriers of lemon grass, Phaseolus beans, and Imperial (Axonopus escoparius) or Brachiaria decumbens grass also markedly decreased erosion, while having some negative effect on yield. Beans were grown in double rows between double rows of cassava, and were fertilized with 2 t/ha of lime and 750 kg/ha of 10-30-10. Growth was vigorous and the yield of BAT 1297 was 649 kg/ha. The barrier of Imperial grass was highly effective in controlling erosion and the cut-and-carry forage can be used to feed a horse or cow. As in previous trials, the use of fertilizers decreased soil erosion by providing a more rapid soil cover. Fertilization also had a most dramatic effect on yields, which increased from 0.3 to 9.3 t/ha. Thus, it may be concluded that by the use of simple agronomic practices, such as fertilization, minimum tillage, live barriers or intercrops, erosion can be reduced to very acceptable levels, while at the same time maintaining or increasing cassava yields.

Cassava Forage Production

While cassava roots contain only about 2.3% crude protein, the tops, and especially the upper leaves, may contain as much as 25-30% protein, which is higher than alfalfa and most other forage legumes. Thus, there may be great potential for using cassava tops as supplemental forage for animals, or young cassava leaves as a vegetable for human consumption. To determine the dry matter and protein production potential two trials were established, one in Carimagua and one in Quilichao. In each location four vigorous and well-adapted varieties were planted, each at four planting distances of 70x70, 60x60, 50x50, and 40x40 cm corresponding to populations of 20.4, 27.8, 40.0 and 62.5 thousand plants/ha.

Plants were fertilized with 1 t/ha of 15-15-15, band applied at planting. The unlignified part of the tops were cut every 3-4 months, or when the first bottom leaves started to fall. Figure 15 shows the total dry matter and crude protein production in 3 cuts during 13 months in Carimagua. Of the four varieties CM 507-37 produced the highest average yield of 4.3 t dry matter/ha, with a crude protein production of 0.89 t/ha. The average crude protein content decreased from 25% in the first to 21% in the third cut. Due to the long dry season in Carimagua there was a six month interval between the second and third cut. The best planting distance was 60x60 cm and there was no beneficial effect in further increasing the plant population.

Figure 16 shows similar data for CIAT-Quilichao, in this case the sum of seven cuts during 24 months, as well as the final root harvest. Highest total dry forage production of nearly 24 t/ha was obtained with the variety Regional Amarilla, planted at 60x60 cm, closely followed by CMC-92 at the same planting distance. Both are cold-climate varieties which produce extremely vigorous top growth when planted at lower elevations. Much less productive were the warm-climate varieties HMC 2 and CMC 40, which did not have the same capacity to resprout quickly after each cut. However, those varieties less productive in forage production were more productive in root yield, especially HMC 2 which produced as much as 52 t/ha fresh roots as well as 16 t/ha of dry forage in two years. Figure 17 shows that the quantity and quality of forage production is highly dependent on rainfall. During the dry seasons dry matter production decreased while the crude protein content increased, while the opposite occured during the wet season. Only during the last cut was there both a decrease in dry matter production and protein content. Thus, while dry matter production varied according to wet and dry seasons, the amount of crude protein produced was fairly constant throughout the year. Total crude protein production varied from 2.0 t/ha with CMC 40 to 3.67 t/ha with Regional Amarilla in a two-year period. The latter level of productivity is close to that of well managed alfalfa in the U.S. (where maximum yields of 4 t/ha of crude protein have been obtained in one year). While this trial was harvested after two years, there is no reason to believe that forage production can not continue for one or more years without having to replant. With the application of 1 t/ha of 15-15-15 at planting, there was no indication of soil exhaustion, as the soil nutrient levels had actually increased after two years.

It may be concluded that varieties differ greatly in their ability to withstand continuous cuttings, and that some cold-climate varieties seem very promising for cassava forage production. A plant population of 28,000 plants/ha, planted at 60x60 cm, was the most productive in both Carimagua and Quilichao. No replanting may be necessary for several years.

Effect of Mycorrhiza

Greenhouse trials were conducted to determine the effectiveness of mycorrhizal strains, the effect of soil acidity, and the development of mycorrhizal infection in cassava.

a) Effectiveness of mycorrhizal strains.

The effectiveness of 15 strains from the CIAT mycorrhizal collection

was evaluated by inoculating rooted cassava plantlets grown in sterilized Quilichao soil. The soil was fertilized with 50 kg P/ha as incorporated Huila rockphosphate. After 2-1/2 months plants were harvested. Table 7 shows the total dry weight produced (tops + fibrous and thickened roots), the total fibrous root length, and percentage infection. Most effective in increasing dry matter production were two Glomus species (C-1-1 and C-3-16) followed by two ecotypes of Entrophospora colombiana (C-24-5 and C-25-6).

These species were also effective in increasing root length and root infection. In general, there was a highly significant correlation between dry matter production of tops and either total root length (r=0.78) or percentage infection (r=0.66).

b) Effect of soil acidity.

Two soils, from Carimagua and Quilichao, were incubated with different levels of elemental sulphur (S) and lime to decrease and increase, respectively, the natural pH of the soil. Figure 18 shows the effect of these soil amendments on pH and exchangeable Al content. Application of 2 t/ha of S decreased the pH of the Carimagua soil to 3.7 and increased the Al content to 7.6 me/100 gm. Both S and lime applications had a more marked effect on pH and Al in the Carimagua than the Quilichao soil, indicating the greater buffer capacity of the latter due to its high organic matter content.

Figure 19 shows the dry matter production of tops of two month old cassava plants inoculated with four VAM strains and grown in sterilized soil. Dry matter production was seriously affected by both low and high pH, the latter mainly due to induction of severe Zn deficiency. Maximum dry matter production was generally attained at pH 4.8-5.0. C-1-1 and C-10 were relatively tolerant of severe soil acidity (pH 4.5) and were the most effective species in most of the pH range studied. Acaulospora mellea (C-15-2) was quite tolerant of low pH but not as effective as C-1-1 and C-10 at higher pH. C-30-1 was quite ineffective at low pH and the only of medium effectivity at higher pH (pH 5). Figure 20 shows that percentage of root infection was equally dependent on soil pH in both soils, but that this relation varied for each VAM species. From this relationship the following critical pH values for VAM infection were determined for each species; 4.4 for C-1-1, 4.5 for C-15-2 and 4.8 for C-10. While all these three species are well adapted to acid soils, C-1-1 (Glomus manihotis) seems to have the greatest tolerance. Glomus mosseae (C-30-1) was not at all adapted and its percentage of infection was not well correlated with soil pH. In the three tolerant species per centage of infection was better correlated with soil pH than with percentage of Al saturation or Ca content.

c) Development of root infection

Plantlets of M Ven 77 were either inoculated with C-1-1 or not inoculated, and grown for 12 weeks in unsterilized Quilichao soil. Every 1 or 2 weeks some plants were harvested and roots were observed under the microscope for the presence of hyphae, vesicles

or arbuscles. Figure 21A shows that VAM infection had already initiated after one week as indicated by the presence of hyphae. Infection by hyphae increased every week, reaching a maximum of 94% at seven weeks after which it declined slightly. Vesicle infection initiated after two weeks and that of arbuscles after three. Both reached a maximum infection of 70-80% after 6-7 weeks, after which it either declined or remained approximately constant.

Length of fibrous roots increased sigmoidally during the first eight weeks, reaching a maximum of 70 meters/plant after which it slightly declined. At this time about 90% of the root system was infected with hyphae, about 60-70% with vesicles and 75-80% with arbuscles.

Spore numbers declined consistently during the first six weeks, while t he roots became infected. Once roots were almost totally infected the reproductive phase reinitiated with formation of new spores.

Three field experiments were conducted on the effect of mycorrhizal inoculation, one in Mondomo and two in Carimagua. In Mondomo, the efficiency of seven strains was tested in a soil with ppm P to which either 0 or 50 kg P/ha was applied as TSP. The soil had been in cassava for two years followed by one year of various green manure legumes and weeds. The average yield of the local variety Sata Dovio was 18.4 t/ha while that of the ICA hybrid HMC 2 was 58.8 t/ha. There was neither a response to P nor to mycorrhizal inoculation, since both the fertility and native mycorrhizal population had been build up by previous croppings and fertilization.

In Carimagua, the efficiency of 14 strains was evaluated in a soil with 1.3 ppm P to which 100 kg P/ha was applied as Huila rock phosphate. Inoculation generally increased yields of both varieties, M Ven 77 and M Ecu 82. However, only in M Ecu 82 was the inoculation effect significant (Figure 22). Inoculation with strain C-4-8 (Acaulospora sp.) increased yields 47% from 9.9 to 14.6 t/ha. Thus, in an infertile soil with low native mycorrhyzal populations (only 46 spores /100 gr at 4 months after planting), yields tend to be low, but these can be significantly increased by mycorrhizal inoculation.

In another trial in Carimagua, different methods of inoculation with strain C-1-1 were evaluated, either with band applied TSP or broadcast basic slag, both applied at 100 kg P/ha. In both varieties (M Ven 77 and M Bra 5) incorporation of Huila rock phosphate was superior to banded TSP, but there was no inoculation treatment by P source interaction. Figure 23 shows that all methods of inoculation increased yields compared with the uninoculated check, but that the use of soil inoculum (containing root pieces with hyphae and spores) was more effective than the use of only 2 or 10 gr of root inoculum. However, mixing 10 gr. of root inoculum with 100 gr of sand, to improve the spatial distribution of propagules under the stake, was as effective as the use of 200 or 500 gr of soil inoculum. Although root inoculum is more difficult to produce than soil inoculum it has the advantage that only 150 kilos per hectare would have to be transported, compared with 3.1 ton when using 200 gr per

plant of soil inoculum. The other alternative of producing inoculum at the farm level is presently being investigated. This trial again showed that with an effective inoculation technique yields in Carimagua can be improved significantly (30%) by mycorrhizal inoculation.

TABLE 1. Cassava root yield and low P adaptation indices of the 20 most adapted and some standard varieties in a single row screening of 630 germplasm accessions in CIAT-Quilichao.

	Root Yield (kg/m^2)		Low P
	oP	75P	Adapt. index
CM 1794-1	10.5	11.3	9.71
M Col 720	6.2	12.2	6.20
M Col 1856	5.8	12.9	6.12
CM 2174-4	6.2	11.2	5.64
M Ven 118	6.5	10.4	5.53
M Bra 97	9.1	7.1	5.27
CM 996-6	5.3	11.9	5.16
M Col 188	8.3	7.5	5.08
M Bra 349	6.2	9.8	4.96
SM 301-3	7.0	8.5	4.84
M Col 1387	5.8	9.8	4.62
M Col 1185	7.2	7.8	4.58
CM 533-6	6.9	8.1	4.52
M Bra 304	7.1	7.7	4.46
M Per 206	5.4	10.0	4.43
M Col 2019	5.7	9.1	4.27
M Col 100A	7.3	7.0	4.17
CM 2368-4	4.8	10.1	3.98
M Col 86	5.7	8.5	3.92
M Col 679	5.7	8.3	3.87
M Col 22	2.1	2.1	0.34
CMC 40	1.5	5.1	0.63
M Col 1684	4.0	3.9	1.27
M Ven 77	2.9	4.5	1.06

[a] Low P adaptation index = $\frac{\text{Yield oP x yield 75P}}{\text{X yield oP x X yield 75P}}$

TABLE 2. Root yield and low P adaptation index of 13 varieties most adapted and two standard varieties in a screening of 77 germplasm accessions in CIAT-Quilichao.

Variety	Cassava root yield (t/ha) oP	75P	Low P Adapt. index[a]
M Ecu 68	50.2	57.1	2.30
M Bra 41	47.5	57.0	2.17
M Col 2061	49.5	44.7	1.78
M Bra 226	49.2	44.7	1.77
M Col 213	48.2	44.8	1.73
M Ven 205	48.3	42.8	1.66
M Bra 234	37.2	55.3	1.65
M Bra 278	41.1	47.8	1.58
M Ptr 8	40.7	48.3	1.58
M Col 118	40.1	46.3	1.49
M Ptr 26	41.1	44.4	1.47
M Col 346	39.8	45.5	1.45
M Col 157	41.4	43.2	1.44
M Col 1684	44.1	47.5	1.68
M Col 22	31.9	38.6	0.99

[a] Low P adaptation index = $\frac{\text{Yield oP x yield 75P}}{\bar{X}\text{ yield oP x }\bar{X}\text{ yield 75P}}$

TABLE 3. Effect of P application on the root yield of 20 cassava cultivars in Las Pilas[a], Mondomo, Cauca.

CULTIVAR	Root yield (t/ha) oP	Root yield (t/ha) 100 P	P adaptation Index[b]
Regional Negrita	5.1	26.6	2.90
Regional Amarilla	6.8	16.3	2.37
M Col 113	3.7	20.3	1.60
M Col 2019	2.9	24.1	1.50
Sata Dovio	3.3	20.3	1.43
Batata	3.4	17.6	1.28
CG 406-6	3.3	17.6	1.24
M Col 2016	3.7	15.4	1.22
CMC 92	2.6	21.2	1.18
CG 487-2	2.8	19.6	1.17
CG 401-3	2.5	21.5	1.15
Americana	2.5	19.3	1.03
Algodona	2.9	12.8	0.79
HMC 2	3.5	9.4	0.70
CG 406-5	2.2	14.6	0.68
CG 403-18	1.3	18.6	0.52
CG 354-2	1.5	13.3	0.43
Seleccion 40	1.9	5.8	0.23
M Col 2006	0.4	6.7	0.06
CMC 40	1.5	1.0	0.03
Average	2.9	16.1	

[a] Soil with 1.8 ppm P (Bray II)

[b] P adaptation index = $\frac{\text{Yield oP x yield 100P}}{\bar{X}\text{ yield oP x }\bar{X}\text{ yield 100P}}$

TABLE 4. Cassava yields and adaptation indices to low P and high acidity of the highly adapted and four standard varieties evaluated during 1984-85 in Carimagua.

Variety	Root Yield (t/ha)			Adaptation index to	
	oP	0 Lime	Lime + P	Low P	High acidity
M Bra 41	7.2	18.4	10.6	3.60	1.90
SM 301-3	5.1	17.1	13.4	3.19	2.23
CM 523-7	4.6	14.6	14.5	3.15	2.07
CM 507-37	4.6	13.9	14.3	3.10	1.92
CM 2298-3	6.1	16.8	9.8	2.80	1.60
CM 996-6	3.3	11.9	16.7	2.61	1.94
CM 2177-2	2.5	16.3	22.1	2.56	3.49
M Bra 5	3.6	21.2	14.2	2.43	2.93
M Bra 29	3.8	12.4	11.8	2.13	1.43
CM 2118-2	3.0	11.5	14.9	2.09	1.66
M Bra 20	2.9	19.7	15.4	2.07	2.95
M Bra 36	4.5	12.4	9.7	2.05	1.18
CMC 40	1.8	13.1	10.0	0.85	1.26
M Ven 77	2.9	14.3	11.0	1.48	1.53
M Col 1684	2.9	10.6	7.9	1.06	0.81
Llanera	0.1	3.2	2.1	0.01	0.06

TABLE 5. Dry matter (DM) production of several green manures and their effect on soil fertility two months after their incorporation in a sandy soil of Media Luna.

TREATMENT	Days to harvest	DM prod. t/ha	SOIL ANALYSES					
			ppm			me/100 grm		
			NH_4-N	NO_3-N	P	K	Ca	Mg
Check	-	-	3.5	1.5	5.7	.03	.40	.10
Native weeds	120	4.73	4.9	2.4	4.7	.05	.64	.22
Crotalaria juncea	60	1.71	3.4	1.7	4.8	.04	.50	.15
Cajanus cajan	120	3.93	3.3	1.9	6.8	.04	.47	.15
Canavalia ensiformis	90	3.29	4.6	2.6	7.3	.06	.71	.20
Vigna unguiculata	60	2.93	3.1	1.7	5.6	.04	.48	.15
Mucuna	90	2.50	3.3	2.1	6.3	.03	.45	.13
Indigofera	90	6.00	3.3	2.5	5.4	.04	.46	.14
Peanut	120	6.56	3.3	2.1	5.7	.05	.50	.17

TABLE 6. Effect of soil and crop management on erosion and yield.

	Soil loss[a] t/ha	Cassava yield[b] t/ha
A. Effect of land preparation:		
1) Planting holes	3.08	8.9
2) Oxen with reversible plot	2.96	9.3
3) Oxen with chisel plow	2.90	5.7
4) Preparation of 1 meter strips, leaving 1 meter without preparation	2.32	8.1
5) Without preparation	1.59	7.9
B. Effect of methods of weed control:		
1) With hoe	3.71	15.3
2) With herbicides	3.55	11.3
3) With machete	2.96	9.3
C. Effect of intercrop or live-barriers:		
1) No intercrop or barriers	2.96	9.3
2) Barriers of lemon grass	2.64	7.7
3) Intercropped with beans	2.16	7.8
4) Barriers of Imperial grass	1.88	7.0
5) Barriers of *Brachiaria decumbens*	1.82	6.2
D. Effect of fertilizers:		
1) Without fertilizers	3.50	0.3
2) With fertilizers	2.96	9.3

[a] Dry soil eroded during 13 months in cassava planted on 40% slope.

[b] Fresh root yield of Sata Dovio after 12 months.

TABLE 7. The effect of inoculation with different VAM strains on total dry matter (DM) production, root length and per cent root infection of cassava plants grown in sterilized Quilichao soil.

	DM. tops g/plant	Root length-m	% Infection
Native strains[a]	5.9	40	60
C-1-1 (Glomus manihotis)	20.3	96	76
C-3-16 (Glomus sp)	20.8	96	23
C-3-19 (Acaul. sp)	13.1	54	32
C-4-10 (Acaul. 007)	12.1	67	61
C-15-3 (Acaul. longula)	10.5	44	18
C-16-2 (Entr. colombiana)	7.5	41	38
C-19-4/5 (Glomus sp.)	7.0	52	44
C-19-6 (Acaul. appendicula)	4.3	17	33
C-20-4 (Acaul. 007)	10.6	111	47
C-20-5 (Acaul. sp.)	9.2	81	35
C-21 (Gigaspora margarita)	1.1	6	1
C-18-6 (Entr. colombiana)	1.0	5	1
C-24-1 (Acaul. morrowii)	8.4	44	36
C-24-5 (Entro. colombiana)	15.4	58	63
C-25-6 (Entr. colombiana)	18.8	58	86
Uninoculated check	1.8	10	0

[a] Uninoculated plants in unsterilized soil.

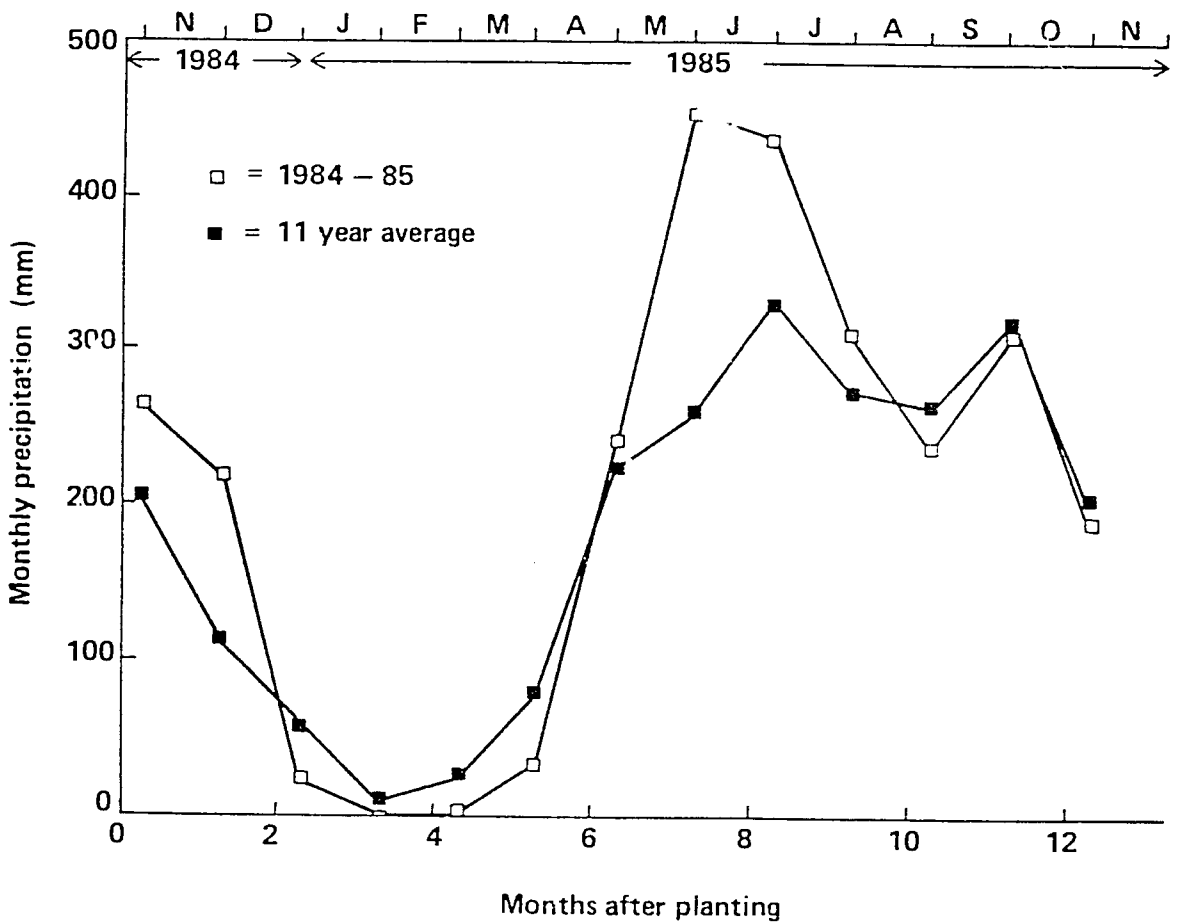


Figure 1. Monthly precipitation in 1984–85 growing season compared with the 11 year average in Carimagua, Colombia.

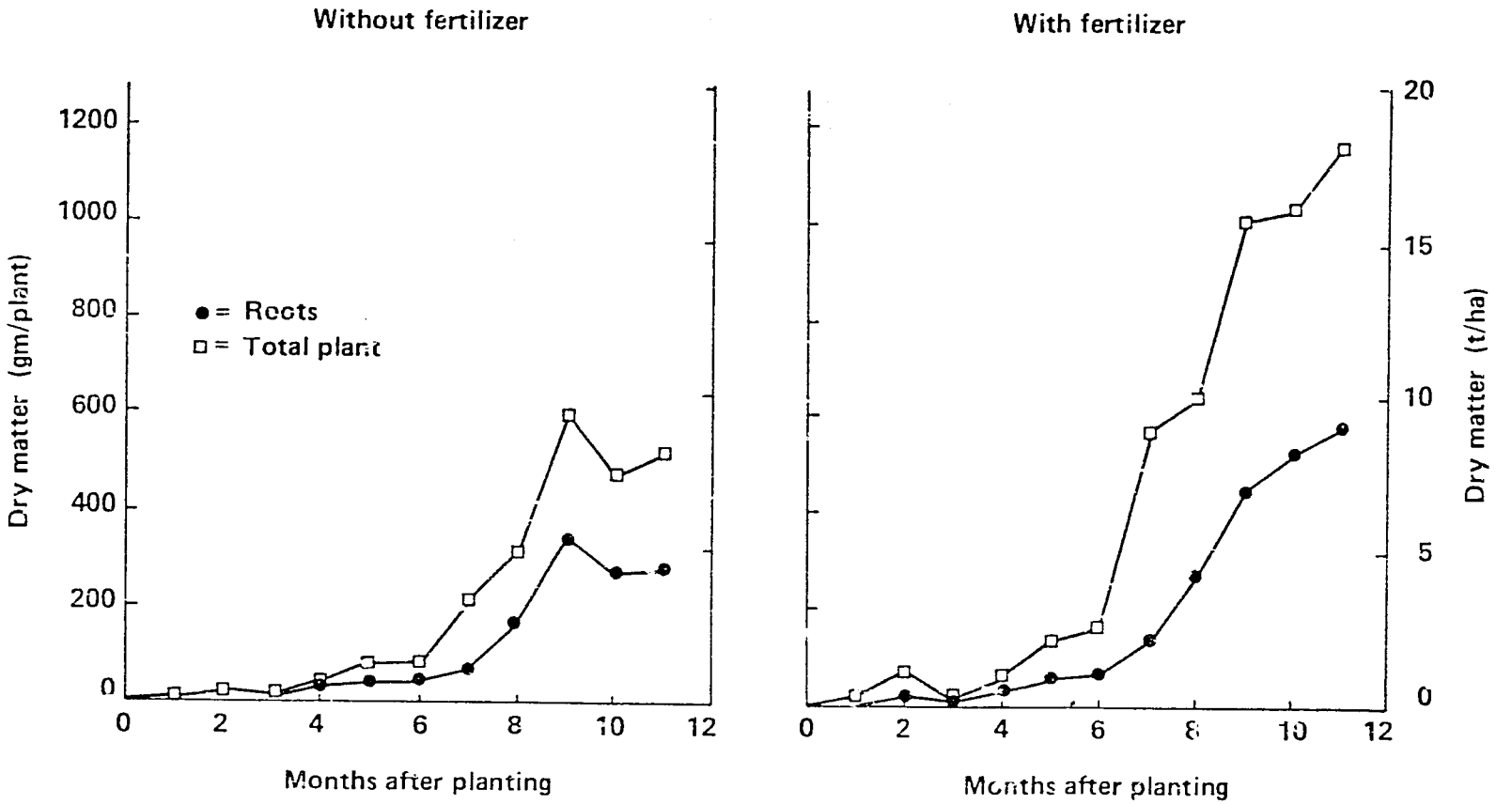


Figure 2. Total plant and root dry matter production during an 11-month growth cycle of cassava, M Ven 77, grown with and without fertilizers in Carimagua.

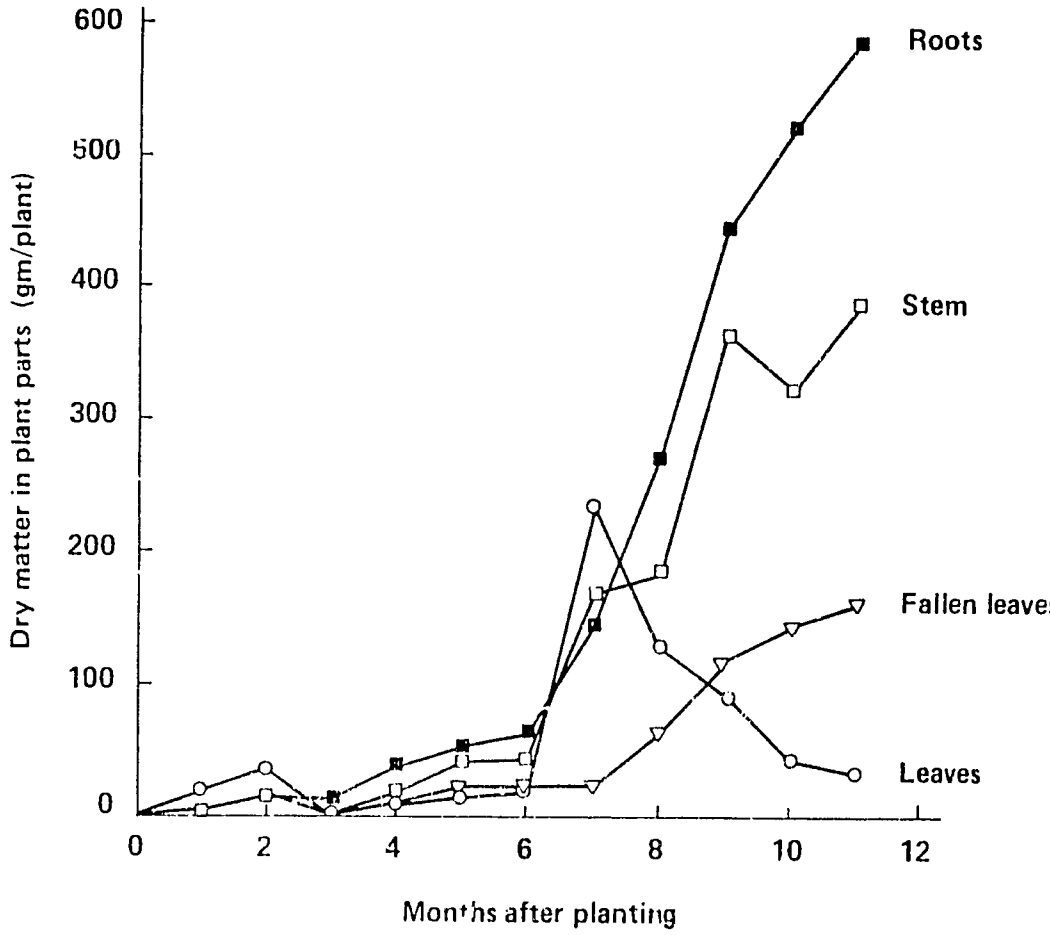


Figure 3. Dry matter distribution between different plant parts of cassava, M Ven 77, during an 11 month growth cycle in fertilized soil in Carimagua.

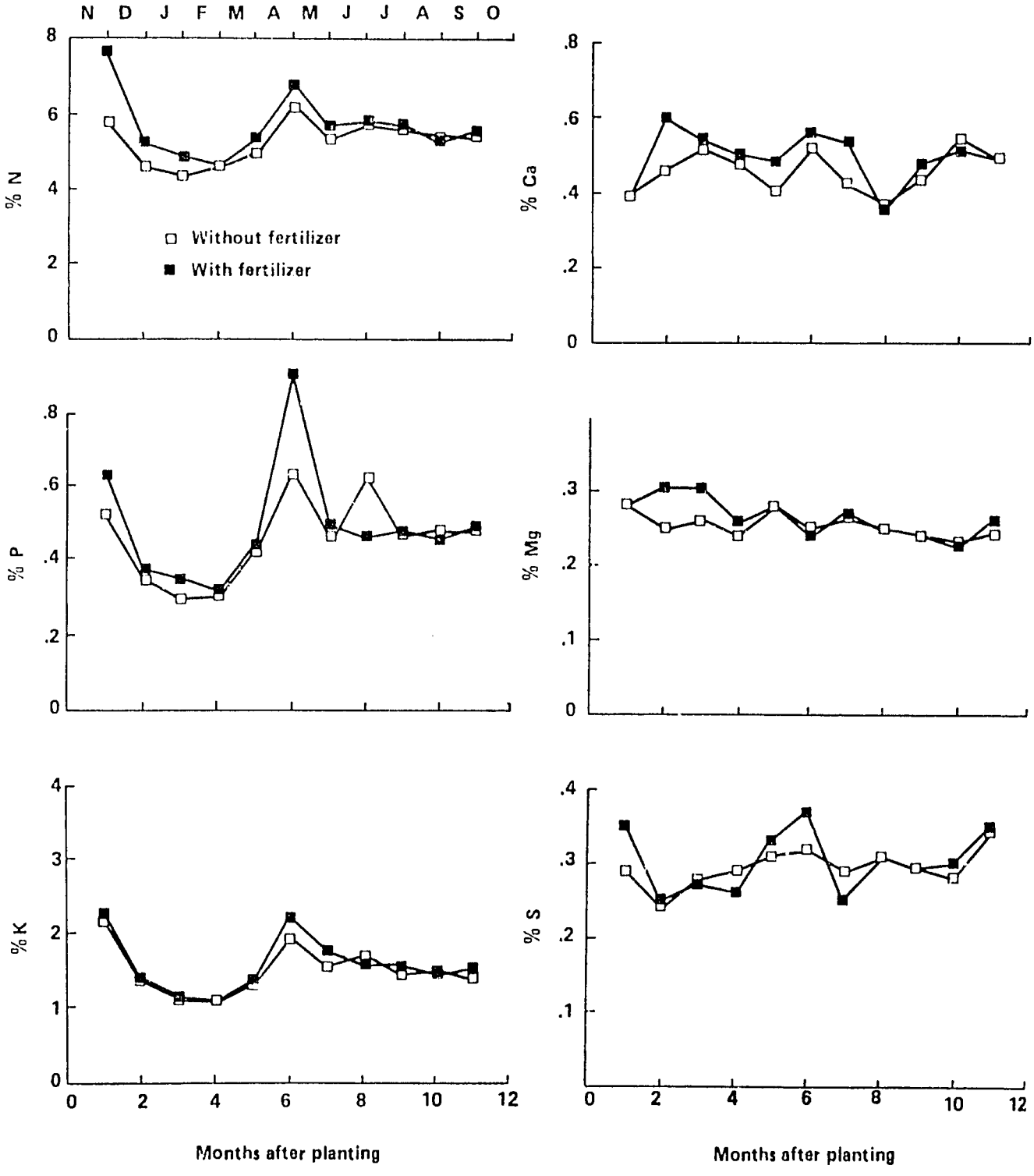


Figure 4. Change in nutrient concentrations in youngest fully expanded leaf-blades of cassava during an 11 month growth cycle in fertilized and unfertilized soil in Carimagua.

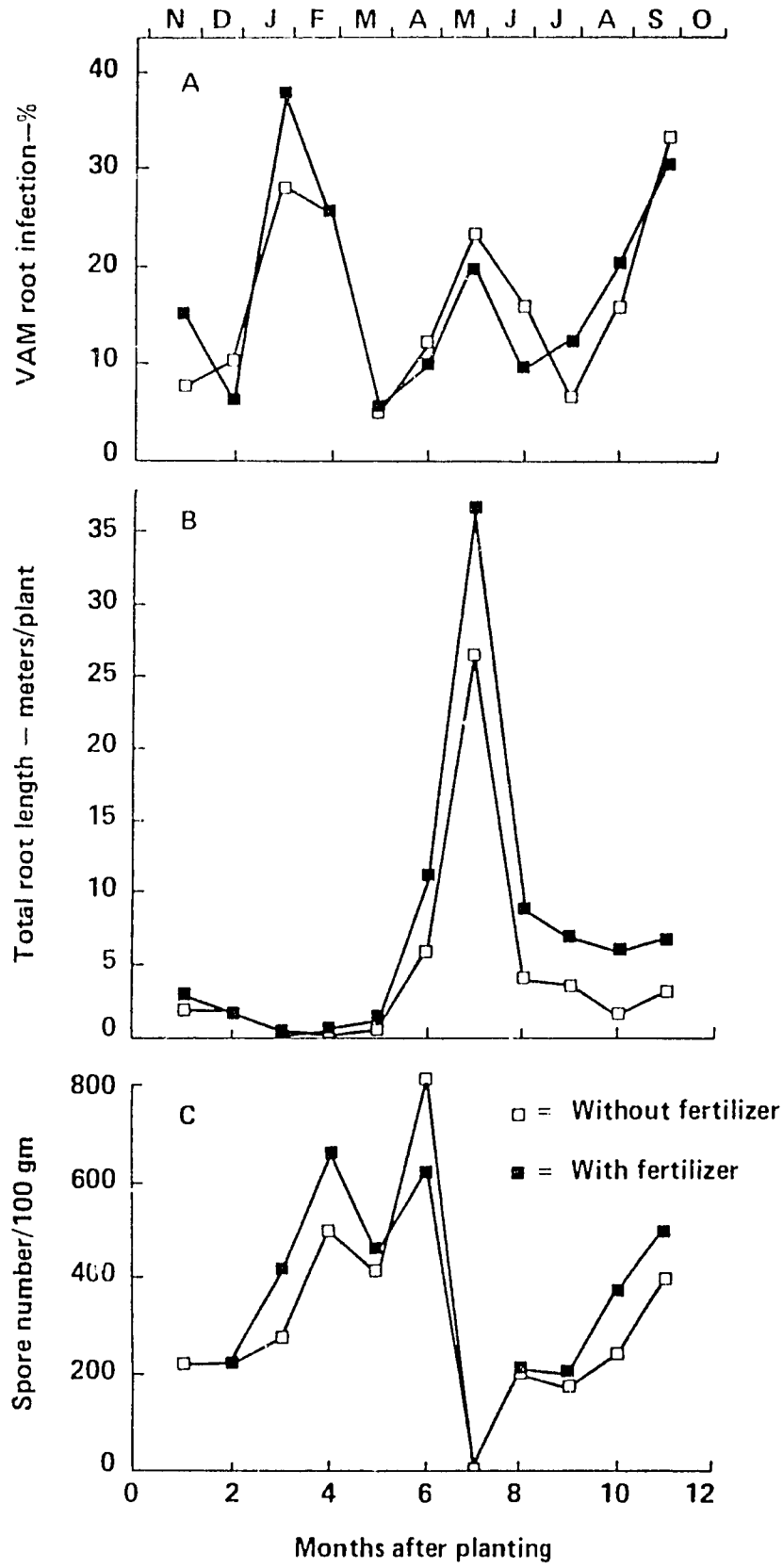


Figure 5. VAM root infection (A) and total root length (B) of cassava, M Ven 77, and the VAM spore numbers in soil (C) during an 11 month growth cycle in fertilized and unfertilized soil in Carimagua.

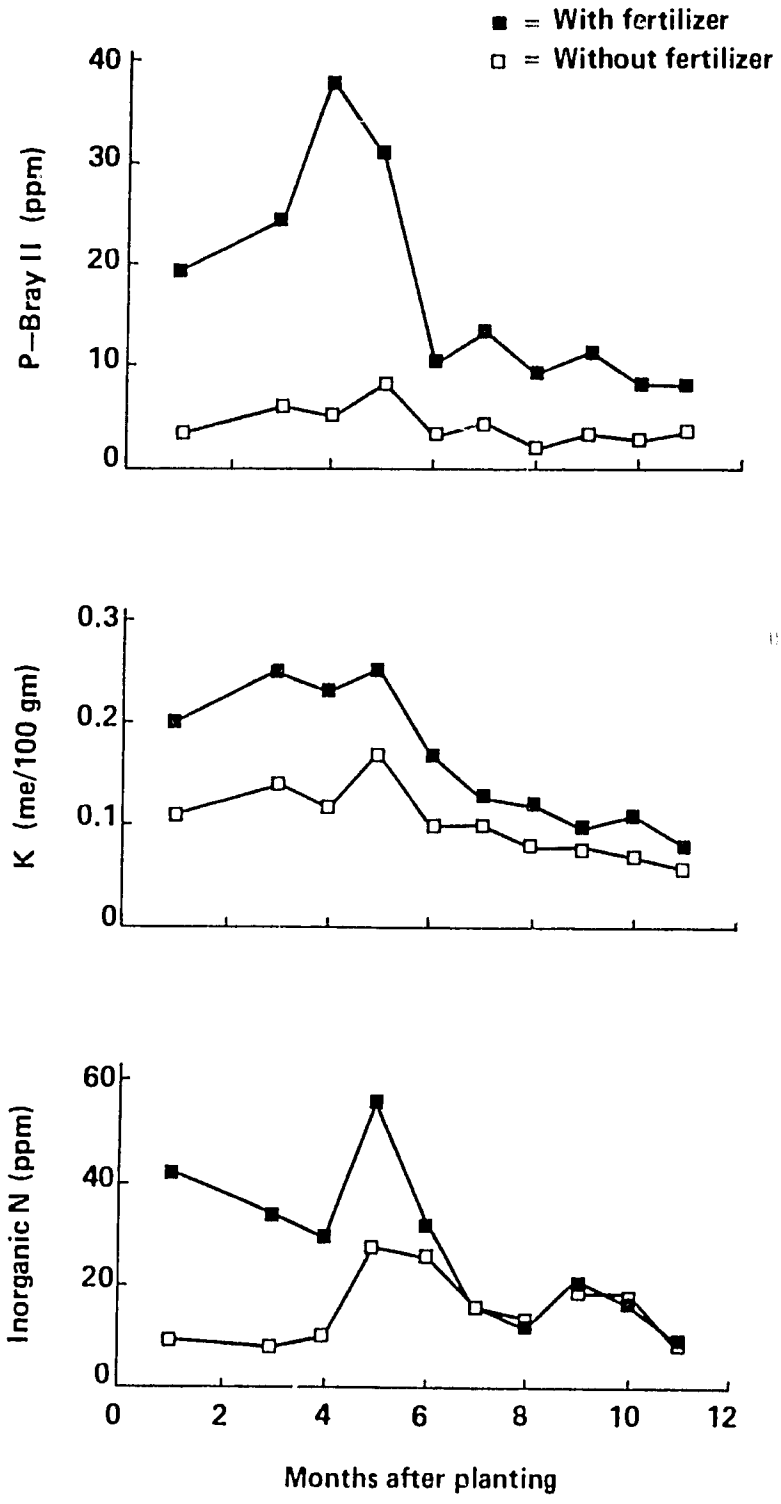


Figure 6. Changes in nutrient content of fertilized and unfertilized soil during an 11 month growth cycle of cassava, M Ven 77, in Carimagua.

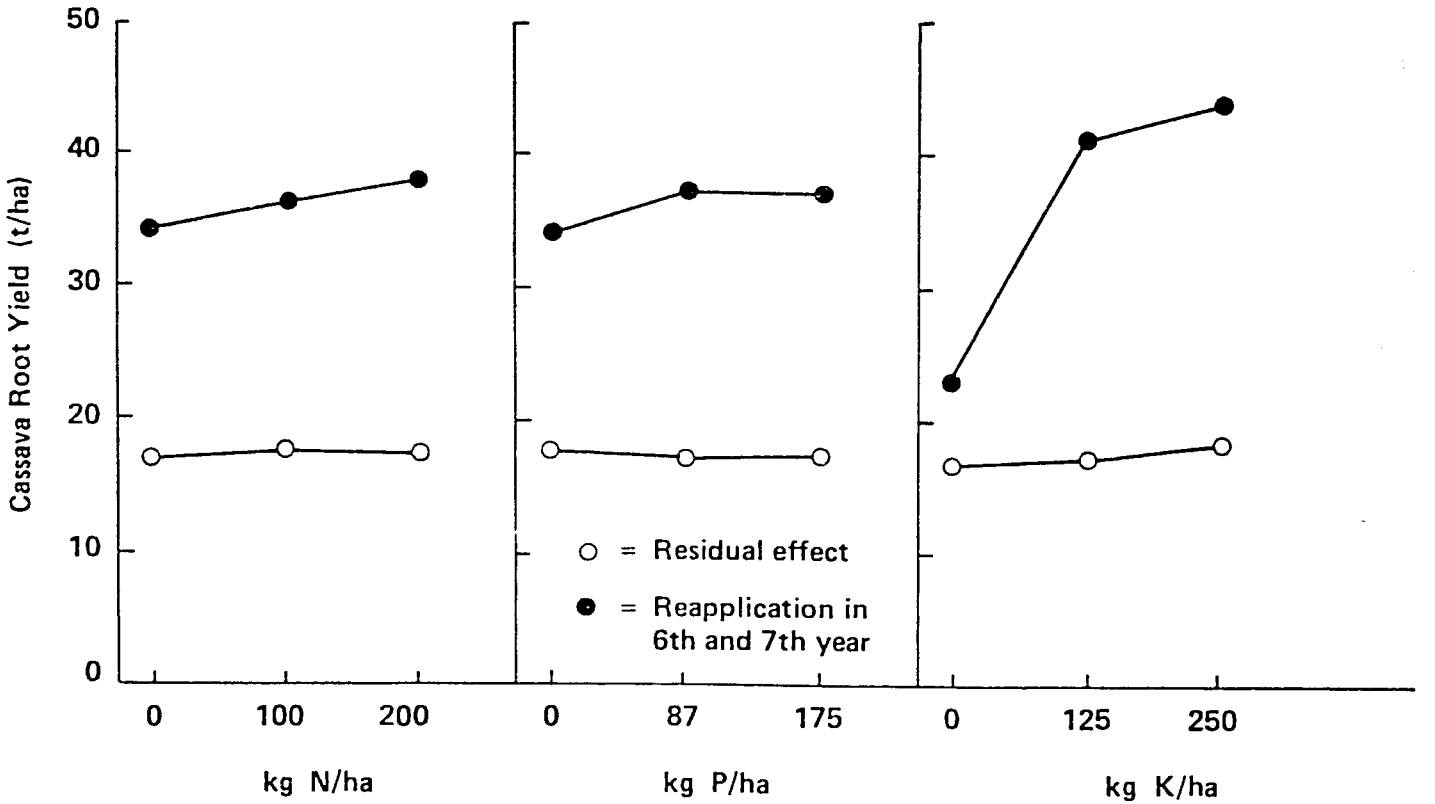


FIGURE 7. Average response of the seventh consecutive cassava crop to the residual effect of N, P and K applied with the first crop in 1977 and to that applied with the first, sixth and 7th crop in Quilichao.

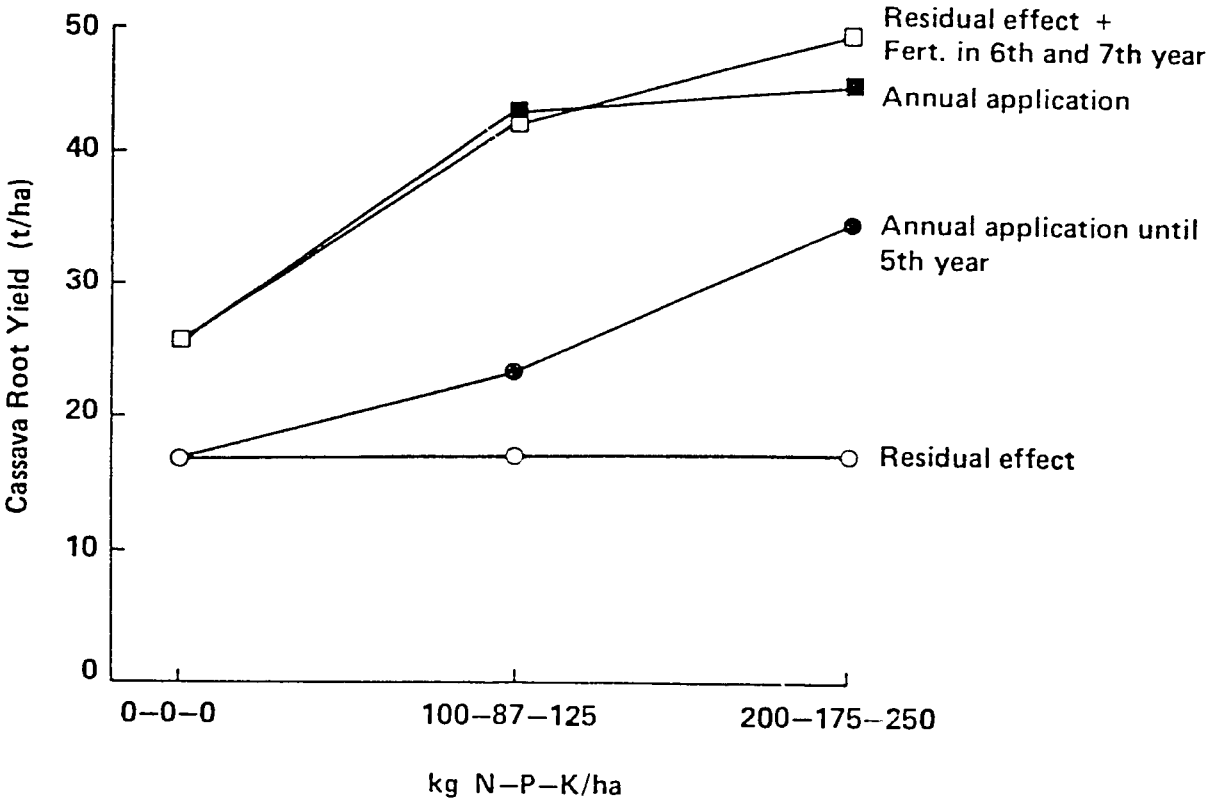


FIGURE 8. Response of the seventh consecutive cassava crop to three levels of N-P-K, applied either only with the first crop (residual effect); with the first, sixth and seventh crop; annually during the first five crops; or annually with all seven crops, in Quilichao.

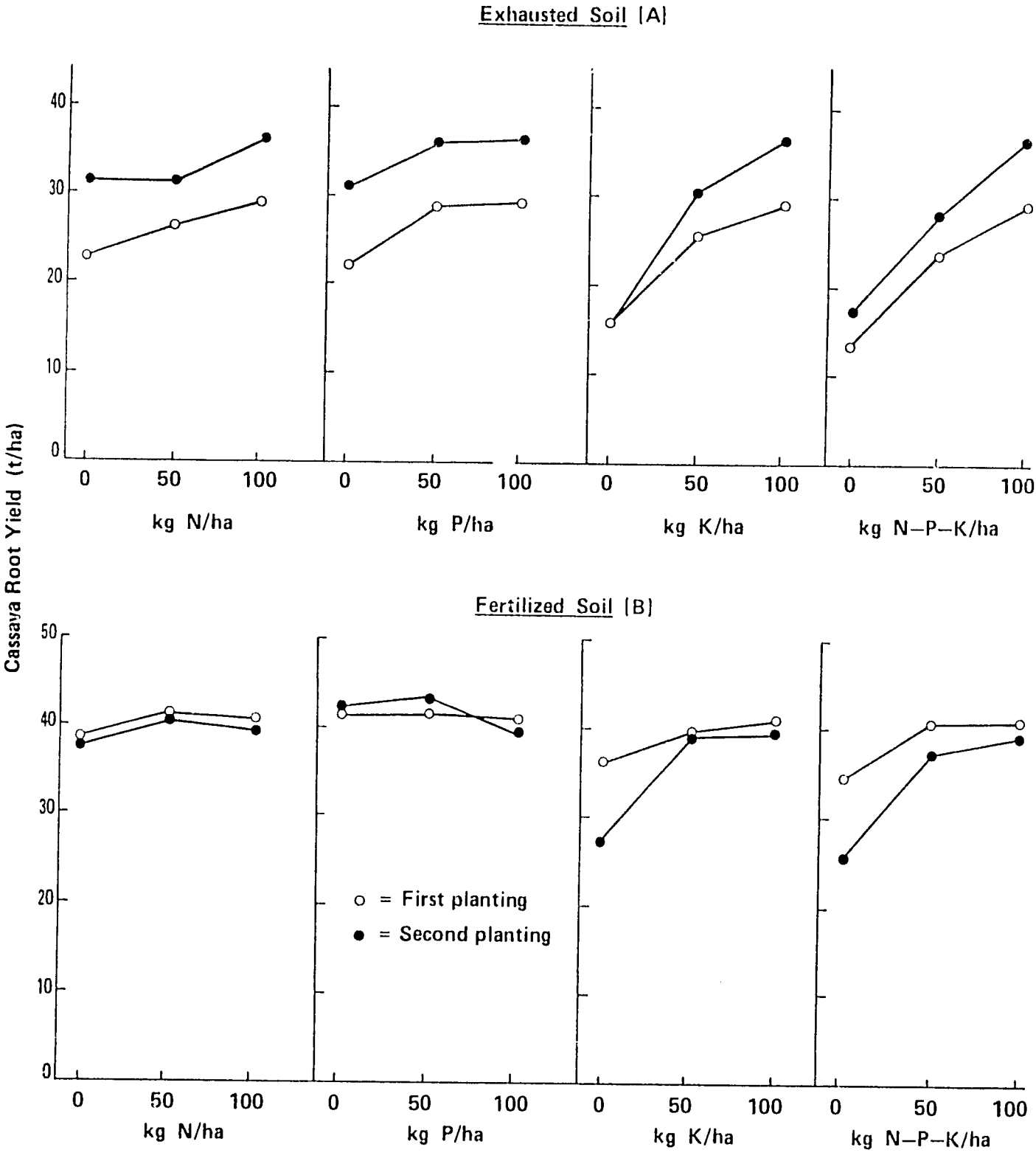


FIGURE 9. Response of two consecutive cassava crops to application of N, P, and K, both in a plot of exhausted soil (9A) and in a previously well-fertilized plot (9B) in Quilichao. Data are average yields of M Col 1684 and CM 91-3.

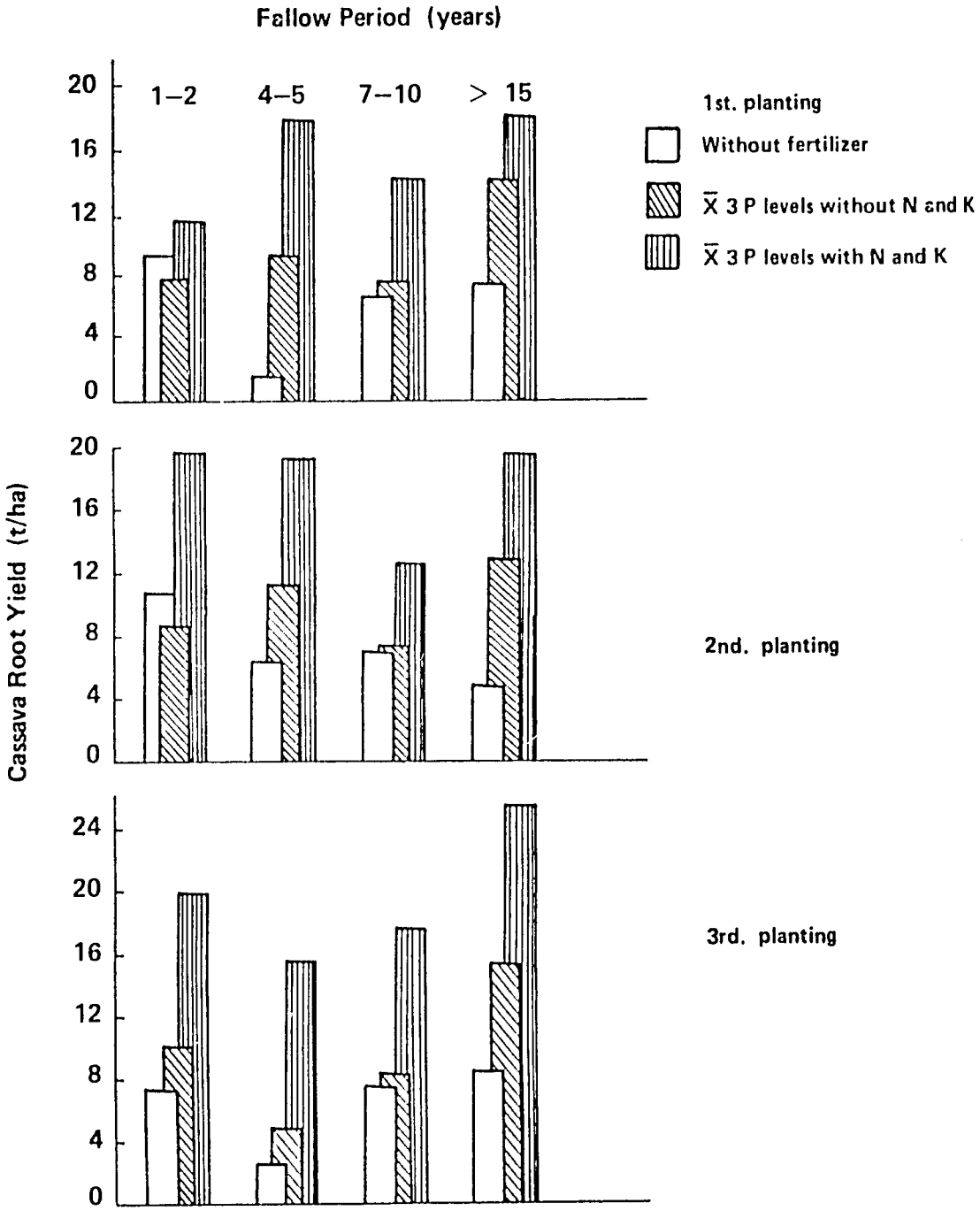


Figure 10. Effect of length of fallow period on yield of three consecutive cassava crops grown with various fertilizer treatments in the area of Mondomo, Cauca.

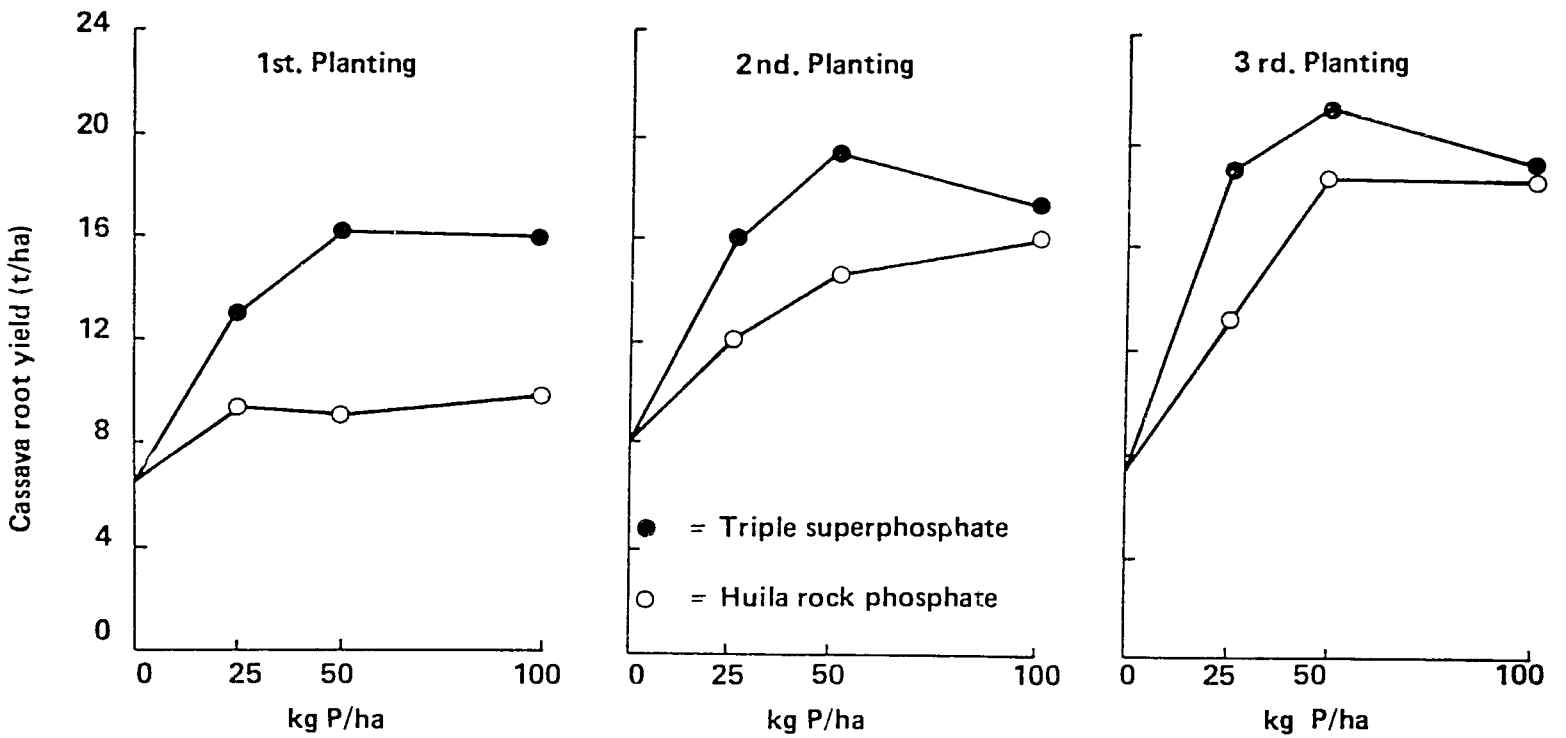


FIGURE 11. Response of three consecutive cassava crops to annual application of three levels and two sources of P application in combination with 100 kg/ha of N and K in the Mondomo region. Data are the average of seven different farms.

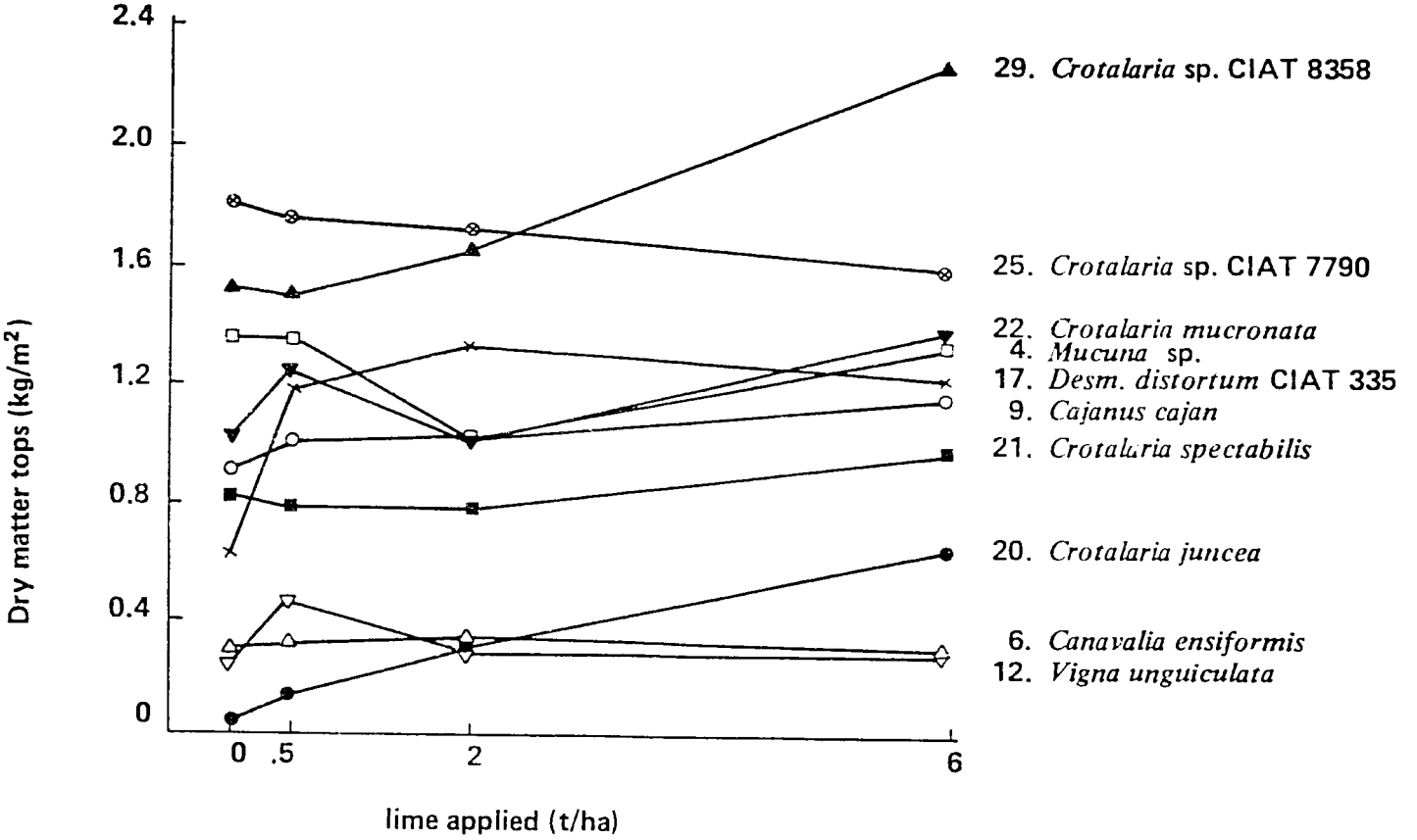


FIGURE 12. Dry matter response of several green manure species to lime application in Quilichao.

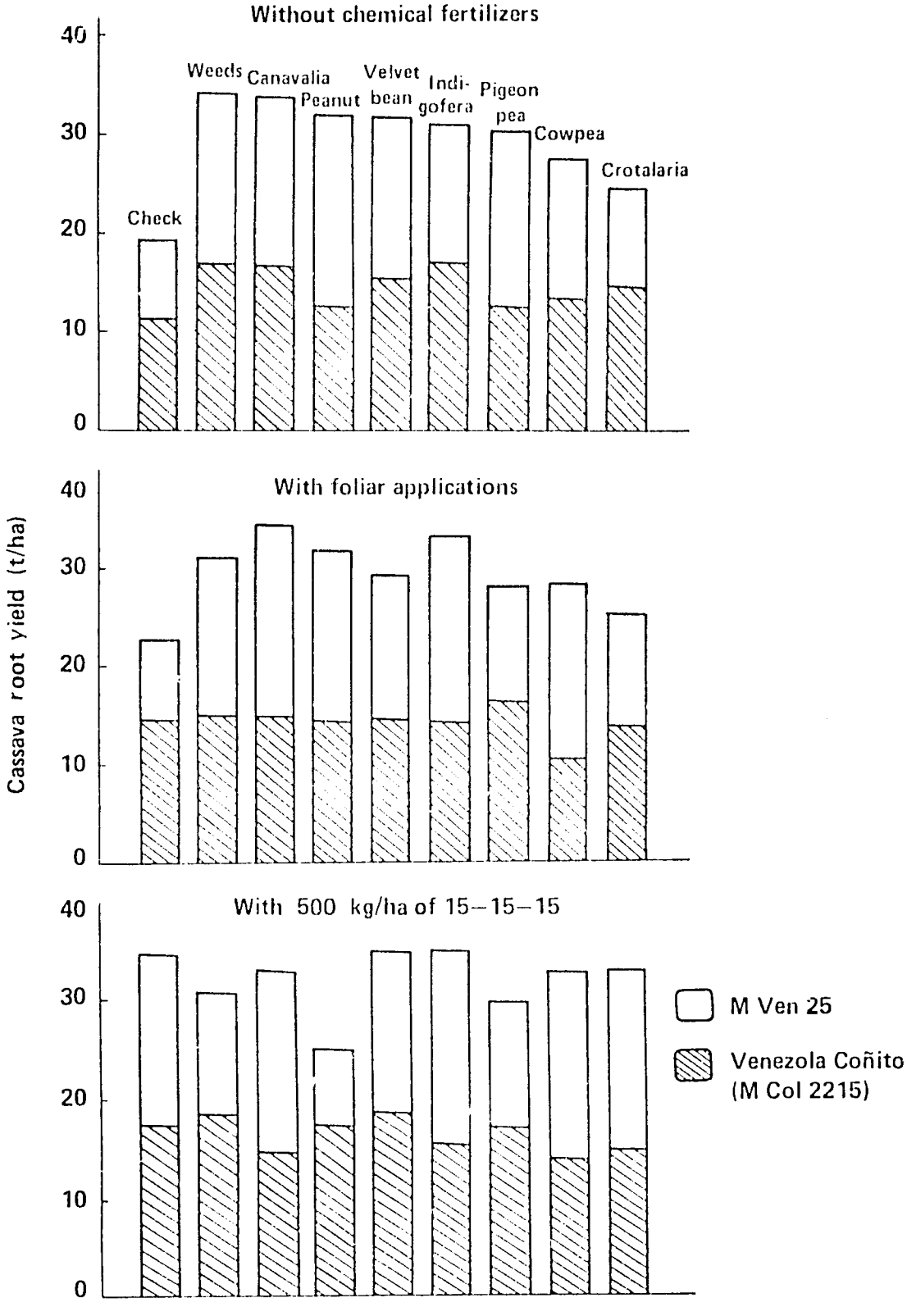


FIGURE 13. Response of two cassava varieties to preplant incorporation of native weeds or several green manure crops either without fertilizers, or with foliar or soil applications of chemical fertilizers in Media Luna.

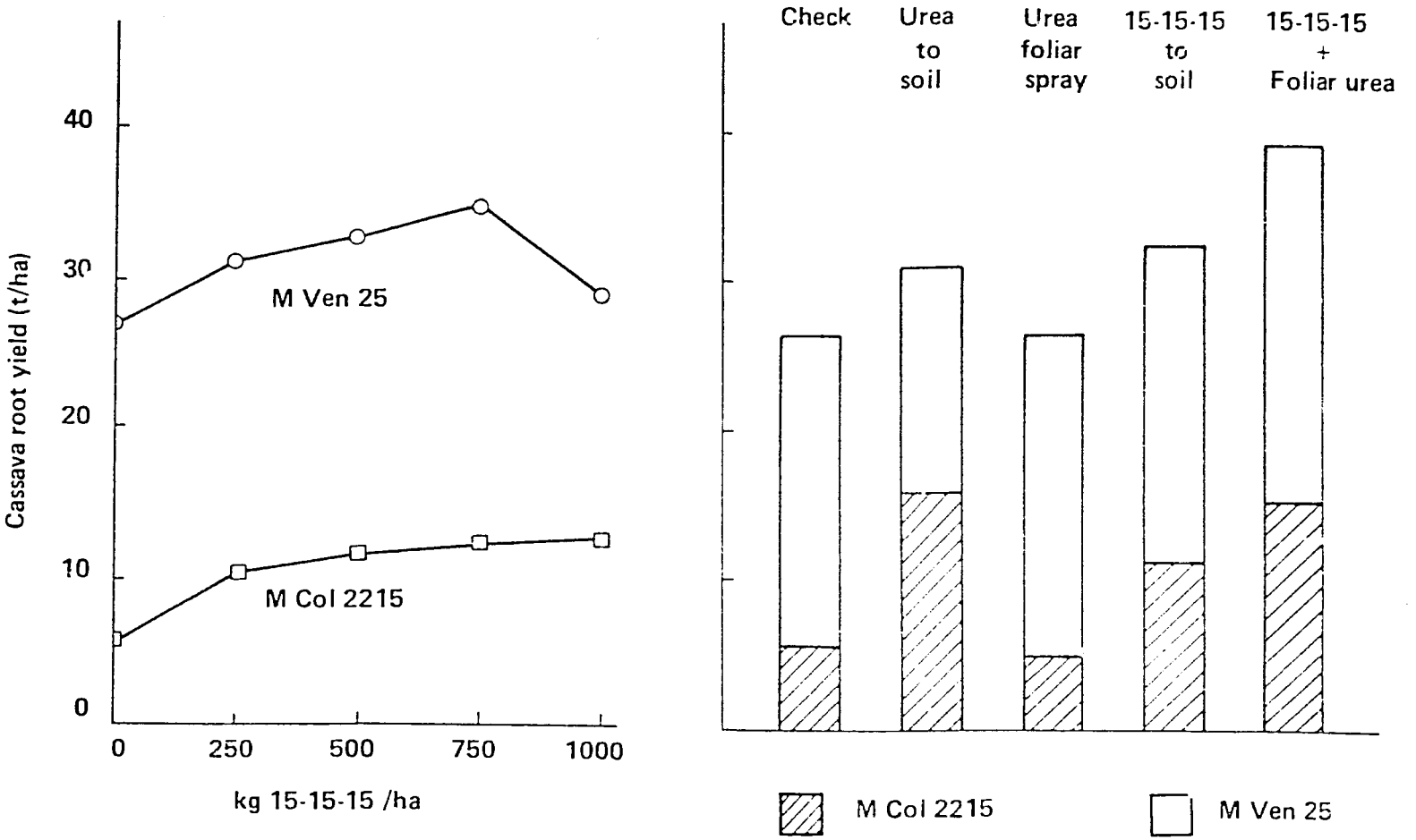


FIGURE 14. Response of two cassava varieties to soil application of several levels of 15-15-15, or to other combinations of soil and foliar applications of either urea (75 kg N/ha), 15-15-15 (500 kg/ha) or 3 foliar sprays with 1 % urea.

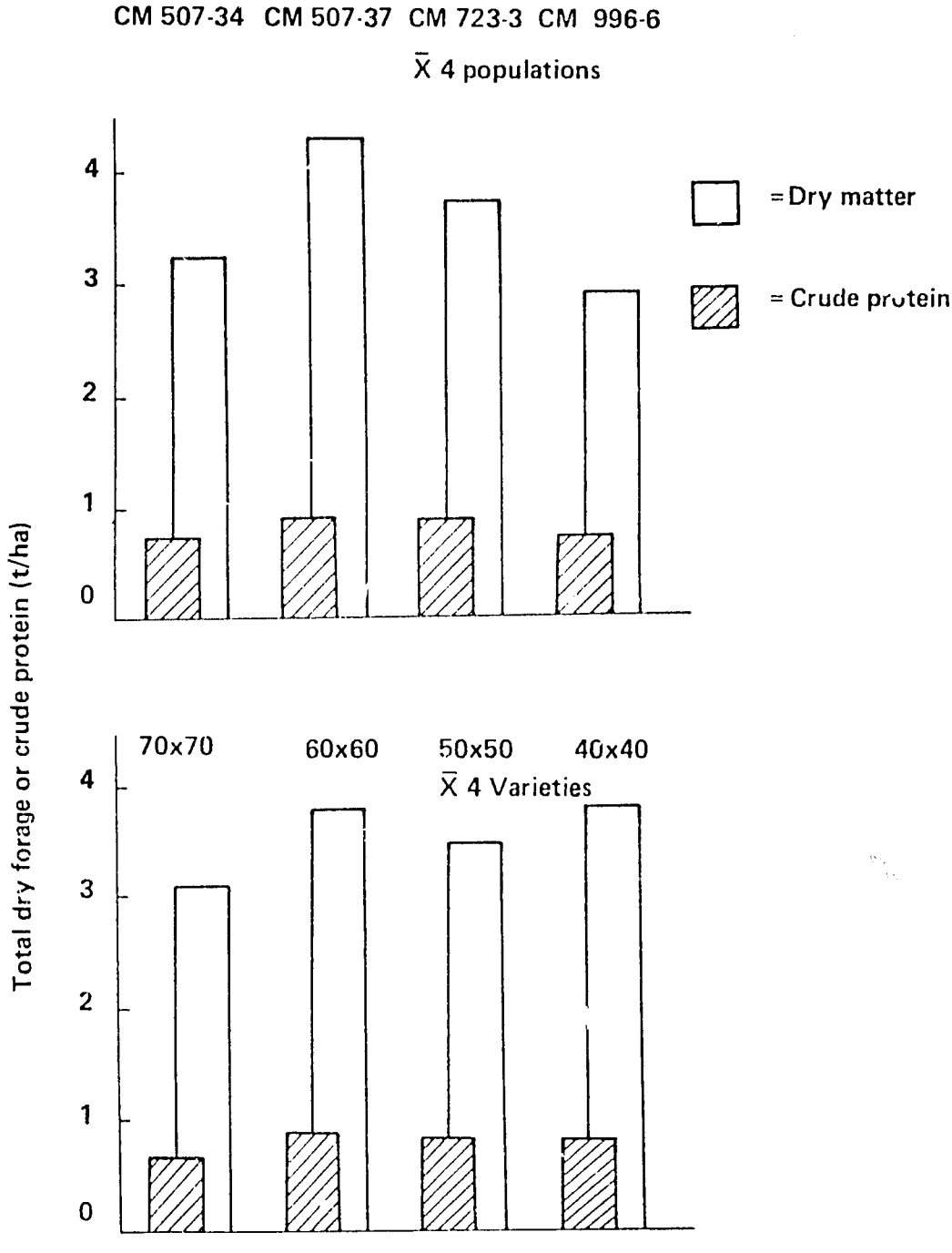


FIGURE 15. Total dry matter and crude protein production in 3 cuts of cassava forage of four varieties (above) planted at four planting distances (below) in Carimagua.

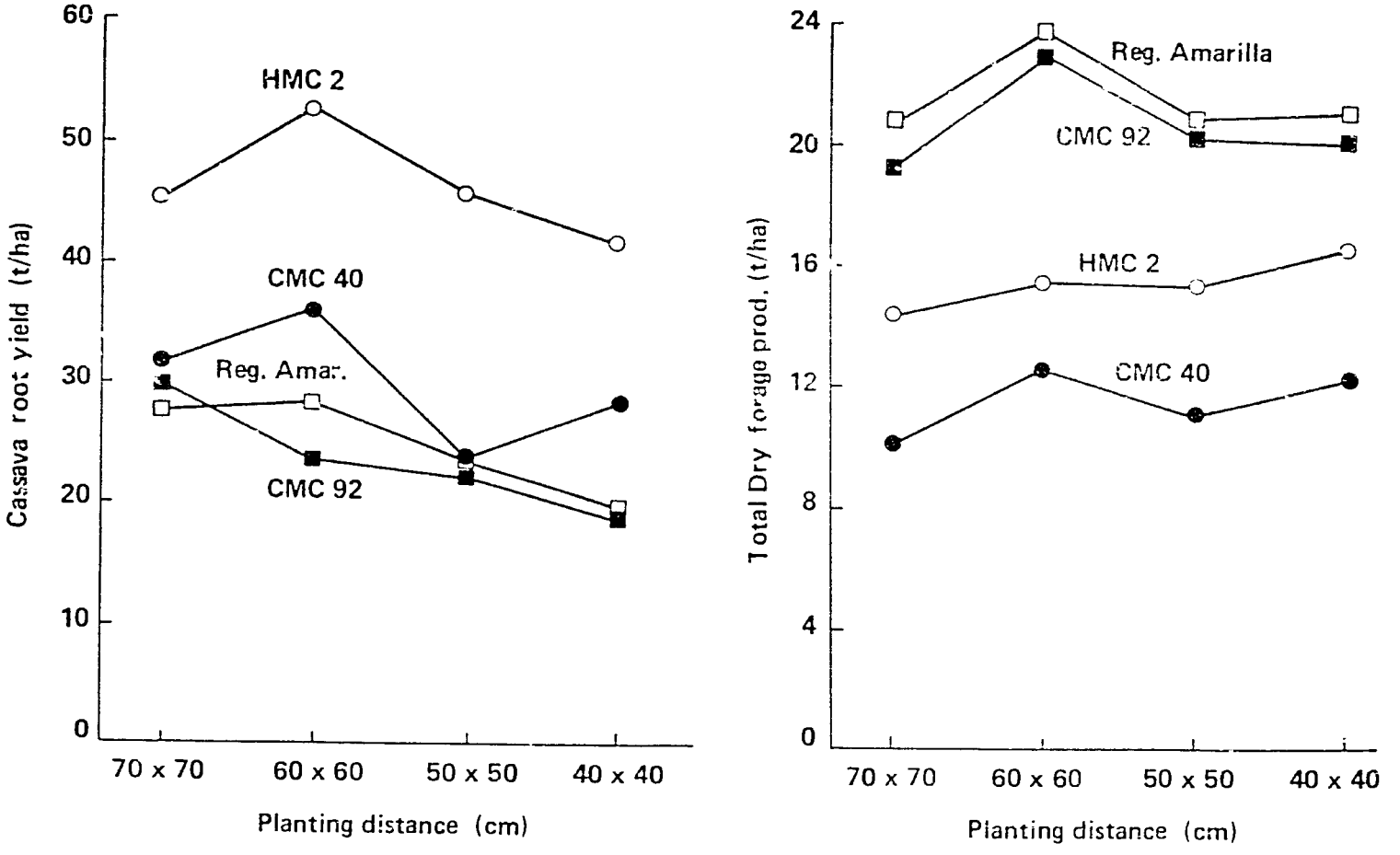


FIGURE 16. Fresh root yield and total dry forage production after seven cuts (in two years) of four cassava varieties planted at four planting distances in Quilichao.

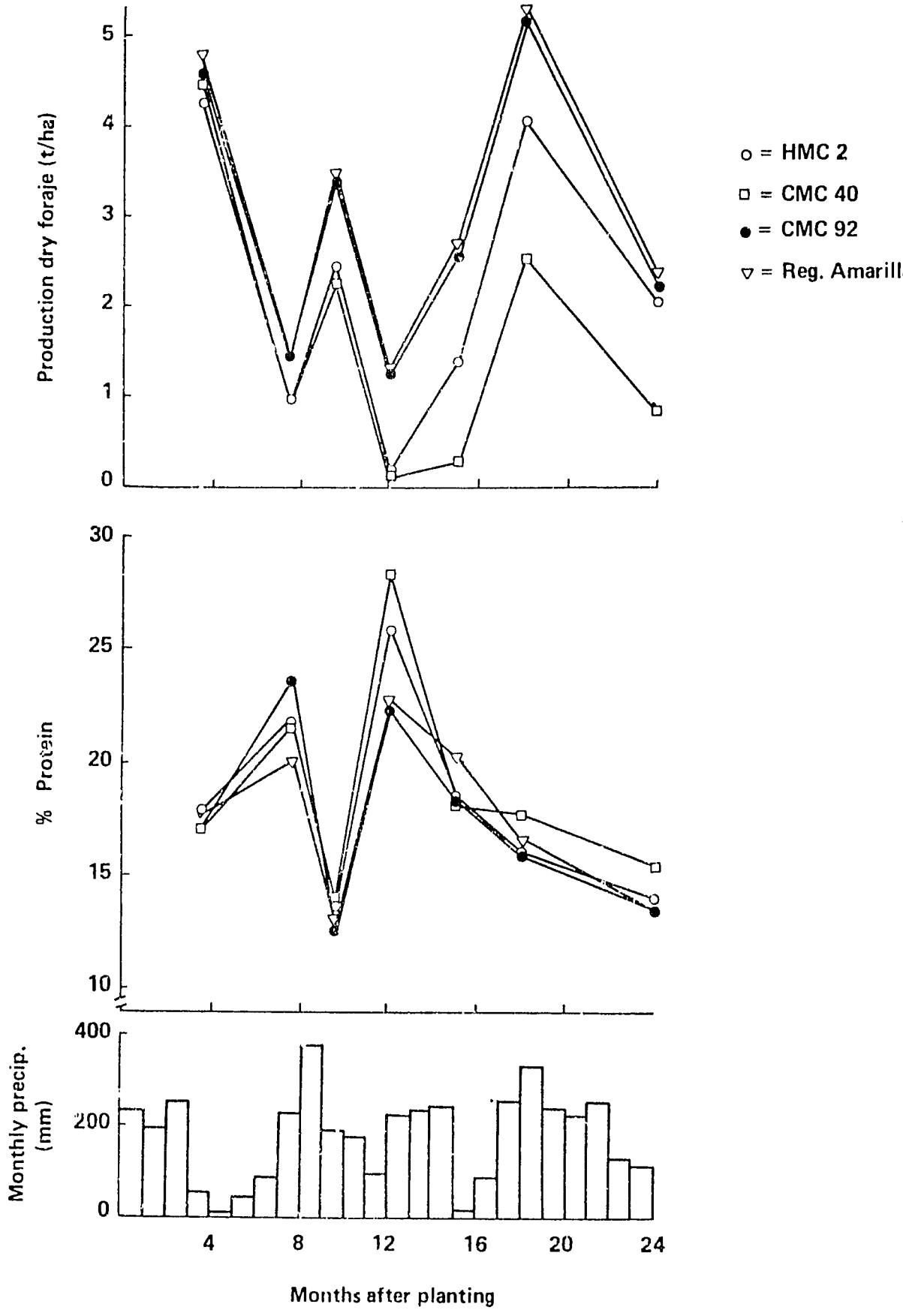


Figure 17. Dry weight and crude protein content of cassava forage from four varieties in each of seven cuts as influenced by seasonal fluctuations of precipitation during a two year period in Quilichao.

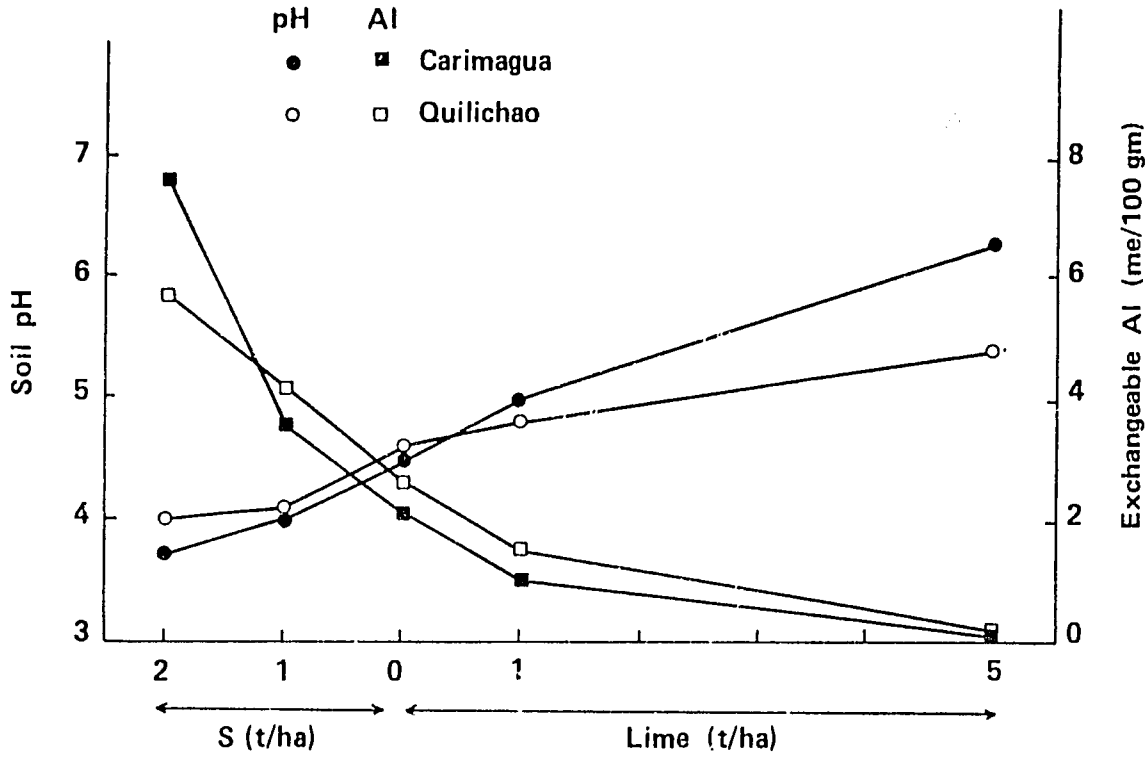


Figure 18. Effect of applications of elemental S and lime on pH and exchangeable Al content of Carimagua and Quilichao soil.

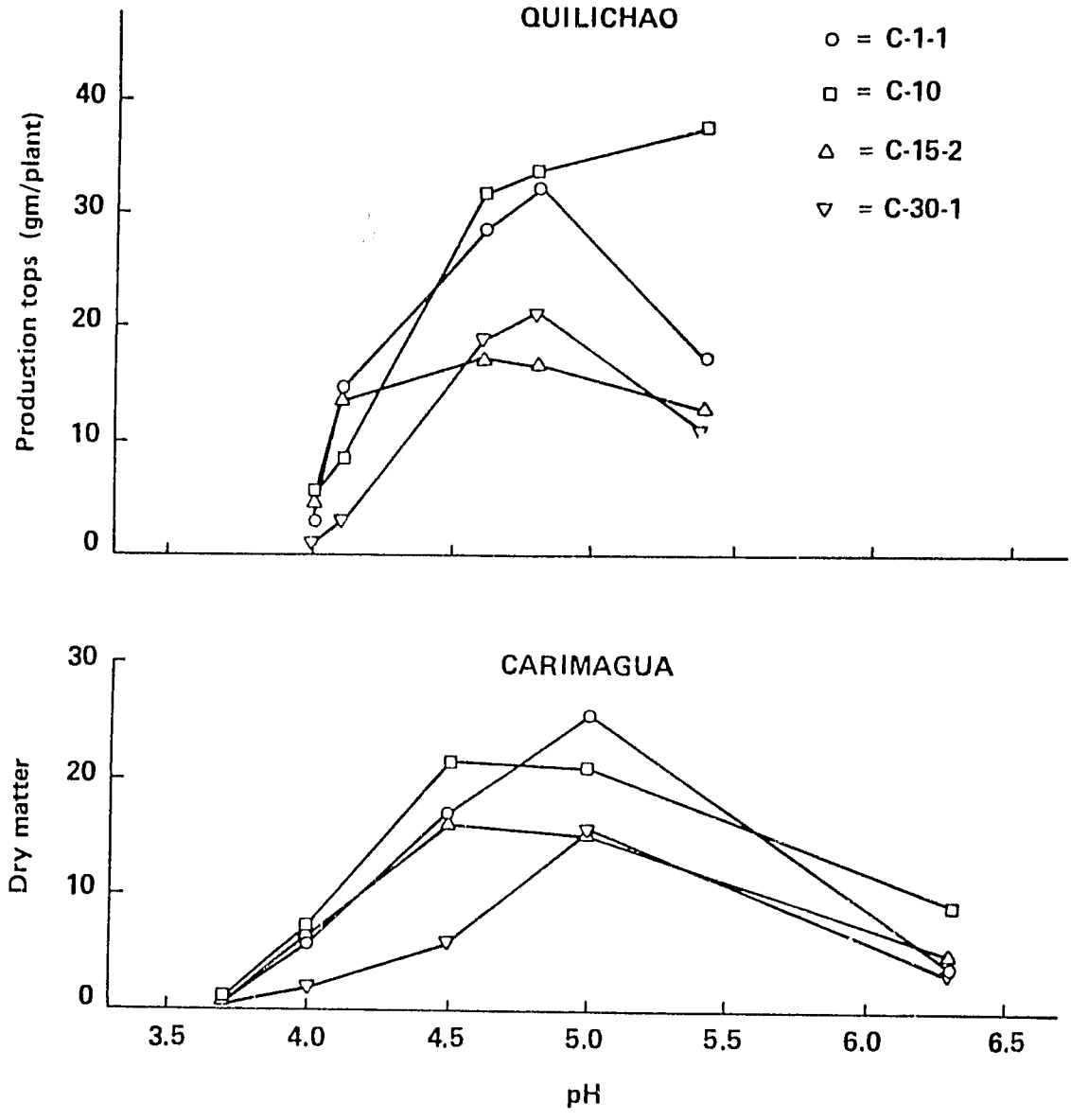


Figure 19. Effect of soil pH on dry matter production of tops of two month old cassava, M Ven 77, inoculated with four VAM species and grown in sterilized soil from Quilichao and Carimagua.

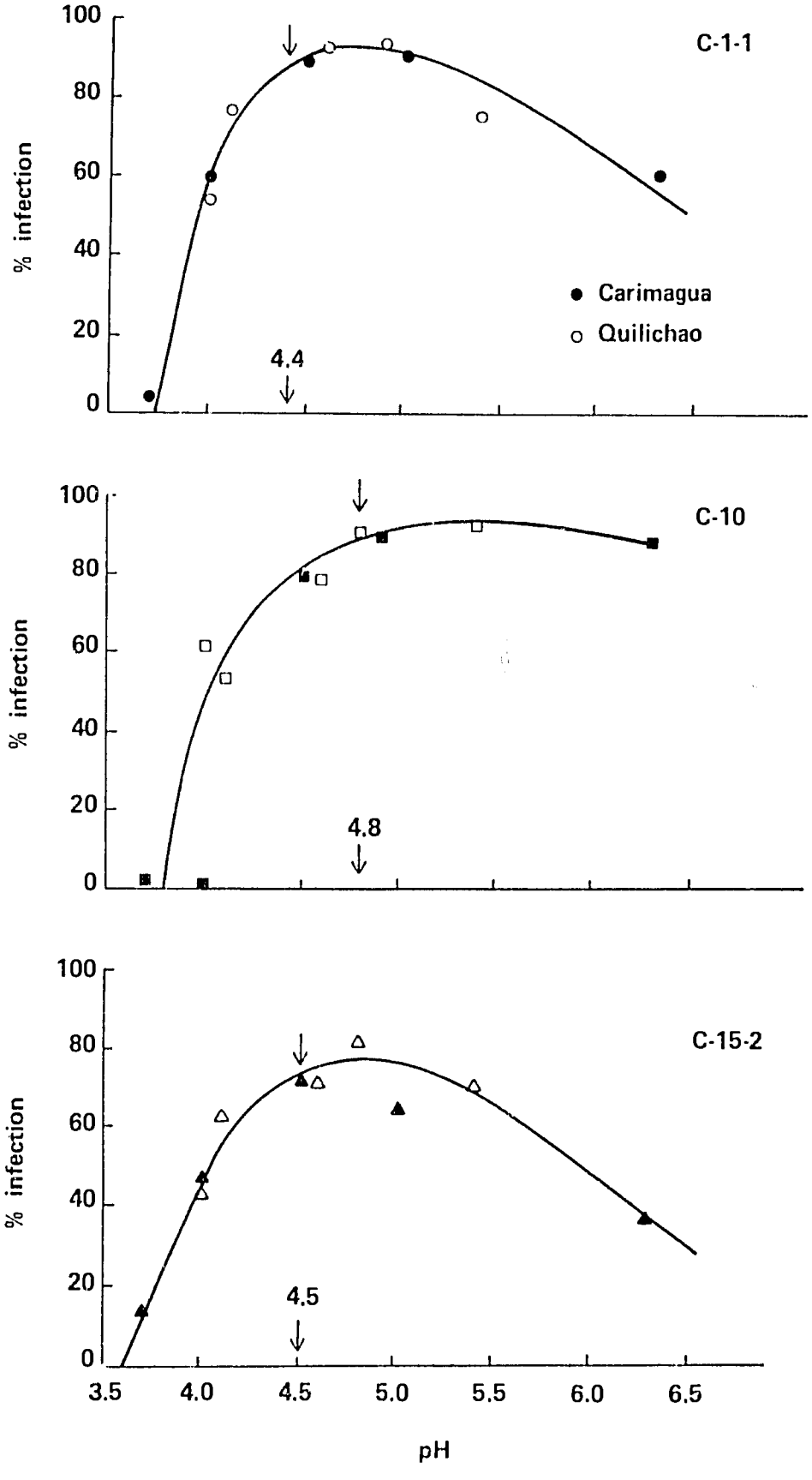


Figure 20. Relation between percentage VAM root infection and soil pH determined for three mycorrhizal species in sterilized soils from Carimagua and Quilichao. Arrows indicate the critical pH, corresponding to 95% of maximum infection.

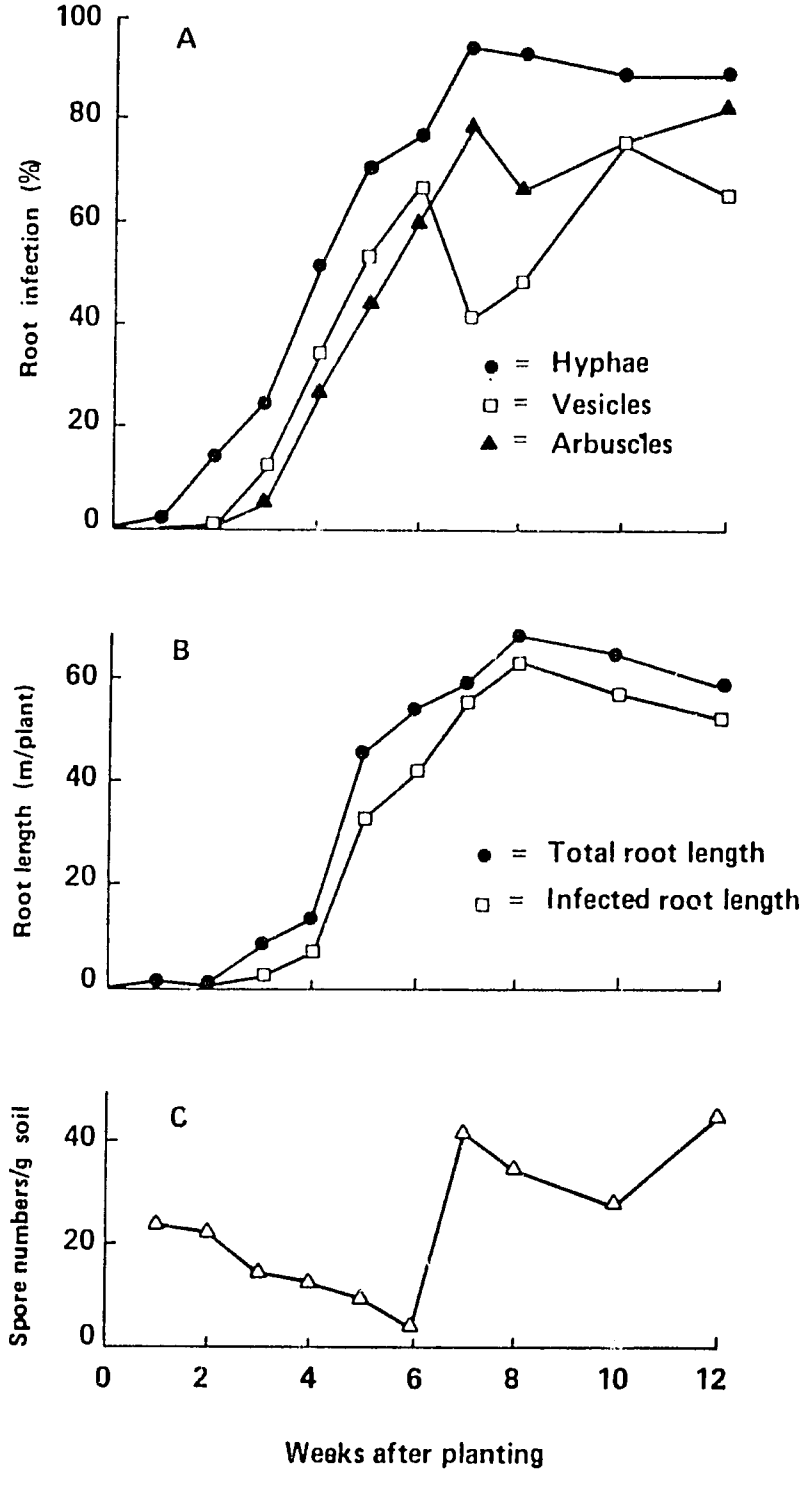


Figure 21. A. root infection by hyphae, vesicles and arbuscles; B. total and VAM infected root length; C. total spore numbers in soil during the first 12 weeks of growth of rooted plantlets of M Ven 77 in unsterilized Quilichao soil. Data are averages of inoculated (with C-1-1) and uninoculated plants.

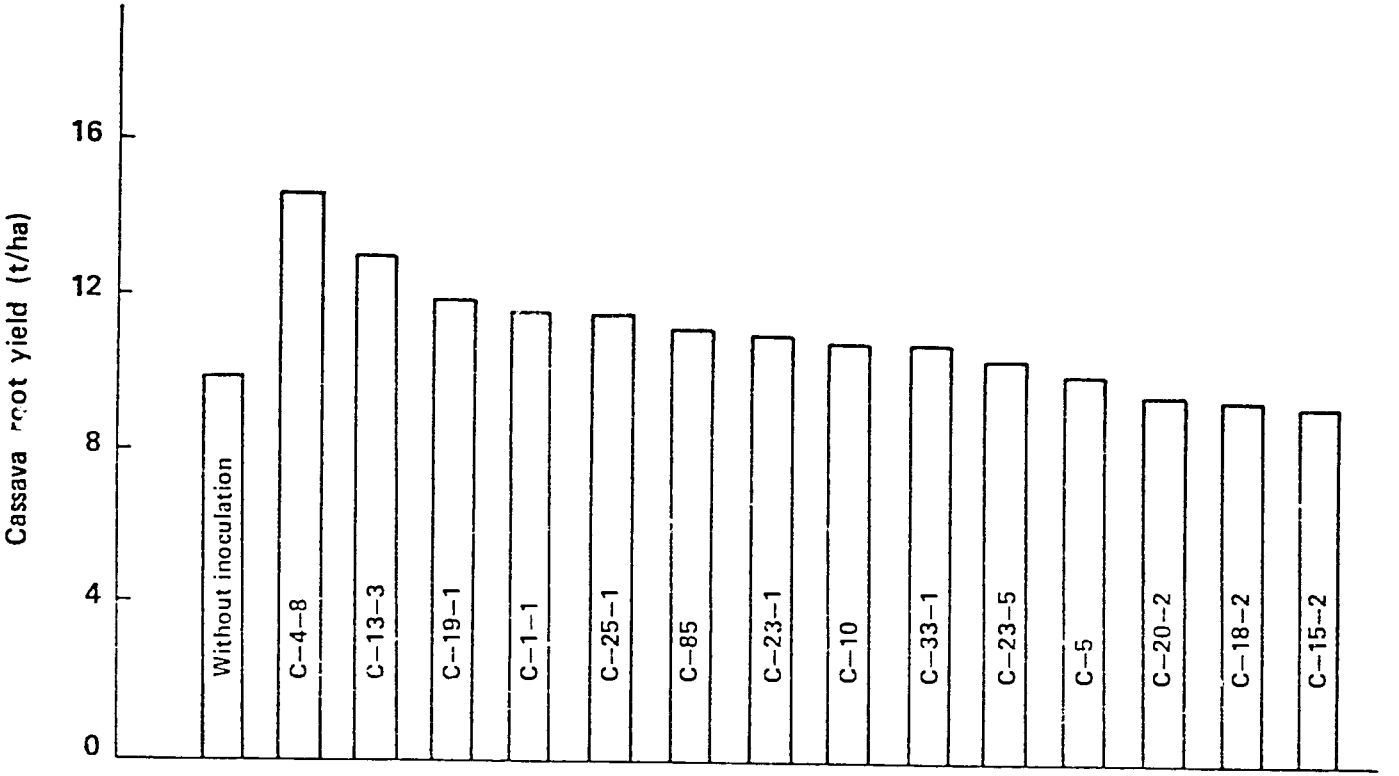


Figure 22. Response of cassava, M Ecu 82 to inoculation with 14 strains of VA mycorrhizal fungi in Carimagua.

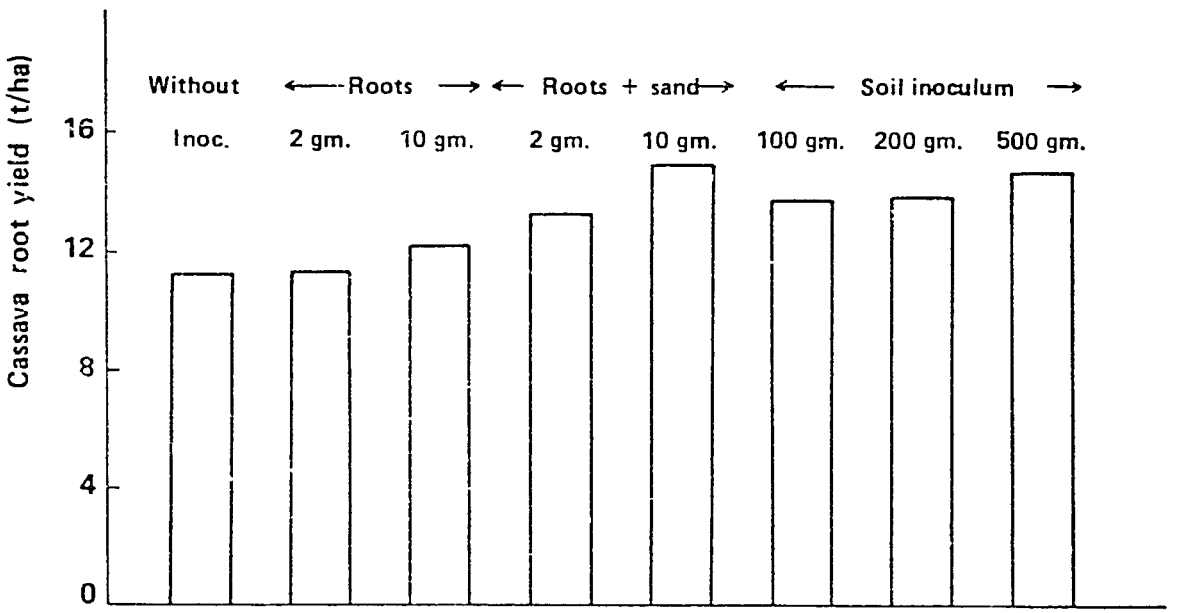


FIGURE 23. Effect of different levels and methods of inoculation with mycorrhizal strain C-1-1 on the average yield of two cassava varieties grown with 100 kg P/ha as band applied triple superphosphate or incorporated Huila rock phosphate in Carimagua.

MYCORRHIZA PROJECT

During 1985 research activities were continued for:

(a) collection and characterization of mycorrhizal fungi

(b) field inoculation trials and observation of persistence of inoculated fungal species

(c) on-farm inoculum production

A. Collection and characterization of mycorrhizal fungi

The mycorrhizal fungi collection was almost doubled from 420 to 800 pure cultures. The number of cold room stored isolates increased from 272 to about 700. One new species of a VA mycorrhizal fungus was described: Acaulospora myriocarpa Spain, Sieverding et Schenck. This species had the code 007 in earlier reports. Also, from pure pot cultures of the CIAT collection it was possible to demonstrate that Entrophospora infrequens forms VA mycorrhiza, a fact that was unknown up to now. This finding substantiates the opinion that the genus Entrophospora belongs to the family Endogonaceae.

Characterization of isolates in the greenhouse

A collection of 54 isolates from acidic soils were tested for effectiviness following the screening procedures for Test I conditions (see CIAT Cassava Program Annual Report, 1984). Highly effective isolates were found within the species A. appendicula (Isolates C-44-1, C-129-6), A. laevis (C-129-10 A), A. myriocarpa (C-29-4), Acaulospora sp. (C-121-3), Glomus clarum (C-121-5 A), G. occultum (C-45-4 B) and Glomus sp. (C-71-1, C-72-2, C-73-2, C-127-1 A).

Another collection of 33 isolates from fertile soils (CIAT Palmira and Caicedonia, Valle) were also tested for effectiviness under Test I conditions using as test substrate a fertile soil from Palmira. Eight isolates were highly effective. These are C-30-1, C-30-2, C-30-13, C-116-5 (all G. mosseae) and C-30-10, C-116-4, C-116-14, C-116-18 (four different Glomus spp.).

B. Field inoculation trials

Cassava/beans intercropping and inoculation trials

Two trials were conducted in the Mondomo area where cassava (cv. Algodona) was intercropped with beans (cv. Carioca). The trials were undertaken to define whether inoculation of the beans alone increased cassava yields. In this case field inoculation would be technically easier. Cassava was planted at a distance of 1 x 1 m and beans were sown in two rows (50 cm distance) between cassava rows, with a distance of 10 cm within each row. In Mondomito "only the beans were inoculated with G. manihotis (CIAT isolate C-1-1). Inoculum was applied under the bean seed at the rate of 200 g per linear meter. In Pescador beans or/and cassava were inoculated.

In Mondomito significant increases in bean yields were found when inoculation was combined with lime or lime and triple superphosphate (TSP) application (Table 1). Cassava yields were increased by

inoculation of beans when triple superphosphate was applied without lime. It is clear from Table 1 that under those conditions TSP applications decreased cassava yields due to severe competition from the more vigorous beans. Similarly, in the presence of lime inoculation significantly increased bean yield, which in turn had a detrimental effect on cassava yields. Application of lime and P markedly increased bean yields, which due to competition resulted in a decrease in cassava yields. In this case, inoculation further increased bean yields without affecting the growth of cassava. Thus, depending on the fertilization level only one plant species responded to mycorrhizal field inoculation due to interspecies competition.

At Pescador (Table 2) the entire trial was fertilized uniformly with 1 t/ha of lime, 1 t/ha of Huila rockphosphate, 50 kg P/ha as TSP, 50 kg N/ha as urea, 50 kg K/ha as KCl, 5 kg/ha Zn and 1 kg/ha B were applied. Under those conditions field inoculation of beans and/or cassava tended to increase the yield of cassava.

It may be concluded from these trials that inoculating beans cropped together with cassava can simplify the inoculation procedure. For planting beans, rows have to be made anyway in which mycorrhizal inoculum can be placed. However, in these trials only one of the associated species responded to inoculation, depending on the fertilization level.

Annual inoculation of cassava

A field trial was established in 1983 to compare the residual effect of this initial inoculation with that of an annual inoculation. Before the planting of each of the two cassava crops, 50 kg P/ha as Huila rockphosphate were incorporated in the soil; 50 kg N as urea and 50 kg K as KCl were applied each year in side bands to the cassava stakes. Soil substrate infected with G. manihotis (C-1-1) was used as inoculum.

The results (Table 3) show that inoculating twice during the growth cycle was most effective in the first year. In the second year an inoculation response was found only when the field either had not been inoculated in the first year or had been inoculated only once in the first year. Thus, once the introduced strain is well established, its presence has a residual effect on the following cassava crop, and reinoculation in that case has no further benefitial effect.

Persistance of introduced fungi in the field

The persistence of G. manihotis, E. colombiana and G. occultum in the field was investigated one or two years after their introduction to the field, corresponding with one or two crop cycles of cassava. The relative numbers of spores of these species in the inoculated and in the uninoculated trial plots was taken as an index for their persistence. At the four sites that were observed, G. manihotis was persistent when rockphosphate had been applied. The relative presence of G. manihotis decreased by TSP fertilization. Persistence of the other two species was site specific and dependend on the applied P fertilizer source as well as on the composition of the indigenous fungal species. These

findings indicate that G. manihotis probably competes well with the indigenous mycorrhiza when inoculation is combined with rock phosphate application.

C. On-farm inoculum production

In last year's CIAT Cassava Program Annual Report, a strategy was presented for production of large amounts of inoculum on-farm. This year soil sterilants were tested for effectiviness to erradicate the native mycorrhizal population under natural conditions; also, the suitability of Brachiaria decumbens to multiply G. manihotis under field conditions in those treated field plots was investigated.

Two sites ("Don Fidel" and "La Angelita") were selected in the Mondomo area. The soils differed in texture (clay and sandy loam) and organic matter content (5.6% and 16%). Both soils had previously been in fallow vegetation. The soils were prepared by hoe and different commercial soil sterilants were applied. Formol (150 ml/m^2 of Formol 46%) and Di-Trapex (75 ml/m^2) were surface applied after diluting with water; Basamid (60 g/m^2) was incorporated to a depth of 15-20 cm. After application of these products the plots were irrigated with about 20 l of water per m^2 and covered with plastic. Methyl bromide (80 g/m^2) was applied to plots already sealed with plastic. There was an untreated but plastic sealed control. Ten days after treatment the plastic was removed and the soil was left for aeration.

Table 4 shows that the mycorrhizal infection potential (MIP defined as percentage root infection in a two months bioassy with tropical Kudzu) decreased by application of Di-Trapex, Basamid and methyl bromide. No significant differences were found in the MIP when soil was sampled 3 or 14 days after starting soil aeration. However, by handling the soil for the MIP test, the soil may have been additionally aerated, so that the data may not represent the natural field conditions.

At 24 days after starting soil aeration, half of the field plots at the "Don Fidel" site were inoculated with 250 g/m^2 of soil substrate which contained a pure culture of G. manihotis (C-1-1). Sexual seed of Brachiaria decumbens was sown as a host plant for reproduction of the fungus. Two months after planting, (MAP) root infection was zero or very low in non-inoculated plots which had been treated with Basamid or methyl bromide (Table 5). Inoculation increased root infection from 12% to 67% on the average of all soil treatments. At 2 and 4 MAP in uninoculated plots, total spore population of mycorrhizal fungi was lower in treated than untreated soil, with the lowest number of spores found in plots treated with Basamid or methyl bromide at 4 MAP. In these plots highest reproduction rates of the introduced G. manihotis were obtained. At 4 MAP, in all treated and inoculated plots, spore numbers of G manihotis represented 95-99% of the total mycorrhizal spore population.

From the trial it may be concluded that in heavy soils all soil sterilants may be useful for reduction of the indigenous mycorrhizal population. Technically, the granular product "Basamid" is safest and most convenient to handle. Four months of growth of B. decumbens is apparently long enough for producing an inoculum with high spore

density. Future trials are needed to show whether the amount of starter inoculum (at the present 6.25 kg/25 m^2) can be reduced. This inoculum production technique will also have to be tested for multiplication of other highly effective mycorrhizal fungi.

D. Other activities

Training courses

The Mycorrhiza Project participated in the conduction of three courses on "Methodology to investigate VA mycorrhiza for practical use in agriculture" outside CIAT.

a) In Costa Rica a "Workshop on techniques to investigate mycorrhiza" was organized by the International Foundation of Science (IFS), from 18 to 28 September, 1985. 22 researchers from 11 Latinamerican countries participated in this course.

b) In Mexico, 15 participants were trained in a course organized together with the Colegio de Postgraduados at Chapingo, from 1 to 8 November, 1985.

c) In Pasto, Colombia, 17 profesionals and university professors were trained in a 5 day course from 25 to 29 November 1985.

TABLE 1. Effect of field inoculation of beans in a cassava/beans intercropping trial on dry grain yields of beans and fresh root yields of cassava in Mondomito.

Fertilization[a]	Grain yields beans (kg/ha)		Root yields cassava (t/ha)	
	Beans not inoculated	Beans inoculated	Beans not inoculated	Beans inoculated
0	378	524	24.5	25.7
+ P	620	539	19.3	23.1*
+ Lime	608	801*	23.3	20.6
+ P + Lime	908	1112*	19.5	20.9

[a] 0 = Basic fertilization: 100 kg N/ha, 100 kg K/ha, 10 kg Mg/ha, 5 kg Zn/ha, 1 kg B/ha, 1 t Huila rock phosphate/ha

+ P = Basic fertilization plus 100 kg P/ha as triple superphosphate, broadcast and incorporated.

+ Lime = Basic fertilization plus 3 t/ha lime.
All fertilizers broadcast and incorporated

* Response to inoculation was significant at P = 0.05.

TABLE 2. Effect of field inoculation of beans and/or cassava in a bean/cassava intercropping trial on grain yields of beans and fresh root yields of cassava, in Pescador.

Inoculation of[a] Beans	Cassava	Grain yield of beans (kg/ha)	Root yield of cassava (t/ha)
-	-	280	6.9
-	+	128	8.9
+	-	216	10.8
+	+	261	9.9

[a] - : Not inoculated

+ : Inoculated with 250 g inoculum (G. manihotis, C-1-1) per linear meter (beans) or with 500 g under each cassava stake; when both plant species were inoculated each plant received half of inoculum.

TABLE 3. Residual effect of field inoculation on cassava (cv Algodona) root yield at Mondomito (Cauca), compared with that of an annual inoculation.

Field inoculation[a]		Fresh root yields (t/ha)		
1st cycle	2nd cycle	1st cycle	2nd cycle	Sum of 1st and 2nd crop cycle
-	-		20.5	34.0
		13.5		
-	+ (2x)		24.3	37.8
+ (1x)	-		21.6	38.5
		16.9		
+ (1x)	+ (1x)		24.1	41.0
+ (2x)	-	21.0	19.6	40.6
+ (2x)	+ (2x)		20.4	41.4

a - : not inoculated

+ (1x): Inoculated with G. manihotis (C-1-1); application of 500 g infected soil under each stake at planting.

+ (2x): Inoculated with G. manihotis; 500 g infected soil per plant; half of inoculum applied under the stake at planting and other half at 5 MAP in bands alongside each plant.

TABLE 4. Effect of soil sterilants on the mycorrhizal infection potential (MIP)[a] in the field.

Site	Date of sampling[b]	Soil treatment				
		Untreated	Formol	Di-Irapex	Basamid	Methyl-bromide
Don Fidel	3 days	60.7	54.7	20.2	27.0	16.1
	14 days	43.4	43.2	31.4	34.2	9.0
	Mean	52.1	49.0	25.8	30.6	12.6
La Angelita	3 days	36.2	42.3	18.7	6.7	11.6
	14 days	42.5	39.3	10.0	8.2	11.5
	Mean	39.4	40.8	14.4	7.5	11.6
Overall average		45.7	44.9	20.1	19.0	12.1

[a] Percentage root infection in a biossy with tropical kudzu, after a two month growth period in these treated soils.

[b] Days after starting soil airation.

TABLE 5. Spore production of mycorrhizal fungi on-farm after treating soil with different soil sterilants and planting of *B. decumbens* at: "Don Fidel", Mondomito, Cauca.

Soil treatment	Inoc. treatment [a]	Root infec. (%)	Two months after planting: No. of spores/100 g [b] MAN	Two months after planting: No. of spores/100 g [b] Others [c d]	Four months after planting: No. of spores/100 g dry soil MAN	Four months after planting: No. of spores/100 g dry soil Others [c]
Untreated	Not inoc.	26.0	24	838 (2.8)	86	996 (8.0)
	Inoc. MAN	62.4	647	436 (60.0)	506	252 (67.0)
Formol	Not inoc.	19.7	4	350 (1.1)	15	313 (5.0)
	Inoc. MAN	71.4	504	232 (68.5)	4338	132 (97.0)
Basamid	Not inoc.	0.0	6	400 (1.5)	38	83 (31.0)
	Inoc. MAN	61.8	538	413 (56.6)	7930	70 (99.0)
Di-Trapex	Not inoc.	14.0	18	528 (32.0)	16	549 (3.0)
	Inoc. MAN	53.0	292	364 (44.5)	3335	181 (95.0)
Methyl-brom.	Not inoc.	2.5	6	387 (1.5)	8	102 (7.0)
	Inoc. MAN	86.6	962	335 (74.2)	12803	83 (99.0)

[a] Inoculated with *G. manihotis* (MAN); 10 g of infected soil was applied to each of 25 planting holes per square meter.

[b] Spore number in soil horizon of 0-15 cm; No./100 g dry soil.

[c] Other species of mycorrhizal fungi were: *G. fasciculatum*, *Acaulospora* sp. *A. myriocarpa*, *A. mellea*, *E. colombiana*, *A. foveata*, *Acaulospora* sp. "FRIJ" *G. mosseae*, *G. occultum* and two *Gigaspora* spp.

[d] Data in parenthesis indicate the relation: Spore number of MAN/Total spore number x 100.

ENTOMOLOGY

Cassava entomology research during 1985 concentrated on four pests: Mealybugs, mites, the cassava hornworm and Cyrtomenus bergi. Exploration for additional predators of the cassava mites resulted in identifying more than 25 species of Phytoseiidae in Colombia. Five of these species have been forwarded to CIBC (Commonwealth Institute of Biological Control) in England for eventual shipment to IITA in Nigeria. Basic bionomic studies of the most important of these species were initiated.

Mealybugs

Mealybug attacks in Africa (Phenacoccus manihoti) and the Brazilian Northeast (P. herreni) have caused severe crop losses. In recent years, considerable research effort has gone into trying to control these pests. Most of this effort has centered around the search, study, mass rearing and release of natural enemies. Research at CIAT with P. herreni has involved biology and ecology of the pest and its natural enemies, yield loss studies and host plant resistance.

Mass Rearing. Successful biological control and host plant resistance research often depends on having available at all times an adequate supply of the pest. CIAT has been able to establish a good working colony of P. herreni in the greenhouse. Every week 50 five week old cassava plants, growing in pots, are infested with six mealybug ovisacs. These are protected from parasites and predators with small leaf cages and the plants are placed in large (1 x 2 meter) fine nylon screened cages. This provides mealybugs at all stages of development at any given moment and 1000 mealybug ovisacs are produced weekly for use in bio-control or host plant resistance studies.

Population Dynamics. The population fluctuations of P. herreni were studied in cassava fields in Carimagua. Groups of plants of the variety M Ven 77 were randomly selected and the total number of infested terminals was determined every 15 days throughout the growing season. In addition, a 3 cm portion of one terminal per plant was studied in the laboratory to assess the stages of P. herreni present.

Results show a strong tendency for an increase in mealybug infestation as precipitation decreases (Fig. 1). During the months when precipitation was above 200 mm, the percentage of infested terminals remained below 20%. As rainfall decreased during the June to December period, mealybug infestation increased to 60% of the terminals infested. Bi-monthly examinations of the 3 cm of terminal resulted in a high correlation between the number of infested terminals and the population of various stages of the P. herreni females.

Biological Control Studies. There are numerous parasites and predators of cassava mealybugs; at CIAT-Palmira and Carimagua five species of parasites of P. herreni have been recorded. There are: Acerophagus cocoois Smith (CIAT), Epidinocarsis diversicornis Kerrich (CIAT), Anagyrus putonophilus Compere (CIAT) and Anagyrus insolitus Howard (Carimagua). During 1985, the parasite Anagyrus insolitus Howard was found parasitizing the mealybug found on cassava in Papaloapan, Mexico.

A colony of A. coccois and E. diversicornis have been established at CIAT. The biology and behavior of both species are being studied. These studies include: (1) the stage of P. herreni most preferred by both parasites; (2) host mortality caused by ovipositor penetration; (3) encapsulation of the immature stages of the parasite by the host; (4) the effect of temperature on the development of the parasite; (5) the development curve of the parasite; and (6) the preference of each parasite for two mealybug species.

1) Preference of mealybug stage by parasites: Epidinocarsis diversicornis showed a clear preference for parasitizing the adult female and 3rd. nymphal instar of the female, the least preferred being the male stages. This is probably due to the host morphology in that the 3rd. instar and adult female are quiescent and corpulent, while the male stages are covered with a cottony cap that hinders the parasite. In contrast, A. coccois showed a preference for the male cocoon (which includes the 3rd and 4th instars), the adult female and 2nd instar female.

2) Host mortality caused by parasite ovipositor penetration: Ovipositor penetration by E. diversicornis caused mortality in all developmental stages of P. herreni; however, the highest mortality 13.2% was in the 1st nymphal instar. The parasite A. coccois did not cause mortality due to ovipositor penetration.

3) Encapsulation of immature stages of the parasite by the host: Encapsulation is a defense mechanism by the host mealybug to isolate and incapacitate the developing parasite within the host. This phenomenon is frequently observed when E. diversicornis parasitises P. herrreni. Studies done during 1985 show that encapsulation decreases as the temperature increases. At 25°C, 14% of the 2nd nymphal instars, and 7.7% of the 3rd and adult females, displayed encapsulation. This decreased to 4.4 and 2.7% respectively at 30° C. These results also indicate that encapsulation decreases with age of the host. Encapsulation is easily observed throughout the mealybug body because of the black spots that are formed. There are no determined sites nor number of spots formed. E. diversicornis also parasitizes P. gossypii but no encapsulation was observed at the two temperatures evaluated. Likewise, parasitism by A. coccois resulted in no encapsulation with both mealybug species.

4) The effect of temperature on parasite development: Temperature has a marked effect on the time and rate of development of E. diversicornis. At 20°C the total development time was 35.7 days; this decreased to 20.1 days at 25°C and to 18.1 at 30°C. Temperature also influences the time and rate of development of A. coccois. At 20°C total developmental time was 39.4 days; this decreased to 18.5 at 25°C and 19.7 at 30°C.

5) The development curve of the parasite: Tracing a temperature curve vs the rate of development results in a sigmoid graph where the central point is an approximation where the rate of development behaves proportional to the temperature. The extension of this line cuts the horizontal axis which corresponds to the temperature. In

the case of both parasite species, the interval used was from 20°C. The results at 30°C suggest that the rate of development begins to decrease.

For E. diversicornis the minimal development threshold was 13.5°C for the total development period (Fig. 2). For A. coccois the minimal development threshold was 15.6°C for the total development period. The day degrees or "physiological time" was calculated for both parasite species. For E. diversicornis the total development time was 231 day degrees (Fig. 2). For A. coccois the total development was 175 day degrees. These results indicate that the parasite A. coccois requires less day degrees than E. diversicornis even though A. coccois has a longer average development time; however its minimal temperature threshold is greater than E. diversicornis and, therefore, its degree days or physiological time is less.

6) The preference of each parasite species for two mealybug species:

a) Epidinocarsis diversicornis vs. P. herreni and P. gossypii. Results show that E. diversicornis clearly prefers to parasitize P. herreni over P. gossypii (Table 1). This preference occurs during the localization phase (12.7 vs. 5.3), the intent to oviposit phase (5.7 vs 1.0) and the ovipositional phase (3.3 vs 1.6). These results indicate that E. diversicornis may be very specific for P. herreni and helps explain the negative results in trials with P. manihoti.

b) Acerophagus coccois vs. P. herreni and P. gossypii. Results show a very strong preference of this parasite to parasitize P. gossypii when given the choice (Table 2). The differences were dramatic; localization phase 10.2 vs 1.8; intent to oviposit phase 7 vs 0.7; and oviposition phase 2.7 vs 0.0. A. coccois will parasitize P. herreni as evidenced in previous experiments, however, when given a choice it clearly prefers P. gossypii, thereby reducing the potential of this parasite in a biological control program for P. herreni when both hosts are present.

Mites

Mites are a universal pest of cassava; representatives of the more than 46 species already identified are found feeding on cassava wherever the crop is grown. In agroecosystems where rainfall is adequate and well dispersed throughout the year, mite populations usually remain below economic injury levels. However, in low rainfall areas with a well defined dry season in excess of three months, mite populations will build up to economic injury levels and cause root yield reduction. Control of mites with pesticide applications can be costly and often ineffective; due to their short generation time, mites readily develop resistance to pesticides.

A complimentary system, linking host plant resistance and biological control is an attainable goal for effective mite control. CIAT research on mite resistance is well documented in previous CIAT Cassava Annual Reports; efforts during 1985 continued to emphasize biological control.

Mite sampling

The accurate evaluation of mite populations and their natural enemies in the field, requires an efficient and quantitative system of sampling the Mononychellus mite. Studies were done to adapt the presence/absence sampling scheme for the Mononychellus mite; this technique was originally developed for sampling the Tetranychus mite in cotton. The study was conducted in the field at CIAT with three varieties of cassava.

Since the cassava plant grows in a synchronized form, the leaves of comparable nodes on the main branches are the same age. The node with the first completely open leaf is designated the first node. Normally the plant does not have more than 50 nodes with leaves on any one branch. In those few cases where there were more than 50, all were grouped together as the 50th node. Each group was examined leaf by leaf for the presence or absence of the Mononychellus sp. A well trained person can do this evaluation, without the aid of a stereoscope. The inspection of the leaves at each node for each plant resulted in the proportion of leaves infested at node X. P(i)X. A mite brushing machine, designed to remove the mites and distribute them uniformly over a glass plate, was used to brush mites on all the leaves from each group onto a single plate. The plate was covered with a thin film of mineral oil to immobilize and preserve the mites for counts which were made by placing the glass plate over a metallic plate, divided into 12 sections. Mites were counted from four sections with the aid of a stereoscope and multiplied by a factor to estimate the number of mites per sample. These counts gave the average number of Mononychellus mites per leaf at node X, X.

Since the possibility exists that the efficiency of the mite brushing machine might vary with the number of mites per leaf and the number of leaves per sample, an experiment was done to measure its efficiency. The comparison between the direct mite count on the leaves and the sub-sample of four of the glass plates resulted in an r^2 of 0.993, indicating that the sub-sample is accurate in estimating the total number of Mononychellus sp.

The relationship was such that the subsample result needs to be multiplied by 3.22 to give the real result. In the presence/absence study done during the dry season, it was observed that plants seldom had more than 15 nodes with leaves. Therefore it is required that the selected node for sampling be between 1 and 15. The best regressions were obtained for nodes 1 and 2. The equations are:

$$P(i)_1 = 1 - e^{-.212X}$$

$$P(i)_2 = 1 - e^{-.174X}$$

The r^2 are .950 and .963 respectively. The regression for the first node can be observed in Figure 3. For the point of view of pest management, the average number of Mononychellus spp. per leaf is less informative than the average density (D/m^2). To calculate the D/m^2, the conversion of P(i)to X, and later X to D/m^2 is:

$$D/m^2 = \quad -1 \; X$$

is that portion of the total population of mites that found at a sampling node. A comparison between the model and field data was made (Table 3). The percentage of error between 4 and 15% is acceptable when trying to predict the density of the population that can vary between 0 and more than 50,000/m^2.

Presence/absence is a system that requires knowledge of plant structure, the distribution of mites on the plant and the relationship P(i), = X. One of the advantages of presence/ absence is its efficiency. During the peak of infestations, direct counts required 180 man hours per plot. In contrast, the inspection of leaf samples in the field required approximately 10 minutes per plot. The presence/absence is precise and sensitive to changes in the level of mite population in the field. An additional advantage is that no sophisticated equipment is required.

Biological Control

The study of the complex of insect and mite predators of cassava phytophagous mites was continued during 1985. A systematic exploration of cassava fields in the Department of Valle, Colombia, was completed. This exploration resulted in the identification of 25 species of Phytoseiid mite predators feeding on the cassava complex (Table 4). These were represented by 8 genera: Amblyseius, Euseius, Galendromus, Neoseiulus, Proprioseiopsis, Typhlodromalus, Typhlodromina, and Iphiseiodes. They were found feeding on six species of phytophagus mites. However, the two major species were Mononychellelus tanajoa and Oligonychus peruvianus (Table 4).

The most important species of phytoseiids identified, in terms of number of localities (municipalities) where they were found, were: Typhlodromalus limonicus (found in 41 of the 42 localities explored); Neoseiulus anonymus (found in 21 or 50% of the localities explored); Galendromus annectens (present in 31.0%) and Euseius concordis (present in 33%) (Fig. 4). All four of these species plus Amblyseius ideaus were shipped to CIBC and IITA for consequent study in the African situation. Typhlodromalus sp. is a new species not yet named. About half of the 25 species were only present in one or two sites and, therefore, probably not very important in a cassava mite biological control program. A morphological description and distribution register has been developed for each of the 25 species similar to that for T. limonicus (Fig. 5).

The biology and behavior of the five aforementioned species that were sent to IITA are being studied. The developmental biology of T. limonicus and N. anonymus at four different temperature regimes was completed using the methodology described in the CIAT 1984 Annual Report.

T. limonicus.

The development of T. limonicus was studied at 15°, 20°, 23°, and 25°C feeding on M. tanajoa.

Results indicate that the temperature inversely effects the rate of development of this species. At lower temperatures developmental time is

longer (Table 5). At 15°C the total developmental time of egg to adult was 14.7 days, while at 25°C it was only 4.8 days. The minimum temperature threshold for development was calculated at 9.6°C with a constant thermal temperature (day degrees) of 79.1 (Fig. 6).

Additional studies were done to determine the predation capacity of T. limonicus. During its adult stage it can consume an average of 4.0 eggs, 10.6 larvae, 6.6 protonymphs and 34 deutonymphs or adults. These results affirm that this species prefers feeding on M. tanajoa adults and only secondarily on the immature stages. In trying to establish colonies of this species it was observed that it will also feed and reproduce on pollen of Ricinus communis and Rosa sp; it is frequently found also on leaves infested by Oidium manihotis and probably consumes its spores. It is also found on plants being attacked by mealybugs (Phenacoccus sp.), possibly feeding on the "honey dew" excrement of the mealybugs. It was previously found that T. limonicus prefers not to feed on the Tetranychus mite due to the excessive webbing of this species; however, when offered cleaned eggs of T. urticae, they were readily consummed. These and other observations indicate that T. linomicus has a tendency to be a facultative or general feeder in that it can consume several kinds of food. This is a favorable condition since it is able to survive on alternative food sources during periods when M. tanajoa, its preferred host, might be in short supply.

Previous studies have shown that M. tanajoa at 28 ± 2°C and 40 to 70% relative humidity completes its cycle in 8.5 to 10.1 days. If we compare the development of T. limonicus at about the same temperature (25°C) it can be seen that T. limonicus will complete two generations to the one of M. tanajoa (Fig. 7). This is an advantageous ratio in a biological control program.

Neoseiulus anonymus

The development of N. anonymus was studied at four temperatures 20°, 23°, 25° and 30°C feeding on M tanajoa.

The results obtained confirm that the rate of development of the different biological stages are temperature dependent; a temperature increase resulted in a shorter or faster development rate, while at lower temperatures the rate decreased for all biological stages (Table 6). At 20°C the developmental time of egg to adult was 8.9 days and decreased to 4.0 days at 30°C (Table 7). The minimum temperature threshold for development was calculated at 11.0°C and the thermal constant (Day Degrees) was 73.5 (Fig. 8).

The population capacity of N. anonymus was determined on two phytophagous mite species, M. tanajoa and T. urticae. Previous studies determined that the developmental time of N. anonymus was the same regardless of the mite species offered (CIAT Cassava Annual Report 1984). However, results from present studies show a preference for feeding on the eggs of T. urticae (Table 8). Feeding preference on the immature and adult stages was about the same. The short generation time of N. anonymus, 4.0 days at 30°C, means that it can achieve two generations during the period that either of two phytophagous species complete one generation.

Cassava Hornworm Erynnyis ello.

Adult hornworm populations were monitored daily using light traps (black light type BLB) from October, 1984 to October 1985 at CIAT, Palmira, and CIAT-Quilichao, Cauca. At the same time that adult populations were being monitored, hornworm oviposition and egg parasitism were also being evaluated by sampling 100 random plants every 15 days.

In general, hornworm populations were low throughout the year at both sites. Peak adult populations occurred at CIAT-Palmira during February, April and July-August and at Quilichao during October-November, 1984. Egg oviposition was also highest during these months at both sites (Fig. 9). Hornworm eggs were parasitized by Trichogramma sp. and Telenomus sp. Telenomus, parasitism was very low at CIAT-Palmira and only slightly higher at Quilichao. Trichograma parasitism is considerably higher. Total egg parasitism was higher at Quilichao,(85%) than at CIAT-Palmira, (61%).

New Parasites

In field cage studies at CIAT-Palmira two additional species of parasites have been observed parasitizing Erinnyis ello eggs. These have been identified by the Commonwealth Institute of Entomology as:

Order:	Hymenopteran
Family:	Encyrtidae
Genus:	Ooencyrtus
Species:	Ooencyrtus submetalicus Howard
	Ooencyrtus sp.

This constitutes the first report of these species parasitizing E. ello eggs. Preliminary observations indicate that the development time of the parasite within the hornworm egg for O. submetalicus is 13 to 18 days and adult duration is 14 to 27 days, resulting in a total cycle of 27 to 44 days.

The Effects of Pesticides on Biological Control.

The effect of pesticides on the action of biological control agents is often a limiting factor in implementing and maintaining effective pest management programs. The cassava Hornworm, E. ello, has numerous natural enemies that are important in maintaining hormworm populations below economic injury level; more than 30 species of parasites, predators and pathogens have been identified (see previous CIAT Annual Reports for details). During severe hornworm outbreaks, farmers have the tendency to apply pesticides for control. Many of these pesticides can have an adverse effect on the natural enemies. A thesis research project was designed to study and evaluate the effect of several pesticides on the action of three hornworm parasites. The parasites selected for the study were Trichogramma exigum and Telenomus sphingis, both egg parasites, and Apanteles congregatus a parasite of the hornworm larvae.

The pesticide products tested were: (1) Ethyl Parathion (1.5 cc/l of water), (2) Dipterex (Tricloform) (2.5 gr/l water), (3) Dimilin (diflubenzaron W.P.) (1.5 gr/l water); and (4) Dipel (Bacillus

thuringiensis) (3.0 gr/l water). Dimilin is a growth inhibitor and prevents hornworm larvae passing from one instar to the following. Dipel is a bacterial insecticide. Both products have been evaluated, as effective in hornworm control (see previous CIAT Annual Reports).

The effects of these products on parasitism were tested in several ways. In one experiment the pesticide products were applied to E. ello eggs and the eggs were then exposed to the Trichogramma and Telenomus parasites. The effect of these products on female parasites that emerged from the treated eggs was examined by evaluating their ability to parasitize hornworm eggs. These products were also applied to parasitized hornworm eggs and their effect on parasite development and emergence was recorded. In addition, all products were applied directly to the adults of the two egg parasites as well as Apanteles, the larval parasite. Pesticides were also applied to recently formed pupa of A. congregatus. Studies were done to evaluate parasite behavior at three temperatures, 20°, 25° and 30°C.

Results show that applications of Dipel and Dimilin on E. ello eggs did not affect parasitism by T. exiguum. Parasitism of untreated eggs (control) was 82%, while with Dimilin and Dipel it was 78 and 80% respectively (Table 9). There were no significant differences in the number of eggs parasitized per female between the untreated, Dimilin and Dipel treated eggs. Dipterex treatment did not significantly reduce egg parasitism (68%) but the number of eggs parasitized, 1.4 per female, was significantly reduced. Parathion resulted in being highly toxic, only a 14% parasitism and 1.0 eggs per female were parasitized.

There was no significant difference in number of adults produced per female parasite between the untreated (46), Dimilin (39) and Dipel (44) (Table 9). Dipterex and Ethyl-parathion treatments reduced the number of adults produced. The number of parasite adults produced per parasitized eggs were statistically the same for the untreated (15.5) and the Dimilin (14.7), Dipel (17.1), and Dipterex (15.7) treatments, but greatly reduced with the parathion (2.7) treatment. Adults longevity was greatly reduced due to Dipterex and Ethyl-parathion treatments; only 34 and 0% respectively of the adult parasites produced survived 24 hours, while 94, 88 and 82% of the untreated, Dimilin and Dipel treated adults survived (Table 9). This survival reduction undoubtedly affected the number of eggs parasitized. The Ethyl-parathion treatment also significantly reduced the number of eggs that produced adults.

The parasitic ability of female parasites that emerged from treated eggs was also studied. The percentage of females capable of parasitism was reduced by Dipetex (56%) and Dimilin (42%) but not by Dipel (72%) when compared to the untreated (85%). Ethyl-parathion treated eggs did not produce enough females to study their parasitic ability. The number of eggs parasitized per female was significantly reduced only by the Dipterex treatment. There was no significant difference in the number of adults produced per female nor the number produced per parasitized egg.

Results of tests with Telenomus sphingis were similar to those of Trichogramma except that T. Sphingis appears to be more adversely

affected by Dipel applications than Trichogramma. The percentage of female parasites that were able to parasitize treated eggs were reduced by Dipel (77%), Dipterex (53%) and Parathion (5%) when compared to the untreated (100%) and Dimilin (97%) treated (Table 10). Ethyl-parathion and Dipterex treatments significantly affected the behavior and reduced the parasitic actions of Telenomus in most aspects studied. Dimilin treatment had the least effect on the parasitic ability of Telenomus and Dipel was intermediate in that there was some reduction in parasitic effectiveness but not as drastic as the chemical pesticides treatments.

When the second generation of Telenomus was studied, that is, when adults produced from parasitized eggs that had been treated by the aforementioned products were evaluated, Dipel was less toxic than Dimilin. The percentage of females capable of parasitism from Dimilin treated eggs was only 60% compared to 97% for the untreated and Dipel treated. The number of eggs parasitized per female, the number of adults produced per female, and adult female longevity were also reduced by the Dimilin treatment.

The effect of these products on E. ello eggs that were parasitized prior to treatment was also studied. The applications of Dipel and Dimilin on parasitized hornworm eggs had no detrimental effect on Telemonus nor Trichogramma in all aspects studied (Table 11 & 12). The direct application of these products to adult Telenomus and Trichogramma resulted in a rapid and high mortality rate with Ethyl-parathion and Dipterex, a moderate level of mortality with Dimilin and none with Dipel.

In general, the results of these experiments indicate that the application of Dipel and Dimilin are compatible with Trichogramma and Telenomus egg parasitism in a hornworm pest management program, whereas applications of Dipterex and Parathion would greatly reduce parasitic action.

The effect of these products on the pupal development, adult emergence and adult longevity of Apanteles congregatus was also studied. Results show that there was no reduction in adult Apanteles emergence from the pupal case when Dipel and Dimilin were applied, but emergence was reduced by more than 90% following applications of Dipterex and Parathion. Likewise, adult mortality was greatly reduced (100%, 6 hours after application) with aplications of Dipterex and Ethyl-parathion and only moderately reduced by Dipel and Dimilin (18 and 24% respectively after 48 hours).

The effect of temperature on parasitism and development was studied for both Trichogramma and Telenomus. Trichogramma parasitized the greatest number of eggs at 20°C (4.2 per female) (Table 13). The greatest percentage of females that achieved parasitism, was at 25 and 30°C, however at 30°C only 69% of the parasitized eggs produced adults, considerably lower than at 20 and 25°C. The number of parasite adults produced per Trichogramma female was highest at 20°C and lowest at 30°C (28%). The number of adult parasites produced per egg was equal at all three temperatures, however at 30°C, 7.6 females were produced per male, while at 20°C this ratio was only 1.5.

The results for Telenomus differred; the greatest number of eggs parasitized per female was at 30°C (6.2) and the fewest was at 20°C (3.1) (Table 14). The percentage of females that achieved parasitism and the percentage of eggs that produced adults, were both greatest at 25°C. The greatest number of adult parasites produced per female Telenomus was at 25°C (21.9) and 30°C (14.8), while the highest number of adults produced per egg recurred at 32.5°C. There was no significant difference in the sex ratio at the four temperatures.

These results indicate that Telenomus may be more efficient or active than Trichogramma at higher temperatures, while Trichogramma prefers the lower temperatures. Further analysis of the data shows that for Trichogramma the minimum threshold development occurs at 13.5°C, with a thermal requirement of 95.6°C degree days. For Telenomus the minimal threshold development is 14.2°C, the maximum is 30°C with thermal requirements of 123.1°C degree days. It should be noted, however, that these results may be species specific and similar studies should be done on additional species before any generalizations are made.

Cyrtomenus bergi

Nymphs and adults of this subterranean sucking insect can greatly reduce the commercial value of cassava roots. The insect feeding action, the insect stylet entering into the fleshy root, combined with soil pathogens, results in brown to black spotting of the root.

1) Starch losses.

Previous studies have measured yield losses in terms of loss in commercial value of the root. Heavily damaged roots, those roots with considerable spotting, are refused at the market level by the consumer, at the farm by the middleman, and also by the processor. An attempt was made to determine the quality losses that occur in damaged roots. A damaged scale of 1 to 5 was defined as follows:

1 = 0% damage to roots surface (no spotting)
2 = 1-25% of root surface with spotting
3 = 26-50% of root surface with spotting
4 = 51-75% of root surface with spotting
5 = 76-100% of root surface with spotting

Roots of all five categories were analyzed to determine losses in starch content. Results show that from levels 3 to 5, that is, when 25 to 100% of the root surface is covered with brown to black spots, there is a dramatic reduction in starch content (Table 15). With less than 25% surface damage there is no reduction in starch content.

At damage level 3 and 4, starch reduction is 33% and at 5 it is 55%. A difference in starch color was also detected at the higher damage levels (4 and 5). The normally white starch takes on a yellow brown tone. At the lower damage levels there was no visual difference in coloration.

2) Population fluctuations

For the third straight crop cycle the dynamics of C. bergi populations were determined at CIAT-Quilichao from October 1984 to May 1985. Two varieties, CMC 40 (low Cynanide (HCN) content) and M Mex 59 (intermediate HCN content) were periodically harvested and root damage and C. bergi populations were assessed.

Results show that adults and nymphs of C bergi begin attacking roots during the first month of crop growth (Fig. 10) and continue feeding on roots throughout the crop cycle. Damage was considerably higher on CMC 40, the low cyanide variety, reaching 60% of the root damage after 8 months. Insect populations were considerably greater on CMC 40 than M Mex 59 (Fig. 11) supporting data from previous studies. Insect populations fluctuated during the early months and increased dramatically from months 5 through 8.

3) Critical growth period vs insect attack.

Two experiments were designed to determine what stage of plant growth is most sensitive or susceptible to pest attack and damage. In one trial, C. bergi was permitted to attack cassava roots for increasingly longer periods, up to 9 months (ie. protection beginning at the first month to harvest; protection from the second month to harvest etc.). The second experiment was inverse to the first trial (pesticide protection until the first month, protection until the second month, etc.).

Results show that there is no critical point in plant growth for control of this pest. In the first trial, the percentage of heavily damaged commercial roots (grade 3-5) fluctuated from a low of 15% during the 8th month to a high of 38% during the seventh month (Table 16). Damage levels in the second trial were generally lower but as in the first trial no trend could be detected. The damage levels in the non-commmercial roots (smaller roots) were much higher than the commercial roots. An average of 68% of non commercial roots were heavily damaged in the first trial and 36.8% in the second trial vs. 27.3 and 13.2 for commercial roots in the first and second trial respectively.

4) High vs low HCN varieties.

Previous studies (CIAT Annual Reports 1983, 1984) show a preference of C. bergi for feeding on low HCN or "sweet" varieties. A study was designed to evaluate the ability of using a high HCN variety as a barrier to prevent damage to low HCN varieties. Plots of 144 plants (12 x 12) of the high HCN variety, M Col 1684, were planted; the center 16 plants of each plot were planted to CMC 40, a low HCN variety. Results indicate that a high HCN variety does not impede C. bergi attack; at harvest 80% of the CMC 40 roots were damaged and 33% of M Col 1684 roots were damaged.

5) Intercropping Canavalia enciformis: Canavalia was intercropped with cassava and compared with cassava monoculture for control of C. bergi. Canavalia is known to possess insecticide qualities for certain pests. Results show that Canavalia has no insecticide or repellent effect on C. bergi. In cassava monoculture, 79% of the

roots were damaged vs. 71% root damage in cassava intercropped with Canavalia.

Cassava Pest Complex

An evaluation of the insect and mite complex at CIAT has been carried out for the fifth consecutive crop cycle. The four varieties used in the experiment were CMC 40, M Col 113, M Col 22 and M Col 1684. Four 36 plant plots of each variety received insecticide treatment and four plots received no treatment. Monthly evaluations of insect and mite populations and plant damage were made and root yield was recorded.

Insect populations and damage, in general, were higher than the previous year. The major pests that attacked these varieties throughout the 1985 growing cycle were trips, mites (Mononychellus sp., Tetranychus sp., and Oligonychus sp.) and lacebugs (Fig. 12). Whitefly population (Aleurotrachewlus socialis and Trialeurodes variabilis) were observed but were very low throughout the year. Mealybug (Phenacoccus herreni) populations and damage was much lower than in previous years. In terms of damage levels, thrips were the most important pest.

All four varieties suffered some yield reduction; this reduction was greatest with the variety M Col 1684 (49%) and lowest with M Col 113 (17.4%). The varieties M Col 22 and CMC 40 were intermediate, with 27.2 and 22.8% respectively (Table 17). Mite and thrips damage on M Col 1684 was high during most of the growth cycle and was probably most responsible for the yield reduction (Fig. 12). M Col 113 is resistant to thrips and therefore damage remained low (Fig. 13). A considerable reduction in planting material was also recorded for M Col 1684 (49.3%) (Table 17).

TABLE 1. Ovipositional preference of *Epidinocarsis diversicornis* for two nealybug species, *Phenacoccus herreni* and *P. gossypii* 1985.

Event	Mealybug Species	No. Rep.	%
Localization	*P. herreni*	10	12.7 A
	P. gossypii	10	5.3 B
Intent to oviposit	*P. herreni*	10	5.7 A
	P. gossypii	10	1.0 B
Oviposition	*P. herreni*	10	3.3 A
	P. gossypii	10	1.6 B

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

TABLE 2. Ovipositional preference of *Acerophagus coccois* for two mealybug species, *Phenacoccus herreni* and *P. gossypii* (1985).

Event	Mealybug Species	No. Rep.	%
Localization	*P. gossypii*	10	10.0 A
	P. herreni	10	1.8 B
Intent to oviposit	*P. gossypii*	10	6.7 A
	P. herreni	10	0.7 B
Oviposition	*P. gossypii*	10	2.7 A
	P. herreni	10	0.0 B

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

TABLE 3. A comparison of results predicted by the model $P(i) = 1 - e^{-bx}$ with field data.

Variety	Node	P(i) Field	D/m^2 Model thousand	D/m^2 Field thousand	% Error
Col 22	1	1.00	42.7	48.6	12.0
	2	1.00	51.8	48.6	6.7
Bra 12	1	0.23	14.3	12.3	15.6
	1	0.37	0.3	0.4	14.4
	2	0.50	10.4	12.3	15.3
	2	0.58	0.3	0.4	14.4
CG5-79	1	0.14	0.2	0.2	4.4
	2	0.18	0.2	0.2	9.8
	2	1.00	51.8	55.8	7.1

TABLE 4. Species of Phytoseiidae and Phytophagous mites associated with cassava in Colombia.

	Associated Phytophagous Species					
Phytoseiidae Species	*T. urticae*	*M. tanajoa*	*M. caribbeanae*	*O. peruvianus*	Tenuipalpidae	Eriophydae
Amblyiseius aerialis		X		X		
A. chiapensis	X	X		X		
A. aff. coffeae		X		X		
A. near curiosus		X		X		
A. herbicolus		X		X		
A. largoensis			X			
Euseius alatus		X		X		
*E. casearia*e		X				
E. concordis	X	X		X	X	X
E. naindaimei		X				
E. sibelius		X		X		
galendromus anneetens	X	X		X	X	X
G. helveolus	X	X	X	X	X	X
Iphiseiodes zuluagai		X	X	X		
Neoseiulus anonymus	X	X	X	X	X	X
N. chilenensis				X		
Proprioseiopsis carinaensis		X		X		
P. aff. neotropicus				X		
Typhlodromalus aripo	X	X	X	X	X	X
T. limonicus	X	X	X	X	X	X
T. peregrinus	X	X		X		
Typhlodromalus n. sp.				X		
Typhlodromina subtropica		X				
T. tropica aristidesi				X		

TABLE 5. The effect of four temperatures on the development of *Typhlodromalus limonicus*. Feeding on Mononychellus tanajoa.

Temperature (°C)	Development time (days) (Y)	Rate of development (1/Y)	Minimum temperature (°C)	Day degrees (°D)
		EGG		
15	5.2	19.3		
20	2.1	46.6	9.9	25.3
23	2.7	37.6		
25	1.5	67.0		
		LARVAE		
15	3.3	30.3		
20	1.6	62.6	10.0	15.6
23	1.1	90.5		
25	1.1	89.4		
		PROTONYMPH		
15	2.2	45.0		
20	1.6	64.3	7.1	19.5
23	1.5	65.8		
25	0.9	106.3		
		DEUTONYMPH		
15	4.1	24.5		
20	1.7	59.0	9.9	19.0
23	1.5	64.8		
25	1.3	79.4		

TABLE 6. The effect of four temperatures on the development of *Neoseiulus anonymus* feeding on *Mononychellus tanajoa*.

Temperature (°C)	Development time (days) (Y)	Rate of development (1/Y)	Minimum temperature (°C)	Day degrees (°D)
		EGGS		
20	3.87	25.7		
23	2.91	34.3	11.8	30.7
25	2.13	46.9		
30	1.73	57.5		
		LARVAE		
20	1.15	86.6		
23	0.70	141.3	14.7	5.83
25	0.55	181.4		
30	0.39	258.0		
		PROTONYMPH		
20	1.75	56.9		
23	1.17	85.0	10.3	14.8
25	0.85	116.3		
30	0.90	124.2		
		DEUTONYMPH		
20	2.14	46.7		
23	1.34	74.5	6.66	24.2
25	1.22	81.8		
30	1.10	90.8		

TABLE 7. The effect of temperature on the development of *Neoseiulus anonymus*

Temperature (°C)	Time of development (Days) (Y)	Rate of development (1/Y)	Minimum temperature (°C)	Day degrees (°D)
		Total Development of Egg to Adult		
20	8.9	11.2		
23	6.1	16.3	11.02	73.5
25	4.7	20.9		
30	4.0	24.8		

TABLE 8. Average consumption rate of adult female *Neosiulus anonymus* during its ovipositional period feeding on *Mononychellus tanajoa* and *Tetranychus urticae*.

Stages consumed	*Mononychellus tanajoa*			
	n	Minimum	Maximum	Average
Eggs	46	0	26	10.78
Larvae	46	0	20	5.15
Nymphs	46	0	9.0	1.91
Adults	46	0	21.0	5.39

Stages consumed	*Tetranychus urticae*			
	n	Minimum	Maximum	Average
Eggs	50	28.0	138.0	78.28
Larvae	50	0	11.0	2.80
Nymphs	50	0	23.0	5.10
Adults	50	0	14.0	4.74

TABLE 9. The effect of several pesticides[1] on the parasitism of *Erinnyis ello* eggs by *Trichogramma exiguum*.

TREATMENT	% Of females achieving parasitism	No. Eggs parasitized per female	No. Adults produced per female	No. Adults produced per egg	% Females* survival	% Eggs parasitized	% Eggs that produce adults
Control	82 a	2.5 a	46 a	15.5 a	94 a	19 a	96 a
Dimilin	80 a	2.9 a	39 a	14.7 a	88 a	25 a	35 a
Dipel	78 a	3.4 a	44 ab	17.1 a	82 a	21 a	87 a
Dipterex	68 a	1.4 b	20 b	15.7 a	34 a	9 b	88 a
E. Parathion	14 b	1.0 b	3 c	2.7 b	0 c	1 c	30 b

* Values with the same letters are not significantly different at the 0.05 level.

[1] Products applied to eggs prior to their exposure to *T. exiguum*.

TABLE 10. The effect of several pesticides[1] on the parasitism of *Erinnyis ello* eggs by *Telenomus sphingis*.

TREATMENT	% Females achieving parasitism	No. Eggs parasitized	No. Adults produced per female	No. Adults produced per egg	Female longevity (days)	% Eggs parasitized	% Eggs producing adults
Control	100 a*	5.5 a	21.4 a	3.9 a	10.7 - a	30.0 a	98.7 a
Dimilin	97 a	6.4 a	15.6 a	3.5 b	11.2 - a	34.0 a	70.2 c
Dipel	77 b	4.5 a	14.2 b	3.7 a	8.3 - b	18.9 b	85.8 b
Dipeterex	53 bc	2.4 b	0.5 c	1.6 c	1.2 - c	7.3 c	5.0 d
E. Parathion	5 c	1.0 b	0.0 c	1.0 c	2.3 - d	0.0 e	3.7 e

* Values with the same letters are not significantly different at the 0.05 levels.

[1] Pesticides applied to eggs prior to their exposure to *Telenomus sphingis*

TABLE 11. The effect of several pesticides on *Erinnyis ello* eggs paratized by *Trichogramma exiguum* 48 hours prior to pesticide application.

TREATMENT	% Eggs that produce adults	No. Adults emerging per egg	No. Parasits not per egg	Sex ratio
Control	98 a*	24.7 a	1.4 b	5.9 : 1 a
Dipel	100 a	24.4 a	0.3 b	6.7 : 1 a
Dimilin	100 a	26.9 a	1.7 b	5.5 : 1 a
Dipterex	30 b	20.1 a	16.9 a	12.5 : 1 b
E. parathion	20 b	12.0 b	19.8 a	6.3 : 1 a

* Values with the same letters are not significantly different at the 0.05 level.

TABLE 12. The effect of several pesticides on *Erinnyis ello* eggs parasitized by *Telenomus sphingis* 72 hours prior to pesticide application.

TREATMENT	% Of eggs producing	No. Adults emerging per egg	No. Parasites not emerging	Sex ratio
Control	98 a*	4.5 a	0.4 b	1.5 : 1 ab
Dimilin	98 a	4.6 a	0.3 b	2.2 : 1 a
Dipel	96 a	4.0 a	0.3 b	1.9 : 1 ab
Dipterex	9 b	1.3 b	4.3 a	0.4 : 1 b
E. Parathion	4 b	1.0 b	5.5 a	0.4 : 1 b

* Values with the same letters are not significantly different at the 0.05 level.

TABLE 13. Parasitism and development of *Trichogramma exiguum* on *Erinnyis ello* eggs at three temperatures.

TEMPERATURE	Eggs parasitized per female	% Females achieving parasitism	% Eggs producing adults	Adults produced per female	Adults produced per hornworm egg	Sex ratio
20	4.2 a	66 b	98 a	59.4 a	14.5 a	1.5 : 1 b
25	2.5 b	92 a	96 a	41.2 ab	16.2 a	7.4 : 1 a
30	2.4 b	90 a	69 b	28.4 b	17.2 a	7.6 : 1 a

Values with the same letters are not significantly different at the 0.05 level.

TABLE 14. Parasitism and development of *Telenomus sphingis* on *Erinnyis ello* eggs at three temperatures.

TEMPERATURE	Eggs parasitized per female	% Females achieving parasitism	% Eggs producing adults	Adults produced per female	Adults produced per hornworm egg	Sex ratio
20	3.1 b	76.7 b	32.7 c	3.0 d	3.0 a	2.0 : 1 a
25	5.9 a	100.0 a	98.7 a	21.9 a	3.7 a	1.4 : 1 a
30	6.2 a	76.7 b	68.7 b	14.8 b	3.5 a	1.2 : 1 a
32.5	4.3 ab	80.7 ab	31.0 c	5.1 c	4.1 b	1.7 : 1 a

Values with the same letters are not significantly different at the 0.05 level.

TABLE 15. The effect of C. bergi damage on the starch content of cassava roots of the variety CMC-40.

Damage grade	% of root surface affected	Starch[a] dry weight	% Starch	Difference %
1	0	114.3	22.9	
2	1 - 25	124.3	24.9	+ 8.0
3	26 - 50	76.5	15.3	33.0
4	51 - 75	75.8	15.2	33.7
5	76 - 100	51.4	10.3	55.0

[a] Sample of 500 grs of peeled cassava.

TABLE 16. Damage to cassava roots under progressive attack *C. bergi*.

Months of attack	Experiment I % roots with 3-5 damage grade[b]		Experiment II % roots with 3-5 damage grade	
	Commercial[a] roots	Non-commercial roots	Commercial roots	Non-commercial roots
1	18.5	70.0	21.5	60.0
2	16.5	67.0	8.0	16.5
3	28.0	69.0	13.5	40.0
4	35.0	60.5	15.0	20.0
5	25.0	66.5	18.5	58.5
6	33.0	58.0	3.5	25.0
7	38.5	79.8	22.0	56.5
8	15.0	61.5	13.5	43.5
9	36.5	78.5	3.5	11.5

[a] Sample of 20 roots

[b] Dimethoate 2 cc/1 H_2O folliage application

TABLE 17. The effect of the CIAT cassava pest complex on the root yield and production of planting material of four cassava varieties.

Variety	Treatment	Roots yield: Total production t/ha	Roots yield: % difference yield (%)	Roots yield: Starch content (%)	Production av. number per plant	Planting mat. difference in stake prod. %
CMC 40	With insecticide	37.8	22.8	30.5	11.3	- 4.4
	Without insecticide	29.2		31.4	11.8	
M Col 113	With insecticide	29.9	17.4	29.2	8.4	19.0
	Without insecticide	24.7		27.7	6.8	
M Col 22	With insecticide	37.2	27.2	36.4	9.9	14.0
	Without insecticide	27.1		34.8	8.5	
M Col 1684	With insecticide	35.5	49.0	30.0	7.1	49.3
	Without insecticide	18.1		31.3	3.6	

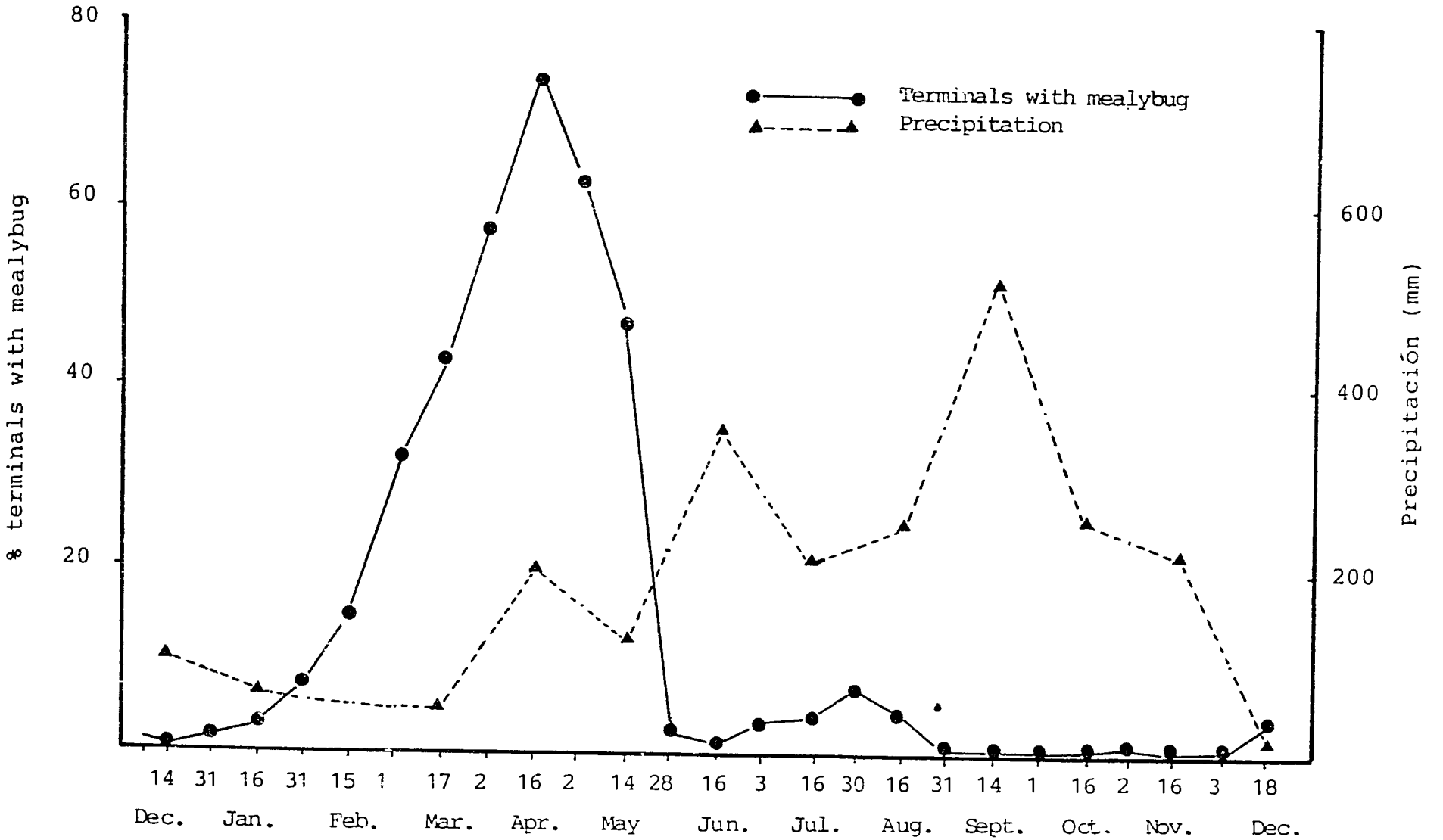


FIGURE 1. Population fluctuation of Phenacoccus herreni determined by the number of terminals infested from December 1983 to December 1984 at Carimagua.

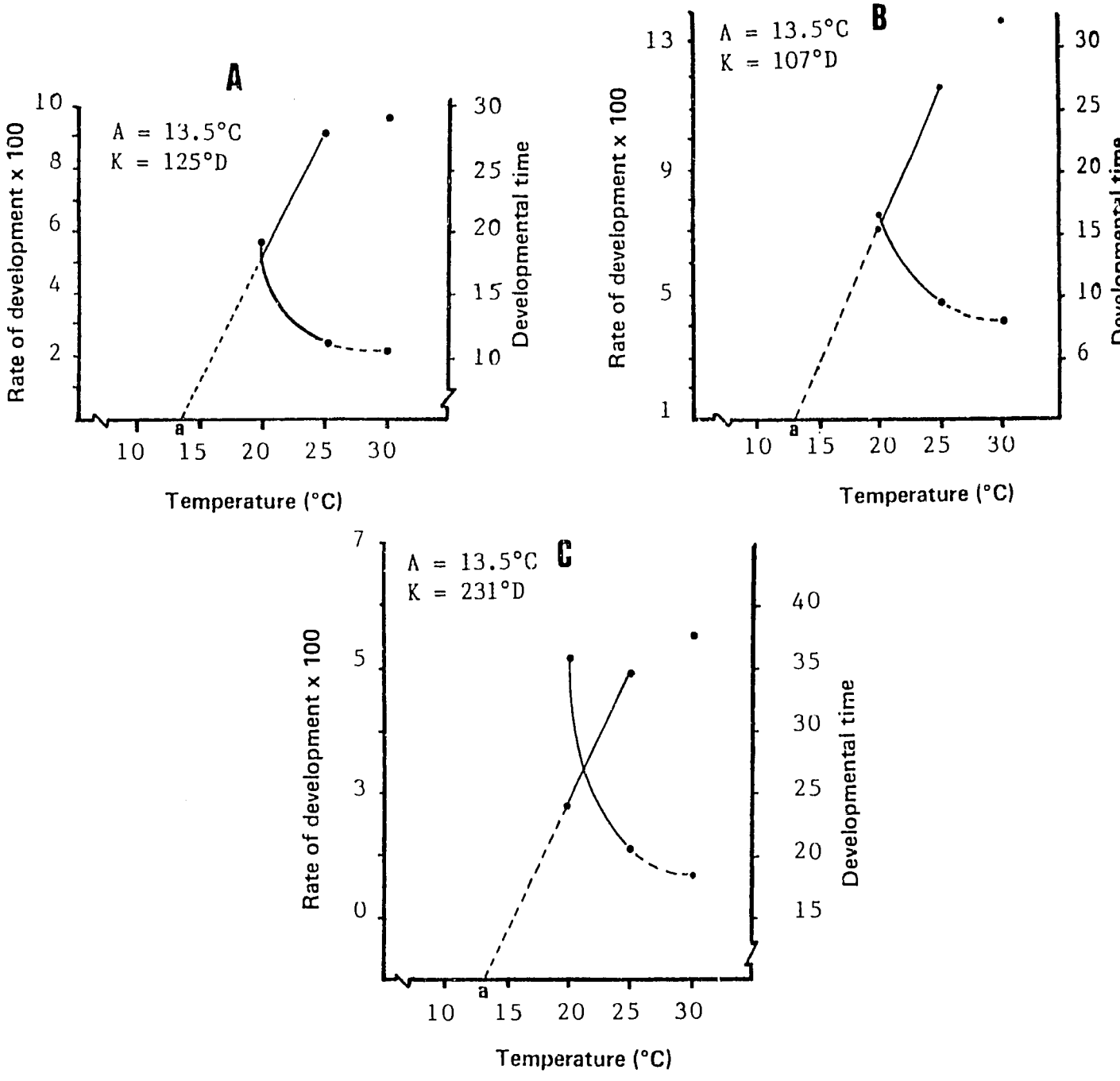


Figure 2. Developmental curve of *Epidinocarsis diversicornis* of the oviposition to mummy stage (A), the mummy to adult emergence (B), and the total development time (C).

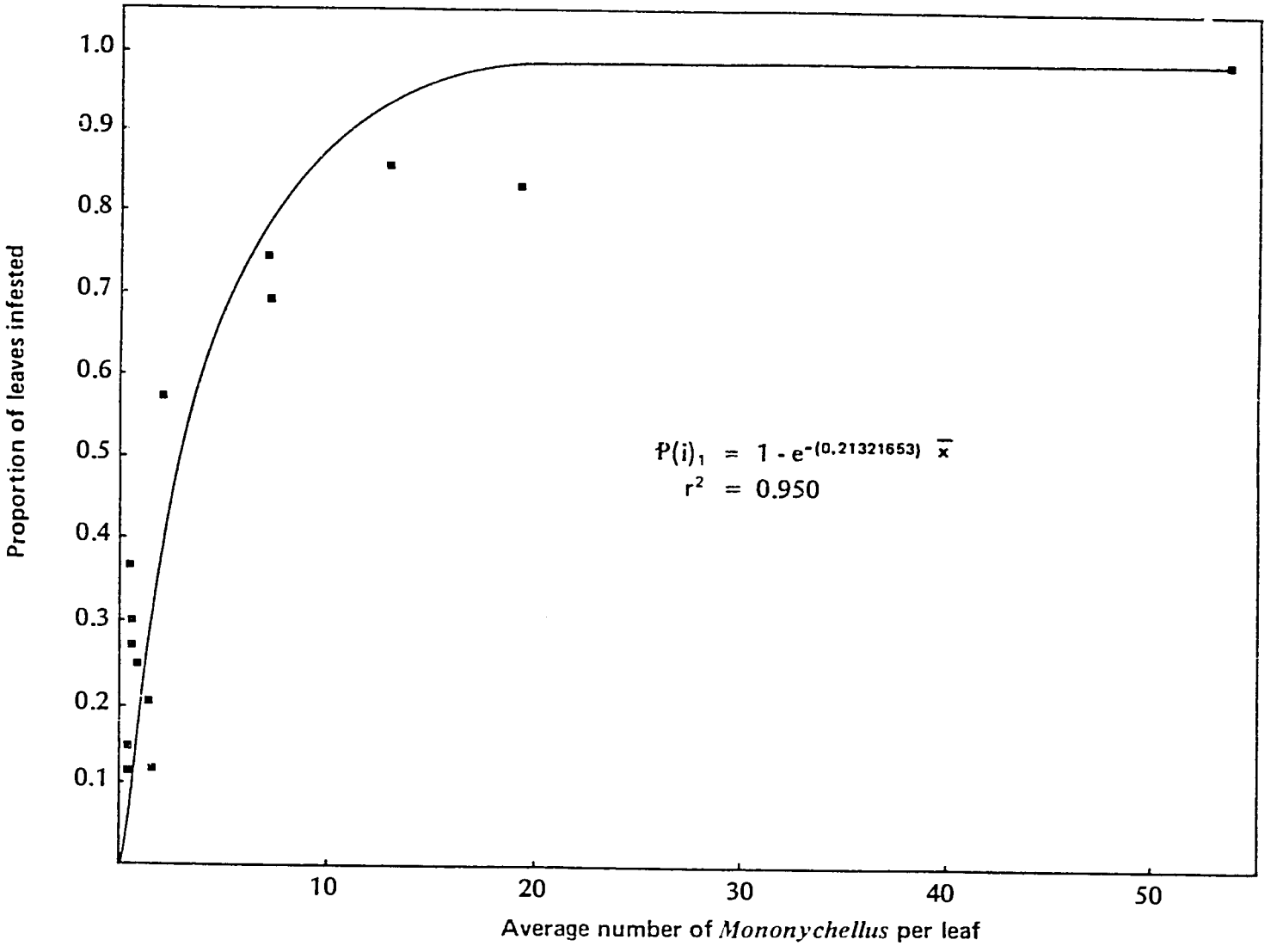


Figure 3. The relationship between P(i), the proportion of infested leaves and $\bar{x}$, the average number of *Mononychellus* spp. per leaf for the first node of the cassava plant.

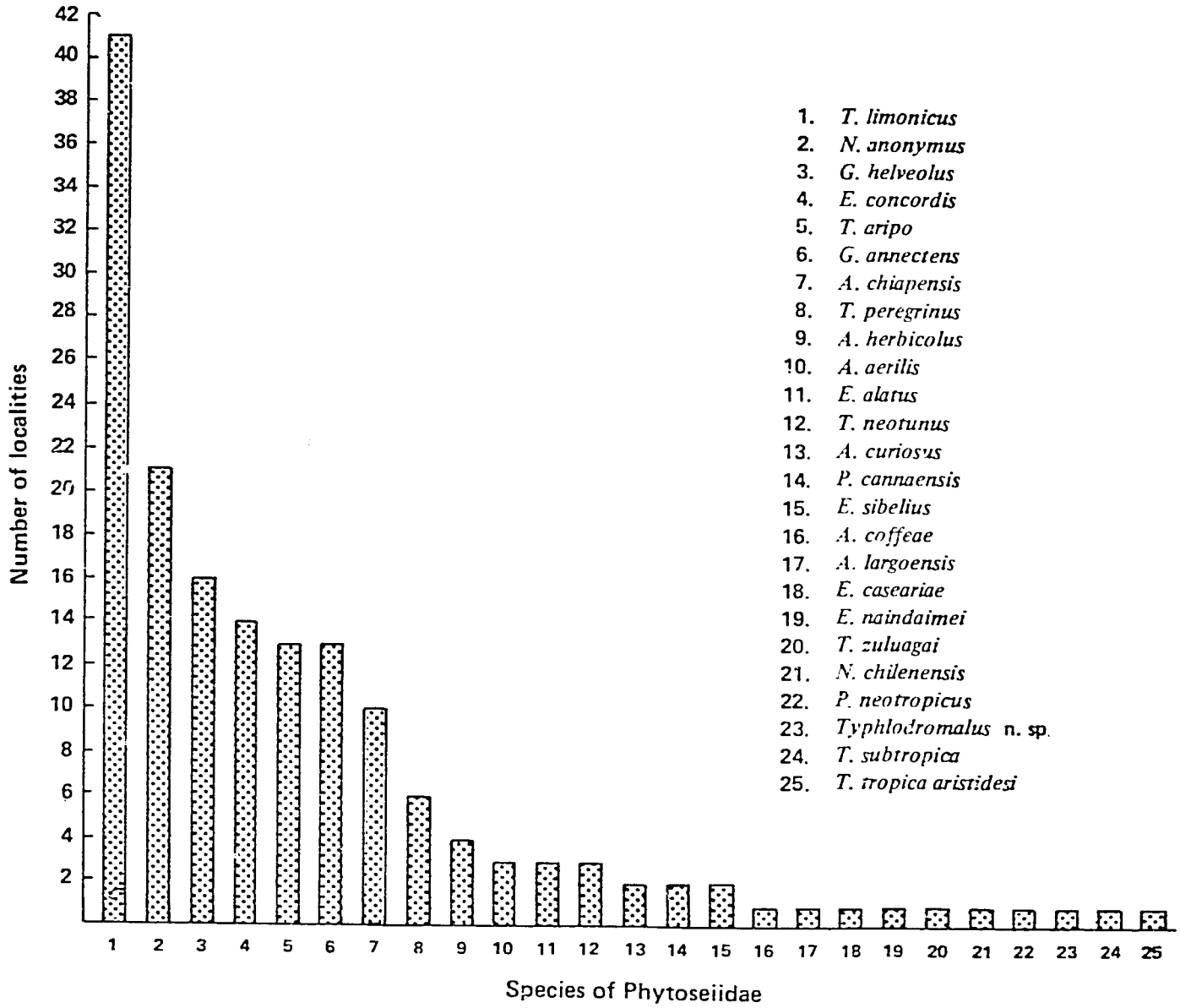
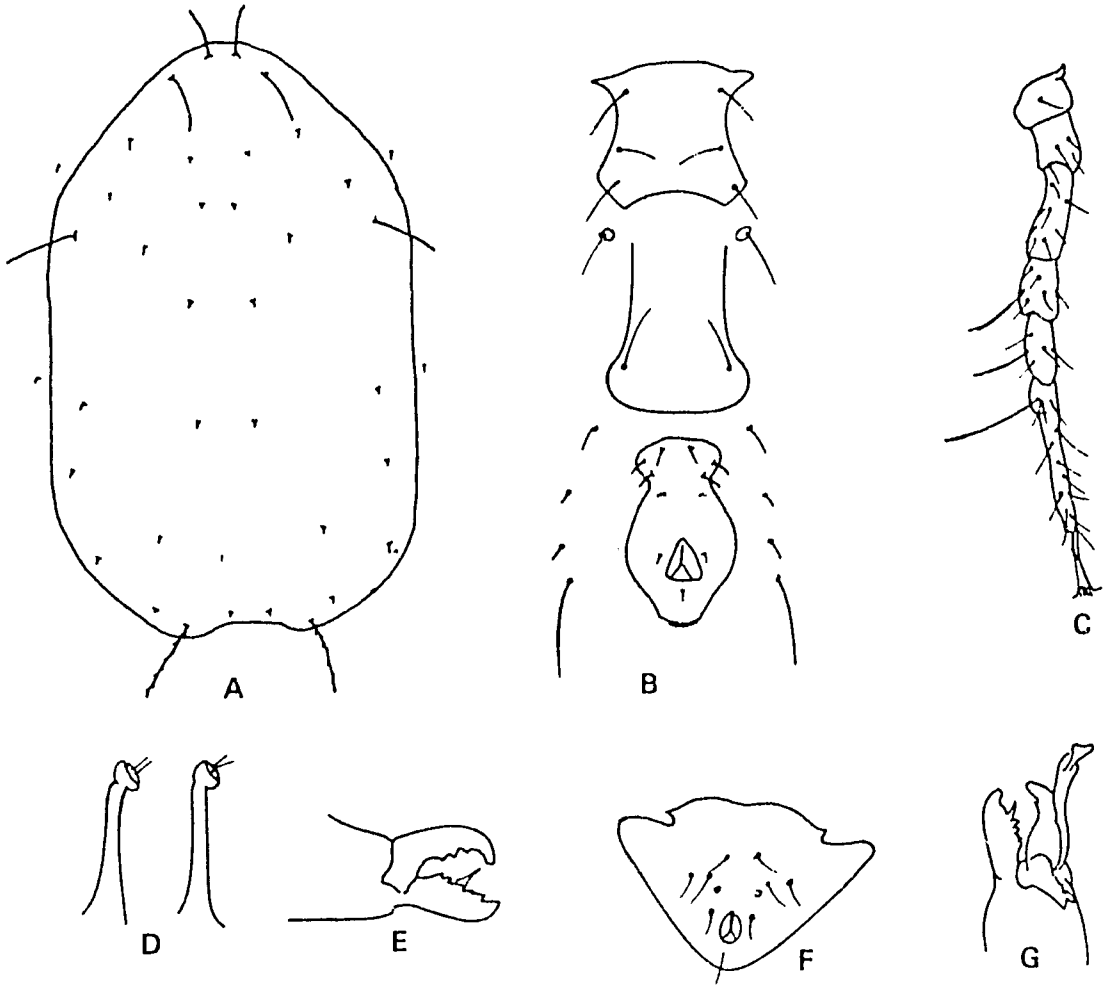
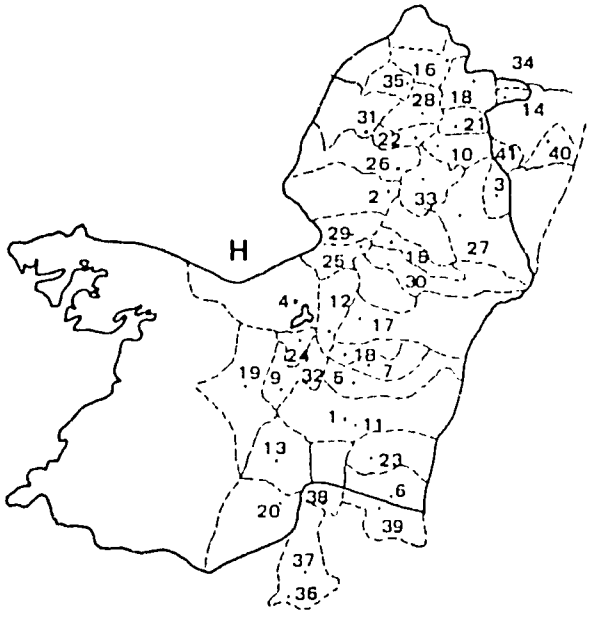


Figure 4. Species of Phytoseiidae present on cassava in different localities in Valle del Cauca, Colombia.





1.	CIAT	21.	Obando
2.	Bolívar	22.	La Unión
3.	Caicedonia	23.	Pradera
4.	Calima	24.	Restrepo
5.	Cerrito	25.	Río Frío
6.	Florida	26.	Roldanillo
7.	Ginebra	27.	Sevilla
8.	Guacarí	28.	Toro
9.	La Cumbre	29.	Trujillo
10.	La Victoria	30.	Tuluá
11.	Palmira	31.	Versalles
12.	Yotoco	32.	Vijes
13.	Cali	33.	Zarzal
14.	Alcalá	34.	Ulloa
15.	Andalucia	35.	Argelia
16.	Ansermanuevo	36.	Mondomo (Cauca)
17.	Buga	37.	Santander de Quilichao
18.	Cartago	38.	Puerto Tejada
19.	Dagua	39.	Miranda
20.	Jamundí	40.	Calarcá (Quindio)
		41.	La Tebaida

igure 5. *Typhlodromalus limonicus* (Garman & McGregor).
A: (Dorsum (♀); B: Ventral shield (♀); C: Leg IV (♀); D: Spermatheca; E: Chelecera (♀); F: Ventrianal shield (♂); G: Spermadactyl; H: Geographic distribution.

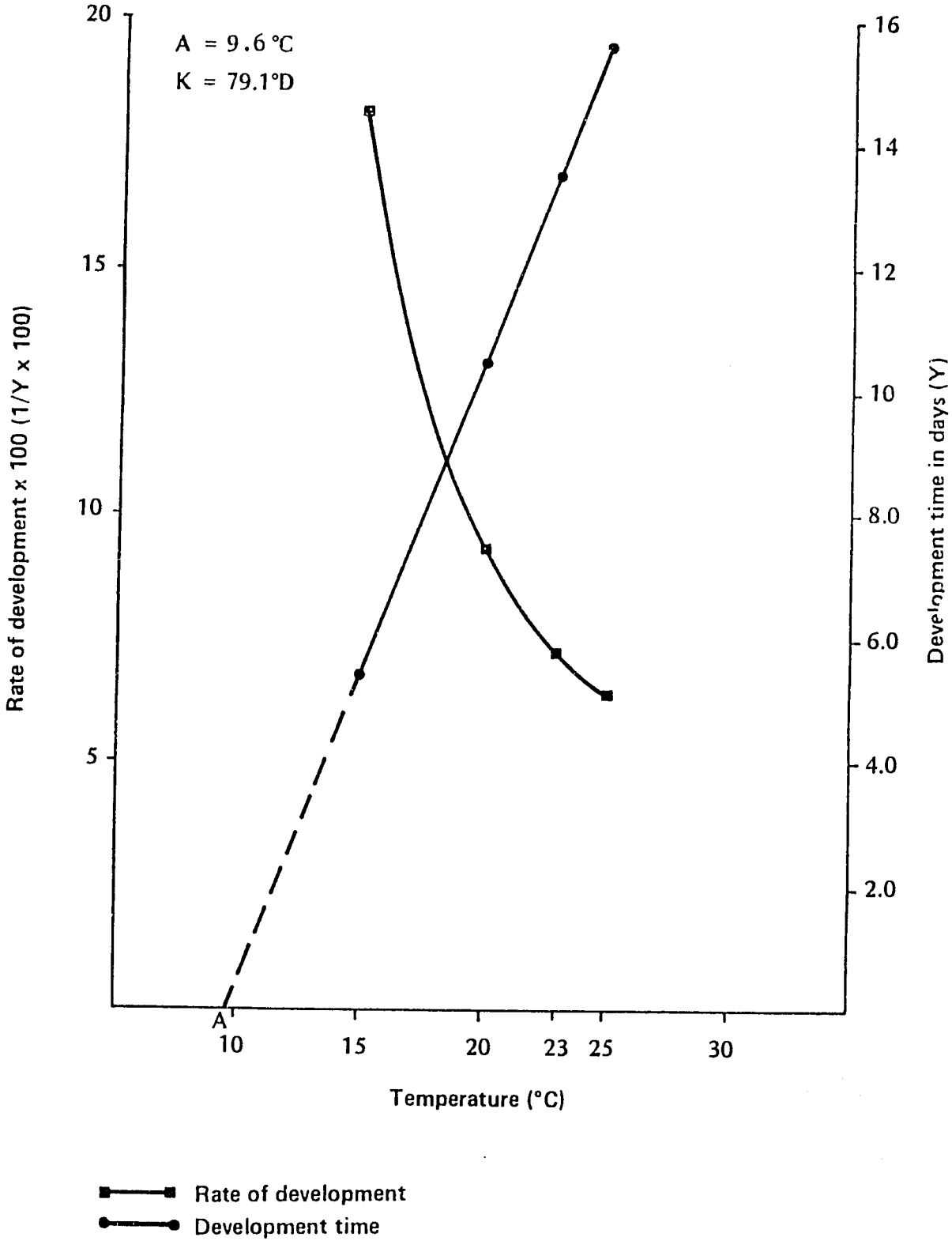


Figure 6. The effect of temperature on the time and rate of development of the inmature stages of *Typhlodromalus limonicus*.

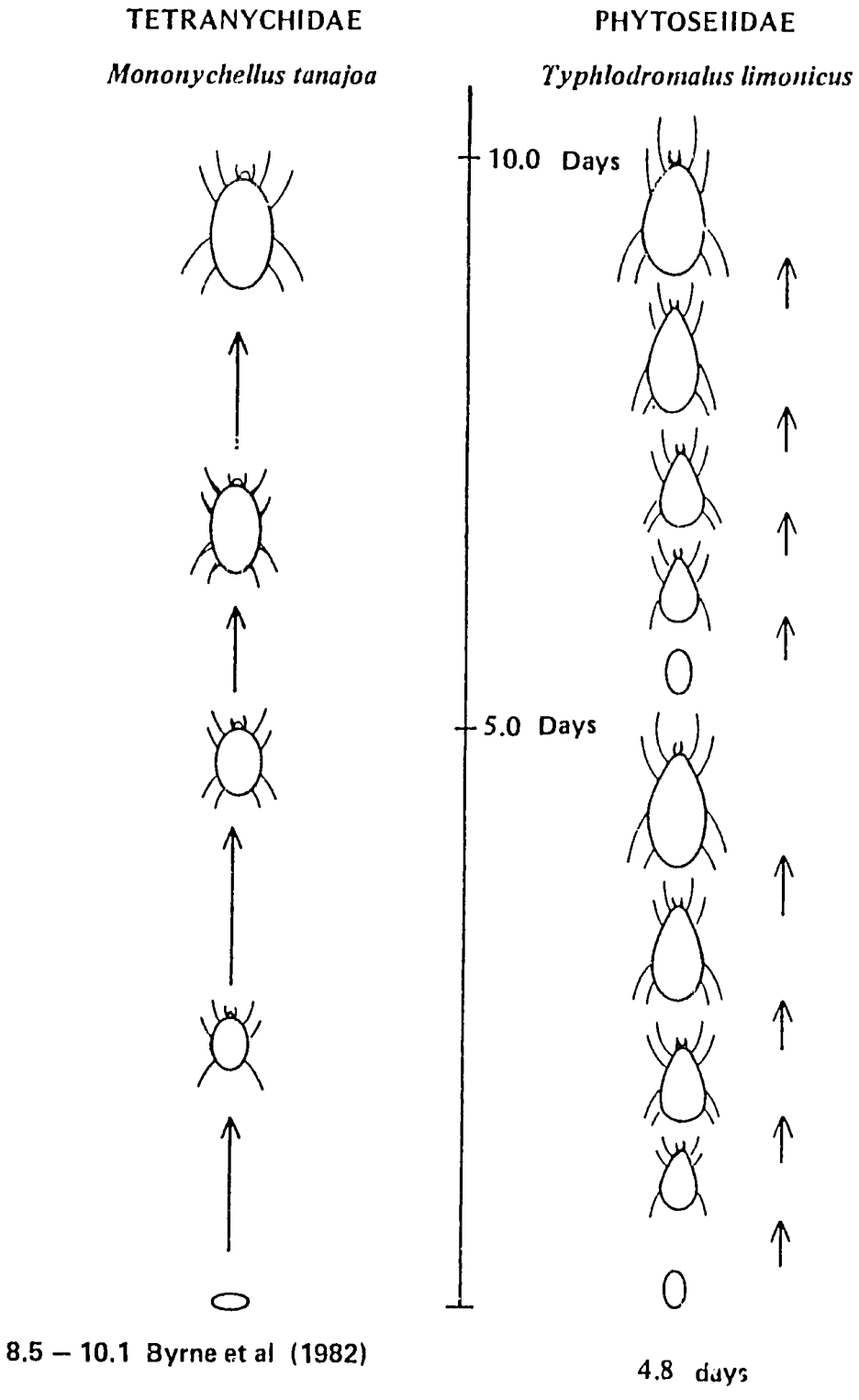


Figure 7. Comparison of development duration between a Phytoseiid mite predator and a phytophagous mites.

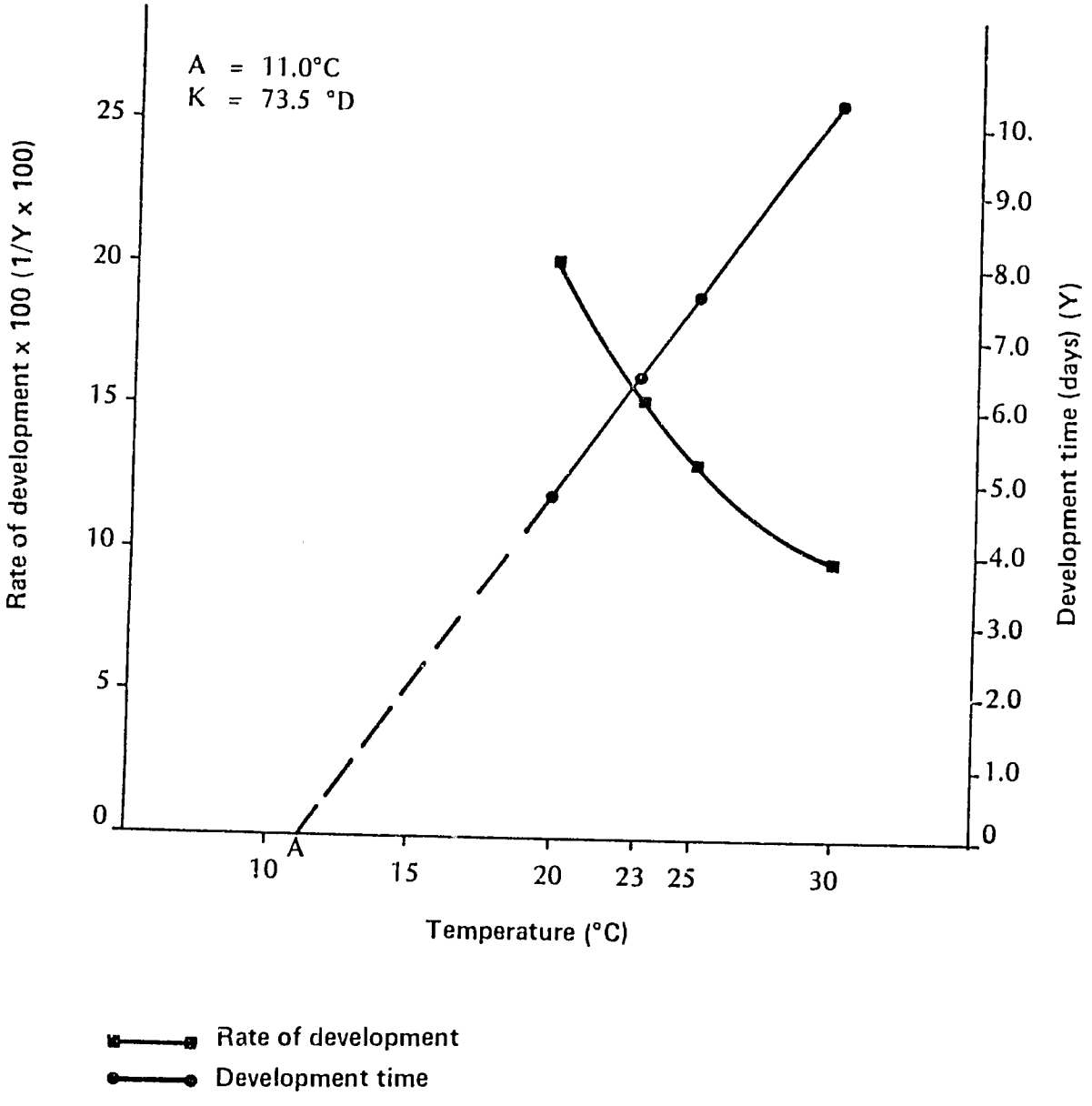


Figure 8. The effect of temperature on the time and rate of development of the inmature stages of *Neoseiulus anonymus*.

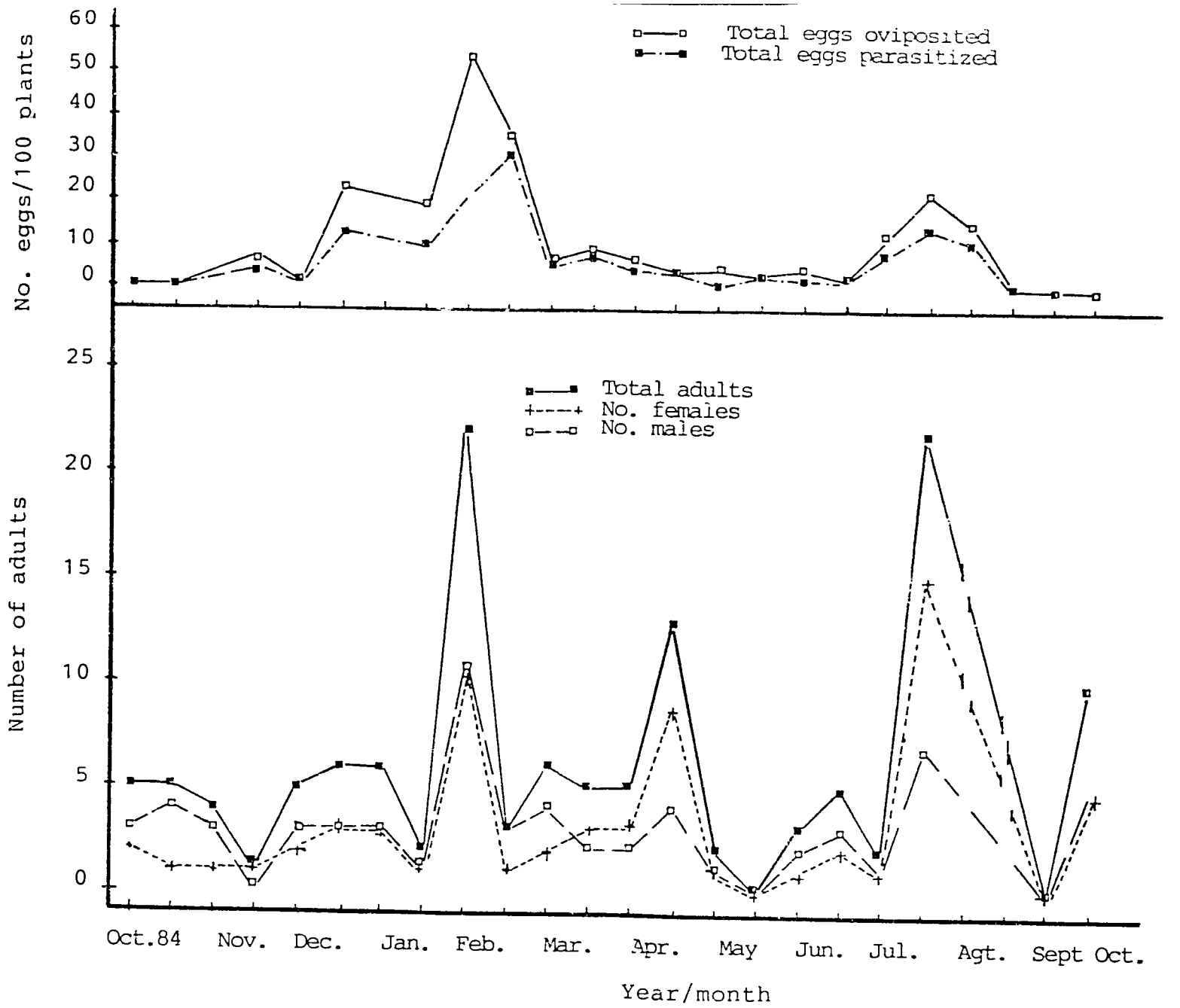


FIGURE 9. The black light trap capture of Erinnyis ello adults and egg parasitism at CIAT-Palmira from October 1984 to October 1985.

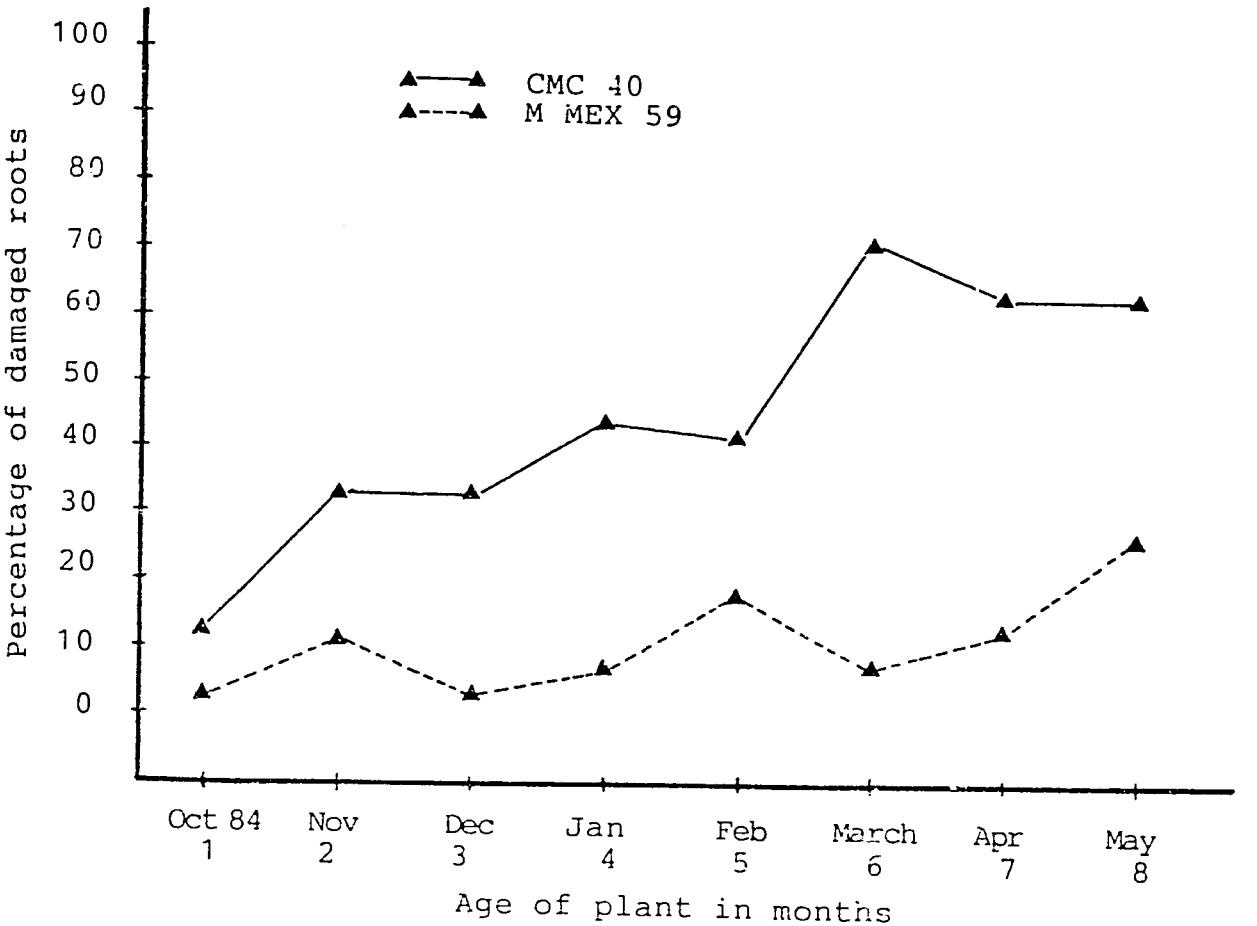


FIGURE 10. Percentage of cassava roots damaged by an attack of the subterranean sucking insect, *Cyrtomenus bergi.*

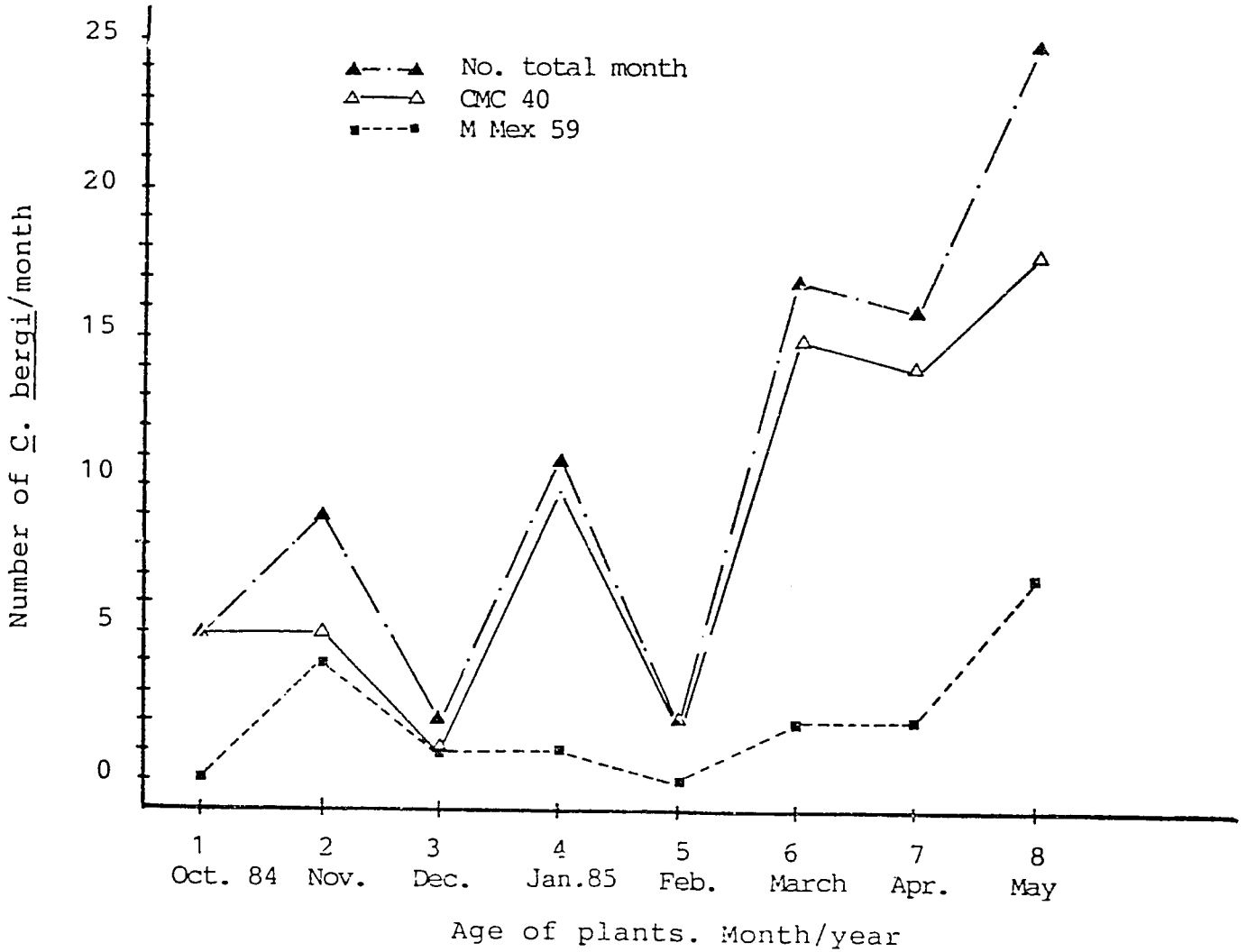


FIGURE 11. Populations of Cyrtomenus bergi associated with cassava roots (varieties CMC 40 and M mex 59) over a 8 month period at Santander de Quilichao.

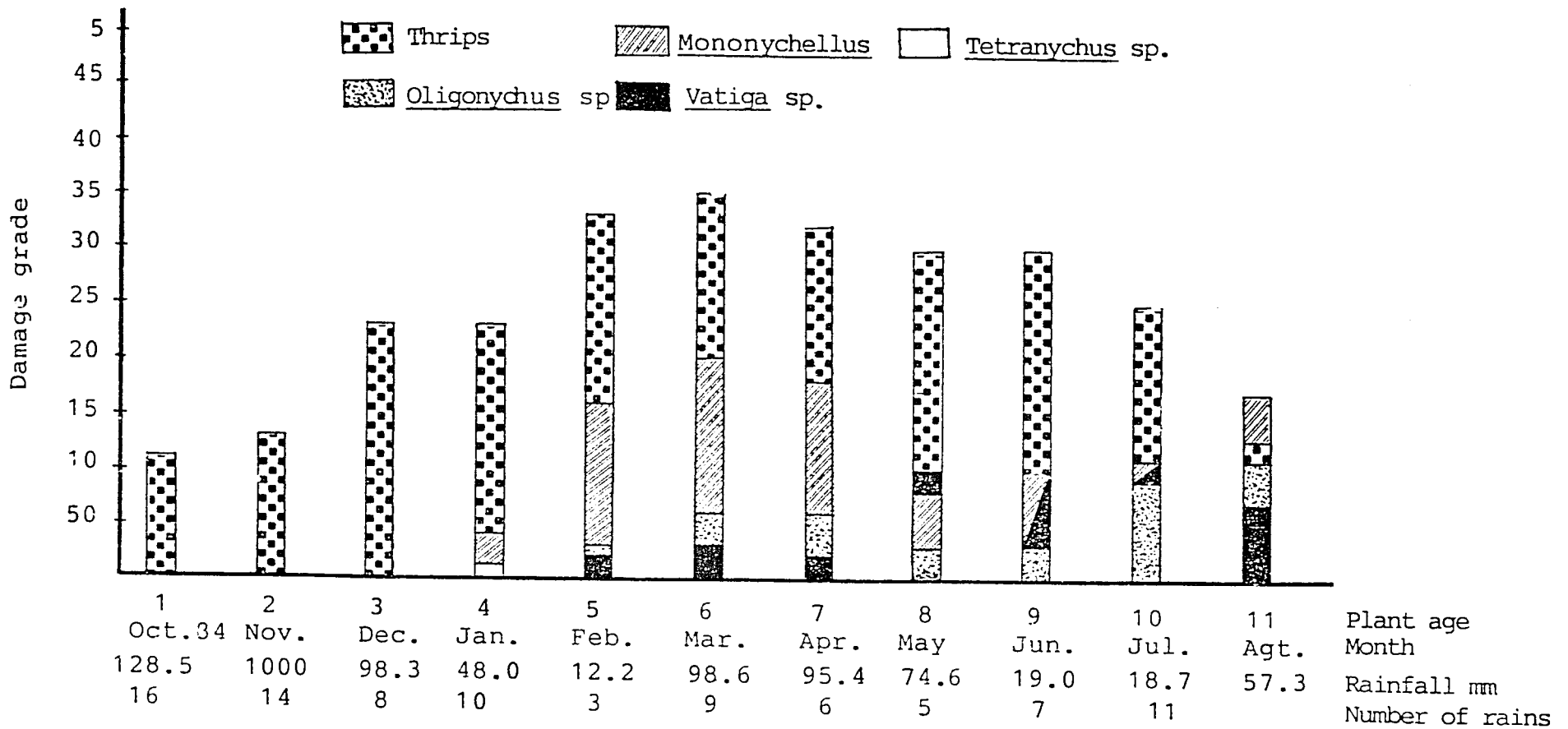


FIGURE 12. Plant damage caused by insect and mite feeding on cassava variety M Col 1684.

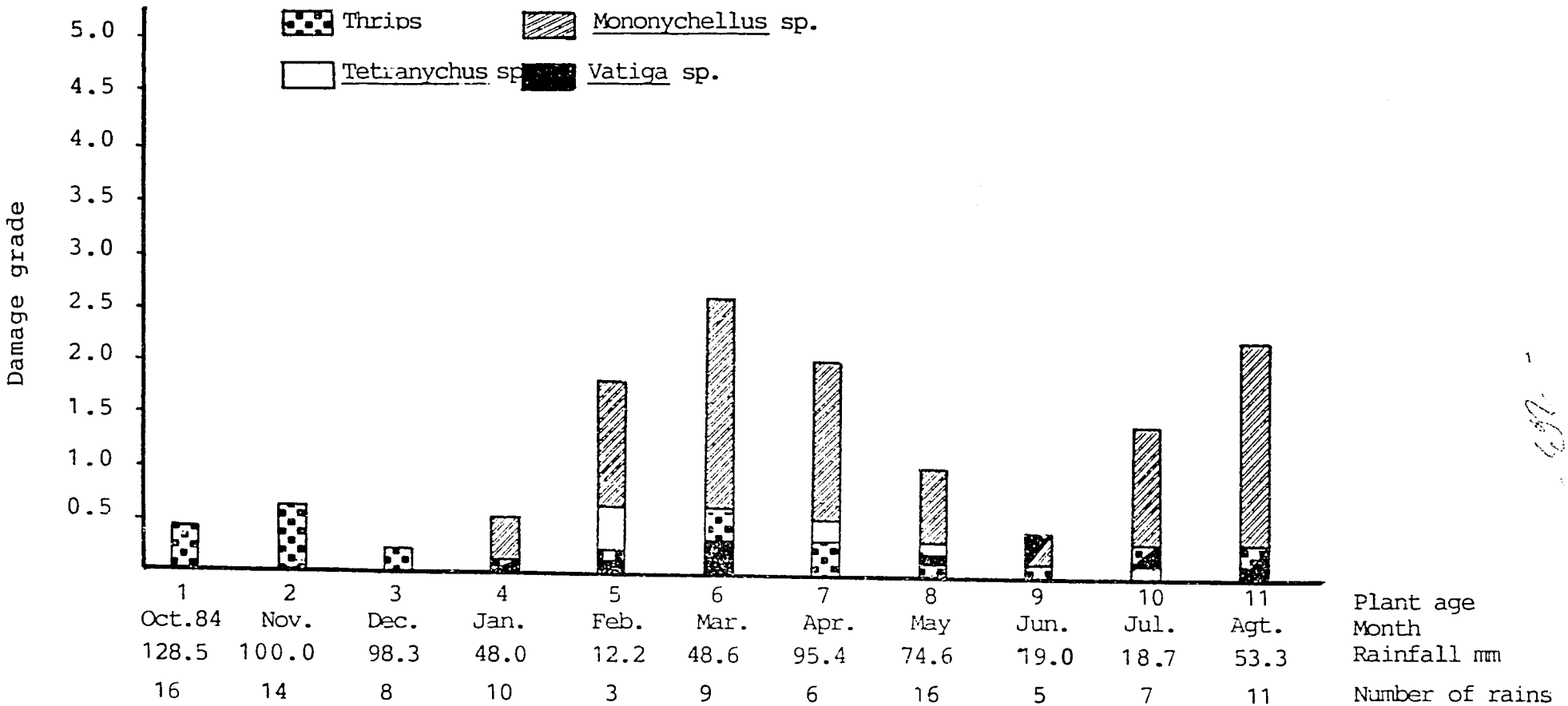


FIGURE 13.. Plant damage caused by insect and mite feeding on cassava variety M Col 113.

PATHOLOGY

Research on several fungal diseases of cassava continued during 1985, with special emphasis on root rots induced by Diplodia manihotis and Fusarium spp. These pathogens are inducing severe losses in several cassava production areas of the Americas, where cassava is cultivated on the same land for several cycles. Emphasis was also given to research on fluorescent pseudomonads, especially on the identification of more efficient strains and their role in natural protection against cassava pathogens. Work on quality of cuttings was also continued this year. Two new cassava production problems -- one induced by a parasitic plant species and the other by clonal contaminants -- were also identified.

I. Pathogenic problems

A. Anchracnosis

Continuing the taxonomic studies initiated last year (CIAT Cassava Annual Report, 1984) the three reported species of Colletotrichum pathogenic to cassava have been differentiated on the basis of (a) morphological and symptomatological features; and (b) according to their pathogenic ability to attack cassava or other differential crop species (Table 1). Generally, the isolated strains of C. gloeosporioides were more aggressive than those of C. gloeosporioides f. sp. manihotis and C. graminicola. All strains required at least 24 h of high RH (more than 90%) after inoculation through plant wounds to create conditions for their establishment. Studies with strains of each of the above species are under way in order to establish their relationships with cassava clones.

B. Diplodia root rots

Diplodia root rot has been found in three of the five edaphoclimatic zones where CIAT is working. It has not been found in zones IV (Popayan) and V (Florencia), but it is a very important disease in zones I (Media Luna) and III (CIAT), and of moderate importance in zone II (Carimagua). In Media Luna, for example, losses on establishment ranged this year from 10 to 85% in farmers' fields planted with the regional clone Venezolana 1 (Coñito). A survey of the sanitary conditions of long cuttings (approximately 1m long) stored for two months in two farmers' fields showed that from 83 to 100% were affected by Diplodia manihotis.

As the control of this disease by varietal resistance appears to be very promising, a system for clonal evaluation was investigated. This work included research on:

1. Inoculum infectivity

The inoculum (pycniospores produced on Petri dishes with acid-PDA) were infective for more than six months when stored under growth chamber conditions (15°C ± 3°C, 80% RH). These results were consistent throughout several replications with different isolates. This indicates a relatively good pathogenic stability of cultures after a long period of storage.

2. Spore production

The highest number of pycnidia per cm^2 (12 pycnidia /cm^2 of surface-medium) and pycniospore production (5 X 10^4 pycniospores/g of fungal growth) were obtained on acid-PDA medium incubated for 12 days under continuous exposure to fluorescent light. Darkness and CO_2 concentration appear to inhibit the formation of pycnidia.

3. Inoculum concentration

A very high reduction in the bud germination of susceptible clones (between 95 to 100%) and almost total invasion of inoculated cuttings occurred when inoculum concentrations were higher than 4 X 10^4 pycniospores/ml. At lower concentrations the germination of buds and invasion of cuttings were lower.

4. Incubation period

Satisfactory inoculation of cuttings (15-cm long cuttings taken from 10 to 12-month-old plants) was obtained by the dip inoculation method. Cuttings were dipped into the inoculum for 20 min and maintained for 72 h at 100% RH and 25°C ($\pm$ 8°C). They were then kept under a glasshouse (25°C $\pm$ 8°C, 80-95% RH and 12 h photoperiod) before planting in plastic pots filled with sandy soil. Readings were taken 30 days afterward in relation to the number of infected plants/clone obtained per number of inoculated cuttings and the percentage of affected area/cutting/clone.

5. Screening for resistance

Resistance to D. manihotis has been reported, but "resistant" clones have later shown instability after several cycles of continuous cultivation in regions where this pathogen is endemic. When cuttings of five clones taken from different sources were inoculated with D. manihotis, different levels of resistance (based on inhibition of bud germination) were recorded on three of the inoculated clones when their cuttings were collected from farmers' fields (Table 2). Inoculated cuttings from plants of the above clones originated from meristem cultures or from farmers' fields, and although they were disinfested with Na-hypochlorite they were highly susceptible (Table 2). Inoculations of cuttings from fields farmers of these or other clones gave inconsistent results.

Fluorescent pseudomonads (P. putida and P. fluorescens) and bacilli species were isolated from washed suspensions of the epidermis of cuttings from farmers' fields. A large number of these isolates inhibited D. manihotis in vitro. In contrast, most of the microorganisms obtained in suspension from washed epidermis of the cuttings from meristem cultured plants were fungi, some of which were of a pathogenic nature; fluorescent pseudomonads or bacilli bacteria were found occasionally but at very low concentrations.

We suggest that the beneficial epiphytic bacteria play an important role in protecting the plants against D. manihotis. This effect masks the direct genetically controlled resistance

mechanism of cassava to this pathogen, and can result in the misidentification of "resistant" clones if not taken into account.

Consequently for screening purposes, several clones were inoculated with D. manihotis, but half the cuttings of each clone were disinfested with Na-hypochlorite before inoculation to eliminate the effect of beneficial bacteria on the establishment of the pathogen. The reactions of the clones that showed the most variable rating to D. manihotis 30 days after inoculation are presented in Table 3. From these results the following conclusions were drawn:

1. Beneficial epiphytic bacteria assert a strong protective effect against the establishment of D. manihotis in cassava.

2. An ample range of clones ranging from susceptible to resistant to D. manihotis exist in cassava.

3. Two mechanisms of resistance to D. manihotis appear to exist in cassava: (a) a direct one related to the host-pathogen relationships, and (b) another related to the host-beneficial bacterial association which could retard colonization, nutritional association and survival of D. manihotis; i.e. clones CG-1-61, CM 2546-1 and M Ven 25 showed higher percentage of bacterial protection than clones CM 2806-2, CG-7-66 and CG-595 (Table 3).

4. The uneven protection of cuttings belonging to the same plant appears to indicate differences in the distribution of the beneficial bacterial cells on the epidermis of the whole plant. This could be related to factors such as stem or plant aging, the initial sites of establishment for the beneficial bacteria, effects of climatic stress on bacterial survival, quantity and quality of inoculum, and differences in the quality and/or quantity of plant exudates in relation to each clone. Further research on these topics will be conducted in the future.

C. Fusarium root rot

Fusarium solani was found affecting around 4,000 ha of cassava in the state of Sergipe, Brazil, where cassava has been cultivated for many years. The lack of either cutting selection and treatment or crop rotation favored dissemination and the occurrence of an actual outbreak. The control of this problem was studied using the following cultural practices:

1. Cutting selection

Cuttings taken from diseased plants were affected in a range of 25 to 78%. Germination decreased on an average of 71%; and plants from infected cuttings showed wilting 1 to 9 months after planting, depending on the intensity of infection at planting. As F. solani is systemic, the selection of only healthy cuttings for planting is crucial to avoid its dissemination and incidence.

2. Planting system

The pathogen normally penetrates plants (grown from healthy cuttings) through young stem tissues that are in contact with infested soils; roots are apparently resistant to this penetration. Young tissues are produced after cuttings sprout and are in contact with soils when cuttings are planted horizontally. The level of plant infection was 33% when healthy cuttings were planted horizontally in infested soils vs only 1.5% infection when they were planted vertically. Lesions on horizontally planted plants always started at the base of the sprouts during the first two months after planting. On vertically planted plants, the base of the sprouts (the most susceptible tissues) were not in contact with infested soils since the germinated buds were not underground. Penetration nearly always occurs during the rainy season.

3. Crop rotation

In plots with more than 10 years of continuous cultivation 68% of the plants were affected versus 2.7% plant infection on similar plots with a rotation the previous year.

Simultaneously, a system for varietal evaluation for resistance to this pathogen was developed. The system is similar to the one reported for evaluating resistance to D. manihotis; however, as most strains of F. solani lose their pathogenicity a few days after storage in test tubes, care should be taken to maintain their level of aggressiveness. Similarly, around 96 h of 90-100% RH is necessary for fungal establishment on the host cuttings. Satisfactory inoculation was obtained by the dip inoculation system, dipping the cuttings for 20 min in a fungal suspension (5-6 X 10^5 conidia/ml produced on acid-PDA medium after 14 days of growth at 27°C); cuttings were then stored for 96 h in sealed plastic bags before planting in plastic pots. They were maintained in a glasshouse (25°-8°C; 80% RH and 12h photoperiod). Readings were taken 30 days after planting according to the percentage of plant establishment in relation to inoculated cuttings. Preliminary results on clonal resistance have shown that F. oxysporum is less aggressive than F. solani and that the resistance to both pathogens is independent in cassava. Research on large scale screening for resistance to these two pathogens is under way.

D. Effect of fluorescent pseudomonads on cassava

A total of 137 isolates of fluorescent pseudomonads were collected from the cassava rhizosphere of several clones from eight different cassava-growing areas. Frequency of isolation was higher for Pseudomonas fluorescens than for P. putida in Carimagua; but in the other areas, P. putida was isolated more frequently (Table 4). Generally, there were more isolates able to inhibit pathogenic bacteria than fungi; but among all isolates collected, those of P. fluorescens showed broader inhibition ability in vitro to the bacterial and fungal species tested than P. putida (Table 4).

Summarizing the above results, four groups of fluorescent pseudomonadas were identified according to their inhibition in vitro of both pathogenic bacteria and fungi; (I) a group of isolates unable to induce or inducing very mild inhibition of pathogenic bacteria and/or fungi; (II) isolates that effect a strongly inhibit pathogenic bacteria, but with no or very mild inhibition of fungi; (III) isolates causing very strong inhibition of fungi, but have no or very mild inhibition of bacteria; and (IV) isolates inducing strong inhibition of both fungi and bacteria

Some strains of these groups of fluorescent pseudomonads were used during various experiments directed to control different pathogenic problems of cassava with the following results:

1. Effect of cassava bacterial blight

Strains of group II, which in vitro induced the highest inhibition to *Xanthomonas campestris* pv. *manihotis*, were used to spray plots of susceptible, intermediate resistant and resistant clones planted at Carimagua, where cassava bacterial blight is epidemic. Results of these treatments are shown in Tables 6 and 7. Both the number of angular leaf spots/leaf and the number of blighted leaves/plant were significantly reduced by foliar applications of *P. putida* to susceptible clones during two growing cycles (1984 and 1985) (Table 5). Yield of the susceptible clone (M Col 22) also increased 2.7 times (Table 6), but did not increase in either the intermediate resistant or resistant clones; this also illustrates the great advantage of using CBB-resistant clones in areas where this disease is epidemic.

2. Effect on root rots induced by fungal pathogens

Strains of *P. fluorescens* (belonging to group III) were able to protect cuttings against *D. manihotis* (Tables 7 and 8). The protection effect was evident when cuttings were treated with the bacterial suspension before or after fungal inoculations; this protection was related to bud germination and fungal establishment and invasion through the tissues of the cuttings (Table 8). The above protection was also evident for three clones, on both inoculated cuttings from farmers' fields and from meristem plants; the bacterial protection was nearly as efficient as that obtained with the best fungicidal treatment available to control this pathogen (Table 8). These results open the possibility of replacing fungicidal treatments with beneficial bacterial treatments to obtain root rot protection before planting. Yield of fresh roots increased when the base of plants was watered with 10 cm^3 of a bacterial suspension of a beneficial strain of *P. fluorescens*. The increased yield values were higher as watering was repeated monthly (Table 9). However, such yield increase values varied in relation to inoculated clones, which may indicate clonal differences to the bacterial strains used or differences in susceptibility to the pathogens that these beneficial bacteria were affecting.

3. Effect on postharvest deterioration (work carried out jointly with Utilization Section)

Research was conducted to investigate the effect of P. putida and P. fluorescens on postharvest microbial deterioration of cassava storage roots. Additionally, a strain of Bacillus sp. was included as well as combinations of Bacillus sp. with P. putida.

An inoculum suspension of 1.1 X 10. cells/ml was prepared for each strain of bacteria; roots were treated by immersion for 10 minutes in the suspension, followed by a 15 minute wait in order to remove the excess moisture before packing into sealed plastic bags. Roots were evaluated according to standard procedures after 1, 2 or 3 weeks of storage at ambient conditions. Tables 11 and 12 show the results for all experiments conducted so far, in which a total of eight strains of P. fluorescens and P. putida and one of a Bacillus sp. were used. The Mertect treatment was included as a reference point for the various bacterial treatments. A treatment was considered successful if equal to or better than the Mertect treatment.

The bacillus strain alone was never as effective as Mertect, nor were pseudomonad strains Pp. c4b, Pf. c88, Pp. c5b or Pp. c7b. Strains Pp. F-56 and Pp. F-44 gave variable results, when mixed with the bacillus strain. However, the strain Pf. c5a gave consistently good control of rotting during the first two weeks of storage only failing in the third week in one experiment (Tables 10 and 11).

Research will continue on testing the effectiveness of strain Pf. 5a, on screening for more effective strains and on improving methods for inoculum production. The eventual aim of using a biological rather than a chemical means for controlling postharvest microbial deterioration in cassava will require a lot of adaptive and applied research in order to develop a practical method for on-farm use.

E. A disease caused by a parasitic higher plant

A disease caused by a parasitic higher plant was found affecting 53% of the plants on a plantation in the Cauca Valley. Most plants had more than three parasitic plants/plant at different stages of development. Affected plants showed dieback or leaf yellowing on the branch plant or part after the attachment of the parasite.

The plant parasite was classified as Phthirusa pyrifolia, a species belonging to Ioranthaceae. This evergreen, parasitic plant has well-developed leaves and stems that are sometimes more than 10cm in diameter. It produces typical green leaves that can carry on photosynthesis, dioecious flowers, and berrylike fruits containing a single seed. It produces haustorial suckers which grow on branches and stems of trees in order to absorb water and nutrients from them. Seeds are spread by birds that eat the seed-containing berries and excrete the sticky seeds on the top of

host cassava. When a seed lands on and becomes attached to the bark of a twig or a branch of a susceptible host, it germinates and produces a germ tube or radicle. This grows along the bark surface until it meets a bud or a leaf base, at which point the radicle becomes broad and flattened on the side of the bark. A rootlike haustorium is then produced from the center of the flattened area of the radicle, which penetrates the bark directly and reaches the phloem and the cambium. The parasite removes nutrients from the host, thereby starving and killing the portion of the branch laying beyond the point of infection. It also saps the vitality of the branch; and, when sufficiently abundant, that of the whole plant. Furthermore, it upsets the balance of hormonal substances of the host in the infected area, causing hypertrophy and hyperplasia of the cells and resulting in swelling and deformation of various shapes on the branches.

The only means of control is by physical removal of the parasite, which can be done either by pruning infected branches or by cutting and removing entire infected plants. Removal of the parasite from other host species around plantations is advisable to eliminate foci of infection.

II. Selection of cuttings according to yield/plant

The effect of using selected cuttings on yield/plant was reported last year (CIAT Cassava Annual Report, 1984); this year, results showed that the advantage of this selection method is much more positive when planting material is selected from clones that have been more affected by different production constraints (susceptible) than those that appear to have more stable resistance. Clones Venezolana 1 and Secundina, considered as susceptible to constraints at Media Luna, and CMC 40, considered to have intermediate resistance to production constraints at both CIAT and Carimagua, showed the highest increase in yield when cuttings were selected from plants with higher yield than the plot average (Table 12). These results stress the importance of selecting clones with stable type resistance to yield constraints in each location for the stabilization of higher yields.

Table 1. General differential features of *Colletotrichum* species pathogenic to cassava.

Characteristics	*C. graminícola*	*C. gloeosporioides*	*C. gloeosporioides* pv. *manihotis*
Seta	Abundant and large (66 - 96 x 3-4)[a]	Only produced by a few strains but they are smaller (46 - 97x 3-5)	Produced by some strains (37 - 98 x 3-4)
Conidia	12 - 35 x 4-6 , falcate, fusiform	6 - 20 x 3-6.5 , oblong, cuneiform or cylindrical	6 - 20 x 3-6.5 , oblong cuneiform
Appresoria	12 - 18 x 10-13 , irregular, some are subglobose	6 - 9 x 5- , subglobose or globose, clavate, ellipsoidal	6 - 9 x 5-7 , subglobose or globose, clavate, ellipsoidal
Pathogenicity	On cassava, sorghum, sugarcane, corn and several grasses	On cassava and fruits of papaya, mango and orange	Only on cassava
Symptoms	Acervuli superficially arranged as concentric rings	Acervuli are subepidermal with with irregular arrangements on the epidermis	Acervuli are subepidermal with irregular arrangements on the epidermis

[a] Data taken from cultures on Ac-PDA medium.

Table 2. Percentage of bud germination of cuttings of five cassava clones from different sources 30 days after inoculation with *Diplodia manihotis*.

Cutting source	Inoculated clones									
	M Col 113		CMC 40		M Col 172		M Col 1684		M Ven 77	
	b.g[a] (%)	a.a[a] (%)	b.g (%)	a.a (%)	b.g (%)	a.a (%)	b.g (%)	a.a (%)	b.g (%)	a.a (%)
From farmers' fields	95	24	60	74	50	64	0	100	0	100
From farmers' fields, but disinfested with Na hypochlorite (3% for 10 min)	0	100	0	100	0	100	0	100	0	100
From meristem culture	0	100	0	100	0	100	0	100	0	100
Uninoculated cuttings from farmers' fields but disinfested with Na-hypochlorite, and meristem culture	100	0	100	0	100	0	100	0	100	0

[a] b.g= bud germination; a.a= averaged affected area/cutting. Data taken from approximately 40 cuttings/clone/treatment. Significant differences were found by the logit (X^2) system.

Table 3. Percentage of establishment of cuttings from different clones which were collected from field plots and disinfested or not with Na-hypochlorite (2% for 30 min) before inoculation with *Diplodia manihotis*.

Clone	Establishment of cuttings (%) treatment		
	Non-disinfested	Disinfested	Control
M Col 22	0 (100)[a]	0 (100)	100 (3)
CG-2612	0 (100)	0 (100)	100 (6)
M Ven 23	0 (100)	0 (100)	100 (6)
CM 2806-2	30 (86)	0 (100)	100 (8.5)
CG 7-66	20 (92)	0 (100)	100 (2)
CG 5-95	40 (73)	0 (100)	100 (4)
CG 1-61	80 (75)	0 (100)	100 (20)
CM 2546-1	90 (57)	0 (100)	100 (5)
M Ven 25	80 (50)	0 (100)	100 (0)
M Mal 1	90 (55)	60 (76)	100 (7)
CM 1890-2	100 (23)	20 (91)	100 (0)
CM 2777-8	90 (53)	60 (80)	90 (16)
CM 1305-3	80 (53)	70 (63)	100 (0)
M Cub 74	90 (37)	80 (43)	100 (0)
M Ven 185	100 (36)	80 (56)	100 (13)
CG 138-9	100 (30)	80 (51)	100 (6)

[a] Results taken from 10 cuttings inoculated/treatment/clone. In parentheses is the average percentage of area affected 30 days after inoculation. Controls were not inoculated.

Table 4. In vitro inhibition of several bacterial and fungal pathogens by some isolates of *Pseudomonas fluorescens* (Ps.f.) and *P. putida* (Ps.p.).

Origin	Beneficial bacterial species	Total # of collected strains	No. of strains able to inhibit bacterial and fungal pathogens							
			a[a]	b	c	d	e	f	g	h
Media Luna	Ps.f.	8	2[b]	5	1	2	1	7	5	7
	Ps.p.	20	0	7	0	3	0	17	12	8
Carimagua	Ps.f.	10	3	3	2	3	6	5	4	5
	Ps.p.	7	0	2	0	0	1	2	4	4
Quilichao	Ps.f.	4	1	2	2	0	3	1	2	3
	Ps.p.	8	1	1	2	0	0	5	3	6
Nataima	Ps.f.	2	0	0	0	0	0	2	1	1
	Ps.p.	13	1	7	0	0	1	9	6	5
Caicedonia	Ps.f.	6	1	2	1	0	2	2	4	3
	Ps.p.	10	1	2	0	1	0	4	6	7
Palmira	Ps.f.	6	1	1	1	0	1	4	3	4
	Ps.p.	11	1	1	0	1	0	5	5	6
Popayan	Ps.f.	5	1	0	0	0	1	2	2	3
	Ps.p.	10	0	5	0	0	0	7	5	8
Quilcace	Ps.f.	0	0	0	0	0	0	0	0	0
	Ps.p.	17	2	2	1	0	1	9	7	7
Subtotal	Ps.f.	41	9	13	7	5	14	23	21	26
	Ps.p.	96	6	27	3	5	3	58	48	51
Total		137	15	40	10	10	17	81	69	77
Percentage		100	10.9	29.2	7.3	7.3	12.4	59.1	50.4	56.2

[a] a=*Fusarium oxysporum*; b=*Diplodia manihotis*; c=*Corticium rolfsii*; d=*Pythium* sp.; e=*Rhizoctonia solani*; f=*Xanthomonas campestris* pv. *manihotis*; g=*Erwinia carotovora* pv. *carotovora*; and h=*Pseudomonas solanacearum*.

[b] Average of 5 replicates/pathogen. Inhibition effect: strong inhibitory halo of more than 10mm width.

Table 5. Control of cassava bacterial blight by foliar applications[a] of *Pseudomonas putida* (strain F-44 and F-88) on two susceptible clones during 1984 and 1985.

Clone	Scoring system	Year of control/strain number		
		1984	1985	
		F-44	F-44	F-88
M Col 22	Angular leaf spots/leaf[b]	1.0a[c]	2.5a	2.5a
	Number of blighted leaves/plant	1.0a[c]	1.5a	1.0a
	Controls	7.0b	5.7b	5.7b
M Col 72	Angular leaf spots/leaf	-	4.3a	4.2a
	Number of blighted leaves/plant	-	2.1a	2.3a
	Controls	-	9.0b	9.0b

a Plants received six foliar applications of a 1×10^9 cells/ml suspension of the respective strain of *P putida* at 15-day intervals. Control plants were sprayed with distilled water.

b Average number of leaf spots/leaf on 15 leaves/plot (three leaves from each of five different plants). Plots contained 36 plants with three replications.

c Average number of blighted leaves/plant on five plants/plot. Plots contained 36 plants with three replications. Numbers followed by the same letter are not significantly different at a 0.05 level of the Duncan Multiple Range Test.

Table 6. Yield of a CBB-susceptible (M Col 22), intermediate resistant (CM 523-7), and resistant (M Ven-77) clone after foliar applications of *Pseudomonas putida* (strain F-44).

Clones	Yield (t of fresh roots/ha)[a]	
	Sprayed plots	Control plots
M Col 22	6.8 a*	2.5 b
CM 523-7	14.7 a	14.0 a
M Ven 77	9.6 a	9.1 a

[a] Yield was recorded from three replicated plots of 30 plants each. Border plants were eliminated.

* Yields followed by the same letter(s) are not significantly different at the 0.05 level of the Duncan Multiple Range Test.

Table 7. Effect of *Pseudomonas fluorescens* (strain Pf. c5a) on bud germination of cuttings (clone M Col 1684) after inoculation with *Diplodia manihotis* (Dm.).

Treatments	Bud germination (%)	Cutting infection (% of invaded tissues)
10 min in Pf. c5a[a] 20 min in Dm.	100[b]	16 b*
10 min in D H_2O 20 min in Dm.	10	97 a
18 h in Dm. 20 min in Pf. c5a	100	36 b
18 h in Dm. 20 min in D H_2O	40	85 a
20 min in Dm.	0	100 a
20 min in D H_2O or Pf. c5a	100	0 c

a Dip treatment in suspensions of 1.1×10^9 cells/ml of *P. fluorescens* (strain Pf. c5a) of D-water followed by a dip treatment in a suspension of 5.8×10^4 pycniospores/ml of *D. manihotis* (Dm.) or viceversa.

b Data taken from 20 cuttings/treatment a month after planting in pots with sterile soils maintained in a glasshouse at 25°C (± 8°C), 80% RH and 12 h photoperiod. Significant differences in germination were found by the logit (X^2) system.

* Cutting infection data followed by the same letter are not significantly different at the 0.05 level of the Duncan Multiple Range Test.

Table 8. Effect of *Pseudomonas fluorescens* (strain PF-88) on bud germination of cuttings of three clones collected from farmers' fields (FF) and from meristem plants (MP)[a] and inoculated with *Diplodia manihotis* (Dm).

		Germination percentage in relation to treatments			
Clone	cuttings	20 min Dm	10 min PF-88[b] 20 min Dm	10 min fungicidal mixture 20 min Dm	Source of Controls
M Col 113	FF	80 (48)****	100 (29)	100 (5)	100 (4)
	MP	0 (100)	100 (29)	100 (26)	100 (17)
M Col 72	FF	60 (47)	90 (22)	100 (0)	100 (8)
	MP	10 (93)	70 (37)	80 (15)	100 (2)
M Col 1468	FF	20 (87)	100 (0)	100 (0)	100 (0)
	MP	10 (98)	100 (2)	100 (1	100 (9)

a Cuttings from meristem plants (MP) were obtained from meristem cultures.

b Dip treatments in suspensions of 5.8×10^4 pygniospores/ml of *D. manihotis* or 1×10^9 cells/ml of *P. fluorescens* (PF-88)***. The fungicide mixture was a water suspension of Captan/BCM (3,000 ppm each).

c Data taken from 40 cuttings/clone/source treated. In parentheses is the average percentage of tissue showing fungal invasion after treatments. Readings were taken a month after growing the cuttings in pots with sterile soils maintained under glasshouse conditions.

Table 9. Average yield of fresh roots of several clones planted in Carimagua, Media Luna and CIAT, in relation to treatments with *Pseudomonas fluorescens* (PF-88).

Location	Clone	Yield (t/ha) in relation to bacterial treatments[a]			
		0	1	2	3
Carimagua	M Col 1914	12.1b[b]	14.5b	16.5a	17.6a
	M Col 1916	11.2b	14.5b	15.7a	17.7a
	M Pan 19	10.7a	10.1a	12.0a	12.3a
	M Ven 77	14.5b	14.5b	18.1a	21.6a
Media Luna	CM 342-170	9.0b	11.1ab	11.3ab	12.5a
	M Col 72	12.5b	16.0a	16.3a	18.3a
	Venezolana	10.3b	11.3b	12.3ab	13.3a
CIAT-Palmira	M Col 1468	38.1b	40.2b	44.5ab	49.3a
	M Col 72	42.1b	46.6ab	46.8ab	47.0a

[a] Bacterial treatments: 10 ml of a bacterial suspension (1.1×10^9 cells/ml) were poured on the base of each plant at: 1= one month; 2= one and two months, and 3= one, two and three months after planting the cuttings.

[b] Data taken from three replicates of 30 plants each/location/clone and treatment. Border plants were eliminated.

Yield data followed by the same letter(s) are not significantly different at the 0.05 level of the Duncan Multiple Range Test.

Table 10. Effect of six strains of *Pseudomonas putida* (Pp.), two of *P. fluorescens* (Pf.) and one of *Bacillus* (Bsp.) on postharvest deterioration of cassava.

Bacterial strain number	Root deterioration (%)/clone after weeks of storage								
	CMC 40		HMC-1		CMC 40		M Col 22		
	1[a]	2	1	2	2	3	1	2	3
Pp. f-56	0.6[b]	30.5	7.0	18.0					
Pp. f-44	8.8	10.0	7.3	23.0					
Bsp.	15.2	32.5	15.3	25.0					
Bsp.+Pp. f-56	6.6	23.5	7.8	28.5					
Bsp.+Pp. f-44	7.0	9.0	7.6	16.0					
Pf. c-5a					0.0	10.0	4.5	9.9	38.0
Pp. c-7a					20.4				
Pp. c-4b					7.8	14.8			
Pf. c-88					11.0	47.3			
Pp. c-5b							7.0	16.5	
Pp. c-7c							5.0	18.0	
Mertect	8.6	13.5	4.8	15.0	1.8	4.0	2.0	8.4	5.6
Control	10.3	34.5	13.8	74.5	32.5	77.0	18.0	64.0	100.0

[a] Readings taken after 1, 2 and/or 3 weeks of storage.

[b] Averaged data taken from 50 roots of approximately one pound each. Score of 0-100.

Table 11. Effect of six strains of *Pseudomonas putida* (pp.), two of *P. fluorescens* (pf.), and one of a *Bacillus* sp. (Bsp.) on external fungal growth of storage cassava roots.

Bacterial strain number	Percentage of external fungal growth/clone after weeks of storage								
	CMC 40		HMC-1		CMC 40		M Col 22		
	1[a]	2	1	2	2	3	1	2	3
Pp. f-56	12[b]	37	7	30					
Pp. f-44	11	26	14	37					
Bsp.	11	46	20	32					
Bsp. + Pp. f-56	10	38	16	31					
Bsp. + Pp. f-44	10	20	13	21					
Pf. c-5a					5	8	7	19	26
Pp. c-7a					63				
Pp. c-4b					20	27		20	27
Pf. c-88					26	47		26	47
Pp. c-5b							11	27	
Pp. c-7c							11	19	
Mertect	6	16	4	20	7	14	1	8	12
Control	19	44	12	74	31	74	21	69	87

[a] Readings taken after 1, 2 and/or 3 weeks of storage.

[b] Averaged data taken from 50 roots of approximately one pound each. Score of 0-100.

Table 12. Effect of cutting selection (according to yield/plant) in three different locations in relation to clonal resistance/susceptibility to production constraints in each location.

Cultivar	Source of cuttings	Yield (t/ha)/location		
		Media Luna	CIAT	Carimagua
Venezolana 2 (Verdecita)	H[b]	7.1a		
	L	7.0a (1)[c]		
Venezolana 1[a] (Coñito)	H	10.3a		
	L	6.8b (52)		
Secundina[a]	H	10.2a		
	L	6.0b (64)		
M Col 113	H		18.7a	
	L		17.7a (6)	
M Col 22[a]	H		38.9a	
	L		33.3b (17)	
CMC 40[a]	H		29.5a	9.6a
	L		18.6b (58)	5.8b (64)
M Pan 19	H			9.0a
	L			7.5a (21)
M Ven 77	H			13.5a
	L			12.2a (21)

[a] Clones which were evaluated as susceptible to production constraints in the respective locations.

[b] H= percentage of plants with higher yield than the plot average; L=percentage plants with lower yield than the plot average.

[c] Data taken from four replicate plots of 30 plants each. In parentheses is the percentage of yield increase obtained by using cuttings from high yielding plants.

The figures on the same column are not significantly different at 0.05 level of the Duncan Multiple Range Test.

VIROLOGY

Method for the detection of double-stranded ribonucleic acid (dsRNA) in virus-infected cassava

Many plant viruses produce detectable levels of viral specific dsRNA during their replication cycle in the plant cell. The presence of dsRNA in a plant is a convenient marker for detecting viral infections in many crop species including cassava. Since the technique does not require prior knowledge of the viral pathogen it is particularly suited for detecting unknown viruses or for viruses which lack a sensitive indexing method. The dsRNA analysis technique has been developed for cassava as a useful supplement to conventional serological and graft indexing methods now in service at CIAT.

The standard procedure includes an extraction, column chromatography, nuclease digestion and electrophoresis step (Table 1). Routinely 16 samples can be processed at a time with results available in 2 to 3 days. Liquid nitrogen should be used in the first step to aid in tissue homogenization and cell disruption. The extraction buffer (pH 6.8) contains: SDS (a detergent protein denaturant), bentonite (a potent ribonuclease inhibitor); 2-mercaptoethanol (a reducing agent to prevent oxidation); phenol (an organic protein denaturant), chloroform (a membrane denaturant); and iso-amyl alcohol (an anti-frothing agent). The above additives aid in the isolation of undegraded plant nucleic acids relatively free from contaminating proteins and other cell components.

Since this total nucleic acid preparation contains cassava single-stranded RNA (ssRNA) and DNA as well as any viral-specific dsRNA, it is necessary to isolate the dsRNA from any host nucleic acids. This is accomplished by exploiting a unique property of the dsRNA molecule; the reversible binding to cellulose fibers in the presence of 15 to 18% ethanol. Cassava ssRNA and DNA do not bind to cellulose at the same ethanol concentration. Using column chromatography it is possible to elute or wash away cassava ssRNA and DNA with a buffer containing 16.5% ethanol while retaining the dsRNA bound to the cellulose. Following the washing step the dsRNA can be eluted from the column in buffer without ethanol. As a precaution, it is advisable to treat the dsRNA sample with nucleases that degrade any trace amounts of host ssRNA and DNA still present. The final samples can be analyzed for the presence of dsRNA quickly (in 3 to 4 hr) and easily on a horizontal agarose gel. Any dsRNA in the gel can be visualized on a UV light box after staining with ethidium bromide - a fluorescent nucleic acid stain. Although dsRNA analysis is a useful indexing tool, the procedure is lengthy thus limiting the number of plants that can be processed. This test is most suitable for the production of small numbers of virus-tested mother plants for multiplication (i.e. elite breeding lines) or for the confirmation of suspected viral diseases. The rather sophisticated equipment, reagents, and specialized training required to do the test may restrict its application to fully-equipped laboratories in institutions with the task of producing certified virus-free cassava germplasm.

The use of an antiserum to a symptomless potexvirus of cassava for virus indexing.

Virologists at the Scottish Crop Research Institute (SCRI), Invergowrie, Scotland, are collaborating with CIAT scientists on a project to identify the etiological agents of several important virus-like diseases of cassava in Latin America. The SCRI contingent includes Dr. Bryan D. Harrison, Dr. Angela M. Lennon, and Maud M. Aiton. The project was initiated on March 1, 1984 to last three years until March 31, 1987. The project has been mutually beneficial and very productive as evident, from the characterization and production of antiserum to a novel symptomless potexvirus of cassava within the first year of the project (B.D. Harrison and A.M. Lennon, personal communication).

In 1983, CIAT scientists mechanically transmitted a similar virus from cassava (cv. Secundina) exhibiting a severe leaf mosaic and mild frogskin disease (FSD) root symptoms, to the virus indicator hosts Nicotiana benthamiana and Chenopodium amaranticolor (CIAT Cassava Annual Report, 1983). A virus designated WF was purified from systemically-infected N. benthamiana and shown to be serologically related to several isolates of cassava common mosaic virus (CCMV) (CIAT Cassava Annual Report, 1983). A symptomless potexvirus was recently isolated at SCRI from FSD affected cassava collected in the Quilcacé region of Cauca, Colombia. The SCRI virus produced local lesions on C. quinoa and was also purified from systemically-infected N. benthamiana. Purified virus was used for the production of an antiserum. The virus was shown to be serologically related to several members of the plant potexvirus group, which include a distant relationship to CCMV. The SCRI virus produced a symptomless infection when transmitted back to cassava (cv. Secundina).

In recent tests at CIAT the original WF virus and the symptomless potexvirus were compared serologically and biologically on several virus indicator plants. Both viruses produced identical symptoms on C. murale, C. quinoa and N. benthamiana, and were symptomless in cassava (cv. Secundina) following mechanical or graft transmission. Likewise a very close serological relationship was demonstrated in the direct ELISA test (Table 2). Since the WF virus and the symptomless potexvirus are the same virus, the WF designation should be dropped to avoid unnecessary confusion.

Symptomless potexvirus antiserum was used for indexing plants grown in an FSD endemic area near Quilcacé (Table 3). The virus was detected in at least one plant for each of the clones tested. However, the virus was found in both FSD-affected and apparently healthy plants leaving in question the role of the symptomless potexvirus in the etiology of FSD. No seed transmission was detected in any of the over 300 seedlings sampled (Table 3).

This antiserum also reacted with an as yet uncharacterized latent viral agent of cassava (CIAT Cassava Annual Report, 1982 and 1984)

(Table 2) isolated from cv. M Col 33. The exact relationship between the symptomless potexvirus and the M Col 33 virus is under investigation.

Comparison of geographical isolates of cassava common mosaic virus. CCMV is found throughout the cassava-growing region of Latin America. A comparison of several geographical isolates was conducted to determine if CCMV exists as biological (host range) or serological strains. The occurrence of distinct strains would make virus indexing difficult because more than one set of host range plants or a range of antisera would be required. Five geographical isolates, one from Brazil, three from Colombia, and one from Paraguay were inoculated onto a set of differential host range plants (Table 4).

All the isolates infected each of the hosts inoculated. However the Paraguayan isolate consistently produced the most severe reaction on cassava, N. benthamiana, and Ricinus communis, whereas Colombian isolate U produced the mildest reaction including a symptomless infection on cassava. There are sufficient differences to maintain separate isolate designations for the Paraguayan and Colombian U isolates. However, the Nieves, BPI 1 and BPI 2 host range reactions were too similar to be maintained as separate isolates. Antiserum developed at CIAT to the Nieves isolate is capable of detecting all the isolates in infected cassava and is routinely used for virus indexing.

Effect of planting date on the incidence of a severe leaf mosaic disease on the cassava clone Secundina in Quilcace, Cauca. The cassava clone Secundina is native to the North Coast of Colombia, where it produced acceptable yields until the outbreak of the Caribbean mosaic disease (CMD) (CIAT Cassava Annual Report, 1981). Secundina is extremely susceptible to CMD infection (CIAT Cassava Annual Report, 1984) and so far is the only clone to exhibit leaf mosaic symptoms on the Colombian North Coast. Later trials demonstrated the extreme susceptibility of Secundina to other viruses and virus-like agents including CCMV, a latent disease (CIAT Cassava Annual Report, 1983), and the FSD (CIAT Cassava Annual Report, 1982). The unusual susceptibility of Secundina has been exploited by using stakes of this clone as virus indicator scions in graft indexing. When Secundina was planted in a FSD endemic area it was one of a few clones that produced aboveground symptoms and the only clone to express a severe leaf mosaic. The occurrence of leaf symptoms on Secundina was not always correlated with the expression of FSD root symptoms.

Secundina was included in a planting date trial in an FSD endemic area near Quilcace, Cauca, to: (1) observe the incidence and rate of dissemination of the severe leaf mosaic agent; and (2) to compare the incidence of FSD in Secundina to other clones planted in surrounding trials. The first planting date was on April 5, 1984 followed by approximate monthly plantings (with the exception of January 1985) until March 20, 1985. The incidence of leaf mosaic was assessed at least two times for each planting date.

Disease incidence varied from month to month but the dissemination rate over the course of the experiment was rapid (Table 5). Nearly 100% of the stakes planted between April and August, 1984 were infected

within 3 1/2 months. The rate of infection appeared to slow between September 1984 and March 1985. Disease incidence in these plots did not reach 100% even after 6 1/2 months (February 13/85 planting). However, the final incidence was still at least 60% (March 20/85 planting).

Results from prior experiments suggested the role of whiteflies in the transmission of FSD (CIAT Cassava Annual Report, 1982) and the Secundina leaf mosaic (CIAT Cassava Annual Report, 1984). The population of adult whiteflies was estimated at the time of planting and on each evaluation date. Whiteflies were consistently observed in the trial but there was not a clear correlation between the estimated population and disease incidence. Whitefly counts should have been taken at weekly intervals to more accurately account for population fluctuation but the distant location of the trial prevented more frequent sampling dates.

Root symptoms of FSD were identified on only two plants in the entire trial at the time of harvest. The incidence of FSD in adjacent plots of susceptible clones was also low with the exception of cv M Col 113. The role, if any, of the apparently vector-borne Secundina mosaic agent in the etiology of FSD is not known at this time. The incidence of the mosaic disease is many-times higher than the incidence of FSD in the area. If the mosaic agent were the sole cause of FSD one would expect a higher FSD incidence. Since this is not the case the mosaic agent is either not involved in the etiology of FSD or part of a viral complex. The latter hypothesis (CIAT Cassava Annual Report, 1983) can now be tested with the availability of the symptomless potexvirus antiserum and the identification of the mosaic disease on Secundina.

Proposed cassava virus nomenclature in light of recent information.

Virus nomenclature evolves as the level of characterization for each pathogen increases. Such is the case with the cassava viruses under investigation at CIAT. In the 1983 CIAT Cassava Annual Report, a list of viruses and a virus-like disorder was presented. This year it is possible to update the 1983 list based on recent developments in cassava virology (Table 6). The nomenclature will continue to change with time until each of the viral agents are isolated and completely characterized.

Table 1. Detection of double-stranded ribonucleic acid (dsRNA) in virus-infected cassava.

1. Freeze tissue in liquid N_2 and powder by grinding in a mortar.

2. Extract tissue in a mixture containing STE buffer, SDS, bentonite, 2-mercaptoethanol, phenol, chloroform, and iso-amyl alcohol.

3. Shake mixture at RT for 1/2 hour, centrifuge for 10 min, collect supernatant, and adjust to 16.5% ethanol.

4. Add CF-11 cellulose powder, shake at RT for 1/2 hour, and load into a small column.

5. After column has formed wash with STE:16.5% ethanol and elute the dsRNA from the column with STE buffer, and precipitate overnight in 70% ethanol.

6. Centrifuge the precipitated dsRNA, dry pellets under vacuum, and resuspend in STE buffer.

7. Treat with nucleases to remove contaminating host DNA and ssRNA, precipitate in 70% ethanol, and resuspend final dsRNA in electrophoresis sample buffer.

8. Load samples onto a 1% agarose gel and electrophoresce for 3 to 4 hours.

9. Stain the gel in ethidium bromide and check for the presence of fluorescing dsRNA bands on a UV light box.

Table 2. Some serological relationships of a symptomless potexvirus of cassava.

Virus isolate	Leaf sap dilution[a]				
	1/10	1/50	1/250	1/1250	1/6250
Cassava common mosaic virus Isolate U	.147[b]	.133	.134	.127	.126
Uncharacterized latent virus Isolate M Col 33	1.334	1.170	.478	.223	.140
Original WF virus (CIAT)	1.979	1.921	1.061	.466	.205
Symptomless potexvirus[c] (SCRI)	1.850	1.778	.893	.359	.182

a Each virus isolate was maintained in *Chenopodium quinoa*.

b Average A_{405} absorbance of ELISA replicates. The A_{405} of a 1/10 dilution of leaf sap from a healthy plant was .154. Two times the A_{405} for the healthy plant control is considered positive reaction.

c Homologous antiserum used in ELISA test was produced at the Scottish Crop Research Institute, (SCRI).

Table 3. Results from ELISA indexing of clones and seeds collected from virus-infected plants from Quilcace, Cauca, Colombia.

	# ELISA Positives[a] / # Plants Tested[b]	# ELISA Positives[a] / # Seedlings Tested[c]
CM 321-188	3/8	0/35
CM 922-2	4/8	
CM 996-6	3/8	
CM 962-4	1/5	
CM 975-1	2/9	
CM 955-2	1/5	
CM 1335-4	3/5	
CM 1305-3	3/6	
CM 342-170		0/19
CMC 40	2/8	0/44
M COL 113	3/7	0/208
M COL 1684	2/7	
QPR	6/6	0/10

a Antiserum to the symptomless potexvirus was used in the ELISA test.

b Stakes were collected from randomly selected plants in the field and sprouted under glasshouse conditions.

c Seeds were collected from graft-indexed positive plants. The seeds were germinated in the glasshouse and the seedlings sampled by ELISA.

Table 4. Host range comparison of five geographical isolates of cassava common mosaic virus, (ccmv).

Isolates[a]	*Chenopodium amaranticolor*		*Chenopodium murale*		*Chenopodium quinoa*		*Euphorbia prunifolia*		*Manihot esculenta*		*Nicotiana benthamiana*		*Ricinus communis*	
	Inoc.[b]	Sys.[c]	Inoc.	Sys.	Inoc.	Sys.	Inoc.	Sys.	Inoc.	Sys.	Inoc.	Sys.	Inoc.	Sys.
Brazil Nieves	Local lesions	-	Local lesions	-	Local lesions	-	Symptom-less	Symptom-less	Severe mosaic	Severe mosaic	Local lesions	Severe mosaic	Mild mosaic	Mild mosaic
Colombia BPL 1	Local lesions	-	Local lesions	-	Local lesions	-	Symptom-less	Symptom-less	Mild mosaic	Mild mosaic	Local lesions	Severe mosaic	Mild mosaic	Mild mosaic
Colombia BPL 2	Local lesions	-	Local lesions	-	Local lesions	-	Symptom-less	Symptom-less	Severe mosaic	Severe mosaic	Local lesions	Severe mosaic	Very mild mosaic	Very mild mosaic
Colombia U	Local lesions	-	Local lesions	-	Local lesions	-	Symptom-less	Symptom-less	Symptom-less	Symptom-less	Local lesions	Ring-spots	Very mild mosaic	Very mild mosaic
Paraguay	Local lesions	-	Local lesions	-	Local lesions	-	Symptom-less	Symptom-less	Severe mosaic	Severe mosaic	Local lesions	Severe mosaic	Severe mosaic	Severe mosaic

a See 1983 CIAT Cassava Annual Report for Brazilian and Colombian isolate designations.

b Symptom expressed on inoculated leaves.

c Systemic reaction expressed on non-inoculated leaves. A (-) indicates infectious virus could not be recovered from non-inoculated leaves. Virus could be recovered from symptomless *E. prunifolia* leaves.

Table 5. Effect of planting date on the incidence of a severe leaf mosaic disease on the cassava clone Secundina in Quilcacé, Cauca.

Planting date	Days after germination	% Infected plants[a]	Rainfall mm/month	Estimated population of adult whiteflies[b]	
				At planting	At evaluation
April 5/84	13 (5/3/84)	3	432	Low	Moderate
	53 (6/13)	62			High
	81 (7/11)	100			Moderate
May 3/84	25 (6/13)	54	231	Low	High
	53 (7/11)	100			Moderate
June 13/84	13 (7/11)	0	374	High	Low
	49 (8/16)	0			High
	82 (9/18)	38			Moderate
	105 (10/12)	89			Moderate
July 11/84	20 (8/16)	0	105	Low	High
	53 (9/18)	15			Moderate
	77 (10/12)	100			Moderate
August 16/84	16 (9/18)	0	90	High	Moderate
	40 (10/12)	64			Moderate
	84 (9/21)	100			Moderate
September 18/84	10 (10/12)	0	280	Moderate	Moderate
	49 (11/21)	72			Moderate
October 8/84	35 (11/21)	9	340	Moderate	Moderate
	187 (5/23/85)	83			Moderate
November 21/84	13 (12/19)	0	72	Moderate	Low
	167 (5/23/85)	71			Moderate
December 19/84	40 (2/13)	0	72	Low	Low
	77 (3/20)	14			Moderate
	139 (5/23)	88			Moderate
February 13/85	22 (3/20)	0	32	Low	Moderate
	85 (5/23)	75			Moderate
	196 (8/14)	79			No data
March 20/85	48 (5/23)	60	40	Moderate	Moderate
	138 (8/14)	60			No data

[a] The average percent infection for 3 plots of 25 plants each.

[b] The average number of whiteflies captured from 3 leaves from 5 different plants. Low= 10 whiteflies/plant; moderate= 10 to 50 whiteflies/plant; and high= 50 whiteflies/plant.

Table 6. A summary of the information currently available on the etiology and detection methods available for cassava viruses and a virus-like disorder under investigation at CIAT.

Viruses[a]	Symptoms on cassava	Mode of transmission[b]			Indexing methods available		
		Mechanical	Seed	Vector	Grafting to Secundina	ELISA	dsRNA
Cassava common mosaic virus							
Type strain (Nieves and BPL isolates)	Mild mosaic	*Chenopodium quinoa*	No	No	Yes	Yes	Yes
Symptomless Isolate (Upali isolate)	Symptomless	*C. quinoa*	No	No	No	Yes	Yes
Severe isolate	Severe mosaic	*C. quinoa*	No	No	Yes	Yes	Yes
Symptomless Potexvirus (WF)	Symptomless	*C. amaranticolor* *N. benthamiana*	No	No (?)	No	Yes	Yes
Severe mosaic virus	Severe mosaic, leaf distortion, stunting in cv. Secundina	No	–	Whitefly(?)	Yes	No	Yes(?)
Caribbean mosaic virus	Moderate mosaic	No	–	Whitefly(?)	Yes	No	Yes(?)
Latent virus	Symptomless in some clones Severe mosaic in cv Secundina	No	–	–	Yes	No	Yes
Frog Skin Disease	Severe root distortion	No	No	–	Yes	No	Yes
Virus-like disorder							
Shoestringing[c] (E.T.)	Severe leaf narrowing and distortion	No	F_1 seed from crosses involving a very limited number of parents	No	No	No	No

a Proposed virus nomeclanture in light of recent information. Refer to 1983 CIAT Cassava Annual Report for description of isolate designations in parentheses.

b A (–) indicates data not available. Preliminary results are followed by a (?).

c All available information indicates that the shoestringing disorder is not caused by a virus.

GERMPLASM AND BREEDING

Objectives and Breeding Strategy

The principal objectives of CIAT's cassava breeding activities are to contribute to yield stability and yield increases in farmers' fields. To achieve these objectives, CIAT provides superior germplasm to national research agencies, and works jointly with national program scientists in the selection process. As the world's major cassava germplasm center, CIAT has available a wide range of genetic variability. In addition, the edapho-climatic diversity of Colombia and a multitude of pests and pathogens provide environments for effectively selecting for most traits of interest to national programs. Nevertheless, the specific combinations of characters required by particular countries or regions within countries are so diverse that the final selections must generally be made in the countries themselves. Thus, CIAT's role is primarily to provide improved gene pools from which superior, locally adapted clones can be selected, or which can be used in crosses with locally adapted varieties.

To produce germplasm for a diversity of local conditions while simultaneously maintaining wide geographic coverage required of an international center, CIAT classifies cassava growing areas into six edaphoclimatic zones (ECZs). These have been described in detail in previous CIAT Annual Reports, and are summarized in Table 1. Each ECZ has a unique combination of soil conditions, climate, pests and diseases.

Breeding trials up to the advanced yield trial stage of evaluation are carried out at six sites in Colombia, which represent five of the six edaphoclimatic zones (Table 2; Figures 1 and 2). Selections from advanced yield trials enter a regional trial network for testing over a wide range of sites within a given ECZ. The regional trials are managed jointly with the Instituto Colombiano Agropecuario (ICA). The objectives of the regional trials are to identify clones with potential as varieties *per se* either for Colombia or other countries, or with potential as cross parents for use either by CIAT or national programs.

National programs receive basic or improved germplasm as clones (*in vitro*) or as botanical seed. In general the better developed breeding programs prefer seed introductions, as far more genetic variability can be managed as compared to clonal introductions. This increases the probability of selecting superior clones for local adaptation. In recent years, several national programs have requested specific crosses designed to upgrade their best clonal materials by incorporating specific characteristics. Clonal introductions, however, remain an important means of germplasm exchange.

Germplasm Introduction, Evaluation, and Utilization

The germplasm collection, which currently contains 3,818 accessions (Table 3), is the genetic base of the cassava breeding program. Germplasm accessions are evaluated in various selection environments to

identify sources of resistance to diseases and pests, and to identify individuals having good environmental adaptation and agronomic traits. Such individuals are used as parental materials in the breeding program. Outstanding accessions may become recommended varieties.

During 1984 and 1985, germplasm accessions were evaluated in single row trials at selection sites in ECZs 1, 2, 3, 4, and 5. Tables 4 and 5 present evaluations of damage levels caused by diseases and pests which were prevalent at the various selection sites. At Media Luna (ECZ 1), damage levels were evaluated for anthracnose (Colletotrichum or Glomerella spp.), brown leaf spot (Cercosporidium henningsii, white leaf spot (Phaeoramularia manihotis) and Oligonychus mites. A small number of clones showed very low levels of damage by brown leaf spot disease. The resistant clones having other desirable traits (such as high yield and dry matter content, good plant growth habit, and resistance to other diseases and pests) will be used as parental materials.

Anthracnose, bacterial blight (Xanthomonas manihotis), and superelongation disease (Elsinoe brasiliensis) were evaluated at Carimagua in ECZ 2 (Table 5). Carimagua generally provides high levels of stress due to these diseases in the first semester planting, allowing the reliable identification of sources of resistance. At Florencia in ECZ 3, around 700 accessions were evaluated for anthracnose, blight leaf spot (Cercospora vicosae) and superelongation disease. Under the relatively low disease pressure currently present there, good levels of resistance to all three diseases were identified.

Around 1100 germplasm accessions were evaluated for thrips damage at CIAT-Palmira (ECZ 4) where thrips and mite populations are usually high enough to provide reliable information on resistance levels. At Popayan (ECZ 5), we are evaluating the Argentine, Bolivian and the bulk of the Brazilian germplasm accessions for adaptation to a tropical highland ecosystem.

Overall evaluations of roots and foliage, as well as of yield and dry matter are used to select promising germplasm accessions for advancement in the selection program. Germplasm accessions (land races) play a particularly important role at the ECZ 1 selection sites. Of the 15 top yielding clones in the first semester 1984 yield trial at Media Luna, 13 were germplasm accessions. About one half of the parental clones in the breeding population for this zone are germplasm accessions.

At Carimagua and at CIAT-Palmira, enough progress has been made through hybridization and selection that very few germplasm accessions perform outstandingly relative to newer hybrids. Thus, none of the 15 top yielding clones in the CIAT and Carimagua 1984 yield trials were germplasm accessions. The most promising germplasm accessions in these environments are included as parental clones in the breeding populations to provide sources of new variation.

There are plans for collection of cassava germplasm in regions of Central and South America which are not well represented in the CIAT

cassava germplasm collection. Arrangements are being made for the acquisition of the major Asian collections, and African mosaic virus-resistant materials are being sent from IITA, Nigeria. These new materials will broaden the genetic base of the cassava breeding program, and will be useful in providing important sources of local adaptation and disease resistance in seed produced for national cassava breeding programs.

Gene Pool Improvement and Hybrid Seed Production

Gene pools for breeding are defined according to the constraints of the various ECZs. Gene pools are being developed for adaptation to ECZs 1, 2, 5 and 6. However, there is considerable genetic interchange among pools, especially between those for ECZs 1 and 2, and between 2 and 6. These ECZ-specific gene pools are continuously being improved through incorporation of selected new germplasm accessions and by recurrent selection.

Hybrid seed is produced by both controlled pollinations and by open pollination in isolated polycross blocks. The number of clones included in each crossing block varies by year and by gene pool. Generally the ECZ 1 and ECZ 2 pools include about 30-50 clones each, and ECZ 5 and 6 about 10-15 each. Separate pools are not established for ECZ 3 or 4. For zone 3, parental selection and definition of selection criteria are still underway. For zone 4, adequate selections can be made from other gene pools since all progeny are maintained at CIAT-Palmira through all stages of selection at the other selection sites.

Seed production during last year is given in Table 6. Sufficient reserves of seed (mostly open pollinated) are kept in stock to meet most requests.

Pollination biology

The use of open pollination schemes in cassava is an alternative to the labor-intensive production of controlled crosses. Though only a few national programs are making controlled pollinations, several have recently begun producing cross pollinated seed in various polycross designs or other open pollination schemes. Two potential problems arise from the use of open pollination in cassava. First, because flowering in cassava is highly asynchronous, and different clones vary widely in flower production, random recombination among clones is virtually impossible to achieve. Second, since there is no control against self pollination, inbreeding effects may arise in the open pollinated progeny.

The cassava literature gives widely conflicting information regarding the pollination biology of cassava. Some reports indicate mostly wind pollination while others show exclusively insect pollination. Since increasing use is being made of open pollination schemes in cassava, it has become important to understand the dynamics of cassava open pollination.

Pollination agents. The extent of wind pollination was studied using two methods. First, 120 microscope slides, covered with a sticky substance to trap airborne pollen, were placed at a distance of one

meter around the perimeter of a cassava field in flower, during three different periods. No cassava pollen grains were observed on these slides. Secondly, about 150 female flowers were covered with mesh bags which allowed the entrance of wind carried pollen, but excluded entrance of pollinating insects. From all of these flowers, a single seed was produced (there was a potential maximum of 450 seeds). These studies indicate an insignificant level of wind pollination in cassava under the conditions of CIAT-Palmira.

Extensive observations were made of insects visiting male and female cassava flowers, and of their activity within the flowers (Table 7). The conclusion was that the common honeybee (Apis mellitera) is the principal pollinating agent. Most of the bees' activity took place from 11:30 AM to 2:30 PM, which coincides with the period of anthesis. Although flowers remain open several hours following anthesis, nectar and pollen supplies are rapidly depleted and visits by bees essentially cease after 2:30 PM. During the period immediately following anthesis, up to seven bees were observed simultaneously visiting the flowers of individual inflorescences. The time which elapsed during a bee's visit to an individual flower ranged from less than one second to 47 seconds, with a mean of seven seconds per visit.

Pollen movement in a field. In open pollination schemes it is necessary to understand patterns of pollen movement in order to design a recombination field allowing maximum intercrossing among clones within a crossing block, while minimizing contamination from clones outside of the crossing block. Pollen movement was simulated by placing phosphorescent powder on male flowers of an individual plant and observing its distribution throughout a crossing field. Female and male flowers which opened on the same day were collected and observed under UV light. Even a single grain of powder on a stigma was readily observable. Ninety-three percent of the powder was distributed within a radius of 10 m, and the maximum distance from the source was 18 m. This confirms our earlier studies indicating that 12 m of isolation are adequate to avoid all but very low levels of contamination by foreign pollen. It should be noted, however, that these data may not be universally applicable, especially when other insect species are the principal pollinating agents.

Levels of self pollination in open-pollinated cassava. No reliable data exist on levels of selfing in cassava when clones are planted in a polycross design. We addressed this question by using marker genes (light vs. dark root surface color), and comparing the proportion of progeny from emmasculated and nonemasculated plants which were homozygous recessive (light color) for root color.

Results using six clones showed a range from 0 to 49% selfing, with a mean of 20%. There appeared to be some relationship between level of selfing and the proportion of male to female flowers. Higher levels of selfing occurred in clones with proportionally more male flowers (Table 8). A mean selfing rate of 20% should be acceptable, since progeny with inbreeding depression will be quickly discarded in a selection program. Lower levels of selfing in prolifically flowering

clones could be achieved by partial emasculation, either by removing some of the male flowers, or by removing entire branches.

Selection Methodology Studies

The move toward further decentralization in cassava breeding at CIAT a few years ago was based on mounting evidence of Genotype x Environment interactions between cassava clones and the six loosely defined edapho-climatic zones where cassava is cultivated (Table 1). At that time a methodology study was initiated to improve selection efficiency. Fifty individual plants were randomly chosen from an F_1 field. At harvest, data were taken on plant architecture, root and foliage yield, root form and root dry matter content. Each clone was then multiplied, and in first semester of 1984, all clones were planted in a simulated selection field with two stages of selection-- an F_1C_1 (individual plant per clone) and a replicated yield trial. The trial was planted in Media Luna, Carimagua and CIAT-Palmira. Data similar to those described for the F_1 were taken, as well as disease and insect resistance evaluations. The principal objectives of this study are to evaluate efficiency of selection for diverse agronomic characters, comparing stages of selection and selection sites. The experiment will be carried out for two more seasons, to obtain data on Genotype x Year and Genotype x Year x Location interactions.

Preliminary data are now available. A simple measure of potential selection efficiency is the correlation coefficient between the comparisons of interest. The advanced yield trial is considered to most nearly represent performance of a clone under commercial conditions. Thus, one of the principal questions to be answered by this study is: with what level of confidence can a particular character be selected in the early evaluation stages? Tables 9-12 show linear correlations between various characteristics for the F_1 or F_1C_1 trials and the advanced yield trials at the three sites.

Architectural traits (plant height, height of first branch, and number of branching levels) were generally highly significantly correlated between the F_1C_1 and the yield trials, both within and across sites (Table 9). Thus, any of the three sites could apparently be used with nearly equal effectiveness to select for architectural traits for any of the other sites. Also, the F_1 plants (from seed) had nearly the same predictive value as the F_1C_1 plants (from stakes). It is interesting to note, however, that there was a significant change in plant type in seed vs. vegetatively propagated plants. The seed propagated plants branched later (greater height of first branch) and had fewer branching levels (Table 13). This should be taken into account when selecting for a particular plant type. A moderately branching plant type in the seed propagated population is likely to be excessively branched when stake-propagated.

Few of the architectural traits had any predictive value for yield. In Media Luna, plant height and height of first branch in the F_1C_1 had a significant correlation (5% level) with yield in the yield trial, while in Carimagua, early vigor and number of branching levels were correlated with yield (Table 9).

Selection for yield in the F_1C_1 was indicated to be effective only on a site-specific basis, and not effective in the F_1 (Table 10). The only exception was a low but significant correlation between yield in the F_1 at CIAT, and yield in the yield trial at Media Luna. For Media Luna and Carimagua (low productivity environments) root yield per se in the F_1C_1 had higher predictive value for root yield in the yield trial than did harvest index, while at CIAT (a high productivity environment) neither harvest index nor yield in the F_1C_1 was of value for predicting yield in the yield trial (Figure 3).

Root dry matter was highly significantly correlated among all selection stages within sites, and between CIAT and Media Luna. Thus, root dry matter content can effectively be selected for at the very earliest stages. In Carimagua, because root yields were very low, only 13 samples were available for dry matter analysis from the F_1C_1 and no correlation was found between the F_1C_1 and the yield trial (Table 11).

General subjective evaluations were made on tops and roots at harvest in all trials except the F_1 at CIAT. These evaluations are an integrated measure of plant type, disease and insect resistance, and overall appearance (for tops); and of root yield, root form and overall appearance (for roots). Either of these evaluations was nearly equally effective in the F_1C_1 for predicting yield in the yield trial at a particular site. These evaluations were as effective or more effective than either harvest index or yield itself in the F_1C_1 for predicting yield in the advanced yield trials (Table 12).

These data suggest that a simple selection based on a subjective evaluation of overall plant and root appearance may be the most effective and efficient selection strategy in the early stages. Results need to be reconfirmed, but they do indicate the importance of integrated evaluations. However, it must be cautioned that the effectiveness of such subjective selection would also be highly dependent upon the expertise of the breeder.

Selection of Elite Clones

ECZ 1 (lowland tropics, low rainfall, long dry season)

Advanced yield trials. CIAT cassava breeding trials were harvested for the first time at the ICA station at El Carmen, Department of Bolivar. This site is intended as a secondary selection site for ECZ 1, with Media Luna, Magdalena as the principal selection site. The two sites represent a range from low to intermediate productivity conditions within ECZ 1 (see Table 2).

All stages of selection, from the F_1C_1 through advanced yield trials, are carried out in Media Luna. Clones selected in the single row trial in Media luna are advanced to a preliminary yield trial in both Media Luna and Carmen de Bolivar. Selection in the preliminary and advanced yield trials will now be based on combined performance at both sites.

Due to space constraints, the trials at Carmen de Bolivar were planted on a hilly, poor section of the station and mean yields were very low-- only 6 t/ha fresh roots (Table 14). Nevertheless, some

hybrids and germplasm accessions yielded well even under these high stress conditions, while the local variety, Blanca Mona, yielded only 2 t/ha fresh roots. Highest yield was shown by the hybrid CM 1223-1, which has also done well in Caribia, Media Luna, Carimagua and CIAT-Palmira. The objective of having two major selection sites within ECZ 1 is to produce clones having broad adaptability within the zone. Data will be analyzed over the next few years to determine suitability of both of these sites for selection over the wide range of conditions found in ECZ 1.

In Media Luna there are now many clones with high yield potential for both first and second semester plantings (early and late rainy season, respectively) (Tables 15 and 16). The first semester trial in Media Luna suffered extensively from poor germination, apparently due to a combination of climatic stresses and Diplodia infection. In the Media Luna area, Diplodia has become a major problem in the last few years because of increasing intensity of cassava cultivation and therefore shorter rotation cycles. The Pathology and Breeding sections are working to develop clones resistant to Diplodia as one control measure (see Pathology section).

Due mainly to this poor germination, mean yields in first semester were lower than normal (12 t/ha fresh roots). Several new introductions from Cruz das Almas, Brazil and from a collection in the Colombian Amazon region showed very good yields in first semester, with acceptable root dry matter.

The combination of good yield with high root dry matter content (> 30%) continues to be a major selection objective for ECZ 1. It is relatively easy to produce high yielding clones with low dry matter, but much more difficult to combine good plant type, high yield, high root dry matter, and adequate disease and insect resistance. The most common clone on the North Coast is Venezolana (CIAT accession M Col 2215). Although no clone approached the high dry matter content of Venezolana in first semester (37%), several clones yielded considerably more and had acceptable dry matter.

Root HCN in the North Coast trials tends to be higher than in other sites. The reasons for this are not fully understood, but are probably due partly to soil and climatic effects, and also to the germplasm base which has been utilized to develop the ECZ 1 gene pool. M Col 1684, very high in HCN, was used extensively as a cross parent in the past. For fresh consumption of cassava roots, HCN levels should be less than 100 ppm CN^-, or about 7 or less on the 1-9 scale used by the Breeding section. Low HCN clones have been used more extensively in recent years to bring down the overall level of root HCN in the ECZ 1 gene pool.

One of the major cassava growing areas of Latin America is the Northeast of Brazil. Although a highly diverse region, much of northeast Brazil can be considered to fall within the classification of ECZ 1 (low rainfall, long dry season, insect and mite pests as important yield constraints). Some of the best materials in the early rainy (A) season yield trial in Media Luna were local varieties from the Northeast of Brazil, maintained in the CNPMF, Cruz das Almas, germplasm

collection. This provides one test of the appropriateness of the Colombian north coast as a selection site for Brazil's Northeast. The reciprocal test of adaptation in the Northeast of germplasm selected in the North of Colombia is presently underway, based primarily on performance of segregating populations.

Regional trials. During the 1984-85 growing season, eight regional trials were planted in the North Coast region of Colombia in the Departments of in Magdalena, Atlantico, Sucre and Cordoba, the most important cassava production region of Colombia (Table 17). Five of these trials were planted near the beginning and three near the end of the rainy season. Late rainy season plantings, though presently of low importance, provide a potential means of extending the availability of cassava in the market throughout most of the year.

Based on combined performance across sites and seasons, the highest yielding clones were M Col 1505 (CMC 76; Verdecita), M Col 1684, M Col 2215 (Venezolana), M Ven 25, CM 681-2, CM 922-2, CM 1223-11, CM 1305-3 and CM 1533-19. M Ven 25 and M Col 1684 showed highest stability of performance, yielding equal to or better than the trial mean across all sites and seasons. M Ven 25 is known to have extremely high root HCN (> 300 ppm CN^-, in dried chips) and should be recommended only for industrial purposes.

Eight clones were planted in both A and B seasons in trials in Magdalena, Sucre and Cordoba to test genotype by season interactions, and determine whether it will be necessary to develop distinct clones for the two planting seasons. An analysis of variance showed significant effects for genotypes, locations, semesters, and for all interactions. Further analysis showed that a large portion of the genotype x semester interaction was caused by the reaction of Venezolana. This clone does well in an early rainy season planting, but not so well in the late rainy season. This corroborates results of a previous time of planting trial (Third Report, Cooperative Project DRI-CIAT). These data show that good performance across planting seasons is possible in the North Coast conditions (e.g., M Ven 25, M Col 1505, M Col 1684), but that it will be necessary to select clones across both seasons to assure that such performance is achieved. A routine testing of advanced clones across seasons will be implemented.

ECZ 2 (lowland tropics, acid soil savannas)

Advanced yield trials. In last year's Annual Report (1984) an analysis was made of yield trends over 10 years for both first and second semester plantings in Carimagua. Mean trial yields of first semester plantings have continually increased over time at a mean rate of 2 t/ha/yr, while in second semester plantings, yields of experimental clones have been relatively constant, and check yields have been constantly declining. This decline in check yields appears to be due to increasing pest problems (mites, mealybugs, thrips and lacebugs) during the dry season. These trends have led to a strategy of emphasizing resistance to disease problems in early rainy season plantings, and mite and insect resistance in late rainy season plantings (along with yield potential, root quality, and plant type). These same basic trends for

yield in the two semesters continued this year (Tables 18 and 19).

Because strong emphasis was placed on bacterial blight and superelongation (SE) resistance for almost 10 years, many clones now combine adequate resistance to these diseases. Although some of the highest yielding clones show some stem elongation toward the end of the rainy season in Carimagua, this level of resistance is probably adequate for nearly any SE-endemic area. Many clones are now available which consistently yield over 20 t/ha fresh roots in the first semester in Carimagua, with good plant type and moderate to high root dry matter content. Furthermore, several of these clones have shown to be widely adapted, being among the highest yielding clones also at CIAT-Palmira. Some of the older selected clones such as CM 523-7 and M Ven 77 continue to produce stable intermediate yields.

Regional trials. Four trials were planted in first semester and one trial in second semester (Carimagua) in ECZ 2. Results showed rather large inconsistencies across sites, with no clones showing outstanding yield performance in all sites (Table 20). The clone which came closest to stable high yield was CM 523-7. Also, some of the newer hybrids which were planted in only one or a few sites appear very promising, although their stability cannot yet be verified. Problems of heavy disease pressure, weed control and theft before harvest also affected some of these trials.

(ECZ 3) lowland, high rainfall tropics

Cassava is grown in extensive areas of the American, African and Asian tropics in lowland, high rainfall environments. Trials to identify cassava genotypes adapted to this ECZ were begun at two sites near Florencia, Colombia in 1984. An observational trial of 729 germplasm accessions, a preliminary yield trial of 181 clones, and a regional trial of 15 clones were planted. Germplasm accessions from Brazil, Colombia, Cuba, Mexico and Peru were included in the observational trial. Sixty-three of the best performing individual accessions were selected for advancement to the 1985 preliminary yield trial. There was not a predominance of accessions from any country among the selected clones. The materials included in the 1984 preliminary yield trial had all reached an advanced stage of selection in at least one of the other selection sites (i.e. ECZ 1, ECZ 2, or ECZ 4). Forty-one top performing clones were selected from the preliminary yield trial for advancement to the 1985 yield trial. Clones which had previously been selected in ECZ 1, ECZ 2, or ECZ 4 were selected in roughly equal proportions. Thus, after one year of trials, no single ECZ has proven superior to the others at providing materials for the ECZ 3 environment.

As in previous regional trials at Florencia, M Col 1684 and CM 507-37 had outstanding yields (24 and 29 t/ha, respectively). M Col 1684 is a collection from the Amazon region, and is one of the parents of CM 507-37. These preliminary results indicate that development of a separate gene pool for ECZ 3 may be necessary to achieve rapid progress in breeding for this zone.

In 1985, due to technical difficulties, only preliminary yield and regional trials were planted at Florencia. Observational, preliminary yield, yield and regional trials are planned for 1986.

ECZ 4 (middle altitude tropics)

Advanced yield trials. As ECZ 4 has relatively low priority, no gene pool is being developed specifically for this zone. However, since all clones selected in other sites are maintained and multiplied at CIAT-Palmira (ECZ 4), there is ample opportunity for selecting clones with good performance at CIAT from other gene pools. The CIAT-Palmira station is also important as a site for screening for thrips and mite resistance, as populations of these pests are usually high.

Mean yields in the advanced yield trials were 30 and 19 t/ha fresh roots for first and second semesters, respectively (Tables 21 and 22). Many clones appear to be promising for this zone, with yields well above M Col 1468 (a popular introduced clone in the region) and with good dry matter content. Several outstanding clones have potential for the fresh market, having HCN levels similar to M Col 113 or M Col 1468. As yield and pest resistance are reaching very good levels, more emphasis is being given to plant type (i.e., upright, late branching) and lower root HCN levels.

Regional trials. Three trials were harvested in the middle altitude tropical zone in first semester of 1985, at Palmira, Quilichao and Quilcace (Table 23). Palmira and Quilichao are both high productivity environments, with trial mean yields of 26 and 37 t/ha, respectively. Although yields at CIAT were only intermediate, virtually all the trial entries performed well compared to the check clones, M Col 113, M Col 1468 and M Col 1684. In Quilichao, similar results were obtained, but with the check M Col 1684 also yielding well in the absence of thrips pressure.

Quilcace represents an area of low soil fertility within ECZ 4. As this was the first year for a regional trial in this site, selection of clones included in the trial was based on little background data. There is a particular need in Quilcace for clones with resistance or tolerance to frog skin disease. Selected clones will be evaluated over several years for stability of reaction to this disease.

ECZ 5 (highland tropics)

Breeding for highland tropical adaptation is directed almost exclusively to the Andean Zone and to the East African highlands. Low temperatures constitute the major production constraint, and *Phoma* leaf spot is also important in Latin America. The CIAT station near Popayan, Cauca, serves as the selection site for this zone.

Trials in Popayan were suspended for almost a year while the experiment station was being prepared with terraces to reduce erosion problems. Thus only one yield trial, corresponding to the 1983A-1984B season, was harvested (Table 24). Yields were low because of heavy disease pressure and soil problems. Trials were reinitiated at the CIAT station in late 1985.

Regional trials. Mondomo, Cauca, is intermediate between ECZ 4 and 5, but past experience has shown that clones from the ECZ 5 gene pool have the best chance of adaptation here. For the first time, new hybrids selected in the Popayan station were tried in this region, and several performed very well (Table 23). CG 406-5 was the highest yielding clone in the trial, with similar results for CG 406-6 and CG 401-6. Good dry matter content is characteristic of most of the clones tested in the lower temperature sites.

ECZ 6 (subtropics)

Since Colombia has no territory lying within the subtropics, CIAT's breeding activities for this zone consist primarily in making crosses among clones selected in the subtropics by national programs, or between these clones and others selected as sources for particular traits. One of the priority objectives is to transfer higher Cassava Bacterial Blight and Superelongation Disease resistance from the ECZ 2 to the ECZ 6 gene pool. Seeds of these crosses have now been sent to Brazil, Cuba, China and to IITA for testing in their East Africa highland program. In all countries testing is only in the preliminary stages.

Characteristics of High Yielding Clones

High root yield is one of the main selection criteria of most cassava breeding programs. Various theories exist as to the modification of biomass production and carbohydrate distribution which will give maximum yield. One theory suggests best gains can be made by maintaining equal total biomass production, but improving harvest index. This approach would function best when the gene pool to be improved has a very low harvest index and excessive foliage growth. Another theory suggests that top growth should remain constant, while improving root yield, and thereby harvest index. This strategy would work best where the working gene pool has appropriate top growth characteristics.

To look at characteristics associated with high yield, data from 27 advanced yield trials in three sites (CIAT-Palmira, Carimagua and Media Luna) were analyzed (Table 25). Various yield-associated traits of the five highest yielding clones in each trial were compared with those of the trial mean and of the local check varieties. There was a surprising consistency across sites for the proportion of yield advantage gained through the various components. Root yield, by virtue of the classification, could be expected to be well above the trial mean. For the best five clones, foliage yield was 20 to 24% higher than that of the trial mean, while harvest index was improved by 15 to 18%. Root dry matter showed little difference (-6 to + 4%) between highest yielding clones and trial mean. These data indicate that for the CIAT gene pools, yield improvement can be achieved by a large increase in total biomass production, and a higher proportion of that biomass distributed to the roots. This holds true for both the high productivity (CIAT-Palmira) and low productivity (Carimagua and Media Luna) environments. Further study is needed to determine the distribution of carbohydrates among leaves, petioles and stems of the high yielding clones, and implications for sustained yield improvement.

Germplasm Distribution

A total of over 50,000 seeds and 134 clones *in vitro* were distributed to national research programs and universities during 1985 (Table 26). Asian countries have been the largest germplasm recipients in the last few years as a result of close ties through the CIAT Asia-Regional Program based in Thailand. High priority is being given to follow up on the performance of these materials, to provide a basis for further improving parental selection at CIAT.

Table 1. Edaphoclimatic zones (ECZ's) for cassava production and their main characteristics.

Edaphoclimatic Zone no.	General description	Regions in Colombia for germplasm evaluation and technology testing	Major yield constraints
1	Lowland tropics with long dry season, low to moderate annual rainfall, high year-round temperature.	Magdalena, Atlantico, Bolivar, Sucre, Cordoba	Drought, mites, thrips, mealybugs, termites, bacterial blight, root rots, viruses.
2	Acid soil savannas with moderate to long dry season, low relative humidity during dry season.	Meta	Low soil fertility, drought bacterial blight, superelongation, anthracnose, leafspots, mites, mealybugs, lace bugs.
3	Lowland tropics with no pronounced dry season, high rainfall, constant high relative humidity.	Caqueta	Low soil fertility, leaf spots, root rots.
4	Medium-altitude (800-1500 msl) tropics with moderate dry season and temperature.	Valle, Cauca	Thrips, mites, mealybugs, bacterial blight, anthracnose, root rots, and viruses.
5	Cool, tropical highland (1600-2200 msl) area with mean temperatures of approx. 17-20°C.	Cauca	Low temperatures, Phoma leafspot, anthracnose, mites.
6	Subtropical areas, with cool winters and fluctuating daylengths.	None	Low winter temperature, bacterial blight, superelongation, anthracnose.

Table 2. Edaphoclimatic characteristics of selection sites in Colombia.

Location	Edapho-climatic zone	Altitude (msl)	Mean temperature (°C)	Rainfall during cycle (mm)[a]	Soil characteristics				
					pH	Organic matter (%)	P (ppm Bray II)	K (me/100g)	Texture
Media Luna, Magdalena	1	10	27.2	A: 780 B: 779	6.3	0.4	3.6	0.07	Sandy loam
Carmen de Bolivar, Bolivar	1	152	26.8	A:1045	7.4	3.5	17.8	0.95	Clay
Carimagua, Meta	2	200	26.2	A:2180 B:2190	4.5	3.5	4.0	0.14	Clay loam
Florencia, Caqueta	3	450	25.0	A:2808	3.8	4.8	14.5	1.09	Clay
CIAT-Palmira, Valle	4	1000	23.8	A: 817 B: 674	6.6	5.6	42.0	0.60	Clay
Popayan, Cauca	5	1760	18.0	A:2628	5.0	25.6	5.0	0.28	Loam

[a] A = first semester planting; B = second semester planting.

Table 3. Source of accessions in CIAT's cassava germplasm collection.

Country of origin	Number of accessions
Argentina	15
Bolivia	3
Brazil	862
Colombia	1569
Costa Rica	149
Cuba	74
Dominican Republic	5
Ecuador	117
Guatemala	92
Malaysia	3
Mexico	64
Panama	75
Paraguay	102
Peru	273
Philippines	2
Puerto Rico	15
Thailand	1
Venezuela	241
CIAT hybrids	156
TOTAL	3818

Table 4. Preliminary evaluation of germplasm accessions for resistance to diseases and pests at Media Luna, Magdalena (ECZ 1) during 1984 and 1985[a].

Disease or pest damage rating[b]	Frequency of clones (%)				
	Anthracnose 1985	Brown leaf spot 1984	Brown leaf spot 1985	White leaf spot 1985	Oligonychus mites 1985
1	0	2.7	2.0	36.4	0.7
2	58.4	18.4	19.6	47.5	70.4
3	30.3	78.2	49.7	14.0	21.1
4	9.2	0.7	28.7	2.1	7.8
5	2.1	0	0	0	0

[a] The 1984 and 1985 trials consisted of 147 and 143 accessions respectively. Both trials were planted during the first semester.

[b] 1 = low damage; 5 = high damage.

Table 5. Preliminary evaluation of germplasm accessions for resistance to diseases and pests in ECZ 2, ECZ 3 and ECZ 4 during 1984 and 1985[a].

	Frecuency of clones (%)						
	Carimagua, Meta (ECZ 2)			Florencia, Caqueta (ECZ 3)			Palmira, Valle (ECZ 4)
Disease or pest damage rating[b]	Anthracnose 1984	Bacterial blight 1985	Superelongation 1985	Anthracnose 1984	Blight leaf spot 1984	Superelongation 1984	Thrips 1985
1	0	0	0	15.9	7.3	85.4	26.8
2	0.8	7.2	9.2	54.6	85.8	8.0	27.3
3	17.5	85.6	22.4	23.7	6.0	3.9	17.7
4	61.1	7.2	51.3	5.4	0.8	2.3	25.0
5	20.6	0	17.1	0.4	0.1	0.4	3.2

[a] The 1984 and 1985 ECZ 2 trials consisted of 131 and 152 clones, respectively; ECZ 3 trial, 710 clones; and ECZ 4 trial, 1096 clones. All trials were first semester trials.

[b] 1 = low damage; 5 = high damage.

Table 6. Production of hybrid cassava seed during 1985 at CIAT, Palmira.

Type of pollination	Zone of parental adaptation	No. of seeds produced
Controlled	1 x 1	7395
	1 x others	6209
	2 x 2	2778
	2 x others	2528
	5 x 5	2015
	6 x 6	275
	Others	1639
	Subtotal:	22,839
Open (polycross)	1	33,069
	2	61,835
	5	46,518
	6	24,380
	Subtotal:	165,802
	TOTAL:	188,641

Table 7. Insects observed visiting cassava flowers at CIAT-Palmira [a]

Order	Family	Genus/species	Activity
Hymenoptera	Braconidae Vespidae Other identified		Occasionally observed on flowers
Diptera	Syrphidae		Occasionally observed taking nectar
Hemiptera	Reduvidae		Occasionally observed taking pollen
Coleoptera	Chrysomelidae	Diabrotica	Occasionally observed takin pollen
Hymenoptera	Vespidae	Polistes	Observed daily taking nectar
Diptera	Tephritidae	Anastrepha	Observed daily ovipositing on young fruits
Hymenoptera	Apidae	Apis mellifera	Observed daily taking pollen and nectar; principal pollinating agent.

[a] Data from Ing. Agron. thesis of L.A. Daza and A. Alvarez.

Table 8. Estimated percentages of selfing in cassava clones planted in a polycross design.

Clone	Estimated level of selfing (%)	Proportion female: male flowers
M Bra 12	4.4	1:5
M Col 22	37.2	1:8
M Cub 50	49.1	1:10
CM 342-170	0[a]	1:7
CM 566-1	0[a]	-
CM 681-2	30.8	1:4

[a] Negative values considered as zero.

Table 9. Linear correlations among sites and selection stages for architectural traits and root yield[a].

Advanced yield trials	F_1 CIAT			F_1C_1 CIAT				F_1C_1 Media Luna				F_1C_1 Carimagua			
	Plant height	Branching height	Branching levels	Vigor	Plant height	Branching height	Branching levels	Vigor	Plant height	Branching height	Branching levels	Vigor	Plant height	Branching height	Branching levels
CIAT															
Vigor	++	NS	NS	NS	NS	NS	NS	NS	+	+	NS	++	NS	+	NS
Plant height	++	++	NS	NS	++	++	NS	NS	++	++	NS	NS	NS	NS	NS
Branching height	NS	++	—	NS	+	++	—	NS	NS	NS	—	NS	NS	++	—
Branching levels	NS	NS	++	NS	NS	NS	++	NS	NS	NS	++	NS	NS	—	++
Root yield	NS	NS	NS	NS	+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Media Luna															
Vigor	++	++	NS	++	++	NS	NS	++	++	++	NS	++	NS	++	NS
Plant height	++	++	NS	NS	++	+	NS	++	++	++	NS	++	+	++	NS
Branching height	+	++	—	NS	+	++	—	NS	NS	NS	—	NS	++	-	-
Branching levels	NS	NS	+	NS	NS	NS	++	NS	NS	NS	++	NS	NS	-	++
Root yield	NS	NS	-	NS	NS	NS	NS	NS	+	+	NS	NS	NS	NS	NS
Carimagua															
Vigor	++	++	NS	NS	++	+	NS	NS	+	+	NS	++	++	NS	NS
Plant height	++	++	NS	NS	++	NS	NS	+	++	++	—	++	++	++	NS
Branching height	NS	++	—	NS	++	++	—	NS	+	+	++	NS	NS	++	—
Branching levels	NS	NS	++	NS	NS	NS	++	NS	NS	NS	NS	+	NS	-	++
Root yield	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	++	NS	NS	++

[a] +, ++, -, —, NS indicate significant positive (0.05 level), highly significant positive (0.01 level), significant negative, highly significant negative, and non-significant linear correlations, respectively.

Table 10. Linear correlations among sites and selection stages for root yield and harvest index.

Root yield in advanced yield trials	F_1 - CIAT		F_1C_1 - Harvest index			F_1C_1 - Root yield		
	Harvest index	Root yield	CIAT	Media Luna	Cari-magua	CIAT	Media Luna	Cari-magua
CIAT	0.20	0.14	0.04	-0.07	-0.06	0.20	0.28	0.03
Media Luna	0.20	0.29[a]	0.31[a]	0.35[a]	0.11	0.21	0.44[b]	-0.18
Carimagua	0.11	0.02	-0.09	-0.16	0.18	0.09	-0.14	0.58[b]

[a] Significant at the 5% level.
[b] Significant at the 1% level.

Table 11. Linear correlations among sites and selection stages for root dry matter content.

Root dry matter in advanced yield trials	Root Dry Matter			
	F_1 - CIAT	F_1C_1 - CIAT	F_1C_1 - Media Luna	F_1C_1 - Carimagua [a]
CIAT	0.50[b]	0.77[b]	0.45[b]	-0.05
Media Luna	0.36[b]	0.46[b]	0.75[b]	0.49
Carimagua	0.16	0.21	0.16	0.19

[a] 13 samples only

[b] Significant at the 1% level.

Table 12. Linear correlations among sites and selection stages for general foliage and root evaluations, and root yield.

Root yield in advanced yield trials	General foliage evaluation, F_1C_1a			General root evaluation F_1C_1a		
	CIAT	Media-luna	Cari-magua	CIAT	Media-luna	Cari-magua
CIAT	-0.33[b]	-0.26	0.17	-0.35[c]	-0.27	-0.08
Media Luna	-0.11	-0.53[c]	-0.05	-0.30[b]	-0.52[c]	-0.14
Carimagua	-0.06	-0.30[b]	-0.58[c]	0.06	0.10	-0.62[c]

Table 13. Trial means and standard deviations (in parentheses) for selected traits from the selection methodology study (50 clones).

Trait	F_1	F_1C_1			Yield trial		
	CIAT	CIAT	Media Luna	Carimagua	CIAT	Media Luna	Carimagua
Plant height (cm)	210(43)	125(38)	228(44)	174(36)	186(48)	228(31)	178(26)
Height of first branch (cm)	137(46)	46(22)	52(37)	51(23)	70(39)	60(32)	55(23)
Branching levels (no.)	1.4(0.08)	3.0(1.4)	3.5(1.0)	3.7(1.4)	3.4(0.8)	3.5(0.8)	3.9(1.0)
Foliage yield (t/ha)	24(11)	9(8)	17(9)	10(7)	28(11)	24(7)	15(6)
Root yield (t/ha)	16(7)	19(14)	20(12)	8(6)	34(9)	21(7)	15(7)
Harvest index	0.42(0.10)	0.69(0.08)	0.52(0.12)	0.45(0.14)	0.56(0.10)	0.47(0.07)	0.52(0.07)
Root dry matter		33(3)	28(4)	28(7)	32(4)	29(3)	19(12)

Table 14. Performance of the selected clones and check varieties in the 1984-85A yield trial at Carmen de Bolivar, Bolivar (ECZ 1).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]
CM 1223-1	CM 323-125 x M Col 1684	24	30	8	9
M Bra 174		15	31	5	8
M Ven 77[b]		15	26	4	7
CM 847-11	SM 76-66 x M Col 1684	15	31	5	9
M Cub 18		14	29	4	5
M Col 2032		14	33	4	7
M Col 2054		13	31	4	5
M Ven 185		12	33	4	7
M Col 1468[b]		10	28	3	7
M Cub 56		10	30	3	7
CM 523-7	M Col 655A x M Col 1515	10	30	3	7
M Cub 43		9	31	3	6
M Col 1684[b]		5	28	1	9
M Col 2063[b]		4	32	1	6
M Col 22[b]		4	29	1	9
M Col 2253[b]		2	36	1	6
M Bra 12[b]		1	20	1	9
Trial mean (103 clones, checks included)		6	28	2	7
LSD (5%)		8.9	5.7	2.8	

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)

[b] Check varieties: M Col 2063 (Secundina) and M Col 2253 (Blanca Mona) are local varieties.

Table 15. Performance of the selected clones and check varieties in the 1984-85A yield trial at Media Luna, Magdalena (ECZ I).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]	Brown leaf spot (1-5)[b]
M Mal 2		26	27	7	9	2
M Bra 125		24	30	7	9	3
M Bra 158		24	29	7	9	4
M Fer 283		21	30	6	8	3
M Bra 12[c]		21	30	6	9	2
M Bra 73		18	28	5	7	3
M Col 2032		17	32	5	9	3
M Ven 25		17	30	5	9	3
M Col 2054		16	30	5	8	3
M Col 1684[c]		15	24	4	9	2
M Ven 185		14	28	4	8	2
CM 523-7	M Col 655A x M Col 1515	14	31	4	9	2
M Col 1823		14	30	4	9	2
M Cub 18		14	30	4	6	3
M Col 1468[c]		13	18	2	5	2
M Col 681-2	M Ven 185 x M Col 22	12	29	4	8	3
M Col 2057		12	30	4	9	2
M Cub 49		12	34	4	8	4
M Col 2215[c]		11	37	4	6	3
M Col 2063[c]		9	33	3	8	3
M Ven 77[c]		7	24	2	8	3
M Col 22[c]		3	25	1	9	3
Trial mean (90 clones, checks included)		12	26	3	8	3
LSD (5%)		7.4	3.6	2.0		

[a] 1 = very low ($<$ 20 ppm CN^-); 9 = very high ($>$ 150 ppm CN^-)
[b] 1 = very low damage; 5 = very high damage.
[c] Check varieties: M Col 2063 (Secundina) and M Col 2215 (Venezolana) are local varieties.

Table 16. Performance of the selected clones and check varieties in the 1984-85B yield trial at Media Luna, Magdalena (ECZ I).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]
CM 1910-112	CM 430-94 x M Col 1684	34	28	10	9
CM 1288-17	CM 430-14 x M Col 1684	30	28	9	9
CM 2157-1	CM 374-22 x M Col 1684	30	24	7	9
CM 1442-204	M Bra 12 x M Col 1684	29	27	8	9
CM 2481-2	CM 834-2 x M Col 1684	28	31	9	6
CM 342-170	M Col 22 x M Col 1468	26	25	6	8
M Col 1684[b]		25	24	6	9
CM 2087-101	CM 727-14 x CM 459-5	25	26	7	7
CM 2146-3	CM 180-5 x M Col 1468	23	26	6	6
CM 2136-2	M Bra 12 x CM 841-106	22	23	5	6
CM 507-37	M Col 1438 x M Col 1684	21	28	6	9
M Col 22[b]		21	28	6	7
CM 1015-16	M Col 22 x M Col 1684	20	27	5	9
M Col 1468[b]		19	23	4	5
M Bra 12[b]		17	27	5	9
M Ven 77[b]		14	28	4	9
M Col 2063[b]		13	31	4	8
M Col 2215[b]		9	29	3	6
Trial mean (26 clones, checks included)		22	27	6	8
LSD (5%)		7.4	5.7	2.2	

[a] 1 = very low ($<$ 20 ppm CN^-); 9 = very high ($>$ 150 ppm CN^-)

[b] Check varieties: M Col 2063 (Secundina) and M Col 2215 (Venezolana) are local varieties.

Table 17. Fresh root yields (t/ha) and dry matter contents (%) of clones harvested from regional trials in ECZ I during 1985. Dry matter content values are enclosed in parentheses.

Clone	Media Luna, Magdalena		Sabanalarga, Atlantico	Santa Cruz, Atlantico	Albania, Sucre	Betulia, Sucre	Carranzo, Cordoba		Relative performance[b]
	A[a]	B	A	A	A	B	A	B	
M Col 22	7(27)	17(27)	19(24)	25(31)	10(32)	5(30)	13(33)	3(32)	1/8
M Col 72	12(34)	19(32)	23(28)	20(33)	11(36)	4(34)		4(36)	3/7
M Col 1505	12(33)	21(30)	27(26)	21(34)	14(35)	6(33)	18(37)	6(28)	5/8
M Col 1684	23(27)	24(26)		20(28)	13(33)	8(30)	16(34)	8(32)	6/7
M Col 2063[c]	3(27)	10(29)							0/2
M Col 2215[c]	13(35)	14(32)	28(32)	17(36)	11(38)	2(35)	18(39)	6(34)	5/8
M Col 2216			18(27)	19(34)					0/2
M Ven 25	17(32)	24(29)		33(31)	11(38)	12(34)	14(38)	6(35)	6/7
M Ven 157	10(29)								1/1
Sardina[c]			17(29)						0/1
CG 1-37	10(30)								1/1
CG 5-99	3(31)								0/1
CG 6-18	4(27)								0/1
CM 681-2	9(29)	23(31)	27(24)	29(33)	12(35)	8(32)	14(36)	8(34)	6/8
CM 696-1		28(24)							1/1
CM 922-2	9(34)	25(33)	24(23)	24(33)	5(35)	6(32)	16(35)	6(35)	5/8
CM 962-4	7(27)	18(26)	24(24)	24(33)	11(31)	5(31)	18(34)	8(33)	5/8
CM 976-15		24(33)							1/1
CM 981-8				16(34)					0/1
CM 1014-2	7(29)				2(32)		6(33)		0/3
CM 1015-16						8(32)			1/1
CM 1015-34		20(28)						6(34)	1/2
CM 1015-42		24(27)							1/1
CM 1016-34						13(31)		6(34)	2/2
CM 1022-4	6(30)						11(33)		0/2
CM 1223-11	13(28)		17(26)	26(30)	12(33)		23(84)		4/5
CM 1286-7		30(21)							1/1
CM 1297-9		21(27)							0/1
CM 1305-3		37(24)	27(24)	22(25)		13(26)		7(30)	4/5
CM 1533-19	14(24)		25(26)	29(27)	12(31)		17(32)		5/5
CM 1785-6		32(29)							1/1
CM 1797-4		30(25)							1/1
CM 1797-8		31(32)							1/1
Trial mean	10(29)	22(28)	23(26)	23(32)	10(34)	7(32)	15(35)	6(33)	
LSD (5%)	4.8(2.0)	5.0(5.4)	12.9(5.4)	10.7(2.7)	6.7(1.9)	3.7(2.0)	6.5(2.9)	2.6(6.7)	

[a] A = First semester planting (1984) and harvest (1985); B = Second semester planting and harvest.

[b] Number of sites in which yield of a clone equalled or exceeded the site mean, over the total number of sites in which that clone was planted.

[c] Local check varieties: M Col 2063 = Secundina; M Col 2215 = Venezolana.

Table 18. Performance of the top selected clones and check varieties in the 1984-85A yield trial at Carimagua (ECZ 2).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]	Super-elongation disease (1-5)[b]	Bacterial blight (1-5)[b]	Mononychellus mites (1-5)[b]	Mealy bugs (1-5)[b]	Anthracnose (1-5)[b]	Brown leaf spot (1-5)[b]	Blight leaf spot (1-5)[b]
CM 2668-6	CM 507-37 x M Ven 77	28	31	9	7	4	3	3	2	3	2	4
CM 2766-5	CM 723-3 x CM 523-7	28	30	8	2	3	3	4	2	3	3	4
SG 104-283	Population 2	26	35	9	9	4	3	3	3	2	3	3
SG 104-284	Population 2	25	30	8	8	3	3	4	3	3	3	4
CM 2596-2	M Ven 62 x CM 841-168	25	29	7	6	3	3	4	3	4	3	4
CM 2563-5	M Col 1910 x CM 507-37	25	30	8	6	4	3	4	3	3	2	3
CG 165-7	M Col 1495 x M Pan 90	24	30	7	8	2	3	4	3	4	3	3
CG 35-3	M Bra 20 x M Ven 77	24	27	6	8	4	3	4	3	3	4	3
SG 107-35	Population 5	24	33	8	6	2	2	3	4	3	4	3
CM 2952-1	CM 1145-1 x M Pan 12B	23	29	7	5	3	2	3	4	3	3	3
CM 2600-2	M Ven 77 x CM 523-7	23	32	7	4	3	3	4	2	3	3	3
SG 104-264	Population 2	23	33	7	9	3	3	3	3	3	3	4
CM 2772-3	CM 727-14 x M Pan 12B	22	30	7	4	2	3	3	3	2	4	4
CM 2766-3	CM 723-3 x CM 523-7	22	32	7	5	3	3	3	3	2	3	3
CM 523-7	M Col 655A x M Col 1515	21	35	7	5	3	3	4	1	3	3	3
M Ven 77[c]		15	28	4	6	3	3	3	4	2	4	3
M Col 1684[c]		11	30	3	9	3	3	4	3	3	3	2
M Col 1468[c]		10	26	3	4	4	3	4	2	3	2	4
M Col 1438[c]		6	30	2	5	4	3	3	3	4	2	3
M Col 22[c]		2	26	1	6	4	4	3	3	4	2	3
M Bra 12[c]		1	23	1	6	4	3	4	3	4	3	3
Trial Mean (76 clones, checks included)		16	31	5	6	3	3	3	3	3	3	3
LSD (5%)		4.7	2.4	1.5								

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)

[b] 1 = very low damage; 5 = very high damage.

[c] Check varieties, M Col 1438 (Llanera) is a local variety.

Table 19. Performance of the selected clones and check varieties in the 1984-85B yield trial at Carimagua, Meta (ECZ 2).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]
CM 2177-2	CM 430-37 x CM 840-138	24	36	9	5
CM 2452-5	CM 727-14 x CM 834-16	19	32	6	8
CM 2087-101	CM 727-14 x CM 459-5	19	35	7	8
SG 265-2	M Bra 12	17	35	6	7
SM 301-3	Mico	17	35	6	9
CM 2174-7	CM 430-37 x CM 523-7	16	36	6	8
CM 2952-3	CM 1145-1 x M Pan 12B	16	32	5	5
CM 3110-8	CM 1362-6 x CM 523-7	16	34	5	6
CM 2298-3	CM 516-7 x M Bra 5	15	37	6	5
CM 854-21	M Mex 17 x M Col 638	15	34	5	5
CM 523-7	M Col 655A x M Col 1515	15	37	6	7
CM 3168-15	CM 1382-7 x M Ven 218	15	35	5	8
CM 2962-4	CM 1145-2 x M Pan 12B	15	35	5	9
CM 1335-4	CM 462-1 x M Col 1292	14	36	5	5
CM 2166-6	CM 430-37 x M Ven 218	14	33	4	5
M Ven 77[b]		13	31	4	8
M Col 1468[b]		13	32	4	6
M Bra 12[b]		11	32	4	9
M Col 1684[b]		7	34	2	9
M Col 22[b]		6	36	2	6
M Col 1438[b]		3	30	1	6
Trial mean (41 clones, checks included)		12	34	4	7
LSD (5%)		6.0	3.1	2.1	

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)

[b] Check varieties: M Col 1438 (Llanera) is a local variety.

Table 20. Fresh root yields (t/ha) and dry matter contents (%) of clones harvested from regional trials in ECZ 2 and ECZ 3 during 1985. Dry matter contents, when given, are enclosed in parentheses.

Clone	Carimagua, Meta (ECZ 2)		Granada, Meta (ECZ 2)	Puerto Gaitan, Meta (ECZ 2)	Acacias, Meta (ECZ 2)	Florencia, Caqueta (ECZ 3)	Relative performance[b]
	A[a]	B	A	A[2]	A[2]	A[3]	
M Col 1438[c]	8	3	16	11	0		0/5
M Col 1468	10	8	20	19	6		2/5
M Col 1495		6					0/1
M Col 1684	6	7	6	23	0	24(33)	2/6
M Col 1895		10					
M Per 245	18		16	14	12		2/4
M Ven 77	13	11		13		17(30)	1/4
Chiroza[c]			20	13	20		2/3
Temprana[c]						25(34)	1/1
CM 91-3			18	13	9	18(32)	1/4
CM 430-37	17	10		6			1/3
CM 507-34			17		11		1/2
CM 507-37	14	13	21	26	13	29(33)	5/6
CM 523-7	16	11	28	17	16	18(36)	5/6
CM 723-3	17		16	11	17		2/4
CM 728-3						14(16)	0/1
CM 854-21		5					0/1
CM 955-2						15(33)	0/1
CM 975-5						16(35)	0/1
CM 995-6	16	18		19		22(32)	4/4
CM 1299-3			7		4		0/2
CM 1335-4	15	10	24	11	10	20(33)	3/6
CM 1585-3	11		11	12	14		1/4
CM 1851-4						18(32)	0/1
CM 1918-3	23		11		9		0/2
CM 1999-5						17(36)	0/1
CM 2086-16	23		16	21	21		3/4
CM 2088-1	18		16	19	13		3/5
CM 2166-4		13					1/1
CM 2298-3		15					1/1
CM 2306-7		15					1/1
CM 2452-5		15					1/1
HMC 1						18(28)	
HMC 2	14		21	16	14	22(30)	
SM 301-3	18		35	16	10		
Trial Mean	15	11	18	15	11	19(32)	
LSD (5%)	2.2	5.9	15.8	6.2	6.4	8(2.4)	
(checks included)							

[a] A = first semester planting (1984) and harvest (1985); B = second semester planting and harvest.
[b] Number of sites at which the yield of a clone equalled or exceeded the site mean, over the total number of sites at which that clone was planted.
[c] Local check varieties: M Col 1438 = Llanera.

Table 21. Performance of the top selected clones and check varieties in the 1984-85A yield trial at CIAT-Palmira, Valle (ECZ 4).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]
CG 35-3	M Bra 20 x M Ven 77	46	32	15	9
CM 1533-19	CM 309-163 x M Col 1684	44	38	17	8
CG 165-7	M Col 1495 x M Pan 90	42	33	14	9
SG 104-264	Population 2	42	35	15	9
CG 3-3	M Bra 12 x M Col 1438	41	33	14	9
CM 2512-12	CM 1278-10 x CM 523-7	41	32	13	8
CM 2610-1	M Ven 218 x CM 180-5	40	37	15	4
CM 2777-8	CM 727-14 x CM 516-6	39	35	14	6
CG 7-66	M Col 113 x M Col 22	39	37	14	5
CM 1834-19	CM 507-34 x M Ven 270	39	31	12	3
CG 165-2	M Col 1495 x M Pan 90	39	36	14	7
CM 2883-1	CM 952-2 x M Ven 77	38	34	13	8
CM 2086-16	CM 727-14 x CM 91-3	38	33	12	5
CM 523-7	M Col 655A x M Col 1515	37	39	15	4
CG 1-56	M Bra 12 x M Col 22	37	37	14	6
M Col 22[b]		35	39	14	9
M Col 1468[b]		33	33	11	5
M Col 1684[b]		31	29	9	9
M Ven 77[b]		30	33	10	5
M Col 1438[b]		25	31	8	6
M Col 113[b]		9	33	3	5
M Bra 12[b]		7	29	2	9
Trial mean (90 clones, check included)		30	35	10	6
LSD (5%)		12.3	3.2	4.3	

a 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)
b Check varieties: M Col 113 (Valluna) is local check.

Table 22. Performance of the top selected clones and check varieties in the 1984-85B yield trial at CIAT - Palmira, Valle (ECZ 4).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]	Mononychellus mites (1-5)[b]	Lodging (1-3)
CG 489-34	M Ecu 72 x M Bra 12	51	33	17	7	2	1
CM 2087-101	CM 727-14 x CM 459-5	31	33	10	7	3	1
CM 2133-5	M Bra 12 x CM 507-34	30	32	10	7	3	1
CM 1203-13	CM 321-252 x CM 477-3	30	34	10	6	3	1
CM 489-1	M Col 882 x M Ven 270	30	31	9	6	2	2
CM 3172-11	CM 1382-7 x CM 841-58	28	33	9	6	3	1
CM 2109-1	M Col 282 x M Col 1684	28	33	9	9	3	2
CM 2146-3	CM 180-5 x M Col 1468	28	34	9	4	3	2
CM 3199-1	CM 1382-14 x CM 523-7	27	34	9	7	2	3
CM 1797-4	CM 516-7 x CM 326-407	27	32	9	6	2	2
CM 507-37	M Col 1438 x M Col 1684	26	31	8	8	2	1
CG 489-31	M Ecu 72 x M Bra 12	26	33	9	9	2	2
CG 1-48	M Bra 12 x M Col 22	25	36	9	7	3	1
CM 2157-1	CM 374-22 x M Col 1684	25	31	8	9	3	1
CM 3123-2	CM 1362-16 x M Col 1515	25	34	9	8	2	1
M Col 1468[d]		17	32	5	5	3	1
M Bra 12 [d]		15	31	5	7	3	2
M Col 22 [d]		11	35	4	5	3	1
M Col 113 [d]		9	28	2	6	3	2
M Col 1684[d]		8	27	2	9	3	1
M Ven 77 [d]		6	25	2	6	4	1
Trial mean (118 clones, checks included)		19	32	6	7	3	2
LSD (5%)		9.4	3.7	3.3			

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)
[b] 1 = very low damage; 5 = very high damage
[c] 1 = little or no lodging; 3 = severe lodging
[d] Check varieties: M Col 113 (Valluna) is a local variety.

Table 23. Fresh root yields (t/ha) and dry matter contents (%) of clones harvested from regional trials in ECZ 4 and ECZ 5 during the first semester of 1985. Dry matter content values are enclosed in parentheses.

Clone	Palmira, Valle (ECZ 4)	Quilichao, Cauca (ECZ 4)	Quilcace, Cauca (ECZ 4)	Popayán, Cauca (ECZ 5)	Relative performance[a]
M Col 113[b]	7(31)	28(32)	11(30)	17(35)	2/4
M Col 1468	22(32)	20(30)	6(29)	10(31)	0/4
M Col 1522[b]				17(33)	1/4
M Col 1684	20(28)	43(32)	10(32)		1/3
M Col 2006				4(33)	0/1
M Col 2016				10(36)	0/1
M Col 2019				21(33)	1/1
M Col 2059[b]				16(34)	1/1
M Col 2060[b]				17(34)	1/1
M Col 2062[b]			10(32)		0/1
M Col 2257[b]				10(33)	0/1
M Col 2258[b]				17(38)	1/1
M Col 2259[b]				12(37)	0/1
M Col 2260				14(35)	0/1
CG 4-27	20(34)	29(34)			0/2
CG 6-18	25(38)	29(36)			1/2
CG 7-64	36(35)	41(35)			2/2
CG 358-3				16(36)	1/1
CG 401-6				18(35)	1/1
CG 406-5				23(35)	1/1
CG 406-6				21(33)	1/1
CM 91-3	20(32)				0/1
CM 305-41	30(35)	50(34)			2/2
CM 321-188			5(33)		0/1
CM 489-1	34(30)	41(30)			2/2
CM 516-7		53(26)			1/1
CM 523-7		44(37)			1/1
CM 849-1	28(35)	37(36)			2/2
CM 903-4		31(36)			0/1
CM 922-2	27(37)		6(35)		1/2
CM 955-2	27(37)	45(35)	19(34)		3/3
CM 962-4	23(32)	29(32)	12(29)		1/3
CM 975-1			10(31)		0/1
CM 975-5	27(35)				1/1
CM 996-6			7(27)		
CM 1014-2	26(37)	32(35)			1/2
CM 1305-3	32(32)		20(29)		2/2
CM 1335-4	26(38)	43(36)	15(35)		3/3
CM 1491-5	26(37)	41(35)			2/2
CM 1999-5	29(33)	36(35)			1/2
HMC 1	26(32)				1/1
HMC 2				21(34)	1/1
Trial mean (checks included)	26(34)	37(34)	11(31)	16(34)	
LSD (5%)	6.2(4.2)	6.8(2.9)	6.3(2.7)	4.8(2.2)	

[a] Number of sites at which the yield of a clone equalled or exceeded the site mean, over the number of sites at which that clone was planted.

[b] Local check varieties.

Table 24. Performance of the selected clones and check varieties in the 1983A-84B yield trial at Popayan, Cauca (ECZ 5).

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Dry root yield (t/ha)	Root HCN (1-9)[a]	Phoma[b] (1-5)
M Col 2060[c]		12	32	4	4	3
CG 402-11	M Col 1522 x M Col 647	11	28	3	6	4
CG 481-3	M Col 2060 x M Ecu 169	10	31	3	5	4
CG 501-1	M Ecu 169 x M Col 2060	10	31	3	6	4
CG 501-2	"	9	30	3	6	4
CG 358-22	M Col 335 x M Col 2060	8	32	3	3	4
M Col 1522[c]		7	30	2	4	3
M Col 2059[c]		5	29	1	3	4
M Col 2061[c]		3	26	1	5	4
M Col 1468[c]		1	-	-	-	5
M Col 22[c]		0	-	-	-	5
Trial mean (15 clones, checks included)		5	30	2	5	4
LSD (5%)		6.3	4.2	2.1		

[a] 1 = very low (< 20 ppm CN^-); 9 = very high (> 150 ppm CN^-)

[b] 1 = very low damage; 5 = very high damage.

[c] Check varieties: M Col 1522 (Algodona), M Col 2059 (Sata Dovio), M Col 2060 (Regional Amarilla) and M Col 2061 (Regional Morada).

Table 25. Means across years for yield-associated characters at three sites: for highest yielding clones, trial mean, and local checks.

Site	Group	Fresh root yield (t/ha)	Foliage yield (t/ha)	Harvest index	Root dry matter (%)
CIAT-Palmira (9 trials)	5 best clones	46.9(66)[a]	36.1(24)	0.57(16)	34.0(4)
	Trial mean	28.3	29.1	0.49	32.8
	Local check	13.9	34.3	0.29	28.6
Carimagua (12 trials)	5 best clones	22.5(76)	16.4(24)	0.58(18)	30.7(1)
	Trial mean	12.8	13.2	0.49	30.4
	Local check	7.3	10.3	0.41	31.4
Media Luna (6 trials)	5 best clones	22.8(68)	13.2(20)	0.63(15)	28.5(-6)
	Trial mean	13.6	11.0	0.55	30.2
	Local check	15.4	7.8	0.66	36.8

[a] Numbers in parentheses indicate percent advantage of 5 best clones over trial mean.

Table 26. Cassava germplasm shipments from CIAT in 1985.

Region	Country	Form of germplasm	No. of seeds/clones
America	Belize	In vitro	11
	Bolivia	In vitro	14
	Brazil	Seeds	11100
	Canada	Stakes	51
	Cuba	Seeds	3800
	Honduras	In vitro	4
	Mexico	In vitro	10
		Seeds	3600
	Panama	In vitro	23
	Paraguay	In vitro	2
	United States	In vitro	1
		Seeds	200
	Venezuela	Stakes	10
		In vitro	14
Asia	China	In vitro	41
		Seeds	4000
	Indonesia	Seeds	8000
	Philippines	In vitro	14
		Seeds	7800
	Sri Lanka	Seeds	1500
	Thailand	Seeds	9300
Middle East	Iran	Seeds	1500
		TOTAL: Stakes	61
		In vitro	134
		Seeds	50800

Figure 1. Monthly total precipitation at CIAT-Palmira, Media Luna and Carmen de Bolivar experimental sites during 1984-85 growing seasons.

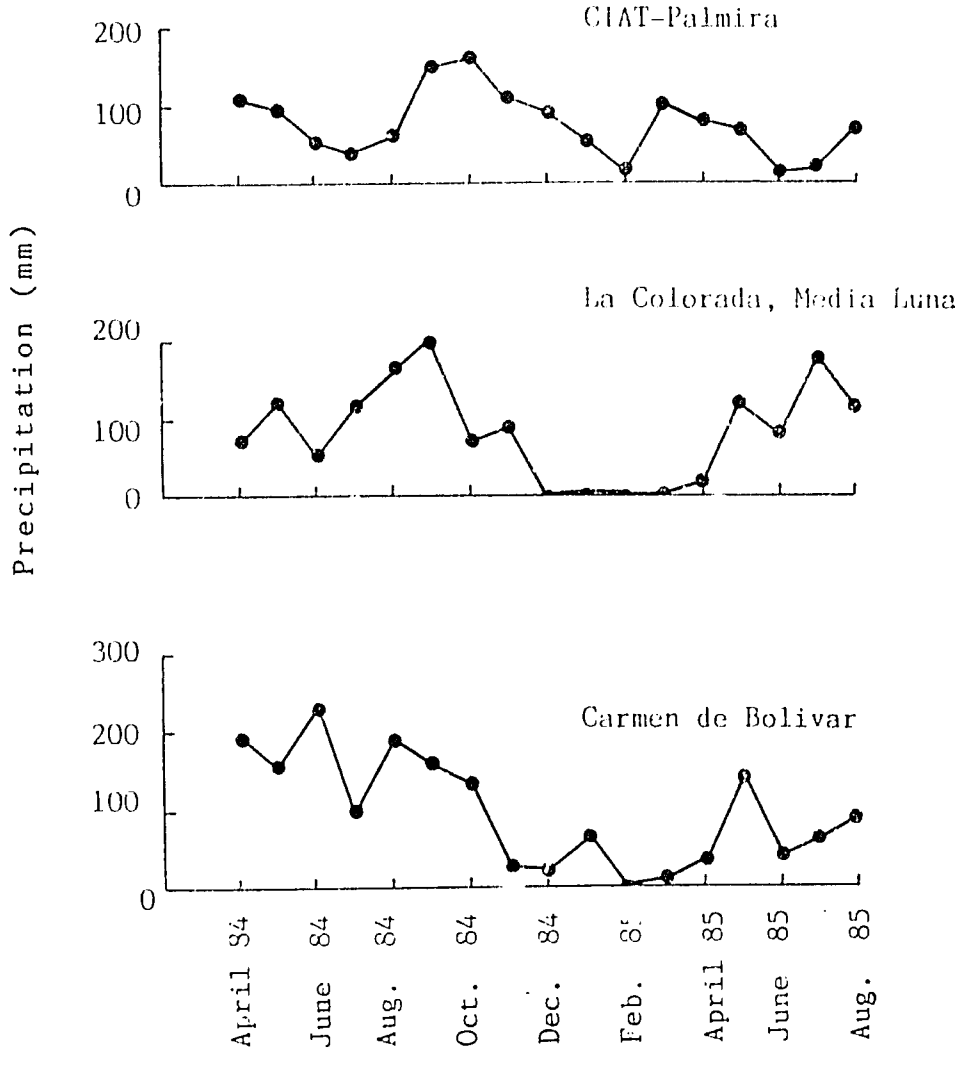
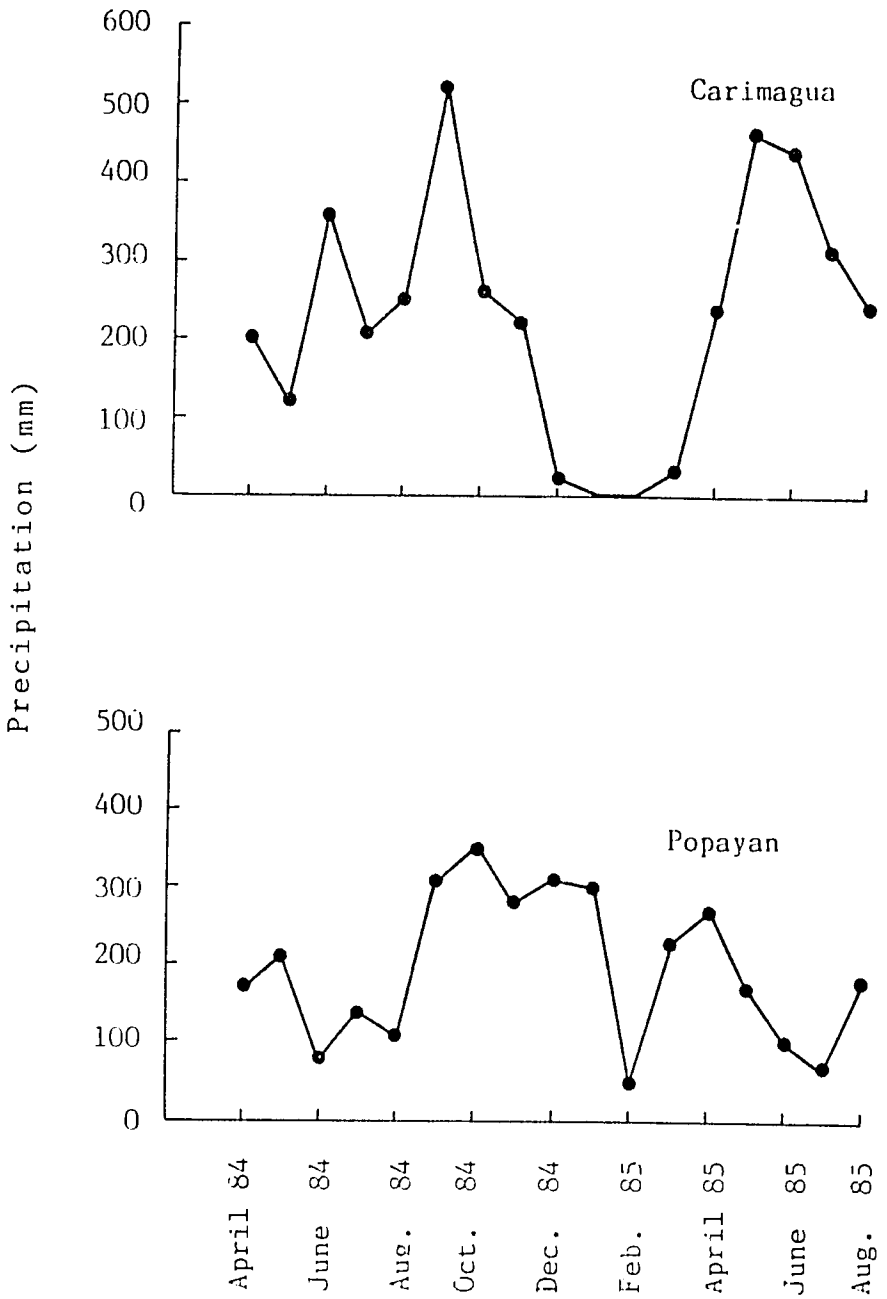


Figure 2. Monthly total precipitation at Carimagua and Popayan experimental sites during 1984-85 growing season.



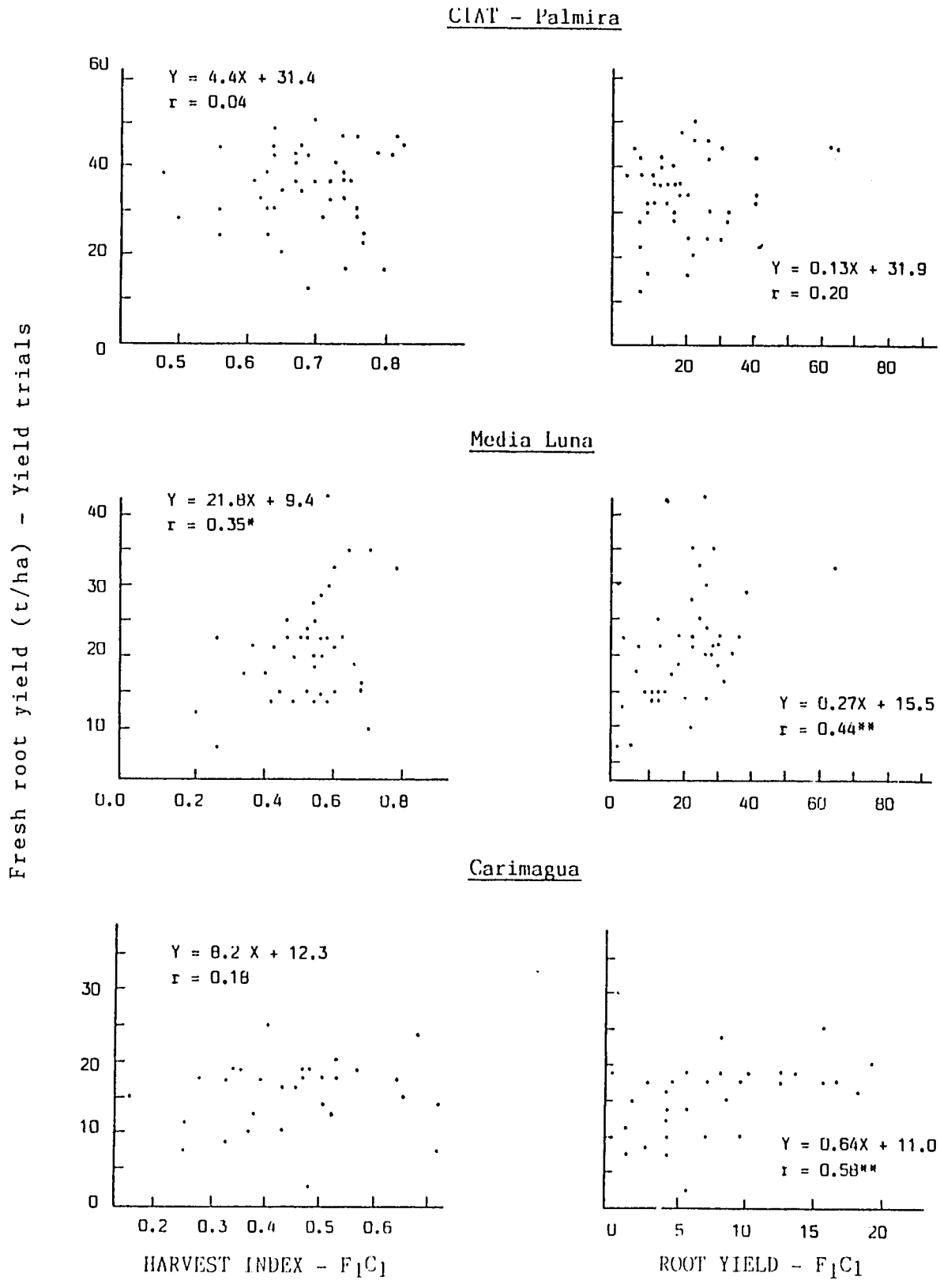


Figure 3 . Root yield in advanced yield trials as a function of harvest index or root yield in the F_1C_1.

BIOTECHNOLOGY RESEARCH UNIT

As stated in the document "CIAT in the 1980s Revisited", those new technologies that can significantly increase the efficiency of plant improvement methods or help resolve problems that escape solutions through traditional procedures. While emphasis is on epplied research, the Unit also assumes responsibility for selected research with high potential pay-off in terms of technology development. In the development of these activities, close interaction with CIAT commodity programs, especially with the breeders, will be established. The Unit will also seek complementarity with advanced institutes and national program scientisis through special research projects.

In 1985, the major activity in the BRU involved research in cell and tissue culture for clonal propagation and for the generation of useful variability. This activity included work carried out at CIAT and at collaborating institutions abroad. Work at CIAT concentrated on continuing earlier work and initiating research to develop tissue culture applications with CIAT crops. Research was initiated abroad to tackle potentially useful areas that require higher specialization at this stage.

Recovery of Healthy Clones

Technique

The disease elimination technique developed previously consists in culturing small (0.2 - 0.3 mm width, 0.1 -0.2 mm hight) meristem tips from apical buds, sprouted at 40°C day and 35"C night (thermotherapy) during 3-4 weeks. In cases where no stakes are available, e.g. germplasm introduced to CIAT *in vitro*, thermotherapy is applied *in vitro*. Rates of virus cleaning depends to a large extent on the size of the explant used for culture and on whether thermotherapy was applied or not (see CIAT Cassava Program Annual Report, 1982), as well as on the virus strain. In general, the following relative order of difficulty has been observed: frog skin disease (less difficult), cassava common mosaic (most cases), cassava caribbean mosaic, latent virus and some strains of common mosaic (more difficult).

Cleaning by this technique needs to be validated through proper virological indexing. Virologists in the Cassava Program have been working in this area, since 1983. The program's Virology Section has checked up a number of clones introduced *in vitro* from various countries as well as clones from the field collection maintained at CIAT. Table 1 summarizes the results of such tests with 461 varieties. With the exception of materials from Colombia and the elite clones, all were transferred to CIAT *in vitro* from various countries. Because of lack of facilities at the National level, heat treatment was not applied prior to culture in all those cases; in addition, the explants obtained for in *vitro* transfer had to be large enough (0.5 - 0.8 mm) in order to secure survival of the small sample (3-4 test tubes/clones) brought to CIAT. In the case of Paraguay for example, 9 clones out of 50 tested had at least one plant reacting possitively for a CCMV strain; when these same clones were exposed to thermotherapy *in vitro*, and again tested using

Table 1. Results of virological testing of cassava varieties after meristem cloning with and without thermotherapy.

Procedence of material	No. vars. tested	Heat treat.	No. vars. with positive (+)[a] reaction				
			Nieves	BPL	WF	FSD	Graft
Brazil	78	no	1	0	-[b]	-	-
Argentina	16	no	0	-	-	-	-
Costa Rica	102	no	0	-	-	-	0
	13	no	0	-	-	-	-
Peru	64	no	0	-	-	-	-
Panama	18	no	0	-	0	-	-
Guatemala	86	no	0	-	1	-	-
Colombia	11	yes	0	0	0	-	-
Elite clones	23	yes	0	0	0	0	-
Paraguay	50	no	9[c]	-	-	-	3
	9[c]	yes	0	-	-	-	-
TOTAL	461		10	0	1	0	3

a (Virus testing carried out by the Cassava Program's Virologist) Nieves and BPL are isolate of CCMV; WF is a latent virus; FSD = frog skin disease; grafting for latent virus.

b - means: non-tested.

c The same varieties with and without thermotherapy.

ELISA, the virus was eliminated from all 9 varieties at 90% rate. This procedure is now applied to all newly introduced clones prior to potting and field transplanting.

Routine Cleaning

The cleaning technique continued to provide healthy material for: (a) distribution of elite clones to national programs; (b) recovery of pest/disease/damaged clones from the field collection; and (c) upgrading important regional varieties for trials by the Cassava Program. Table 2 shows the number of clones cleaned from various diseases during 1985; including these clones, a total of 1300 cassava clones infected with viruses, bacteria and fungi and other apparently disease-free clones, have been processed by this technique in the last 5 years.

Germplasm Exchange

Distribution from CIAT.

In 1985, a total of 200 elite cassava clones were shipped *in vitro* to 10 countries (Table 3). In several instances, the same hybrid or variety was sent to more than one country. In every case, the material was accompanied by a Colombian Phytosanitary Certificate, a CIAT Phytosanitary Statement which describes the procedures, treatments and pathogen testing carried out on the material in preparation for shipment, a list of clones, and a recommended handling procedure.

For appropriate handling of cultures upon arrival at their destination, personnel with minimum training are required, especially for shipments lasting more than two weeks.

Feed back information on handling has been received from various countries. Table 4 shows that after a nearly three-week trip to VISCA, Philippines, plants were recovered from all but one of 9 clones despite the fact that several of them developed medium to severe chlorosis during the trip. Utilization of a micropropagation technique by node cuttings and appropriate potting can be pointed out as two main factors for success. In another shipment to the SCATC, Hainan Island, China, only 6 tubes out of 114 shipped this year arrived with deteriorated or dead cultures. An earlier shipment to South China Institute of Botany, at Guangzhon was efficiently micropropagated, potted and two clones were identified as high yielding in preliminary trials (Fig. 1). Micropropagation by node cuttings was also used at CATIE, Costa Rica to yield 100 plants from each of the 24 clones shipped *in vitro* in 1980. Furthermore, most of the 42 clones shipped *in vitro* to Mexico in the last five years have been distributed (as stakes and/or potted plants) from the recipient INIA Center (CAEZACA, Zacatepec) to two INIA stations located in Veracruz and Guerrero (Table 5); and in Panama, 18 clones introduced from CIAT via *in vitro* techniques have been multiplied at the IDIAP Station in Rio Hato for use in regional trials.

Introduction to CIAT

Following procedures established earlier (Tissue Culture, CIAT Cassava Program, Annual Report, 1983), 148 cassava clones were introduced *in vitro* to CIAT in 1985 as part of a collaborative effort with the IBPGR. These materials comprised: 28 clones (collected from Junin Pasco, San Martin, Huanco and Ucayali), sent from Peru and 120

Table 2. Cassava clones cleaned by thermotherapy and meristem culture in 1985.

Cleaning	No. Clones
Frog skin disease (CIAT field collection)	167
Super elongation disease (CIAT field collection)	4
Elite clones (preventive cleaning)	39
Regional varieties (preventive cleaning)	7
Total	217

Table 3. Distribution of elite clines *in vitro* by country and institutions in 1985.

Country	Institution	No. Clones
Argentina	Min. of Agriculture, Resistencia, Chaco	12
Barbados	CARDI, St. Michael	15
Bolivia	IBTA, Cochabamba	7
China	Academy SINICA, Kwangchow	19
	SCATRC, Hainan Island	22
Ecuador	INIAP, Portoviejo	9
Honduras	Escuela Nacional Agricola, Catacamas	4
Mexico	INIA, Zacatepec	19
	INIA, Huimanguillo	6
Panama	IDIAP, Rio Hato	51
Philippines	VISCA, Leyte	6
	UPLB, Los Banos	14
Trinidad	CARDI, St. Augustine	16
	Total	200

Table 4. Results of handling first *in vitro* shipment of cassava elite clones at VISCA, Leyte, Philippines*.

Clones	No. tubes per clone	General arrival condition	No. cultures dead at arrival	No. node cuttings for microporpag.	No. Potted plants
MBra 12	5	Severe chlorosis	1	4	0
CM 681-2	5	Slender, green	0	16	2
CM 982-20	5	Green	0	12	3
MCub 74	4	Med. chlorosis	1	6	5
CM 342-170	5	Green	2	8	5
MVen 156	5	Green	0	10	5
CM 981-8	5	Green	2	10	7
CM 523-7	5	Med. chlorosis	1	7	6
CM 507-37	5	Med. chlorosis	0	13	5

* Information kindly supplied by N. T. Thanh-Tuyen, VISCA.
Date of shipment: Feb. 10, 1984
Date of arrival at VISCA: Feb. 29, 1984

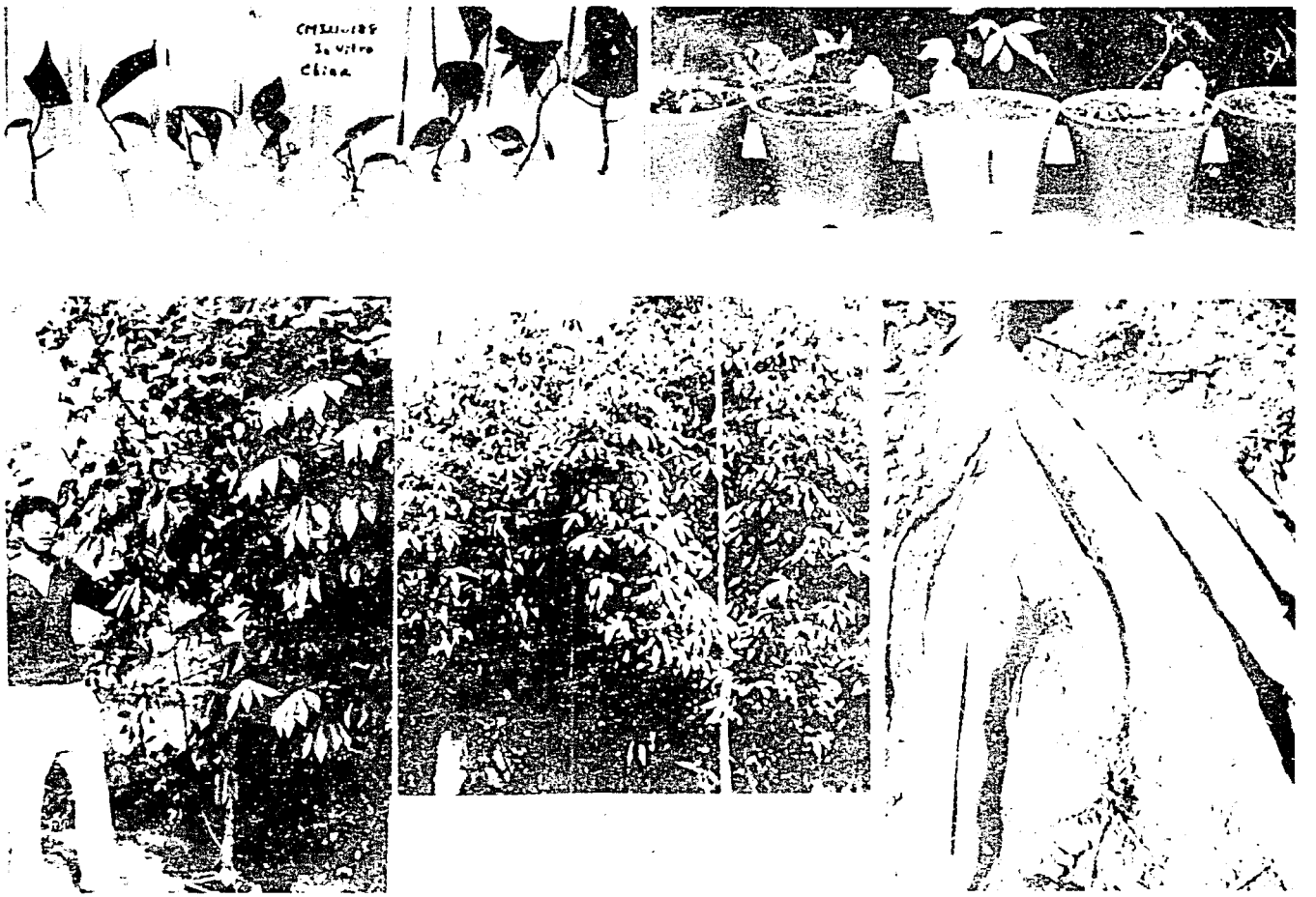


Figure 1. Micropropagation, potting and field trial at Guangdong, China, of clone CM 321-188 shipped *in vitro* in 1983. Photos supplied by K. Chun-Yen, South China Institute of Botany, Guangzhon, China.

Table 5. Distribution within Mexico of cassava elite clones shipped *in vitro* from CIAT to CAEZACA, Zacatepec, from 1981 to 1985[a].

Clones	Dates of arrival in Mexico[b]	Recipient INIA Stations[c]	
		CAECOT	CAEIGUA
CM 321.188	1	X	X
CM 342-55	1	X	X
CM 430-37 (x)	1, 5, 6	X	
CM 489-1 (x)	1, 2, 5	X	X
CM 507-37 (x)	1, 2, 5, 6	X	X
CM 523-7 (x)	1, 2, 5, 6	X	X
MCol 22	1, 2	X	X
MCol 1468	1, 2	X	X
MCol 1684	1, 2	X	X
MCol 1940	1	X	X
MMex 17	1	X	X
MMex 59	1, 4	X	
MVen 23 (x)	1, 5, 6		
CM 91-3	2, 3	X	X
MCol 638	2	X	X
MCub 51	2	X	X
CM 517-1	2	X	X
CM 391-2	3	X	X
MCol 12	3	X	X
MCol 1894	3	X	X
MCol 1964	3	X	X
MCol 2058	3	X	X
MBra 5	3	X	X
MPan 97	3	X	
CM 981-8	4	X	
CM 1305-3	4	X	
MCol 72	4	X	
MCol 1522	4	X	

CONT....

Table 5. Distribution within Mexico of cassava elite clones shipped *in vitro* from CIAT to CAEZACA, Zacatepec, from 1981 to 1985[a].

Clones	Dates of arrival in Mexico[b]	Recipient INIA Stations[c]	
		CAECOT	CAEIGUA
MCol 2061	4	X	-
MBra 12	4	X	-
MEcu 72 (x)	4, 5, 6	X	-
MPer 245	4	X	-
MVen 77	4	-	-
MVen 156	4	X	
CM 849-1	5	-	-
CM 1335-4 (x)	5, 6	X	
MCol 1916	5	-	-
MCub 74 (x)	5, 6		
MVen 25 (x)	5, 6	X	
HMC-1 (x)	5, 6	X	
MCol 1914 (x)	6		

a Data supplied by Ing. R. Méndez, CAEZACA (INIA), Zacatepec, Morelos.

b Arrival dates of *in vitro* cultures: 1 = October 18, 1981; 2 = August 12, 1982; 3 = December 7, 1982; 4 = December 15, 1983; 5 = December 14, 1984; 6 = July 11, 1985.

c INIA Stations receiving stakes and/or potted plants: CAECOT (Cotaxtla, Veracruz), CEIGUA (Iguala, Guerrero).

X Material remaining at CAEZACA, Zacatepec.

— Clones lost.

clones from Paraguay (collected in 1983 and 1984), including 113 cassava varieties and 7 wild species.

As mentioned above, after a short establishment phase, these cultures will be subjected to thermotherapy *in vitro*, subcultured twice, and moved to a glasshouse for virological testing.

Germplasm Conservation

Minimum Growth Storage

This year, the number of cassava clones placed into *in vitro* storage has reached 2,783. As shown in Table 6, nearly 40% are Colombian varieties, 26% are Brazilian, followed by Paraguay, Peru, Costa Rica and Guatemala; the remainder are materials from twelve other Latin American, Caribbean and South East Asian countries.

Under current storage conditions, 24-25°C day and 18-20°C night with 12 hrs. of 1500 lux illumination), cultures are transferred to a fresh medium every 18-24 months. Previous research on the effect of various treatments, e.g. lower temperature, mineral starvation and medium osmotic concentration, demostrated the feasibility of further extending the culture transfer period. Addition of mannitol, as osmoticum, to the medium has been investigated more throughly. Earlier it was found that low mannitol concentration exerted growth reduction as long as it was accompanied by sucrose (Tissue Culture, CIAT Cassava Program, Annual Report, 1983).

In order to elucidate the question of whether the effect of mannitol is purely osmotic and independent of the effect of sucrose as a carbohydrate source for the cultures, work was initiated this year using two varieties and a series of sucrose/mannitol combinations to obtain three total molarities, 0.1, 0.2 and 0.3M. Table 7 shows preliminary results of this work with MCol 22.

Culture growth increases with sucrose only, but viability tends to be higher at the lower sucrose concentrations (Treatments 1 and 2) than the control (No. 3) which has a total molarity of 0.1. If this molarity is maintained by adding mannitol to the medium a significant reduction in culture growth rate and high viability in terms of both leaf retention and propagation potential (No. tips per culture), is achieved (Treatment No. 5). This treatment contains the same sucrose level as No. 2 plus mannitol.

Increasing the total molarity of the medium with sucrose and/or mannitol resulted in a great reduction in growth rate and very low viability. Thus, appropriate storage conditions can be provided by reducing carbohydrate availability to about one third of the standard medium concentration. When mannitol is added to this medium, the total molarity should not exceed 0.1M in order to achieve similar results. The fact that this result can not be obtained solely by increasing sucrose concentration, suggests that in addition to low sucrose levels, a reduction in water and nutrient uptake by the cultures is necessary in order to maintain slow growth and high viability. Mannitol seems to exert this effect when used at low concentrations.

Table 6. No. of cassava clones by source country maintained in the *in vitro* gene bank as of December 1985.

Source Country	CIAT code	No. clones
Argentina	M. Arg.	16
Bolivia	M. Bol	1
Brazil	M. Bra	730
Colombia	M. Col	1101
Costa Rica	M. Cr	135
Cuba	M. Cub	23
Dominican Republic	M. Dom	2
Ecuador	M. Ecu	18
Guatemala	M. Gua	92
Malaysia	M. Mal	3
Mexico	M. Mex	35
Panama	M. Pan	29
Paraguay	M. Par	215
Peru	M. Per	191
Philippines	M, Fil	2
Puerto Rico	M. Ptr	3
Thailand	M. Tai	1
Venezuela	M. Ven	50
Hybrids (CIAT)		136
	TOTAL	2,783

Table 7. Effect of sucrose and mannitol concentrations on growth and viability of stem-tip cultures maintained at 24-25°C day and 18-20°C night, 12 hours of 1500 lux illumination.

No.	Treatment			Growth[a]	Viability[a]	
	Sucrose (M)	Mannitol (M)	Total (M)	cm per month	% leaf retention	No. tips per culture
1	0.01	0	0.01	0.4	78	1.5
2	0.03	0	0.03	0.6	88	2.3
3[b]	0.10	0	0.10	1.3	58	2.0
4	0.01	0.09	0.10	0.6	42	1.0
5	0.03	0.07	0.10	0.5	59	2.5
6	0.20	0	0.20	0.4	26	1.3
7	0.01	0.19	0.20	0.2	41	1.8
8	0.03	0.17	0.20	0.2	0	1.2
9	0.30	0	0.30	0.3	10	1.3
10	0.01	0.29	0.30	0.1	0	0.8

[a] Average of 4 replications/treatment.

[b] Represents standard medium for cassava micropropagation (control).

Cryogenic Storage

This research has been conducted during the last 3 years at the Biotechnology Institute, Saskatoon, Canada with the support of IBPGR and with CIAT's collaboration. The project aimed at developing methods for preserving cassava shoot-tip cultures in liquid nitrogen (LN). This project finished this year and the following conclusions were drawn. The main achievement was the recovery of cassava plants from shoot-tips stored in liquid nitrogen. The procedure which resulted in this achievement consisted in placing the tips in microdroplets (0.2 1) of a freezing medium containing 1M Sorbitol, 9% sucrose, and 5% dimethyl sulfoxide (DMSO) in the Murashige and Skoog liquid medium, without growth hormones. Prior to cooling,, the meristems were allowed to equilibrate gradually in 9% sucrose for 18 hrs, 0.4M Sorbitol and 9% sucrose for 6 hrs, and 1M Sorbitol and 9% sucrose for 18 hrs. using the same liquid medium. The best cooling rate was 0.5° C/min to 30° C, prior to immersion in liquid nitrogen. After 1 - 3 hrs in LN, rapid thawing and washing in the liquid medium was carried out at 37° C. Regrowth of meristems was obtained by transferring them to cassava plant regeneration medium. This procedure was carried out with 12 cassava genotypes with variable success levels. Although tissue survival following retrieval from LN was high (up to 60%), only 2 to 20% plant regeneration was achieved with these genotypes. A large part of the surviving tissues grew into calli without shoot formation. Variability in response was attributed to the physiological condition of donor plants and the range of cell types comprising each shoot-tip.

This work provides the basis for further research into cryo-preservation of cassava. Among the factors which should be looked at, pre-conditioning of plants and tissues seems important. Since it is now possible to regenerate cassava plants by somatic cell embryogenesis (see below), these embryos should provide an appropriate explant for freezing. In theory such embryos ought to be physiologically more adapted for standing cooling and freezing than shoot-tips.

Material of 4 varieties retrieved from LN storage has been multiplied at CIAT and planted in the field for evaluation of phenotype stability. Results of this trial will be available next year.

Evaluation of Clones Retrieved From Minimum Growth Storage

Of the evaluations made last year of first cycle plants (C_1 plants) 5 varieties showed no changes in morphology and biochemistry that could be attributed to *in vitro* storage. Increase in yield and changes in morphology of two varieties was attributed to the elimination of frog skin disease through *in vitro* culture (Tissue Culture, CIAT Cassava Program Annual Report, 1984).

Stakes, obtained from plants of C_1 generation, and from their non-stored meristem culture-propagated and traditionally-propagated counterparts, were planted in the field (C_2 plants) for a second cycle evaluation. Table 8 shows the results of this evaluation.

Except for total plant height, which does not significantly change with the propagation type, in all other variables, meristem culture micropropagation resulted in increments; plants derived from *in vitro*

Table 8. Evaluation of cassava plants grown from cultures stores *in vitro* in comparison to meristem-micropropagated and stake-propagated plants[a].

Variables	Treatments	M Mex 20	M Col 650	M Col 2197	CM 305-38	CM 323-375
Plant height (m)	Stakes	1.4 ± 0.3	2.1 ± 0.2	1.4 ± 0.3	1.7 ± 0.2	1.7 ± 0.1
	Meristem	2.1 ± 0.2	1.9 ± 0.2	1.3 ± 0.2	1.6 ± 0.2	1.8 ± 0.1
	Storage	2.1 ± 0.4	2.0 ± 0.2	1.3 ± 0.2	1.7 ± 0.2	1.8 ± 0.1
Height, 1st. branch (m)	Stakes	0.7 ± 0.4	1.4 ± 0.5	0.5 ± 0.1	0.6 ± 0.5	0.3 ± 0.2
	Meristem	1.3 ± 0.5	1.5 ± 0.2	0.5 ± 0.1	1.2 ± 0.4	0.7 ± 0.6
	Storage	1.3 ± 0.5	1.7 ± 0.1	0.8 ± 0.4	1.0 ± 0.5	0.7 ± 0.6
Root F.W./plant (kg)	Stakes	0.3 ± 0.4	8.0 ± 1.4	3.1 ± 1.0	15.0 ± 4.9	12.5 ± 2.1
	Meristem	15.0 ± 3.0	8.6 ± 2.3	3.2 ± 1.5	12.5 ± 4.5	14.7 ± 2.3
	Storage	13.1 ± 5.0	10.0 ± 1.8	2.0 ± 0.7	11.1 ± 0.7	15.5 ± 1.9
No. stakes/plant	Stakes	5.1 ± 3.3	6.7 ± 1.8	5.3 ± 2.1	6.0 ± 1.8	5.4 ± 1.5
	Meristem	7.3 ± 2.6	8.1 ± 3.1	5.7 ± 2.2	5.5 ± 1.4	7.6 ± 2.0
	Storage	8.6 ± 4.2	9.0 ± 2.4	5.1 ± 2.1	5.8 ± 1.4	7.7 ± 2.3

[a] Second year propagation (C_2 plants)

Data represents average and standard deviation of 20 plants in 4 replications.

stored cultures tend to be equal or slightly higher than meristem propagation. This is especially striking for the variety M Mex 20, which showed symptoms of frog skin disease in the stake-propagated plants. Thus, the height of first branching, yield of roots and commercial stakes increase as a consequence of meristem micropropagation.

Thus, it can be concluded that the phenotypic changes observed in the plants derived from in vitro storage are mainly due to the elimination of diseases which occur in the process, and that in vitro storage per se does not change the phenotype of the five varieties studied.

Cassava Genotype Identification by Electrophoresis

As the world collection increases, it is becoming expensive and time-consuming to identify and catalog varieties on the basis of classical vegetative criteria since morphological characters usually vary with variable agroclimatic conditions. Assuming that each cultivar is genetically distinct, it should be possible to use electrophoretic patterns of cassava proteins for identifying crop cultivars. On a short term basis, these methods could be applied to sort out duplicates in the collection, cluster germplasm accessions and to help to identify particular genotypes from clonal mixtures.

With the support of IDRC, a research project was established between the University of Manitoba, Winnipeg, and CIAT. This project has been underway for one year and the progress achieved at the University of Manitoba now follows.

Out of 16 enzymes extracted from each of 5 different tissues and studied under 5 different huffer systems, four enzymes, EST (, esterase), GOT (glutamate oxaloacetate transaminase), PGI (phosphoglucoisomerase) and ACP (acid phosphatase), were selected on the basis of band quality, relative mobility and number of bands. Out of these EST resulted the best isozyme system. Root tissue grown from stakes produced the most intense and clear band patterns, both on starch and polyacrylamide gels, but 12% polyacrylamide gels gave better band resolution (Fig. 2). Basic extraction and trisborate electrode buffer were found to be the best. It was found that genotypes showing very similar root enzyme patterns could be discriminated or confirmed by extraction from a mixture of young shoot parts (apical bud, leaves with petioles, and stem), (Figs. 2B and C). This technique should be further tested with more cassava varieties. Computerization of the analog data, after conversion into a digital system, should speed up analysis and data storage.

Computarization of Cassava in vitro

As described above, the number of cassava clones being processed in vitro is steadily increasing. Over 1300 varieties have been cleaned up from various diseases; more than 2,700 clones are currently included in the in vitro gene bank and hundreds of clones are exchanged every year with various institutions around the world. A systematic treatment of these operations should greatly speed up the entering and retrieval of data, link one in vitro operation with another or with the main files

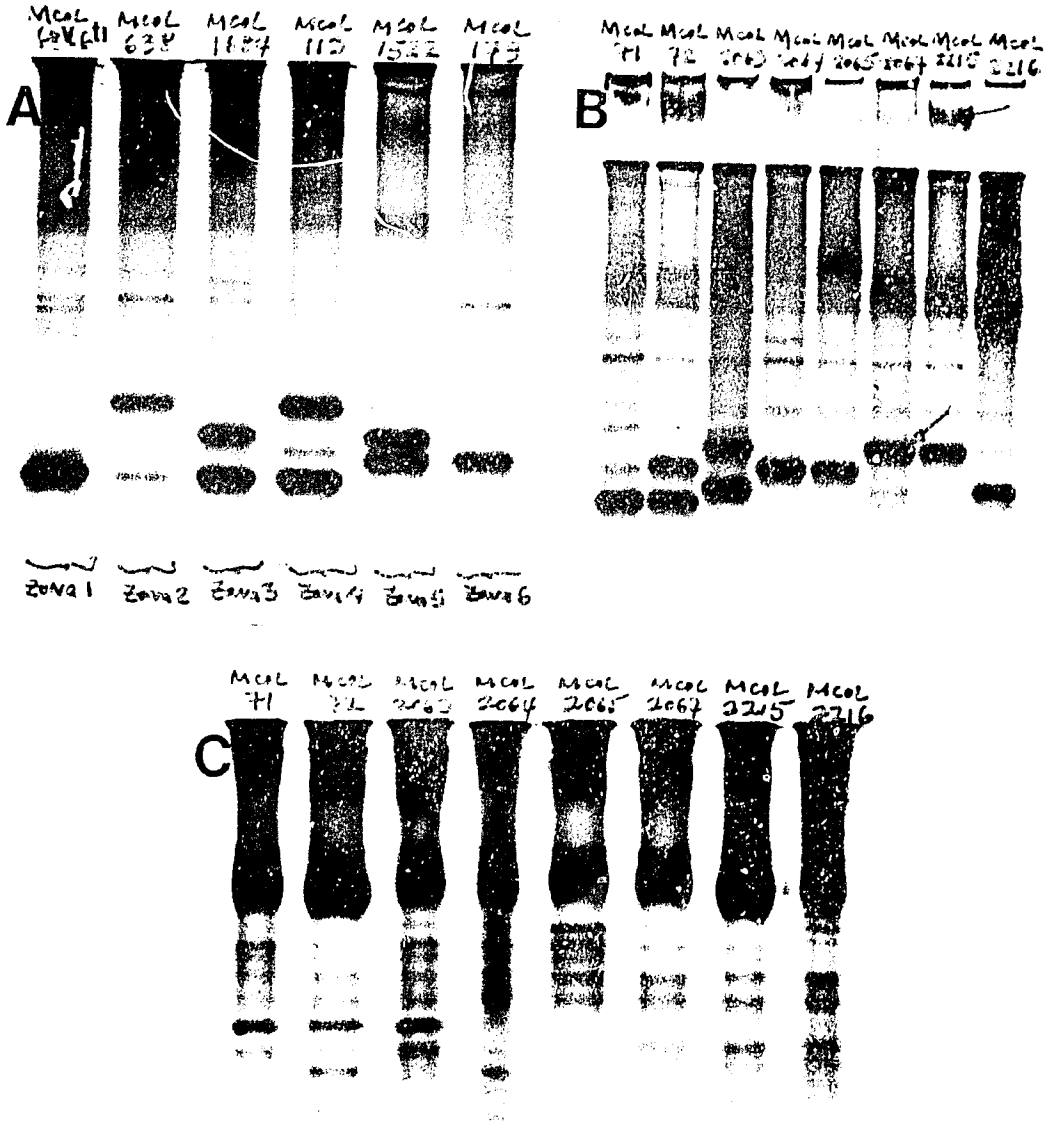


Figure 2.

α β - esterase (extracted from root tissues) electrophoretic patterns of six cassava cultivars in polyacrylamide gels.

A. From left to right, each cultivar represents the Agroclimatic zones 1 to 6, according to the cassava Program's classification. Note the very thick and thin bands characteristic for each genotype.

B. Root tissue banding patterns of 8 cassava cultivars that grow in agroclimatic zone No. 1. Note the stricking similarity of M Col 2067 and 2215.

C. Shoot tissues (apical bud, leaf with petiole and stem) banding patterns of the same 8 cassava cultivars from zone 1, as in B. Note similarities between M Col 2067 and 2215 still exist but a very small difference in migration of the thickest band can be seen. (Photographs provided by W. Bushuk, A. Hussain and H. Ramirez, Univ. of Manitoba, Winnipeg, Canada).

in the Cassava Program, and reduce risks of human errors in the number of steps that comprise the in vitro operations.

With the collaboration of the Data Services Unit, the preparation of a database package for cassava in vitro was initiated this year. This package can be linked to the cassava germplasm collection files, passport and evaluation packages (Fig. 3), and comprises a disease/pest cleaning up operation, in vitro gene bank operations and evaluation of stored material. The germplasm in vitro exchange data is already included in the Cassava Program's data base along with germplasm exchange in the form of seed and stakes.

The in vitro gene bank package will include entry number, CIAT code, species, origin and procedence of material, virus testing results, date of introduction to CIAT, culture medium, number of tubes in storage, number of tubes retrieved from storage, date of retrieval, reason for retrieval, number of tubes subcultured and observations. This data can provide various types of information for users, e.g. permanent current inventary, comparisons of storage time for varieties, movement of entries and retrievals, etc. In addition, the system should allow a constant checking for accuracy.

Tissue Culture Regeneration of Cassava

Tissue culture is the route through which the various forms of in vitro genetic manipulation should pass in transition from the laboratory to the field. Therefore, the ability to regenerate cassava plants from non-meristem tissue cultures (e.g. callus, cells and protoplasts) is a necessary first step for the utilization of these techniques.

Regeneration of cassava plants by means of two methodologies is being studied at CIAT: somatic cell embryogenesis and protoplast culture.

Somatic Embryogenesis of Cassava

As shown previously, somatic embryogenesis was induced when immmature leaf segments were cultured on a medium containing high concentration of 2,4-D. The induced somatic embryos "germinated" into plantlets when transferred to a regeneration medium containing a cytokinin and very low levels of 2,4-D. The induction of secondary embryogenesis, when the somatic embryos were sub-cultured in the induction medium, was also reported (Tissue Culture, CIAT Cassava Program Annual Report, 1984).

This year, research in this area aimed at establishing conditions for sustained proliferation of somatic embryos, germination of embryos into plantlets, transfer of plantlets to pots, field evaluation of plants, and response of embryogenic cultures to stress applied in vitro.

Following induction on a solid medium, continuous proliferation of secondary embryos occurred when the embryogenic cultures were maintained in the induction medium in darkness (Fig. 4A and B). Upon transfer of these cultures to light, and regeneration medium, the embryos stoped proliferation and developed structures (e.g. cotyledons) characteristic of incipient germination (Fig. 4C). With the addition of cytokinin

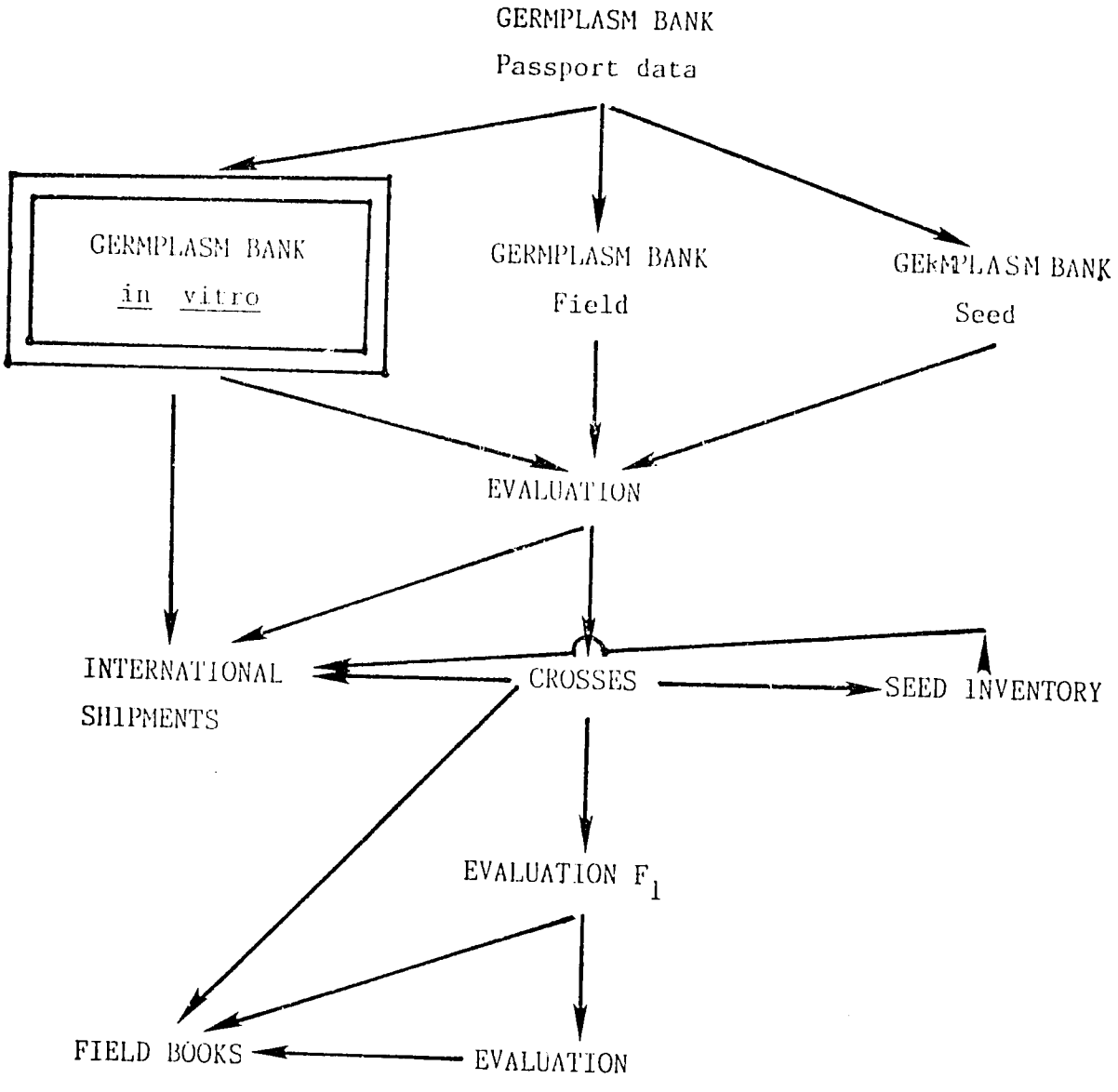


Figure 3. Inter-relations of Cassava *in vitro* database with the germplasm bank and breeding data of the Cassava Program.

complete individual plantlets formed (Fig. 4D). These plantlets were potted in the greenhouse and were transplanted to the field after 1-1.5 moths (fig 4E).

It was also found that the number of leaf explants forming embryogenic structures increases with very high 2,4-D concentrations (Table 9). Agitation of liquid medium in a shaker helped proliferation by separating small embryogenic structures being formed on the initial explant.

Long-term embryogenic cultures have been established and maintained for over 12 months without loss of the plant regeneration potential. This is significant with somatic cells require protracted regenerative capacity during treatment application and selection.

The question of whether induction of somatic embryogenesis, on the one hand and embryo proliferation on the other, can occur under specific selective conditions such as high salt concentration, was also investigated. Although embryogenic calius could be formed on leaf explants of MCol 1505 cultured in the induction medium with up to 1.0% NaCl, embryos differentiated only up to 1.5% NaCl (Table 10). On the other hand, when embryogenic structures of MCol 22 and MCol 1505, induced on standard medium, were transferred to the same liquid medium but stressed for 2 months with NaCl, proliferation of embryos (as measured by fresh weight) occurred up to 1.0% NaCl in MCol 1505, but proliferation continued even at the highest concentration, (2.0% NaCl) in MCol 22.

Thus, M Col 22 cultures seem to tolerate higher salt concentration than MCol 1505. More work is needed to establish the threshold concentrations above which salt stress can induce only tolerant cells to grow to form somatic embryos and plant.

At this stage it is important to know if cassava plants regenerated through somatic embryogenesis are true to type. If not, the extent to which useful variability (intra-clonal) can be recovered would be worth investigation. Regenerated plants have been moved to the field after 1, 2, 3, 6 and 12 months subculture periods. Since these experiments have been initiated this year, only partial data is available from plants regenerated inmediately, i.e. without sub-culturing. The performance of the somatic embryo plants is being compared with micropropagation (using meristem tips), stored cultures in vitro, rapid propagation (two node cuttings) and stakes. Table 11 shows preliminary results obtained after 6 months field evaluation of M Col 1505.

Out of nine morphological descriptors studied, no differences were found in the color of petioles nor in the form of the central lobe. The largest differences in the remaining 7 descriptors were for the color and pubescence of unopened apical leaves, petiole length, and the length of the central lobe (Table 11). From Table 11, a hierarchy of variability (C.V.) among the various methods of plant reproduction can be established: somatic embryogenesis (highest variability among plants), in vitro conservation, rapid propagation, stake propagation and

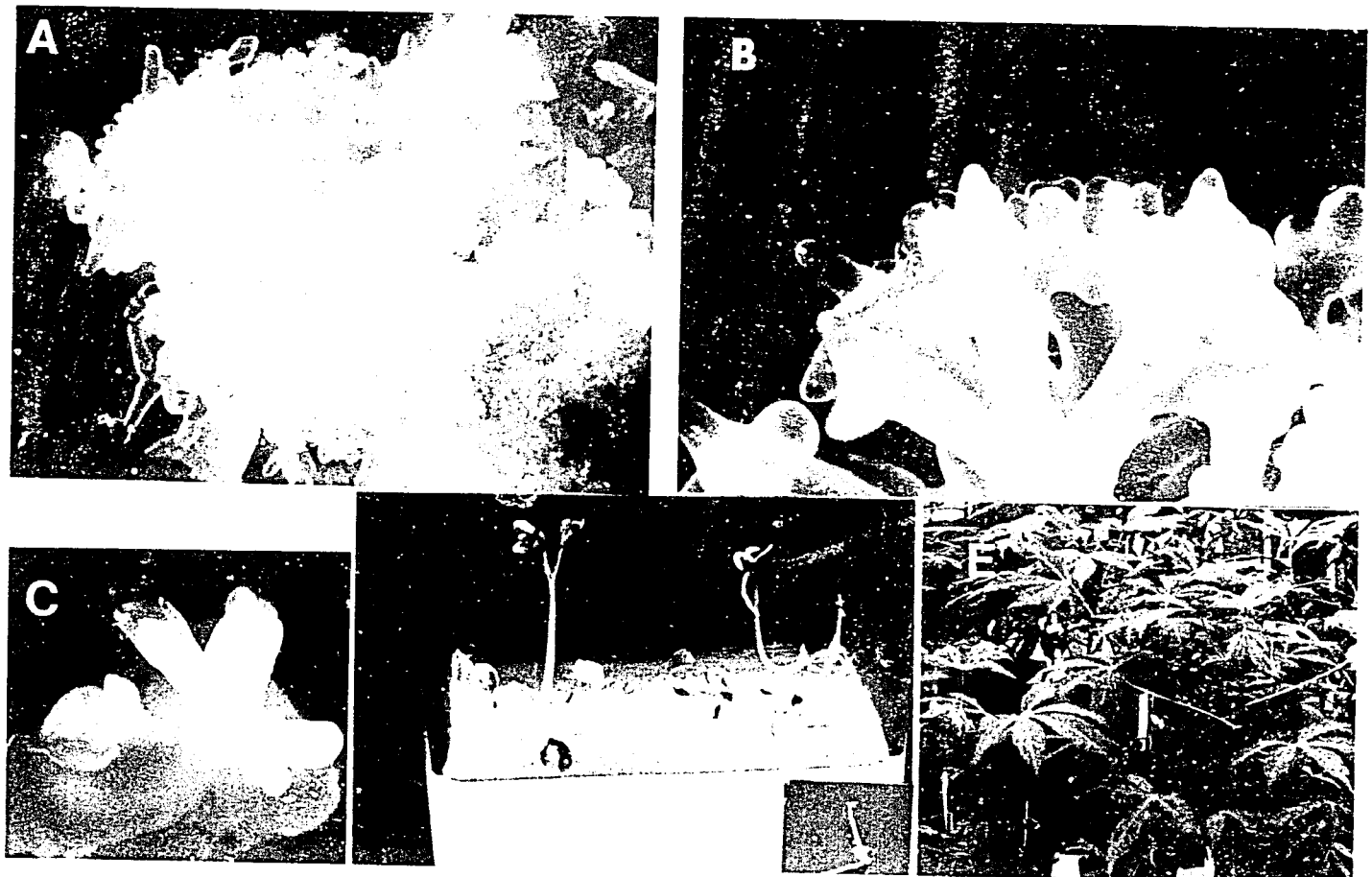


Fig. 4. Regeneration of cassava plants by somatic cell embryogenesis.

A. Continuous proliferation of secondary embryos in induction medium in darkness.
B. Finger-like secondary embryo initials at tip of primary embryos.
C. Development of cotyledonary embryos upon transfer of cultures, as in A, to light.
D. Germination of somatic embryos on solid, regeneration, medium. Inset: individual plantlets, each grown from a single somatic embryo.
E. Potted, somatic embryo-derived cassava plants ready for field transplanting.

Table 9. Effect of auxin concentration on the induction of somatic embryogenesis in three cassava varieties (percentage of explants forming embryogenic structures).

Cassava Varieties	2, 4-D concentrations mg/l				
	1	2	4	8	16
M Col 1505	19	31	46	64	86
M Ven 25	15	17	40	70	50
CMC-40	14	38	38	38	50

Table 10. Induction of somatic embryogenic structures on leaf explants of M Col 1505 maintained in NaCl - supplemented induction medium during one month.

Structures induced	Concentration of NaCl (%)						
	0.0	0.05	0.1	0.2	0.5	1.0	2.0
Amount embryogenic callus/explant	++++	++++	++++	++++	+++	++	-
% explants with embryos	30	20	50	15	20	0	0

++++ Callus formed on whole explant

+++ Callus formed on 3/4 explant

++ Callus formed on 1/2 explant

— Without callus formation

Table 11. Phenotypic stability of cassava plants regenerated by somatic embryogenesis, *in vitro* stored, stake, and rapidly propagated plants (M Col 1505)[a]

Morphological descriptors[b]	Somatic embryogenesis		In vitro conservation		Micro-propagation		Rapid propagation		Stakes	
	X	CV%	X	CV%	X	CV%	X	CV%	X	CV%
A. Color stem	1.2	24	1.0	0	1.0	0	1.0	0	1.0	0
B. Color mature leaves	4.6	15	4.7	12	5.0	0	5.0	0	5.0	0
C. Color unopen apical leaves	4.8	42	3.6	31	3.0	0	3.0	0	3.3	17
D. Pubescence young leaves	3.3	29	5.0	5	5.0	0	4.9	5	5.0	0
E. Length petiole	4.7	22	5.5	12	6.9	7.0	6.7	10	7.0	5
F. No. lobes mature leaves	6.6	8	7.2	4	7.0	0	6.9	4	7.0	0
G. Length central lobe (cm)	13.9	7	16.1	8	16.7	8	15.6	12	17.9	7

[a] Average obtained of 27 plants in 3 replications.

[b] A: Silver green, 2. light grey, 3. dark grey. B and C: 3. light green, 5. dark green, 7. purple green, 9. purple; D: 0. abscent, 3. little, 5. moderate, 7. hight, E: 3. short, 5. med., 7. long.

micro-propagation (lowest variability). These results should be taken with caution at this stage until a final evaluation at harvest is carried out as well as a second propagation cycle. Agronomic analysis, (e.g. harvest index, fresh and dry weights), and biochemical analysis, (e.g. isozyme electrophoretic patterns), will complement these data. What occurs with protracted sub-culturing of embryogenic structures in terms of stability is still to be determined. A highly stable system would be useful as a means for mass vegetative propagation; perhaps the possibility of embryo encapsulation procedures can be studied later.

Cassava protoplast culture

Protoplasts have been isolated from leaf mesophyll cells and shoot-tips of test tube plantlets and from somatic embryos. Isolated protoplasts could resynthetize cell walls and divide with frequencies up to 35% (Tissue Culture, CIAT Cassava Program Annual Report, 1984). Rates of protoplast division frequency were variable for the various types of explants and genotypes used; these results and the formation of cell colonies which ensured following protoplast division are shown in Table 12. Highest divisions and callus/colony formation ocurred with leaf explants followed by shoot-tips. Somatic embryos and induced leaf lobes yielded small, highly dense protoplasts which divided with great difficulty.

A series of experiments were carried out attempting to induce morphogenesis in the protoplast-derived cell colonies of 12 cassava genotypes. Two media of different mineral salt composition (MS and B5) were supplemented with a range of combinations of the following additives: casein hydrolyzate (100 and 200 mg/l), glutamine (30 m M and 600 mg/l), proline (50 mM), coconut milk (4 and 5%), sucrose (0, 1, 0.3, 1, 2, 3, and 5%), charcoal (0.5%), indol acetic acid (0.1 and 1 mg/l), naphthaleneacetic acid (0.02, 0.1, 0.3, 1 and 2 mg/l), 2,4-dichlorophenoxyacetic acid (0.01, 0.1, 1, 4, 8 and 12 mg/l), kinetin (0.5, 3 and 5 mg/l), zeatin (0.5, 1 and 2 mg/l), benzylaminopurine (0.04, 0.1, 0.5, 1, 2, 5 and 20 mg/l), gibberellic acid (0.05, 0.1, 0.2, 2,4 and 10 mg/l), and abscisic acid (0.1 and 0.3 mg/l). No morphogenesis has been observed with these treatments to date.

Protoplasts have been isolated from shoot tips and immature leaf lobes. As shown above, tissues of these organs have the capacity to form somatic embryos. It is reasonable to expect the expression of the embryogenic capacity of protoplast-derived colonies originated from these tissues.

Isolated protoplasts from these organs were usually smaller and more compact when compared to leaf mesophyll protoplasts; sometimes they contained a few chloroplasts, more frequently they were colorless. When fractionated in Ficoll step gradients (0-20% Ficoll), 1000 rpm for 10 min. centrifugation, the majority of the shoot-tip protoplasts were collected at 10-15% Ficoll concentrations (Figs. 5 B, C and 6 B, C). Leaf mesophyll protoplasts formed sharp bands at 2.5-7.5% Ficoll. This difference is due to the higher density and smaller diameter of the shoottip protoplasts (Fig. 5A). There was a compact, cytoplasm rich type of protoplasts in the more dense fractions (C-protoplasts). The C-protoplasts had no chloroplasts, they were most probably released from

Table 12. Protoplast division frequency and callus/colony formation from various explant types in ten cassava genotypes.

Genotype	Explant type	Division frequency	Callus/ colonies
MCol 22	- leaf	up to 38%	callus
	- shoot-tip	2-4%	callus
	- induced leaf lobes[a]	-	
MCol 1505	- leaf	3-6%	callus
	- shoot-tip, leaf lobes	1-3%	colonies
	- induced leaf lobes	few	few colonies
	- somatic embryos	-	
	- cotyledon	1-2%	few colonies
MCol 1940	- leaf		callus
	- leaf lobes	several	colonies
	- somatic embryos	-	
MMal 1	- lef	3-5%	callus
	- induced leaf lobes	several	colonies
MCol 1438	- leaf	5-12%	callus
	- shoot-tips	1-2%	callus
MPer 302	- leaf	10-18%	callus
	- induced leaf lobes	5-7%	callus
MCol 2017	- leaf	up to 30%	callus
CMC 40	- leaf	3-8%	callus
	- leaf lobes	-	
	- induced leaf lobes	few	few colonies
MBra 739	- leaf	5-9%	colonies
M. cecropaefolia	- leaf	3-5%	colonies

[a] induction of embryogenic structures with 2, 4-D

meristem cells and comprised 50-60% of the protoplast population (Fig. 5A) in the dense fractions. Isolated shoottip protoplasts resynthetized cell walls and divided when cultured. There were marked differences in the division capacity of each protoplast fraction; leaf protoplasts divided at higher frequencies than shoot-tip protoplasts (Fig. 6A). Dividing protoplasts formed colonies and callus.

Experiments are in progress to attempt induction of morphogenesis in shoot-tip derived protoplasts and to screen a wide range of cassava genotypes for their morphogenetic capacities.

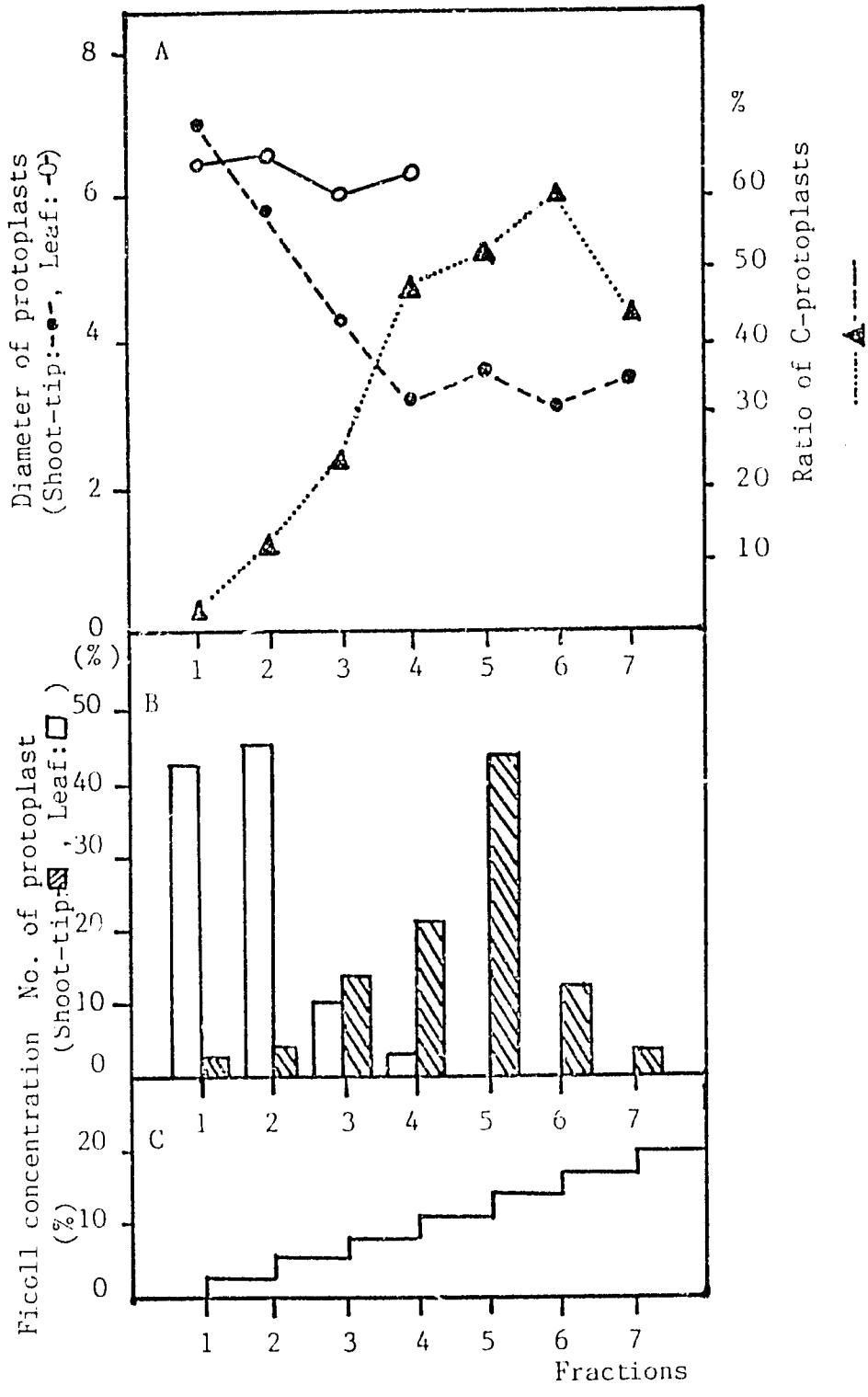


Figure 5. Fractionation of shoot-tip and leaf-derived protoplasts of M. Col 1940 in Ficoll gradients.

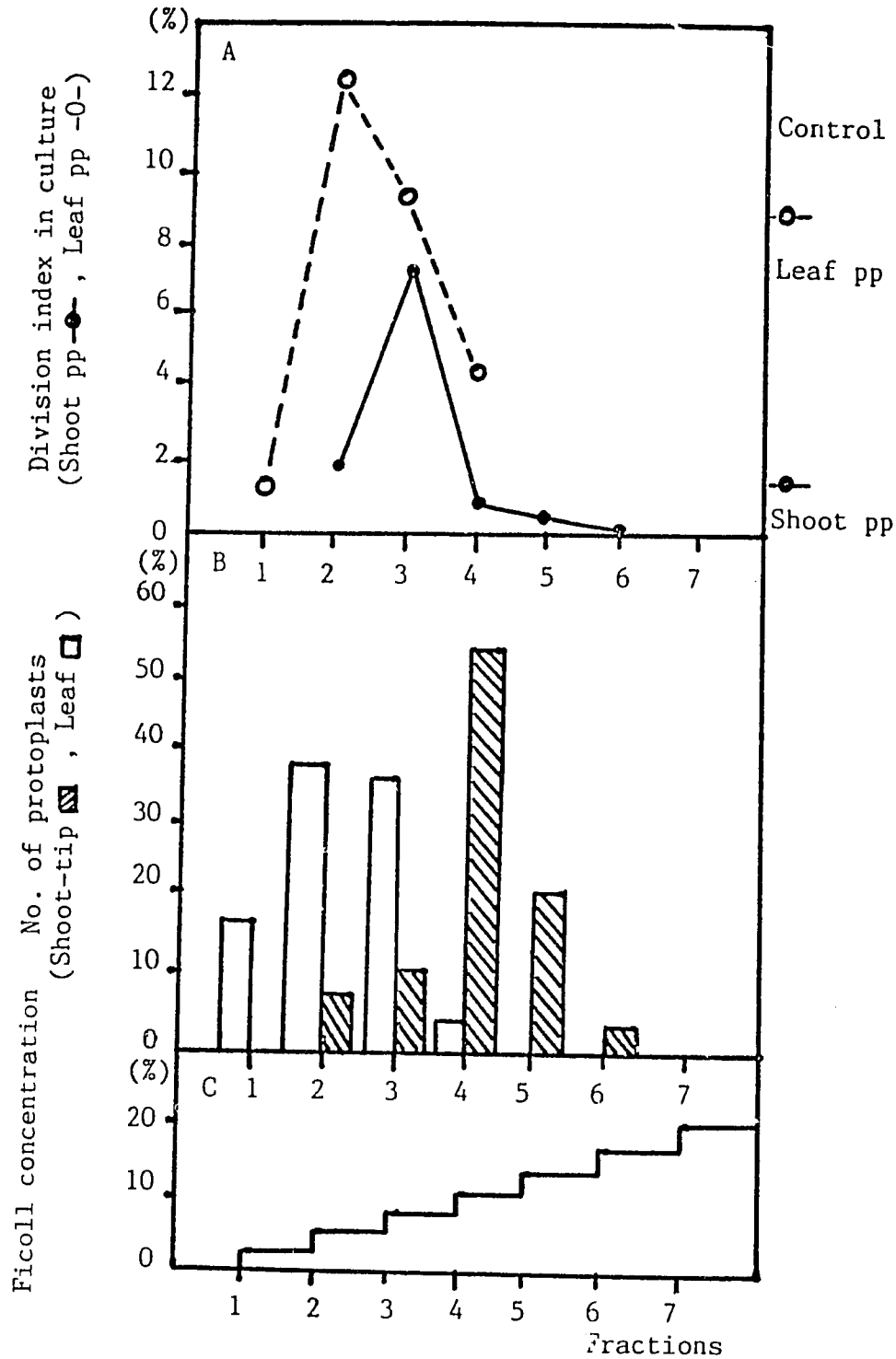


Figure 6. Fractionation and culture of shoot-tip and leaf-derived protoplasts of M. Col 22.

DEFINITION OF MICRO-REGIONS FOR CASSAVA ON COLOMBIA'S NORTH COAST

1. Introduction.

The increasing orientation of the Cassava Program towards integrated projects is creating a demand for detailed data relating to environmental and socio-economic conditions and production constraints within certain regions of special interest.

The Agroecological Studies Unit has been designing a methodology for cataloging and classifying information about cassava producing areas. It has identified the concept of a homogeneous "Micro-Region" within which certain basic conditions which influence the production of cassava are relatively uniform. Because of their uniformity, these serve as an organisational framework for other data describing production of the crop.

2. Micro-region definition

Objectives.

Work was undertaken both in CIAT and in the field to test the methodology for defining micro-regions. This was based on gaining a fuller understanding of those aspects of the physical environment of the Colombian North Coast which affect the cassava plant, and on identifying the most important environmental and socio-economic factors which control or constrain cassava production there.

Analysis of Secondary Data.

Available climate and soils data were studied to describe the general characteristics of the area. The climate can be classified as Marine Savanna Tropical (Papadakis) with a dry season of from three to six months, a mean annual temperature of 27 degrees centigrade, and a mean annual rainfall of from 1000 to 1500 millimetres. Soils can be broadly divided into "Savanna" and "Alluvial" types. The former are composed of moderately evolved neutral clays and sands, the latter of neutral and acidic alluvial deposits, both sands and clays. Socio-economic data from local sources, CIAT data, and agricultural census data provided some idea of the types of agricultural activity, land holding size and cropping systems of the area. No causal relationships could be discerned between agricultural activities, particularly cassava production, and the physical and socio-economic environments, such as might allow us to choose certain factors to delimit micro-regions.

The onus of the study therefore moved to field study to identify these relationships at first hand.

Variables used for micro-region definition.

Environmental Considerations.

Alternate wet and dry seasons on Colombia's North coast bring seasonal

shortages and excesses of moisture. While cassava has a remarkable tolerance to drought stress, its lack of tolerance to flooding or waterlogging is equally notable. One of the most surprising findings of the field period of this study was that cassava production in the region is not restricted to the areas where soil drainage is favourable to the crop. In areas of low, flat relief, or where the water table is locally high, conditions for cassava production are marginal for much of the year. In the wet season losses due to root rots can be considerable in these areas. Nevertheless, many farmers cultivate cassava in such conditions, either through choice or through necessity.

One of the advantages of these areas is that they have available moisture reserves in the dry season which prolong the effective growing season. Where mechanised land preparation is practised, farmers attempt to take advantage of the favourable characteristics of these soils and reduce potential losses by ridging. This option is not universally available; use of tractors on cassava producing farms was found to be restricted to certain parts of the coast, as will be described below. Elsewhere, if they have no alternative place to grow cassava, farmers have to risk the loss of their crop or plant at the end of the wet season. The latter practice is common along the banks of the Magdalena and other large rivers, flood recession agriculture.

In areas of higher relief the rotting problem is less common, although not absent. In soils with a high clay content, periods of very prolonged rains in the wet season can cause similar losses. However, lack of soil moisture during the dry season is the real disadvantage of these areas, halting even the growth of cassava.

Two important a[illegible] can therefore be distinguished on the basis of seasonal fluctuations in available soil moisture: Those where dry season reserves are limiting to cassava growth, but where wet season conditions are not; and those where dry season moisture availability is favourable to cassava growth but where wet season conditions are limiting. Table 1 describes these characteristics for the micro-regions defined in Figure 1.

Farm size and Land Tenure.

Available data show that the farms of the north coast are predominantly small. Data from the 1970/71 agricultural census are presented in Table 2. More than fifty per cent of all farms have less than 5 hectares of land. One quarter of all farms have less than one hectare according to this data. Almost three-quarters of all farms in the region can be considered "Small farms", with less than twenty hectares of land.

The role of cassava on the farm changes as farm size increases. The crop's importance for subsistence declines and its importance as a cash crop increases. Farm size is the first limit on the quantity of cassava produced. Ideally, therefore, we might wish to define micro-regions according to spatial differences in the farm-size distribution. Unfortunately, data at a level of disaggregation sufficiently small to allow this are not available for this region. Nevertheless, sufficient data exists to note that in Cordoba, for example, there is a much

greater concentration of the very smallest farms than in the other departments. In Atlantico these farms are far less important on a percentage basis than in the other departments. On Colombia's North coast a number of different tenure types were identified in the survey. The importance of recognising them in the micro-region definitions stems from their spatial distributions. These are not random but insted have strong regional concentrations.

Two tenure types with insecure access to land were recognised to have strong geographical concentrations, one associated with a form of share-cropping on old pasture land in the north of the region, and the other being cash-renting of land in Cordoba. Conversely, in Sucre and parts of Bolivar land tenure is more variable; more secure tenure types, such as land ownership and provisional tenure of agrarian reform land, were found to be concentrated in these areas. Table 3 shows the types of land tenure identified in the field study for each micro-region.

Land Preparation and Fertility Management.

Land preparation techniques on Colombia's North Coast can be divided into two types. In many areas farmers still practise slash and burn agriculture and prepare the soil manually. In other parts mechanised preparation has replaced the traditional system. A strong concentration of this type of land preparation was identified during the survey in Cordoba and Sucre departments.

The spatial distribution of the two different methods is governed by a number of factors. Topography is the primary control on mechanisation. The areas of steepest slopes were delimited as seperate micro-regions, in accordance with survey data indicating the distribution of the two types. Figure 2 gives an indication of the distribution of non-mechanisable land which was used as an aid to map these. Taking this restriction into account does not fully explain the concentration of mechanised land preparation described. It is probable that tractors are more common in the southern departments, Sucre and Cordoba, than in the north because of the importance in the former of large cotton, sorghum and rice farms. In addition, farm income is probably higher for farms with more secure forms of tenure particularly in Sucre. Table 4 indicates the dominant form of land preparation in each micro-region.

Soil fertility maintenance, as in all areas of slash and burn cultivation, depends on fallowing of the land to permit recuperation of fertility. To some extent this system still prevails in some parts of the region. In others pressure on the land is reducing the length of fallow period to one or two years, and at half the places surveyed land is no longer fallowed.

Table 5 summarises survey data relating to fallowing practices and soil fertility problems noted at 43 places visited. Incidence of soil fertility problems, manifest in declining yields, is inversely related to the length of fallow period practised.

The decline of fallowing can be related partly to insecurity of tenure, its absence being more notable in those areas where land is

rented or sharecropped to clear pastures (Table 6). The length of time land is left in fallow is very variable, but a pattern is evident. Farmers in the more isolated and mountainous regions of the coast still maintain long fallow cycles (micro-regions 6, 11 and 12). In Sucre fallowing is also common on farms on the "Sabana", (micro-region 14). In contrast, in micro-regions 1, 2, and 4 in Atlantico and Bolivar, 13 in Sucre, and 16 and 17 in Cordoba, fallowing is not practised. Fallow periods are given for the micro-regions in Table 7.

Comparing Table 7 with Table 3 confirms that those micro-regions with long fallow periods are associated with more secure forms of land tenure (micro-regions 6, 10, 11, 12, and 14). Those where fallowing is not practised (1, 2, 3, 4, 5, 16, 17, 18 and 19) have less secure tenure. There are exceptions which do not fit this pattern however (micro-regions 7, 8, 9, 13 15 and 20).

These conclusions about soil fertility problems and maintenance were based on farmers opinions, from the survey.

Micro-region Definition

The micro-regions are primarily defined by the physical environmental factors identified during the study. However, it must be appreciated that there are important socio-economic differences between the units identified, despite the fact that it is often more difficult to map these. Some, such as land preparation techniques and fallowing practices, can be related to the influence of the physical factors used to define micro-regions. In the non-mechanisable mountainous areas competition for land is relatively lower than elsewhere, and this is reflected in the maintenance of fallowing in these areas (micro-regions 6, 11, and 12). Elsewhere land tenure types were shown to be spatially concentrated in certain areas and this data has been used here to seperate some of them (micro-regions 14 and 16 for example). Other socio-economic data which does not show strong spatial distribution, such as farm size data, can be added as descriptive information as part of the data base described below.

Cassava micro-regions data-base for the north coast.

Data-base organisation.

The Agroecological Studies Unit is currently creating a computerised data-base using the defined micro-regions as an organisational framework. All the characteristics of interest associated with each micro-region will be stored in a file with the region's name. This will include information such as descriptions of climatic and edaphic conditions, socio-economic characteristics such as land tenure, and information related directly to cassava production. Cropping systems, varieties, planting dates, pest and disease problems of the area can all be stored within the system, according to the interests and needs of Cassava Program Scientists. It is hoped to extend the data base in the near future to include information on parts of Eastern Paraguay and Coastal Ecuador, where the Cassava Program has special interests.

TABLE 1. Subdivision of micro-regions according to environmental characteristics affecting available soil moisture.

Environmental characteristics	Micro-regions
1. Low-lying land with high water table. Excess moisture in wet season, dry season reserves.	1(a, b), 7, 10, 13, 15, 17, 20.
2. Raised/high land. Wet season moisture supplies adequate. Dry season moisture augmented by micro-climatic influence of the sea.	3, 6, 11, 18.
3. Raised/high land. Wet season moisture adequate; dry season moisture inadequate.	2(a, b) 4(a, b, c). 12, 14, 16(a, b), 19. A, B, C, D.
4. Low-lying land. Adequate to excess moisture in wet season; edaphically induced shortages in dry season.	5, 8, 9.

TABLE 2. Farm size distribution, by percentage, for five departments on Colombia's North Coast.

Department	Farm size				Total number of farms
	1ha	1- 5ha	5- 20ha	20ha	
Atlantico	6,0	44,4	28,6	20,9	10,622
Bolivar	13,2	34,1	21,7	31,0	34,097
Cordoba	39,6	21,7	16,0	22,7	50,611
Magdalena	13,8	31,0	18,2	37,0	23,266
Sucre	25,2	33,5	17,9	23,4	21,398
Total/Average	24,2	29,8	19,0	27,1	139,994

Source: Censo Agropecuario 1970/71. Departamento Administrativo Nacional de Estadisticas DANE, Bogota, 1974.

TABLE 3. Dominant form of land tenure in the micro-regions. (Note that where a micro-region is listed twice, both types of tenure are considered equally important).

Tenure form	Micro-regions
Pasture-clearance (Sharecropping) (insecure)	1-6, B, C, D.
Cash-renting (insecure)	9, 16-20.
Land reform occupancy, colonisation and land invasion (secure)	7, 8, 10, 12, 13, 15. A.
Land-ownership (secure)	2, 6, 11, 13, 14.

TABLE 4. Dominant form of land preparation for the micro-regions.

Land Preparation	Micro-regions
Manual; slash and burn.	1 - 12 18 - 20 A - D
Mechanised	13 - 17

TABLE 5. Survey data describing soil fertility decline and maintenance at 43 sites. Incidence of yield decline decreases inversely with length of fallow. (Chi Squared significant at 0.01 level).

Fertility conservation practices	Fertility declining	Crop yields not declining
No fallowing	4	14
1-2 years fallow	8	5
3 or more years fallow	9	3

TABLE 6. Fallowing practices compared with main form of tenure at 62 survey sites.

Dominant tenure type	No fallowing	Falloging
Land ownership	5	11
Land-Reform, Colonists and land invaders.	3	8
Cash renters	11	8
Pasture clearance	13	3

TABLE 7. Length of fallow for Micro-Regions.

Length of fallow Period (years)	Micro-regions
0	1-5, 7, 8, 13, 15-19, A-D
2 - 4	6, 9, 10, 11, 14, 20.
4	12

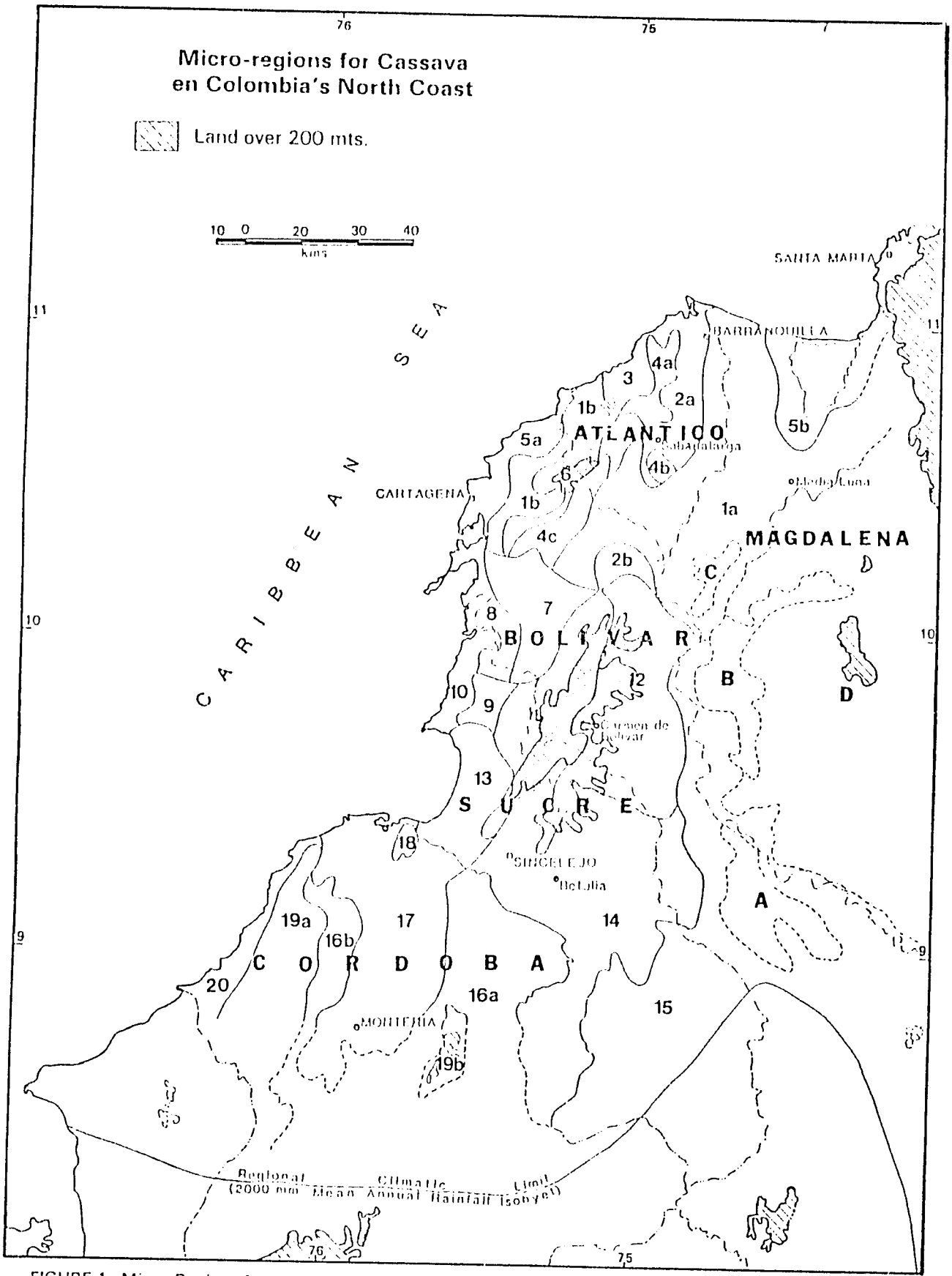


FIGURE 1. Micro-Regions for Cassava on Colombia's North Coast.

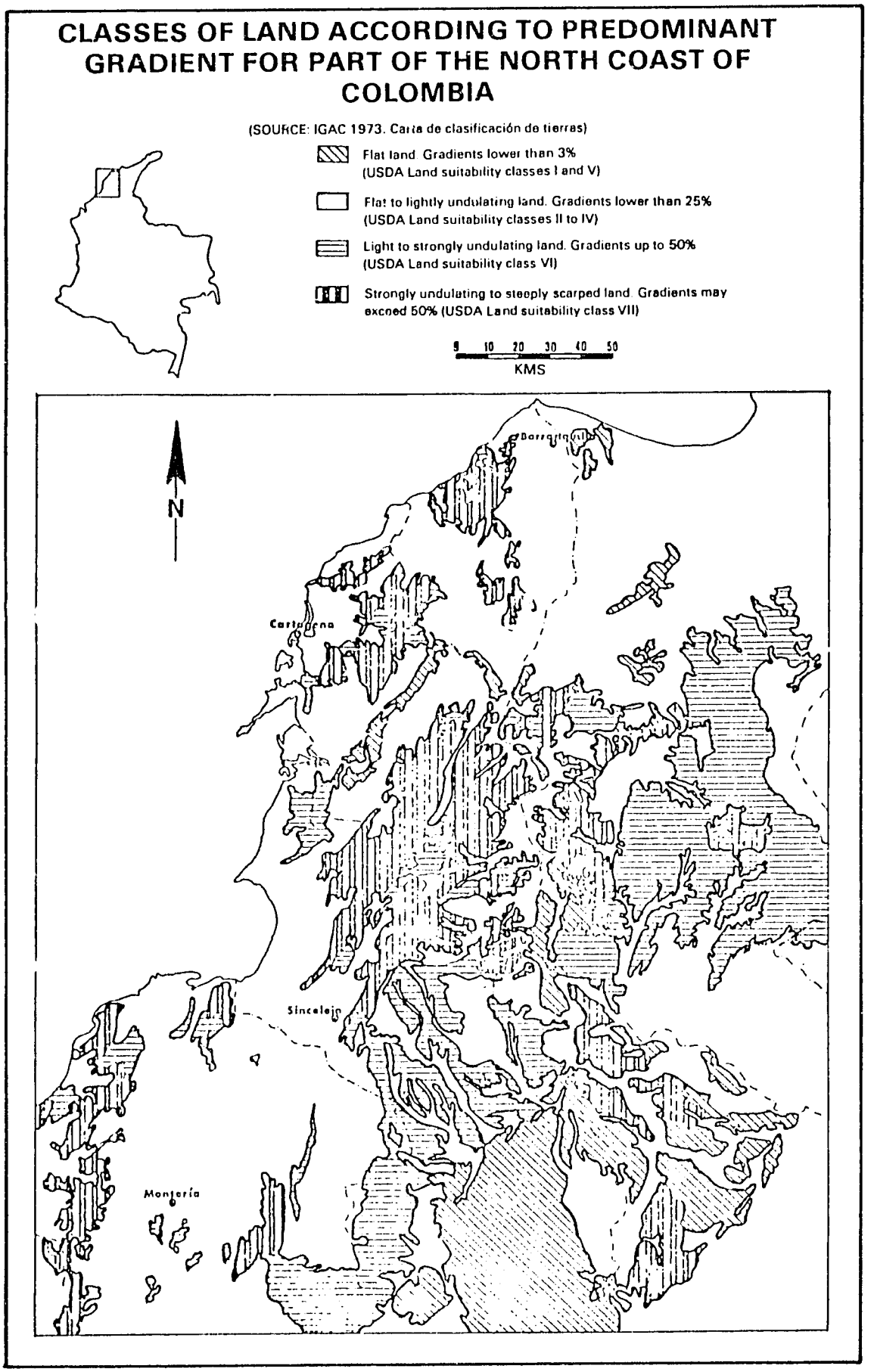


FIGURE 2. Gradient on Colombia's North Coast. (Class VII considered to steep for mechanized land preparation).