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CASSAVA PROGRAM

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CIAT

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CONTENTS

CASSAVA PROGRAM ANNUAL REPORT 1988

INTRODUCTION

The annual report of the cassava program is presented in a new form this year. Each section has made a brief report of progress highlighting some of the more important results obtained. In addition sections that have completed projects have presented these in a form ready for publishing either in journal, symposia proceedings or as CIAT publications. It is felt that this format will give the reader a better idea of the activities of the program and also will allow the reader to appreciate completed projects in a readable form rather than having to trace them back through a series of partial reports in the annual reports.

The year of 1988 has been one of consolidation and progress. Finally after several years with the sword of Damocles hanging over our heads, the TAC approved the interim plan which gives stability to the program and recognition of the importance of the crop.

Several years ago the program began to place greater emphasis on collaboration with Asian national programs. The results of these efforts are now beginning to be felt. In the area of plant improvement, national programs are beginning to release new well adapted genotypes and these are spreading rapidly. In Indonesia the local cross Adira IV was selected in a joint effort involving CIAT breeders. This variety has high starch content and good yield which have made it popular in the areas where starch is the main end use of cassava. In Thailand the cross between CIAT and local germplasm, Rayong 60, continues to spread. Demand for cuttings is large as farmers like the varieties high yield potential coupled with good vigor that allows it to grow well in poor conditions. In China the variety Nan-Shi 188 introduced from CIAT via tissue culture continues to be multiplied using simple in vitro techniques and is spreading rapidly. In Malaysia a new clone, selected from CIAT crosses, well adapted to the peat soils is about to be released. Malaysian officials believe that such materials can be used to open up these extensive acid peat areas. These new varieties are the tip of the iceberg with a large number of new well adapted materials now in the well established network which allows germplasm to flow smoothly through all the stages of selection.

Work on agronomy began somewhat later in the Asian area. A major effort has been made to compile the available information much of which is in obscure reports. A workshop held in late 1987 brought together much of this information and this has now been added to and published. This knowledge base has formed the basis for planning of research activities in the area directed towards production systems that maintain soil fertility and minimize losses due to erosion.

The CIAT team in Asia also assisted in the organization of the most recent symposium of the International Society for Tropical Root and Tubers Crops in Bangkok. This society provides an independent forum for the presentation of the ideas and results on the root crops and an opportunity for many developing country scientists to make contact with each other and broaden their outlook.

Activities in Latin America have continued to centre on the integrated production, processing and marketing projects. The basic hypothesis supporting these projects in Latin America is that small farmers who produce cassava can only increase their incomes if they have a readily saleable product, and the means to produce it. Past efforts that concentrated only on production technology led to little impact. Evidence is now coming in from Colombia and Ecuador of a strong response of farmers on the production side once the processing and marketing constraints are removed. This creates a demand for new technology: In Colombia the variety Manihoica P12 is spreading rapidly and new production technology packages are in the preproduction testing phase before recommendation. In Ecuador the farmers are adopting artesanal seed production systems so as to ensure the basis for their production efforts. In Mexico farmers have adopted a complete package developed by the national program: uptil the present they have depended on only one variety but the national program expects to be releasing one or two new clones in 1989. Cuba has over the last ten years quadrupled its total production: improved management practices coupled with a strategy of different clones for different times of the year has led to increased yield and year round availability of cassava. Further expansion is dependent on the success of the new drying plants and silage production schemes that are being set up.

In spite of delays in obtaining special project funding for the establishment of a cassava drying industry in the North East of Brazil, CIAT has been involved in training efforts in the region and small scale drying plants are being linked with the local flour factories (casas de farinha) so as to ensure a minimal effective floor price for cassava in the region and hence protect the farmer against low prices whilst stimulating production to the extent that shortages for the consumer will not occur.

In Ecuador the individual associations of cassava producers and processors have been formed into a union of associations (UAPPY). This UAPPY is playing an important role in marketing cassava products, training members of the associations, providing credit and ensuring the availability of inputs for the producers. This type of organization is a model for autonomous development in other areas of Latin America supporting many activities presently carried out by exclusively official international or national agencies. Hopefully these types of organization can link up in Latin America.

Efforts in this area were consolidated with the formal establishment of the Latin American Cassava Network at a meeting held early in 1988 in CIAT.

The collaborative study of cassava in Africa being executed by IITA with assistance from CIAT has now begun. In September of this year collaborators from the different African countries involved, met with invited experts and resource persons to begin the detailed planning of this major study. The methodologies to be used were defined in broad terms and a preliminary work plan has now been produced.

CIAT has also increased the exchange of germplasm with Africa, both receiving mosaic tolerant lines for incorporation in the breeding program as well as sending hybrids to African national programs via IITA for testing.

The regional efforts of the program depend on the constant provision of new genetic material, technologies and experience in development. New discoveries and initiatives often take many years before they have a positive impact on improving the livelihood of those who live in the tropics. Certain exciting discoveries have been made and new developments begun to take shape in 1988 that bode well for the future; a few examples suffice to show the type of advances made:

- Root yield was found to be closely correlated with field measurements of photosynthesis.

- Mealy bugs reduce calcium content of leaves and markedly reduce leaf phtosynthesis.

- Indications of flood tolerance were found.

- Germplasm from Latin America looked very promising in the African highlands.

- New methods of evaluating materials with farmer participation were tested successfully.

- High yield and good eating quality are now being combined.

- New methodologies for demand analysis for new products look at consumer needs rather than statistical data.

- A network for advanced research on cassava was established after a meeting of interested parties.

- In the area of cropping systems research effective working relations were established with several national programs. The successful combined efforts of ICA and CIAT in this area have formed the base model for this type of relationship.

These new developments in the cassava program are bringing us ever nearer to reaching our goal of improving the conditions of the rural poor in the marginal areas where cassava is produced whilst at the same time contributing to urban food supplies and general economic development.

Response of cassava to an early and prolonged water stress

Research at CIAT during the last 8 years (CIAT Annual Reports 1980-1987) have shown that cassava tolerates a relatively long period of drought once the crop was established. In these studies with limited number of clones, a stress period of 2 to 3 1/2 months was imposed at 3 to 4 months after planting and the crop was later allowed to recover from stress for the rest of the growing season with the aide of rainfall and supplementary irrigation. Compared with the control, the final root yield of the stressed crop was increased in the vegetatively vigorous clones (e.g. cv. Mex 59), was reduced in less vigorous types (e.g. cv. M Col 22), and slightly reduced or remained unchanged in intermediate clones (e.g. cv. M Col 1684 and CM 507-37). These responses were closely related to leaf area characteristics (i.e. peak leaf area index and leaf area duration over the growing cycle) as well as to patterns of photoassimilate partitioning between top growth (stems + leaves) and storage roots. The positive response to stress in the vigorous types was due mainly to reduction in top growth and the increase in the harvest index, whereas the negative response in the less vigorous types was attributed to the extreme reduction in leaf area to levels below the optimum leaf area index. On the other hand, the stability of root yield in the intermediate types under favorable and stressful environment was due mainly to their ability to maintain their leaf area near the optimum during a major portion of the growing cycle. These information are valuable in identifying different plant types for different environments.

Nevertheless, CIAT researchers were tempted to find out to what extent cassava crop can tolerate a more extended period of water stress imposed at an earlier stage of growth. Another objective in mind, was to simulate, as close as possible, growing cassava near the end of a rainy season, let it pass through a long period of no rain, and then allowing it to recover in a second wet cycle. Cassava farmers often practice this pattern of planting. In the 1987/1988 growing season, eight cassava clones (Table 1) were planted in the field drainage lysimeter (total area including borders is about 3000 m^2) at Santander de Quilichao on November 25, 1987. Due to the deficits in rainfall in December 1987 (94 mm) and January 1988 (81 mm), three irrigations were applied. Two months after planting, prior to imposing the stress, supplementary irrigation was applied to bring the soil water content to near field capacity within the 2.3 m soil profile. The available soil water within the 2.3 m profile of the experimental site is about 250 mm between -0.03 and -1.5 MPa. Half of the experimental area was covered with white plastic sheets to exclude rainfall from day 60 to day 180 after planting. At this stage of growth, cassava crop has less than 0.8 leaf area index and less than 2 t ha^{-1} total dry biomass (See CIAT Annual Report 1987). During the stress period of 4 months, the control plot received about 540 mm of rain plus three heavy irrigations within the first and second month to compensate for the deficit in rainfall in that period. The total amount of water received by the control plot in 4 months was greater than the potential evapotranspiration at the Quilichao Station ($\simeq$ 4 mm day^{-1}). The plastic cover was removed on the first week of June, 1988. From June to Oct. 20, the total rainfall was

656 mm. Supplementary irrigation to both the stressed and the control plots was applied twice in June, July and August to compensate for the low rainfall during that period. The total rainfall received from planting to harvest was 1406 mm in the control and 865 mm in the stressed plots.

During the stress period, field measurements of leaf gas exchange, both CO_2 uptake and H_2O loss, were made with a portable infrared CO_2 analyzer (LICOR 6000) on single attached upper canopy leaves at solar radiation greater than 1000 μmol m^{-2} s^{-1}. These measurements were normally made between 9 am to 1 pm each week within the first 2 months, and biweekly within the last 2 months of stress. Light interception, leaf water potential and soil water content were also monitored. Final harvest was made on October 20, 1988 (11 months after planting) and the total standing biomass, root yield and dry matter content of roots were determined.

Table 1 summarizes data of final standing total biomass, root yield, harvest index and dry matter content of storage roots. In the control plot, the total biomass ranged among cultivars from 23 to 38 t ha^{-1}, fresh root from 42 to 59 t ha^{-1}, dry root from 14 to 21 t ha^{-1}, dry matter content from 32 to 39% and the harvest index from 45 to 71%. In the stressed plot, the ranges were 18 to 28 t ha^{-1} for total biomass, 41 to 59 t ha^{-1} for fresh root, 14 to 19 t ha^{-1} for dry root, 30 to 38% for dry matter content and 62 to 76% for harvest index.

There were notable varietal differences in response to stress. Fresh and dry root yields were decreased by stress in M Col 1684, whereas they were increased in CM 507-37. Previous studies with these two genetically related clones (CM 507-37 is a hybrid between M Col 1684 and M Col 1438) have shown that CM 507-37 is more vegetatively vigorous and leafy type (CIAT, Annual Report 1985). In other cultivars, the yields were relatively unchanged with the exception of cv. CM 2136-2 where there was a notable decrease in dry root due, mainly, to reduction in dry matter content from 35.5% to 31.1%.

Across all cultivars, the water stress as compared with the control reduced total biomass by 12%, no change in fresh root, reduced dry root by 3.4%, reduced the dry matter content by 3.3% and increased the harvest index by 10%. These data clearly demonstrate the ability of the cassava crop to tolerate prolonged water stress that is gradually induced at an early stage of growth. Furthermore, the crop is able to recover and compensate, in terms of economic yield, for the adverse effect of stress. In areas with intermittent rainfall and with long period of drought, cassava should produce reasonably well providing good crop management (e.g. weed control and adequate fertilizer) are practiced and deep soils with good water holding capacity are available.

The physiological mechanisms that underly the tolerance of cassava to severe water stress are illustrated by the data of Tables 2 and 3 and Figures 1-3. The capacity of the cassava leaves to fix the atmospheric CO_2, a basic process for dry matter accumulation, during the stress period was 80% of the control. This indicate that the photosynthetic process in cassava was not greatly inhibited by stress. A second and important physiological mechanism of cassava leaves is the ability to partially close its stomata in response to water stress. There was 43% reduction in leaf conductance to water vapor in the stressed plot (Table 2). The partial closure of stomata enabled, partly, the cassava leaves to maintain the midday leaf water potential at levels comparable to the control leaves (leaf water potentials at 2 p.m. across all cultivars were -1.13 and -1.12 MPa for the control and stressed leaves, respectively, See Table 3). In addition to its beneficial effect by preventing severe leaf dehydration, and consequently preventing impairment of the photosynthetic capacity of the leaf, the partial closure of stomata in response to water stress reduces water loss through transpiration (See Fig. 3) and hence maximizes the water use efficiency (the amount of CO_2 fixed per the amount of water transpired). A third and equally important physiological mechanism that enables cassava to withstand severe water stress, is the ability of the cassava plant to maintain a predawn leaf water potential in the stressed plants comparable to the control (leaf water potential at 6 a.m. across all cultivars were -0.39 and -0.40 MPa for the control and stressed leaves, respectively). This is achieved, partly, by reducing total leaf area (as indicated by the 30% reduction in light interception in the stressed plot, Table 2), and hence reducing total canopy transpiration, and by withdrawing water from the deeper layer of the soil profile (See CIAT Annual Report, 1987). During water stress, cassava roots extend into the deeper wet soil (more than 2 meters) from which it can extract from 20 to 40% of its total water uptake (CIAT Annual Report, 1987).

Not only cassava can tolerate long periods of soil-water deficit, but also it reacts to changes in atmospheric humidity (CIAT Annual Reports 1982-1985). Stomata of cassava leaves are sensitive to air humidity irrespective of soil water content. It close rapidly in dry air when evaporative demands are high. This mechanism enables cassava to maximize its water use efficiency during period of prolonged drought. When air humidity is high (e.g. early in the morning and during rainy periods), stomata of cassava remain open. Thus, in humid atmosphere and in presence of soil-water deficits, cassava leaves remain photosynthetically active, conditions which are usually encountered in the cassava growing area in the Pacific Coast of Ecuador where cassava produces well (8-12 t fresh root ha^{-1}) with 400 mm of rain falling in 3-4 months. In that region, the intensity of solar radiation is low due to cloudy skies and hence low evaporative demands.

In the present trial, the 4 months imposed soil-water stress coincided with one of the rainfall peaks (total rainfall in April and May 1988 at Quilichao was 400 mm). During April and May 1988, the last two months of the water stress period, the photosynthetic rates of the stressed plants were 60-70% of the rates in the control plants (See Fig. 1). This remarkable photosynthetic activity of the stressed cassava should be partially attributed to the favorable effects of the high humidity by keeping the stomata partially open (Fig. 2).

Table 1. Final yield and biomass of eight cassava cultivars as affected by an early and prolonged period of water stress. From day 60 to day 180 after plantings, plants were deprived of rainfall and then were allowed to recover under irrigation and rainfall for the rest of the growing cycle. Rainfall was excluded by convering the soil of the stressed plot with plastic sheets. Experiment was conducted at Santander de Quilichao - planting date, Nov. 25, 1987. Harvested October 20, 1988.

	CONTROL					STRESS				
Cultivar	Total dry biomass	Fresh root	Dry root	% Dry matter in roots	Harvest index %	Total dry biomass	Fresh root	Dry root	% Dry matter in roots	Harvest index %
	t ha^{-1}					t ha^{-1}				
M Col 1684	27.0	50.5	16.9	33.5	63	18.2	41.8	13.9	33.1	76
CM 489-1	26.4	59.6	18.8	31.6	71	26.8	59.0	17.5	29.6	65
CM 507-37	22.6	42.2	14.1	33.3	62	24.0	52.6	17.2	32.6	72
CM 523-7	25.8	42.7	16.3	38.2	63	26.9	45.6	17.4	38.2	65
CM 922-2	24.8	42.7	16.9	39.4	68	26.0	44.3	17.0	38.3	65
CM 1335-4	29.8	51.6	20.2	39.3	68	26.5	51.0	19.1	37.5	72
CM 2136-2	38.0	58.7	20.9	35.5	55	27.7	55.4	17.3	31.1	62
CM 3306-32	33.8	41.3	15.2	36.7	45	24.5	41.1	15.2	37.0	62
Average of all cultivars	28.5	48.7	17.4	35.9	61	25.1	48.9	16.8	34.7	67
(Control-Stress)/Control x 100						%				
						-12	0.0	-3.4	-3.3	+ 10

Table 2. Leaf gas exchange characteristics of eight cassava cultivars as affected by an early and prolonged period of water stress. Values are means of all measurements made during the stress period from day 60 to day 180 after plantings. Measurements were made weekly for the first 2 months and every two weeks in the last 2 months of stress (12 measurements x 3 replications).

Cultivar	CONTROL				STRESS			
	Leaf CO_2 uptake	Leaf conductance to H_2O	Mesophyll conductance to CO_2	Light interception	Leaf CO_2 uptake	Leaf conductance to H_2O	Mesophyll conductance to CO_2	Light inter-ception
	μmol CO_2 m^{-2} s^{-1}	mmol m^{-2} s^{-1}		%	μmol CO_2 m^{-2} s^{-1}	mmol m^{-2} s^{-1}		%
M Col 1684	21.4	815	85	64	18.0	485	76	46
CM 489-1	25.6	1001	104	58	19.6	557	89	37
CM 507-37	23.1	940	92	62	17.3	515	72	45
CM 523-7	24.1	937	97	68	16.2	440	69	42
CM 922-2	25.8	992	102	58	22.3	553	99	37
CM 1335-4	20.6	833	82	61	18.2	565	77	50
CM 2136-2	26.2	1033	104	65	20.6	606	86	37
CM 3306-32	24.9	850	101	63	17.8	492	78	51
Average of all cultivars	24	925	96	62	19	527	81	43
$\frac{\text{Control-Stress}}{\text{Control}} \times 100$					%			
					-21	-43	-16	-31

Table 3. Leaf water potential of eight cassava cultivars as affected by an early and prolonged period of water stress. Values are means of all measurements made during the stress period from day 60 to day 180 after planting. Measurements were made weekly for the first 2 months and every two weeks in the last 2 months of stress (12 measurements x 3 replications).

Cultivar	CONTROL Hour 6 a.m.	CONTROL Hour 8 a.m.	CONTROL Hour 11 a.m.	CONTROL Hour 2 p.m.	STRESS Hour 6 a.m.	STRESS Hour 8 a.m.	STRESS Hour 11 a.m.	STRESS Hour 2 p.m.
	(- MPa)							
M Col 1684	0.38	0.69	0.99	1.07	0.40	0.80	1.02	1.07
CM 489-1	0.38	0.76	1.05	1.10	0.41	0.83	1.09	1.15
CM 507-37	0.38	0.79	1.08	1.19	0.39	0.88	1.16	1.18
CM 523-7	0.40	0.77	1.04	1.09	0.39	0.83	1.06	1.09
CM 922-2	0.39	0.75	0.98	1.11	0.42	0.87	1.05	1.12
CM 1335-4	0.38	0.80	1.12	1.20	0.38	0.87	1.19	1.19
CM 2136-2	0.38	0.80	1.12	1.18	0.43	0.94	1.19	1.15
CM 3306-32	0.42	0.72	1.02	1.09	0.41	0.76	0.97	1.02
Average of all cultivars	-0.39	-0.76	-1.05	-1.13	-0.40	-0.85	-1.09	-1.12

Soil erosion studies in cassava-based cropping systems

Cassava is grown by small farmers in marginal and steep lands in the tropics. The problem of soil erosion and runoff results in large losses of the thin top soil and could lead to a permanent deterioration in the soil properties. The methods of soil preparation, once the natural vegetation was eliminated, and the various culture practices followed by the cassava farmers are pivotal factors in controlling soil erosion. The soil and plant nutrition section of the cassava program has conducted field studies on soil erosion in cassava-based cropping systems for the last several years. The research has led to some useful technology in controlling soil erosion in the hilly region around Mondomo, Department of Cauca, where cassava is commonly produced both for subsistence and for income.

The cassava physiology section in collaboration with the University of Hohenheim, Stuttgart, Federal Republic of Germany, has continued the research on soil erosion at Santander de Quilichao and Mondomo. For the last two years, a Ph.D. student from Germany has conducted field studies on different methods of soil-crop management in relation to soil erosion. The experimental sites were selected in lands with 7-13% slope gradient at Santander de Quilichao and 13-20% at Mondomo. Seven soil-crop management treatments were as follows:

Treatment No. 1: Tilled-fallow which was kept free of weeds. The plots were flat and frequently tilled.

Treatment No. 2: Cassava planted on the flat after preparing the soil with either chisel plough (Santander de Quilichao) or by Ox-plough at Mondomo. Cassava was planted at equidistance of 1m x 1m.

Treatment No. 3: Cassava planted on contour-oriented ridges. Cassava was planted at equidistance of 1m x 1m.

Treatment No. 4: Cassava planted on vertically-oriented ridges. Cassava was planted at equidistance of 1m x 1m.

Treatment No. 5: Cassava intercropped with cowpeas at Santander de Quilichao and with field beans at Mondomo. After preparing the soil, crops were planted on the flat. Cassava was planted on contour-oriented rows, 1.7m between rows and 0.6m between plants. Cowpeas and field beans were planted in 0.25m rows between the cassava rows. Population density was 110.000 plants ha^{-1} for cowpeas and 220.000 plants ha^{-1} for field beans.

Treatment No. 6: Cassava planted on the flat after preparing the soil and keeping 1-m strips of natural grass at 10m distance in Quilichao and at 8m in Mondomo. Cassava population density of 10.000 plant ha^{-1} was used.

Treatment No. 7: Minimum tillage (Cajuelas) where cassava was planted at 1m x 1m in prepared pits and leaving the remaining area intact with its natural grass cover.

Water and soil collectors were installed at the lower end of each plot to monitor both runoff and eroded soil. All the planted plots were adequately fertilized. On both sites rain gauges with a monthly recording period were installed to obtain information on the erosivity of the rains.

The patterns of rainfall distribution and erosivity index (EI_{30}) are illustrated in Figures 4 and 5. Although the total amount of rainfall were below the long-term mean annual precipitation, there were periods with intense rains falling within a very short time. The highest intensity was recorded in Quilichao during a rainstorm on April 4, 1988 with 21 mm in 7 minutes. In Mondomo a peak intensity of about 11 mm in 3 minutes was recorded on August 19, 1988. These data indicate that highly erosive storms not only occur during the normal rainy season but can also occur in less rainy season. The erosivity index of rain storms was significantly correlated with soil loss in Quilichao ($r = 0.7$, $P < 0.01$) but not in Mondomo.

The runoff in Quilichao during April-November 1987 is illustrated in Fig. 6. The strongest runoff occurred when cassava was planted on vertically-oriented ridges (treatment 4). The minimum tillage, tilled fallow and cassava-cowpeas treatments were intermediate. The other treatments, cassava planted on the flat with (treatment 6) or without grass barriers (treatment 2) and cassava planted on contour-oriented ridges (treatment 3), had the least runoff. Similar trends were observed in Mondomo (data not shown). The strongest runoff coincided with the highest rainfall intensity in April-May and October-November (compare Figs. 3 and 5). Also, the largest amount of eroded soil of 26.4 t ha^{-1} occurred in May, 1987 with cassava planted on vertically-oriented ridges, a treatment with the highest runoff (compare data of Fig. 5 with Table 4). This amount of eroded soil was much greater than the tilled-fallow treatment (15.9 t ha^{-1}). At that time, the cassava plants were just 2 months old with very small canopy cover, hence the vertically-oriented ridges enhanced runoff and soil erosion. On October-November, when cassava was 6-7 months old and the canopy reached its peak, the intensive runoff did not result in significant soil loss (2 t ha^{-1} with cassava on vertically-oriented ridges as compared with 28 t ha^{-1} in tilled-fallow, Table 4).

Intercropping cassava with grain legumes (e.g. cowpeas and field beans) resulted also in strong runoff (See treat. 5, Fig. 6) and large amount of eroded soil (See Tables 4 and 5). In Mondomo, where the soil erosion was aggravated by higher runoff in 1988, the amount of eroded soil from cassava-bean plots were 44 t ha^{-1} as compared with 87 t ha^{-1} in tilled-fallow and 37 t ha^{-1} in sole cassava (See Table 5). Unfortunately, in these trials there were no sole beans or cowpeas checks in order to determine the real magnitudes of runoff and soil erosion attributed to these crops. However, it is evident from the present data that intercropping grain legumes with cassava results in more runoff and soil erosion than cassava monoculture.

Tables 4 and 5 summarize data on the amount of soil loss in Quilichao and Mondomo as affected by the different soil-crop management practices. In the 1987/88 season, the highest amount of soil loss (49 t ha^{-1}) occurred in Quilichao in the tilled-fallow treatment, followed by the vertically-oriented cassava ridges (30 t ha^{-1}). The least amount of soil loss occurred with the minimum tillage, followed by contour-oriented cassava ridges (1.9 and 3 t ha^{-1}, respectively). Cassava planted on the flat with or without grass barriers lost equal amount of soil (5 t ha^{-1}).

However, due to the short down-slope length of each plot (16 m), the beneficial effect of the grass barriers was not evident. Cassava farmers use large strips of land on steep hills and in this case natural grass barriers should be effective in minimizing soil loss by erosion. In the current 1988/1989 season, the same trends were observed but with more soil erosion occurring in the first 7 months. The severity of soil erosion with certain management practices is remarkably illustrated by the amount of soil loss of 26 to 30 t ha^{-1} occurring in May 1987 and April 1988 with cassava grown on vertically-oriented ridges. Although the minimum tillage treatment was the most effective in preventing soil erosion, it produced very low yield (data not shown). In terms of cassava production, the minimum tillage is ineffective. The aggressiveness of the natural grasses in competing with cassava for water and nutrients argue against its utility. Soil loss in Mondomo followed the same patterns observed in Quilichao. Cassava intercropped with grain legumes appears to be a risky practice as indicated by the magnitude of soil loss in the current season of 1988. This cropping pattern (treatment 5) resulted in 21 and 44 t ha^{-1} of eroded soil in Quilichao and Mondomo, respectively (See Tables 4 and 5). The eroded soil carries with it valuable nutrients whether native or applied (See data of Table 6). In order to sustain productivity in these marginal soils in the tropics, not only improved genotypes with low-input requirements are the solution but also proper culture practices and soil conservation measures are equally important. Once the precious soils were lost, the improved genotypes with low-input requirements will have no place to grow even with high inputs.

Response of cassava to association with forage legume species.

Permanent ground cover with forage legume species is effective in reducing soil loss by erosion and to a certain extent in nutrient recycling. In 1987/1988 field trials were conducted in Santander de Quilichao to investigate the response of cassava to association with some forage legume species that were provided by the Tropical Pasture Program of CIAT. The species used were: kudzu, acc. 9900 (*Pueraria phaseoloides*); *Zornia latifolia*, acc. 728; *Arachis pintoi*, acc. 17434; siratro, acc. 535 (*Macroptilium atropurpureum*); *Centrosima acutifolium*, acc. 5277; *Desmodium ovalifolium*, acc. 13089. The fertility level of the experimental site was very low due to continuous cassava growing for the last several years. One experiment was conducted without fertilizer and the second one received 500 kg of 10-20-20 NPK. The forage legumes were planted at the same time with cassava on mid-October, 1987 and were left under rainfed conditions. All forage legumes, except *Arachis pintoi*, germinated and rapidly established full cover within 3-4 months after planting. *Arachis pintoi* was the slowest and the least effective in establishment. The two clones of cassava M Col 1684 and the hybrid CM 507-37 (a hybrid of M Col 1684 x M Col 1438) were planted at 1m x 0.8m. CM 507-37 is a more vigorous and leafy type than M Col 1684 and form more fibrous roots in the upper soil (CIAT, Annual Report, 1985). In addition to the various cassava-forage legume associations, there were three check treatments, i.e. cassava alone: with weed controlled by a machete and were left as mulch; weed controlled with a hoe and then removed; and weed controlled with herbicide. Gramaxone was applied after weeds have formed a complete cover so that the dead weeds served as a mulch.

Dry root yields at 11 months are given in Tables 7 and 8. With and without fertilizer, the vigorous clone CM 507-37 significantly outyielded M Col 1684 irrespective of methods of weed control and cassava-legume associations. In both clones, the highest yields were achieved when weeds were either cut with machete and left as mulch or controlled with post-emergence herbicides. Compared with these two treatments, the cassava-legume association significantly reduced yield of both cultivars. With fertilizer application, the yields of CM 507-37 in association with Zornia, Desmodium, Arachis, Centrosima, Pueraria and Macroptilium were 85%, 81%, 78%, 72%, 66% and 63% of the maximum yield, respectively. With M Col 1684, these associations (in the above ranking order) gave 82%, 75%, 97%, 69%, 42% and 57% of the maximum yield. Except with Arachis pintoi, the reductions in yield due to association with forage legumes were greater in M Col 1684 than in CM 507-37. These data suggest that the vigorous CM 507-37 competed better with the legume covers. This clone form finer and more dense fibrous roots in the surface soil, an important characteristic for water and nutrient absorption that enhance its ability to compete with legume covers.

Without fertilizer application, the yields of CM 507-37 in association with Pueraria, Macroptilium, Arachis, Centrosima, Zornia, and Desmodium were 84%, 70%, 69%, 62%, 62%, 52% of the maximum yield. With M Col 1684, these associations (in the above ranking order) gave 41%, 16%, 40%, 27%, 35%, and 36% of the maximum yield. It is clear that the magnitude in yield reduction due to the association with forage legumes is much greater in M Col 1684 than CM 507-37. Furthermore, the differences between the two clones in their ability to compete with legume covers were more pronounced in the low fertility soil than when fertilizer was applied. This suggests that the vigorous cassava clones with more efficient fibrous root system are more suitable for association with forage legumes.

In view of the ability of cassava to produce reasonably well in association with forage legumes, it is of great interest to further explore the potential of this cropping system in areas prone to soil erosion such as Mondomo and Pescador, Dept. of Cauca, Colombia, where cassava is widely grown on steep marginal lands. The expected long-term benefit of this cropping system is the conservation of soil and the maintenance of soil fertility.

It has been shown from soil erosion studies in Quilichao and Mondomo (See previous section) that certain soil-crop management methods (e.g. barriers of natural grass and contour-oriented ridges) are effective in controlling runoff and soil erosion. Combining some of these methods with some favorable forage legume covers (providing acceptance by farmers) would enhance both the control of soil erosion and the maintenance of soil fertility.

However, in areas with low rainfall and with long period of drought, cassava productivity could be adversely affected by association with forage legumes due mainly to competition for the limited soil water.

Nutrient recycling by earthworms in sandy soil, Media Luna

Where land is abundant, small farmers in most of the tropics practice shifting cultivation by clearing the vegetation cover from part of the land, cultivate crops for a few years and then shift to another uncultivated land. This pattern of cultivation coupled with no input of chemical fertilizer produces reasonable yield by allowing the cultivated land to recover its fertility before using it for another cycle of cultivation. Mineralization of nutrients, organic matter accumulation and the biological activity of the soil fauna are essential components of maintaining soil fertility. Nevertheless, with increasing human population, demand for land increases and farmers tend to permanently cultivate whatever land is available. The lack of the "fallow system" in absence of fertilizer application leads to depletion of soil nutrients and to declining productivity. In Media Luna, North Coast of Colombia where cassava is produced by small farmers with limited available land, reduction in yield has been observed for the last two years. Declining soil fertility, beside severity of plant diseases, might be a major factor behind loss of yield. Data of Table 9 indicate the extremely low content of organic matter and nutrients in soil samples collected from 6 fields of farmers in Media Luna. However, during collecting these samples, it was observed that earthworm castings were accumulating on the surface of the soil and differences in activities of the earthworms between fields, as indicated by the relative amount of castings, were apparent. Uncultivated fields (grass fallow) were showing more earthworms activity than cultivated fields. Samples of earthworm castings were collected for chemical analysis. There were substantial increases in organic matter, the cation exchange capacity and in major and minor nutrients in the earthworm castings as compared to casting-free soils (Table 9). Notably there were more than 300% increase in organic matter, NH_4-N, phosphorus, calcium and magnesium. These findings are not surprising since earthworms have long been known for their role in enriching soil fertility through their ability to recycle nutrients from plant residues and soil fauna. Nevertheless, appreciation of this phenomenon by farmers and agricultural scientists alike is warranted. Cultural practices and methods of soil and crop managements that might adversely affect the benefical activity of earthworms, and perhaps other soil microorganisms, should be avoided as much as possible in these marginal soils.

Long-term response of cassava to fertilizer application

The sixth year responses of cassava (cv. M Col 1684) to levels of NPK at Santander de Quilichao are illustrated in Figs. 7-14. In the plots where the fertility level was adequate 6 years ago, there was no response to application of either nitrogen or phosphorus in terms of fresh root yield (Fig. 7). Yields were as high as 50 t ha^{-1} with 0, 50 and 100 kg ha^{-1} each of N and P_2O_5. However there was slight increase in dry root yield (Fig.8) which is attributed mainly to the increased dry matter content in roots due to application of N and P (Fig. 9). Similarly, there was a response to N and P application in terms of above-ground growth (Stems + leaves) (Fig. 10). On the other hand, there were striking responses to potassium application in terms of fresh root, dry root, root-dry matter content and in shoot growth.

In the plots where the fertility level was low 6 years ago, still there is no observed response to nitrogen application and the fresh and dry root yields were relatively high around 40 t ha^{-1} and 14 t ha^{-1}, respectively (Figs. 11, 12). Phosphorus application up to 50 kg ha^{-1} P_2O_5 significantly increased fresh and dry root yield. Root dry matter content remained relatively unchanged with N and P application (Fig. 13). Shoot biomass was incresed by 38% and 22% with 100 kg ha^{-1} of N and P_2O_5, respectively (Fig.14). The largest responses in yield, dry matter content and shoot biomass were observed with potassium application. Application of 50 kg ha^{-1} K_2O increased fresh root by 100%, dry root by 160%, dry matter content by 10% and shoot biomass by 143% as compared with no K.

It appears from these data that soil N and P levels were sufficient to sustain cassava growth and maintain high yields for the last 6 years of continuous cultivation of cassava. However, an average cassava crop is able to recycle back to the soil from 4 to 6 t ha^{-1} of fallen dry leaves. It seems, therefore, that the lack of response to nitrogen and to a certain extent to phosphorus is partially attributed to the recycling of these two elements by fallen cassava leaves. Another possible reason for the lack of response to nitrogen application after several years of continuous cassava growing, is the ability of cassava fibrous roots to explore deeper soil layers which were found recently to contain higher levels of nitrogen. In Santander de Quilichao, nutrients content within 2-m soil profiles have been monitored in the 1987/1988 season which indicate that nitrogen leaching from top soil down to deeper layers may be significant. In this case, cassava clones with more extensive and deeper root system would be advantageous in recycling leached nutrients.

The striking response to potassium application with continuous cassava growing is expected. More than 60% of total K uptake by cassava is removed along with the storage harvestable roots. Several years of cassava cultivation would result in significant depletion of soil K content. As a highly productive root crop, cassava requires a reasonable level of K ($\simeq$ 50-80 kg ha^{-1} K_2O) when the soil becomes deficient in this element.

TABLE 4. Top soil erosion in Santander de Quilichao as affected by different methods of soil preparation in cassava-based cropping system. 1987-1988 growing season. (tons of eroded soil ha^{-1}).

Treatment	April 87	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec. 87	Jan. 88	Feb. 88	March 88	Season
1	1.6	15.9	0.1	0.2	0.0	0.0	8.8	19.9	0.3	0.9	1.5	0.0	49.2
2	0.3	1.9	0.2	0.3	0.0	0.0	0.9	0.9	0.1	0.3	0.2	0.0	5.1
3	0.2	0.9	0.1	0.2	0.0	0.0	0.5	0.6	0.1	0.2	0.2	0.0	3.0
4	0.5	26.4	0.3	0.5	0.0	0.0	1.1	1.0	0.1	0.3	0.2	0.0	30.4
5	0.2	4.1	0.1	0.3	0.0	0.0	1.2	1.5	0.1	0.3	0.1	0.0	7.9
6	0.2	3.0	0.1	0.2	0.0	0.0	0.6	0.7	0.1	0.3	0.2	0.0	5.3
7	0.1	0.8	0.0	0.1	0.0	0.0	0.4	0.3	0.1	0.1	0.0	0.0	1.9

1988-1989 growing season

Treatment	April 88	May	June	July	Aug.	Sept.	Oct. 88	Total
1	27.9	9.3	10.1	0.0	1.0	2.3	5.7	58.1
2	8.6	1.1	0.7	0.0	0.3	0.4	0.4	11.5
3	0.8	0.4	0.6	0.0	0.2	0.3	0.3	2.6
4	30.3	17.0	7.7	0.0	0.3	0.6	0.6	56.5
5	15.1	2.8	2.0	0.0	0.2	0.3	0.3	20.7
6	7.6	1.9	1.7	0.0	0.1	0.1	0.1	12.0
7	0.8	0.1	0.2	0.0	0.1	0.1	0.1	1.4

TABLE 5. Top soil erosion in Mondomo as affected by different methods of soil preparation in cassava-based cropping system. 1987-1988 growing season. (tons of eroded soil ha^{-1}).

Treatment	April 87	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec. 87	Jan. 88	Feb. 88	March 88	Season
1	0	1.1	0	3.5	0	6.3	12.9	2.6	18.2	0	0	0	44.5
2	0	4.0	0	0.1	0	1.2	3.9	0.2	0.5	0	0	0	9.9
3	0	0.4	0	0.2	0	0.3	0.3	0.1	0.2	0	0	0	1.5
4	0	15.2	0	4.6	0	5.5	6.5	0.3	1.7	0	0	0	33.8
5	0	10.1	0	0.3	0	2.2	5.6	0.3	1.3	0	0	0	19.8
6	0	0.4	0	0.1	0	0.3	0.3	0.1	0.2	0	0	0	1.3
7	0	0.9	0	0.3	0	0.6	0.6	0.1	0.2	0	0	0	2.7

1988-1989 growing season

Treatment	April 88	May	June	July	Aug.	Sept.	Oct. 88	Total
1	10.2	0.1	11.9	3.3	50.0	0	11.6	87.1
2	12.3	0.7	3.6	0.8	18.6	0	0.8	36.8
3	0.6	0.1	0.3	0.1	0.6	0	0.2	1.9
4	1.0	0.1	0.4	0.1	7.4	0	0.5	9.5
5	27.2	0.8	0.8	0.2	14.0	0	0.7	43.7
6	0.4	0.1	0.3	0.1	1.0	0	0.2	2.1
7	1.2	0.1	0.2	0	0.3	0	0.1	1.9

TABLE 6. Losses of organic matter and nutrients in sediment, Santander de Quilichao April 1988-October 1988.

Treat-ment	Soil Loss	Organic Matter	P	K	Ca	Mg	N-total
	t/ha		kg/ha				
1	58.1	3.78	0.26	2.27	5.71	0.71	132.3
2	11.5	0.81	0.26	0.90	6.94	0.84	27.9
3	2.6	0.15	0.03	0.19	2.06	0.15	5.1
4	56.5	3.56	1.07	3.76	24.00	3.71	118.1
5	20.7	1.28	0.73	2.02	13.52	1.54	44.0
6	12.0	0.77	0.25	0.99	9.38	0.99	25.4
7	1.4	0.08	.0.01	0.14	1.51	0.09	2.5

TABLE 7. Dry root yield (11 months) of 2 clones of cassava planted in association with forage legumes in low fertility soil in Santander de Quilichao. 1987/1988. (Values followed by the same letters are not significantly different at 5%).

Clone and Treatment	Dry root t ha^{-1}
CM 507-37: weed cut with a machete and left as mulch	11.7 A
CM 507-37: weed controlled with herbicides	10.2 B
CM 507-37: In association with Pueraria Phaseoloides (9900)	9.8 BC
M Col 1684: weed controlled with herbicides	9.7 C
CM 507-37: Weed cut with a hoe and removed	8.7 D
M Col 1684: weed cut with a machete and left as mulch	8.5 DE
CM 507-37: In association with Macroptilium atropurpureum (535)	8.2 E
CM 507-37: In association with Arachis pintoi (17434)	8.1 E
CM 507-37: In association with Centrosima acutifolium (5277)	7.3 F
CM 507-37: In association with Zornia latifolia (728)	7.3 F
M Col 1684: Weed cut with hoe and removed	6.9 F
CM 507-37: In association with Desmodium ovalifolium (13089)	6.1 G
M Col 1684: In association with Pueraria phaseoloides (9900)	4.0 H
M Col 1684: In association with Arachis pintoi (17434)	3.9 H
M Col 1684: In association with Desmodium ovalifolium (13089)	3.5 HI
M Col 1684: In association with Zornia latifolia (728)	3.4 I
M Col 1684: In association with Centrosima acutifolium (5277)	2.6 J
M Col 1684: In association with Macroptilium atropurpureum (535)	1.6 K

TABLE 8. Dry root yield (11 months) of 2 clones of cassava planted in association with forage legumes in adequately fertilized soil in Santander de Quilichao. 1987/1988.
(Values followed by the same letters are not significantly different at 5%).

Clone and Treatment	Dry root t ha^{-1}
CM 507-37: Weed cut with a machete and left as mulch	19.5 A
CM 507-37: Weed controlled with herbicides	18.6 B
CM 507-37: Weed cut with a hoe and removed	17.4 C
CM 507-37: In association with Zornia latifolia (728)	16.5 D
CM 507-37: In association with Desmodium ovalifolium (13089)	15.7 E
CM 507-37: In association with Arachis pintoi (17434)	15.2 E
CM 507-37: In association with Centrosima acutifolium (5277)	14.1 F
M Col 1684: Weed controlled with herbicides	13.7 FG
M Col 1684: Weed cut with a machete and left as mulch	13.5 FGH
M Col 1684: In association with Arachis pintoi (17434)	13.3 FGH
M Col 1684: Weed cut with a hoe and removed	13.0 GHI
CM 507-37: In association with Pueraria phaseoloides (9900)	12.8 HI
CM 507-37: In association with Macroptilium atropurpureum (535)	12.2 I
M Col 1684: In association with Zornia latifolia (728)	11.2 J
M Col 1684: In association with Desmodium ovalifolium (13089)	10.3 K
M Col 1684: In association with Centrosima acutifolium (5277)	9.5 L
M Col 1684: In association with Macroptilium atropurpureum (535)	7.8 M
M Col 1684: In association with Pueraria phaseoloides (9900)	5.7 N

TABLE 9. Chemical analysis of soils and earthworm castings in fields of Media Luna, Dept. of Magdalena, Colombia. Values are averages of 6 fields of different farmers.

	PH	% O.M.	Total N	NH_4 N	NO_3^- N	P	S	B	Zn	Mn	Cu	Fe
			ppm									
Soil	6.0	0.8	373	0.13	1.2	2.5	14.4	0.52	2.8	24.0	0.32	7.9
Earthworm Castings	6.6	2.7	1064	33.7	2.4	20.1	27.0	1.18	7.4	58.8	0.34	6.4
	%											
Casting / Soil x 100		338	285	(25923)	200	804	188	227	264	245		

	Ca	Mg	K	Na	CEC
	meq/100 g soil				
Soil	0.79	0.25	0.06	0.04	1.5
Earthworm castings	3.0	1.14	0.12	0.05	4.6
	%				
Casting / Soil x 100	379	456	200	-	307

LEGENDS TO FIGURES

Figure 1. Response of cassava leaf photosynthesis to a prolonged water stress (120 days) imposed at 60 days after planting.

Figure 2. Response of cassava stomata to a prolonged water stress (120 days) imposed at 60 days after planting.

Figure 3. Response of cassava leaf transpiration to a prolonged water stress (120 days) imposed at 60 days ater planting.

Figure 4. Rainfall (histograms) and erosivity index (EI_{30}) at Santander de Quilichao.

Figure 5. Rainfall (histograms) and erosivity index (EI_{30}) at Mondomo.

Figure 6. Cumulative runoff at Santander de Quilichao. Numbers in graph correspond to soil-crop management treatments (See text for explanation).

Figure 7. Sixth year response of fresh root yield (cv. M Col 1684) to NPK fertilizer. Fertile soil.

Figure 8. Sixth year response of dry root yield (cv. M Col 1684) to NPK fertilizer. Fertile soil.

Figure 9. Dry matter content of roots (cv. M Col 1684) in response to NPK fertilizer (6th year). Fertile soil.

Figure 10. Sixth year response of shoot biomass (cv. M Col 1684) to NPK fertilizer. Fertile Soil.

Figure 11. Sixth year response of fresh root yield (cv. M Col 1684) to NPK fertilizer. Low fertility soil.

Figure 12. Sixth year response of dry root yield (cv. M Col 1684) to NPK fertilizer. Low fertility soil.

Figure 13. Dry matter content of roots (cv. M Col 1684) in response to NPK fertilizer (6th year). Low fertility soil.

Figure 14. Sixth year response of shoot biomass (cv. M Col 1684) to NPK fertilizer. Low fertility soil.

Figure 1.

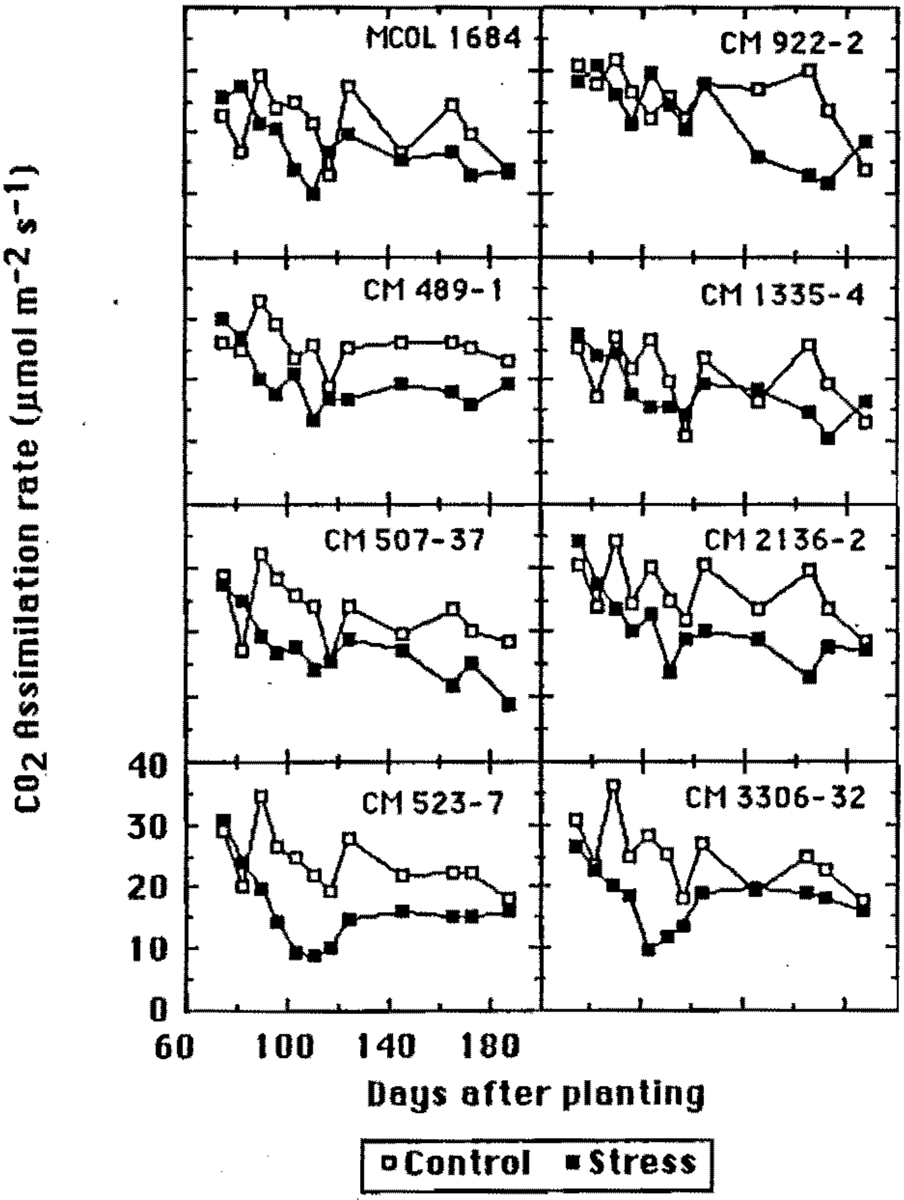

MCOL 1684
CM 922-2
CM 489-1
CM 1335-4
CM 507-37
CM 2136-2
CM 523-7
CM 3306-32
CO_2 Assimilation rate (µmol m^{-2} s^{-1})
40
30
20
10
0
60
100
140
180
Days after planting
Control
Stress

Figure 2.

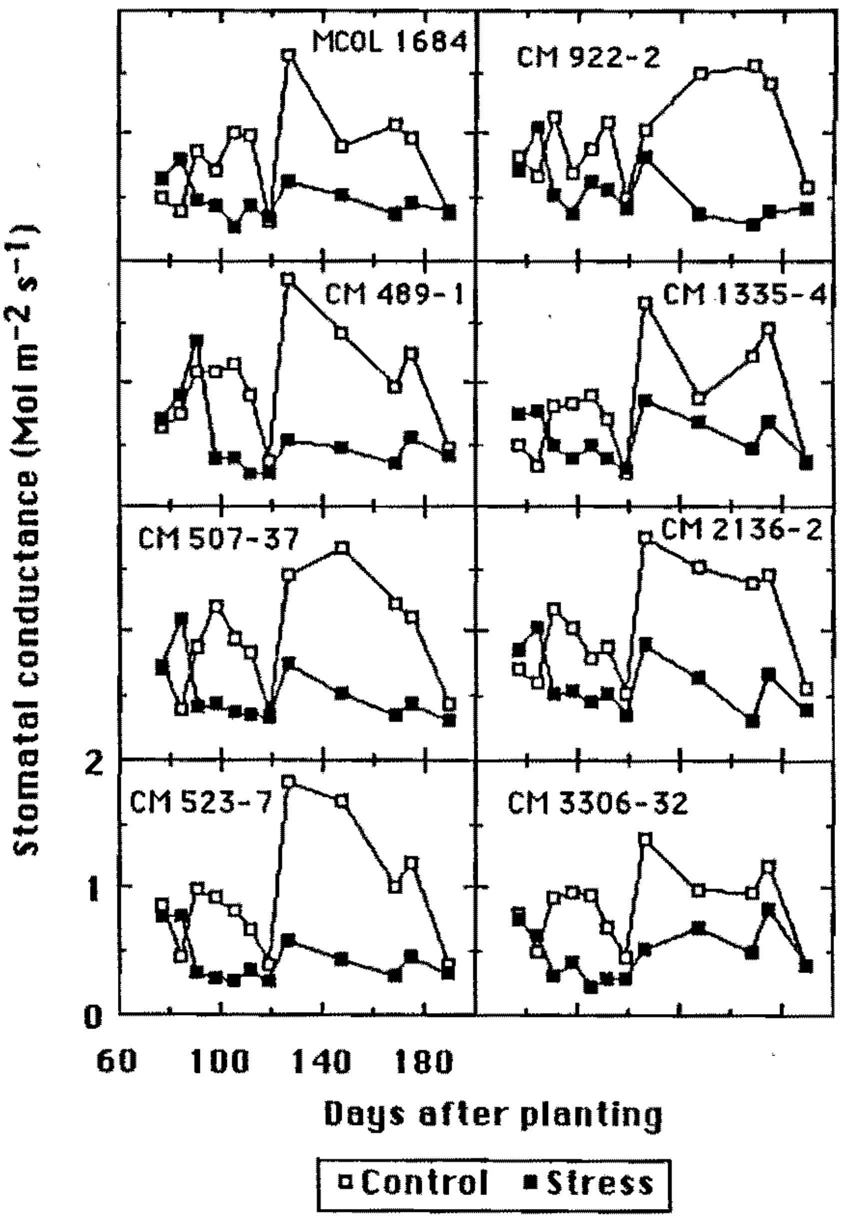
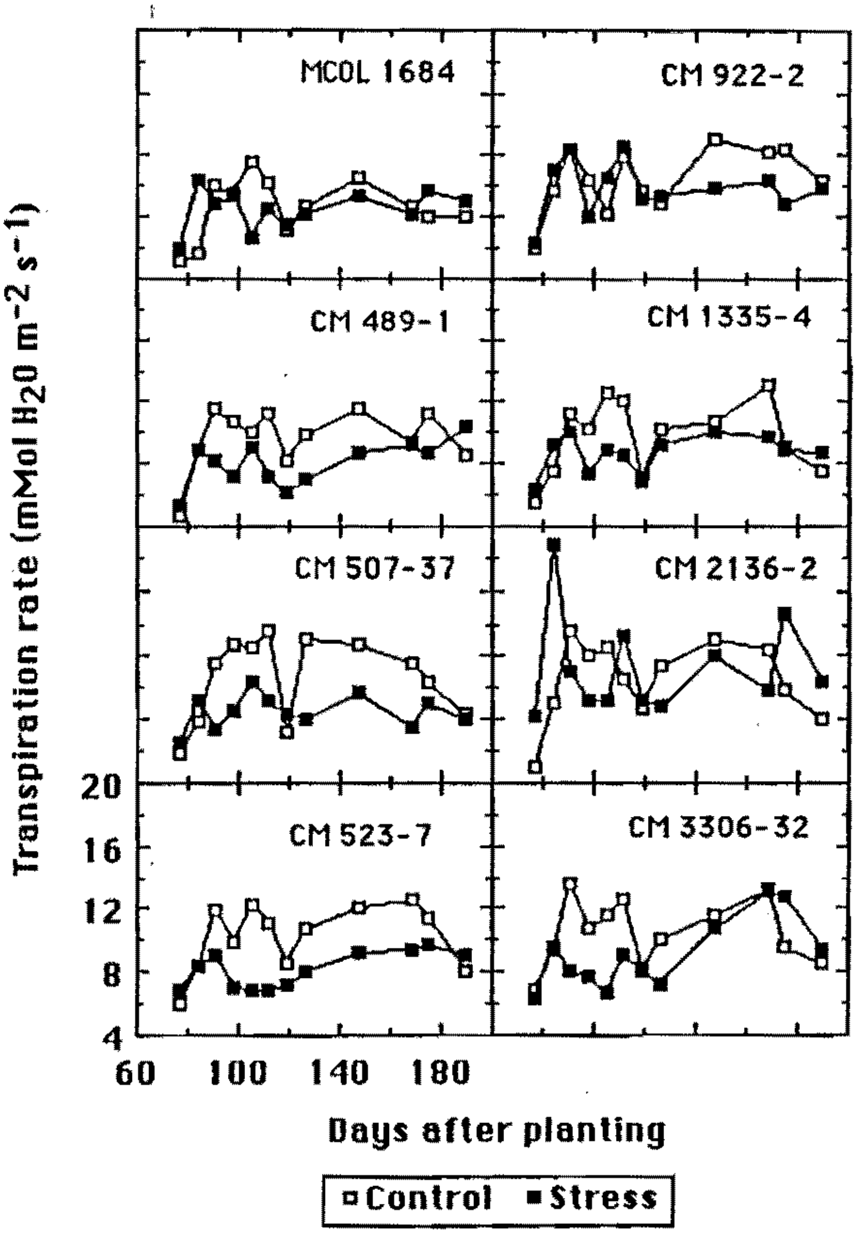
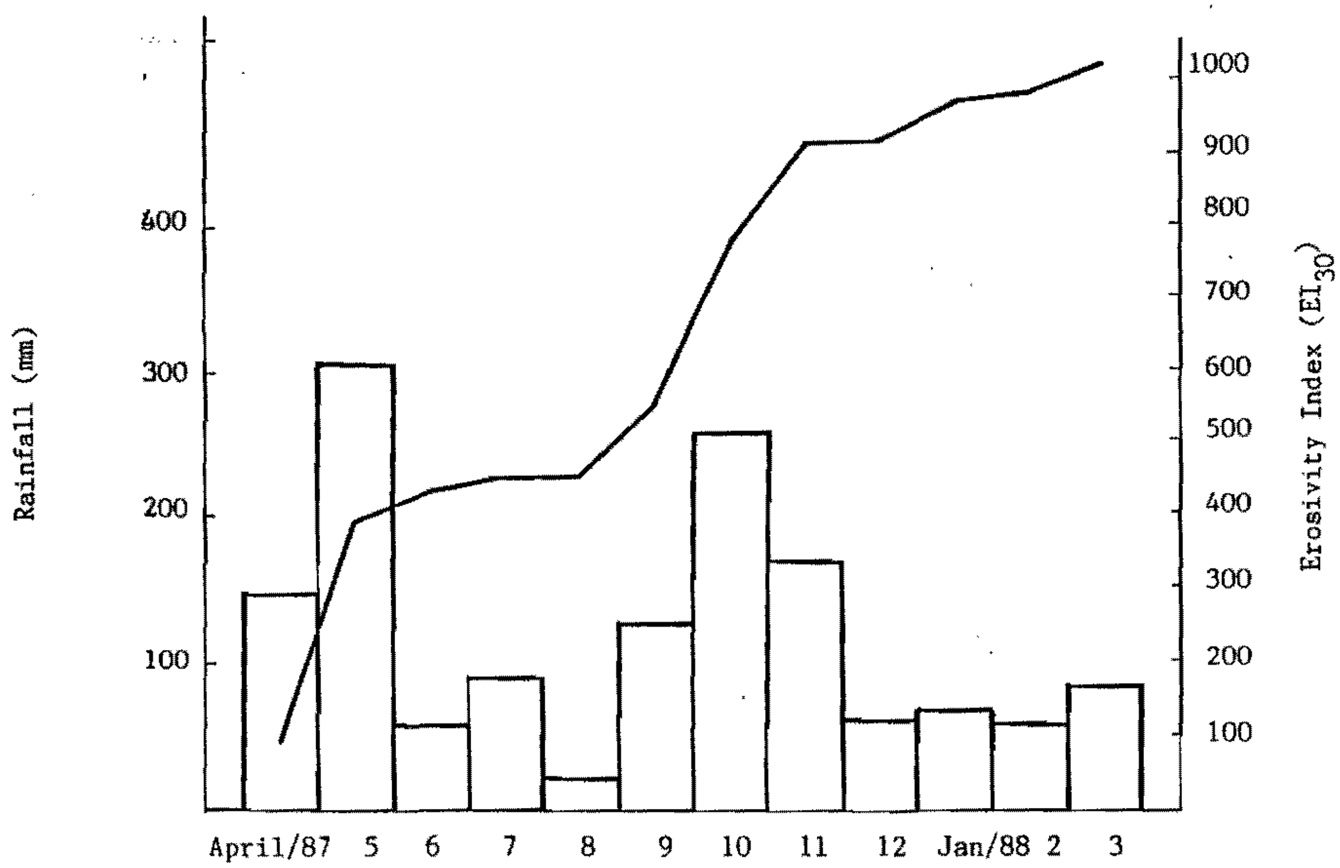

MCOL 1684
CM 922-2
CM 489-1
CM 1335-4
CM 507-37
CM 2136-2
CM 523-7
CM 3306-32
Stomatal conductance (Mol m-2 s-1)
2
1
0
60
100
140
180
Days after planting
Control
Stress

Figure 3.



MCOL 1684
CM 922-2
CM 489-1
CM 1335-4
CM 507-37
CM 2136-2
CM 523-7
CM 3306-32
Transpiration rate (mMol H_2O m^{-2} s^{-1})
20
16
12
8
4
60
100
140
180
Days after planting
Control
Stress

Figure 4.


Rainfall (mm)
400
300
200
100
April/87 5 6 7 8 9 10 11 12 Jan/88 2 3
Erosivity Index (EI_{30})
1000
900
800
700
600
500
400
300
200
100

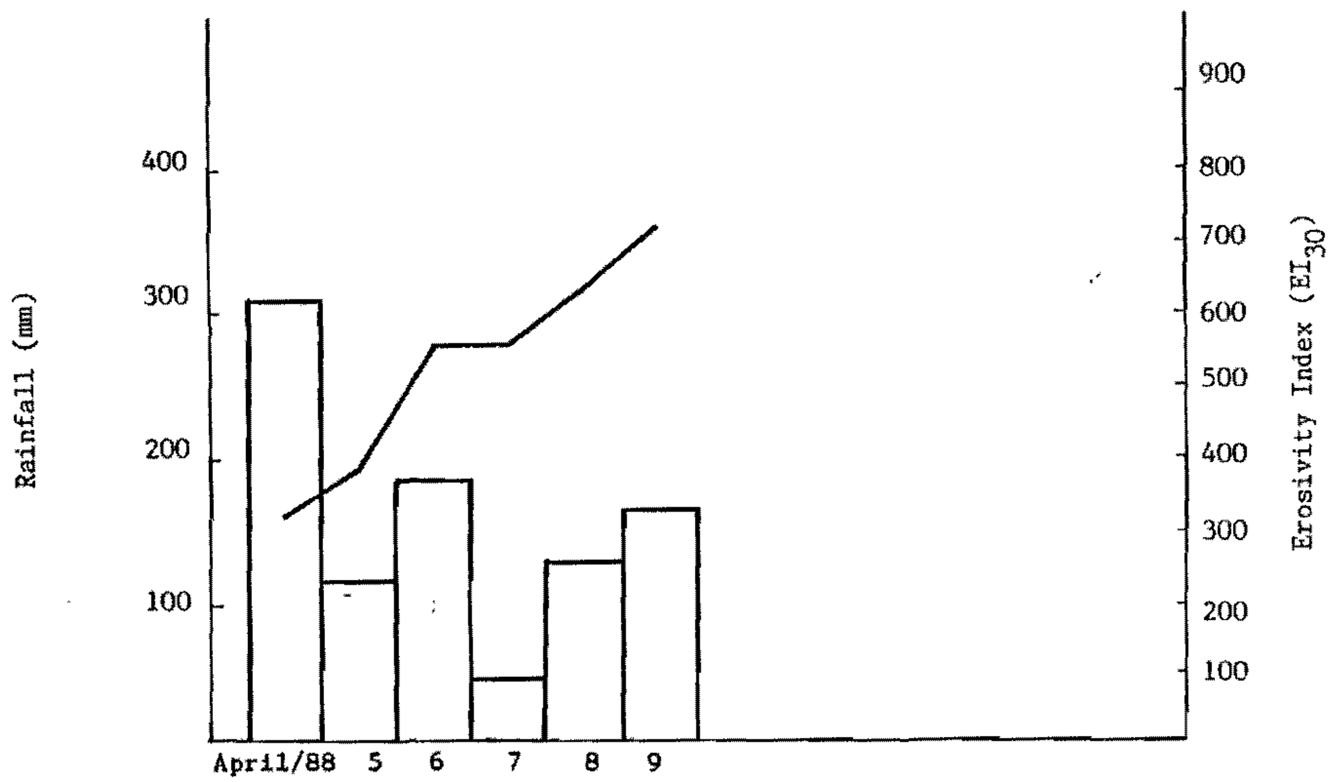
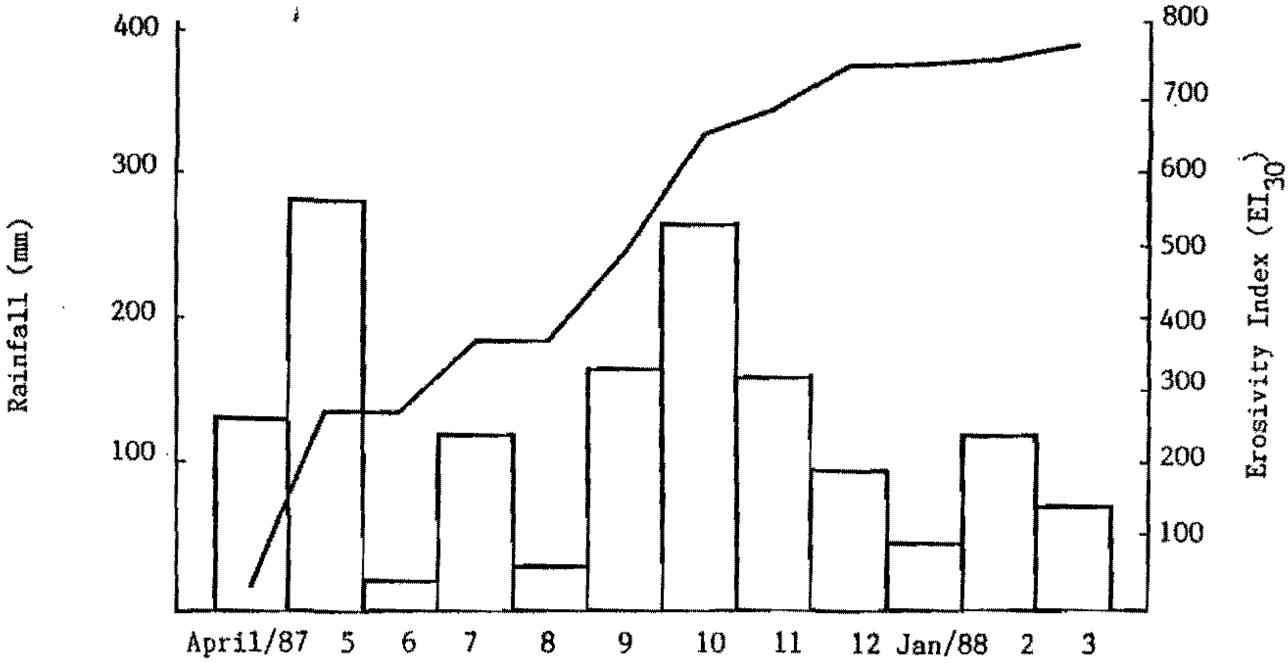
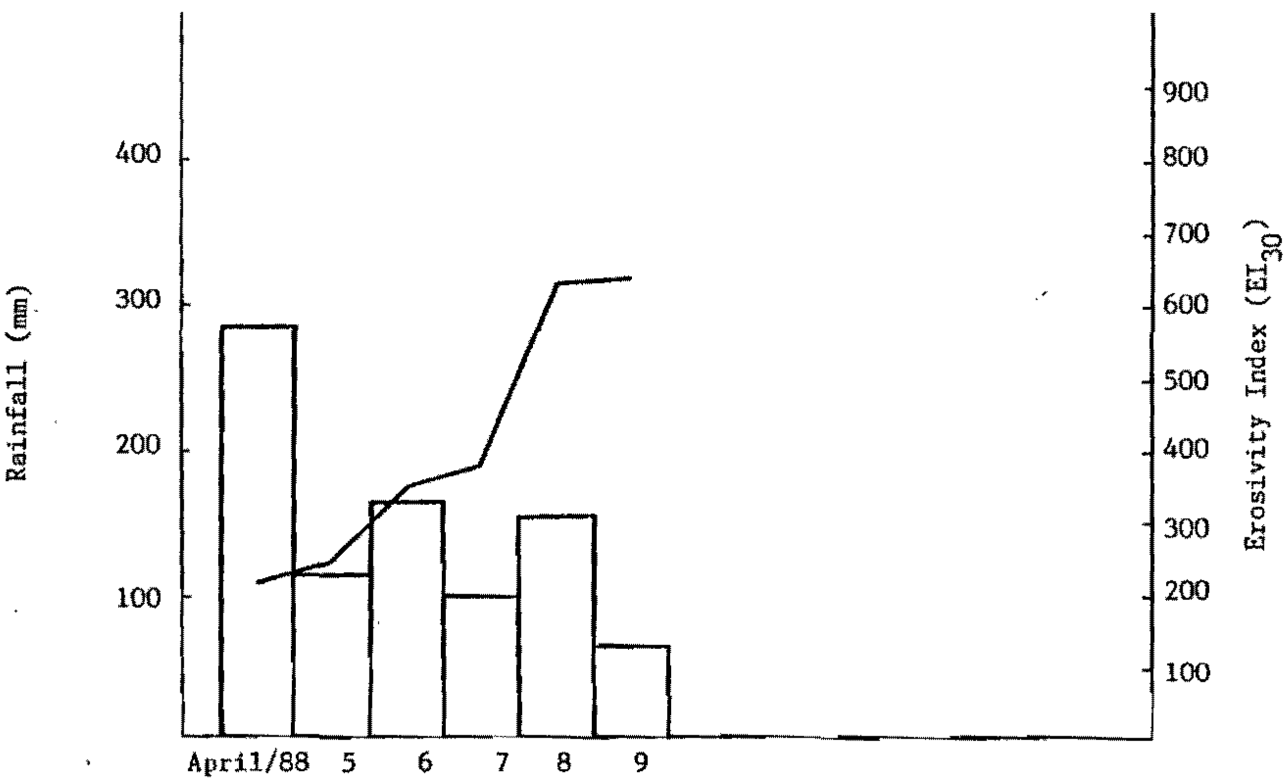

Rainfall (mm)
400
300
200
100
April/88 5 6 7 8 9
Erosivity Index (EI_{30})
900
800
700
600
500
400
300
200
100

Figure 5.



400
300
200
100
Rainfall (mm)
800
700
600
500
400
300
200
100
Erosivity Index (EI_{30})
April/87 5 6 7 8 9 10 11 12 Jan/88 2 3



400
300
200
100
Rainfall (mm)
900
800
700
600
500
400
300
200
100
Erosivity Index (EI_{30})
April/88 5 6 7 8 9

Figure 6.

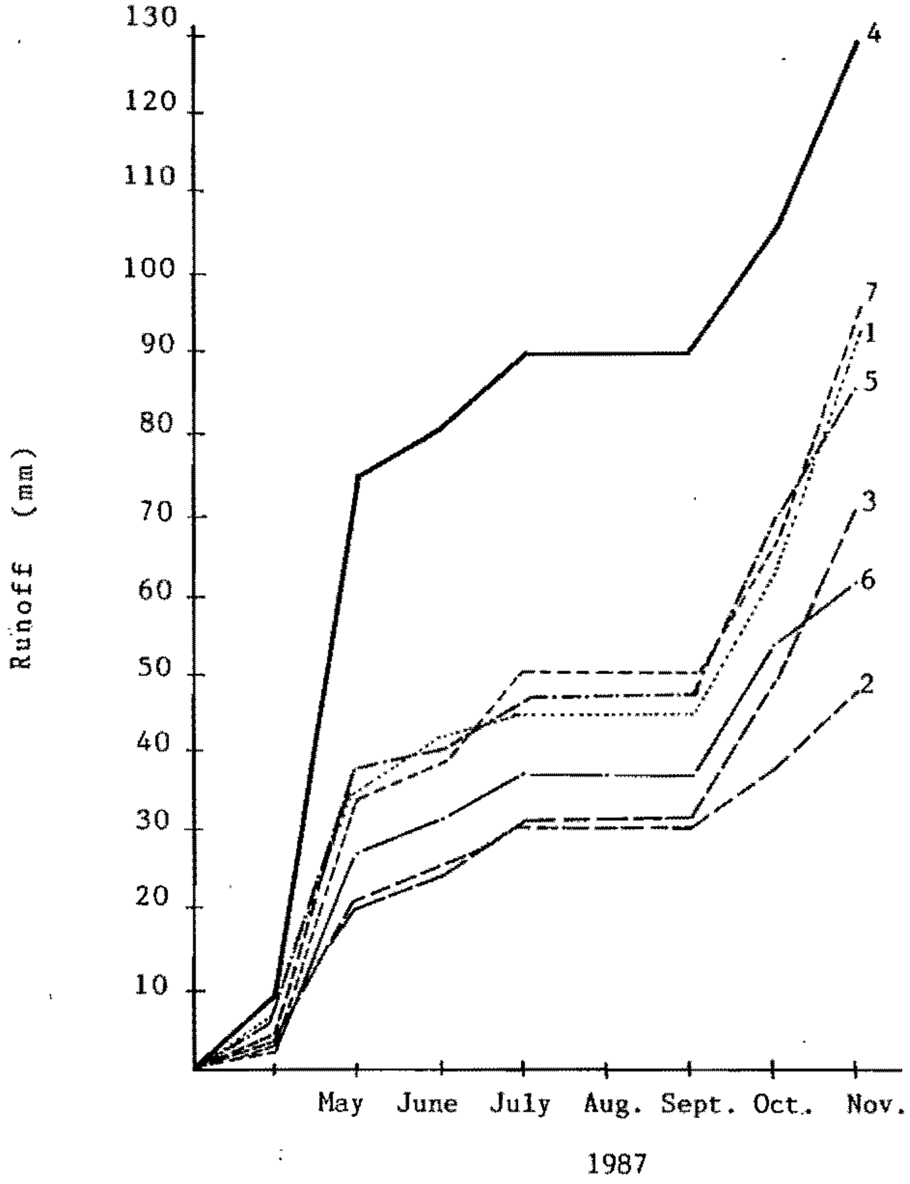
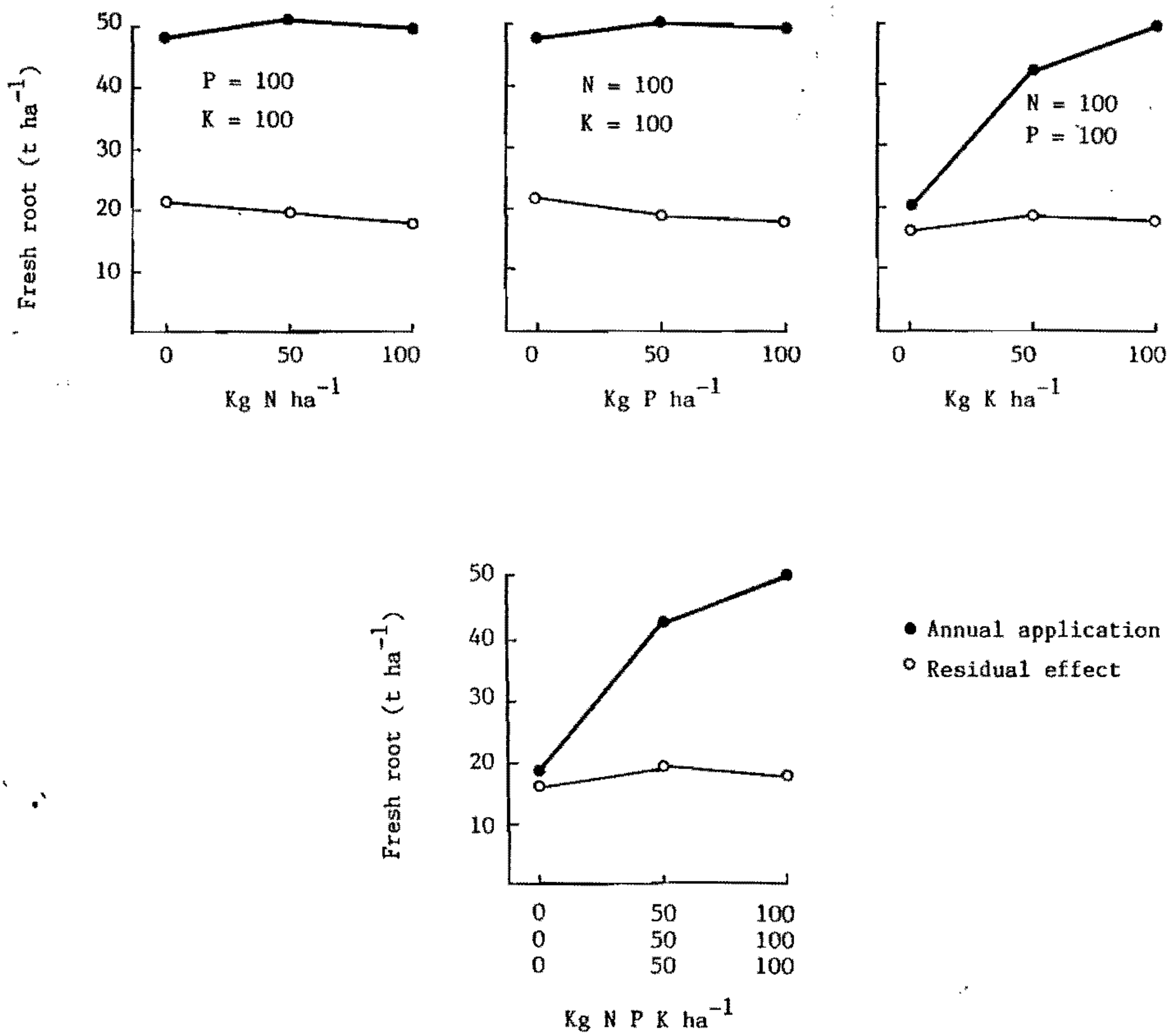


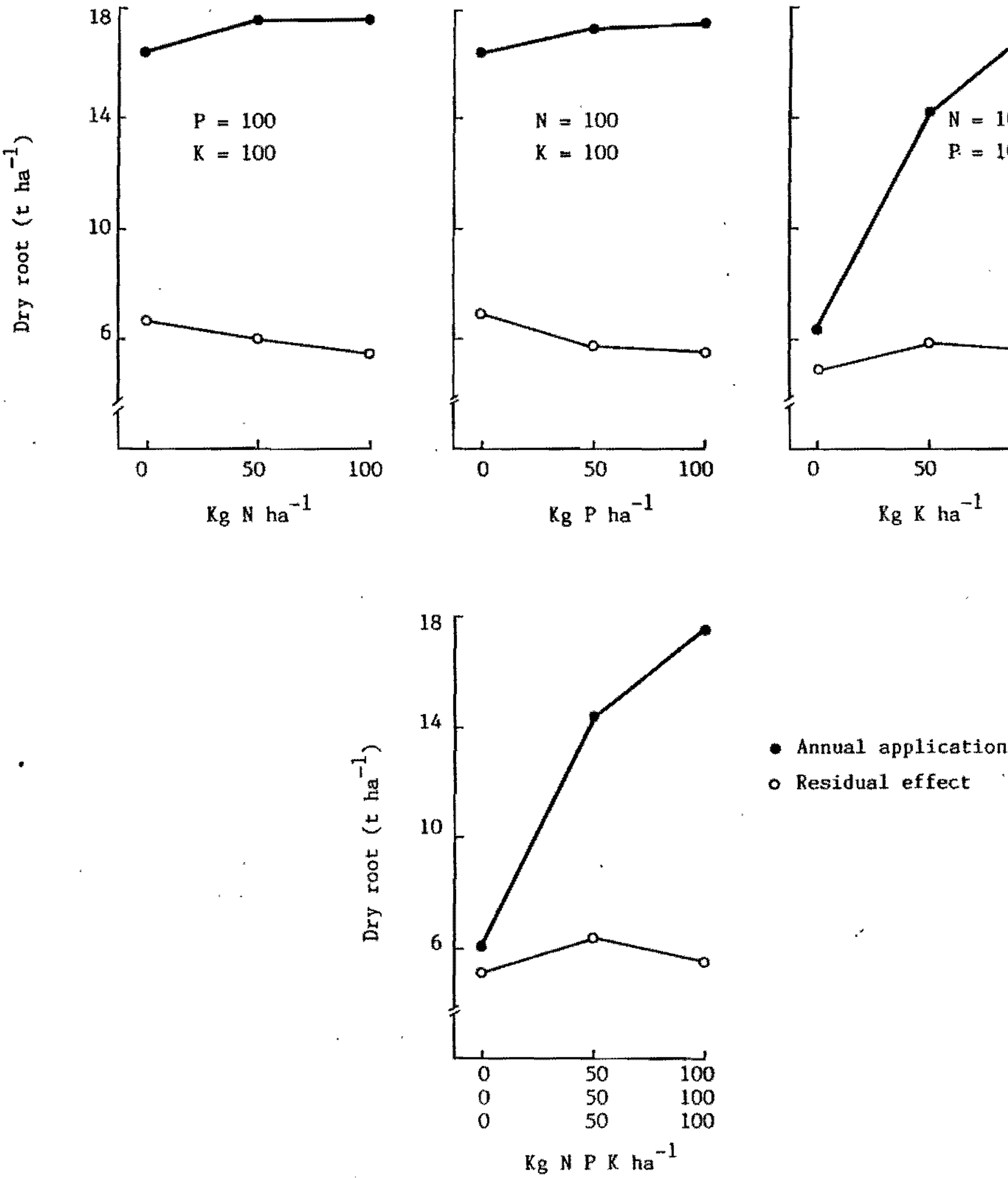
Fig 6

Figure 7.



Fresh root (t ha^{-1})
50
40
30
20
10
P = 100
K = 100
0
50
100
Kg N ha^{-1}
N = 100
K = 100
0
50
100
Kg P ha^{-1}
N = 100
P = 100
0
50
100
Kg K ha^{-1}
Fresh root (t ha^{-1})
50
40
30
20
10
0 50 100
0 50 100
0 50 100
Kg N P K ha^{-1}
● Annual application
○ Residual effect

Figure 8.



18
14
10
6
Dry root (t ha⁻¹)
P = 100
K = 100
0
50
100
Kg N ha⁻¹
N = 100
K = 100
Kg P ha⁻¹
N = 100
P = 100
Kg K ha⁻¹
0 0 0
50 50 50
100 100 100
Kg N P K ha⁻¹
Annual application
Residual effect

Figure 9.

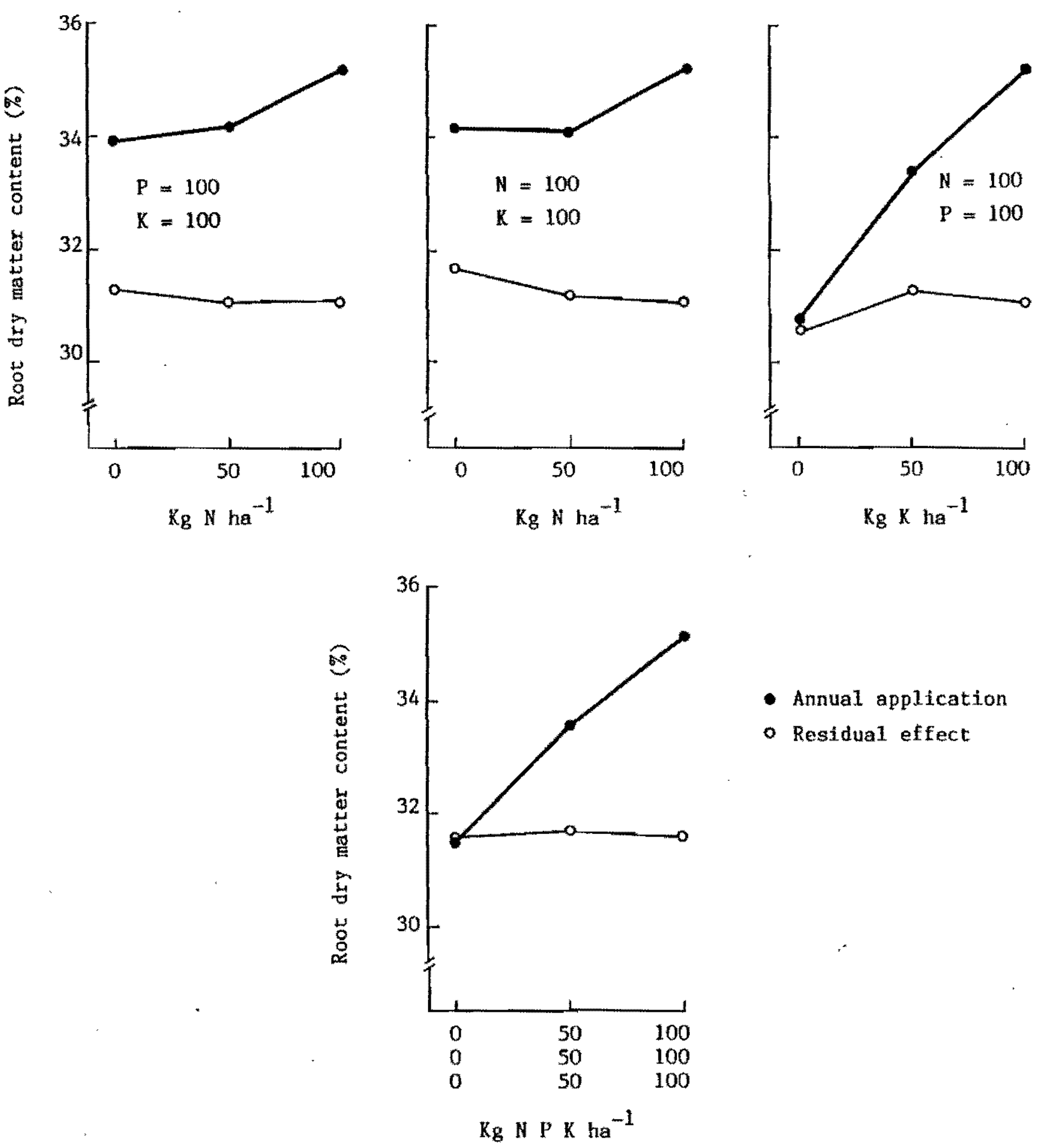
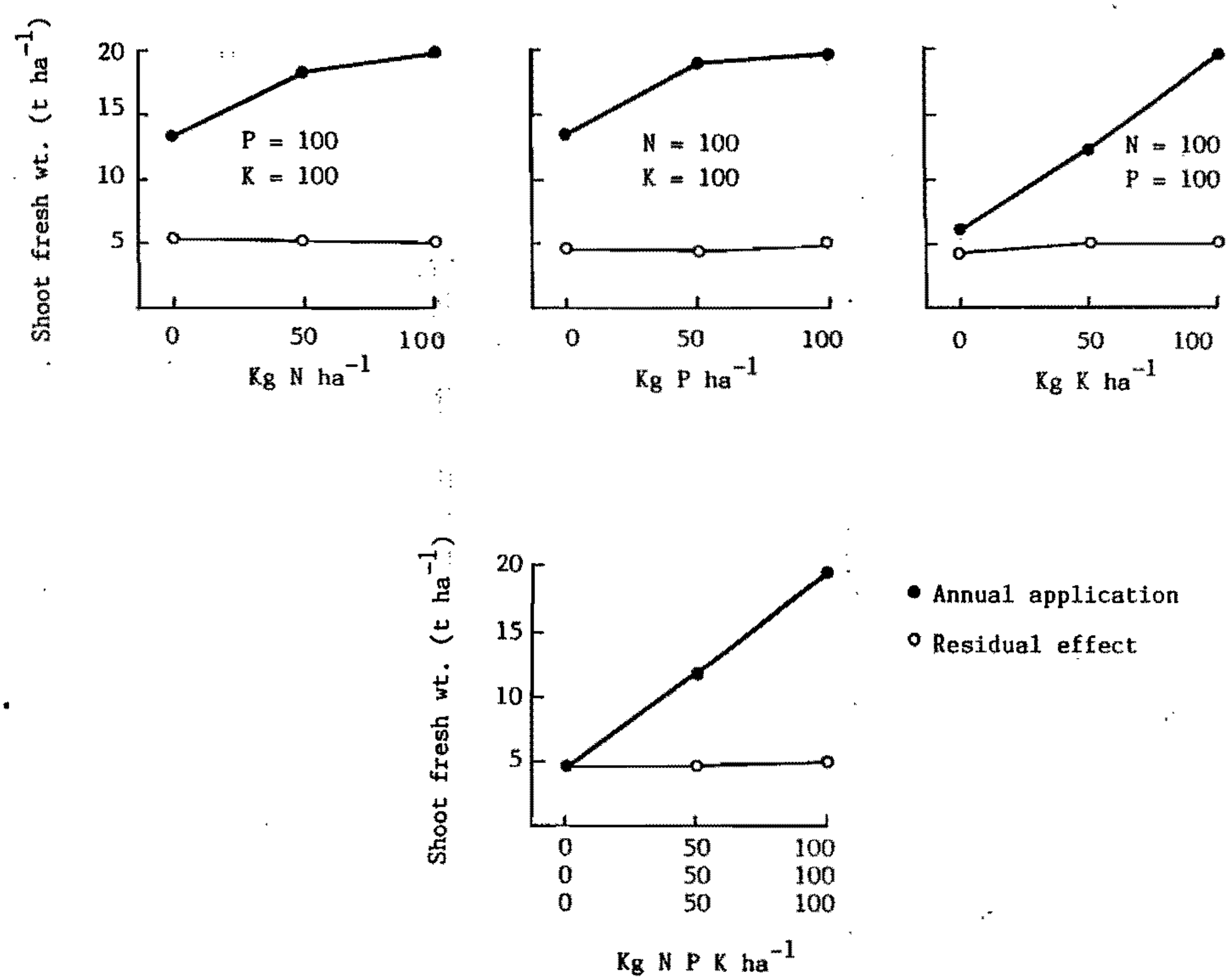
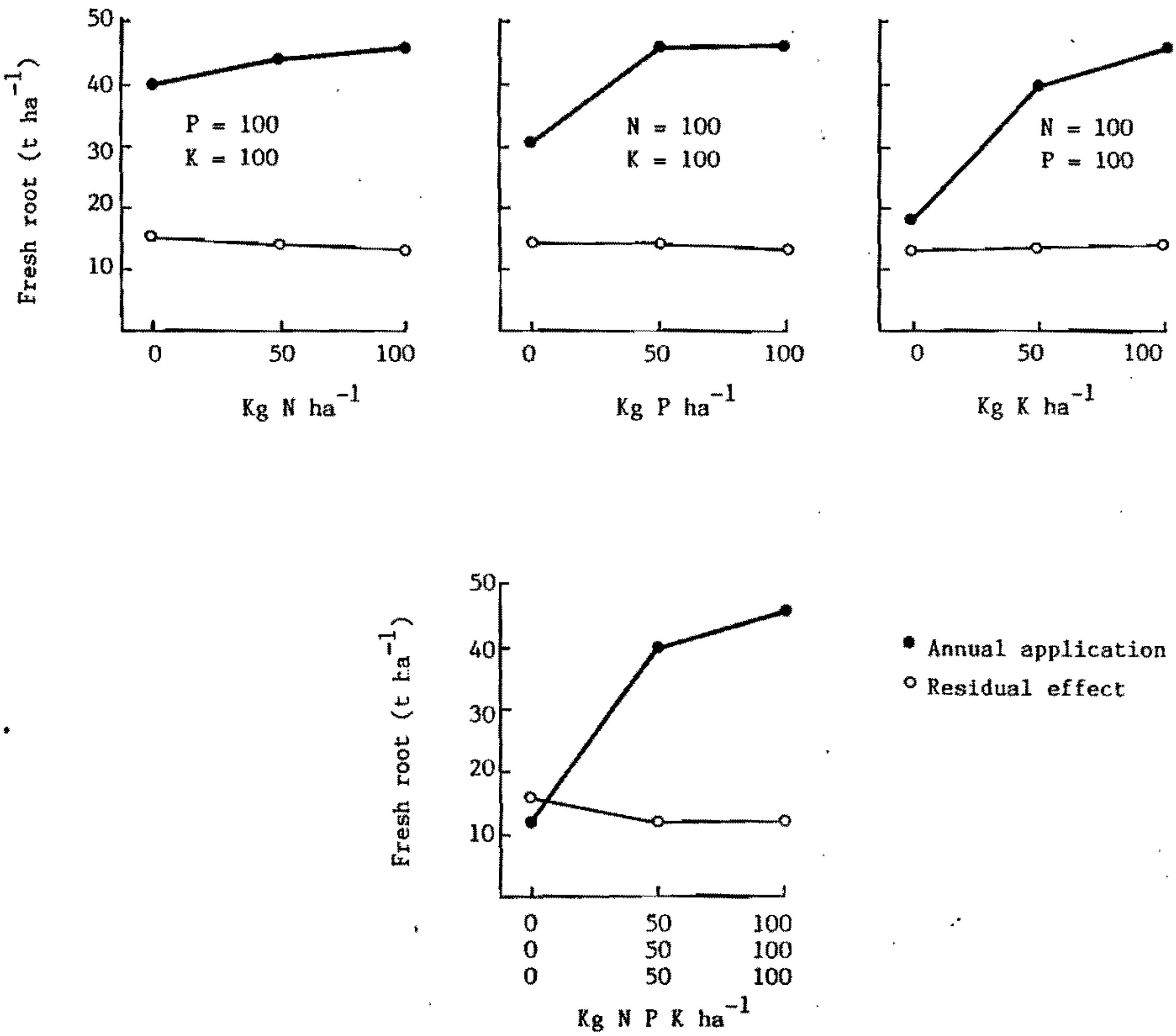

36
34
32
30
Root dry matter content (%)
P = 100
K = 100
0
50
100
Kg N ha-1
N = 100
K = 100
0
50
100
Kg N ha-1
N = 100
P = 100
0
50
100
Kg K ha-1
36
34
32
30
Root dry matter content (%)
0 50 100
0 50 100
0 50 100
Kg N P K ha-1
● Annual application
○ Residual effect

Figure 10



Shoot fresh wt. (t ha-1)
20
15
10
5
P = 100
K = 100
0
50
100
Kg N ha-1
N = 100
K = 100
0
50
100
Kg P ha-1
N = 100
P = 100
0
50
100
Kg K ha-1
Shoot fresh wt. (t ha-1)
20
15
10
5
0 0 0
50 50 50
100 100 100
Kg N P K ha-1
Annual application
Residual effect

Figure 11.



Fresh root (t ha^{-1})
50
40
30
20
10
P = 100
K = 100
0
50
100
Kg N ha^{-1}
N = 100
K = 100
0
50
100
Kg P ha^{-1}
N = 100
P = 100
0
50
100
Kg K ha^{-1}
Fresh root (t ha^{-1})
50
40
30
20
10
0 50 100
0 50 100
0 50 100
Kg N P K ha^{-1}
Annual application
Residual effect

Figure 12.

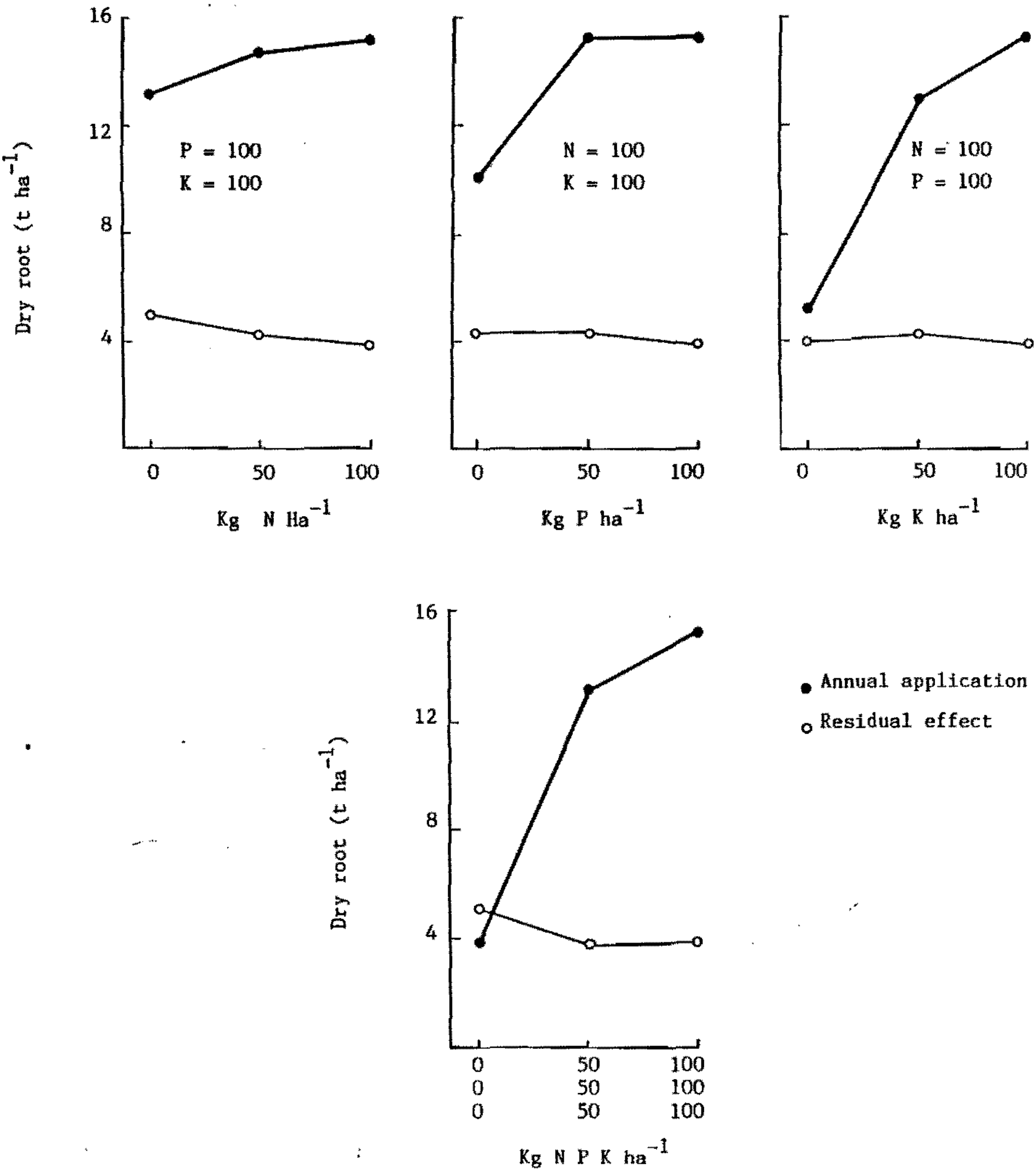

16
12
8
4
Dry root (t ha^{-1})
P = 100
K = 100
0
50
100
Kg N Ha^{-1}
N = 100
K = 100
Kg P ha^{-1}
N = 100
P = 100
Kg K ha^{-1}
Annual application
Residual effect
Kg N P K ha^{-1}

Figure 13.

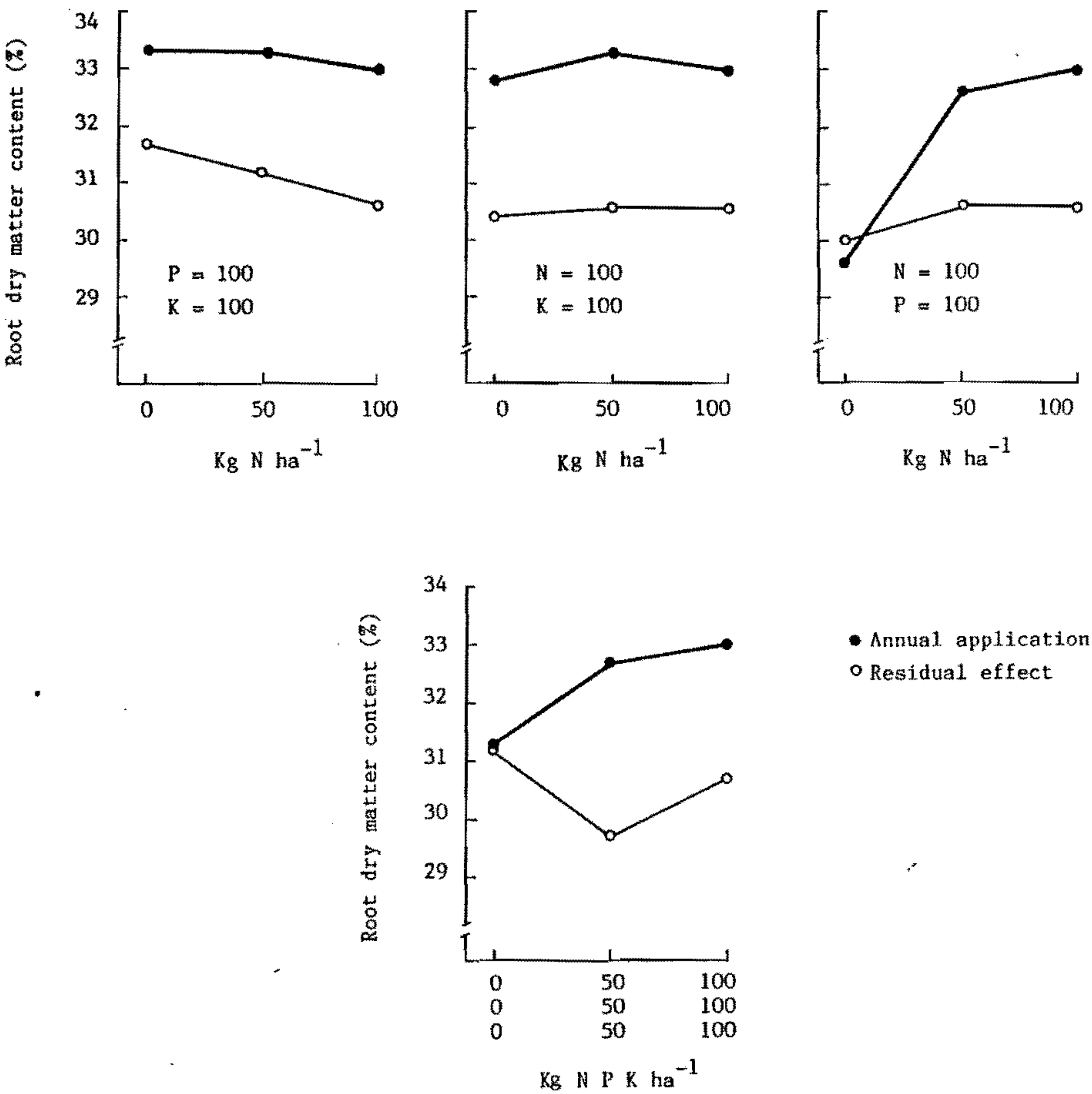
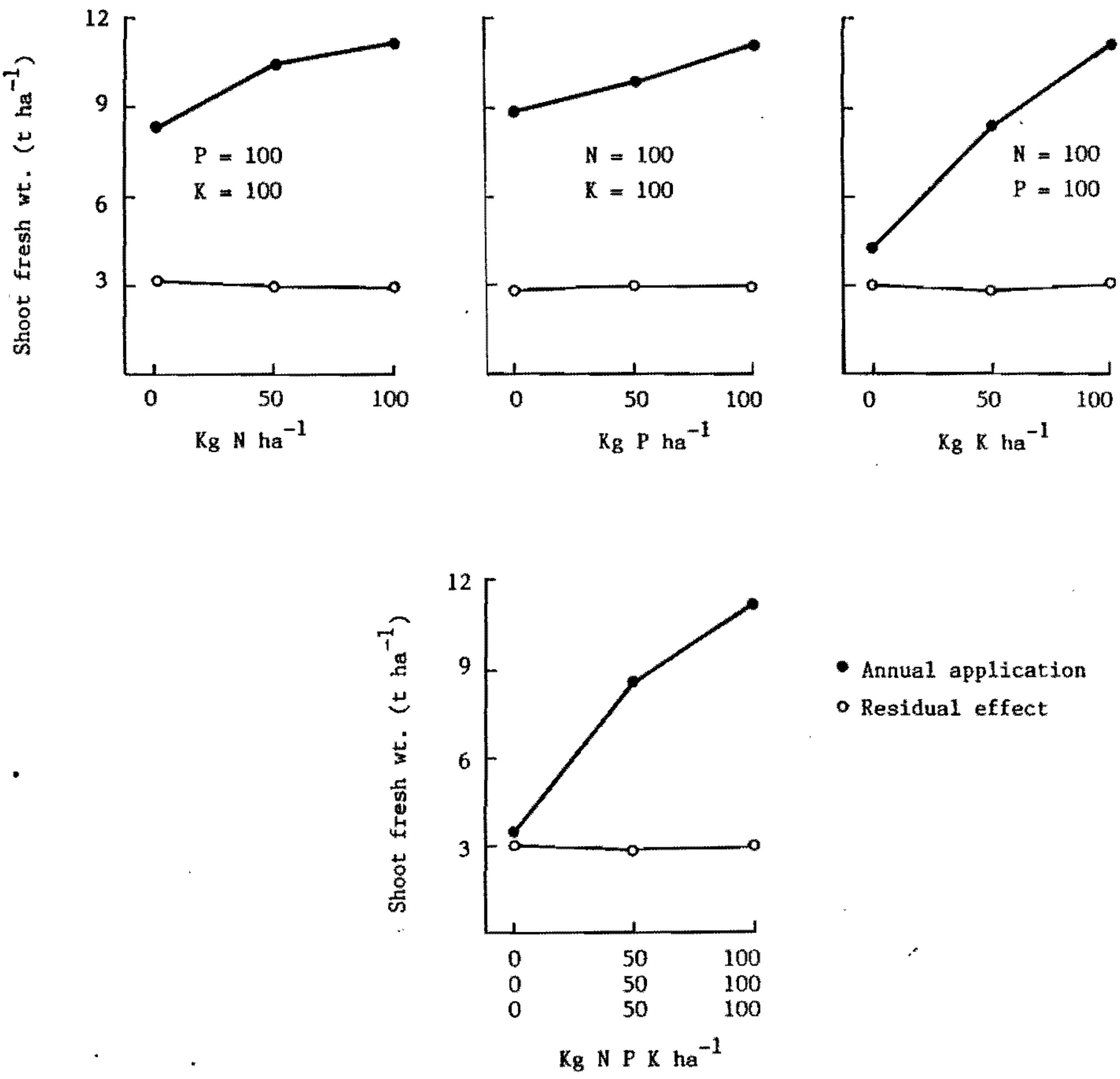

Root dry matter content (%)
34
33
32
31
30
29
P = 100
K = 100
N = 100
K = 100
N = 100
P = 100
0
50
100
Kg N ha^{-1}
0 0 0
50 50 50
100 100 100
Kg N P K ha^{-1}
● Annual application
○ Residual effect

Figure 14.



12
9
6
3
Shoot fresh wt. (t ha^{-1})
P = 100
K = 100
0
50
100
Kg N ha^{-1}
N = 100
K = 100
0
50
100
Kg P ha^{-1}
N = 100
P = 100
0
50
100
Kg K ha^{-1}
12
9
6
3
Shoot fresh wt. (t ha^{-1})
0 50 100
0 50 100
0 50 100
Kg N P K ha^{-1}
● Annual application
o Residual effect

CASSAVA VIROLOGY - 1988

Results from several research projects culminated during 1988 will be highlighted in this report. 1) Virus disease surveys were conducted in the departments of Cauca and Magdalena, Colombia and in Paraguay with the objective of monitoring the incidence and severity of cassava virus diseases in farmers' plantations in these regions. 2) A group of selected elite clones was evaluated for reaction to viruses under field conditions at three sites: CIAT-Palmira; Quilcacé, Cauca; and Media Luna, Magdalena. The objectives of these trials were to select clones with virus tolerance within and across sites and to estimate the virus inoculum pressure at each of these sites. 3) The effect of cassava common mosaic virus (CCMV) on the root yield of plants derived from virus infested planting material was measured.

Virus Disease Surveys

The two surveys in Colombia were conducted as described in the 1987 Report. Plantations were examined for any obvious foliar symptoms, cuttings were taken from 10 randomly selected plants per plantation and the roots of at least one of the selected plants were examined. Cuttings collected during the survey were sprouted under glasshouse conditions at CIAT, examined for foliar symptoms, graft-indexed on M Col 2063 and tested for CCMV and cassava virus X (CsXV) by the ELISA test.

Cauca. Results from the survey of 15 plantations located in the Caldono and Morales regions of Cauca are presented in Table 1. Root symptoms of the cassava frogskin disease (FSD) were observed on some plants in the Morales area but not in Caldono. No other foliar or root symptoms of viruses were observed in the field. However the symptomless CsXV was present in all 15 plantations surveyed and in 43% of all plants sampled. CCMV was not detected in any of the plants collected in this survey. Of the 150 plants grafted onto M Col 2063 only the 4 plants with FSD root symptoms produced mosaic symptoms on this indicator clone.

These results give further support the assumption that CsXV originated in the Cauca region of southcentral Colombia. The high incidence of CsXV in farmers' plantations is alarming and likely to increase since the virus is symptomless in cassava and is associated with an insect vector. Field trials are in progress at CIAT-Palmira to assess the effect of CsXV on root yield. The low incidence of FSD is as expected since the regions surveyed were above 1500 msl. There is increased incidence of FSD at lower altitudes. The observation that only plants with FSD root symptoms (4/150) were graft-indexed positive on M Col 2063 further demonstrates the applicability of the graft inoculation test for the detection of the FSD agent. Although graft inoculation may be a "traditional" detection method it remains a sensitive, reliable, and simple diagnostic tool.

Magdalena. The results from a survey of 5 plantations located within La Colorada and 10 plantations located in the vicinities of Media Luna, Sevilla, and Ciénaga, Magdalena are presented in Table 2. CsXV was detected in plants from three different areas of the survey, and this is the first report of CsXV in the region. It is recommended that the transfer of planting material from the region should be restricted to avoid the introduction of CsXV into other areas; mainly the principal production areas west of the Rio Magdalena where CsXV does not yet occur (1987 Ann. Rep.). The incidence of FSD root symptoms was low and symptoms were only detected on plants near Sevilla where climatic conditions are more favorable for the expression of root symptoms. However, a mosaic agent was detected in many apparently symptomless plants within La Colorada and nearby La Idea by graft inoculation to M Col 2063. All 5 plants with FSD symptoms in Sevilla contained this agent. Trials are in progress to measure the effect of this agent on clones that do not express foliar or root symptoms under the climatic conditions in La Colorada. CCMV was not detected in the region.

Paraguay. CCMV-infected plants were found in 7 of the 14 sites evaluated, including 3 research stations. The percentage of infected plants in infested plantations ranged from 8 to 90%. The highest incidence and most severe symptoms were observed on the clones Caballero, Concepción and Pomberí. Field symptoms on the important commercial clone Tacuara say-yû were mild and not easily detected. CCMV was found in all of the production zones surveyed with the exception of Ybycuí, near Asunción. CsXV was not detected in any of the plants sampled.

Evaluation of Elite Clones for Resistance to Viruses

A group of seventy-five elite clones was evaluated at CIAT-Palmira, Media Luna and Quilcacé. The incidence of both CsXV and the frogskin disease were highest in the trial planted at Quilcacé (Table 3). The incidence of these diseases in trials planted at CIAT and in Media Luna was much lower. Based on these results Quilcacé, Cauca is the site with the heaviest, uniform inoculum pressure for the evaluation of clones for resistance to CsXV and FSD. At Quilcacé 10 clones were not infected with CsXV after one season and 2 clones were FSD negative (Table 4). These clones have entered a second year of evaluation. Because of the low rate of virus dissemination in CIAT and Media Luna in 1987 it was not possible to compare the reaction of clones across sites. Groups of over 80 elite clones have been planted at these sites in 1988.

Affect of CCMV Infection on Root Yield

In a preliminary yield loss assessment trial comparing plants derived from virus-infected vs. healthy planting material, CCMV reduced the root yield in 30 of the 35 clones evaluated. Percent yield loss ranged from a high of 78% for M Bra 12 to a low of 14% for M Col 1914. The root yield of over half of the clones was reduced by more than 40%. The clones in which root yield was not reduced were CG 313-5, CG 914-3, M Col 1468, M Col 1495, and M Ven 45A. Eight clones from this trial have been planted in a larger replicated trial for further evaluation.

Table 1. The incidence of cassava viral diseases in farmers' fields in the Cauca Department of Colombia

Farm Location	Viral Disease CsXV	FSD	CCMV
Caldono			
101	0/10	0/10	0/10
102	3/10	0/10	0/10
103	10/10	0/10	0/10
104	8/10	0/10	0/10
105	4/10	0/10	0/10
106	3/10	0/10	0/10
107	5/10	0/10	0/10
108	3/10	0/10	0/10
	38/80	0/80	0/80
Morales			
201	7/10	0/10	0/10
202	1/10	0/10	0/10
203	3/10	1/10	0/10
204	5/10	0/10	0/10
205	5/10	2/10	0/10
206	1/10	1/10	0/10
207	5/10	0/10	0/10
	27/70	4/70	0/70
Total (%)	65/150 (43%)	4/150 (3%)	0/150

Table 2. The incidence of cassava viral diseases in farmers' fields and on an agricultural research station in the Magdalena Department of Colombia

Farm Location	Viral Disease			
	CsXV	FSD		CCMV
		Root	Graft	
La Colorada				
1	0/10	0/10	0/10	0/10
2	0/9	0/10	3/10	0/10
3	1/9	0/10	5/10	0/10
4	2/10	0/10	5/10	0/10
5	0/9	0/10	3/10	0/10
	3/47	0/50	16/50	0/50
La Idea				
1	0/9	0/10	6/10	0/9
2	0/10	0/10	3/9	0/10
	0/10	0/20	9/19	0/19
Avianca				
1	0/10	0/10	0/10	0/10
2	0/10	0/10	0/10	0/10
	0/20	0/20	0/20	0/20
Sevilla				
1[a]	1/9	2/12	5/10	0/9
2	1/10	3/10	4/10	0/10
3	0/8	0/10	0/10	0/8
4	0/9	0/10	0/10	0/9
	2/36	5/42	9/40	0/36
Ciénaga				
1	1/8	0/10	0/10	0/10
2	0/10	0/10	1/10	0/10
	1/18	0/20	1/20	0/20
Total (%)	6/140 (4%)	5/152 (3%)	35/149 (23%)	0/145

[a] Agricultural Research Station

Table 3. A comparison of virus inoculum pressure on 75 elite clones grown at three sites during the 1987A-88 season

	CsXV Incidence		FSD Incidence			
			Root Symptoms		Graft	
	# Clones[a]	% Plants[b]	# Clones	% Plants	# Clones	% Plants
CIAT-Palmira	10/72	3	7/72	3	9/72	4
Media Luna	0/73	0	0/73	0	24/73	10
Quilcacé	64/74	41	42/74	32	72/74	70

[a] Number of infected clones/Number of clones tested

[b] Percentage of plants infected in trial

Table 4. Elite clones indexing negative for CsXV and the FSD agent after one growing season in Quilcacé, Cauca

CsXV[a]	FSD Agent[b]
CM 489-1	CM 2157-1
CM 516-7	SM 301-3
CM 723-3	
CM 1553-19	
CM 1785-6	
CM 2632-2	
CM 2766-5	
CM 2777-8	
CM 3251-4	
SG 302-1	

[a] Plants were tested by ELISA

[b] Plants were tested by graft inoculation to M Col 2063

CASSAVA PATHOLOGY - 1988

The following is a summary of the research highlights of the Cassava Pathology group.

A. Phytophthora root rot

Losses induced by *Phytophthora drechsleri* in the Amazonas State of Brazil were calculated (for 1987) at more than 30% of all cassava produced in this State; severe losses were also reported in Pará, Sergipe, Alagoas and other Brazilian States as well as in Mexico and Colombia. Due to the importance of the disease several research projects were initiated during 1988; results are summarized as follows:

1. Etiology

Strains of the causal agent were collected in different cassava growing areas of Latin America. Mycelia growth was not affected by light-dark exposure; the best growth was obtained on Lima-bean-dextrose-agar and on acidified potato-dextrose-agar (Table 1). However, fungal growth was affected by temperature: the optimum temperature for mycelium growth ranged from 20 to 27°C (Table 2). Morphological and cultural studies indicated that there are at least two distinct groups of strains able to infect cassava; they can be differentiated by the shape and size of zoosporangia, presence of clamydospores *in vitro*, ramification of mycelia and sporangiospores, and temperature requirements for zoospore production (Table 3).

2. Screening for resistance

Three methods for screening for resistance to Phytophthora root rot were tested with the aim of developing a reliable and simple screening method. The soil infestation method was variable, showing a relatively low percentage of root infection (Table 4), and required at least 45 days incubation after inoculation. The plantlet immersion method showed the highest level of infection (Table 4), constant rate of reproducibilty and shorter incubation period (20 days). However, this system requires 45-day old plantlets obtained by the shoot rooting method. In contrast, the root-bored inoculation method gave an even level of infection, within an 8 day incubation period and is simple (Table 4). Further research on this subject will continue with a larger number of clones.

3. Chemical control

The fungistatic effect of 17 fungicides was tested *in vitro* against isolates of *Phytophthora drechsleri*. The best fungicides were those that included Cu derivatives. Selected fungicides were tested for their protectant effect on plantlets of suceptible clones. Results showed relatively good protection. Similarly, Difolatan (Captafol) and Fosetyl Othocide (Captan) are also effective; however, more research is necessary before any recommendations can be given.

4. Control by cultural practices.

Planting on ridges has been one of the most effective methods for the control of this disease in several locations of America (CIAT Annual Reports 1973, 1974). Recent preliminary results showed that crop rotation with rice or corn is also efficient however fallowing maintains inoculum potential at high relative levels. A cooperative research project with UEPAE-Manaos (Unidade de Execucao de Pesquisa Agropecuaria de Ambito Estadual), EMBRAPA and CIAT was initiated this year in Manaos. The project includes research on control by chemical treatment of cuttings, cultural practices (crop rotation, mixedcropping, planting on ridges, and selection of planting material), and varietal resistance. Results will be later validated in several locations of the Amazones, Para, Macapá and Alagoas States of Brazil with the cooperation of researchers from State enterprises who are being trained at CIAT for this purpose.

B. Diplodia root rot

Diplodia manihotis is able to affect several plant species causing stem and root rot, and dieback. Isolates collected in Media Luna (a Diplodia endemic area) from different plant species were pathogenic to Manihot esculenta; their severity varied between isolate vs. inoculated cassava clones (Table 5). This indicates the broad pathogenic behavior of the pathogen and a possible low pathogenic specialization among hosts.

The broad pathogenicity of this pathogen was also evident when botanical seeds of several crop species were inoculated (seed immersion in 4×10^4 pycniospores/ml) before or after seed wounding (Table 6). The pathogen was able to infect seeds of all inoculated species, but unwounded seeds of sorghum (var. ICA-Nataima-1) were not affected; wounded seeds of sorghum were mildly affected, but at a very low percentage (Table 6). It is evident from these results that sorghum appears to be the best crop to be used for crop rotation in Diplodia-affected areas; Crotolaria, cowpea and sesame should not be used as rotating crops since they are readily infected by this pathogen.

C. Biological control

The possibility of production of growth regulators by strains of beneficial fluorescent pseudomonads from cassava rhizospheres was suggested because of the increased number and size of roots produced by shoots after treatments with bacterial suspensions or crude extracts of bacterial growth of some strains of fluorescent pseudomonads (CIAT Annual Reports 1986 and 1987).

Plus and minus L-tryptophan culture (P. putida, strain F-44) supernatants were spotted in silica gel thin-layer chromatography plates developed in three separate solvent systems: chloroform: ethylacetate: formic acid (CEF); ethylacetate:isopropanol: ammonia (EIA); and ethylacetate:butanol:ammonia (EBA). Rf's fractions similar to standard indolacetic acid (IAA) controls were obtained in EBA-plates spotted with the L-tryptophan + supernatant (Table 7). Hypocotyls of beans, and cassava (clones M Col 2059 and M Col 2061) treated with water suspensions of the L-tryptophan + supernatant on EBA-spotted plates showed elongation as did IAA standard treated controls; they were significantly longer (0.05 levels) than distilled water treated controls. Treated corn-hypocotyls were not elongated; the effect was negative as shown by corn hypocotyls IAA-treated controls, indicating insensitivity to those compounds. The number of roots produced by hypocotyls of beans and cassava treated with IAA (0.876 ppm) or with the Rf=0.88 L-tryptophan + supernatant at 0.5 concentration was significantly (0.05 level) higher than water treated control (Table 8).

These and previous studies (CIAT Annual Reports 1986, 1987) provide more evidence that strains of P. putida (and very possibly P. fluorescens) from cassava rhizosphere may act as biocontrol agents as well as plant growth promoters by the production of phytohormones such as IAA. Their importance is therefore very suggestive.

D. Relationship between Phymatotrichum root rot and flooding tolerance.

In collaborative studies between the Pathology and Breeding sections, twenty-six cassava clones growing in plastic pots with non-sterile soil were flooded for up to 48h and evaluated after 12 days for tolerance to flooding. Four of the clones were rated as resistant based upon the level of wilting and root damage. Samples from rotted roots consistently yielded Fusarium oxysporum and Phymatotrichum spp. infection. Further swollen root evaluation for resistance to these two pathogens showed a positive correlation (0.82) between resistance to Phymatotrichum root rot and flooding. No correlation was found between resistance to flooding and to F. oxysporum.

This tolerance to flooding was later confirmed by planting shoots from plantlets of four "resistant" and four "susceptible" (rated as such under the above unsterile system) in a sterile hydroponic system. Results showed sharp differences among the susceptible/resistant clones specially in relation to leaf retention (Fig. 1), plant size, root dry weight, and stem and leaf dry weight 12 days after flooding (Table 9).

The above results strongly suggest the existence of tolerance to flooding in cassava; the relationship of this type of resistance with the resistance to Phymatotrichum root rot in infested soils could be related to the penetration system used by the pathogen to infect the cassava roots. This merits further research. On the other hand, the hydroponic growth system under sterile conditions used appears to be a very reliable method for screening for resistance to flooding, since it is possible to eliminate the effect of root pathogens that can control results.

E. Clonal stability

Clonal stability at high production levels is a highly desirable objective for selection in cassava improvement programs. It is partially the result of the genetic resistance to biotic and abiotic constraints in a given edaphoclimatic zone. Even though highly stable clones exist for different ECZ's, variability in their performance have been sometimes observed. To investigate factors that can decrease stability of resistant clones for Carimagua (ECZ II), a location with severe edaphic and biotic constraints, selected fungicide treated cuttings of a resistant (M Ven 77) and two susceptible (M Col 1468 and M Col 2066) clones from two different sources (meristem derived plants and Carimagua fields) were planted. The following results were obtained: a) susceptible clones were not able to survive even though cuttings were selected and chemically treated before planting; they should not be planted in this environment; b) yields of the resistant clone (M Ven 77) were stable in plots planted with selected, treated cuttings from Carimagua fields, but they decreased when selected-treated cuttings were taken from meristem derived plants grown at CIAT (Table 10). As reported previously (CIAT Annual Reports 1986, 1987), native microflora, eliminated by the meristem culturing system, play an important role in protecting and maintaining the intrinsic genetic stability of the resistant clones. Bacterization to meristem derived plants may overcome this problem.

The stability of the resistant clone M Ven 77 was evident for two cycles in plots planted with cuttings from CIAT and Carimagua fields, but decreased (comparing the first with the second cycle) at significant levels (0.01) in plots planted with cuttings from meristem derived plants (Table 11). Both bacterization and chemical treatments increased yields significantly (0.05 levels); these were higher on plots planted with cuttings taken from Carimagua fields than from CIAT (Table 11). These results show the positive effect induced by chemical or bacteriological treatments to cuttings. Consequently, the stability of highly resistant clones at high yielding rates can be maintained by visual selection and cutting treatments in addition to appropriate cultural practices specially applied to plots maintained for production of cuttings.

F. Cultural practices

The effect of some cultural practices on disease control (especially root rots) has been evaluated in several locations. A summary of the highlights of this investigation is as follows:

1. Crop rotation or fallow

Plots planted in Media Luna (sandy soils with low organic matter content), were fallowed or rotated with corn, sesame (*S. inducum*) and cowpea (*Vigna ungiculata*) for a year before planting cassava, and compared with plots under continuous cassava planting. Results showed that the highest cassava yield (t/ha) and NPK uptake (determined by leaf nutrient analysis) were present in fallowed plots. Similarly, microbial recovery at planting showed that the lowest concentration of *Fusarium* spp (a soilborne inhabitant capable of inducing root rots) was found in fallowed plots (Table 12). Additionally, the number of earthworms castings were around four times higher on fallowed plots than on either corn-sesame or corn-beans plots; microbial population in the castings had a high concentration of bacterial species, most of which are capable of inducing *in vitro* growth inhibition of *F. oxysporum* and *F. solani* cultures. The low root rot pathogen population may explain the higher yields in fallowed plots (Table 12) in addition to the improved nutritional effect that the earthworms are contributing. Results also explain growers' preference to fallow instead of crop rotation to obtain better yields in Media Luna. Research on all these interactions is being carried out with the physiology group (see Cassava Physiology section).

In contrast, similar trials planted at CIAT- Palmira (a clayey soil with high organic matter content) showed that the best yields were obtained in rotated crop combinations (Table 13). Bacterial populations on unrotated plots was considerably low while *Fusarium* and *Phytophthora* species populations were very high (Table 13). It appears that rotation favored beneficial bacterial activity in these soils which resulted in yield increase and root rot biocontrol.

2. Mixcropping

The effect of mixcroppig cassava with corn was evaluated at Media Luna by planting plots where two cassava rows alternated with two rows of corn. Results showed that the severity of both CBB and brown leaf spot (two foliar diseases) was significantly (0.05 level) less in mixcropped than in monocropped plots. Yields were also significantly higher (Table 14) and results also showed a positive effect of mixcropping in controlling root rots (Table 14).

The reduction of both severity and incidence of CBB by mixcropping cassava with corn was evident in a commercial farmer field (Table 15). The above results indicate that mixcropping with corn effectively reduces foliar diseases as well as root rots, as reported previously, in Media Luna ECZ (CIAT Annual Reports, 1986 and 1987).

3. Pruning

Pruning cassava plants in infected plantations at the end of the rainy season is a CBB-control measure that was reported in 1972 (CIAT, Annual Report 1972). During this year, due to the abnormally long rainy period in the North Coast of Colombia CBB severity was particularly high; this allowed us to validate the pruning practice on several commercial cassava plantations. Results showed the practice to be highly effective (Table 16): both disease incidence and severity were much lower on pruned plantations than on unpruned ones. However, on mixcropped cassava-corn plantations CBB incidence and severity was much lower (Table 16). Consequently, pruning most of the above ground portion of infected plants and eliminating by burning infected debris in severely infected plantations to control CBB is effective due to slowing down the spreading of the pathogen and decreasing inoculum potential. However, this practice should only be done at the end of the rainy period in order to avoid new reinfections by the effect of rainfall splashing.

G. <u>Storage of planting material</u>

A summary of the research of storage on planting material of cassava was reported last year (CIAT Annual Report, 1987) showing the factors involved and its general negative effect on production especially on susceptible clones, thus suggesting that this practice should be avoided. However, if it is absolutely necessary, by watering during the first two weeks of storage and using long, treated cuttings, yields of stored-resistant clones can be maintained or improved compared to susceptible clones (Table 17). By watering long cuttings during the first days of storage they can root and sprout allowing them to maintain satisfactory nutrient levels to feed the new shoots arising from the short cuttings used for planting.

H. <u>New method for the interchange of indexed vegetative planting material of cassava</u>

The exchange of vegetative planting material of cassava is being done as meristem culture derived plantlets in test tubes. Material under this condition is accepted everywhere with few quarantine restrictions; however, due to the weakness of the plantlets in the

test tubes, losses are common (sometimes 100%) as well as delays in obtaining adult plants (normally between 1.1/2 to 2 years).
In order to overcome these problems the following system has been developed: 30-days old shoots from indexed mother plants (meristem-derived plants previously tested for their sanitary status) are cut into 10cm sections and deposited in a container with deionized water to avoid dehydration during the cutting. Shoot cuttings are then removed from the water and dusted with Arasan (Thiram); each of their extremes (1-2cms) are wrapped with parafilm. Shoot cuttings are then organized in bundles of 5 shoot cuttings each and their bottom first-half is wrapped with paper towels previously sprayed with a Benomyl-Captan (3g/l each) suspension. The paper towel wrapped portion of the bundles is then covered with a plastic bag and sealed with rubber bands. Bundles are then arranged in cardboard boxes, which should have several holes to allow air exchange, for shipping. Under this system shoot cuttings have a shelf life of more than 15 days.
At the recipient locality, shoot cuttings should be planted in pots with sterile soil and covered with plastic bags with 4 to 6 holes which maintains a high RH and permits air exchange. Soil should be kept moist but not saturated. Ten to twelve days later, when shoots have rooted and buds germinated, the plastic bags should be removed. Two weeks later the new plants can be planted in the field.
Following the above system it is possible to obtain 90 to 100% establishment at 20 days after packing and adult plants 7 to 10 months later. If mother plants are virus indexed and maintained free from insect vectors of cassava viruses quarantine risks can be minimized.

I. A cassava production system for the Media Luna area (ECZI)

The following system for cassava production was tested in Media Luna on a farmer's field:

1. Land: Selected land was previously planted with corn and then fallowed for a semester. Weeds were incorporated into the soil before planting cassava by plowing once and discing 3 times.
2. Cutting sources: Twenty-cm cuttings from eleven-months old high yielding plants of Verdecita (M Col 1505) were visually selected and treated for 20 min in a suspension of Systemin (2cc/l), Benomyl and Captan (3g/l each) before planting.
3. Weed control: Plots were sprayed after planting with Karmex (2kg/h) and Lazo (3l/ha) as a preemergent weed control practice. Three months later weeds were controlled by machete 3 times during the growing cycle (11 months) as required.
4. Fertilization. Plots were foliar sprayed twice with $ZnSO_4$, Mg_2SO_4, and urea (30g/18 liters of water each) at the 3rd. and 5th. months of planting.

   Results following the above system are shown in Table 18 in comparison with the yield obtained by the traditional system used in an adjacent plot. The traditional system consisted of using plots previously planted for 3 years to cassava; preparation by plowing and 1 discing; hand weed control; and no fertilization.

Planting material was not selected or treated. Further investigation, including economic analysis and additional inputs, is being carried out with the aim of defining a technological package for cassava production in this area.

Table 1. Growth of *Phytophthora drechsleri* on different media under continuous fluorescent light or dark exposures at 27°C for 15 days.

	Mycelial growth (cm)	
	Light	Dark
Growth medium	(f.c.)	
Lima-bean-dextrose-agar	9*	9
V-8 juice-agar	6	7
Potato-dextrose-agar	9	9
Mineral salts	0	0
Petri medium	3	1

*Average data for 25 strains planted in 5 Petri dishes each/medium used.

Table 2. Temperature effect on growth of *Phytophthora drechsleri* strains on different media and incubated for 15 days under continuous fluorescent light.

	Growth (cm) under different temperatures(°C)			
Growth medium	15	20	27	34
Lima bean-dextrose agar	0*	9	9	0
V-8 juice-agar	0	6	6	0
Potato-dextrose-agar	0	9	9	0
Mineral salts	0	0	0	0
Petri medium	0	3	3	0

*Average data for 25 strains in 5 Petri dishes each/medium and temperature used.

Table 3. Morphological and cultural characteristics of two groups of strains of *P. drechsleri* grown on potato-dextrose-agar under continuous fluorescent light at 27°C for 15 days.

Characteristics	Group 1	Group 2
Mycelia	Branched	Simple
Zoosporangiophores	Branched	Simple
Zoosporangia	Papillate (50x26)	Non-papillate (43-46X31-32)
Chlamidospores	Not produced *in vitro*	Abundant *in vitro*; spheric and terminal
Optimum temperature	28-31°C	26-30°C
Zoospore production	At 5°C after 1h incubation	At 25°C after less than 5min incubation

Table 4. Percentage of root rot of several clones inoculated with *Phytophthora drechsleri* by three inoculation methods.

Clone number	% of root rot/inoculation method soil* infestation	 root-bored* inoculation	 plantlet* immersion
M Col 113	–	100	100
M Col 1684	49	53	86
M Col 523-7	52	65	78
M Col 1468	–	51	54

* Inoculation methods: 1) soil infestation: 20ml of inoculum (9.4×10^3 sporangia/ml) was poured to 45 days-old potted plantlets; 2) swollen roots of 10-12 months-old plants were bored and discs of agar-mycelium (two weeks-old growth on PDA) were introduced into the hole; 3) forty five-days-old plantlets were immersed for 20min in a suspension of 9.4×10^3 sporangia/ml.

Table 5. Pathogenicity of 5 isolates from different plant species to 3 cassava clones under controlled greenhouse conditions.

	Inoculated cassava clone		
Isolate source	M Col 1468	M Col 1684	M Col 2065
Cassava . (*M. esculenta*)	100*	100	100
Mango (*Mangifera indica*)	46	52	100
Crotalaria (*C. espectabilis*)	100	65	100
Totumo (*Crescentia cujete*)	77	85	100
Espinoso (*Senegalia westiana*)	98	91	100

* Average percentage of tissue affected/inoculated cutting after 20 days of incubation at 90-100% RH. Data of at least 10 inoculated cuttings/ strain/cassava clone

Table 6. Percentage of seed infection ten days after inoculating wounded and unwounded seeds of 10 crop species (20 seed/crop) with *D. manihotis*.

	Seeds			
	Wounded		Unwounded	
Crop species	Germination (%)	Seedling damage (%)	Germination (%)	Seedling damage (%)
Cotton (*Gossypium hirsutum*)	100	75*	100	90*
Crotalaria (*C. espectabilis*)	10	100	25	88
Soybean (*Glycine max*)	70	65	20	90
Cowpea (*Vigna unguiculata*)	90	50	40	92
Bean (*Phaseoulus vulgaris*)	60	70	0	100
Sesame (*Sesamum indicum*)	20	96	0	100
Corn (*Zea mays*)	80	30	70	80
Sorghum (*Sorghum bicolor*)	100	0	92	8

* Percentage of seedling: visible damage, taken 10 days after seed inoculation as well as stem and root tissue discoloration.

Table 7. Rf's in silica gel thin layer chromatography plates spotted with +-L-tryptophan culture (*Pseudomonas putida*, F-44) supernatants developed in three separate solvent systems.

Culture supernatant source	Solvent		
	CEF*	EIA*	EBA*
L-tryptophan +	0.40	0.33	0.88
L-tryptophan -	0.38	0.30	0.78
IAA-control	0.58	0.37	0.88

* Solvent: CEF=Chloroform: ethyl acetate: formic acid;
EIA=Ethylacetate: isopropanol: ammonia;
EBA=Ethylacetate: butanol: ammonia.

Table 8. Effect of the Rf= 0.88 fraction obtained in silica gel thin layer chromatography plates spotted with L-tryptophan + culture (*Pseudomonas putida*, F-44) supernatants on beans (*Vigna mungo*), corn (var. Swan 1) and cassava (clones M Col 2059 and M Col 2061) hypocotyls, 10 days after treatments.

	Root number and length/fraction concentration							
	0		0.1		0.5		IAA controls (0.876 ppm)	
Hypocotyl source	N*	L**	N	L	N	L	N	L
Beans	9.4	4.7b	10.2	7.8a	12.0	7.2a	10.8	7.5a
Corn	4.0	20.0ab	5.6	23.8a	4.3	15.4b	3.0	13.4b
M Col 2059	4.2	22.5b	5.2	38.6a	7.5	40.2a	7.2	40.0a
M Col 2061	5.2	50.2c	6.4	92.8a	6.2	88.6a	6.1	78.8ab

* N= Average number of roots produced by 15 hypocotyls/treatment;

** L= Average length (mm) of roots produced by the 15 hypocotyl treated; numbers followed by different letters are significant (0.05 levels) as fraction concentration increases.

Table 9. Decrease (%) on plant size, root, and stem and leaf dry weight of 8 clones rated as resistant or susceptible to flooding 12 days after a 48h period of flooding.

Clone number	Plant size	Root dry weight	stem and leaf dry weight
M Bra 125 (R)*	61**	17	35
M Ind-4 (R)	72	60	46
M Ven 156 (R)	72	65	49
CG 165-2 (R)	76	64	54
$\bar{X}$	70.3	51.5	46.0
M Cub 74 (S)	94	82	79
CM 2766-5 (S)	94	70	67
CM 975-1 (S)	9[illegible]	79	64
M Col 22 (S)	8[illegible]	80	83
$\bar{X}$	[illegible]0.8	77.8	73.3

* Evaluation for resistance to flooding based on percentage of wilting and root deterioration (R= resistant, less than 30%); S= susceptible, more than 30%).

** Data taken from plantlets/clone.

Table 10. Fresh yield (t/ha) of a resistant (M Ven 77) and two susceptible (M Col 1468 and M Col 2066) clones after three consecutive cycles by using selected and chemically treated* cuttings from two different sources: (Carimagua fields (FF) and meristem derived plants (MDP) grown at CIAT).

Cycle number	Fresh yield (t/ha)/clone/cutting source					
	M VEN 77		M COL 1468		M COL 2066	
	MDP	FF	MDP	FF	MDP	FF
I	7.6**	8.2	2.3	1.9	1.5	1.2
II	6.9	8.4	1.3	0.8	1.2	0.2
III	5.4	8.0	1.0	0.5	0.3	0.0

* Chemical treatment: immersion for 5 min in a suspension of Systemin (2cc/1); Benomyl and Captan (6g/1, each).

** Average data taken from 4 replicates with 30 plants each.

Table 11. Fresh yield (t/ha) of a resistant clone (M Ven 77) planted in Carimagua for two consecutive cycles by using selected cuttings from three different sources and treated with fungicides or bacterized.

Source** of cuttings	Cutting treatments*: Bacterization	Chemical	Untreated Controls
MDP			
Cycle I	9.1a***	10.5a	7.2b
Cycle II	8.3a	8.9a	5.8b
CIAT			
Cycle I	9.5a	9.7a	6.2b
Cycle II	9.0a	9.9a	6.8b
Carimagua			
Cycle I	10.6a	11.5a	8.6b
Cycle II	10.4a	11.2a	8.2b

* Cutting treatments: Immersion for 5min in a suspension of: a) beneficial fluorescent bacteria (1×10^9 cfu/ml of *Pseudomonas putida*, F-44); b) chemical: Systemin (2cc/ml); Benomyl and Captan (3g/l, each).

** Source of cuttings: MDP= Meristem derived plants grown at CIAT; CIAT= Cuttings for the first cycle were taken from CIAT farmers' plots; Carimagua= Cuttings for first and second cycles were taken from Carimagua fields.

*** Average data taken from 4 replicates with 30 plants each. Data followed by different letters were significant at 0.05 levels.

Table 12. Effect of fallow and crop rotation at Media Luna (sandy soils with low organic matter content) on yield, N-P-K uptake and *Fusarium* spp. concentration. Plots were not fertilized.

Cropping system	Fresh yield (t/ha)	Nutrient uptake (Kg/ha) N	P	K	*Fusarium* spp. (spores/g of soil)
Cassava-fallow-cassava	8.0a*	91.6	7.5	35.1	$2.2x10^1$
Cassava-cassava-cassava	7.2a	70.4	5.6	22.8	$1.1x10^2$
Cassava-corn/sesame-cassava	6.3ab	57.8	5.2	18.8	$5.8x10^3$
Cassava-corn/cowpea-cassava	4.8b	60.3	5.1	19.9	$2.4x10^4$

* Data taken from 4 replicates/treatment with 30 plants each. Data on fresh yield followed by different letters are significantly different at 0.01.

Table 13. Effect of fallow and crop rotation at CIAT-Palmira (clayey soils with high content of organic matter) on fresh yield of cassava and microbial populations.

Cropping system*/year	Fresh yield** (ton/ha)	Concentration (cfu/g of soil) of fungal species: Aspergillus	Penicillium	Fusarium	Bacterial population (cfu/g of soil)
1. Cassava-sorghum/sorghum-cassava	24a	$3.0x10^1$	$2.9x10^3$	$6.5x10^2$	$2.0x10^6$
2. Cassava-corn/corn-cassava	19a	$2.2x10^3$	$3.5x10^2$	$1.3x10^2$	$2.2x10^6$
3. Cassava-corn/sorghum-cassava	20a	$1.6x10^2$	$2.2x10^3$	$3.3x10^2$	$1.8x10^6$
4. Cassava-sorghum/corn-cassava	20a	$1.9x10^3$	$3.1x10^2$	$7.3x10^2$	$1.8x10^6$
5. Cassava-beans/sorghum-cassava	23a	$1.1x10^2$	$4.7x10^3$	$5.7x10^2$	$2.0x10^6$
6. Cassava-corn-beans-cassava	18a	$1.9x10^3$	$1.4x10^2$	$1.5x10^3$	$3.5x10^5$
7. Cassava-sorghum/beans-cassava	24a	$2.0x10^1$	$7.2x10^3$	$6.0x10^3$	$6.0x10^5$
8. Cassava-beans/corn-cassava	21a	$2.4x10^3$	$0.6x10^2$	$4.2x10^2$	$1.3x10^5$
9. Cassava-beans/beans-cassava	24a	$8.4x10^2$	$1.2x10^3$	$2.4x10^3$	$6.7x10^4$
10. Cassava-fallow-cassava	19a	$1.0x10^1$	$5.0x10^3$	$7.0x10^3$	$1.8x10^5$
11. Cassava-cassava-cassava	7b	$2.1x10^2$	$4.9x10^3$	$2.5x10^6$	$1.3x10^2$

* The following clones/vars. were used for cropping: cassava=M Col 1468; sorghum=ICA-Nataima; corn=Swan 1; bean= *Phaseoulus vulgaris*, PVD-916 Type 1.

** Data taken from 4 replicates/cropping system with an area of $150m^2$/plot. Yield data followed by different letter are significant at 0.05 level.

Table 14. Effect of cassava (M Col 2215)-corn mixcropping on fresh yield (t/ha), and cassava bacterial blight (CBB) and brown leaf spot (BLS) severities.

Planting system	Fresh yield (t/ha)	Root root (%)	Disease severity CBB	BLS
Cassava-corn mixcropping	16.7a	2.3b	2.4b	2.3b
Cassava monoculture	9.6b	13.7a	3.7a	3.5a

* Disease severity: CBB: 1=leaf spots; 5=plant death or diebacked BLS: combined data on affected leaf area and percentage of affected leaves/plant.

** Average data taken from four plots/treatment with 400 cassava plants mix-cropping every two rows with corn and 800 cassava plants under monoculture. Data between planting systems followed by different letters are significantly different at 0.05 levels.

Table 15. Incidence and severity of cassava bacterial blight (CBB) on five-months old commercial plantations under corn-cassava mixcropping and cassava monocropping systems in Mandinga, North Coast of Colombia.

Cropping system	CBB-severity*			Incidence (%)
	Minimum	Maximum	Average	
Cassava monocropping	1.0	4.0	2.5	85
Corn-cassava mixcropping***	1.0	2.5	1.6	30

* Disease severity: 1=angular leaf spots; 5=plant diebacked or death. Incidence=percentage of infected plants in the whole plantations.

** Average data taken from plantations ranging 0.5 to 2.5ha.

*** Alternated rows of cassava and corn.

Table 16. Incidence and severity of cassava bacterial blight (CBB) on five to six months old commercial plantations with cassava monocropping (pruned or unpruned) and cassava-corn-mixcropping in Mandinga (Bolivar, North Coast of Colombia).

	CBB-severity*			
Cropping system	Minimum	Maximum	Average	Incidence* (%)
Cassava monocropping (unpruned)	2.0**	4.5	3.6	100
Cassava monocropping (pruned)***	1.0	2.5	1.6	50
Corn-cassava mixcropping***	1.0	2.0	1.1	10

* Disease severity: 1=angular leaf spots; 5=plant diebacked or death. Incidence: percentage of infected plants in the whole plantations.

** Average data taken from plantations ranging 0.5 to 2.0ha.

*** Pruning: most cassava plant above ground was cut, collected and burnt. Mixcropping: alternated rows of cassava and corn.

Table 17. Fresh yields of M Col 1468 (resistant to storage) and M Col 1684 (susceptible to storage) from plots planted with cuttings from 1.2m (average) stems stored during 90 days by planting them under open field and watering daily for two weeks or every 5 days during the storage period.

Storage treatment*	Fresh root yield (t/ha)	
	M Col 1468	M Col 1684
1. Daily watering for 15 days		
.stems stored separated	29**	19
.stems stored as bundles	28	18
2. Every 5 days watering for 90 days		
.stems stored separated	29	19
.stems stored as bundles	28	15
3. No watering during storage period		
.stems stored separated	16	11
.stems stored as bundles	16	9
4. Unstored stem controls	26	32

* 1.2m long cuttings treated for 20min with Captan-Benomyl (6g/l each) before the storage period. Each bundle contained 30 long cuttings. the short cuttings (0.2m length) were treated again before planting.

** Yield data from 4 replicates/treatment with 64 plants each.

Table 18. Comparative yield (as weight of fresh roots and of selected cuttings) obtained in a farmer's field by applying a technological package* and the traditional system for cassava production in Media Luna.

Production system	Number of plants/ ha at harvest	Fresh root weight (t/ha)	Weight (t/ha) of selected cuttings produced
With technology	9.250a	28.8a	16.2a
Without technology	5.813b	8.2b	1.9b

* See the technological package description in the text. Data between production systems follow by different letters are significantly different at 0.05 levels.

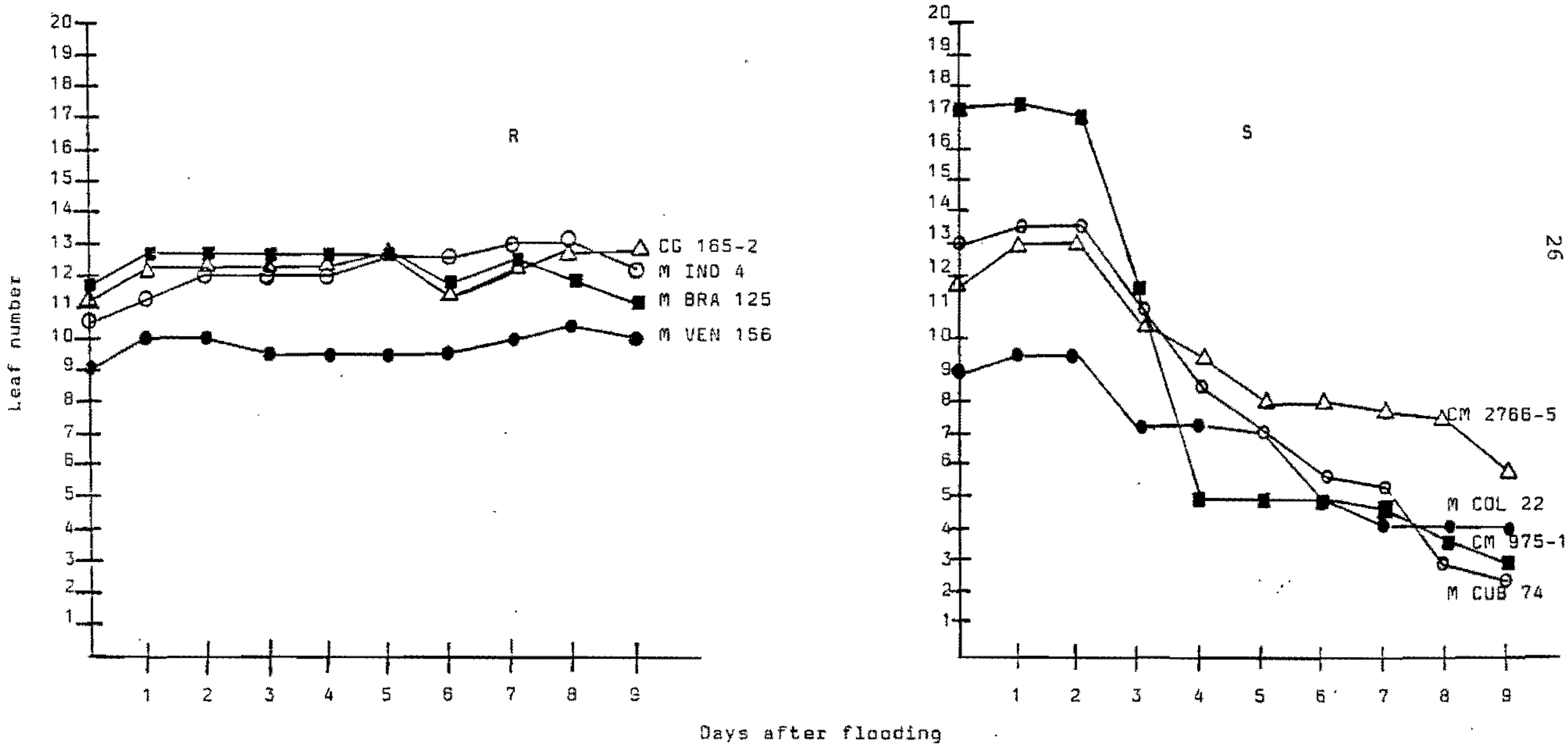


Fig. 1. Leaf retention of eight cassava clones (Resistant=R or Susceptible=S) after a 72 h period of flooding.

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Mealybugs

Yield losses in cassava due to the feeding of the mealybug Phenacoccus herreni have been measured as high as 80%. The effect of mealybug infestation on the germintion of stem cuttings and the subsequent root yields was also measured. Cassava cuttings with 50 to 100% of this surface and buds infested with mealy bugs were compared to planting material free of mealy bugs. The effect of a pesticide treatment on the germination of infested cuttings and their subsequent yield was also evaluated.

Germination was most reduced on CMC 57 on both the treated (32%) and untreated (37%) cuttings (Table 1). In general the treatment of mealy bug infested cuttings with a pesticide dip improved germination. Reduction in plant vigor and the production of planting material was also most severe in CMC-57 especially on those plants that resulted from untreated cuttings. M Pan 70 showed no reduction in yield for the treated or untreated cuttings while for M Bra-12 and CMC-57 yields were reduced considerably.

The effect of P. herreni attack on cassava plants at different ages was determined in field studies in Carimagua. Cassava plants at 2, 4, 6, and 8 months of age were infested with 3 mealybug ovisacs and then harvested at 12 months. Results show a correlation between plant age at the time of mealybug attack and reduction in plant vigor and root yield (Table 2). Plants infested at 2 months resulted in 100 percent plant mortality. Root yields were reduced by 50, 37, and 11 percent when mealybug infestation occurred at 4, 6, and 8 months respectively and dry matter content was reduced by 35, 24, and 8% for each corresponding treatment. These results indicate that cassava is most susceptible to mealybug attack during its early stages (0 to 6 months) of crop growth and that yield reductions are minimal if attacks occur during the latter stages (8 to 12 months).

Previous studies have shown that mealybug (P. herreni) feeding will extract considerable amounts of calcium from leaf tissue. It is concluded that this extraction contributes to the leaf, stem, and plant deformations that are characteristic of P. herreni feeding. Addittional studies have determined the effect of P. herreni feeding and damage on photosyntethic rate. The varieties SM 301-3 (0.54% Ca content) and CM 2087-101 (0.78% Ca content) were infested at 30 days of age with one P. herreni ovisac. When compared to non-infested plants, infested plants showed a considerable reduction in photosynthetic rate, transpiration, mesophil efficiency, and a moderate increase in water pressure deficit, internal CO_2, and leaf temperature (Table 3). The reduction in photosynthetic rate for SM 301-3 was 54.2% and for CM 2087-101, 45.4%, indicating that those varieties with a higher Ca content may be more tollerant to P. herreni attack.

Biological Control

Methodologies have been developed for the mass rearing of P. herreni predators. Three shipments of the Coccinellidae, Cleothera notata have been sent to CIBC in England for subsequent shipment to IITA in Nigeria.

Mites

Field Surveys in Colombia

Thirty cassava farms in the north coast of Colombia were divided into 4 groups, based on climate and agronomic characteristics, referred to as Tolu, Sincelejo, Betulia, and Cordoba. Each farm was visited 4 times during the dry season. Fifty young and fifty mature leaves were sampled randomly from cassava plantings on each farm. Tetranychids were counted with a stereoscope and adult phytoseiids were collected for subsequent identification.

Mean tetranychid density per leaf was 5.9 (SD = 5.5), 10.4 (SD = 7.4), 5.8 (SD = 8.3) and 4.5 (SD = 4.8) in November, January, February, and March respectively. Olygonychus spp. were twice as abundant as Tetranychus spp. and nearly 4 times as numerous as Mononychellus spp. The highest phytoseiid density per leaf ($\bar{X}$ = 0.26, SD = 0.19) occurred in November (Table 4). Phytoseiid numbers declined from November to March, and were found in 100, 87, 67, and 45% of the samples respectively.

The most common species were Typhlodromalus limonicus (TL) (found in 54% of samples), Typhlodromips dentilis (18%), Amblyseius aeriales (7%) and Proprioseiopsis cannaensis (6%) (Table 4). Significantly higher phytoseiid densities were found in Tolu and Sincelejo than in Betulia; Cordoba was intermediate (Table 5). Tolu had lower densities of phytophagous mites than the other sites, and the ratio of predators to prey there was twice than of Betulia (Table 6).

Effect of Cassava clone on Phytoseiid Predators

Field Studies

Cassava green mite (CGM) (M. progresivus) and its phytoseiid natural enemies were sampled 10 times in 20 field-grown cassava clones. The number of phytoseiids on 10 randomly chosen leaves per clone in each of 3 blocks was counted directly in the field. The number of CGM per leaf was counted under magnification.

CGM densities peaked when evaporation-precipitation was negative, and phytoseiids appeared to respond in a density-dependent fashion to CGM (Figure 1). When mite density peaked at over 100 per leaf, some clones had fewer than 10 CGM per leaf. There was considerable variation between clones in the number of phytoseiids per leaf, especially during the period of peak CGM density, and significant differences between clones were found in predator-prey ratios ($P \leq 0.05$) (Figure 2). Clones with predator-prey ratios above the mean (0.059 phytoseiids/CGM) were CG354-2, CM342-170, CM681-2, CM849-1, CM1015-16, M Col 1684 and HMC-1.

Laboratory Studies

Life tables were constructed for CGM reared on each of 14 cassava clones. Colonies of CGM were then established on 5 clones with contrasting CGM life table parameters and life tables were constructed for TL, offering CGM reared on each clones as prey. All experiments were conducted at 25°C; 70 ± 5% R.H.; 12:12D photoperiod.

Survival of CGM from egg to adult was ⩾ 85% in tolerant and susceptible clones and ⩽ 76% in resistant clones. Egg-to-adult development time was significantly shorter ($P \leqslant 0.05$) on tolerant and susceptible than on resistant clones (Table 7). CGM reared on clones which resulted in early first reproduction and in long-lived adult females produced more eggs per female (Table 8). Resistance delayed and dampened reproduction and resulted in short-lived females with low fecundity. The intrinsic rate of increase (r_m) was more highly correlated with net reproductive rate (R_o) ($r = 0.99$) than with development time ($r = 0.79$), suggesting that clone has a greater influence on reproduction than on development time of CGM.

The lowest yield losses from CGM should occur on clones which support a low r_m in CGM and a high r_m in CGM predators. These conditions are satisfied by the clones M Mex 59 and M Cub 72 (Figure 3). Favorable r_m of TL on clones which are poor hosts for CGM indicates that resistance factors not detrimental to the third trophic level are available in the cassava germplasm.

Predator-prey Population Dynamics

Unsprayed field plots (at CIAT) were compared with plots where predators were eliminated with permethrin. In the predator elimination treatment, CGM densities peaked at a mean of 300 mites/leaf ($n = 60$) when evaporation-precipitation was negative (Figure 4). In plots where predators were present, CGM densities remained below 80/leaf. The phytoseiids TL, *A. anonymus*, *Euseius concordis* and *E. caseariae* were found at densities ⩾ 0.03/leaf, whereas *T. aripo*, *Galendromus annectens* and *A. californicus* densities never exceeded 0.15/leaf. TL and *E. concordis* were found on all sampling dates. TL appeared to respond in a density-dependent fashion to CGM, and *A. anonymus* density was inversely related to that of TL. *E. concordis* numbers remained fairly constant except when evaporation-precipitation rose above 40 mm; under wet conditions *E. concordis* density rose to 1.2/leaf.

Releases of *A. californicus*, a species not found at CIAT, were made between 1700 and 2200 degree-days (DD). Recoveries were made from 2400 DD until the final sampling date at 3100 DD. An increase in *A. californicus* density was coincident with a rise in evaporation-precipitation to above 40 mm.

Phytoseiid Life Tables

Life tables were completed for 11 phytoseiids comparing *T. urticae* and CGM as prey. There was little effect of prey species on reproductive parameters (Table 9) except in TL which has longer-lived adult females, which oviposited for longer and laid more eggs with CGM as prey. A negative r_m was observed when T. urticae was offered as prey (Table 10). R_m was in the range of 0.14 to 0.24 for all species except E. concordis which had a low value on both prey species.

Role of Non-acarine Foods in the Diet of T. limonicus

In laboratory experiments at 25°C; 70 5% R.H., TL was able to complete development with Ricinus communis pollen, cassava exudate, mildew (Oidium manihotis), Frankliniella williamsi, CGM or T. urticae as food. Development time was longest on exudate and T. urticae. Oviposition occurred with all diets except exudate, and total fecundity was greatest with the CGM diet.

Olfactometry

A. californicus, A. anonymus, Cydnodromella pilosa, A. aerialis, G. annectens, Typhlodromalus neotunus, Phytoseiulus macropilis, E. concordis, A. idaeus, P. persimilis, and TL were tested in a y-tube olfactometer[1] to determine which react to odors emitted by CGM feeding on cassva leaves. Leaves infested with 200 adult female CMG were placed in one arm of the olfactometer with no odor source in the second arm. Female phytoseiids were introduced individually and the number which walked upwind to the far end of the olfactometer was scored for each arm. Mites which did not make a choice within 5 minutes were not included in the analyses.

A. californicus, A. anonymus, C. pilosa, P. persimilis, and TL reacted positively to the presence of CGM-infested leaves (Table 11). These species were retested in a trial comparing CGM-infested leaves with clean leaves. All chose the arm with infested leaves with significantly greater frequency (P 0.05), indicating that the odor to which the predators orient has both a prey and a host plant component.

Cyrtomenus bergi

The cassava burrowing bug C. bergi reduces the commercial value of cassava roots by introducing pathogens that cause root deterioration. C. bergi feeds only on sweet or low HCN varieties. Previous studies have shown that certain pesticides or intercropping with Crotalaria (Sunne Hemp) will reduce C. bergi damage.

Present studies show that Chlorpyrifos (Lorsban) applied to the soil every 45 days gave effective control of C. bergi (Table 12) with only 12% of the roots damaged and a very low damage rating of 0.1 (on a 1 to 5 scale). Applictions of Carbaryl (Sevin), Endosulfan (Thiodan) and Dimethoate did not give satisfactory results.

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[1] The olfatometer was provided by the International Quarantine for Mite Predators (IQMP), University of Amsterdam, and the experiments were conducted in collaboration with IQMP.

Intercropping Crotalaria between every row of cassava gave effective control but intercropping Crotalaria every two rows of cassava or planted around the cassava field resulted in 62 and 31% of roots damaged respectively. The most severe root damage occurred in the untreated control field (Table 12).

The Cassava Hornworm

(see attached paper: "The Biological Control of the Cassava Hornworm, *Erinnyis ello* (Lepidoptera: Sphingidae) with Emphasis on the Hornworm Virus").

TABLE 1. The effect of mealybug populations[1] and stake treatment on the germination, production of planting material and yield of three cassava cultivars.

Cultivar	% Reduction in germination		% Reduction Stakes/plant		% Reduction Yield	
	Treated[2]	Untreated	Treated	Untreated	Treated	Untreated
M. Bra 12	6.0	15.5	39	42	56	34
M Pan 70	0.5	19.0	0	33	0	0
CMC 57	32.0	37.0	14	64	4	47

[1]Mealybug populations covered from 50 to 100 of stake surface and buds.

[2]Treatment: 1.5 cc of fyfanon + 10 cc of triona + 5.0 grams of zinc sulfate-D, per liter of water

TABLE 2. The effect of plant age at time of mealybug (<u>Phenacoccus herreni</u>) infestation on cassava (Var M Ven 77) plant growth and yield at Carimagua, Colombia.

	% REDUCTION				
Plant age Months	Plant Height	Root* Yield	Dry Matter	Production of cuttings	Germination
2	100 % mortality of infested plants				
4	24	50	35	32	38
6	17	37	24	38	4
8	14	11	8	43	0

* Harvested at 12 months

TABLE 3. Physiological parameters affected by *Phenacoccus herreni* attack on two cassava cultivars

	CLONES					
	SM 301 - 3			CM 2087 - 101		
	Without Mealybug	With Mealybug	% Difference	Without Mealybug	With Mealybug	% Difference
PHOTOSYNTHESIS						
mgr CO_2 $dm^{-2}hr^{-1}$	31.0	14.2	54.2	24.02	13.1	35.4
TRANSPIRATION						
gr H_2O $dm^{-2}hr^{-1}$	1.9	1.3	31.6	1.4	1.1	21.42
EFIC of H_2O UTILIZ.						
mgr CO_2 $gr^{-1}h_2O$	17.7	11.8	33.3	17.9	10.9	39.1

TABLE 4. Phytoseiidae collected on 4 expeditions (1987-88) to the Colombian North Coast*

Species	November	January	February	March	Total
T. limonicus	267	222	23	4	516
Typhlodromalus sp.	21	30	3	0	54
T. dentilis	13	87	64	11	175
T. bellottii	10	9	2	0	21
T. aripo	1	5	4	1	11
A. aerialis	20	30	11	2	63
G. annectens	5	1	5	0	11
N. anonymus	6	1	0	0	7
I. zuluagai	0	8	3	1	12
P. cannaensis	42	13	4	0	59
E. naindaimei	2	1	0	0	3
P. macropilis	2	0	0	0	2
P. purseglovei	0	14	8	5	27
Total (adult specimens mounted)	389	421	127	24	961
Total (adults, nymphs, larvae)	767	589	170	36	1572
Mean no./leaf	0.26	0.20	0.06	0.03	0.14
Predator-prey ratio	1:22	1:52	1:97	1:151	

* Values are summed over 4 sites

TABLE 5. Effect of date and location on tetranychid and phytoseiid numbers in the Colombian North Coast.

	P > F			
Factor	*Mononychellus* spp. (no./leaf)	*Tetranychus* spp. (no./leaf)	*Oligonychus* spp. (no./leaf)	Phytoseiidae (no./50 leaves)
Date	0.01	0.001	0.009	0.0001
LSD	Mar. 1.3 A	Jan. 3.3 A	Jan. 60 A	Nov. 12.8 A
	Jan. 1.1 A	Feb. 1.9 AB	Nov. 4.6 A	Jan. 9.8 B
	Feb. 1.0 A	Mar. 1.7 BC	Feb. 2.3 B	Feb. 3.1 C
	Nov. 0.2 B	Nov. 1.0 C	Mar. 1.6 B	Mar. 1.5 C
LOCATION	NS	0.004	NS	0.02
LSD	Cordoba 1.2	Betulia 3.2 A	Cordoba 5.3	Sincelejo 9.6 A
	Tolu 1.2	Sincelejo 1.8 AB	Sincelejo 4.6	Tolu 9.3 A
	Betulia 0.3	Cordoba 1.6 BC	Betulia 3.0	Cordoba 8.4 AB
	Sincelejo 0.3	Tolu 0.8 C	Tolu 2.4	Betulia 5.7 B

TABLE 6. Phytoseiidae collected Nov. 1987 - Mar. 1988 from 4 sites on the Colombian North Coast*

SPECIES	SITE Betulia	Cordoba	Sincelejo	Tolu
T. limonicus	83	306	69	58
Typhlodromalus sp.	28	6	10	10
T. dentilis	11	109	11	44
T. bellottii	1	15	3	2
T. aripo	4	5	0	2
A. aerialis	34	10	17	2
G. annectens	8	0	2	1
N. anonymus	3	0	3	1
T. zuluagai	5	1	5	1
P. cannaensis	15	20	14	10
E. naindaimei	2	0	1	0
P. macropilis	1	0	1	0
P. purseglovei	0	5	2	20
Total (adult specimens mounted)	195	471	138	150
Total (adult, nymphs, larvae)	323	803	231	205
n	59	96	24	22
Mean no./leaf	0.10	0.17	0.19	0.19
Predator-prey ratio	1:65	1:47	1:36	1:23

* Values are summed over 4 collecting trips

TABLE 7. Effect of cassava clone on survival and development of *Mononychellus progresivus.*

Clone	Resistance rating	% Survival egg to adult	Egg to adult development time (days)
M Bra 12	T	99	9.9 H
CG5-79	T	95	9.9 H
CMC 40	S	94	10.3 F
M Col 22	S	87	10.6 DE
M Cub 74	U	86	11.5 B
M Mex 59	U	84	10.2 FG
CM 1091-2	U	82	10.5 E
CM 696-1	U	82	10.0 GH
CM 723-7	U	82	10.2 FG
CG 427	U	81	10.9 C
CM 507-37	U	77	11.5 B
M Cub 72	R	76	12.2 A
M Col 1351	R	58	10.7 CD
M Ecu 85	U	56	11.3 B

T = tolerant, S = susceptible, R = resistant, U = unknown . Values followed by different letters are significantly different (Duncan's Multiple Range Test; $P \leq 0.05$).

TABLE 8. Effect of cassava clone on reproduction of *Mononychellus progresivus*.

CLONE	Resistance rating	Age of first reproduction (days)		Adult female longevity		Total eggs per female	
M Cub 72	R	13.9	A	5.4	E	6.3	E
CM 507-37	U	13.5	B	11.4	BC	7.3	E
M Cub 74	U	13.2	C	9.8	C	16.4	CD
M Ecu 85	U	13.1	C	10.9	C	13.9	D
M Col 1351	R	12.7	D	7.8	D	6.6	E
CG 427	U	12.2	E	11.4	BC	13.0	D
M Col 22	S	11.9	F	12.6	BC	15.4	D
CM 1091-2	U	11.6	G	8.2	D	16.3	D
CM 723-3	U	11.6	G	11.1	BC	38.4	B
CM 696-1	U	11.6	G	9.6	C	22.1	C
M Mex 59	U	11.6	G	9.9	C	29.5	B
CMC 40	S	11.1	H	26.1	A	59.3	A
M Bra 12	T	11.0	H	13.1	H	26.9	B
CG 5-79	T	11.0	H	11.8	BC	36.0	B

T = tolerant, S = susceptible, R = resistant, U = unknown. Values followed by different letters are significantly different (Duncan's Multiple Range Test; $P \leq 0.05$).

TABLE 9. Effect of prey species on reproduction by 10 species of phytoseiidae.

	Adult female longevity		Duration of Oviposition		Total eggs per female	
SPECIES	TU	MP	TU	MP	TU	MP
G. annectens	18	17 NS	12	10 NS	18.0	22.4
N. idaeus	16	17 NS	11	11 NS	17.8	20.9
P. persimilis	21	10	10	7	31.3	22.6
N. chilenensis	54	43	17	15	43.7	34.8
E. concordis	27	27 NS	14	14 NS	12.6	12.7 NS
P. macropilis	45	44 NS	21	22 NS	67.4	33.0
A. aerialis	44	47 NS	15	18	16.1	22.6
T. limonicus	5	20	1	11	2.0	25.4
C. pilosa	16	17 NS	9	10 NS	29.6	29.0 NS
N. anonymus	19	11	13	4	32.6	6.5

TU = *T. urticae*; MP = *M. progresivus*; Longevity and oviposition are expressed in days. Comparisons are significant (P 0.05);Student's T Test except where indicated

TABLE 10. Effect of prey species on life table parameters of 8 species of Phytoseiidae.

	Ro		T		Rm	
SPECIES	TU	MP	TU	MP	TU	MP
G. annectens	7.3	11.2	16.1	15.6	0.12	0.15
N. idaeus	10.5	11.8	12.0	12.1	0.20	0.20
P. persimilis	20.0	11.9	14.7	10.2	0.20	0.24
N. chilenensis	29.9	25.3	17.4	16.7	0.19	0.19
E. concordis	1.7	4.6	18.0	18.6	0.03	0.08
P. macropilis	45.3	28.4	19.4	20.9	0.20	0.16
A. aerialis	19.8	24.5	21.1	22.5	0.14	0.14
T. limonicus	0.0	19.4	11.2	14.2	0.43	0.20

TU = *T. limonicus*; MP = *M. progresivus*; Ro = Net reproductive rate; T = Mean generation time (days); Rm = Intrinsic rate increase.

TABLE 11. Response of Phytoseiid females in a Y-tube olfactometer when offered *M. progresivus* vs. clean air.

SPECIES	n_i [1]	n_f [2] MP	Ø	P	
T. limonicus	50	32	13	0.0003	**
A. californicus	38	25	10	0.0008	**
A. anonymus	34	20	10	0.049	**
C. pilosa	62	36	19	0.015	**
A. aerialis	31	12	18	0.181	NS
T. annectens	30	11	19	0.100	NS
T. neotunus	42	21	19	0.437	NS
P. macropilis	51	30	20	0.100	NS
E. concordis	29	9	7	0.400	NS
A. idaeus	32	15	15	0.570	NS
P. persimilis	21	16	4	0.006	**

1 n_i: Number of mites tested.

2 n_f: Number of mites which chose tube with MP (*M. progresivus*);

Ø : Clear air

**Significant (Binomial Test)

NS Not significant (P 0.05)

TABLE 12 . A comparison of chemical and botanical control of *Cyrtomenus bergi* on the cassava variety "Chiroza Gallinaza"

TREATMENT	Yield t/ha		% Root damage		Root damage rating	
Endosulfan	38.	B*	37	D	0.5	E
Dimethoate	44	A	32	D	1.0	C
Cassava + Crotalaria(1)	30	D	8	E	0.5	E
Cassava + Crotalaria (2)	34	BC	62	B	1.5	B
Cassava + Crotalaria (0)	34	BC	31	C	0.8	DE
Carbaryl	37	C	48	BC	0.6	CD
Chlorpyrifos	37	BC	12	E	0.1	F
Control	38	B	77	A	2.9	A

* Figures with the same letter are not significantly different at the 0.05% level.

(1) Crotalaria planted between every row of cassava

(2) Crotalaria planted between every two rows of cassava

(0) Crotalaria planted arround cassava plots

CASSAVA BREEDING - 1988

The cassava breeding section aims to assist national programs in their efforts to develop improved cassava varieties. CIAT activities involve direct and indirect assistance in the form of maintaining a world germplasm collection, developing breeding methodologies, providing germplasm improved for specific characters, training, and consulting in project and network development. The following is an overview of activities in these areas during 1988.

Germplasm

Collection and conservation

Since 1985 CIAT has accepted responsibility as global repository for cassava germplasm. Since the crop originated and completed the major part of its diversification in Latin America, the most emphasis has been, and will continue to be, collection and conservation of this gene pool. As of the end of 1988 the collection consisted of 4566 accessions, shown by country of origin in Table 1.

The major gap in CIAT's collection continues to be the relatively low representation of Brazilian germplasm. This is due primarily to the lack of a centralized collection in Brazil and the difficulty of organizing introductions of the various state-held collections. At the end of 1988, representatives from CNPMF, CENARGEN and CIAT met to plan a coordinated project for cassava germplasm management in Brazil. The first step will be centralization of the Brazilian cassava germplasm at CNPMF (working collection) and CENARGEN (base collection), while still maintaining the state and local collections in their respective sites. A duplicate of each accession will also be introduced to CIAT. This is to be followed by complete characterization and documentation. The project is expected to last for three years.

Seventeen new IITA hybrids were introduced to CIAT via a strict virus indexing protocol at the Scottish Crop Research Institute. These complement the two Cassava Mosaic Disease (CMD) resistant clones introduced last year (Table 2). Hybrids between these resistant clones and Latin American germplasm will be the bridge for introducing important new diversity into Africa.

It is expected that for the forseeable future, small collections will continue to be added to CIAT's world collection, but that growth will be minimal after addition of the Brazilian germplasm over the next three-year period.

Cassava conservation is closely coordinated between the Biotechnology Research Unit (BRU) and the Breeding Section of the Cassava Program. *In vitro* aspects of conservation are reported separately by the BRU.

Characterization and duplicate identification

The IBPGR, in consultation with national programs, CIAT and IITA, has developed a descriptor list for cassava based on morphological characteristics. These descriptors are now generally adopted by most curators. In addition, powerful biochemical descriptors--polymorphic isozyme markers--have been developed by a joint University of Manitoba/CIAT project (see BRU annual reports for 1986-87). By 1988, isozyme techniques were sufficiently well developed to begin isozyme characterization of the entire cassava germplasm collection. Objectives are two-fold: to have additional stable and reliable criteria for variety description purposes, and to have an additional tool for identification of duplicates in the collection. The collections processed for analysis of $\alpha\beta$-esterase banding patterns were:

Brazil -	693	accessions
Paraguay -	110	"
Colombia (Vaupés)-	51	"
CIAT hybrids -	219	"

Duplicate identification will involve the following steps:

1. Morphological characterization
2. Agronomic evaluation
3. $\alpha\beta$-esterase isozyme characterization
4. Computer analysis to identify similarity groups
5. Field comparisons to confirm duplicates
6. Elimination of duplicates

We expect that most duplication will be found within collections of the same country, rather than across countries. Thus, analysis for duplicate identification will begin as each country's germplasm collection is processed. We estimate that the present collection should be reduced by 20-25% by duplicate elimination.

Agronomic evaluation

Colombia encompasses a wide diversity of cassava-growing environments, with both physical and biological stresses common to cassava-producing areas world-wide. In the case of biological stresses, Colombia has a much wider range than either Africa or Asia. This fact bestows on CIAT two major responsibilites in the area of agronomic evaluation of cassava germplasm: 1) to provide information on resistance or susceptibility of local germplasm to pests and pathogens not presently in a country, but which could be potential threats; and, 2) to provide information on sources of resistance to existing or potential problems, so that a country can make informed decisions on germplasm introductions.

To give one example, during 1988 most of the Asian collections held by CIAT were evaluated for resistance to thrips (CIAT-Palmira), bacterial blight (CBB) and superelongation disease (SED) (Carimagua). Very high pressure for these pests and diseases was observed in the respective sites (Table 3).

Considerable resistance to thrips exists in this germplasm (primarily in the Malaysian materials), but resistance to CBB and SED was generally low. While it is not surprising to find relatively low levels of resistance to these problems (of the three, only CBB exists in Asia), it is somewhat surprising to find such a high frequency of thrips-resistant clones in the Malaysian collection. This may indicate that much of the Malaysian material is derived from the drier areas in Latin America where thrips are endemic and resistance has evolved. Conversely, the somewhat higher resistance to CBB and lower thrips resistance in the Indonesian collection suggest this germplasm probably derived principally from the wetter areas of Latin America. Further characterization will be needed to clarify this hypothesis, and to expand upon the possible implications for cassava improvement in Asia.

As is true also for cassava germplasm in general, a very low proportion of clones showed combined resistance to CBB, SED and thrips. The notable exception is South China 205 (M Chn 1), the most common clone in subtropical China. Other clones with moderate combined resistance were: SL 26 from Indonesia; Silon, Ubi Ladang, and Variety D from Malaysia.

Marker gene studies

"Marker gene" is the term generally used to refer to single genes controlling qualitative traits which are expressed only in two easily distinguishable states. Marker genes have value as means of studying linkage groups, in studying mating systems, and sometimes are directly important as selection criteria. In some well-studied crops like maize or peas (*Pisum sativum*), several hundred marker genes are known. In cassava, only three marker genes have been previously reported: broad (recessive) versus narrow (dominant) leaf lobe shape; light (recessive) versus dark (dominant) root surface color; and male sterility (recessive) versus male fertility (dominant). During 1988 CIAT studied inheritance of several other traits and described four new marker genes related to stem growth habit, stem collenchyma color, albinism, and root parenchyma color (Table 4).

Gene Pool Development

CIAT is unable to produce finished varieties for all, or even most, of the world's cassava growing environments, due to a range of differences in physical and biological environmental conditions, as well as highly localized criteria for plant growth features, root quality and others. Thus CIAT's basic breeding strategy has been two pronged: first, to develop elite clones with potential adaptation to some of the major cassava growing environments, with quality traits known to be crucial for acceptance within given regions; and second, to develop broad based gene pools from which national programs select for local adaptation and acceptability. This strategy, along with a description of the major edaphoclimatic zones for which gene pools are developed, is described in detail in previous CIAT Annual Reports. In this report we give a brief summary of advances in selection of parental components of the gene pools in Colombia, with selected examples of progress in national programs toward selection of new cassava varieties. Many of the elite selections become parental components of the gene pools, so these two facets are closely interrelated.

Lowland tropics with low to intermediate rainfall and long dry season (Edaphoclimatic Zone 1)

Improving this gene pool has proven to be more complex than first anticipated. Drought and high temperatures impinge on the expression of a wide range of characters: yield, plant architecture, disease and insect pressure, and (often the most intransigent), root quality. Most clones react to the long dry season with high HCN levels and low root dry matter content. Strong selection therefore has gone into improving these two traits, while maintaing high yield potential and insect resistance. While few clones exceed the best local varieties of the north coast of

Colombia (principal selection site for this gene pool), most exceed the local clones in yield, and some have equal quality. Nevertheless, the quality requirements of Colombia's north coast appear to be uniquely high among the world's cassava growing environments, so this gene pool should provide acceptable quality and high yield potential for many regions.

Figure 1 illustrates yield trends for some promising hybrids and local checks tested over years in Media Luna and Carmen de Bolívar on the north coast (ECZ 1) and CIAT-Palmira (ECZ 4). The hybrids CG 1141-1, CM 3306-4 and CM 3306-9 have high yield potential compared to the common local clone M Col 2215 (Venezolana), and have good eating quality. The hybrid CM 3555-6, which has shown very high yield stability, appears to have special advantages under high stress conditions within ECZ 1. These hybrids are now widely distributed throughout the north coast region in on-farm trials.

Lowland tropics with acid soil savannas, and high rainfall (Edaphoclimatic Zone 2)

During 1987-88, the principal selection site for ECZ 2 was moved from Carimagua to ICA-La Libertad, near Villavicencio. Carimagua continues as a site for evaluating selected clones under very high CBB and SED pressure. After almost 15 years of selection in Carimagua, the ECZ 2 gene pool has very good levels of CBB and SED resistance, and moderate to high yield potential. Thus, emphasis for this gene pool has shifted to further improving yield potential and quality, and resistance to dry season pests such as thrips and cassava green mite (CGM). These considerations, in addition to the higher development potential for cassava in the piedmonte region as compared to the "inner" llanos, led to a move to selection in ICA-La Libertad.

As expected, during the first year of trials, disease pressure was low, as even susceptible checks were only moderately affected. Probably 2 - 3 years will be required to build up moderate and uniform inoculum for CBB, SED and anthracnose. In any case, all materials selected in preliminary and advanced yield trials are also planted for observation of disease reaction in Carimagua.

One surprise of the La Libertad trials was the high level of CGM infestation, in spite of a shorter dry season than in Carimagua. If this trend continues, the site should prove highly advantageous for combining high levels of mite resistance into the ECZ 2 gene pool.

Several excellent clones from this gene pool have been developed, and some have been tested in advanced yield trials for 5 or more years. These have been sent in recent years to many Latin American countries having similar pest and disease problems

As hoped and expected, nearly all the clones which previously showed good adaptation and high yield in Carimagua were also superior in La Libertad. The strategy of selecting under a high stress environment, as a means of achieving relatively broad adaptation across various levels of the similar stress components, has proven effective.

Some of the best hybrids and germplasm accession checks are compared in Figure 2. M Ven 77 is the only germplasm accession which has combined good disease (CBB and SED) resistance and moderate yields over many years. M Col 1468 (Mantiqueira) was selected in Brazil as a CBB resistant, high yield potential clone, but it does not hold up under the severe conditions of Carimagua. The hybrids CM 2177-2, CM 2166-6, CM 2766-5 and CG 165-7 all have very good yield potential and disease resistance over a range of environments within ECZ 2. CM 2766-5 and SG 107-35 are notable in their ability to yield well under very high stress conditions. CM 2766-5 probably comes closest to following an ideal yield response under different environments, with yields well above trial means or best checks across all environments. Of the hybrids listed, all are good for fresh consumption with the exception of CG 165-7, which is high in HCN.

Humid tropics; dry season short or absent (Edaphoclimatic Zone 3)

Two principal factors have led us to give gene pool development for this zone a relatively low priority. First, the demand from national programs for materials for these conditions has been comparatively lower; and secondly, the biological problems, apart from root rots, generally are not limiting in these environments, or are similar to those found in ECZ 2. Thus, it has been found that materials from both ECZ 1 and 2 gene pools (but especially the latter) are often well-adapted in the humid tropics. Further development of this gene pool in the Colombian Amazon region (Florencia) was discontinued, and selected materials given to ICA for further evaluation and multiplication.

Middle altitude tropics (Edaphoclimatic Zone 4)

While this zone has been defined primarily for the Andean Zone, agroecological studies have shown that large areas of northeast Brazil show similar temperature and rainfall patterns. The most notable features of the CIAT-Palmira screening site are the high thrips pressure in nearly all years, and the frequently high mite populations. This provides excellent opportunity for selection for resistance to these pests. Since CIAT is used as a central site for maintenance and multiplication of all the gene pools, opportunity is taken to select for resistance in all the pools, at different levels of intensity depending upon the importance in the target areas for a given pool. A continually increasing number of clones are now adapted across two or more ECZs, owing to combined resistance to several pests and diseases.

Tropical highlands (Edaphoclimatic Zone 5)

A continuing concern about the highland gene pool is its relatively narrow genetic base compared to other gene pools. Most of the components of this gene pool trace back to several highland-adapted clones from southern Colombia. As the highlands (1600-2000 masl) represent an extreme condition for cassava growth, this narrow base is not surprising. Incorporating genes from lowland clones as a means of broadening the base has been only moderately successful, since it requires several cycles of recombination to eliminate unfavorable genes. In 1987-88, 833 new germplasm accessions were screened in Popayan. As expected, most showed very poor adaptation, but a significant number of clones (54), including several of Brazilian origin, developed well. These are now being retested in a yield trial, and even if only a few prove well adapted, it will be an important new source of variation for low temperature adaptation.

Subtropics (Edaphoclimatic Zone 6)

CIAT is unable to select for subtropical adaptation within Colombia for the obvious reason that the country lies fully within the tropics. In order to partially meet the germplasm needs of subtropical regions such as China, Southern Brazil, Paraguay and Cuba, clones selected directly by national programs in those regions are brought to CIAT as in vitro cultures, incorporated into the germplasm collection, and intercrossed with clones expressing traits desired for incorporation by national programs. One of the major problems of the subtropics is CBB, and most local clones have been found to be susceptible. Therefore, one of the most common types of crosses for the subtropics has been between local varieties from the subtropics and the ECZ 2 gene pool, as a source of CBB resistance; or crosses from within the ECZ 2 gene pool. The success of this strategy is beginning to be seen in all the above-mentioned subtropical regions.

Elite Clones

CIAT maintains a set of "elite" clones based on superior performance over several years in given edaphoclimatic conditions. These are considered some of the best possibilities for programs wishing to introduce clonal materials either for direct selection of new varieties or for use as parental material. Elite clones are kept continually available as virus-indexed in vitro cultures, and generally can be shipped immediately upon request. A summary of the characteristics of these clones is given in Table 5.

A system of maintaining virus-indexed elite clones under controlled conditions is being developed by the Virology Unit. Small, partially lignified stakes are available for sending to national programs which accept this form of introduction. Preliminary experiences indicate easier establishment and more rapid initial growth as compared to in vitro plantlets, and may be especially useful to programs not having conditions for processing in vitro introductions or any program wishing to expedite the more rapid multiplication of introduced material (see further details in Pathology section).

Developments in On-farm Evaluation

In many parts of Latin America cassava has been cultivated for centuries, and traditional cultivation and processing systems have evolved regionally. Often these technolgies are deeply ingrained in farmers' and consumers' habits and preferences, and an attempt to introduce new technology can only succeed if based on adequate baseline information.

In areas where cassava is more recently introduced, or where changes in farming systems or consumption patterns have been changed due to external forces, there is often a less rigid set of criteria established and more openness to adopt new technologies.

These phenomena suggest a breeding strategy that takes into account, among other criteria, farmers' reactions at the earliest possible stage, and certainly before varietal release is contemplated.

In 1987-88, 69 on-farm trials to test promising cassava clones were planted in ten departments of Colombia, in collaboration with various national agencies and the Participatory Research Unit of CIAT. While data from trials harvested in 1988 are highly variable in quality due to the novelty of farmer participation in research for many of our collaborators, some important findings are beginning to emerge.

Some of the most important results have come from the open interview of farmers at harvest time--their responses to the question: what are the traits of this clone that you do or do not like? The most frequent responses from the north coast departments of Cordoba, Bolivar and Magdalena are given in Table 6. Not surprising for this part of Colombia, nearly every farmer mentioned eating quality, even though many had access to the drying plants to market their cassava. This reinforces the probable need to produce dual purpose varieties for this region. Even with alternative markets, farmers will always hope to sell as much as possible of their produce in the higher priced fresh market. Ease of harvest, yield, and yield-related traits also figure prominantly in importance, as does production of good quality planting material. CIAT has placed strong emphasis on all these criteria except ease of harvest, which may need to be looked at more closely in the future.

Early harvestability does not enter into the criteria since the trial design itself contemplates both an early and a late harvest. However, this criteria emerged as very important in the first year's trials (which had only one harvest date) and provided the justification for having two harvest dates in subsequent trials.

Using information from trials where data are most complete and most reliable, several clones begin to stand out as potentially superior to the local check by farmers multiple criteria (Table 7). While the data still need to be considered preliminary, clones such as CG 1141-1, CG 915-1, CM 3306-4, CM 3306-9, CM 3435-5 and MCol 2253 have begun to catch the attention of many farmers. If the superiority of these clones is confirmed in the 1988-89 trials, some of these materials should be considered for release.

While CIAT is heavily involved in the initial stages of setting up a network of on-farm trials, the goal is to develop interest and capacity within the national program to completely take over management of these trials over the next few years. As the methodology is refined, we will introduce it to other national programs. Preliminary work in Ecuador has begun in similar trials.

Country Reports

While it is well beyond the scope of this report to present fdetails on all the collaborative aspects of cassava varietal development, a few highlights from selected countries in Latin America and Africa are given. A detailed report on Asia breeding programs is given separately by the CIAT-Asia Regional Program.

Latin America

Mexico. A new cassava development initiative began last year in Campeche State, based primarily on substituting imported grains with locally produced dried cassava chips for use in pig rations. Though a cassava technology package has been developed for Tabasco State, soil and climatic conditions in Campeche are markedly different. Thus, the research program has had to embark on adapting the technology for the region, including new varieties. Some 15 clones were introduced from CIAT in mid-1988, and these will be tested next year.

In Tabasco, with a mature cassava research program, seed and clonal introduction has been steady over the past 6 years. Clones selected from seeds introduced in 1982 are now being advanced to semi-commercial trials, with release of one or more of these expected in the near future.

Panama. While operating on a very limited budget, Panama has successfully evaluated considerable germplasm from CIAT, introduced both as *in vitro* cultures and segregating populations. A clone from CIAT introduced in 1984, and locally named Dayana, is being multiplied for commercial production, and release is expected next year.

Colombia. The clone M Col 1505, released by ICA in 1985, continues to gain popularity in the north coast region, where it has gained acceptance for its yield potential, eating quality and resistance to Diplodia root rots common in the area. A CIAT hybrid (CM 523-7), an introduced germplasm accession (M Ven 77), and the landrace variety Venezolana (MCol 2215) are being studied for release next year by ICA. Several new hybrids are showing promise in extensive on farm trials managed jointly by CIAT, ICA and other national entities.

Ecuador. The principal weakness identified in the varieties of the Manabi province region is low root dry matter. Apparently low overall genetic diversity exists, and there appears little possibility of selecting high dry matter clones from among local varieties. In preliminary trials, the variety Venezolana from Colombia's north coast has shown both early maturity and very high dry matter content. Since the dry matter content has important implications for the efficiency and economics of the chip drying process, this variety could make a major contribution.

Paraguay. Although Paraguay has one of the highest levels of per capita cassava consumption in the world, research on the crop is given low priority. With collaboration from CIAT and IBPGR, a national germplasm collection was established between 1983 and 1986, and this is now beginning to be evaluated.

In 1986, CIAT sent seed populations to the research station at Capitan Miranda in the southeast, where CBB is a major production constraint. The resistant crosses selected from the ECZ 2 gene pool looked promising in preliminary trials, while susceptible checks were severely affected by CBB. This is a good indication that the ECZ 2 gene pool can contribute to improving subtropical germplasm.

In another collaborative project with Paraguay, CIAT has virus-indexed some of the most common Paraguayan clones, and sent these back to Paraguay for multiplication and distribution. While it is still unknown what may be the yield advantages of the virus-free material, it is known the cassava common mosaic virus is endemic in much of the country.

Brazil. The process of decentralization of cassava variety selection is continuing in Brazil. During 1988, new initiatives were taken in establishing collaborative projects between the national cassava center (CNPMF) and state or regional programs in the south and Cerrado regions. In both areas, CBB is a major constraint, and segregating populations of both Brazilian and CIAT origin are being evaluated with very promising initial results.

Early in 1988, superelongation disease was found for the first time in a major cassava producing region of Parana State. To date, the pathogen appears to be contained to a relatively small area, but conditions are appropriate for epidemic levels of disease unless appropriate control measures are taken. CIAT has sent highly resistant clones to CNPMF for dispatch to this region.

Africa

CIAT collaborates with national programs in Africa through our sister institution in Nigeria--IITA. While much closer collaboration is expected with appointment of a CIAT scientist to be posted at IITA in 1989, germplasm introductions have been carried out for several years. One of the principal regions with interest in Latin America germplasm has been the East Africa highlands, since few African clones appear to be adapted to these cool conditions.

Rwanda. Cassava is grown on about 55,000 hectares in Rwanda, making it the fourth most important crop after bananas, beans and sweet potato. The crop nearly always occupies areas of poor soils (especially steep hillsides) and dry areas where other crops are risky. Cassava green mite and cassava mosaic disease are the principal biological constraints. Cassava mealybug has been introduced, but is still quite limited in distribution.

ISAR received CIAT materials in 1984, through IITA. The populations had been selected for mite resistance at CIAT, but not highland adaptation. ISAR selected clones from this population over four years, and in 1988 harvested an advanced yield trial in Karama and Rubona stations, including CIAT, IITA and local materials (Table 8). Although the CIAT population had not been previously selected in Colombia for either highland adaptation or CMD resistance, several clones are very promising in the region, and indicate a high possibility of Latin American germplasm making even more significant contributions if populations are more stringently selected.

Burundi. Cassava in Burundi is grown under similar conditions to Rwanda and suffers similar production constraints. However, the mealybug has become a more severe problem, especially on the southern border with Tanzania. The Burundi research organization, ISABU, introduced highland-adapted material from CIAT in 1987, and this was planted in Mosso station, the main cassava research center for the country. Since Mosso is only 1250 masl, this station is being used primarily to produce the first vegetative generation of material, for subsequent testing at higher altitude stations (up to 2100 masl at Kisozi). As this is the first highland population to be introduced to Africa from CIAT, it will be a key test case for assessing possible contributions of Andean zone material in the East Africa highlands.

Table 1. Cassava germplasm in CIAT's collection as of 1988.

Region/Country of Origin	No. of accessions
Meso-America & Caribbean	
Costa Rica	148
Cuba	74
Dominican Republic	5
Guatemala	91
Mexico	102
Panama	42
Puerto Rico	15
South America	
Argentina	16
Bolivia	3
Brazil	801
Colombia	1874
Ecuador	117
Paraguay	194
Peru	406
Venezuela	241
North America	
United States	9
Asia/South Pacific	
China	1
Fiji	6
Indonesia	50
Malaysia	67
Philippines	6
Thailand	8
Africa	
Nigeria	19
CIAT/Hybrids	271
TOTAL:	4566

Table 2. IITA (Nigeria) cassava hybrids introduced into CIAT's germplasm collection.

CIAT code	IITA code
M NGA 1	TMS 30001
M NGA 2	TMS 30572
M NGA 3	TMS 30040
M NGA 4	TMS 30211
M NGA 5	TMS 30555
M NGA 6	TMS 30786
M NGA 7	TMS 40160-P6-1
M NGA 8	TMS 42025
M NGA 9	TMS 50395
M NGA 10	TMS 60142
M NGA 11	TMS 60444
M NGA 12	TMS 60506
M NGA 13	TMS 63397
M NGA 14	TMS 83350
M NGA 15	TMS 84537
M NGA 16	TMS 90059
M NGA 17	TMS 90257
M NGA 18	TMS 90853
M NGA 19	TMS 91934

Table 3. Evaluation of Asian cassava germplasm for pest and disease resistance at CIAT-Palmira (thrips) and Carimagua (CBB and SED). (1 = highly resistant; 5 = highly susceptible).

Country of origin	Local name	CIAT code	Other codes	Resistance to: Thrips	CBB	SED
CHINA	SOUTH CHINA 205	M CHN 1		2	3	1
INDONESIA	NO. 53	M IND 1	UJF 45	5	3	4
INDONESIA	W 1435-83	M IND 2	UJF 21	5	3	4
INDONESIA	KRETEK	M IND 3	UJF 29	5	4	4
INDONESIA	M 31	M IND 4	UJF 22	5	3	2
INDONESIA	W 236-29	M IND 5	UJF 61			
INDONESIA	B-61	M IND 6	UJF 82			
INDONESIA	M 30	M IND 7	UJF 3	4	4	3
INDONESIA	KETAN MERAH	M IND 8	UJF 10	5	4	4
INDONESIA	SL 13	M IND 9	UJF 95			
INDONESIA	W 1510	M IND 10	UJF 81	5	4	4
INDONESIA	X 396	M IND 11	UJF 26			
INDONESIA	WV 65	M IND 12	UJF 4	5	4	4
INDONESIA	B 6-2	M IND 13	UJF 83	5	4	2
INDONESIA	SL 44	M IND 14	UJF 93	5		
INDONESIA	B 16-3	M IND 15	UJF 85	5	3	2
INDONESIA	B 18-1	M IND 16	UJF 87	5	4	2
INDONESIA	SL 26	M IND 17	UJF 97	1	3	3
INDONESIA	SL 1	M IND 18	UJF 88			
INDONESIA	SL 15	M IND 19	UJF 91	4	3	3
INDONESIA	KELAM HITAM	M IND 20	UJF 74	3	4	4
INDONESIA	W 1672	M IND 21	UJF 24	4	4	4
INDONESIA	W 1058	M IND 22	UJF 12	2	5	3
INDONESIA	MARTOLEPO	M IND 23	UJF 8	2	4	4
INDONESIA	W 236-41	M IND 24	UJF 63	4	4	4
INDONESIA	SL 37	M IND 25	UJF 99	3		
INDONESIA	W 1435-87	M IND 26	UJF 20	5	4	4
INDONESIA	FAROKA	M IND 27	UJF 6	5	3	2
INDONESIA	SL 4	M IND 28	UJF 89	5	4	3
INDONESIA	W 1166	M IND 29	UJF 16			
INDONESIA	ADIRA 1	M IND 30	UJF 27			
INDONESIA	SL 7	M IND 31	UJF 90	5	3	3
INDONESIA	NO. 1-B2	M IND 32	UJF 30			
INDONESIA	NO. 734-5	M IND 33	UJF 52	1	4	5
INDONESIA	CM 3998-13 UJF	M IND 34		1	4	4
INDONESIA	CM 3993-28 UJF	M IND 35		1	4	4
INDONESIA	CM 3997-26 UJF	M IND 36		4	3	4
INDONESIA	CM 3970-4 UJF	M IND 37		2	3	5
INDONESIA	CM 4013-3 UJF	M IND 38		2	5	4
INDONESIA	CM 4031-10 UJF	M IND 39		1	4	2
INDONESIA	CM 4045-6 UJF	M IND 40		2	4	3

(Continued)

Table 3. (continued)

Country of origin	Local name	CIAT code	Other codes	Resistance to: Thrips	CBB	SED
INDONESIA	CM 4050-2 UJF	M IND 41		1	5	3
INDONESIA	CM 4058-9 UJF	M IND 42		2	4	3
INDONESIA	CM 4066-2 UJF	M IND 43		1	4	2
INDONESIA	W 236-22	M IND 44		5	4	4
INDONESIA	SL 31	M IND 45	UJF 92	3	4	4
INDONESIA	MANAIAG 1	M IND 46	UJF 72	3	5	2
INDONESIA	SL 10	M IND 47	UJF 94	4	3	2
INDONESIA	CM 4049-7 UJF	M IND 48				
MALAYSIA	M4	M MAL 1		5	4	4
MALAYSIA	BLACK TWIG	M MAL 2		3	4	4
MALAYSIA	C5	M MAL 3		5	3	4
MALAYSIA	C4	M MAL 4	MM 152			
MALAYSIA	C3	M MAL 5	MM 151			
MALAYSIA	C2	M MAL 6	MM 150	3	4	4
MALAYSIA	C1	M MAL 7	MM 149	4	4	4
MALAYSIA	TIGA BULAN	M MAL 8	MM 156	2	4	5
MALAYSIA	I.T.U. 8/1 426/2	M MAL 9	MM 155	2	4	4
MALAYSIA	PANTAI	M MAL 10	MM 154	2	4	5
MALAYSIA	C5	M MAL 11	MM 153	5	4	4
MALAYSIA	BANGKOK 1	M MAL 12	MM 101	5	4	2
MALAYSIA	BETAWI	M MAL 13	MM 104	4	4	4
MALAYSIA	FOWLFAT 146 42/A	M MAL 14	MM 110	1	4	4
MALAYSIA	GREEN TWIG	M MAL 15	MM 112	3	5	3
MALAYSIA	JURAI	M MAL 16	MM 116	5	3	2
MALAYSIA	LEMAK	M MAL 17	MM 124	2	5	5
MALAYSIA	LLANERA	M MAL 18	MM 125			
MALAYSIA	MERAH BERCABANG	M MAL 19	MM 128	5	5	4
MALAYSIA	PULUT	M MAL 20	MM 132	3	4	4
MALAYSIA	PERANCIS	M MAL 21	MM 131			
MALAYSIA	PAKA	M MAL 22	MM 130	2	4	4
MALAYSIA	PUTIH 1	M MAL 23	MM 133	1	4	4
MALAYSIA	PUTIH 2	M MAL 24	MM 134	2	5	5
MALAYSIA	SAKAI	M MAL 25	MM 135	2	4	5
MALAYSIA	SEMBAWA BIRU	M MAL 26	MM 136	4	4	2
MALAYSIA	SILON	M MAL 27	MM 137	2	3	3
MALAYSIA	TANGKAI	M MAL 28	MM 138	5	5	5
MALAYSIA	TELUR	M MAL 29	MM 139	5	5	5
MALAYSIA	TRINIDAD 146 52/A	M MAL 30	MM 140	3	4	5
MALAYSIA	UBI LADANG	M MAL 31	MM 141	2	3	2
MALAYSIA	UBI MELAKA	M MAL 32	MM 142	2	4	3
MALAYSIA	VARIETY 'A'	M MAL 33	MM 143	2	4	2
MALAYSIA	VARIETY 'C'	M MAL 34	MM 145	2	5	5
MALAYSIA	VARIETY 'D'	M MAL 35	MM 146	2	3	2
MALAYSIA	VARIETY 'E'	M MAL 36	MM 147	3	4	4

(Continued)

Table 3. (Continued)

Country of origin	Local name	CIAT code	Other codes	Resistance to: Thrips	CBB	SED
MALAYSIA	YELLOW TWIG	M MAL 37	MM 148	1	5	2
MALAYSIA	SUTING	M MAL 38	MM 158	3	5	3
MALAYSIA	FOWLFAT 146 42 20/IB	M MAL 39	MM 159	1	4	4
MALAYSIA	LOHOT	M MAL 40	MM 160	3	4	4
MALAYSIA	TEROH	M MAL 41	MM 161	3	4	5
MALAYSIA	PETEH	M MAL 42	MM 162	1	4	4
MALAYSIA	THAI	M MAL 43	MM 164	1	5	3
MALAYSIA	MELAKA (JP)	M MAL 44	MM 167	1	4	3
MALAYSIA	MELAKA (UPM)	M MAL 45	MM 168	1	4	2
MALAYSIA	LEMAK (JP)	M MAL 46	MM 169	1	4	4
MALAYSIA	LEMAK (UPM)	M MAL 47	MM 170	1	5	4
MALAYSIA	RED TWIG	M MAL 48	MM 171	1	5	3
MALAYSIA	BATAK	M MAL 49	MM 165	4	4	4
MALAYSIA	YELLOW TWIG (UPM)	M MAL 50	MM 166			
MALAYSIA	BANGKOK 2	M MAL 51	MM 102	1	5	3
MALAYSIA	BRAZIL 146 56/A	M MAL 52	MM 106	3	5	3
MALAYSIA	BULUH	M MAL 53	MM 107	2	4	3
MALAYSIA	EL SALVADORE 8/1 326/2	M MAL 54	MM 109	1	5	3
MALAYSIA	DEL DR. HAMILTON	M MAL 55	MM 111	1	4	4
MALAYSIA	JANTUNG	M MAL 56	MM 115	1	5	4
MALAYSIA	HALBAN	M MAL 57	MM 113	5	4	5
MALAYSIA	KEMENYAN	M MAL 58	MM 117	1	4	5
MALAYSIA	KERDIL	M MAL 59	MM 118	5	4	4
MALAYSIA	KERITING	M MAL 60	MM 119			
MALAYSIA	K.G.T. 44	M MAL 61	MM 120	1	4	3
MALAYSIA	KUCIR	M MAL 62	MM 121	1	4	4
MALAYSIA	KUNING 2	M MAL 63	MM 122	4	4	3
MALAYSIA	KUNYIT	M MAL 64	MM 123	3	5	3
MALAYSIA	MARKONA	M MAL 65	MM 126	2	4	4
MALAYSIA	MERAH JAMBU	M MAL 66	MM 129	4	4	4
MALAYSIA	VARIETY B	M MAL 67	MM 144			
MALAYSIA	BLACK TWIG	M MAL 68	MM 105	3	5	4
MALAYSIA	BANGKOK 3	M MAL 69	MM 157			
THAILAND	RAYONG 1	M TAI 1		2	5	3
THAILAND	RAYONG 2	M TAI 2		1	4	5
THAILAND	RAYONG 3	M TAI 3			4	4
THAILAND	OMR 23-29-15	M TAI 4		2	4	5
THAILAND	CMC 76 X V43	M TAI 5		4	3	3
THAILAND	27-77-10	M TAI 6		2	4	4
THAILAND	29-77-5	M TAI 7		1	5	3
THAILAND	RAYONG 60	M TAI 8		2	4	4

Table 4. New marker genes described for cassava

Trait	Recessive phenotype	Recessive genotype	Dominant phenotype	Dominant genotype
Stem growth habit	Zig-zag	zz	Straight	Z_
Stem collenchyma color	Dark green	gg	Light green	G_
Seedling chlorophyll	Albino	aa	Green	A_
Root parenchyma color	White/cream	yy	Yellow	Y_

Table 5. Description of CIAT's elite cassava clones.

CLONE	COMMON NAME OR CROSS PARENTS	ZONE: PRPL	ZONE: SCND	YIELD AND QUALITY: YLD	DM	HCN	CUL QLT	PEST AND DISEASE RESISTANCE: TRP	MON	CBB	SED	BPL	MORPHOLOGICAL TRAITS: ROOT COLR	FLSH COLR	PGMN CRTX	BRN-CHNG	PLNT HGHT
CG 915-1	MBRA 12 X MCOL 1643	1	4	5	4	3	2	3	2	2	4	5	3	1	1	2	3
CG 917-5	MBRA 12 X MCOL 1818	1	4	4	4	3	2	2	2	3	5	1	3	1	Y	1	4
CG 1141-1	MMEX 11 X MCOL 65	1	4 2	5	5	3	1	2		3	3	1	3	1	0	2	3
CG 1220-2	MCOL 976 X MVEN 77	1		4	3	3		2				5	3	2	0	2	4
CG 1355-2	CM 922-2 X MMAL 3	1		5	3	3		3		3	4		3	1		2	4
CG 1372-5	MBRA 12 X MMAL 3	1		5	4	2		3		2	5		3	1	0	2	5
CG 1413-3	MCOL 976 X CM 507-37	1		5	3	4	4	2		4	2		2	1	0	2	3
CM 962-4	CM 309-93 X MPAN 70	1	4	5	3	4	4	3	2	3	3	5	3	1	1	3	2
CM 1014-2	MCOL 22 X MCOL 655A	1	4	4	3	4	3	3		5	4	4	3	1	1	2	4
CM 1442-204	MBRA 12 X MCOL 1684	1		5	3	5	5	2	3	4	5		3	1	Y	1	3
CM 3281-4	MBRA 12 X MCOL 22	1	4	5	4	3	2	2		4	5		1	1	0	2	3
CM 3299-4	CM 849-1 X MCOL 22	1	4	4	4	3	2	2		3	4	2	1	1	Y	3	4
CM 3306-4	MCOL 22 X CM 523-7	1	4	4	5	2	2	2		4	3	5	3	1	0	2	3
CM 3306-9	MCOL 22 X CM 523-7	1		4	5	2	2	2		3	5	5	2	1	0	2	2
CM 3320-4	MBRA 20 X CM 523-7	1		4	3	3	3	3		3	4		3	1		3	3
CM 3372-4	CM 517-1 X CM 840-31	1	4 2	4	3	2	2	3		2	2	5	3	1	0	3	3
CM 3555-6	CM 841-106 X MCOL 22	1		4	4	2	3	1		3	4	1	3	1	0	2	3
CM 3750-5	CM 1117-3 X MCOL 22	1		4	4	4	3	1		3	4	1	2	2	2	2	2
CM 3997-1	CM 681-2 X CM 849-1	1	4	4	4	3	3	3		4	4		3	2	Y	3	4
CM 4042-4	CM 1015-13 X CM 180-5	1		5	4	4	3	2		4	3		1	2	Y	2	3
CM 4181-1	CM 847-1 X MCR 2	1		4	4	5				3	3		3	1	Y	3	4
M BRA 191	AMARELA CASCA ROXA	1		4	4	2	2	1		4	4	1	3	3	Y	2	4
M COL 1505	MANIHOICA P-12	1	4	4	3	2	2	3	3	3	3	2	2	1	2	2	3
M COL 2215	VENEZOLANA	1	4	4	5	2	1	3	4	4	5	5	3	1	0	3	3
M TAI 1	RAYONG 1	1	4	4	4	4	4	2	3	4	4	3	1	1	0	2	5
SG 455-1	MCOL 1684	1		4	5	4	5	2		3	5	5	3	1	0	4	4
CG 32-22	MBRA 20 X MPAN 97	2	4	4	3	3	3	3	2	2	2	1	3	1	0	2	3
CG 35-3	MBRA 20 X MVEN 77	2		5	3	4	3	5		2	2		3	1	0	2	3
CG 165-7	MCOL 1495 X MPAN 90	2	4	5	3	4	5	3		2	2	5	3	1	0	2	4
CG 1139-2	MBRA 5 X MECU 82	2	4	4	3	4	2	2		3	2		3	1	Y	2	4
CM 523-7	MCOL 655A X MCOL 1515	2	3 4 1	4	5	2	2	3	3	2	2	5	3	1	1	3	4
CM 2166-6	CM 430-37 X MVEN 218	2	1	5	3	2	2	2	2	2	1	5	3	1	Y	3	3
CM 2177-2	CM 430-37 X CM 840-136	2	4	5	3	2	1	2	2	2	2	2	3	1	0	3	3
CM 2600-2	MVEN 77 X CM 523-7	2	4 1	4	4	2	3	3		2	2	4	3	1	3	4	4
CM 2766-3	CM 723-3 X CM 523-7	2	3 1	4	4	3	3	3		2	1	5	3	1	3	3	4
CM 2766-5	CM 723-3 X CM 523-7	2	4	5	4	3	1	3		2	1	5	3	1	2	3	4
CM 2770-7	CM 727-14 X MVEN 77	2		4	2	3	3	3		2	2	5	2	2	2	3	4
CM 2772-3	CM 727-14 X MPAN 128	2	3	4	2	2	2	3		2	3	5	3	3	Y	2	5
CM 2909-36	CM 1011-4 X CM 523-7	2		4	4	3		3		2	2	3	3	1	0	4	5
CM 2952-1	CM 1145-1 X MPAN 128	2		5	2	2	2	3		2	1		3	1	0	3	5
CM 2952-3	CM 1145-1 X MPAN 128	2		4	3	3	2	3		2	3	4	3	1	0	2	4

(Continued)

Table 5. (Continued)

CLONE	COMMON NAME OR CROSS PARENTS	ZONE PRPL	ZONE SCND	YIELD AND QUALITY YLD	DM	HCN	CUL QLT	PEST AND DISEASE RESISTANCE TRP	MON	CBB	SED	DPL	MORPHOLOGICAL TRAITS ROOT COLR	FLSH COLR	PGMN CRTX	BRN-CHNG	PLNT HGHT
CM 3064-4	CM 1326-5 X MVEN 77	2		4	4	2	1	2		3	1	5	3	1	2	3	4
CM 3380-7	CM 586-1 X CM 523-7	2		4	4	3		2		2	3	4	3	1	1	3	3
CM 3401-2	CM 621-169 X CM 523-7	2		4	3	4	3	3		3	2	3	3	2	Y	1	3
CM 3544-9	CM 840-138 X CM 523-7	2			3	4		3		2	2						
CM 3894-1	CM 1307-3 X CM 523-7	2		4	3	4		2		1	3		2	1		3	2
CM 4157-34	CM 586-1 X MBRA 12	2		5	3	3	2	2		2	2		3	1	0	3	4
M PAN 51	BRASILENA	2		3	3	2	2	3	3	3	2		3	1	2	4	5
SG 104-264	VAR 2	2	3 4	5	3	4	5	3	2	1	1	2	2	1	1	2	4
SG 104-284	VAR 2	2	4	4	3	3	1	3		2	2	4	3	1	0	4	4
SG 107- 35	VAR 5	2	3 4	4	3	2	1	4	3	1	2	1	3	1	0	3	4
SG 250-3	MCOL 1912	2		4	3	4	2	3		2	2	5	3	1	2	3	4
SG 695-1	CM 723-3	2		4	3	2	1	2		2	2		3	1	0	3	4
CM 507-37	MCOL 1438 X MCOL 1684	3	2 4	5	2	4	4	4	4	2	3	5	3	2	1	5	2
CM 1999-5	CM 516-15 X CM 517-1	3	4	5	4	3	4	3	3	4	4	4	3	3	2	3	4
M MAL 2	BLACK TWIG	3	1	4	4	3	4	4	4	3	5	1	3	1	1	3	5
CG 1-37	MBRA 12 X MCOL 22	4	1	5	3	3	4	1	3	4	5	3	1	1	0	2	4
CG 5-79	MCOL 22 X MCOL 414	4		4	4	2	3	1	1	5	5	5	1	1	0	2	4
CG 996-6	MCOL 1413 X MPTR 19	4	1 2	5	4	2		2		2	2	5	3	1	0	2	4
CG 1534-10	M MEX 1 X CM 922-2	4		5	4	2		2		3	3		3	1	1	3	4
CM 321-188	MCOL 22 X MVEN 270	4	6	4	3	3		2	3	5	5		1			2	4
CM 489-1	MCOL 882 X MVEN 270	4		5	2	3	4	3	3	4	5	5	2	2	1	3	5
CM 849-1	SM 76-66 X MVEN 218	4	2	5	2	4	4	3	3	3	3	4	3	1	Y	2	5
CM 922-2	MPTR 19 X CM 314-20	4	1	4	5	2	2	2	3	4	4	4	3	1	3	2	3
CM 955-2	CM 309-37 X MVEN 218	4	1	5	4	2	3	2	2	4	4	3	3	1	Y	2	4
CM 1305-3	CM 446-22 X MCOL 1684	4	3	5	2	5	5	3	3	5	5	4	3	1	2	4	4
HMC 1	MANIHOICA P-13	4	3 2	3	4	2	1	3	3	2	4	3	3	1	2	3	4
M BRA 383	VASSOURAO	4	1	4	4	4		1		3	4		3	1	1	1	4
M COL 1468	MANTIQUEIRA: MANIHOICA P-11	4	6 1	4	2	3	2	5	4	3	3	5	3	1	3	3	3
M CUB 74	SENORITA	4	6	4	4	2	1	2	2	5	2	5	3	1	2	2	4
CG 354-2	MCOL 309 X MCOL 1468	5		4	4	2		2	2	4	5	4	3	1	0	3	3
CG 358-3	MCOL 335 X MCOL 2060	5		4	3	1		2	3	3	5	3	3	1	0	3	3
CG 401-3	MCOL 1522 X MCOL 340	5		5	4	3		2	2	4	4	2	3	1	0	3	4
CG 402-11	MCOL 1522 X MCOL 647	5		4	3	3		1				3	3	1	0	3	4
CG 406-6	MCOL 1522 X MECU 169	5		5	4	3		1	3	4	5	5	1	2	0	3	3
CG 481-3	MCOL 2060 X MECU 169	5		5	4	3						3	2	1		3	3
CG 501- 2	MECU 169 X MCOL 2060	5		5	4	2		1					1	1	0	3	3
CG 501-18	MECU 169 X MCOL 2060	5		4	4	2							1	1		3	3
CG 1118-32	MCOL 2017 X MCOL 2060	5		4	3	3							2	1		3	4
CG 1235-1	MCOL 2006 X MCOL 2019	5		4	4	1		1					2	1	0	4	4
M COL 1522	ALGODONERA AMARILLA	5		4	4	2		1	2	4	5	5	3	1	0	3	3
SG 350-23	MCOL 1522	5		5	4	1							3	1		2	5
SG 350-42	MCOL 1522	5		5	4	2							2	1		3	3

(Continued)

Table 5. (Continued)

DESCRIPTION OF CODES FOR ELITE CLONES

ZONE = EDAPHOCLIMATIC ZONE OF ADAPTATION
PRPL = PRINCIPAL ZONE OF ADAPTATION
SCND = SECONDARY ZONE(S) OF ADAPTATION

1: TROPICAL LOWLANDS; LONG DRY SEASON
2: ACID SOIL SAVANNAS
3: HUMID TROPICS
4: MIDDLE ALTITUDE TROPICS
5: HIGHLAND TROPICS
6: SUBTROPICS

YIELD AND QUALITY
(1 = LOW; 5 = HIGH)

YLD = YIELD POTENTIAL IN ZONE(S) OF ADAPTATION
DM = ROOT DRY MATTER CONTENT
HCN = ROOT HCN CONTENT
CUL QLT = CULINARY QUALITY (1 = GOOD; 5 = POOR)

PEST AND DISEASE RESISTANCE
(1 = RESISTANT; 5 = SUSCEPTIBLE)

TRP = THRIPS
MON = MONONYCHELLUS TANAJOA
CBB = CASSAVA BACTERIAL BLIGHT
SED = SUPERELONGATION DISEASE
DPL = DIPLODIA ROOT ROT; GREENHOUSE EVAL.

MORPHOLOGICAL TRAITS

ROOT COLR = ROOT SURFACE COLOR
1 = LIGHT
2 = MEDIUM BROWN
3 = DARK BROWN

FLSH COLR = ROOT FLESH COLOR
1 = WHITE
2 = CREAM
3 = YELLOW

PGMN CRTX = PIGMENTATION OF ROOT CORTEX
0 = ABSENT
1 = SLIGHT PINK
2 = LIGHT PURPLE
3 = PURPLE
Y = YELLOW

BRNCHNG = BRANCHING HABIT
1 = VERY LITTLE BRANCHING
5 = VERY HIGHLY BRANCHED

PLNT HGHT = PLANT HEIGHT
1 = VERY SHORT
5 = VERY TALL

Table 6. Criteria used by farmers in Cordoba, Bolivar and Magdalena departments of Colombia to evaluate acceptability of new cassava varieties.

Frequency (%)*	Description of criteria
99	Eating quality
70	Ease of harvest
70	Yield
70	Root size
43	Fresh root dry or watery
38	Production of planting material
35	Root surface and cortex color
31	Starch content
26	Bitterness
26	Better than Venezolana (local check)
20	Flavor
18	Acceptability for market
16	Root flesh color
7	Presence of fibrous core in root

* Based on 116 farmer responses.

Table 7. Selected farmer evaluation criteria in on-farm trials in Cordoba, Sucre and Magdalena in 1987-88 in early (H1) and normal (H2) harvests.

Clone	Eating ~~quality~~[1]		General evaluation[2]		Root yield[2]		Seed production[2]		Compared to Venezolana[3]	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
CG 915-1	2.0	1.5	1.0	1.0	1.0	1.0	-	3.0	-	1.0
CG 1141-1	1.0	2.0	1.0	-	1.0	1.0	1.0	1.0	-	-
CM 523-7	2.0	2.0	1.5*	1.0	1.0	2.0*	1.0	3.0*	2.0	3.0
CM 962-4	3.0	4.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	3.0
CM 3281-4	2.0*	3.5	1.6*	-	*	*	-	1.0	2.0	1.0
CM 3306-4	2.0	2.0	1.0	1.0	1.0	1.0	2.0*	1.0	1.0	1.0
CM 3306-9	2.5	2.5	1.0	-	1.0	1.0	-	1.0	-	-
CM 3320-4	2.0*	4.0	1.5*	1.0	*	1.0	1.0	1.0	-	-
CM 3372-4	2.0*	4.0	1.0	2.0*	-	1.5*	1.0	1.0	-	-
CM 3408-1	2.0*	3.0*	1.6*	1.3	*	2.0*	1.0	1.0	1.5*	2.0
CM 3435-5	1.0	2.0	1.0	2.0*	*	2.0*	1.0	1.0	2.0	-
CM 3555-6	2.0	4.0*	1.0	2.0	2.0	2.0*	-	1.0	-	-
CM 3624-1	4.0	2.5	2.0	2.0	*	2.0	1.0	1.0	3.0	2.0
CM 3750-5	3.0	-	1.0	-	2.0	-	-	1.0	1.0	-
M BRA 191	2.5	2.5	1.0	2.0*	3.0	2.0*	-	1.0	-	-
M COL 2054	1.5	2.0	1.0	1.0	*	1.0	1.0	3.0*	1.0	2.0
M COL 2215	1.5	2.0	1.5	2.0	*	2.3	-	-	-	2.0
M COL 2237	4.0	-	3.0	-	2.0	-	-	-	-	-
M COL 2253	2.0	2.0	1.3	1.0	*	1.0	3.0	2.0*	3.0	1.0
M COL 72	2.0	3.0	1.0	3.0	-	1.5	3.0	2.0*	-	-
M CUB 18	2.0	3.0	2.0	1.0	-	1.0	-	2.0*	-	1.0
M CUB 49	3.0	3.5	2.3*	2.0	*	2.5*	1.0	1.0	-	3.0
VENEZOLANA	1.5	1.5	1.0	1.0	1.0	3.0	-	3.0	-	-

[1] 1= excellent; 5 = poor

[2] 1 = good; 3 = poor

[3] 1 = better; 2 = equal; 3 worse

* Data with very high variability

Table 8. Performance of ISAR cassava selections in advanced yield trials at two sites in Rwanda.

	Root yield (t/ha)			(1 = resistant; 5 = susceptible)	
Clone	Karama	Rubona	Mean	CMD	CGM
* M.COL 1413 (MTS.4)/60	24	49	36	2.3	2.0
GACYACYALI 2/555	16	54	35	1.5	3.0
GACYACYALI 1982 (MTS.4) /554	19	47	33	1.3	3.0
KIBOMBOGORO 83-84 (MTS.4)/537	22	44	33	2.0	3.0
* M.COL 1413 (MTS.4) /10	18	44	31	2.5	2.5
* M.COL 974(A) MTS.4 /122	21	35	28	2.0	2.0
* M.COL 1552 (MTS.4) /184	18	36	27	1.5	2.5
KIRYUMUKWE 83/663	8	46	27	2.3	2.0
* COL 1552 (MTS.4)/181	19	35	27	1.5	3.0
30572 OP. WEST BANK 3 /572	15	39	26	1.3	2.5
PAKARE	21	30	26	2.3	2.5
* M.COL 1710(MTS.4)/101	21	29	25	2.5	3.0
30572 OP MIT BANK/404	24	25	24	1.0	2.5
* M.ECU 160 (a) (MTS.4) /164	14	35	24	1.3	3.0
30572 OP WEST BANK 83 /559	18	30	24	1.5	1.8
* M.BRA 12 (MTS.4)/242	18	29	23	1.8	2.0
30572 OP MIT BANK 83 /418	19	26	22	2.0	2.0
PYT BULK 1980/83 (MTS.4)/369	20	23	21	1.5	3.0
30395 OP 1980/83 (MTS.4)339	20	22	21	1.3	2.5
PEPINIERE 80/77/593	15	26	21	2.5	2.7

(Continued)

Table 8. (Continued)

Clone	Root yield (t/ha) Karama	Rubona	Mean	(1 = resistant; 5 = susceptible) CMD	CGM
30555 OP 80-3/437	16	26	21	1.3	2.5
KIBOMBOGORO 83-4/535	9	31	20	1.3	2.5
KIBOMBOGORO 83-4 (MTS.4)/525	11	29	20	1.0	3.0
PYT BULK 1980/83 (MTS.4)/362	11	28	20	1.0	2.5
UYT BULK 1979 (MTS.4) /304	8	31	19	1.3	3.0
* M.BRA 12 (MTS.4)/238	9	29	19	2.5	2.5
* M.COL 825 (B) (MTS.4) /203	14	24	19	1.5	2.5
30572 OP. MIT BANK/83 /421	14	23	19	1.0	2.0
* M.BRA 12 (MTS.4)/352	10	26	18	1.0	2.8
MAGURU 8/82/510	11	33	17	1.3	3.0
UYT BULK 1976/84 (MTS.4)/328	11	22	17	1.3	2.5
General mean	16	33	24	1.6	2.5

* CIAT origin.

SOURCE: L. Gahamanyi and J. Mulindayabo, ISAR, Rubona, Rwanda

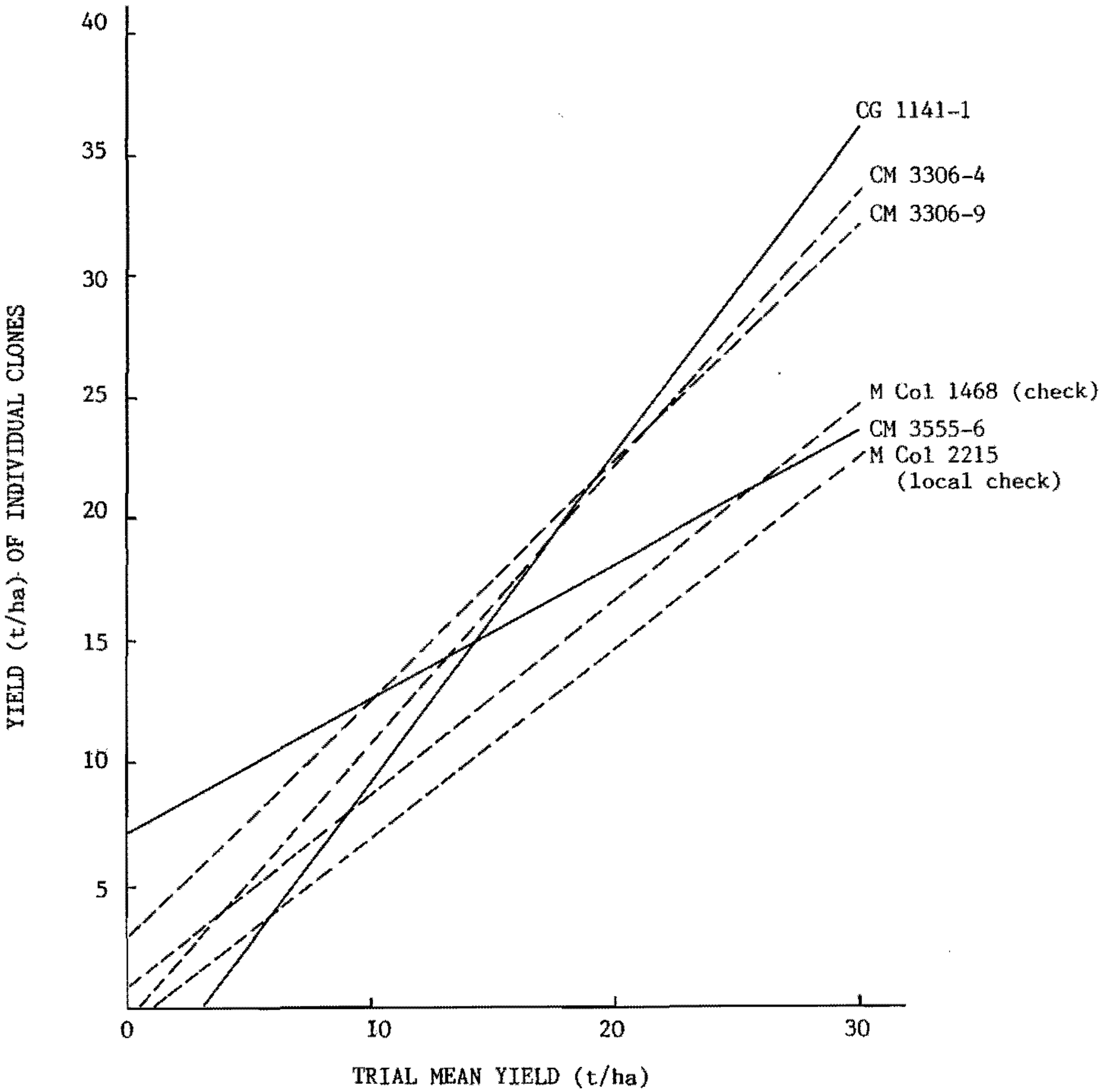

Figure 1. Yield performance of promising hybrids and check varieties across years in Media Luna, Carmen de Bolívar, and CIAT-Palmira.

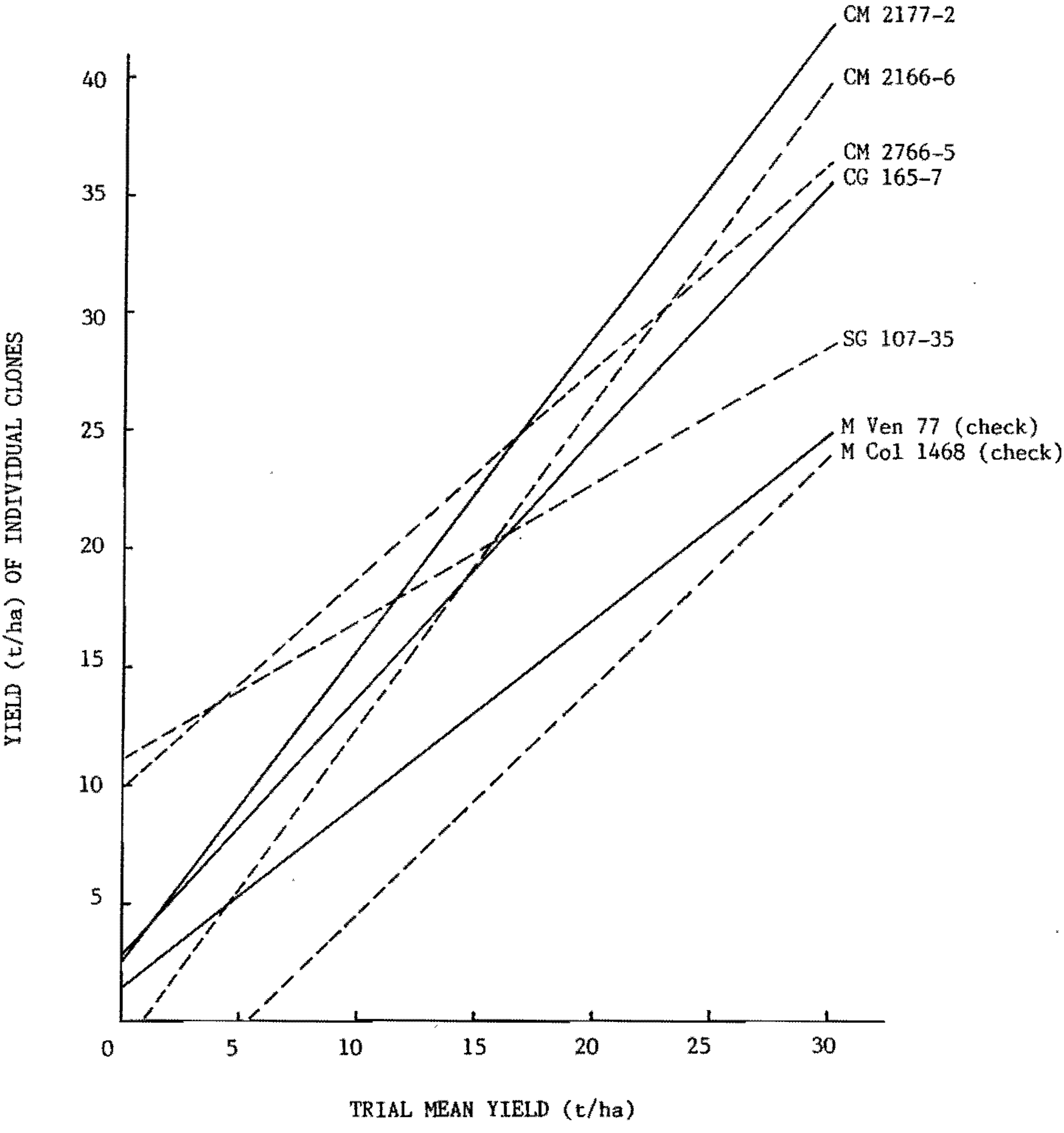

Figure 2. Yield performance of promising hybrids and check varieties across years in Carimagua and La Libertad.

Cassava Agronomy Asia - Annual Report 1988

R. Howeler

The CIAT Cassava Agronomy program in Asia initiated in December 1986 with the stationing of an agronomist/soil scientist at the CIAT Regional Office for Asia in Bangkok, Thailand. The objective of this program is to develop, in cooperation with Asian national programs, crop and soil management practices that will increase cassava yields, reduce per unit cost of production, and allow for sustainable cropping systems. The first step to attaining those objectives was to visit the national cassava programs, characterize the socio-economic as well as edapho-climatic conditions for cassava production in each country, collect and review the research on cassava cultural practices already conducted by national programs, to determine production or marketing constraints and establish priorities for collaborative research in each country.

During 1987 and 1988 several trips were made through the cassava growing areas of Thailand and the following countries were visited: China 4 times, India 3 times, Indonesia 7 times, Malaysia 2 times, Philippines 2 times, Sri Lanka 1 time, Vietnam 1 time. The most important data on socio-economic and edapho-climatic conditions as well as the cassava utilization patterns for each country have been described in the trip reports.

From October 24 to 30, 1987 the principal cassava breeders and agronomists in Asia participated in a "Workshop on Cassava Breeding and Agronomy Research" held in Rayong, Thailand, with the objective to review the current situation in cassava breeding and agronomy and to establish priorities for future collaborative research projects. During the workshop the agronomists discussed the cassava production statistics, the edapho-climatic conditions of the cassava growing regions and reviewed the research on cassava agronomy conducted in each country. Much of this information had previously not been published or was published only in the native languages. On the final day of the workshop the agronomists were asked to prioritize the ten topics which they considered of most importance in cassava agronomy in their country. Table 1 shows a summary of this priority listing. It is clear that nearly all countries considered erosion control and soil fertility maintenance as the most important topics for future collaborative research. Other topics considered of great importance were on-farm research, integrated weed control and reduced tillage. The proceedings of this workshop were published in October 1988 and give an excellent overview of the present status of cassava production in Asia as well as the breeding and agronomy research that has been conducted.

After defining the cassava growing conditions and the economic future potential of the crop in each country, and taking into account the priorities for future research that were established by national scientists, the following collaborative research projects were initiated (Table 2):

Thailand

In Thailand cassava is grown in areas of sloping topography with very light textured low organic matter soils that are extremely susceptible to erosion. In many areas farmers have been growing cassava as a monocrop almost continuously for 10 or more years. Since fertilizers are very expensive in Thailand and the crop has a rather low value, very few farmers apply the recommended dosage of fertilizers, if any at all. Under these conditions the yields are low (~14 t/ha) and may have actually been declining recently due to nutrient exhaustion of the soil and degradation caused by erosion. Besides being too expensive for most cassava farmers, chemical fertilizers are also not efficiently utilized, as most soluble nutrients are rapidly leached out because of low levels of clay and organic matter in the soil. Thus, erosion control and the maintenance of soil fertility through intercropping, under-cropping or green manuring with legumes were considered priority research topics. Additional agronomic research on time of planting and harvesting and on methods of planting were initiated in collaboration with scientists of Kasetsart University and the Field Crops Research Institute. Table 2 shows the topics and location of the research projects. Most of the experiments are still in progress and the results will be reported in detail by national scientists with joint CIAT authorship. Preliminary results of the erosion trial indicate that contour ridging, subsoiling, intercropping with peanuts and fertilizer application are the most promising management practices to control erosion on the sandy soils of Thailand.

Indonesia

In Indonesia cassava is grown mainly in Java by small farmers on steep slopes with rather degraded soils. Although the slopes are much steeper than in Thailand the soils are much heavier and not as susceptible to erosion. Still, erosion is a serious problem, as evidenced by the heavy sediment loads of the rivers during the early part of the rainy season. Due to the small size of most farms (less than 0.5 ha) cassava is generally intercropped with upland rice and/or maize in the early part of the growing season and with peanuts, soybean or rice-bean after harvest of the first intercrop. Depending on the relative value of each crop cassava is closely spaced (1 x 1 or even 0.80 x 0.80) when its price is high or widely spaced (3-5 meters between rows) when the intercrops are considered more valuable. Trees and grass strips are also grown within the cassava field to supply firewood and cattle feed. With these very intensive cropping systems the soil is exposed to the impact of raindrops only in the very early part of the growing season before cassava or the intercrops cover the soil.

In southern Sumatra cassava is an important crop both for small subsistence farmers and large cassava plantations with starch factories. The former use complicated intercropping systems, similar to those used in

Java, while the latter grow cassava mainly in monoculture and with partial mechanization. Due to heavy subsidies on fertilizers, their use is quite common in Indonesia, especially in the big plantations, but also by small farmers. When the cassava price is good, farmers may actually over-fertilize with N, producing tall plants but not necessarily good root yields. Fertilizer placement is often suboptimum resulting in leaching and run-off losses. Thus, in Java, either in the eastern or central part of the island, collaborative trials were initiated on erosion control, fertilizer placement, long term effect of NPK, and spacing and fertilization of cassava intercropped with maize, rice, peanuts and soybeans. The latter two trials are also repeated in a Transmigration area of southern Sumatra, where small farmers grow cassava for the starch factory, but grow it intercropped with other food crops. These trials are conducted in collaboration with agronomist at the Bogor and Malang Research Institutes for Food Crops as well as with scientists at Brawijaya University in Malang. In addition, collaborative trials are conducted on erosion control and long-term fertility maintenance on a cassava plantation in S. Sumatra. The first year's results show that erosion can be reduced and yields increased by a reduction in tillage practices. Thus, instead of using the Rome harrow followed by disc plow, disc harrow and ridger, it was found to that the Rome harrow can be followed directly by a ridger. In the long term fertility trial, the first year's results indicate mainly a response to N, up to 100 kg N/ha, less response to P and no response to K.

Malaysia

In Malaysia cassava is grown by small farmers as well as large plantations mainly for cassava starch production. During the past 10 years the production area has declined due to changes in government land policies and due to competition from cheap imported Thai cassava starch. However, there appears a future potential mainly for use in animal feed and for production of liquid glucose/fructose. On mineral soils cassava has to compete with the much more lucrative plantation crops like rubber and oilpalm. The latter are grown in the flatter and more accessible areas, while cassava is grown only on small plots in the hills. Here erosion can be a serious problem. On the extensive areas of peat soils in the country, cassava competes only with pineapple. Because of their acid-soil tolerance these two crops seem to have the greatest potential on these very acid (pH 3.5) soils. With adequate applications of NPK as well as lime cassava yields of 30-40 t/ha can be obtained. However, yield declines have often been observed in cassava crops grown continuously an peat soil. The cause of this decline is presently being investigated in a long-term fertility trial. Therefore, trials in Malaysia were recently initiated on erosion control on mineral soils and on long-term fertility maintenance in peat soils in collaboration with the breeder/agronomist of the Malaysian Agric. Research and Development Institute.

Philippines

In the Philippines cassava is grown in the central and southern part of the country. It is grown mainly as a subsistence foodcrop as well as a commercial crop for animal feed and starch production. Cassava is extensively grown as a staple food in the southern-most muslim islands of Basilan, Sulu and Tawi-Tawi. In these islands, as well as anywhere where the crop is grown by subsistence farmers, it is grown mainly under old coconut palms and/or on steep slopes where soil fertility is too low for maize production. The recent establishment of a large starch factory in Bohol has resulted in an important market-outlet for cassava grown by small farmers on the acid soils of the northeastern part of the island. In this economically-depressed island increased cassava production on previously under-utilized and *Imperata*-infested land has greatly improved the wellfare of small farmers. In the absence of a sufficient market outlet for fresh cassava, farmers hand-chip and dry their cassava roots and sell them for the animal feed market. Unfortunately, the animal feed industry is concentrated near Manila and thus far removed from the cassava producing areas. Thus, high transport costs and the need for middlemen makes this alternative presently less-attractive for cassava farmers. The pilot feedmill at VISCA in Leyte has shown that cassava and sweet potato-based animal feed can be produced economically on a small-scale for local use. This would greatly reduce transport costs and make cassava production more attractive in the economically depressed central and southern islands.

Since cassava production under coconut palms remains a common practice in much of the Philippines as well as in India, a collaborative project was initiated to define the cultural practices required for this cropping system. This project includes trials on spacing, time of planting as well as age at harvest and fertilization for cassava grown under coconut. Another project was initiated on erosion control. Both these projects are in collaboration with cassava agronomists at the Philippines Root Crop Research and Training Center located at VISCA in Leyte. Another project on cultural practices for cassava monocropping in Bohol will be initiated in early 1989.

China

In China cassava is grown only in the southern provinces of Hainan Island, Guangdong, Guangxi, and in the southern parts of Fujian and Yunnan. It is grown from 18°N up to about 26°N, where there is danger of frost during 1-2 months of the year. Cassava is generally planted in March-April and harvested in November - January. Thus, planting material has to be stored during 3-4 months and be protected from frost damage in the northern regions. Since flat land in southern China is invariably used for rice, vegetables and sugarcane production, cassava is grown almost exclusively on terraced or unterraced hillsides in areas of undulating or mountainous topography. When planted on narrow terraces in the hills it generally grows on exposed subsoils and suffers from severe nutritional problems, mainly P and K deficiencies. When grown on unterraced hillsides erosion can be very severe, resulting in a rapid decline of productivity. Thus, in Guangxi collaborative trials were established with the Guangxi Subtropical

Crops Research Institute on long-term fertility maintenance, on method of planting and on storage of planting material during the winter. A project on erosion control is planned for 1989. In Hainan cassava is mainly grown in the hills and mountains of the central part of the island. These areas are being brought under cultivation mainly for production of rubber, sugarcane and pastures. Cassava is economically attractive only when the price in very high or as an intercrop between young rubber trees or during pasture establishment. The roots are used for starch production or are hand-chipped and dried for feeding home-grown pigs or for export. No commercial chipping or pelleting plants have yet developped like in Thailand. In collaboration with the South China Academy of Tropical Crops a project was initiated on erosion control and on spacial arrangement of cassava intercropped with various pasture legumes and grasses. Preliminary data indicate that erosion is more serious than expected, even on gentle slopes and on soils of clay-loam texture.

India

In India cassava is grown mainly (~70%) for human consumption in Kerala state and for starch production in Tamil Nadu. In Kerala it is grown by small farmers (average is less than 0.5 ha) on gravilly lateritic soils of relatively low fertility and with hilly topography. In Tamil Nadu it is grown as a commercial crop on slightly larger farms (1-2 ha) on much better soils and with high inputs of fertilizers and irrigation. Under these conditions the crop produces extremely high yields of over 30 t/ha, while yields in Kerala, with very limited inputs, are still a very respectable 18 t/ha. These high yields in Kerala are obtained using mainly local varieties with low yield potential but excellent eating qualities, and using highly intensive cultural management, including hand preparation of soil, application of farmyard manure, ash and chemical fertilizers, and good weed control. Some cassava is also planted on low-land rice soils, resulting in very high yields.

During the past 25 years the Central Tuber Crops Research Institute (CTCRI) in Trivandrum, Kerala has done intensive research on all aspects of cassava production, from cytogenetics to utilization. They have developed 6-7 high yielding hybrids; these have not been used extensively in Kerala but some are now widely grown in Tamil Nadu, contributing significantly to the high yields obtained there. While cultural practices are very well-defined for areas in and around Trivandrum they have not been sufficiently tested in other parts of Kerala, especially in areas where cassava is grown under coconut. These aspects may be further researched in future collaborative trials. During 1988 a Memorandum of Understanding between the Indian Council for Agric. Research (ICAR) and CIAT was signed and collaborative projects will be initated in early 1989.

<u>Sri Lanka</u>

In Sri Lanka cassava is grown only on a very small scale for direct human consumption by the poorest sector of the urban and rural population. It is usually grown as a backyard crop or under old coconut palms. With the recent development of a large irrigation scheme in the dry zone of the east-central part of the island more rice will become available for human consumption, which is likely to replace cassava as a human food. However, within the irrigated zone there are large areas of uplands, which are unsuitable for rice and lack enough rainfall for maize. These areas are only recently being brought under cultivation and have relatively good soils. They seem to have a good potential for cassava, either for production of starch or animal feed. The Central Agricultural Research Institute (CARI) with funding from IDRC is presently conducting cassava breeding and agronomy trials in this area in order to define the yield potential and optimum cultural practices. Some additional collaborative trials may be initiated in 1989.

Vietnam

Cassava production in Vietnam is much more important than was previously realized. Although production statistics are difficult to obtain, there may be as many as half a million hectares under cassava. In most of the country the crop is grown as a subsistance crop, partially used for human consumption and for on-farm feeding of pigs. In South Vietnam there is considerable commercial planting of cassava for production of starch and starch-based products like noodles, macarony, bread and cookies. Although cassava is an important food crop throughout the country and has considerable potential as a commercial crop in South Vietnam, very little research has been conducted on the crop. The Institute of Agricultural Technology of South Vietnam (IAT) is presently conducting small-scale variety and agronomic trials. The introduction of better germplasm and the development of better cultural practices should lead to a rapid increase in yield, from the present very low levels of 6 t/ha, making the crop more economically attractive for production of various human foods, for animal feed and possibly for export. Collaborative projects will be initiated in early 1989.

Table 1. Priority of research topics in cassava agronomy, identified by national program scientists in Asia.

Research topic	China	India	Indon.	Malays.	Philip.	Sri L.	Thail.	Ave.
1. Soil fertility maintenance								
erosion control	9	10	10	10	10	5	10	9.1
NPK fertilization(long term)	6		5	4	9		8	4.6
green manures		6	2				9	2.4
alley cropping	2		3		2	4		1.6
intercropping	8		8	3	3	9	6	5.3
2. Weed control								
efficient-manual control						6		0.9
chemical control	5			2				1.0
integrated weed control	7	4	1			10	7	4.1
3. Land preparation								
reduced tillage		5	4	9		8	1	3.9
4. Stake storage								
in dry season		8						1.1
in cold season	10							1.4
5. Intercropping								
spacing and arrangement			2	7		6	4	2.7
fertilization			7	6	4	3		2.9
spacing under trees	3	9			5			2.4
6. Time of planting and harvest	4	1				2	2	1.3
7. Irrigation								
frequency, quantity method		7				1		1.1
8. On-farm research	1	2	6	1	8	7	5	4.3
9. Water management on peat				5				0.7
10. Cultural management under trees					7			1.0
11. Development inoculants of N fixing bacteria					6			0.9
12. Pruning as a form of storage					1			
13. Mechanization				8				1.1
14. Techniques for field establishment of stakes		3						0.4
15. Test production package in each region							3	0.4

1 = low priority
10 = high priority

Table 2. Collaborative research projects in Cassava Agronomy in Asia initiated in 1987/88.

Country	Topic	Location
Thailand	Erosion control	Sri Racha Exp. Station
	Erosion control	Sri Racha farmer's field
	Erosion control	Pluak Daeng King's project
	Date of planting	Sri Racha Exp. Station
	Method of planting	Rayong Research Center
	Intercropping with grain legumes	Rayong Research Center
	Alley cropping	Rayong Research Center
	Cover crops	Pluak Daeng King's project
	Green manures	Pluak Daeng King's project
Indonesia	Erosion control	Umas Jaya Farm, Sumatra
	Erosion control	Brawijaya Exp.Farm,E. Java
	Long term fertility trial	Brawijaya Exp.Farm,E. Java
	Long term fertility trial	Umas Jaya Farm, Sumatra
	Method of fertilization in cassava/maize	Farmer's field, E. Java
	Fertilization cassava/maize/rice/peanut	Yokyakarta, C. Java
	Fertilization cassava/maize/rice/peanut	Tamanbogo, S. Sumatra
	Spacing trial for cassava/maize/rice/peanut	Tamanbogo, S. Sumatra
	Spacing trial for cassava/maize/rice/peanut	Yokyakarta, C. Java
Malaysia	Erosion control	MARDI, Kuala Lumpur
	Long term fertility trial on peat	Peat station in Pontian
Philippines	Erosion control	Farmer's field, Baybay,Leyte
	Cassava spacing under coconut	VISCA, Baybay, Leyte
	Time of planting and harvest under coconut	VISCA, Baybay, Leyte
	Fertilization under coconut	VISCA, Baybay, Leyte
China	Erosion control	Farmer's field Hainan
	Cassava/pasture intercropping	Farmer's field Hainan
	Long term fertility trial	Ming Yuan state farm,Nanning
	Stake storage in winter	Ming Yuan state farm,Nanning
	Method of planting	Ming Yuan state farm,Nanning

CIAT Cassava Asian Regional Program
(1988 Annual Report)

Kazuo Kawano

Cassava in Asian agricultural community

Cassava's peculiar adaptability to upland conditions, particularly where there are either soil or moisture constraints, and its multiple end-markets give cassava a certain flexibility in adapting to different production and demand situations. Cassava is an important food source in Southern India, Indonesia, Vietnam and some areas of the Philippines. It is an important source of starch in all countries and is an important export crop in Thailand, Indonesia and China. Cassava's role in each country's agricultural economy will be different, but in each case cassava can be the basis for meeting multiple policy objectives (Table 1).

Potential recipient of technology

In the predominantly subsistence farming system where cassava is grown and consumed as fresh human food within family or small community, modern agricultural technology many not provide a means of improving the living conditions. The present production method is often an adequate, sustainable scheme within the given context. If a change is to occur, it would be caused by a change in macro socio-economic conditions.

With the development of new processing/utilization schemes for human consumption, animal feeds and industrial uses, cassava is incorporated into a marketing economy. Under this scheme, demands for comparatively low input technology for better production and processing efficiency and sustainable soil management will be strong. The major recipient of the technology will be the small farmers who conduct their production and living on comparatively poor soils under largely unpredictable rainfall scheme.

With the development of export oriented production/processing complex of cassava chips and pellets or large scale starch production scheme for internal and expert markets, needs will arise for efficient production technology adapted to poor to moderately fertile soil areas at moderate input levels. The major recipient of the technology will still be the mass of small farmers. Large scale producers for starch such as cassava plantations in Sumatra or state farms in China and Vietnam will also be the significant, immediate recipients of the technology, yet, the large mass of consumers of the food products will be the indirect recipient of technology in these cases.

Aside from these production oriented technology, Socio-economic analyses on the present production/processing/utilization scheme and marketing mechanism and the future demand in each component of this scheme will greatly help the public and private policy makers and national research program leaders.

Status of national research programs and demand for technology

A crude assessment of the present status of national cassava research programs in Asia is given in Table 2. The situation is highly contrasting from country to country depending on the socio-economic condition of the country and the relative importance of cassava in national economy.

Potential demand and utilization of cassava technology by Asian research programs and the work partition between the national programs and CIAT are also assessed (Table 3 and 4). In addition to the previously recognized areas such as training and communication, and advanced germplasm, a need for the development of cooperative research for sustainable production system is strongly felt and a substantial demand for high yielding, low HCN cultivars (dual purpose cultivar) also exists although nearly all research officials deny the importance of cassava for direct human consumption. Processing and utilization continue to be important and in this particular area, CIAT as well as national research programs can learn a lot from the Asian practices so as to develop a comprehensive cooperative research. Socio-economic analysis can contribute in defining research strategy and the analyses linking between the micro and macro economic situations are much desired.

Form of cooperation

Given the comparatively advanced stage of national agriculture research organizations in Asia and the small size of the CIAT Cassava Asian Regional Program, our activities are always through cooperative research with the national research programs.

In the countries where no national cassava research program exists, a preliminary survey of cassava production and utilization in cooperation with technical officials and identification of research institution and technical personnel who can potentially conduct cassava research on a continuous basis are necessary before starting any cooperation. Training of the research personnel is typically the first step of cooperation. A demonstration of efficient cassava production by conducting a simple varietal trial with a generally recommendable cultural practice may be a typical way of starting research. This may appear primitive, yet, many currently functioning cassava varietal improvement programs had started their activities in this form.

After national cassava research program is established and the key research personnel are reasonably trained, a basic capacity to conduct comprehensive breeding trials and standard cultural practice experiments is first to be secured. At this stage, contribution from CIAT of advanced breeding materials is essential. Application of cultural and crop protection technology developed at CIAT is often very helpful. Capability to conduct long term experiments for production sustainability and socio-economic analysis on production/utilization/marketing mechanism is much desired but usually deficient. Many national programs lack mechanism to transfer developed technology to the farmers.

At every step of this process, CIAT can be a help to the national programs. Providing cooperative research contracts which include a small, specific funding to temporarily stopgapping the weak point of the national program may often enhance the total efficiency. For the success of cooperation, the presence of experienced CIAT staffs working hand in hand with the national program officials on the spot is crucial not only in accurately executing the technical experiments but also in learning together the problems faced by the national program researchers.

When a national program matures, the relationship between it and CIAT passes to the stage of a real collaboration and the each party becomes an indispensable part of the integration. The national program continues to benefit from CIAT in the areas of training and communication, germplasm, advanced cultural and crop protection technology, and socio-economic analysis. CIAT relies on the national program in testing some of the basic technology developed by CIAT. The collaborative program produces advanced breeding materials to be adapted to neighbor countries with similar edapho-climatic conditions and market requirements. Even at this stage, comparative advantage of CIAT and national program is clear so that the integration gives much higher efficiency than when the two institutions operate in isolation.

Table 1. Potential role of cassava in agricultural policies of Asian countries.

Agricultural policy objectives	Contribution according to country						
	Thailand	Indonesia	Vietnam	India	China	Philippines	Malaysia
Food and nutrition policies							
a. Flexibility in rice policies		X	X	X			
b. Nutrition of the poor		X	X	X		X	
Farm income and land use							
a. Higher small-farm income in upland areas	X	X	X	X	X	X	X
b. Exploitation of frontier areas		X	X		X	X	X
Balance of payments							
a. Increased export earnings	X	X			X		
b. Import substitution		X				X	X

Table 2. Present status of National Cassava Research Program in Asia.

	Existence of NARS	Cassava Research Program	National Cassava Research Coordination	Cassava Research Capacity	Technology transfer	Research by Private sectors
Laos	0	0	0	0	0	0
Cambodia	0	0	0	0	0	0
Nepal	+	0	0	0	0	0
Sri Lanka	+	+	+	+	0	0
Vietnam	+	+	0	+	++	0
China	+	+	0	++	++	0
Malaysia	+	+	+	++	0	0
Philippines	+	+	++	++	0	0
India	+	+	+	+++	+	0
Indonesia	+	+	+	++	+	++
Thailand	+	+	++	+++	++	+

Table 3. Potential demand and utilization of cassava technology by Asian research programs.

	Training and commnication	Basic germplasm	Advanced germplasm	High yielding low HCN cultivars	Basic cultural practice	Sustainability technology	Crop Protection	Processing/ utilization	Socio-economic analysis
Laos	+	0	+	+	+	?	?	?	?
Cambodia	+	0	+	+	+	?	?	?	?
Nepal	+	0	+	+	+	?	?	?	?
Sri Lanka	+	0	+	+	+	+	+	?	?
Vietnam	+++	+	+++	++	++	++	+	+++	++
China	+++	+	++	+	++	++	++	++	++
Malaysia	+	0	++	0	0	+	0	0	++
Philippines	++	+	++	++	+	++	+	++	+++
India	++	+	+	++	+	++	++	++	+
Indonesia	+++	+	+++	+++	+	+++	+	+++	+++
Thailand	+++	++	+++	+	+	+++	+	++	+

Table 4. Work partition between NARS and CIAT.

Research area	NARS	CIAT
Training	50% (20)	50% (80)
Communication	40 (10)	60 (90)
Basic germplasm	10 (2)	90 (98)
Advanced germplasm	50 (20)	50 (80)
Low HCN cultivar	80 (?)	20 (?)
Varietal release	90 (90)	10 (10)
Basic cultural practice	80 (50)	20 (50)
Sustainability technology	70 (30)	30 (70)
Processing and utilization	60 (80)	40 (20)
Socio-economic analysis	50 (40)	50 (60)

Desirable (Present)

CROPPING SYSTEM RESEARCH IN THE NORTH COAST OF COLOMBIA

Highlights for 1988

Cropping systems research during 1987-88 was conducted mainly in the North Coast of Colombia, as part of the Cassava Research Network that the Program and ICA have organized in the Region. At present, this network comprises 15-20 researchers and extension personnel from different national institutions, is operating mainly in the Departments of Cordoba, Sucre, Atlantico and Bolivar.

During the period of this report, the network met on four occasions to plan and coordinate field research and to discuss more specific topics such as cassava "seed" production by farmers and the coordination with ICA and CIAT's Agroecological Studies Units, to improve the characterization of the most important production environments of the North Coast.

From the institutional point of view, the most relevant activity of the cassava network this year has been the incorporation of the network's research plans into the PLANIA planning system of ICA and the coordination with the recently created regional CRECEDs offices. The CRECED's approach to training, research and extension was discussed by the network with each of the offices and joint activities planned for the future. This coordination with the CRECED offices ensures the continuity of the network activities and increases its coverage as well. The Cassava Program has been active in these new institutional developments both at the regional level and at ICA's Headquarters in Bogota.

During this year, eleven members of this regional cassava network received trainning at CIAT's headquarters in analysis of field data and use of microcomputers for research. This is the second phase of this type of training for this group.

As a result of the regular joint planning activities and adecuate training in data analysis, the first publication of the network's field results was released this year. The Cassava Program provided general logistic support and editing assistance for this publication: results are mostly from on-farm experiments. This is the first Colombian publication that summarizes research results of cassava-based cropping systems.

The development of an improved methodology for on-farm research with cassava-based cropping systems is one of the most important objectives of CIAT's collaboration with the network. In 1985, CIAT designed and tested a standard type of field trial to study the ability of both maize and cassava cultivars to growth in association. That year CIAT's staff planted this type of experiment in 14 farmer's fields with almost no ICA participation. For the 1987-1988 cropping season, 18 trials in farmers fields to test different maize varieties, intercropped with cassava, were planted by ICA personnel as part of their regular activities, following the same type of field design previously used by CIAT. Approximately the same number of these trials are planned for the next cropping seasons.

This year's results with cassava/maize intercopping experiments gain resulted in better performance, in terms of yields, of the improved over the traditional maize varieties both in sole crop and when intercopped with cassava. The recently released improved maize cultivars V-156 and V-109 outperformed the rest of the cultivars in every locality tested. The maize cultivar V-156 resulted in higher yields when intercropped with cassava, particularly under favorable growing conditions, such as the Cordoba Department. The local maize cultivar always resulted in lower maize and cassava yields than with the improved varieties. In 17 field trial the new maize cultivar V-258 did not perform as well as expected by the ICA Maize Program. Table 1 is a summary of maize yields (data from only 8 farms with at least 2 reps/farm). In these farms, CIAT personnel together with the farmers planted and harvest the experiments.

As shown on Table 1 the maize cultivar SV-901 yielded 40% less when intercopped with cassava. The cassava cultivar Venezuela also yielded 38% less when intercropped with the maize cultivar SV-109 (Table 2). The cassava cultivar Venezolana yielded significantly less only when intercopped with the local maize variety "Puya".

In another set of on-farm trials, the same methodology that is being used to test different maize cultivars is also being used to test different cassava cultivar's ability to grow in association with maize.

The cassava varieties MCol-22; MCol-72; CM 681-2 and CM 962-4 were selected for this purpose due to their good relative performance in several regional trials. These varieties were intercopped with the maize cultivar V-156 in 4 farms (2 reps/farm) in the Departments of Cordoba and Bolivar.

A significant difference in terms of fresh root weight was recorded between the tested cassava cultivars. In a general average and considering both its yield in monocrop as well as in association, cv M Col 22 outyielded the rest of the varieties by 3-5 ton/ha of fresh roots. Relative yields of cassava varieties differed when they were cultivated in sole crop or in association with maize.

Table 3 summarizes the results of this experiment, which the cultivar CM 962-4 not only yielded less when intercropped with maize (40%) but also caused the largest reduction in maize yield (34%), as shown on Table 4.

From these cassava/maize intercrop experiments, it can be stated that within the range of the cassava cultivars tested and under ecological conditions similar to the North Coast of Colombia, the regular test of new cassava cultivar in its ability to grow with maize will improve the selection process of new cassava varieties.

In addition to the on-farm testing of newly released varieties, within the network activities, CIAT's personnel have temporarily taken full responsibility for the on-farm testing of some technology components such as "seed" selection and chemical treatment of planting material.

With regard to seed selection, an on-farm experiment was designed to firstly test the farmers capacity to produce good planting material and also the farmer's ability to properly select good planting material. Three treatments of seed selection were tested with 17 farmers (usually three reps/farm) for a total of 17 reps for each treatment:

- Farmer planting material selected and prepared for planting by the farmer.

- Farmer planting material selected and prepared for planting by CIAT's staff.

- Planting material identified as good quality by CIAT's staff and selected and prepared by CIAT's staff.

In an overall analysis, farmer planting material selected and prepared for planting by CIAT's staff was significantly superior to the rest of the treatments, but only at the 10% level of significance. Table 5 summarizes average yields for each treatment.

These results imply that farmers are indeed capable of producing good planting material although the amounts in which this material is produced is probably a subject for another study. At the same time these results show that the selection of planting material conducted by CIAT's personnel tends to increase yields but with no indication of the amount of land that can be planted using this selection pressure that resulted in higher yields.

An interesting result of this experiment is that there was no correlation (r = .41 ns) between the number of plants that were harvested and the yields obtained. Other than yield in terms of ton/ha of fresh roots, no other variable was significantly affected by the treatments.

In another set of experiments the effectiveness of chemically protecting the cassava planting material, previous to planting was tested under farmers conditons in 16 farms across the North Coast of Colombia. A mixture of Benlate, Orthocide and Systemin was used for this experiment. The farmer's stakes of the cultivar Venezolana, were separated in two groups to which the chemical treatment and no treatment (check) were randomly applied. At least three reps/farm were planted.

The number of plants harvested was significantly different for treated and untreated planting material. An average of 500 more plants/ha were harvested in the treated plots (CV = 7.3%). In an overall analysis considering the totality of the localities (Departments) where the experiment was planted, a positive significant difference (5%) in terms of total fresh roots weight/ha in favor of the treated seeds was registered (17.0 vs 15.8 ton/ha).

There was also a significant interaction between localities and yields and between farmers and yields. This interaction indicate that not always seed treatment resulted in better yields. In fact this positive response to seed treatment was true in 11 out of the 16 farms included in the experiment. Table 6 summarizes the results by localities.

Table 1. Average yields of different maize cultivars in sole crop and in association with cassava cultivar Venezolana. Average from 8 farms. Atlantic Coast, Colombia 1987.

Maize Var.	Maize Yield(ton/ha)		% Reduction due to intercrop
	Sole crop	Intercrop	
V-156	2.7	1.8	33
V-109	2.6	1.7	33
SV-901	2.2	1.3	40
Local (Puya)	1.8	1.3	27
V-258	2.3	1.5	33
Average	2.30	1.54	33

Table 2. Average yield of cassava variety Venezolana in sole crop and in association with different maize cultivars. Averages from 8 farms. Atlantic Coast, Colombia, 1987.

Maize Var.	Cassava yields (ton/ha)		% Reduction due to maize
	Sole crop	Associated with maize	
V-156	15.9	11.9	25
V-109	16.1	11.2	31
SV-901	16.1	10.1	38
Local (Puya)	16.3	9.8	40
V-258	16.3	11.0	33
Average	16.11	10.80	33

Table 3. Average yields of different cassava cultivars in sole crop and associated with the maize variety V-156. Average from 4 farms. Atlantic Coast, Colombia 1987.

Cassava Var.	Yields Sole crop	Yields Associated with maize	General average	% Reduction due to maize
M Col 22	26.3	20.0	23.2	24
CM 962-4	25.0	14.9	20.0	40
M Col 72	18.7	15.7	17.2	17
CM 681-2	17.4	13.6	15.5	28

Table 4. Average yields of maize cultivar V-156 in sole crop and in association with different cassva cultivars. Average from 4 farms. Atlantic Coast. Colombia, 1987.

Cassava Var.	Yields of maize (ton/h) Sole crop	Yields of maize (ton/h) Associated with maize	Reduction due to cassava
M Col 22	2.6	2.0	25
CM 962-4	2.6	1.7	34
M Col 72	2.5	2.0	21
CM 681-2	2.4	1.9	32

Table 5. Fresh root weight of cassava produced under different seed selection and preparation criteria. Average from 5 farms. Atlantic Coast. Colombia 1987.

	Treatments[a] 1	Treatments[a] 2	Treatments[a] 3
Yields	15.9 b	17.0 a	15.6 b

[a] 1 = Farmer planting material selected and prepared by themselves.
2 = Farmer planting material selected and prepared by CIAT's staff.
3 = CIAT's planting material selected and planted by CIAT's staff.

Table 6. Average yield of cassava planted with and without surface stake treatment in differents localities and farms. Atlantic Coast. Colombia, 1987.

Locality	Farmer	Yields (ton/ha) Treated	No treated	Sta. Signif. %	%CV
Cordoba	1	34.8	29.3		
	2	22.0	23.0		
	3	12.5	11.9		
	4	21.1	19.1		
	5	20.5	19.1		
Average		22.2	20.5	10	7.8
Sucre	1	10.7	8.4		
	2	19.5	18.2		
	3	12.8	13.0		
	4	18.5	16.7		
	5	18.8	15.5		
Average		16.0	14.4	15	14.4
Atlantico	1	14.0	15.6		
	2	14.6	15.5		
	3	11.7	11.6		
	4	12.6	12.9		
Average		13.3	13.9	ns	14.6
Bolivar	1	14.6	12.9		
	2	13.9	9.5		
Average		14.2	11.2	10	11.3

CASSAVA UTILIZATION - 1988

A. RESEARCH

1. Pedal operated cassava chipper

A pedal operated cassava chipper was built last year, based on an original design from the Philippines. Such a machine would enable individual farmers to chip small quantities of cassava efficiently, for production of dried chips for animal feed. However, this machine showed some deficiencies, and an improved design was produced in collaboration with the Universidad del Valle, Cali (Design and Technology Section of the Faculty of Engineering). The new prototype has improved ergonomics (seat, pedal and handle positions) as well as adjusting the disc and blade dimensions so as to optimize the use of the force employed. The disc weighs 8 kg, with a diameter of 65 cm, and has 8 blades arranged radially over the surface. The blades are trapezoidal and produce roughly rectangular chips with dimensions of 60 x 7 x 5 mm. The machine can chip 400 kg/h when operated by 2 people taking 10 minute turns. The machine costs Col.$75,000 (US$235), of which 60% is due to the cost of materials.

2. Evaluation of some methods for moisture content determination in cassava.

No standard method for measuring the moisture content of cassava roots exists. In CIAT, freeze drying is used, as well as oven drying at 60 and 70°C for 24-48h. Some industries which purchase dried cassava use oven drying at much higher temperatures (ñ 100°C) for short times. There is a need for a rapid, accurate method of determining moisture content in dried cassava. A thesis project 1/ was carried out with the objectives of determining a standard method for moisture content determination in cassava, and evaluating some more rapid methods of possible interest to cassava drying cooperatives and feed companies. The lack of a standard methodology has caused commercial difficulties for the cassava drying cooperatives in Colombia in the past.

In the first stage of the study, freeze drying, and oven drying at 60, 70°C and a combination of 70 and 100°C were evaluated. Freeze drying at ambient temperatures gave the best results as regards residual moisture and the smallest changes in total carbohydrate contents. Oven drying at 60 and 70°C were calibrated against the freeze drying method using the following equations:

60°C $y = 0.973\, X1 + 2.21$ S.E. 0.511 2/
70°C $y = 0.976\, X2 + 1.55$ S.E. 0.627

1/ Valencia Carlos Eduardo y Prieto May-Ling. 1988. Study of standard methods and development of a rapid, practical method for moisture content determination in cassava.

2/ S.E. = Standard Error.

Where X1 = moisture content (on wet basis, %) from oven drying at 60°C.
X2 = moisture content (on wet basis, %) from oven drying at 70°C.
y = corrected moisture content (freeze drying).

In the second stage of the study, three rapid methods were evaluated: infrared lamp, distillation with vegetable oil and the moisture-content determination oven (Brabender). These were calibrated against oven drying at 70°C for 24 h.

The correction equations for these methods are:

$y = 1.009\ X1 - 1.78$ Brabender oven at 130°C S.E. = 0.31; $y = 0.996\ X2 - 0.38$ Infrared lamp with 1.5 amp. S.E. = 1.13; $y = 0.978\ X3 + 3.13$ Distillation with vegetable oil at 140°C S.E. = 0.86.

Where
y = corrected moisture content (%, wet basis)
X1, X2 y X3 are the contents found for each method.

Of the three rapid methods studied, distillation of vegetable oil at 140°C was the most practical method for use by the cassava drying cooperatives for determination of moisture content in the final product. It is planned to test this method with drying cooperatives over the next few months.

3. Adjustments to the pilot plant producing dried cassava for human consumption.

Continuous operation of the CIAT pilot plants for the production of flour for human consumption has enabled adjustments to be made to the management and operation of several of the items of equipment with the overall objective of efficiently obtaining a high quality product. These adjustments have lead to improvements in the design of some of the machinery used.

a) Microbiological quality

Many microbial analyses of the final product have been made with the objective of correcting some deficiencies in the washer and adjusting washing times, and to check the degree of hygiene with which the operations are being carried out (chipping, drying, pre-milling and sieving) and also to take into account the cleanliness of the plant workers.

The following table shows how drying method was found to affect product quality.

Table 1. Summary of the microbial analyses carried out on cassava flours using roots washed with tap water.

	Maximum Permitted values (crude flours)	Drying method		
		Natural (tray)	Mixed	Artificial at 60°C
Total number of colonies/g	30,000	1,430,000	1,240,000	30,000
N.M.P. total coliforms/g	150	240	420	50
N.M.P. Escherichia coli/g	<3	Negative	Negative	Negative
Staphilococus aureus coagulase positive	100	Negative	Negative	Negative
Salmonella/25 g	Negative	Negative	Negative	Negative
Fungi and yeasts (colonies/g)	2,000	300	60	20
Bacillus cereus (colonies/g)	1,000	1,300	1,100	80

In the root washing operation, concentrations of 0.3 and 1.0% Sodium Hypochlorite were used. These results are not presented since no differences were found with the results from using tap water. Drying method had no effect on fecal coliforms, stafilococus or salmonella, nor on fungi or yeasts which were consistently absent. However, natural drying systems using inclined trays and also the combination of natural and artificial drying at 60°C did not guarantee a good quality product as regards 'total colony count' and 'total coliforms' present per gram of flour. These results obtained during the trials carried out in the conditions of the CIAT pilot plant imply that only by using artificial drying at 60°C could a good quality product fit for human consumption be guaranteed.

b) Proximal Analysis

Table 2 shows the range of values of crude fibre, ash, total and free HCN found in flour samples obtained by both natural and artificial drying.

Table 2. Values of HCN, fibre and ash contents of cassava flours produced by the CIAT pilot plant

Characteristic	Natural Drying	Artificial Drying
Crude fibre (% d.b.)	2 - 3	2 - 3
Ash (% d.b.)	1.2 - 2.5	1.2 - 2.5
HCN (total)	20 - 40	60 - 80
% HCN free	70 - 90	50 - 70

By washing roots and sieving the flour to produce particle sizes less than 250 microns, it was possible to obtain low values for fibre and ash. Natural drying on inclined trays, which takes 36 h, is capable of eliminating most of the fresh root HCN, and thus the final flour only contains between 20 and 40 ppm, of which 70-90% is free HCN. The efficiency of HCN elimination by artificial drying at 60°C for 8-10 h is not so good, and therefore the flour contains between 60 and 80 ppm HCN, of which only 50-70% is free. Care must therefore be taken when selecting the cassava varieties to be used for flour production, since artificial drying is required to produce a flour of acceptable hygene, yet this drying method is the least efficient in HCN elimination.

c) Redesign of equipment

The new manual for the construction of the Thai-model cassava chipper will include the Colombian-model disc, with 8 blades of trapezoidal cut which produce more uniform, rectangular chips, designed especially to produce flour for human consumption. These blades are also being tested for the production of chips for animal feed. Nevertheless, the material used to date is not sufficiently robust and blades will be redesigned using thicker calibre steel.

A premilling machine for dry chips is being built in a workshop in Cali, based on the first draft of a construction manual. The direct contact between builders and designers will allow corrections to the manual before its distribution to interested parties.

4. Fresh cassava quality research

Continuing the project initiated last year with ODNRI and Nottingham University, UK, in which the factors affecting organoleptic quality of fresh cassava are being studied in relation to the physico-chemical properties of the root tissues, cassava samples were regularly sent to both institutions for analysis. At CIAT, the expert taste panel evaluated all samples sent, thus allowing the eating quality to be directly compared with the results of the physico-chemical studies. In addition to the samples of fresh and stored cassava of differing eating qualities sent as in the previous year, samples of roots from pruned and unpruned plants were also taken, since pruning negatively affects root quality. Thus samples with extreme variations in quality are available for analysis. Results to date at Nottingham are inconclusive, but many aspects of starch properties and characteristics remain to be investigated (Table 3).

The expert taste panel has continued to function on a regular weekly basis at CIAT, with approximately 15 members. In addition to the samples evaluated relevant to the ODNRI project, other variables were also studied. A comparison was made between fresh cassava of good eating quality, cassava stored for two weeks using the CIAT/ODNRI storage technology, and commercially available frozen and vacuum packed cassava from Cali supermarkets (Table 4). The results show that quality changes during the two weeks of storage were few , confined to a sweeter taste and a decrease in bitterness, whereas both frozen and vacuum packed cassava were of very poor quality, with many characteristics

TABLE 3. Comparison of fresh cassava quality evaluations from pruned and unpruned plants of M Peru 245 and CMC 40 by the cassava expert taste panel

	UY-8819 PAN 09068 M Peru 245			UY-8816 PAN 09018 CMC 40		
	Prune	Unpruned	*	Prune	Unpruned	*
Color	63	36	***	55	38	***
Starch	53	125	***	91	125	***
Glassy	97	26	***	68	23	***
Moist	70	72	NS	59	72	*
Fresh	93	120	***	97	121	***
Yuca Smell	107	78	***	91	105	***
Smell Deterioro	19	16	NS	24	22	NS
Sweet taste	53	39	*	48	33	**
Bitter taste	25	24	NS	27	27	NS
Yuca taste	64	106	***	65	112	***
Fibre	25	22	NS	23	29	***
Hardness	87	53	***	89	35	***
Consistency	62	92	***	46	91	***
Dry	37	58	***	44	64	***
Bitter aftertaste	24	25	NS	28	26	NS
Like	63	114	***	51	106	***

Key evaluations: minimum 0, maximum 150; higher number = greater intensity of character.

+++ = Means significantly different at 0.1% level
++ = " " " " 1% "
+ = " " " " 5% "
NS = Means not sigificantly different.

TABLE 4. Comparison of fresh 2 week stored, frozen and vaccum packed cassava, by expert taste panel

	Fresh	2-weeks Stored		Fresh	Vacuum packed		Fresh	Frozen	Significance
Color	57	52	NS	45	76	***	40	75	+++
Starch	101	100	NS	121	104	***	114	53	+++
Glassy	37	40	NS	32	55	***	33	93	+++
Moist	70	81	NS	75	41	***	49	99	+++
Fresh	105	113	NS	119	75	***	118	85	+++
Yuca smell	97	100	NS	99	51	***	98	67	+++
Deter. smell	21	20	NS	22	97	***	25	49	+++
Sweet taste	34	92	***	25	22	NS	42	33	NS
Bitter taste	40	19	***	24	26	NS	30	36	NS
Yuca taste	95	86	NS	113	49	***	102	49	+++
Fibre	45	42	NS	32	39	NS	28	28	+++
Hard	37	39	NS	40	114	***	68	41	+++
Consistency	88	86	NS	106	35	***	86	81	NS
Dry	41	33	NS	45	47	NS	68	35	+++
Bitter aftertaste	36	20	***	20	28	***	29	38	+
Like	94	88	NS	109	27	***	102	36	+++

Key evaluations: minimum 0, maximum 150; higher number = greater intensity of character.

+++ = Means significantly different at 0.1% level
++ = " " " " 1% "
+ = " " " " 5% "
NS = Means not sigificantly different.

significantly different from fresh cassava. These samples were evaluated after boiling: it is possible that differences were less for fried cassava. Nevertheless, the poor quality of the commercially available frozen and vacuum-packed cassava will limit the market for these products, given the premium price they command in the market, unless improvement to the processes are made.

Advantage was taken of many experiments carried out by other sections of the cassava program, to take samples for quality analyses in order to determine the importance of a range of environmental and other variables on fresh root quality. Samples were taken from experiments comparing drought stressed and unstressed cassava, different fertilizer treatments, different soil types, different levels of insect attack, and different cropping systems. Most of these samples are under analysis at present and only two completed experiments have been full analysed to date. These show that cassava grown in association with maize at CIAT was of similar quality to the same variety grown in monocrop as regards dry matter starch and total and reducing sugar contents and cooking time and eating quality. Similarly, and experiment looking at the effect of mealy bug attack failed to find differences in dry matter or starch contents related to the level of infestation, but significant differences were found for both reducing and total sugar contents and cooking time, although the eating quality of all treatments was poor. Detailed results from the experiments currently in progress and under analysis will be reported next year.

B. PILOT PROJECTS

a) Fresh cassava conservation projects

During 1988 the DRI-CIAT fresh cassava storage project in the north coast has made significant advances. More small farmer cooperatives have been trained in the use of the conservation technology, as have the personnel of the national institutions involved in giving technical assistance to the cooperatives. Additionally, progress has been made in Barranquilla, with all major supermarket chains now selling cassava in bags, and in August a cooperative of small shopkeepers started marketing the product to cooperative members. These chops are located primarily in low income residential areas of the city. By October, volumes traded had reached 12-15 ton/week.

In order to obtain further significant increases in product volumes, an extra component is required: promotion. Urban consumers in general are not yet aware of the quality and convenience advantages of the cassava in bags, despite their presence in shops and supermarkets. Therefore, a coordinated distribution and promotion plan was drawn up in mid 1988, and DRI agreed to finance the development and distribution of the following promotional material: poster for shops, leaflet for shopkeepers, leaflet for consumers and point-of-sale material for supermarkets. In addition, a brand name (Yucafreska, or fresh cassava) was selected and legally registered in the name of the Association of Cassava Cooperatives, after consumer testing. This brand name was used to design a logo for the bag and all promotional material. A campaign slogan was also selected (ÑCalidad por largo rato', or (roughly) Ñquality that lasts'). Finally, a new, improved design for the bag was selected which included logo, instructions for use, price and weight information. At the time of writing, this promotional material was in print, and expected to be available for use shortly. In the medium term, finance is being sought by DRI to develop more promotional material (TV and radio commercials, press adverts, etc.).

During 1989 the first positive effects of the promotional campaign on sales volumes are expected in Barranquilla. These will directly benefit the small farmers selling cassava to the cooperatives, the small shopkeepers selling a better quality product and urban consumers. Market studies of Bogota, Cali and Medellin are planned by DRI to which CIAT will give technical assistance, to determine the optimal strategy for marketing cassava in bags in these major Colombian cities.

In Bucaramanga, the farmer cooperative has sold less fresh cassava to the city than before, mainly due to the increasingly serious public order problems in the production region which have involved frequent road closures, making a consistent marketing operation almost impossible. However, the cooperative has expanded into dried cassava production, using credit from the land reform agency, and will re-emphasize fresh cassava in bags as conditions permit.

In Ecuador, market and consumer surveys of Guayaquil have been conducted and are currently under analysis, in order to determine the optimum strategy for commercial introduction (see Economics section report). One preliminary result is the need to expand into other production regions to ensure year-round availability of cassava in bags in the city.

b) Milling and Mixing

The dried cassava produced for animal feed by the small farmer cooperatives is currently sold directly to one of several large animal feed companies. A better option for the farmers is to use their drying facilities to dry other feed components locally available, and to formulate and sell their own balanced feed rations. Three cooperatives near Betulia, Sucre Department were interested in this approach, and decided to merge and pool their resources. The DRI-CIAT project is thus providing technical assistance in setting up and operating the milling and mixing plant which is being jointly built with CORFAS finance. The installations are now nearing completion and trial operation is expected shortly.

c) High quality cassava flour for human consumption

Following the completion of the IDRC financed project with CIAT/IIT and Univalle on developing the process for the small scale production of high quality, refined cassava flour, principally for substitution of 5-15% of wheat flour in bread, a second phase has been presented to IDRC for finance. This would involve the construction of a pilot plant for high quality flour production in order to test the technical and economic feasibility of the process under small farmer operation. It has become apparent that cassava flour has many uses in addition to wheat flour substitution in bread: there are a range of bakery products, food industry uses etc. which are more suitable for cassava flour than bread; i.e. % incorporation in products can be higher. The pilot project will therefore use the flour produced to evaluate the market potential of the product over a wide range of uses. If the project is funded, plant construction will start in 1989.

C. COMMERCIAL/EXPANSION PHASE

Dried Cassava for animal feed

The 36 cassava drying cooperatives on the Colombian worth coast are operating successfully, with over 5,200 ton of dried cassava produced in the 1987/88 season. CIAT's role in technical assistance to existing plants is much reduced now that the technical teams of national institutions have been strengthened by further experience and CIAT training: a course was held in March 1988 to train personnel both in dried and fresh, storable cassava. However, the project is entering a further expansion phase with the number of plants set to double over the next 3 years. Therefore, continued DRI-CIAT technical assistance to new drying cooperatives and the technical support teams set up to service them is required. Additionally, the National Rehabilitation Program of the Colombian government is to finance a series of cassava drying plants in other Colombian regions (Santander and Eastern Plains) in which CIAT will have a technical assistance and training role similar to that of the DRI project.

Finally, the encouraging event of 1987-8 has been the rapid expansion of the dried cassava industry beyond the institutional framework of the DRI-CIAT project. Several privately run, small scale drying plants have appeared; small cassava starch processors have produced dried cassava at times when the starch price is low, and many individual small farmers have been chipping cassava manually, drying on any available space and selling, often through intermediaries, to feed companies. Hence, although the DRI-CIAT project produced over 5,000 ton of dried cassava in the 1987-8 season; the feed companies report national purchases of over 12,000 ton. The multiplier effect of cassava based pilot projects can thus be clearly seen.

The total drying area increased by 18% to 5.100 m^2, the fresh to dry cassava conversion rate fell to 2.49 from 2.57 and the price paid to farmers for the raw material increased by 39% (well above the rate of inflation in Colombia).

ECONOMICS - 1988

Latin American cassava network

In November 1987 a workshop was organized in Mexico by the National Agriculture, Livestock and Forestry Research Institute (INIFAP) and CIAT to take stock of the patterns in which cassava national programs in Latin America had been evolving. The meeting sought to identify common development trends and approaches, as well as those which were peculiar to the specific conditions of any particular country. Eight country representatives were invited to present a state of the art paper on the institucional context of their cassava program. The need was expressed, at that time, for establishing more permanent and direct linkages among the national programs. Hitherto, it was felt, CIAT has played a pivotal facilitator role in the exchange of information and technology, among countries. Now the programs manifested to be ripe for a less centralized structure in which a new division of labor between CIAT and the national program.

These concerns were discuseed again in April 1988 during a meeting expressely organized at CIAT with this aim in mind. This time the meeting sought to ascertain the extent of the support for the notion of a structure which would continuously contribute to the direct exchange of information and resources among national programs. Furthermore, it attempted to operationalize areas in which inter-program cooperation could become a reality, if sufficient interest in permanent decentralized international cooperation mechanism was evidenced. The staff from the eight latin American countries invited to this event expressed their support for the creation of a network of latinoamerican cassava programs.

The participants coincided on perceiving that the relevance of the role that cassava was playing and would play in the future was dependent on multi-sectorial and multi-institutional interventions. Hence, the network would welcome the active involvement of researchers, extension agents, farmers, industrialists and decision making leaders. The network was also open to any other group interested in promoting the production and agroindustrial utilization of the crop to facilitate and unchain social economic development for society at large.

The participants ranked cassava marketing, technology transfer and production research methods, in that order, top priority concentration areas for the network in the immediate future. While focusing on these concerns, the network was expected to back up the exchange of personnel, equipment, materials and know-how between national programs. CIAT was asked to provide technical expertise and training support and contribute to the general awareness of activities taking place in the different regions of Latin America. The network would have its own bulletin, and CIAT would contribute to its publication and especially its distribution, given that it has a fairly comprehensive cassava international directory of personnel and institutions. The network's general secretariat for the 1988-1989 administration was placed in Colombia.

Since then, the network has been quite active. Under the joint sponsorship of CIAT, CIP and IITA, a workshop was organized in September in

Cartagena, Colombia to discuss possible avenues for improving the diagnostic capacilities for Roots and Tubers Production Systems. Another workshop is being organized for June 1989. This time the workshop will take place in Cuba, and will focus on cassava marketing and seed production.

New members have joined the network. A biotechnology chapter was constituted in September to improve germplasm conservation and in vitro exchange, development of immunological methods to control virosis, and micropropagation for seed production. In addition, many individuals joined the network. CIAT's directory of national programs' staff has been substantially updated and streamlined as a result of its involvement in the network.

The network is proving to be an important vehicule for promoting the exchange of information among national programs. It has so far published its bulletin's first two issues. It plans to print in 1989 a catalog of commercially available production and processing machinery, and a special publication to encourage cassava marketing, which will include current information on the market, profiles of cassava-based industries, price time series, commercial promotion approaches, new products in the market and technical norms for national and international cassava trade.

The network will also contribute to multiplying CIAT's efforts on cassava training. It is expected that in the immediate future an increasing number of international training activities will be organized and carried out directly by national programs, according to their comparative advantages. This new arrangement will allow CIAT to re-define diversify and expand the set of institutions and individuals with whom it will transact. This will make CIAT's support for cassava development more effective and long lasting.

Support for the Colombian cassava program

This year the Colombian executive branch declared cassava and six other commodities strategic items in its thrust towards national food self-reliance. It requested from the Integrated Rural Development Fund (DRI) to draft a national plan for the development of cassava production and utilization. DRI, in turn, invited CIAT to participate in the design of such plan, and in the assessment of the main features of cassava production and marketing arrangements in three regions of the country where the national plan could potentially operate. In addition to providing input into the plan's design, the Economics section's contribution to this effort has, so far, consisted of the following activities:

a. Rapid Appraisal of the cassava production areas in the Santander and Norte de Santander Departments. The cassava production area in the Santander and Norte de Santander Departments amounts to 7,550 hectares. Baseline information was gathered for three regions within these departments. It was found that cassava is an important cash crop for the farmers. Over 65%of the production is sold off-farm. Whereas most of the farmers trade with cassava as a fresh produce for consumption in large and medium-size cities, an important number of them chop up and dry the roots for the feed industry. Some 8,000 tons of fresh cassava are dried yearly.

Machetes are used for producing these cassava chips. Although most of the dried cassava is sold to middlemen, at least 1,500 tons of dry cassava have been sold directly to feed mills. In the recent past years, despite the lack of institutional support, drying patio construction has increased. The current total sundrying area covers 3,000 sq. meters, but most of the drying takes place ad-hoc spaces managed by individual farmers. A very bright prospect is foreseen for these Departments regarding the development of state-backed projects for fresh and dried cassava.

b. Participation in the design of a survey to assess cassava's role in three major cities of Colombia. A questionnaire to identify the main cassava consumption and buying patterns currently prevailing in Bogota, Cali and Medellin was constructed and pilot tested. Basic training sessions in interviewing and questionnaire handling procedures were provided for national personnel who will be directly in charge of conducting the survey.

Economic analysis of the process of production of wheat/cassava composite flour.

A comparative analysis of the production costs of flours of wheat, cassava and a 85% wheat - 15% cassava mix was conducted. The study first determined the costs of production in a cassava-corn-ñame cropping system at Col.$7,5/kg. Fixed-, variable-, and financial costs involved in the production of cassava chips were then calculated. The total cost of a kilo of dried cassava was estimated at Col.$42. The costs of raw material and processing for wheat-and cassava flour were Col.$88 and Col.$58, respectively. The cost to produce one kilo of composite flour was $83. Producing composite flour at this cost was found to be profitable up to a 50% margin between producer and the mill.

Spatial integration of the beans and cassava markets in Brazil.

Cassava and beans wholesale price time series for major Brazilian cities were gathered, coded and adjusted. Thirteen services for farinha and 12 series for beans were used, all from the 1970-1986 period. The Autoregressive Integrated Moving Average model was estimated for each one of the series. Path diagram analysis and regression analysis were performed as well. Data is still being processed.

Economic profiles and cost structures of wheat flour mills.

A survey was conducted to study wheat flour mills in eight Colombian Departments. A questionnaire was administered to 34 mill owners or managers. It was found that over 80% of the mills were small and medium-sized. Most mills underutilize their processing and storage capacity by an average of 35%. A large percentage of mills mixes flour produced out of imported and national wheat. The share of flour from domestically produced wheat ranges from 11% to 46%, which determines the existence of three grades of flour. Few mill operators had experimentally used composite flour.

The were given samples of cassava flour and cassava chips to be used for the production of a wheat/cassava composite flour. The mill operators indicated that minor adjustments were required concerning the best timing for mixing the flours. Nevertheless they would regularly use cassava flour if the supply flow and quality of the raw material were constant.

Economic description of Bogota's bakeries.

A study was carried out to ascertain the bakeries' facilities, raw material buying patterns, production capacity, product lines and familiarity with composite flours. One hundred questionnaires were administered in bakeries of different income brackets. Half of the bakeries purchased flour every month, the rest of them buying it every forthnight or even weekly. About 60% of the flour was purchased directly from the mills, and between 45% and 70% percent of the bakers (irrespective of their income group) bought it on credit for up to 26 days after the purchase. Bread baking was more demanding than cookie or pastry baking in terms of the quality of the flour used. Hence, bakers tended to favor the usage of a few flours with constant quality. Bakers in the lower economic strata used a larger share of their installed processing capacity than bakers in upper strata. Less than 10% of the bakers had used composite flour. Their experience had been very positive in this regard. They indicated that some demonstrations and testing but no additional equipment, would be required for other bakers to start using composite flour as well.

Panel to evaluate consumer reaction to a bread made out of wheat/cassava composite flour

A panel was organized which included 200 families from 5 neighborhoods which represented as many social strata. Bread consumption patterns data was first gathered. Consumers were then asked to blind-test two kinds of bread, one made out of wheat flour and the other one baked with a 85% wheat - 15% cassava composite flour. Over 80% of the consumers liked the latter type of broad, and 15% of them preferred it to wheat bread. Bakers were also asked to test bread making with composite flour. According to them, the usage of composite flour requieres substantial adjustments in the receipies for bread making, particularly as far as the amount of sugar and yeast involved is concerved. Composite flour is perceived highly appropriate for pastry but inadequate for baking french bread since the flour tends to render bread darker and less spongy. The physical appearance of bread can be improved, however, by reducing the proportion of cassava flour in the mix.

Assessment of current outlets for fresh cassava and opportunities for cassava flour in Guayaquil, Ecuador.

A study was carried out to described the current market structures and consumption and buying patterns for fresh cassava and wheat flour. Surveys were designed for cassava sellers (from wholesalers to retailers) and consumers. 320 consumers, 100 retailers and 16 wholesalers were interviewed. The analysis of these surveys is still being carried on.

Assessment of the current usage of cassava in farmer households in Paraguay.

Visits to randomy select farms were used to determine the amount of animls in each farm, how they are fed and the aims for animal production, as well as area cultivated to cassava and main areas of cassava utilization. It was found that most farmers have animals which are fed with products and subproducts grown in the farm. The most important crops for animal feeding are cassava, corn and sugar cane, in that order. Cassava peel and foliage are also used as supplementary feed. Cassava is harvested throughout the year as required, and no silage system is used.

Animal production has steadily increase in Paraguay since the 1950s (6% annual increase for poultry, 5% for swine, 3% for goats and 1% for bovines).

Changes in the area cultivated to cassava in Manabi, Ecuador and Cordoba, Colombia.

A study was conducted to estimate increases or decreases in the area planted to cassava in the last year. The goal was to verify wheather the opening of new markets have had any impact on the supply side. The study is one component of a larger longitudinal assessment of cassava production. Sixty four Ecuadorian farmers and 20 colombian farmers were interviewed. In Ecuador, almost 70% of the farmers in the sample increased their cassava production area, while 7% of them reduced it. In Colombia, over 60% of the farmers increased the area, while 10% reduced it. Those farmers who increased their area indicated that they were thus responding to the existence of floor prices and guaranteed market outlets for cassava as a result of the drying plants. Those who decreased their production area, on the other hand, explained that the reduction was the consequence of adverse climatic conditions, a lack of available land, and preference for more profitable crops. In the last year the cassava production area increased by 58% in Ecuador and by 21% in Colombia where the alternative markets have been in existance for a larger period.

DRI-CIAT Cooperative Project

Since 1982, CIAT has produced annual reports on the status of the Integrated Rural Development (DRI) - CIAT Cooperative Project. The reports followed up the development of cassava drying plants in the Atlantic Coast of Colombia. CIAT is happy to announce that DRI has assumed full responsibility for the preparation and publishing of the annual reports from 1988 onward. A copy of the sixth Annual Report for the december 1986 to november 1987 period, published by DRI in June, is available for reference in our offices.

Varietal Improvement in Asia (1988 Annual Report)

Kazuo Kawano

CIAT germplasm in national programs

Genetic variability of a given crop species is richest in the center of origin and diversification of the species. The cassava breeding materials provided by the CIAT cassava program are based on Latin American germplasm. They are expected to increase the gene frequency that is commonly desirable to Asian national programs. Local germplasm, on the other hand, may be an excellent source of adaptation to the traditional cultural environments and requirements of the locality. However, a significant jump, either in yield or resistance, is unlikely to occur as long as the breeding program uses local germplasm only: by nature it possesses limited genetic variability. Incorporating Latin American germplasm into Asian breeding population is the most appropriate way to improve cassava cutivars.

Three types of germplasm materials, i.e., germplasm accessions, hybrid clones, and hybrid seeds, are available from CIAT in the form of (1) stakes, (2) meristem cultures, and (3) true seeds. Emphasis has shifted to sending hybrid seeds from selected parents. During the past years, approximately 190,000 hybrid seeds from some 3200 crosses have been distributed to cassava breeding programs in Asia (Table 1). In many national programs, these seed populations are regarded as sources for immediate varietal selection while programs such as the one in Thailand have also selected cross parents from the seed populations to be used in their hybridization schemes. These materials are being processed through evaluation steps in each national program. The Thai/CIAT collaborative breeding scheme produced many thousands of hybrid seeds adapted to the Asian conditons and some of these have been distributed to other Asian cassava breeding programs and to the CIAT headquarters breeding program.

Varietal release

During 1988, two cultivars have been added to the list of CIAT related cassava clones officially released as recommended cultivars by Asian national programs, thus, making the total number of the cultivars seven in four countries (Table 2).

VC 2 is originally a selection from a Brasilian cross made many years ago at Campinas, Sao Paulo, Brasil, where it is known as Mantequella. It was introduced to Colombia during the 1960s and is known as CMC 40 in the Colombian national program varietal collection. CMC 40 was introduced to the CIAT world cassava collection during the early 1970s and was registered as M Col 1468. After passing through the CIAT series of multi-locational evaluations, M Col 1468 was considered as one of the promising germplasm accessions and was sent to the Philippines together with eleven other clones in 1978. After being evaluated in regional trials for more than five years, the Philippines Seed Board decided to release M Col 1468 as a recommended cultivar for fresh human consumption. VC 2 can be harvested in early months with good fresh eating quality. It is moderately high yielding with acceptable plant type. Its main liability is its low root dry matter content especially when planted under dry climates or harvested in more than ten months after planting.

Perintis (CM 982-7) is a selection by MARDI in Malaysia from a cross CM 321-170 x M Col 1684 made at CIAT in 1977 and introduced to Malaysia in 1977. CM 321-170 was a selection from a cross M Col 22 x M Ven 270. After clearing through initial steps of selection, CM 982-7 has been evaluated in regional trials for several years and shown a remarkeable yielding ability with very high harvest index especially on peat soils. However, its root dry matter content is distinctly low compared with the leading local cultivar, Black Twig, although the total dry matter yield is significantly higher than Black Twig.

<u>Present status of yield breeding</u>

In many parts of Asia as well as in the American tropics, traditional cassava cultivars for human consumption are well adapted to small scale plantings, often in the backyard in predominantly subsistence farmings, where major varietal criteria are eating quality and yield per plant rather than yield per area. The great majority of the existing land races in the Latin American tropics are of low harvest index type. Those cultivars for human consumption in Asia are in general of low harvest index also. When the need arises for new cultivars for larger scale commercial productions, yield per area, rather than yield per plant, becomes more important varietal requirement. Successful industrial cultivars such as Rayong 1 in Thailand, Adira 4 in Indonesia, Black Twig in Malaysia, South China 205 in China, and cultivars for starch production in Tamil Nadu in India, are characterized by improved harvest index.

The results of 43 yield trials in which four representative cultivars were compared in experiment stations in Thailand give a clear stastistical background to the perspective presented above (Fig. 1). The stem and leaf weight of Hanatee, the fresh consumption cultivar, was similar to that of Rayong 1 and higher than those of Rayong 3 and Rayong 60, the more recent cultivars, thus, the cause of low yield of Hanatee was the low harvest index, or the low efficiency of transfering and storing the photosynthesized product into the roots. Both total biomass and harvest index of Rayong 1 were far superior to those of Hanatee, suggesting that Rayong 1 was a simultaneous improvement in total biomass production and harvest index over the traditional fresh consumption cultivar. Rayong 3 gave a lower fresh root yield than Rayong 1 but this difference was compensated by its higher root dry matter content. The harvest index of Rayong 3 was significantly higher than that of Rayong 1, however, the stem and leaf weight was drastically reduced compared with that of Rayong 1, resulting in a significantly reduced total biomass. The harvest index of Rayong 60 was much higher than that of Rayong 1 and the stem and leaf weight was smaller than that of Rayong 1 but larger than that of Rayong 3. Thus, the root yield was significantly higher than any of the other. The total biomass was about the same as that of Rayong 1.

Similar comparison in 34 on-farm trials, in which Hanatee was not included since no farmer was interested in good tasting but low yielding fresh consumption cultivar, gave basically the same relative result (Fig. 2). Rayong 1 gave an average yield virtually equal to the national average yield, suggesting that the trials could be regarded as a good representation of the average cassava growers in Thailand and the evaluation in the experiment stations could be trusted. The higher yield of Rayong 60 was much to do with its high harvest index and the stem and leaf weight was not greatly smaller than that of Rayong 1. These suggest that new cultivars with high harvest index have a chance in average farmers' fields as long as the canopy establishment and strength are not too drastically reduced.

The data from recent trails for more advanced clones at Rayong station seemed to suggest the future direction of our yield breeding although the statistical basis of the results was much less conclusive since the data were taken from only two experiments (Fig. 3). Highest yields were obtained by those clones with extremely high harvest indices (0.66-0.76 as opposed to 0.45 of Rayong 1). The total biomass production by those clones was about the same as or slightly higher than that of Rayong 1. These suggest that selection for yet higher harvest index is possible and this may be a sound approach to obtain higher yields under well managed cultural conditions. One clone, CMR 26-72-7, gave an enormous biomass production maintaining a similar harvest index to Rayong 1. It is difficult to conclude that this much enhancement in biomass production (46%) over Rayong 1 by breeding is always possible, yet, the result is an encouragement leading to a possibility of increasing total biomass production without sacrificing the harvest index of highly successful industrial cultivar.

Throughout these trials, there was no sign of root dry matter content declining with the improvement in fresh root yield. This suggests that the genetic improvement opportunity in dry root yield has not been exhausted yet.

We can detect a very similar pattern in Southern Sumatra (Fig. 4).

Kretek, the traditional cultivar, is an equivalent of Hanatee in Thailand. Adira 4, the successful new cultivar for starch processing, is a somewhat improved version of Rayong 1 and CM 4049-2UJ, a promising new selection, may be an equivalent of Rayong 60. The situation in Malaysia is somewhat different yet we could discern a similarity (Fig. 5). Black Twig, the successful cultivar for starch processing, is the counterpart of Rayong 1 and CM 982-7, the new cultivar "Perintis", appears to be an equivalent of CMR 25-34-217. CM 982-7 is a sure example of high yield selection through elevating harvest index to the extreme under highly productive cultural environments, yet, the immediate task is to improve its desperately low root dry matter (or starch) content.

Summarizing all these, the cassava cultivar improvement through harvest index and total biomass is schematically presented in Fig. 6. Current successful industrial cultivars are the improvement over traditional fresh consumption cultivars both in harvest index and total biomass. To go beyong this, we are left with the following three theoretical possibilities: (A) improvement in total biomass keeping the same harvest index, (B) improvement in harvest index keeping the same total biomass, and (6) simultaneous improvement in harvest index and total biomass. The alternative A leads to a lower efficiency of water and nutrient use per yield, thus, it is not generally a wise choice. Yet, under very tough growing environments this might be one alternative because of the vigorous growing habit. B is most attainable, however, a question remains as to how the new cultivars with extremely high harvest index and much reduced stem and leaf weight would perform under less favorable growing environments. C is the most ambitious choice and improving the harvest index maintaining the same canopy strength of the existing industrial cultivars would be the practical guideline for the actual field selection. If this is attained, new cultivars would have a good chance of yielding well even under less favorable, low yielding cultural environments.

Comparison between CIAT and Asian hybrds

The CIAT cassava hybrid seed populations distributed to the Asian national programs are based on those cross parents selected through the evaluation schemes which include a wide variation of edapho-climatic and biological growth constraints. The collaborative work between the Department of Agriculture, Thailand and CIAT at Rayong Field Crop Research Center has also produced hybrid seed populations which have been distributed to other breeding programs in Asia. The majority of the cross parents for the Rayong hybrids are the locally selected clones of CIAT origin. Rayong 1 is widely used in the hybridization but other local germplasm is not extensively used. Breeding materials from these two sources were compared. At Rayong, Rayong hybrid clones showed superiority over CIAT clones in all the characters evaluated, i.e., fresh root yield, plant type, harvest index, root dry matter content and germination (Table 3). CIAT clones were particularly inferior in plant type and germination under somewhat erroneous rainfall.

A different set of the two populations were compared in a single-row trial and a preliminary trial in Southern Sumatra (Table 4 and 5). CIAT clones tended to give higher fresh root yield while the two populations gave similar harvest indices. Rayong clones showed better plant type and higher root dry matter content. Another set of comparison, conducted in Palembang, Indonesia, between CIAT hybrid clones and clones crossed and selected at Bogor, Indonesia also indicated that the CIAT clones were inferior in plant type (Table 6).

The Rayong result was predictable because the cross parents for Rayong hybrids had been selected on the spot. The Indonesian results gave a more fair basis to comparison because none of the cross parents for the two populations had not been selected on the spot. The inferior plant type of CIAT hybrids may be caused by the disease and pest resistant clones which are extensively used in the CIAT hybridization scheme and are usually of poor plant type. The successful germination habit of Rayong clones even under an erroneous rainfall was a reflexion of intensive selection for this character on the spot where stable germination is one of the most important, if not the most, yield factor in Thailand.

We can conclude as follows:

1. CIAT hybrid is a good source of high yield selection while Rayong hybrid offers good plant type, higher root dry matter content and successful germination under erroneous rainfall.

2. Selection of cross parents on the spot is highly recommendable.

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

Year Country	1975	1977	1978	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Thailand	900	6170	7720	3050	1400	7450	7900	8000	9300	8000	11800	14200	85890
Indonesia	900		700				4600		6000	4950	3130	8600	28880
Philippines	900		950		5100	4700	5500	2350	5000			3850	28350
China						2300	6100		3500	1800	2100	4400	20200
Malaysia	900	1500		2050	1250	4050				200		1490	11440
India	900		850				1050	7900					10700
Vietnam							1900						1900
Rep. China(Taiwan)	500					1200							1700
Total	5000	7670	10220	5100	7750	19700	27050	18250	23800	14950	17030	32540	189060

Table 2. CIAT related clones officially released as recommendable cultivar by Asian national programs.

Name	Country	Year of decision to release	Clonal code	Cross parents	Year of hybridization made	Location of hybridization	Means of introduction to National Program	Location of selection	Main feature
Rayong 3	Thailand	1984	CM407-7	M Mex55 x M Ven307	1974	CIAT	Seed	Rayong	High starch
Rayong 2	Thailand	1985	CM305-21	M Col113 x M Col22	1973	CIAT	Seed	Rayong	For snack food
VC 1	Philippines	1986	CM323-52	M Col22 x M Mex59	1973	CIAT	Stake	CIAT/PRCRTC	High yield
Nanz-zhi188	China	1987	CM321-188	M Col22 x M Ven270	1974	CIAT	Mersitem culture	CIAT/SCIB	High yield Early harvestability
Rayong 60	Thailand	1987	CMR24-63-43	M Col1684 x Rayong 1	1980	Rayong	Cross parent by stake	Rayong	High yield Early harvestability
VC 2	Philippines	1988	M Col 1468		before 1970	Brazil	Stake	CIAT/PRCRTC	Good early yield for fresh food
Perintis	Malaysia	1988	CM 982-7	CM321-170 x M Col1684	1977	CIAT	Seed	MARDI	High yield on peat soils

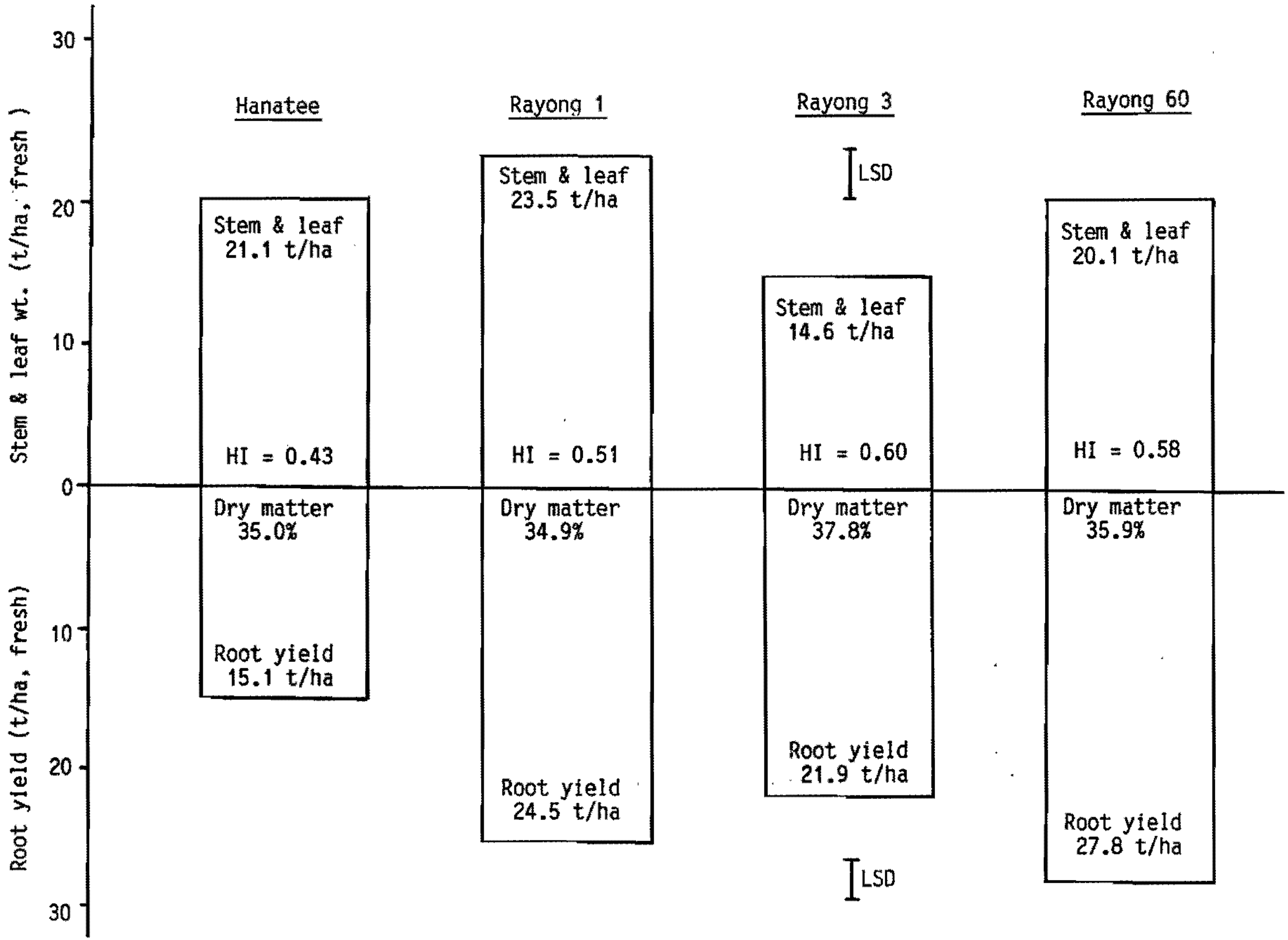

Fig. 1. Schematic demonstration of yield characters of four clones in Thailand (Average of 43 replicated yield trials conducted in experiment station; Data source, Field Crop Research Institute, Thailand).

ON-FARM TRIALS

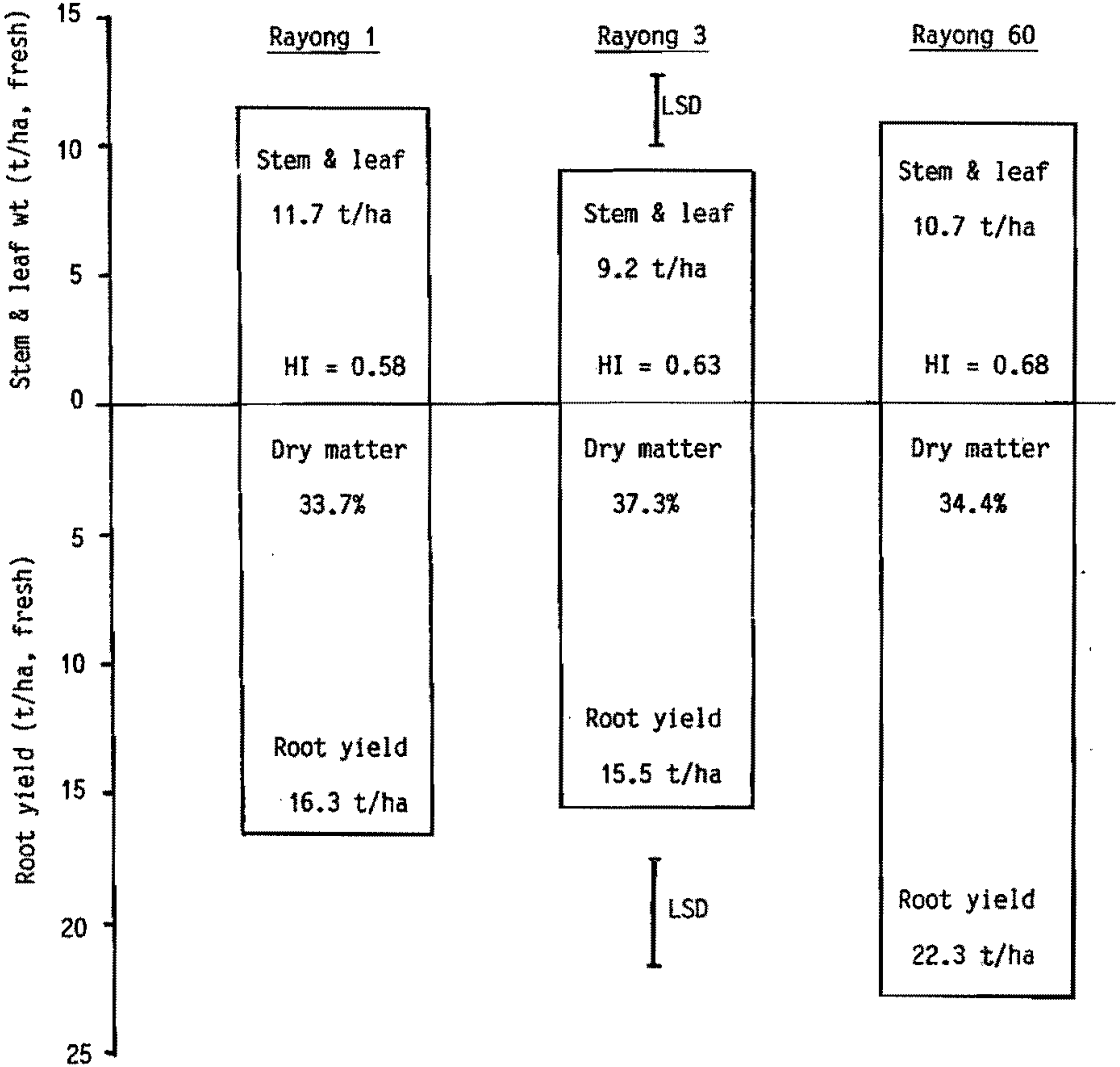

Fig. 2. Schematic demonstration of yield characters of three clones in On-farm trials (Arerage of 34 trials outside experiment station, 1987/88) in Thailand

SELECTION TRIAL

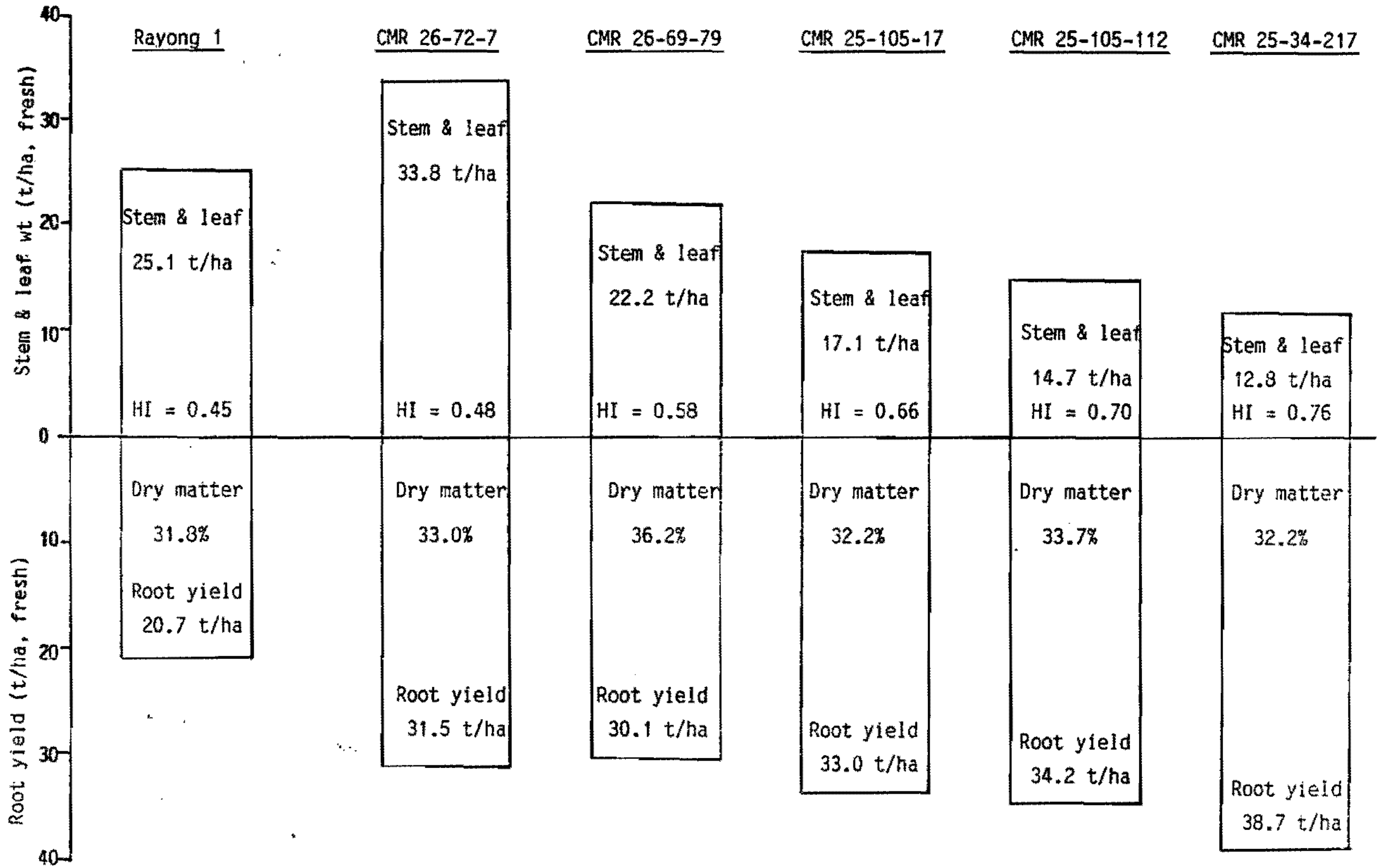

Fig. 3. Schematic demonstration of yield characters of five promising clones (Data from two selection trials at Rayong Research Center in 1986/87 and 1987/88).

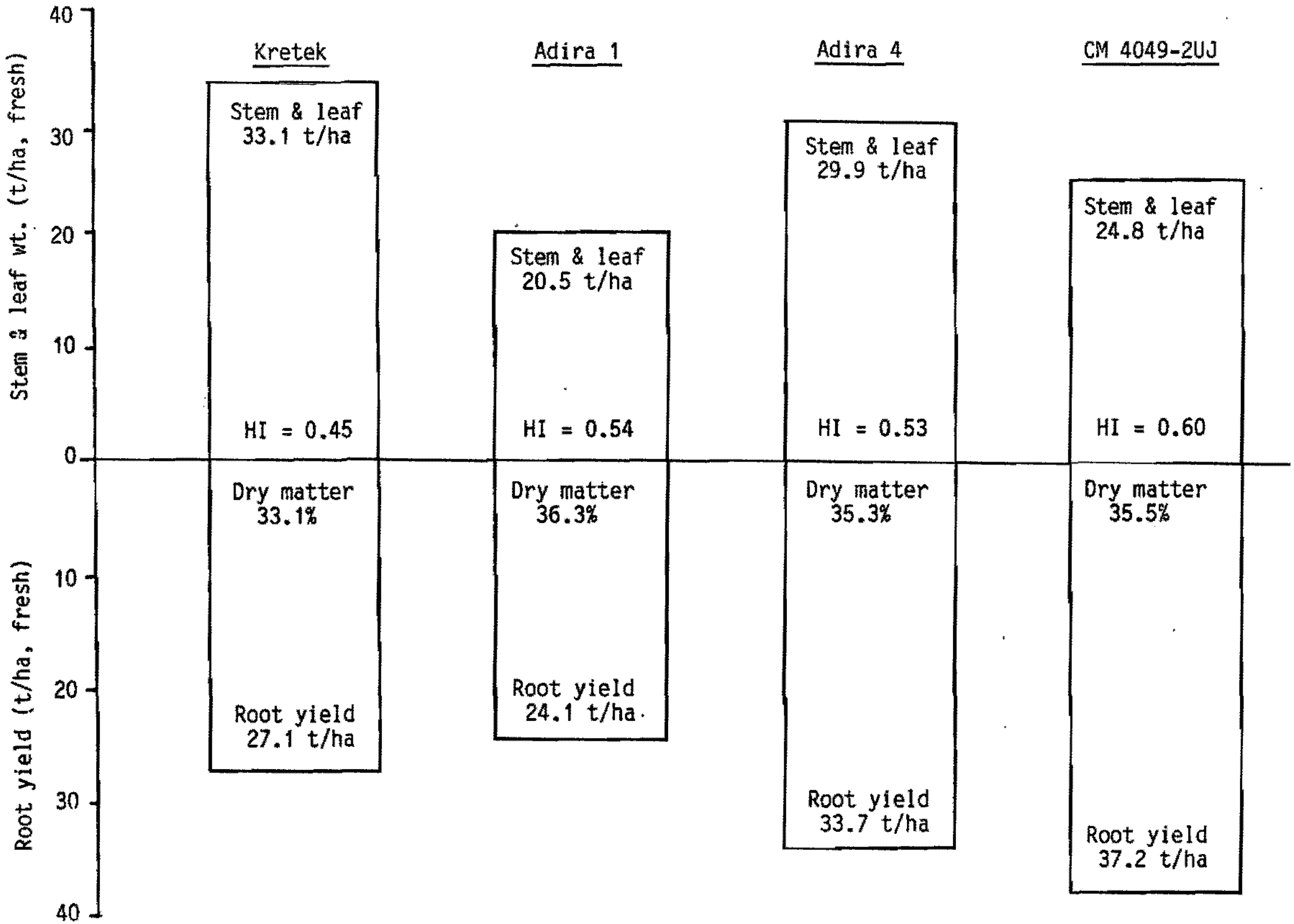

Fig. 4. Schematic demonstration of yield characters of four clones in Sumatra, Indonesia (Average of 5 replicated yield trials conducted in experiment station, Data Source, Umas Jaya Farm/CRIFC, Indonesia).

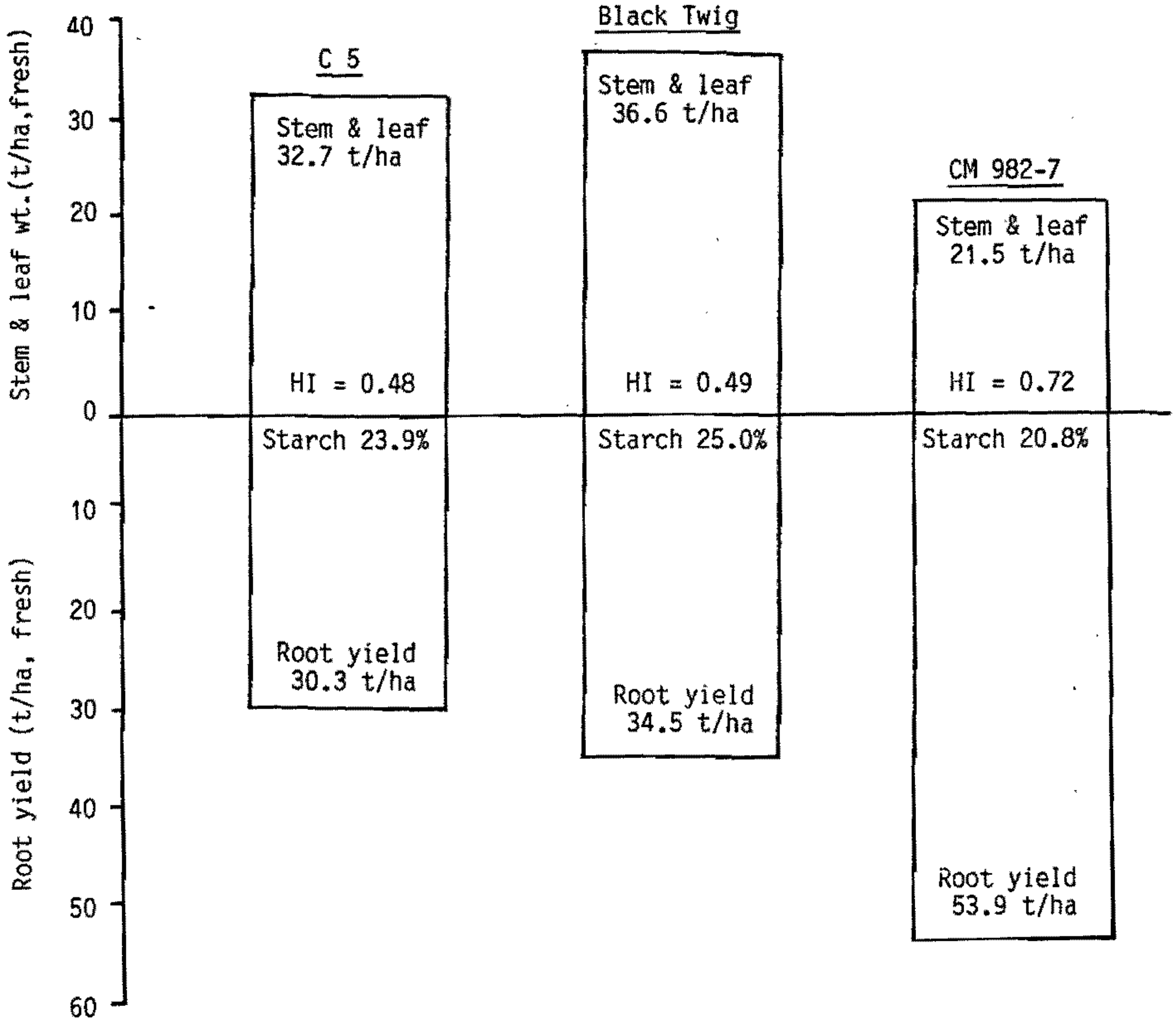

Fig. 5. Schematic demonstraton of yield characters of three clones in Malaysia (Average of 9 replicated yield trials conducted in experiment station; Data source, MARDI, Malaysia).

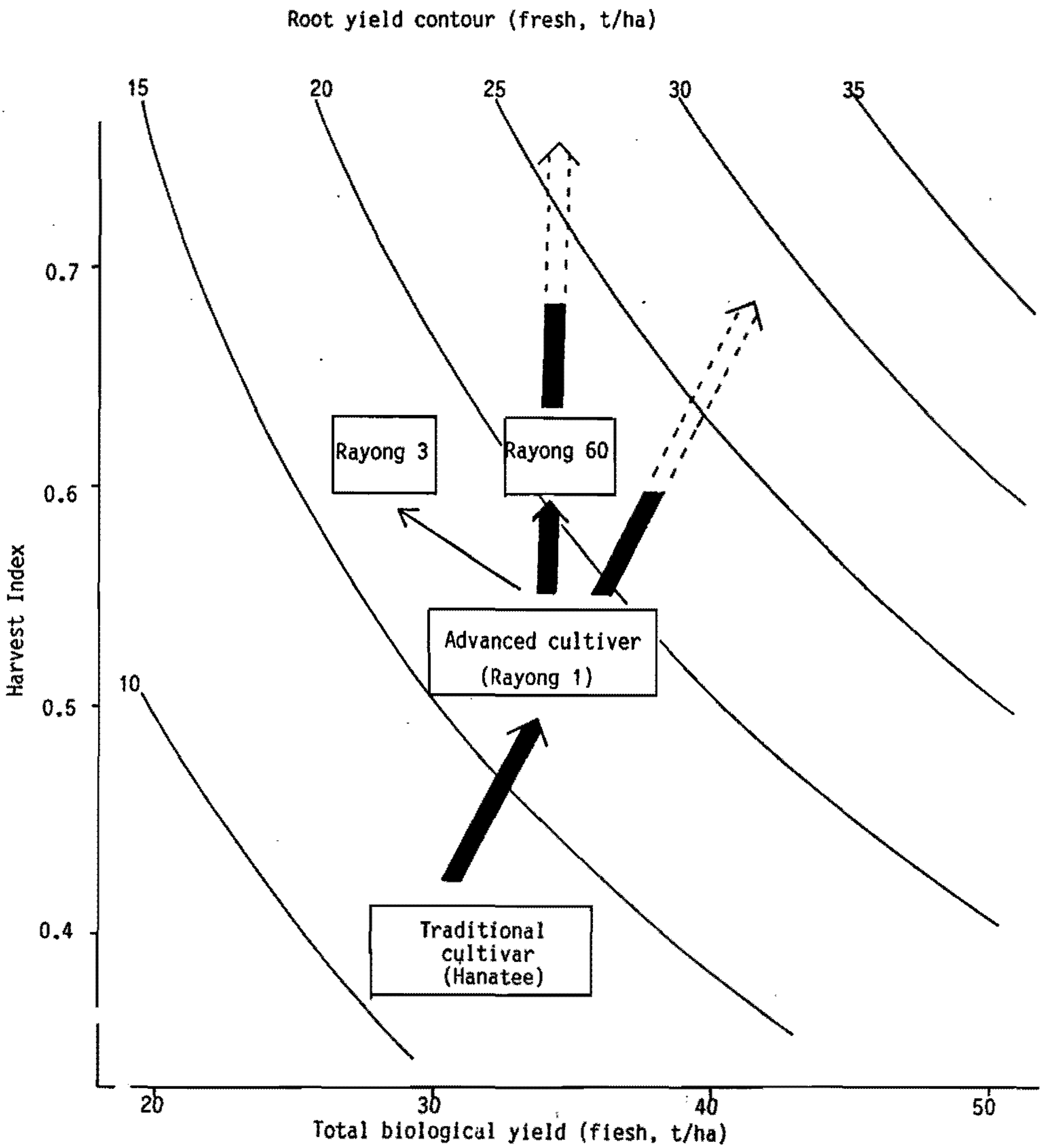

Fig. 6. Schematic presentation of root yield improvement by breeding for low-input growing conditions.

Table 3. Comparison in growth and yield characters between CIAT and Rayong hybrid clones in Rayong, Thailand.

Average of	CIAT clones (no. clones)	Rayong clones (no. clones)
Fresh root yield (kg/plant)[1)]	2.44 (735)	3.21 (1228)
Plant type rating[1)]	2.87 (735)	3.42 (1228)
Harvest index[1)]	.507 (735)	.562 (1228)
Root dry matter content (%)[2)]	32.9 (164)	34.3 (280)
Germination/survival of planting stakes (%)[3)]	45.3 (29)	72.6 (76)

1). Data from all entries in Single-row trial, Rayong, 1986/87 (Plant type rating, 1 = very poor, 5 = very favorable).
2). Data from preliminary selection from Single-row trial, Rayong, 1987/88.
3). Data from Preliminary yield trial, Rayong, 1988/89.

Data source: Field Crop Research Institute, Thailand.

Table 4. Comparison between CIAT and Rayong hybrid clones in a single-row trial in Indonesia.

Average of	CIAT clones (205 clones)	Rayong clones (270 clones)
Fresh root yield (kg/plt)	1.78	1.56
Harvest Index	0.500	0.509
Root dry matter content (%)	28.4	29.2

Data from Single-row trial 1986/87 at UJ Farm, Lampung, S. Sumatra
Data source: UJF/CRIFC, Indonesia.

Table 5. Comparison between CIAT and Rayong hybrid clones in a yield trial in Indonesia.

Average of	CIAT clones (30 clones)	Rayong clones (41 clones)
Fresh root yield (t/ha)	37.6	32.3
Plant type rating	3.43	4.15
Root dry matter content (%)	34.9	35.4
Harvest index	.629	.623

Data from Preliminary yield trial, 1987/88, at UJ Farm, Lampung, S. Sumatra.
Data source: UJF/CRIFC, Indonesia.

Table 6. Comparison in plant type rating between CIAT and Bogor (Indonesian) hybrid clones in Indonesia[1].

Plant type rating[2]	% clones	
	CIAT clones	Bogor clones
1	13	3
2	31	6
3	26	19
4	25	44
5	5	28
Average	2.78	3.88
Total no. clones	177 (100%)	250 (100%)

1). Data from a single-row trial 1986/87 at Sepakat Siantar, Palembang.

2). Plant type rating: 1 = very poor, 5 = very favorable.

RESEARCH FOR DEVELOPMENT

James H.Cock and John Lynam

INTRODUCTION

The development of research plans in agriculture in the third world have frequently been based on the premise that increasing productivity is the objective and that this will benefit the population of the developing countries. We believe that this view is far to simplistic and that by careful planning of the research and development agenda it is possible to ensure that the development process is targeted to certain segments of the population and that it meets specific political objectives that can be predetermined. In most developing countries apart from the generally low average per capita incomes there are large differences in the income level of different segments of the population. The concern of many people today is how can those that live in abject poverty be raised to a reasonable level of existence. This then leads to the political decision to direct development efforts towards specific sectors of the overall population rather than general development objectives that are frequently biased towards those sectors that are already favored. In our particular case of the CIAT cassava program we were involved in a program that was directed towards the increased productivity of cassava, however due to a series of reviews that cast doubts on our ability to reach this objective in the farmers field, we were forced to go through a more complex planning exercise with specific social objectives in mind.

The environment in which we were working, a non profit research based development organization supported by donations from various sources, and our own personal convictions lead us to fix the social objectives as: primarily to improve small farmer incomes and food supply and also whenever possible to simultaneously increase the overall food supply to the urban population. In addition we were constrained to working with the cassava crop. Furthermore as a research organization without either the authority or the necessary financial support to be directly involved in the development process, we had to concentrate our efforts on providing the information required by others to achieve the development with equity that was enshrined in our raison d'etre.

We believe that the evolution of our program and our experiences may be useful to others who are involved in research with well defined social goals as their final objective. In this paper we will first of all set out a brief overview of the agricultural sector vis-a-vis the development process in the third world. The crop with which we work, cassava, will then be described and then the development of a planning frame in view of the crop characteristics. This will be followed by a series of case studies on cassava based development which depended on a range of development strategies varying from new technology to political decision for their success.

AGRICULTURE AND DEVELOPMENT

Development at the national level is almost invariably associated with urbanization. The urbanization process is frequently accelerated by highly skewed land distribution that allows little opportunity for employment and income generation of landless labor and the smaller farmers who look to the cities for a better life. This process is often fuelled by a concentration of agricultural development resources on export crops produced in large plantations and food price policies that militate against the small farm producer of basic foodstuffs and are biased in favor of the urban consumer. However when urbanization is accompanied by industrialization or the development of efficient service industries there is increased wealth in the urban sector and demand for agricultural products either for food or as the raw materials for manufacturing. This demand for agricultural products leads to a buoyant agricultural sector that requires the services and products of an urban society. If the two sectors develop in a balanced fashion then society as a whole becomes better off. In the early days of the industrial revolution such a balance occurred and when rural demand within a country was not sufficient to absorb products and services the export markets were opened. The less developed countries paid for these imports through the export of agricultural commodities or natural resources.

In the developing countries at present there is a rapid process of urbanization. The export markets for industrial goods are highly competitive and it is often difficult for developing countries to enter them. This is particularly true of the export of goods to the developed world. However good opportunities exist for trade between the developing countries. Thus the basis for urban development has to be a buoyant rural demand for the low technology products that can be produced by a society that is at the same time developing and urbanizing. This indicates that not only must there exist the potential for income generation in the rural sector but also that it must be relatively evenly distributed so as to ensure the demand for low technology goods. If only a small number of large producers receive the benefits of increased agricultural production they will tend to purchase more sophisticated goods from developed countries whereas a large number of smaller producers will tend to purchase such goods as bicycles, radios and refrigerators.

The smaller scale producer often produces low value, own price inelastic goods. Thus as a group they have little scope for increasing their income drastically unless they can markedly reduce their unit production costs or markedly increase their total production. They are normally constrained from reaching the latter alternative due to limited access to land, inputs and efficient technology. Even if they were able to increase production prices would drop and the net income increase would be small or even negative. The resolution of this dilemma appears to lie in farmers selling new products that are more own price elastic. This can be achieved either by producing novel crops or by processing traditional crops into different forms. The changing pattern of crops or of processing for end uses are a normal part of the development process. Monke (1983) has shown that the use of maize changes from that of direct human consumption to indirect uses as countries develop. This changing use pattern requires changes in the post harvest processing of the crop.

The maize is sold to the final consumer as poultry or pork, not as maize. The example of maize illustrates a new use for an old crop: the dramatic increase of such crops as soybeans in the US and rape in Europe are examples of changes to more own price elastic crops.

Similar changes are already occurring in the developing countries as part of the development process. In most cases the technological basis for these modifications in the utilization of basic food crops has been imported from the developed countries and depends on possessing crops that are also grown in the temperate areas. Those crops that are exclusively grown in the third world have largely been excluded from this process. Unless these crops are included in the research and development process their comparative advantage is likely to be eroded. Furthermore the developed world has in many cases a comparative advantage in producing those crops that can be grown in the temperate zones thus making it difficult for the developing countries to compete. However certain of the tropical crops are biologically extremely efficient and have the potential to compete with the temperate crops. An obvious case in point is that of the sugar industry where there is little doubt that cane can be used to produce sugar more cheaply in the tropics than beet in the temperate zones. It is also notable that sugarcane has received a high level of research investment compared with most other tropical crops. Sugarcane is however an exception. Research investment in the developed countries has eroded away the comparative advantage of many of the tropical crops. The tremendous increase in yields of the grain crops in the USA and Europe since the second world war bare testimony to the great advances in technology that have resulted from this research effort.

The importation of grains or other agricultural products by the developing countries is not, however, a viable solution to their development process as in general they do not have the industrial exports to pay for them unless their wages remain at extremely low levels. At the same time it is questionable whether it is advantageous to produce local agricultural goods above world prices.

At present world agricultural prices, at least for grain and dairy products, do not reflect production costs. A series of subsidies and price support systems mainly in the developed countries have distorted world prices. These distortions have led to the use of intensive high input systems for the production of basic grain staples which in turn has resulted in a world grain surplus. In general the unit cost of production decline as yields are increased through the use of new technology up to a certain yield level, after which unit costs tend to rise. A recent study by Ortman et al. (1986) shows clearly that the unit cost of maize production in the extensive systems practiced in Argentina is much less than the intensive systems used in the United States of America, (under broadly comparable climate and soil conditions), indicating that the latter country may already have passed the input level associated with minimum production costs. The high costs of subsidies to farmers in Europe and the USA is now being questioned by the population at large and political pressure is increasing to lower support levels. This suggests world prices will eventually move into line and reflect production costs. When this occurs it must be expected that a more rational use of land resources and inputs will lead to a decline in total production and the present surpluses. Prices will then move upwards until there is a balance between the supply and demand. This tendency will be reinforced by the rising world population which will tend to move prices upwards and hence the curve of yield and costs to the right. This will then lead to more possibilities for expansion of less intensive systems such a those in Argentina and Australia. These systems are however based on extensive land holdings and mechanization. The question is whether labor can substitute for the capital in machinery and thus allow small units to compete effectively at world prices in the developing countries.

At present most agricultural research agencies concentrate on raising the yield levels, and not on how to develop technology appropriate to meet the needs of rural development. For example in the CGIAR less than 5% of the total budget is for post harvest work and the biggest component by far is genetic improvement geared to raising yield levels. This distribution of research efforts in the agricultural sector is also found in the national programs for both research and development of the agricultural sector. This approach may well lead to the production of low cost food supplies for the urban sector but will not necessarily contribute to the rural development and stimulate urban development through increased demand for industrial goods and services.

In the following sections cassava is used as an example of how we believe that research and development efforts in the changing agricultural scene can be targeted so as to meet the dual goals of achieving accelerated rural development and also contribute to increasing demand for urban goods and services.

CASSAVA: PRESENT STATUS

Cassava is the fourth most important crop in terms of calories produced for consumption within the tropics. It is generally produced in the more marginal areas without irrigation. As a crop it is naturally tolerant of drought, low levels of soil fertility and extreme soil acidity. In the areas where cassava is grown farmers often have few if any alternative crops due to the harsh climatic and soil conditions. In present production systems farmers rarely use inputs commonly associated with modern agriculture. In spite of this levels of productivity at about 2-4 t dry matter/ha year are reasonable considering that it is normally grown in areas where only one crop cycle per year can be obtained. Almost all cassava is grown by small farmers and it is an important source of food and income for millions in the tropics.

The cassava is mostly consumed on the farm or is sold in the local rural markets. In these areas it is a traditional staple and demand, particularly for traditional processed products is generally inelastic. The fresh root appears to have more elastic demand characteristics but is highly perishable after harvest; it starts to deteriorate within as little as 24 hours after harvest. Urban markets however require non perishable convenient foods. Fresh cassava does not meet these requirements and as societies urbanize the overall demand for cassava tends to decrease. This situation is aggravated by the fact that due to its perishability fresh cassava, whilst being a cheap rural staple is an expensive urban food.

The perishability problem has been partially resolved in certain areas by processing the cassava into a variety of flours or dried products such as Farinha in Brazil, Gari in West Africa and Gaplek in Indonesia. These traditional dry products are generally not preferred goods and are own price inelastic. They also face competition from imports of cheap subsidized grains from The USA and Europe.

This rather dismal picture is brightened by the fact that cassava is a multiple use source of carbohydrates. If suitably processed it should be able to enter into new markets and if price competitive should be able to substitute for various cereal based products. In this latter case elasticity would at least initially be high as its market share would be so small that increases in supply would have negligible effects on the overall market. However cassava products can only enter into these new markets if the raw material is sufficiently low priced to be competitive and if the processing does not add excessively to the final cost of the product. Furthermore as increased rural income is a desired goal the value added should occur in the rural sector. At the same time the product should be of sufficiently high quality that it is readily acceptable in the urban markets.

The characteristics of cassava and the possible new markets for cassava products were sufficient to indicate the possibility improving production and utilization of this crop so as to benefit the small farmer. The question was then how to design programs that could realize this potential.

CASSAVA BASED DEVELOPMENT

In order to plan with specific social goals in mind it was necessary first to define those goals or objectives. In the case of cassava we have, as stated above, defined the primary objective as: <u>to increase rural incomes by producing low cost goods with an elastic urban demand.</u> Wherever possible these goods should be directed at providing final products which are consumed by the poorer segments of the urban population. This latter condition is however secondary to the rural income objective and is considered as a side benefit that is advantageous when it can be simultaneously achieved. We shall see in later sections that these two objectives are not necessarily mutually exclusive.

In order to determine how the stated objectives can be met it is necessary to look at the overall system terminating in the sale of a product that will generate income. In fact the approach is to work down from the salable product, through marketing channels, processing and finally production of the raw material. In the early sections of this paper we established that basic traditional cassava products are inelastic. Thus we must first of all define the demand characteristics of alternative products, based on cassava. Those that are shown to be more elastic can be further studied to analyze how they can be marketed and the required product characteristics to enter the market. This knowledge is then used to determine the appropriate processing technology in terms of product quality and also so as to ensure the generation of income in the rural sector. This then allows the determination of where and how to produce the basic raw material. The overall system then has to be analyzed to determine whether it is socially, economically and technically viable.

This type of analysis cannot be carried out on a global scale. For example in different regions the availability of competing products will differ, the type of product will be determined by local needs or preferences, the policies concerning prices and importations will vary and the production potential of cassava will depend on local conditions. Thus a separate analysis is required for each country or region. The methodology for this analysis will however be similar for the different conditions. Furthermore the analysis is not rigorously carried out for all possible cassava products: Judgement will generally be used to preselect the most likely lines of success and efforts concentrated on these.

In developing this methodology a holistic approach is required as the cassava system cannot be looked at in isolation. For example it is only possible to determine the potential for cassava in the animal feed market by analyzing the demand for different animal products, the relative price of other energy sources, the availability of alternative sources of protein and how all these are affected by government policies. Thus within the general methodology of first identifying the products with the required demand characteristics special emphasis is placed on evaluating cassava's ability to compete with alternative products and the constraints on its entering the markets. These constraints are highly variable and are certainly not all on the production side. In fact as will be seen in the following sections the supply side does not normally dominate. Furthermore although one aspect or constraint may dominate in the initial phases of development the resolution of this constraint will normally uncover other constraints, thus an integrated approach that predicts and resolves multiple constraints must be adopted. The analysis of the viability of a possible development project can be seen to be extremely complex and dependent on a large number of variables that are difficult to estimate. Hence the approach adopted has been to evaluate the potential of a project in rather broad terms and then to set up a pilot project so as to determine in practice its viability, and uncover the second generation constraints that appear. The development of this type of integrated approach is illustrated in the following case studies which highlight different initial constraints.

CASE STUDIES OF DEVELOPMENT STRATEGIES

Social organization. In the North Coast of Colombia in the last years of the decade of the seventies the Integrated Rural Development program provided credit and technological assistance to increase cassava production in the region. This traditional production oriented approach did indeed lead to increases in cassava production in the region, however local markets were rapidly saturated and prices dropped in such a manner that farmers were not able to recover their costs. To resolve the problem the Integrated Rural Development program set up a post harvest committee to study alternative markets. At the same time our organization, the

Centro Internacional de Agricultura Tropical (CIAT) was studying the possibility of using dried casssava in animal feed rations in Colombia. The two efforts were integrated so as to assess the possibilities of entering into this alternative markets. The studies clearly showed a large and expanding market for animal feed in the Colombian market. Initial analysis indicated that cassava at the current prices could not enter into competition with locally produced or imported sorghum. However more in depth studies on the production costs of cassava indicated that it could be produced for the animal feed market at a competitive price and still leave a respectable profit margin for farmers. Two questions remained unanswered. Firstly why were cassava farmers only willing to produce limited quantities of cassava and secondly if the process was potentially so profitable why had a cassava drying industry not grown up spontaneously.

Most of the cassava in the area was used for on farm consumption or sold to the local fresh markets. The fresh markets had very stringent quality requirements and at least part of the harvest had to be left in the field as waste. Furthermore due to large price fluctuations in prices farmers were only willing to produce cassava at a price considerably above production costs. They were not willing to take the large risk involved in planting more cassava with more inputs as they had had the bad experience of not being to sell their cassava at any price on some occasions. This created an illusory price for cassava that did not reflect production costs but rather the risks inherent in marketing the product and the wastage related to the high quality requirements.

The lack of a drying industry that could lead to a stable price floor was also puzzling. The large feed mills that produce most of the balanced diets faced a deficit of energy sources for their rations and at least one major feed company was interested in using cassava. Further investigation indicated that the feed mills required a certain minimum quantity of dried cassava before they would incorporate it. On the other hand without an established market farmers were not willing to plant more cassava and dry it. Furthermore in view of the high and fluctuating prices of fresh cassava entrepreneurs were not interested in establishing drying plants.

The problem was how to break this deadlock. Various solutions were analyzed. The most promising appeared to be the establishment of farmers associations to dry the cassava and sell it to the feed mills. This solution was attractive for the following reasons. Firstly individual farmers did not not have a sufficiently large resource base to establish drying plants whereas associations did. Secondly if the price of cassava for the fresh market was high the farmer producers could sell in to this market and make substantial profits to pay of loans on the drying plants. The low quality cassava not fit for the fresh market could still be sold to the plants which could function at a low level. If the price of fresh cassava dropped below a threshold value than farmers could sell all their cassava to the plants and still make a profit. This would place an effective floor price on cassava thus stimulating farmers to produce more.

In order to test this development model a pilot project was established to test the viability of the model and the drying technology. This model did indeed prove to be successful and has been used as the basis for the establishment to date of 36 such plants in the region. Monitoring of the project indicates that the model has indeed been effective in increasing small farmer incomes in the region. However it also indicates that the process has turned full circle and the major constraint at present is on the production side. Efforts are now being directed to resolving this problem through the use of new technology to increase productivity and also policies that will give the small farmer producers greater access to land.

New Technology. The per capita consumption of fresh cassava is less in the urban areas of Latin America than in the rural zones. The rapid urbanization in the period of 1950-1980 led to a decrease in the demand for fresh cassava and farmers faced a declining market. Conventional wisdom indicated that urban consumers considered cassava to be an inferior good. If this were true then the possibilities for maintaining or increasing rural income through expansion of the fresh cassava market appeared dismal. The conventional wisdom was however backed up by very little concrete data and did not seem to fit with comments concerning cassava made by housewives.

In Colombia a series of surveys and analysis of cross sectional data indicated that fresh cassava was indeed a preferred food and equally as desired as potatoes and rice (Janssen 1986). However it was risky to buy and often of low quality. Furthermore the marketing margins of such a perishable crop were extremely high: The farmer price often being less than 25% of the final consumer price. The high marketing margins are related to handling a highly perishable product. Thus both the negative response of urban consumers to cassava and the high cost in urban markets are due to the perishable nature of the product. This suggested that by reducing the perishability of cassava two objectives could be achieved. First the market could be expanded with a positive impact on farmer incomes and second that marketing margins could be reduced thus providing the urban consumer with a lower cost food supply. Improved production technology was certainly not the solution, rather research on post harvest technology to reduce the perishability of fresh cassava offered great promise. Research on perishability over a number of years indicated that the problem could be resolved. Cassava kept in a humid atmosphere immediately following harvest did not deteriorate rapidly. However it did often spoil due to microbial attack favored by the humid conditions. Further research indicated that the microbial attack could be controlled by the use of the extremely safe fungicide, thiabendazole. These results were used to develop a practical conservation technology. Roots immediately after harvest are packed in plastic bags and sprayed with thiabendazole.

Once a viable technology existed it had to be tested under commercial conditions and consumer response to the new product evaluated. A commercial pilot project was established in the department of Santander in Colombia. Farmers found the technology acceptable and consumers evaluated the product favorably. The farmers did however find that it was necessary to select the roots carefully to obtain good results: Damaged roots did tend to deteriorate more rapidly than undamaged ones and it seemed difficult to devise a technological solution to this problem. This resulted in much waste and low profitability. Nevertheless economic analysis indicated that small scale drying plants, similar to those described above, could be profitable and could function with the damaged roots. The farmers have established a small drying plant to process the damaged roots and sell the dry chips to the local feed industry.

The expansion from the pilot to the fully commercial phase is only just beginning at the time of writing, nevertheless initial results are promising. They indicate that by analysis of the market constraint and subsequent technology development directed specifically to the major constraint development objectives can be met. It is also true to say that other constraints are now appearing, such as how to guarantee a continual supply of good quality fresh roots to be used in the process and also how to maintain quality as production increases. This then indicates a need for further agronomic research.

Policy decisions. The North East of Brazil is economically the poorest area of the country. The population is less urbanized than the rest of Brazil with about 50% of the population in the rural sector. The basic staple of the population is a product called farinha da mandioca. The cassava in the region is almost exclusively produced by small farmers on the less fertile lands with less rainfall. (The best land with the highest rainfall is used largely for sugarcane production in the alcohol program.) The cassava once harvested is processed in small "casas de farinha" or literally flour houses, into a flour or meal called farinha da mandioca.

The North East of Brazil is noted for its extremely variable rainfall patterns. In fact it is probably due to cassava's tolerance of sporadic rainfall that it is the dominant staple in the area. Nevertheless as a result of the climatic fluctuations, although the cassava crop never fails completely, yields do fluctuate widely. As farinha is a typical basic staple in its demand characteristics it is own price inelastic. Hence as the supply of farinha varies, prices show tremendous variability. This is not conducive to giving farmers a stable income nor is it advantageous to the consumers who have to face uncertainty in the price of their basic staple. The farmers are loathe to increase their production of cassava as they fear that prices will be very low in good rainfall years, whilst in the drought years the landless labor and the urban consumer have to pay extremely high prices.

The solution would seem to be in the establishment of a floor price for farinha. One method of doing this would be for the government to establish a floor price for farinha with storage facilities. This could become extremely expensive for the government if there were several bumper years of cassava production. Furthermore the building of storage facilities would require a large up front investment. This strategy is not attractive for these and other reasons. An alternative strategy is to look for a large alternative market into which the cassava could enter in the case of a bumper year and drop out to a certain extent in a drought year. The animal feed market seems to be such a market. Most of the animal feed in the form of balanced rations in the region is made with energy sources imported from other areas of Brazil.

An analysis of the production and transport costs of dried cassava and other products for animal feed in Brazil showed that cassava was indeed competitive. However when prices were looked at cassava was not able to compete, as the transport of other sources such as maize were heavily subsidized. The government of Brazil is now reducing these subsidies and as a result it would appear feasible to establish a cassava drying industry to use all excess production over the farinha market. This would effectively place a price floor on the price of cassava in the region.

In several of the North Eastern states of Brazil development plans are already under way to establish a small scale drying industry. Efforts on research and development are turning to satisfy the needs of this industry and hence to assist the farmers in increasing their income. If successful this project will also stabilize at a lower price the farinha and will make available cheaper poultry for the general public. It is in the lower income groups that the demand for poultry products is rising most rapidly. Hence this approach to cassava based development, made possible by a change of policy, can reach multiple social goals.

Production technology. It may appear surprising that up to the present in these case studies improved production technology, the traditional product of agricultural research agencies, has hardly been mentioned. In general we feel that production technology *per se* is only the limiting constraint on raising farmers incomes when the capacity of the market to absorb increased production is ensured. In the case of Indonesia this seems to have occurred with a whole series of outlets for cassava products in a highly structured market. Fresh cassava is appreciated by the urban and rural consumer and commands the highest price. This market would however appear to be quite limited and expanded production soon saturates this market. Under this market is the buoyant starch market, which can use cassava roots destined for the fresh market or industrial varieties of lower eating quality. The starch market is underpinned by the Krupuk market. Krupuk is a preferred delicacy or snack produced form cassava starch. Furthermore cassava starch can is used in a whole range of food products. In the last few years the price of cassava roots has remained high and cassava has not entered into the third level of the Indonesian market, dried cassava pellets for export. In fact cassava starch has been imported from Thailand in the last few years. Nevertheless the existence of the third level gives farmers confidence that they will not have the bottom fall out of the market.

Area planted to cassava in the island of Sumatra in the Lampung district has responded to the situation of demand being greater than supply. Much of this expansion has been by plantations, however at least part has been by the smaller farmers in the region. They probably have limited access to extra land resources and their only manner of increasing income through cassava production is through greater productivity. In the Asian context cassava is an introduced crop and the germplasm base for development of improved varieties is limited. It would appear *a priori* that introduction of exotic germplasm from the center of origin of the crop and the development of new high yielding varieties could assist farmers in increasing their incomes. Furthermore these new varieties need to be fitted into the intricate Asian cropping systems, hence work is required in the area of agronomy and farming systems. Much work is now in progress in Indonesia and can be expected to benefit the small producers. Although it is too early to measure the impact of the research effort in Indonesia we can infer from similar experiences in Southern India that the probabilities are high. In the early fifties demand for cassava products was high: The Central Tubers Crop Research Institute in Kerala developed improved production technology and yields in the region have increased from 5t/ha to 16 t/ha (Cock 1985). Farmers have benefitted from increased incomes and consumers benefitted from a larger supply of low cost calories.

LOOKING TO THE FUTURE

The analysis up to the present looks at developing new uses of cassava and/or production technology but not at radical changes in the crop which might be wrought by using modern techniques. Such changes have been seen as so costly and needing such a long time frame to be achieved that they have been given orphan status. However there do exist possilities that may not result from the approach advocated upto the present in this article. For example we suspect that this approach would never have led to the developemnt of hybrid maize or the semi-dwarf rices.

We use the case of cassava from true seed to illustrate the approach required in these cases. Cassava is biologically very efficient under drought conditions, however planting material is always a major problem particularly when drought is prolonged over several years. Planting material is to bulky to bring in from other areas and is often diseased and not well adapted. This is a major constraint for small farmers. This problem could largely be overcome if we produced cassava from true seed. We could be creating a new crop! In order to achieve this we would need 15 to 20 years of concerted effort in the areas of in vitro techniques to produce haploids, a better understanding of cassava genetics, breeding for seed based cassava, agronomy of seed production, agronomy of production of cassava from seed etc. Working on one apect in isolation will achieve little or nothing. The question is then as to whether it is worhtwhile to mount a long term coordinated research proposal with many cooperating agencies with the objective of producing for example "A viable technology for farmers to produce cassava from true seed by the year 2010". The authors feel that this type of major effort may in the long term have very high pay off, however the risk of little or no pay off will also be high.

CONCLUSIONS

In order to fulfill overall national social and political goals the agricultural sector will have to orient itself not only to providing food for the urban sector but also to increased wealth in the rural sector so as to create demand for locally produced industrial goods and services.

This can only be achieved if the increased wealth is relatively evenly distributed.

Greater wealth in the rural sector will not necessarily be achieved merely by increasing rural production. Increases in rural production must be geared to increasing those goods with elastic demand. As countries become more developed these are generally not the basic staples, or at least the basic staples in their traditional form. Furthermore if the wealth created is to be evenly distributed then a large number of small producers is likely to be the most effective model. Hence in designing an agricultural research plan it is necessary to look for goods that can be produced by the small farmer sector and analyse the demand for such goods. It should be noted that here we are talking not only of primary products such as the fresh roots in the case of cassava, but also the secondary products that result from processing and give the value added to the producer and processor in the rural sector. Those with large market potential should be chosen and efforts should be concentrated on relieving the constraints on their entering the markets. This may involve research on a whole range of fields from policies through processing to production. This indicates that (i) agricultural research should be integrated into the overall development policy and (ii) that overall policy goals should determine the research agenda. If this line is followed then it is our belief that research can be directed in such a manner that its beneficiaries are chosen. This approach does however not encompass high risk major research efforts that could revolutionize the crop.

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FARMERS' ORGANIZATIONS FOR DEVELOPING AGRICULTURAL TECHNOLOGY

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Farmers' Organizations and Agricultural Development

Social scientist working on agricultural development, particularly when relying on survey methodology, sometimes describe farmers as if they acted only as individuals or separate families, or as if impinging social factors manifested themselves only as such impersonal forces as demands, opportunities, or information. Yet when we are in the field, we see that farmers are parts of social networks and groups, that they are members of cooperatives or extended families, that sometimes all the fields of a village or ethnic group look alike, and that new varieties sometimes diffuse along social pathways. Farmers are organized, something that development praticioners, more than scientists, take into account, since they work with cooperatives, village councils, and other organizations, especially in smaller projects.

Esman and Uphoff find that development literature into the 1970's had neglected the role of local organizations in rural development, and that several schools had seen local organization as an obstacle. The positive functions of local organizations, so evident in Europe, the United States, and Japan, had been ignored by writers who concentrated on the many real defects in particular cooperatives, farmers' associations, or local governments. Perhaps their summary should be tempered by noting a large cooperativist literature and, at least in Latin America, the many treatments of class-based rural movements and organizations. At any rate, Esman and Uphoff then cite the emergence in the 1970's of more positive attitudes towards local formal organization, and a recognition of the kind of informal organization discovered by central place theory (1984:42-57).

The view of this article is that such local and second-order organizations, linked to agricultural sector institutions, are pertinent to development activities of the kinds promoted by the IARC system: technology design, and, secondarily, methods of adaptation, transfer, and monitoring with national programs. 2) Experimental projects with farmers' organizations at the local and regional level are a powerful method for creating technology that meets farmers needs, to be used with other methods of bringing the farmers' perspective to technology generation, such as diagnostic surveys, on-farm research, and participatory methods.

The kind of farmers' organization that is the subject of this article is common. The primary activity of the group is agroindustry, marketing, or production; organizationally, it comprises basic local groups united in a higher-level or regional agrupation. The group has links to service agencies, which may themselves be organized in a network or project. The authors already cited see social science support for the utility of this kind of a group, and it is the variant that they favor (*ibid.*). The recommendation to vertically integrate and to establish horizontal linkages is well known, for cooperatives (e.g. Advisory Committee 1971:15) and for development projects in general (Smith *et al.* 1981).

In summary, this case study of a cassava-processing project in Ecuador will describe 1) adaptation of technology to the needs of farmers' organizations, 2) the active role of a farmers' organization in technology transfer, 3) collaboration between the organization and researchers, and 4) institutional means for integrating the organization with research and extension agencies.

Technology design and adaptation

Sometimes it is necessary to take famers organizations into account so that we may understand their needs for technology and better design that technology. For example, we might discard a technology as inappropriate for individual small-scales farmers, even though it might be feasible with an organization. Cooperatives for example, can assume some of the risk associated with new technology, supply complementary inputs, dampen environmental disturbances, and implement expensive technology that is beyond the reach of individual members. Second, farmers organized in one way may need one kind of technology, while farmers organized in a different way may need a packet with another emphasis, even when their individual farms look similar. Finallly, as we shall see in later sections, organizations themselves are potential clients for new technology, and they have needs that vary from environment to environment, just do those of individual farms. If this is true for the technology embodied in tools, machinery, or seed, it is even more so for such human aspects of technology as work routines, management, and social organization of the implementing group.

Finally, one of the roles of farmers' organizations is to state the needs and priorities of farmers, including the need for new technology or research that will provide that technology. Organizations can provide the forum and the skills to make farmers' requirements known to research organizations.

Participation in research and extension

Beyond technology design, farmers' organizations can play important roles in research and extension, working in teams with government agencies, non-governmental organizations, and others. They can participate in what CIP calls the "farmer-back-to-farmer" cycle: diagnosis, research, testing, evaluation, and adaptation(e.g. Rhoades 1984:32-38). Though the CIP method does not require organized participation, some cases of its application have in fact involved groups, as will be shown in the following section on inter-institutional cooperation. Even small organizations can organize on-farm trials (Advisory Committee 1971:11), try a technology as a group, provide information, and even fund some parts of investigation, while large cooperative federations, liken ay company, budget for research and development and may publish research results.

When the technology is ready, organizations may be an efficient means of diffusion. At its simplest, extensionists take farmer's groups into account by meeting with several people at once or sending messages through groups. The training and visit technique is an example of using small, simple groups to enhance the efficiency of extensionists, and proponents of the system note that its costs are justified only when the linkage farmer meets with a group of his peers; conversely, a fault of the system is that such groups do not always function.

Complex farmers' groups, especially those with some history, are more than sets of farmers, and their resources allow them to overcome some of the usual constraints on technology adoption, by, for example, reducing risk. Such groups need not be passive; they may take the initiative in searching out information, and they may actively invite the attention of extensionists or research stations. The group may have the capacity to field its own extensionists, either certified or informal, and to run demonstrations, field days, or trials, perhaps with outside financial assistance. "Cooperatives can employ extension agents. Or, if the agents are government employees, the cooperative can be the organization through which the farmers are reached" (Advisory Committee 1971:11). At the least, the group may relieve the extensionists of some of the non-technical roles that they typically assume for farmers: scribe, accountant, social worker, etc. Farmers' groups can be active participants in technology transfer.

The actions that farmers' groups take to promote technology are quite varied. One set of case studies of local level organizations that only marginally treats the subject mentions technology promoted by organizations to control crop diseases, control erosion, increase productivity, diffuse a technical packet, process crops, control quality, supply new kinds of inputs, improve traditional wells, and complement traditional activities with new sources of income (Uphoff 1986). I found particularly interesting the cases in which organizations implemented technologies with long-term payoff, such as tree planting, erosion control, or regional insect management; such technologies are hard to sell to farmers without special incentives.

The same case studies also illustrate some of the many ways that an organization may transfer technology: sponsor paid or unpaid promotors, provide loans for recommended inputs, sell chemicals, seed or equipment, buy new kinds of equipment for their own use, generate resources for new technology, exchange technological information, and create a market for improved crops. The cases also note problems: failure to adequately explain quality control, unworkable technology, expansion of technology into inappropriate environments, and others.

A case of farmer-extensionists comes from the El Ceibo federation of Bolivia. El Ceibo, with 35 affiliates and 850 farmers, processes and markets cacao. When government officials could not deal with a blight, the federation, with European technical and financial assistance, established an extension division. Farmers went to Colombia, Ecuador, and Brazil for advanced training, and they contained the blight. Later, the federation established a program for new farmer-extensionists, and eventually they became involved in environmental protection, vegetable gardening, and literacy training (Healy 1988:38).

Organizations have several features that enhance their effectiveness for technology transfer. For example, combining technical assistance with credit seems to be effective, as indicated by an evaluation of USAID projects in Ecuador, which notes that supervized cooperative credit reaches more farmers than specifically agricultural cooperatives, though the latter do implement improved technology (Soos 1986:10-F2). Technical assistance to and through cooperatives is often a package for improving many activities. The most common are post-harvest processing and financial practices; others are agricultural production, handling of credit, marketing, and general administration, as shown by a review of USAID projects with cooperatives in Latin America (USAID compilation of post-project evaluation summaries). Because cooperatives are often marketers, they can combine technical assistance with quality controls and price incentives, a powerful combination.

Inter-institutional relations

If farmers' organizations are to play the noted positive roles in technology adaptation and extension, at least the smaller ones must establish relationships with research and extension agencies, either within the government or outside. One simple means of coordination, neither very strong nor very weak, is an inter-institutional working group and coordinating committee at the local and micro-regional levels (Smith et al. 1981:25), having as its common focus implementation of a research and development effort with a farmers' group.

Participants in this very Farmers and Food Systems Seminar saw such working groups, albeit in their early and somewhat insecure stages, in the fields visits to Cusco, Peru. They illustrate interesting relations among researchers, extensionists, and groups of farmers. The projects, which involve CIP and the national potato program of INIAA (Instituto de Investigación Agropecuaria y Agroindustrial), work with highland cooperatives and villages that make some corporate agricultural decisons. In Arariwa, Cusco Department, a non-governmental, church-affiliated organizations receives virus-free planting material from Cusco University, multiplies it, and provides it to communities. The Swiss are funding the project, and CIP provides training and technical back-up. The communities, in their assembly, choose farmers to reproduce and distribute the planting material, particularly to high altitude farmers who have no other access to such inputs. The project is new and has not yet distributed seed; its long-term economic feasibility is not clear, since seed production credit and payments for seed will not cover costs. Ye it is an interesting case of working with corporate villages to reach inaccessible farmers, and its good relations with villagers permit research to procede that would otherwise be difficult.

On the Planes of Anta, a land reform area that has both cooperative and individual land holdings, a potato seed program run by technicians reproduces virus-free seed of a traditional variety on cooperative plots or on land of farmers chosen by the cooperative; input loans are repayed with seed potatoes. The technicians hope for community specialization in seed production, with distribution among communities. The program has required a subsidy, since low official prices for potatoes make it impossible for farmers to pay the total costs of producing the seed. Nearby, there is a new community storage facility, built with CIP-INIAA technical assistance, which will allow farmers to take advantage of seasonal price fluctuation. The institutional constellation of these projects includes the National Potato Program, PRODERM, Funders (e.e.c. and Holland), the cooperative, communities, and CIP.

A notable feature of both the CIP cases and those previously cited is the encouragement and financial support supplied by international and national agencies. This is a stimulant for starting operations and for development activities that are socially benevolent, yet subsidies are rarely sustainable. There are cases of overcoming this problem; Colombia's coffee federation has institutionalized research and extension functions, a development made possible by the success of coffee exports. In general, the transition from donations to normal financing is a painful rite de passage that stimulates and requires improved management, to the cooperative's benefit (Tendler 1983:218-223). Research would have to be very productive, or the cooperative very successful, to survive a lack of outside funding.

An experiment in technology adaptation and transfer

We now turn to the Ecuadorian case study of an project that set out to work with farmers' organizations to reduce the costs of extension, to integrate research with development, and to replicate interinstitutional cooperation, as well as to increase production and income of small-holders. The project is in Manabi Province, on the coast of Ecuador, where a small (400 members) and new (three years old) union of village-level associations is implementing post-harvest technology to process cassava (yuca, mandioca, Manihot esculenta) into flour, among other products. From the point of view of the farmers, this is a small development project; from a researcher's vantage, it is also an experiment in technology adaptation and transfer, and it is designed to implement social science conclusions from an earlier study of a cassava project in Colombia (3).

There is no unified, funded project; the collaborating agencies are autonomous and provide most of their own staff and funding. They include the farmers' organization, known as the Union of Cassava Producers and Processors (UAPPY), the national agricultural research institution (INIAP), the Ministry of Agriculture (MAG), a private research and development foundation (FUNDAGRO), the national farmer training institute (INCCA), and non-governmental organizations. These institutions receive technical assistance from CIAT and, in one sub-project, CIMMYT. Investment funding derives from PL-480 funds, administered by USAID and MAG, and FUNDAGRO provides some for incremental operating costs.

After three years, the project has passed through an experimental phase to commercial production. There are twenty local groups profitably producing 1,100 MT of flour in 1988; after another year's experience, they should double that figure. Demand is strong enough to justify expansion.

The technologies

The project promotes technologies for processing cassava, principally for animal feed and secondarily for human consumption, including hardware and complementary social organization for work, farmers' groups, and institutions.

Hardware

The technologies implemented by the UAPPY and its affiliates were developed by exporters in Asia and introduced starting around 1980 to Colombia, followed by other countries of Latin America. In late 1985, they were passed from CIAT to Ecuador's INIAP for trial and adaptation, and they, and other technologies, are now in various stages of transfer to farmers (Table 1). In part, the Manabi area was chosen because it has a traditional, artesanal cassava starch industry that already used many of the elements in CIAT's packet.

The basic activity is that of dehydrating starchy cassava roots for animal feed, using a large but simple chipper and any of three drying methods: sun drying on a concrete floor, drying on mesh trays, or artificial drying with diesel fuel (Best 1979; more recent descriptions of the technology by the same author are available in mimeograph form from CIAT's Cassava Utilization Section). A second technolgy is that of conserving cassava roots with a fungicide plus conditions of heat and humidity. Untreated roots develop dark stains after three days, with rot following ina week; treated roots last for three weeks. A third technology comprises introducing several Colombian practices into local artesanal starch extracting techniques: some mechanization of processing, use of ceramic tiles for hygiene, use of clean water, etc. (see Figueroa et al., 1986, a useful bibliography). A fourth set of techniques involve multiplying corn to maintain pure seed lots and rapidly multiplying cassava varieties. The corn technology is promoted by CIMMYT. The cassava technology is significatn because it would otherwise take about ten years to multiply enough planting material for a new variety to have economic impact. Other technologies, notably agronomic practices for increasing productivity, are in the research stage.

Social technology

The social technology of the cassava packet includes 1) work routines immediately tied to the hardware, 2) management and organization of the implementing group, 3) the network of individuals or entities that directly contribute to implementing the technology or that receive its output, and 4) the organization of indirect support for implementing the technology, principally institutional actions.

Cassava drying requires a substantial number of people. Operations need a three-person work crew available at odd times of the day or night; there is an advantage to being able to call on six to ten workers for peak moments. The plant requires a manager with a good sense of scheduling, mechanics, and record keeping. That role supposes some training or experience, but not a professional background. Given funder's requirements, the implementor requires someone to keep financial records. It is advantageous to have a network of more than 100 cassava providers that can be both reliable and flexible in delivery schedule. Since the cost of a processing plant ranges between $5,000 and $15,000 (more and less expensive versions may emerge), founding a plant requires financing, prior assets, links to an institution, etc. The appropriate buyers are factories; this is a bulk business. Supporting characters include mechanics, machinists, extensionists, and others (Table 2).

In Latin America, the technology has proven very compatible with groups of farmers organized as associations or local level cooperatives, comprising principally farmers with few resources or even the landless, and supposing broadly based community support (see, for example, Bode 1986). There are more than forty such business in Colombia, twenty in Ecuador, several in Panama and Mexico, and an indeterminate number in

Brazil. It was decided that the base groups might be usefully integrated into a second-order group, which became the UAPPY. Another aspect of social technology also designed on the basis of the Colombian experience, and in accord with routine social science recommendations, was replication of the inter-institutional working groups as described in later sections.

Technology modification with and for farmers' group

Hardware packet

It has been claimed that the nature of a farmers' group may determine the characteristics of the technology appropriate to it. This point will now be illustrated. A cassava processing plant is relatively simple agroindustrial system, but even so it has several technological variants and many organizational aspects. In Ecuador, the elements of the packet have been selected or emphasized to social and natural conditions of the plant (Table 3). The packet is still changing, and the project has yet to work out how to implement cassava drying with large scale cattlemen (whose cattle suffer from lack of dry season pasture), milk producers (on-station tests show a substantial rise in milk production with a cassava and chicken manure supplement), individualistic farmers (who might be interested in a hand-operated chipper), pig producers (who might use cassava sillage in certain months, according to a diagnostic survey), and others.

Other technological adaptations have occurred during the project, all of them modest. Elements have been added: a guard to protect workers while chipping, use of a chlorine to reduce water contamination, a mix of local and recommended building techniques, a modified kind of mill for making flour, and use of banana boxes to ship cassava.

Social technology

New work routines were invented for conserving relatively large amounts of cassava for export, and it was found that, contrary to expectations, workers did not find it difficult to dry using many (over 150) trays, the first commercial application of that technology. The work routines for drying on concrete floors are copied from Colombia. Those for starch making are like those used by local artesans, but as the women's groups add more products (flour for human use) and as they strive for a cleaner product, they may have to re-arrange their activities.

Most of the groups are attempting to combine basic cassava flour production with other activities, either using cassava or not. Conserving the best roots and drying the rejects has been a very profitable combination. Peeling large roots, drying the very small ones, and giving the peels to animals has also worked well. While flour is the main business, groups have tried other activities-conserving cassava one year and dropping that activity the next or shifting among markets according to demand. Complementary activities that do not involve cassava are also in trial. Since the cassava harvest runs only from September to December, the Union has bought portable corn degrainers and a peanut sheller to rent to the local associations from May to July. The coffee harvest fills the space from July to August.

Technically, only minor modifications to the cassava processing plants would allow the associations to process coffee, and the groups could certainly improve the quality of post-harvest coffee technology. Nevertheless, the task is not easy; coffee marketing is tightly organized already and it is a business that requires large amounts of cash. In general, the associations are developing their strategies to make more complete use of their investment.

We now turn very briefly to the social technology applied to organization and institutional support. On the basis of studies of the Colombian cassava project and initial experiences in Ecuador, several techniques were adapted to reduce the cost of technology transfer and replicate successful institutional arrangements. These methods included farmer-to-farmer technology transfer to supplement official extension, replication of efficient inter-institutional working groups, vertical linkages, more accurate criteria for siting plants, continuing use of social science to reduce wastage, better focusing of social science, and creation of a higher-order farmers' group to supplement official agencies and to allow farmers to assume more responsibility and to recycle funds.

Possible general principals

Perhaps the flexibility that characterizes the cassava technology can be built into other technologies; some of the elements that allow the associations to experiment with variations are general, while others are particular to post-harvest packages (Table 4).

The characteristics of the packet are part of the technology; they give flexibility. The realization of that potential has resulted from the process of applying the technology commercially and opportunistically. The cassava technology packet has been self-modifying in the sense that the modifications and changing emphases have arisen from implementing it, albeit with technologist's participation. No one knew *a priori* which elements to select or emphasize in the many natural and social environments of Coastal Ecuador, and many actors made decisions about the technology: the groups themselves, the second-order UAPPY, CIAT staff from many disciplines, INIAP technicians, a visiting Colombian farmer, representatives of a banana exporter, extensionists and local masons. The work routines for conserving cassava, for example, resulted from two weeks' of trials involving the exporter's staff, an association, and CIAT personnel. Both technologists and social scientists have been part of this process. For example, INIAP's investigations were important for evaluating, confirming, and generalizing technical items, and anthropological, geographic, and economic studies helped us to perceive environmental differences. Still, the dialogue based on science, farmer experience, commercial results, and the project monitoring system has been more important than formal studies.

Technology difusion and farmers' organization

This section deals with the active steps taken by the farmers' organization to difuse new technology. Second, it shows that working with a farmers' organization can make the difference between failure and success.

Of the technology transfer methods that are being tried in the cassava project, fomenting farmer-to-farmer training has been the most striking. In 1985 and 1986, an experienced Colombian farmer visited Ecuador to teach the first four groups how to dry cassava. In 1987, local promoters, having had two season's experience, worked for the first time, with only modest success. In 1988, seven promoters successfully formed six groups and took part in many training activities. The main elements in the farmer-to-farmer technology transfer activity are the following:

- arranging tht new groups visit functioning plants
- promoters' visits to new groups
- promoters' technical assistance visits
- workshops organized by the UAPPY with farmer participation
- UAPPY supervision of promoters

The UAPPY workshops have covered such themes as constructing cement floors, building drying trays, motor maintenance, machinery operation, accounting and group formation. The Union employs a rural secondary-school teacher to organize one or two courses per week. This training activity complements that of other institutions, and cooperation has been notable. INIAP, for example, often provides a locale for a workshop, and INIAP professionals have taught several courses on cassava production. Occasionally, an INIAP non-professional takes part in a Union course; for example, the station mechanic taught the motor maintenance course. Official extensionists from the MAG cover legal statutes, accounting, group organization, some production practices, and other topics.

The promoters receive a minimal payment ($US2) for each day worked. Half of this is paid by the new association, and half by the UAPPY.

There have been problems with the farmer-to-farmer program. First, the promoters were not efficient in their first year. Second, there was some feeling among officials extensionists that the promoters were trying to replace them; a meeting called to resolve this issue focused on complementarities, apparently successfully. Finally, there is the issue of replicability and sustainability. Nevertheless, if they do no more than they already have, with the formation of six groups in 1988 (five of them already profitable), the local promoters have already succeeded.

We will now examine two cases of technologies that were presented to Ecuadorian farmers without result because the social context was not right; now, in the hands of a farmers' group with interinstitutional support, they have more of a chance. They are the rapid multiplication techniques for cassava and the cassava chippper.

In 1984, INIAP was practicing CIAT's rapid multiplication techniques for cassava as part of a MAG program to provide clean seed to farmers in the eastern part of the country. This program suffered from major defects; there was no technical advantage for Manabi seed in the Oriente, nor did farmers there feel a need for seed. When the technology hit technical problems, it was abandonned, and some seed was sent from normal lots.

In contrast, in 1988, the technology is being adapted for use by the farmers' organization in conjunction with INIAP incorporating such elements as local construction materials, lower costs, no reliance on piped water, etc. Several groups have been trained, and both the institutions and the UAPPY are putting up funds for the costs of trying the technology. The project has created a demand for high-starch varieties that can be harvested early in the year. INIAP has identified a promising variety, but it would take 10 years to test the variety and multiply it. To cut the time needed to achieve impact, the last years of varietal trials will be done on farmers' fields using participatory techniques, and the farmers' group will do the rapid multiplication, for which they see a need.

We cannot know if this scheme will work; the countryside is littered with scrapped windmills and other appropriate technologies that somehow did not make it from trial to success. Yet we do know that the institutional context was wrong four years ago and that the technology did not succeed; this time, it may go, and the criteria of its success will be the degree to which farmers have an early chance to evaluate the promising new variety now represented by a few plants on INIAP's station.

The second case is the cassava chipping technology. Since the early 1980's three entrepreneurial groups have tried unsuccessfully to produce yuca chips in Ecuador. The technology fell on fertile ground only when the organizational and institutional arrangements that had succeeded in Colombia were replicated, with adaptations; interestingly, now that the technology is working, it is possible to modify it for entrepreneurs as well, particularly those who used it as a secondary activity.

My conclusion from these and other cases is not that there is any one form of organization appropriate for the cassava processing technology, but rather that there are several points of equilibrium among technology, institutional arrangements, social conditions, financial possibilities (including subsidies), markets, agronomic conditions, and, especially, farmers' needs, strategies, and organization.

Should social technology be part of the packet?

Is it useful for research organizations to make explicit the social and contextual components of a technology, or can we take them for granted as something that extension or development agencies will discover without assistance or explicit models? It varies from one technology to another, and according to the goals of the technology institute. If a new variety is much like older ones, and if farmers are already used to managing new varieties, then work routines, inputs, etc. can be taken for granted. But when we consider agro-forestry, post-harvest processing, or cultural practices, or when we aim a technology into new areas (social or ecological), or towards a particular beneficiary group, then the packet's chance of success are enhanced by describing how to modify it for different social and natural environments or at least the social conditions under which it has been successful. Since a very large number of factors are potentially related to implementing a technology, the decision on inclusiveness must include cost and utility of the information.

Also, what is listed in the packet depends on who is defining it, what resources they control and what actions they have to take to implement it. For example, the actions that a farm family takes to implement a new technology include not only what happens in the field but also changes in resource allocation, in work patterns, and perhaps even in nutrition and social organization; for them, these might be part of the packet. From the point of view of a project planner, the paquet may include not just on-farm changes, but also training programs, financial arrangements, staffing, and so on. An anthropologist or historian might define the packet in very broad terms.

Participation in studies

The UAPPY, having a strong relation with INIAP, collaborates with studies of cassava production, post-harvest technology, socio-economic conditions, and project progress and impact (Table 5). The organization also contributes the true criterion for success of the project technology: its profitability and impact as farmers implement it. Themes for research, suh as methods of producing cassava with higher starch content, have come out of the project.

At the present time, the UAPPY is beginning construction of a rural demonstration center that will have prototypes of new kinds of processing machinery. Researchers from INIAP will conduct trials using that machinery, including economic evaluations. If warranted by these first trials, a neighboring farmers' group, now in formation, will undertake semi-commercial production using the new machinery, thus allowing design of social technology. The center, is hoped, will have a small, commercial metal workshop to allow modifications to the designs.

Integrating farmers' organization with other institutions

Some of the institutional factors that allow the project to include the farmers' organization in such an active role are an appropriate constellation of institutional actors, subsidies for some activities (combined with a highly profitable central activity), and an adequate internal structure for the UAPPY.

The actors in the cassava project are similar to those of the Peruvian projects earlier described, and on of the lessons learned from studies of the Colombian cassava project was that regular institutional meetings at the local departmental level could be an effective way to mobilize effort. At the provincial level, the actors participating in the Peruvian, Colombian, and Manabi cases include governmental agricultural researchers, extensionists, non-governmental organizations, funders, and outside technical assistance, in these cases by international agricultural research centers. In Colombia, there was no second-order farmers' organization to participate, as there is in Ecuador. As recommended by development sociologists and organizational specialists, this network of actors has links to the national centers and to local places, with at least weak coordination at several levels (Smith, Lethem, and Thoolen 1981).

In the Ecuadorian case, FUNDAGRO is promoting interinstitutional cooperation as a means of integrating research, extension, and education. It provides a coordinator, publications, and some project costs, including some to strengthen UAPPY's administration, extension capacity, and participation in investigation. Thus, as in the Peruvian and Bolivian cases cited, outside subsidies have allowed the farmers' organization to attempt activities that are not directly profitable, such as participating in some kinds of research. On the other hand, the profitability of the central activities of the UAPPY is what fuels both farmer participation and institutional interest in the project, and some of the technology trials are simply investments being made with the assistance of investigators who will later write up the results. The UAPPY's willingness to work in risky environments, with marginal groups, and in general with new technology results from the subsidies it receives; the adaptations that result are purely for economic feasibility.

The internal structure of the UAPPY is the final institutional element that has allowed it to asssume its roles. The general structure of the UAPPY-local cooperative-style associations with a central service organization is similar to that recommeded by Esman and Uphoff (1984) for "intermediary" organizations. The specific organizational features that allow it to participate in technology adaptation and transfer are 1) special personnel capable of administering activities and funds beyond the basic agroindustrial activity of the group, particularly a "chief of projects" who can write projects and reports of the kinds required by funding institutions plus a capable bookkeeper, 2) a training capacity comprising a leader who sets up one or two workshops per week and the corps of farmer-promoters, and 3) willingness to respond to appropriate technical assistance. The functionaries of the UAPPY, with one exception, are farmer-members or their more educated children, so they have the trust of the membership; the exception has been a "broker" active in management (see Tendler 1983 on the broker's role). It is worth noting that none of this would have any effect if the core activities were not economically viable.

Replication with emphasis on limitations and cautions

What I have tried to present in this article is a reasonably successful case of linking technology adapatation, extension and development, putting emphasis on institutional roles and especially that of a farmer organization. The institutions have certainly been able to "move the technology" with immediate benefits to small-scale farmers. I think that this sort of activity is fairly common and that it should be recognized in the development literature, studied, improved, and incorporated into both research and development projects, and that in general the social aspects of technology (work routines, the broadly defined packet, and organizational requirements) should be studied and improved.

However, without minimizing the dedication, skills, and efforts of the farmers' organization, I have also tried to be realistic in this presentation: the project is still young and eventual success is not guaranteed; the farmers' group did not make radical changes in the technologies; they had technical assistance from several agencies, including people acting as "brokers"; some of their more appealing activities had outside subsidies; and through inattention, some initiatives were lost. Nor, in the general Latin American context, has technical assistance to farmers' organization been as successful as hoped, no matter what its origin, type, duration, or politics.

Even if this project continues to be successful, it should not be supposed that all projects with farmers' organization will work. For example, this project is focused on post-harvest technology and marketing, which is known to be particularly compatible with farmers' organization. Second, the auspicious characteristics of the organization are not universal. For example, the goal of the farmers' organization is clearly production and marketing for economic return; a less-focused group might not be as successful. Also, the intermediate size of the group has been an advantage. The question of scale is a difficult one; it has been noted with reference to popular participation in development projects in general,

> The [World] Bank and Borrowers do not always recognize that community participation is much more difficult to implement successfully in large projects than in small ones... In small projects administered by voluntary or religious agencies or community development organizations, for instance, community participation can be tailored to existing differences in local capabilities and interests, and can be made flexible and slow in pace. Intensive use is also made of dedicated field staff. But in large projects such as those financed by the Bank, the approach necessarily becomes more standardized, operates according to a fixed and probably inflexible schedule, and may suffer from inadequate supervision and support... (Perret and Lethem 1980:18)

Third, the scale and style of outside funding and technical assistance has been appropriate; while many foundations and bilateral programs do support such activities, others insist on projects that are much larger or smaller.

In summary, I feel that the project is replicable and provides lessons for development efforts, but the degree to which is generalizable and expandable are not yet known.

Summary of the Case study

1. Technology design. The elements of the cassava-processing technology packet were selected, emphasized, or modified in accord with the needs of local farmers' organization. Appropriate social technology, including work routines and organization, were developed by the farmers' organization working with investigators and buyers.

2. Technology transfer. The farmers' organization was an active agent in technology transfer, fielding promoters and trainers and working with several specialized institutions. The farmers' organization was an appropriate recipient of technology that before had not been successful.

3. Studies. Collaboration between the farmers' organization and researchers made several studies possible, and it was the organization that provided the ultimate test for new technology: economic feasibility.

4. Institutional teams. A certain constellation of actors appears in several development projects in Ecuador and elsewhere; at the provincial level, they include a farmers' organization uniting village affiliates, governmental agricultural researchers, extensionists, non-governmental organizations, funders, and outside technical assistance, in these cases by international agricultural research centers. This constellation may be an appropriate way of uniting research, extension, and development in pilot efforts, presuming that the farmers' organizations is an active participant, not just a communications channel.

5. Replicability. The roles described in the case study for mid-size farmers' organization are probably replicable in other projects, but it should be noted that the conditions for the initial success of the cassava project are not universal, nor is it clear how much the project can be expanded or standardized.

Notes:

1. The author gratefully acknowledges funding provided by FUNDAGRO of Quito.

2. That is, I will deal with an explicit, modern type of farmers' organization. This is perhaps not the best place to fight the notion that traditional communal land tenure, risk sharing, extended families, social networks, and even non-banking financial arrangements are impediments to development, nor to suggest that some development efforts can and do work with such institutions.

3. Anthropological research in Colombia in 1984 and 1985 was conducted as a Rockefeller Foundation post-doctoral fellow with the CIAT Cassava Program.

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Table 1. Several technologies of the Ecuadorian cassava project.

Area	Technology	Stage of Transfer
Cassava processing	Cassava drying	Installed and profitable
	Starch extraction improvements	Installed in two plants
	Conserved cassava	Adapted, tried on semi-commercial basis
Seed multiplication	Corn varieties	Two groups in trial; one lost seed
	Cassava "seed" multiplication	Farmers in training
Agricultural production	Varieties, stake treatment, practices, etc.	In trials

Table 2. Materials and actions directly required for a new company.

The basic technology	Chipper, drying method, warehouse.
Work and work routines	3-10 people working in the plant with certain skills; larger crew for start-up; 13 people for cassava conservation; 10 for starch extraction. Construction and woodworking routines. Management (searching for raw material, keeping records, paying wages, controlling costs, etc.). Organization (decisions, choosing competent leaders, etc.).
Raw materials	Cassava; construction materials; increasing plantings.
Tools	Produce and service the tools embodying technology, e.g. cassava chippers.
Community support	Flexible provision of raw material. Minimal opposition, including those who decide that the technology is not suitable
Institutional support	About one person-year initially, including technical assistance, organizational support, cultural brokerage
Power/influence	Solve problems at local, regional level.
Services	For example, land preparation.
Market and marketing	Means to sell the product, including contacts, quality control, problem-solving, etc.
Funding	About $10,000, on acceptible terms.

Table 3. Technological variations for producing cassava flour in use in Manabi Province in 1988, by type of producer.

Participant group	Technology
Association ofsmall-scale farmers in norma environment	Drying on concrete floor, with some trays.
New, weak organization	Tray drying (for relocation and risk reduction).
Very small-scale production	Small chipper (currently hand powered).
Women's group	High value, lower bulk starch and flour for humans.
Entrepeneur	Adapt to pre-existing diesel driers (not new construction).
Artesanal starch producer	Use of pre-existing grater.
Central facilities	Mills to service primary groups. Diesel drier (in construction; for risk reduction for surrounding groups). New, unproven machinery.
Group in cloudy environment	Tray drying (for efficiency).
Favored environment	Conservation and export (occasional)

Table 4. Characteristics that would seem to make a technology packet adaptable.

Feature	Explanation
Modular	Elements of the packet can be used or not; various combinations are feasible.
Risk reduction	The packet has features that make it less risky to try different elements and combinations; a low-risk, low cost version is available.
Incremental	The basic technology functions, even as new elements are tried.
Menu	The alternative parts of the technology are easily identified for potential users.
Robust	Delays, problems and trials can be tolerated.
Social	The technology includes or allows for variation in work routines, organization, and externalities.

Table 5. Services provided by the UAPPY to researchers.

Research area	Collaboration
Longitudinal farm monitoring	Members in sample; facilitate contacts.
Post-harvest technology trials	Provide facilitates, raw materials, organization.
Technology impact studies	Provide production records and lists of beneficiaries.
On-farm trials	Provide access to members.
Farmer preference trials	Members in sample.
Money, labor, materials	Exchange services with NAR.

REPORT ON MEXICO'S CASSAVA PROGRAM, 1977-1987

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INTRODUCTION

In November 1981, a group of 20 farmers initiated in Huimanguillo the cultivation of cassava under the auspices of the national Cassava Program. This event constituted the culmination of years of patient preparation of the technological, institutional and political conditions conducive to the Program's implementation.

As early as 1975, the Ministry of Agriculture (SAG, today SARH), the National Institute for Agricultural Research (INIA, today INIFAP), and the now closed College of Tropical Agriculture (CSAT) had shown interest in establishing technological cooperation with CIAT for cassava. INIA had cassava seed collections dating from the 1950s that included international materials. It also had cassava experimental plots in several states, In many cases, economic endorsement had been provided by the National Bank for Rural Credit (Banrural). In 1976, the Bank of Mexico's Trust for Agricultural Concerns (FIRA) manifested its interest in the potential use of cassava as pig feed by supporting the organization of an International Seminar on Tropical Livestock Production.

These institutions agreed that Mexico needed to create a national cassava program. The first proposal defining the Program's objectives and strategies was drafted in early 1977 at the request of Banrural. An official "Project for Research on Cassava" drafted by CSAT, INIA, FIRA and CIAT staff was sanctioned in June 1977. A few months later, CSAT and INIA staff initiated the National Cassava Program's research activites.

By 1980, INIA assessed that it had made sufficient progress on variety selection and production technology generation to warrant the organization of a training course for extension agents, INIA and INIP researchers, and functionnaries of agricultural support organizations. One year later, the commercial Cassava Program was launched.

During its five years of development, the commercial Program has provided farmers with important services, and large amounts of capital and other resources have been invested by the state in this effort. Yet the results are still disconcertingly unstable.

The Program has been organized in such a way that too many critical activities are controlled and managed by state agencies. Farmers have a very limited opportunity to voice their views on ways in which the Program should operate and could be improved. Production and processing input and output decisions, market outlet and marketing strategy definition and even profit distribution decisions are all in the exclusive domain of Program officials. This arrangement is not efficient. The Program depends heavily on rigid and less than efficient institutional procedures which discourages increments not only in production but also in processing and selling. Very little effort has been invested to tailoring cassava production according to the particular conditions of the farmers and the product's commercial outlet. There is an excessive concern on the part of state officials regarding the expansion of the area under cassava production without ensuring the conditions for such growth.

Cassava development under the Program continues to be a highly risky business. Production, processing and marketing are planned and implemented without coordination nor clear linkages among each other. Production and profitability are lower than expected, because of the untimely delivery of state controlled inputs and services, and the lack of incentives for farmers to carefully tend their fields. There is plenty of processing technology resources available but they have been utilized in an unplanned and inefficient fashion. Marketing of the produce has been conducted in an ad-hoc and rather passive manner, and has concentrated it efforts on very limited market outlets often with low capital liquidity. As a result, the Program is perceived by a disturbingly large proportion of the farmers as a disappointment and a postponement of many hopes and expectations.

This report describes the elements that contribute to making the Cassava Program fall short of its potential. It concludes that a broad spectrum of interventions are required to reorient the Program in a way which encourages the farmers' committed and stable participation, and the economic soundness of the project. These interventions are expected to alleviate the pressure that results from the Program's Achilles heels.

Highlights of the Agroindustrial Cassava Program

The Cassava Program has provided farmers with several benefits. Cassava cultivation incorporated into commercial production idle land which was marginal. Prior to the creation of the Cassava Program, farmers left a large proportion of their lots in bush fallow with no intention to produce from them. For most farmers, extensive cattle ranching on those lands is ruled out due to the relatively high capital requirements of this enterprise and the relative small size of the farmers' plots. (Most family landholdings are less than 10 hectares).

Cassava production has increased from approximately 1% of the land under cultivation in the municipality of Huimanguillo in 1981, to some 20% in 1985. (These calculations are based on data provided in SPP 1985. This should be used with caution, however, because SPP's crop data is not exhaustive). Cassava rated higher in reference to the savannah region only. Since then, the proportion of cassava in the total agricultural land has probably reduced some, but it is still very significant. The main transformations in recent years have been the expansion in the production of citrus, rubber, and pineapple. Pineapple occupied 250 hectares in 1986. It is perhaps the most profitable crop of the savannah. Although it requires higher capital investment per hectare, there is not bank credit available for its production. Rubber trees were planted in 1982 and 1983, and cover some 300 hectares. FIDEHULE has provided credit for planting and fertilization. Most plants, however, have not been grafted, and hence their productive development has been stunted. Citrus trees were planted in 1984 and 1985 and cover a total of 825 hectares. Competition for resources with cassava is expected in the near future, especially from citrus and pineapple.

The Cassava Program has also created a source of employment for over 500 savannah inhabitants who have participated in the production of the crop since 1981, and some 45 farmers who are engaged in cassava drying, some of whom are not cassava producers. In addition, the Program has been instrumental in setting up 14 pig farms, and by providing raw material for feed, it has contributed to the operation of silos in the Plan Chontalpa development program, 3 pig farms in Yucatan and Puebla, Albamex of Merida, and to a few other feed users.

Another important gain for cassava producers but also farmers in general has been the construction of infrastructural facilities as a part of the state support of the Program. Perhaps, the most significant investment of this sort has been the building of roads. It is calculated that the most direct beneficiaries of this intervention are the some 7,500 savannah inhabitants spread throughout 5 communities.

Farmers have also profitted from the Program insofar as they have been able to broaden the use of production factors that were made available primarily for cassava cultivation. A large proportion of the land that was cleared from brush and tress in 1983 and 1984 is no longer under cassava cultivation, although it remains under crop production. Also, a considerable percentage of the farmers in the Cassava Program regularly use inputs included in its technological package for growing other crops. Fertilizers stand out among these inputs. On occasions, herbicides and mechanical traction have also been diverted. These inputs are used largely for the production of subsistence crops, such as maize and beans. Since there is no credit available for the production of either of these staples, and the poor quality of the savannah's acidic soils is not conducive for their growth, this is an important albeit unplanned benefit resulting from the Cassava Program.

An important contribution of the Program which usually goes unmentioned is the reinforcement of the market for fresh cassava. As previously stated, the Program has concentrated on cassava production for feed. Consequently, the improved variety "Sabanera" that INIA released in B1980 was not bred for its pallatability or response to other desirable traits for human consumption. In comparison to customary varieties, this new variety is perceived by farmers as more resistant to plagues but more fibrous and woody. Hence, "Sabanera" generally is less suited for the preparation of some dishes. These traits, nevertheless, have not prevented the use of finely shredded "Sabanera" mixed with corn dough in the making of tortillas. The relevance of the cassava produced under the Program in the tortilla making business is partially indicated by the fact that private traders buy truck loads of "Sabanera" for this purpose. At present, cassava produced in Huimanguillo is being sold in the municipalities of Cunduacan, Jalpa, and Nacajuca. Although no studies are available to ascertain the proportion of cassava that is sold in Mexico's rural and urban markets, my observations in Tabasco and other suggest that cassava has more commercial importance than it is commonly given credit for.

The Cassava Program has also contributed to the general development of agriculture and, indirectly, to the livelihood of Tabasco's farmers. It should be recalled that prior to the creation of the Program, research on annual cultivars was virtually non-existent in Tabasco. Only investigations on pastures for beef production were being carried out by CSAT. This indicates the relatively low involvement of the government in the development of agriculture in the state up to that point, with the exception of the Grijalba and Chontalpa development schemes. In this setting, the Cassava Program heightened the awareness of state officials of the many possible contributions that the tropical zone could grant to the nation as a whole. Cassava gained national visibility for Tabasco and southern Mexico. The Program was the most important catalyst for governmental interest in agriculture for the entire region in the early 1980s. Hence, it indirectly contributed to the development of many crops under the auspices of official institutions. Certainly, a critical mass of organizations and resources that were nucleated around cassava were eventually used for other annual crops. Similarly, a good deal of technical personnel who today work with other cultivars gained their initial expertise through their involvement in the Cassava Program.

In synthesis, the Cassava Program has contributed to the development of Tabasco on several areas. It made possible the incorporation of underutilized land into commercial production, and was instrumental in the creation of jobs for rural inhabitants. The program served as a catalyst for the state to build roads and bridges, and broaden the scope of agricultural production in the region. Finally, if reinforced the supply of foodstuff for rural and urban dwellers.

Inadequacies of the Agroindustrial Cassava Program

While the contributions of the Cassava Program to date have been significant, there are still areas in which an improvement is needed. There are impediments which have emerged throughout the implementation of the program, that were not foreseen in the past but must be resolved today. These impediments require immediate attention as they are intrinsic to the program goals. By overcoming these obstacles the growth and strength of the cassava program will be facilitated both at the state and the national level.

1. There was/is very limited integration between production, processing and marketing of cassava.

When the Program was created in Southeast Mexico, there had been relatively little history in production and utilization of the cassava root. Most cassava was produced in small quantities in tiny areas within the farmers' plots. Generally, farmers used either a team of horses or oxen to draw the plow or small tractors. Manual weeding and harvesting were usually associated with this crop. The norm was to use no chemical fertilizers, and, in general cash requirements were extremely low. If investmnet were made, these were short term. By and large, cultural practices were stable and well defined, even though there was room for an improvement in the mean net return. Most cassava was used for on-farm consumption as a vegetable or as fodder. This situation still largely applies to cassava production in areas outside the Program's domain.

Thus, the Program necessarily defined demand in terms of potential demand. The argument was that Mexico was not self-sufficient in the production of carbohydrates. Although some 8.5 millons of tons of corn and 5.5 millons of tons of sorghum had been produced yearly in the early 1970s, Mexico had been forced to import 2 millon tons of corn and 350 thousand tons of sorghum. At that time, these imports amounted to almost 320,000 dollars. It was reckoned that if Mexico could produce cassava these imports could be at least reduced. In order to substitute half of the imports, however, Mexico had to establish over 100,000 has. At that time there were some 3,000 has cultivated to cassava, most of them in Chiapas state. Southeastern Mexico was importing grainfeed for swine and poultry production. Very little sorghum was produced in the area.

The Program's goals, unmodified since 1977, called for a sharp increase in the production areas and productivity of cassava within a very short time period. In 1977, the Program aimed at having 120,000 hectares under cassava production by 1983. In 1981, the target area for 1986 was sensibly reduced to 10,000 hectares. During the past four years, quoting specific production goals has become both unfashionable and politically unwise, but the dramatic change is still expected to occur.

The initial assessment of the potential demand for cassava as feed was perhaps too optimistic but there was enough potential demand to warrant the Program. The Program was launched. Alas, the way it was planned and implemented was haphazard and uncoordinated. The potential demand was not systematically estimated in a market analysis but in 1986, i.e. ten years after the program was initiated (Saez 1986). Furthermore, the Program did not define a clear and consistent strategy for the potential demand to be realized.

In 1977, the Program's plans recognized the need for interventions in the areas of production, processing and marketing of cassava. Yet over time the Program's goals and activities became increas .gly focused almost exclusively on production. This is explained in part by the fact that practically all the professionals involved in one capacity or another were specialists on production, but also because there was no plan showing the way in which production, processing and marketing would be integrated. By 1981, the Program was no longer an agroindustrial cassava program but rather a cassava production one. The goals were defined in terms of expanding the area under production. Production was not perceived as one step in a chain which comprised processing and marketing. The aim was not to produce animal feed which was accepted in the market, but instead to produce cassava. Another source of distortion was the Program's definition of production tasks solely around technical concerns. Very little effort was devoted to encouraging the active and profitable participation of farmers in the Program.

In 1981 it was expected for an artificial drying plant operated experimentally by INIA to process all the cassava produced under the Program. This drying plant turned out to be ineffective both technically and economically. Thus, cassava planted in 1981 was harvested in 1983 and sold directly by farmers as a vegetable for human consumption. Despite the lack of a reliable and cost-effective processing technology and the absence of linkages with feed processors, Program officials encouraged an increment in cassava production. One hundred and four hectares were cultivated in 1981. One year later 227 hectares were cultivated, and 852 hectares were planted in 1983. By 1982, the group of 20 farmers who initiated the Program declined to continue producing cassava under its direction. Since the soil was already prepared for cultivation, extension agents were drafted to plant cassava instead of the farmers. A high incidence of bacteriosis contributed to a decline in yields. In 1983 it was necessary to use a mix of local varieties, varieties from Centla, Tab. in addition to the new variety Sabanera. Planting lasted till March, in the midst of the dry season, and then continued from June to August. By now, cassava was partly dried at INIA's drying plant and partly stored in silos in the neighboring Plan Chontalpa. The construction of another drying plant started in 1983, but it was never functional.

Although five sundrying patios were built in 1981, amounting to 1,400 sq. meters in total, they were not provided with chippers, motors nor other supplementary equipment needed for their operation. Thus did not process cassava until 1983. At the same time, the Program did not launch a much needed strong campaign to render farmers aware of the potentials of sundrying and consumers knowledgeable of the uses of dried cassava. This situation lasted till 1984, when processing began in two patios. Active opening of market outlets for processed cassava was still inexistent, though. Processed cassava was sold to the now closed CSAT. In 1985, as a result of the cassava glut a renewed interest in cassava sundrying emerged. The Program built 10 more patios, this time amountings to 12,000 m^2 total. For these patios, however, only 7 had chippers and only 6 had motors to operate the chippers. None of the patios built hitherto had wooden rackets, a weighing scale, plastic cover for the product, shovels and wheel carts. All of these tools are essential for the efficient operation of a patio. The situation of unavailability of credit and market demand for processed cassava persisted. Even under these conditions, 211 tons of dried cassava were obtained in 1985. In 1986, Banrural gave credit for the operation of some patios, for the first time. Part of this credit was diverted by farmers for the purchase of tools needed for operation, which were not provided by the Program. Meanwhile, extension agents could not provide technical assistance due to a lack of transportation vehicles. Despite these constraints, 763 tons of dried cassava were produced in 15 patios in 1986. At the end of 1986, 7 more patios were incorporated into the Program, totalling 14,000 m^2. Only one of them had chipper and motor. None of them had the required support tools. By March 1987 this situation was finally corrected. All 17 patios were given the required instruments for their normal operation.

During the past year, Program staff have assigned a high priority status to getting the two industrial processing plants into full operation. This focus, however, has inadvertedly conveyed to farmers the notion that these are mutually exclusive technologies. Some patio operators have reported that they reduced or completely ceased sundrying cassava in response to official claims that the processing plants would soon be functioning at full capacity. As a result, the potential complementarity of fuel - and sun-based processing technologies has been missed.

Both methods of cassava drying are currently operating well below their capacities. The drying patios have never processed over 10 tons of fresh cassava a day which would be their expected top performance. Also the quality of the processed product is still very uneven. The industrial plants still function at very low levels of economic efficiency with low outputs. The estimated costs of producing one ton of cassava flour in the plants are 50% higher than its commercial price. The plants are processing some 14 tons of fresh cassava per day, about 80% lower than their originally advertised capacity. Once technical and administrative adjustments are completed, it is expected that their processing performance will be considerably higher.

Thus, the Program was characterized by a sustained offensive effort insofar as production is concerned but a rather improvised and uncoordinated effort on processing and marketing.

2. The profitability of cassava production under the Program is very low.

Every year an estimated cost of production statement is prepared by the officers of SARH for consideration by Banrural and ANAGSA staff. Upon its approval, Banrural agrees to grant credit for the crop and ANAGSA insures this investment. It is the norm to estimate the costs of land preparation, planting, fertilization, and weed control according to prevailing commercial rates. The costs of plague control and harvesting that are included in the budget, however, are not real or even possible costs. They are supposed to represent unknown figures that will vary due to inflation. It is impossible to make these calculations since the period before harvest may last up to two years, due to problems in findings market outlets or restrictions in the processing capacity of the Program. Because of the use of such estimations, the figures that the official budgets quote seriously underrate the real costs of some activities, and hence reduce the total cost of production. The costs of harvesting one hectare of cassava are for instance, frequently stated at one-third the daily rate per laborer.

Real harvest cost have been used to elaborate Table 1, which shows the costs of producing cassava and its returns under the program during the 1985-86 cycle. In 1987 Program officials offered a credit for harvesting which amounted to M$5 per kilogram of the root harvested. Costs for other items in the budget have been obtained from two reports on the development of the program by SARH and SEDES. It should be stressed, though, that the costs presented in the Table are still short of the actual production costs, and hence better describe the amount of credit given to farmers than production expenses. While there are no official records available that readily present the actual costs for an agricultural year, both farmers and the program staff agree that the credit for cassava production does not fully cover all the costs for labor requirements. Farmers reckon that under ideal conditions they would need up to 35% more capital than that officially budgeted for labor. Labor costs constitute the most expensive direct costs of the budget.

Table 1. Cassava costs of production and benefits per hectare, in Mexican pesos, agricultural cycle 1985-86.

ITEM	1985-86	
Machinery		
Chapeo	3,000	
Barbecho	6,000	
Restreo	7,000	
Rayado	2,500	
Chapeo		
Subtotal		18,500
Labor		
Plantacion	6,600	
Tratamiento de semilla	2,100	
Aplicacion de fertilizante	6,600	
Aplicacion de herbicida	2,200	
Desyerbe	15,400	
Aplicacion de insecticida	6,000	
Arranque	60,000	
Subtotal		98,900
Inputs		
Material vegetativo	8,000	
Tratamiento de semilla	1,878	
Fertilizante	16,208	
Herbicida	3,000	
Insecticida	2,640	
Subtotal		31,726
Total direct cost		149,126
Seguro		7,456
Interes bancario		47,720
Total costs		204,302
Value of crop		225,000
Benefit		20,698

At the prevailing average yield of 12 tons/ha the profitability of cassava production for farmers is very low. For the 1985-86 cycle, the estimated total benefit per hectare accrued from cassava cultivation under the program was less than $25,000 (approximately US$12). Program staff and farmers agree that a similar situation has characterized previous agricultural cycles (cf. Tabasco, Gobierno del Estado 1987:91).

3. The current credit structure hinders rather than facilitates the development of the Program.

The Program heavily depends on bank credit to operate and concentrates around Banrural many of its crucial activities. Participant farmers are required to receive credit for production from Banrural. Agricultural inputs, including access to machinery, are distributed to all farmers from one single channel following Banrural disbursements. The bank provides credit for some of the Program's most important buyers.

Farmers, nonetheless, generally admit disappointment vis-a-vis Banrural's service to clients. The bank's loan disbursements, for cassava or any other crop, have always been consistently untimely and slow. In the case of cassava those delays have resulted in late field preparations, shortages of fertilizer and other inputs, overdue harvests and the general reduction of the capacity to process, sell or buy cassava.

Credit is essential for agricultural production. Capital rather than land is the most critical limiting factor for production in this part of the country. Wealthier farmers tend to engage in livestock production. Only small and medium-size-farmers cultivate the land.

At the same time, Banrural does not provide farmers with detailed and reliable account records. Ejido members are unable to figure out the status of their accounts since the Bank does not produce disaggregate information for individuals in ejidos. Yet, frequently farmers entitled to individual accounts as "colonos" equally ignore the details of their accounts. Furthermore, farmers complain that the Bank does not register their repayments and, thus, they continue to pay interests on the total capital lent. This has been the case for producers who sold their crop to independent buyers, but especially those who traded with the Chontalpa silos. The Bank does not issue periodic balance statements but rather yearly statements. Even this agreement has not been fulfilled. In November 1986 the Bank presented its first report on farmers' accounts in the six years of the commercial program.

Farmers have difficulty in understanding the bank's balance statements, as do the Program staff who are well educated and relatively familiar with accounting procedures. This creates a situation where the farmers' control of their account is nearly non-existant. This leads to extreme frustration and distrust regarding the Program on the part of the producers.

Banrural's regulations result in exaggerated paperwork and administrative red tape. The requirements to apply for credit are excessively convoluted. Farmers must produce seven documents and have them registered in three different institutions prior to turning in their application. This process requires frequent trips to Villahermosa and Cardenas, and imply relatively long waiting periods and considerable expenses for the farmers. Once the application is submitted, it has to go through another lengthy process which includes field inspections. Only then are the documents presented to the bank's legal advisor who still may veto the application.

As a result of this procedure, a considerable amount of the extension agents' time is devoted to paperwork for the bank instead of agricultural advice for the farmers. Program staff provide instructions on how to meet the requirements for bank loans. They often present application on behalf of bewildered farmers. They also convoke and lead meetings among farmers before, during and after the credit application period. They often go house by house asking people in ejidos to sign on the program or at least authorize members of the community to join it. If one adds to these bank-related actitivies other administrative demands, it is not surprising that the extension agents' time tied to desk activities may well exceed the the time for direct contact with farmers in their fields, even during months of peak agricultural activity.

High interest on bank loans have acted in the recent past as one of the most important desincentives for cassava production since it contributed decisively to increasing the total cost of production. Interest rates are calculated according to official inflation rates, and hence have increased dramatically over time. Whereas in the 1981-82 agricultural cycle the average bank loan interest rate was 16% by 1983-84 it reached the 37% mark and in 1986-87 it climbed to over 80%.

Evidently, Banrural officials are in no way responsible of setting interest rates. They simply abide by instructions from the Ministry of Economy. Farmers feel, nonetheless, that the interests on loans have contributed decisively to increasing the total costs of cassava production. They, however, are not allowed to take small loans to reduce these costs. The bank sets a fixed amount of credit for all cases, regardless of the farmers' production plans or the quality of their fields. Hence, farmers are forced to either take the credit as it is, even if this means increasing their chances of indebtedness, or dropping out of the Program. It is likely that there would be fewer farmers joining the Program in the immediate future unless the costs of production are considerably reduced, the credt policies change so as to allow for the amount of each loan to vary according to farmers' preferrences, and the yields, sales volume and comercial price of the crop increse.

Since Banrural is primarily concerned with the repayment of its loans, it has taken an extremely strong role in the sale of cassava. Most of the crop is commercialized through the bank's direct intervention. In these cases Banrural also provides credit to the cassava buyers. Another share is sold independently of the bank, but Banrural discourages these types of exchanges. The idea is that income from cassava sales should be used first to repay the bank debt, and only once the debt is cancelled can the remaining funds be distributed among farmers.

In practice, Banrural's direct or indirect involvement in commercializing cassava has become a greater liability than asset. Its participation has slowed down the selling process by withholding purchasing capital, restricting sales to a reduced selection of buyers, and discouraging the farmers' direct sale of their produce. Also, since the Bank's statements are frequently inaccurate very few debts have been cancelled, regardless of the industriousness of the farmers. The combination of these circumstances has seriously reduced the farmers enthusiasm for the Program.

In addition most Bank loans for cassava production have represented high fiscal expenditure for the Banks. The Program's loan recuperation rate is exceedingly low. Up to the present, Banrural has been fully repaid only for the loans extended for the first two production cycles. During the first year, SARH paid the debt on behalf of the farmers in exchange for cassava stakes. SEDES cancelled the second year's debt with payment in kind, by providing access to machinery for land preparation during the 1985-86 cycle. Forty-five percent of the loans of the 1983-84 cycle and the loans of the 1984-85 and 1985-86 cycles are past due and farmers have been charged delinquent interest rates. Also, the state government granted farmers virtually interest free production loans during the 1983-84 and 1984-85 agricultural cycles. Only 11% of the 1983-84 loans have been repaid (cf. Tabasco, Gobierno del Estado, 1987:86-88).

Most of these default cases are related to the fact that farmers have not been able to harvest within the year-long time limit on loan. It has often taken the Program over 24 months to harvest cassava. In fact, half of the crop produced under the Program over the years remain to be harvested (Table 2). Harvest delays have resulted especially from the Program's inability to find commercial outlets for cassava, and to a lesser extent Banrural's and Program staff's untimely provision of credit and machinery, respectively.

Relatively few cases of cassava loan defaults have resulted from crop failure, due mostly to pest problems. In theory, crop failure should not have a negative impact on farmers' accounts since all the fields which are cultivated with Banrural's credit are by law insured through ANAGSA. In practice, though, less than 20% of the cases of crop failure are investigated by ANAGSA. This happens since ANAGSA's insurance coverage runs out twelve months after the crop is planted. Yet there has never been one single year in which cassava has been harvested within that twelve month grace period. Hence, farmers do not benefit from ANAGSA's insurance.

4. The Program has been unable to establish a strong position in the market

From the Program's inception, commercialization of cassava has been a major challenge. In fact, selling the crop has been the most crippling bottleneck in Program expansion. During the first two years, no substantial outlet for cassava was identified, and producers were forced to

Table 2. Area of cultivated and harvested cassava, up to July 1987

	HECTARES					Tons
Cycle	Cultivated	Harvested	Unharvested	Failure	Ton/ha	Harvested
1981-82	104	101	-	3	18	1,818
1982-83	227	212	-	15	14.2	3,010
1983-84	852	843	-	9	11.7	9,863
1984-85	2,404	1,577.5	826.5	-	12.6	19,877
1985-86	667	191.5	433.5	42	11.4	2,183
1986-87	1,086	-	1,086	-	-	-
Total	5,340	2,925	2,346	69	13.5	36,751

sell their cassava to any buyer they could locate. Both the Plan Chontalpa cassava silos and the sun-drying patios contributed to alleviating the cassava glut. The volume of cassava processed by these means, however, was insignificant prior to 1985.

In the 1981-87 period, 21,488 tons of fresh cassava were marketed through the Program (Tabasco, Gobierno del Estado 1987:76) as presented in Table 3.

Table 3. Cassava commercial outlets, 1981-1987.

Outlet	Tons	%
Silos	11,009.7	51
Drying patios	5,586.8	26
Fresh feed and vegetable	3,221.7	15
Industrial plants	1,670.0	8
Total	21,488.2	100

The pace with which the crop has been sold, however, has been exceedingly slow. As stated before, under the Program, cassava has never been harvested within the prescribed 12 months. Harvesting has taken place from 16 to 24 months after planting, whereas customarily produced cassava is harvested 8 months after planting. Presently, 35% and 71% of the cassava grown in the 1984-85 and 1985-86 agricultural cycles, respectively, remain in the field while the farmers await its overdue harvest.

These delays in harvesting have functioned as a way to coping with the oversupply of large volumes of fresh or processed cassava. Although the social costs of this decision have been high, especially in terms of lowering farmer morale, its economic costs have been relatively low apart from credit costs. By not harvesting 2,300 hectares cultivated to cassava have been "put on hold".

Processing has been the Program's second best approach to handling cassava oversupplies. Thirty percent of all the cassava harvested has been used as feed for the Plan Chontalpa piggeries. There are 10 silos in the Plan Chontalpa area, each with a storage capacity of 1,200 tons of fresh cassava, but only five of these silos were actually used for processing the roots. The Program also used cassava drying as a way to both prevent the crop's spoilage and create a new marketable product. Some 5,590 tons of fresh cassava were sundried and additional 1,670 tons were dried in two large industrial plants. This amounts to 16% and 4% of the total cassava harvested, respectively.

The most important obstacle, however, has remained: The lack of a sound market for cassava. In lieu of identifying potential cassava buyers, the program has concentrated its sales within a very small group of buyers. Dried cassava has been sold to two factories which produce feed in Yucatan (SANJOR and ALBAMEX), a group of feed producers from Puebla, the plan Chontalpa piggery operators, and FERMEX, an enterprise which is currently exploring industrial alternative uses for cassava. To date the volumes sold have been low, and the payments have been delayed.

The program has not explored new uses for cassava nor new groups of buyers who could be convinced to switch animal feed for cassava. Little or no effort has been made to educate others about the advantages of using cassava as animal feed. No promotional compaigns with offers of free samples, for instance, has been attempted. In short, no attention has been paid to the needs or wants of the consumers.

Although the silos have been the Program's most reliable outlet, the Program can not base its strategy for commercial expansion on the silos alone. As stated, five out of the ten Plan Chontalpa silos are already using cassava in their piggeries. Four of the remaining silos lack roofs and two silos and their respective piggeries are abandoned. Above all, the silos are operated by ejido famers. None of the silos are sufficiently capitalized to buy large quantities of cassava.

Given the Plan Chontalpa's present lack of funds, it is improbable that the processing capacity of its silos will expand. Actually, it may decrease in the near future. Expansion of silo operation depends on silo operators having access to credit or raising their own capital through marketing of the pigs they grow.

It is unlikely, however, that the solution will come from Banrural. Although the bank may open credit accounts for silo operators to purchase cassava, the loans are in practice only effective after a long and laborious process. Some silos are authorized by Banrural only a fraction of the credit requested to operate at full capacity. At the same time, cassava producers are frequently forced to advance deliveries of cassava to the silos months before the silo operators are actually extended the credit. As a result, entire cargos or large fractions thereof are bought on credit from small producers who can ill afford awaiting payment. In April 1987, the silo operators had not paid to the cassava producers the equivalent of some 1,850 tons of cassava which they had purchased on credit one year earlier. Undoubtedly, few producers will remain willing to continue their commercial transactions with silo operators unless payment conditions are improved. This situation has a strong negative impact on the Program's market. Since it is critical to solve the plan Chontalpa's credit limitations, it will be extremely important, in the long run, for credit sources other than Banrural's to be explored if this bank does not radically improve its performance.

The core of the Program's constraints is the lack of markets for cassava, rather than a reduced processing capacity. The inexistence of a strong market to meet the increments in cassava production has created an ever expanding stock of cassava. This situation has contributed to creating an impression that the Program's drying patios are inadequate and ineffective. The proposed solution, then, is to dry cassava in industrial plants. The argument boils down to an appeal for a transformation of the available processing technology in order to solve the problem of cassava oversupply. There is a chance, however, that the current excess of fresh cassava will turn into an excess of cassava flour produced in the industrial plants, unless market outlets are identified and there is a guarantee that the product will be sold. In other words, processing clearly does not eliminate but rather in some instances increases the need for actively searching for a market. Focusing on the patios purpoted ineffectiveness as the source of the problems for the cassava program prevents program staff and farmers from perceiving the real problem.

A final note: According to official sources, the volume of fresh cassava has amounted to some 3,000 tons or .5% of the total cassava sales. It seems, however, that the real share of fresh cassava is being underrated. There are some 15,000 tons whose sale is not accounted for. This figures represent the difference between total cassava harvested and total cassava marketed in the program (Tables 6 and 7, respectively). Conceivably some of that cassava was used for domestic consumption among the producers' house-holds. It is also possible that some was transformed into feed. The most traditional cassava market being that of human consumption, though, it is extremely likely that at least 10,000 tons of cassava produced in the Program have been introduced into customary markets. If this is the case, the fresh cassava outlet for human consumption may be as important as or even more important than cassava processing in silos. This would also mean that almost half of the cassava produced in the market has been disposed of in one way or another directly by the producers.

5. The Program's strategy has sought a rapid expansion of the area under cultivation but has not ensured the existence of necessary requirments to meet its goals.

The Program's rationale, and hence its challenge, rests on its ability to increase production and yields of cassava in order to replace imported grain feeds. This goal necessitates the introduction of new varieties and technology for production and processing, as well as developing a stable product market. This notwithstanding, it also requires a sound management of the technology transfer and its implementation. In this section, I will discuss the form in which these elements have been articulated.

The Program's technological component has largely provided a solid foundation for cassava production. A set of recommendations has been generated for the Huimanguillo area which encompasses the release and broad usage of the improved variety "Sabanera", and the prescription of norms for the selection and preparation of cuttings, dosages for fertilizer application, planting dates, plant spacing, and weed and pest control. These recommendations have been tested and refined over time although there are still areas necessitating further research and evaluation.

In 1981, INIA released two varieties, "Sabanera", (M Pan 51) and "Coste_a" (M Mex 59). "Sabanera" was resistant to bacteriosis and thrips and tolerant to superelongation. "Coste_a" was tolerant to bacteriosis, superelongation and thrips. Under experimental conditions, "Sabanera" and "Coste_a" produced 32 tons/hectare when monocropped. The local varieties, on the other hand, yielded an average of 12 tons/hectare without using fertilizers (Holguin, Acosta et. al. 1981). By 1982, "Coste_a" was found to be susceptible to field problems and was discarded from INIA's technological package. Since then, "Sabanera" has been the only recommended cassava variety avaiable in Mexico.

Despite the adoption of new varieties, the Program's records have shown yields which have consistently been only slightly higher than yields of local varieties. The average yield for the 1981-86 period is 13.6 tons/hectare. Furthermore, recommended variety yields have steadily decreased. Yields in 1985 declined 37% over the 1981 yields, (Table 4).

Table 4. Average cassava yields and farm-gate prices per agricultural cycle, 1981-86.

	Yields		Price	
Cycle	Ton/Ha	%	M$/Ton	%
1981-82	18	100	3,500	100
1982-83	14.2	79	6,000	171
1983-84	11.7	65	8,500	243
1984-85	12.6	70	17,000	426
1985-86	11.4	63	18,750	536

These registered low yields are not the consequence of purported deficiencies of the variety "Sabanera". Rather they are largely, related to the management of the Program. Specifically, they are the combined result of inaccurate record keeping, lax administrative selection of farmers and fields, deficient usage of improved varieties and the technological package, insatisfactory harvest arrangements, and farmers' resistence to the Program design which have resulted in poor crop management. In turn, all of these factors are derived from an excessive adherence among high level officials to a strategy based on the rapid expansion of the production area of the Program.

The area that farmers report under cassava production tends to be significantly higher than that actually cropped with cassava. This over-estimation is in response to the structure of input distribution. Briefly stated, the larger the area claimed for cassava production the larger the share of fertilizers, credit for labor, and so on that the producer is entitled to. After harvest, calculations of the yield per hectáre are based on the producer's proposed area for cassava production rather than the actual areas. This result in the recording of lower yields per hectare than those actually obtained. Program staff are aware of such situation but do not exercise tight control to prevent it from happening. If it was more closely monitored, provided that the staff had the resources required to measure the land under production, the overall area of the Program would shrink. This decrease could then erroneously be interpreted by some higher level officials as a sympton of weakness both in the Program and the staff activities.

Cassava's low yields under the Program are also related to the inclusion of poorly selected fields for cultivation and the farmers' lack of committment to cassava production. Again, this is allowed to happen by staff in order to obtain an increase in the total area of the Program. In many instances, lowland fields susceptible to flooding are planted to cassava. Also, the Program includes small- to medium-size absentee landlords who produce cassava with the sole purpose of having their land under production, thus preventing these lands from falling under the jurisdiction of the Agrarian Reform, which could jeopardize their ownership of idle fields. Neither these landowners nor the overseers managing their lands are interested in harvesting cassava. Additionally, low yields result from the fact that there are farmers who permanently migrate to other states midway through the agricultural cycle abandoning their cassava plots in search of more profitable economic activites. Sometimes, this happens with the consent of the local authorities.

Finally, there are ejido farmers with established histories of bank loan defaults who, nevertheless, are extended additional credit for their continued participation in the Program, and who may not be committed to agricultural production. None of these farmers participate in the Program because of their commitment to cassava. These free riders, however, not only damage the overall performance of the Cassava Program, but they also reduce the opportunities for other farmers' participation.

It is important to remember that individual ejido producers are not the direct recipients of bank loans. Credit is awarded to the ejido as a corporate entity. Generally though, only a few ejido members submit a loan request together. Once the loan is granted, it is internally distributed among those farmers partaking in the common project. Theoretically, an ejido may have more than one loan from the bank during any fiscal year for different crops and/or livestock projects. If the loan is not repaid in full, the ejido becomes inelegible for further credit. If one ejido member does not pay his debt to the bank, the whole ejido is excluded, even if all other loan recipients fully repaid their shares of the collective debt. Ejido administration regulation includes mechanisms to bring pressure on individual loan defaulters. However, these regulations are infrequently enforced. Credit default is one of the major reasons ejido farmers are prevented from continuing their participation in the Program. Due to these reasons, it is critical to weed out free loaders who deprive industrious farmers of opportunities.

In the past, there have been cases where the overwhelming concern for rapidly expanding area of the program has led to the production of cassava with little regard to the Program's technological package. Communities that produce cassava with their own resources are included in the Program. These communities, however, do not follow INIFAP's technological recommendations nor receive technical assistance. They tend to use fertilization dosages other than those suggested in the program as well as unimproved varieties. This situation results in either actual or reported lower yields per hectare. At the same time, facing a shortage of improved variety stakes to meet expected expansion goals, Program staff have on occassions, gained access to and widely distributed stakes of the unimproved varieties. As a result, whole crops have failed or yielded poorly. Finally, the planting dates recommended have only rarely been followed. Cassava has frequently been planted well beyond the deadline.

In addition, low yields have resulted from frequent defoliations due to attacks of cassava horn worm (Errinyis ello), and uneven and deficient treatment of the cassava stakes with fungicide prior to planting. These factors can be easily controlled from the technical viewpoint. They, however, require the timely intervention of both Program staff and farmers. In the past, this has been the exception rather than the rule.

Harvesting arrangements also contribute to yield reduction. The use of mechanical harvesters presents several disadvantages. This situation is due in part to limitations in the design of the harvester, but moreover to the deficient way in which many fields are cultivated. A large proportion of the fields are carelessly prepared by tractor operators. When harvesting time comes, the operator must harvest rows which are not parallel. Also, throughout the field the spacing between the rows is frequently uneven. Once the cassava tops have been removed from the fields, there is no marking to assertain where the roots are. This situation is further exacerbated by the growth of thick vegetation since fields are weeded very infrequently. Weeds prevent the harvester from moving through and the crops can not be harvested without causing a great deal of damage to the roots.

Often, as a result of the combination of those factors, the machinery crushes many roots and leaves from one-fourth to one-third of crop in the ground. Until recently the system of manual collecting of the roots once the harvester has unearthed them has been used. This has generally been arranged through contracts based on the area harvested rather than the quantity of the crop collected. Motivated to complete the job quickly, the contract laborers moved through the field as fast as they could with no regard for thoroughness. Presumably, the unharvested cassava was collected and sold by the farmers to the market of their choice circumventing channels controlled by the Program. The latter requires farmers to sell cassava primarily and almost exclusively through officially established outlets in order to insure that producers repay their loans to the bank. Because few farmers have realized economic gain by following these channels, a partial harvesting of their fields may have been perceived as economically advantageous.

All the above mentioned shortcomings of the Program can be related to the fact that the Program staff has been overly concerned with meeting ambitious production goals. During the first four years of the commercial phase of the Program, political commitments were established on promises of rapid expansion of cassava production so as to effect an equally dramatic reduction of grain feed imports. These commitments transformed the Program's goals into rigid expectations in terms of increases of areas cropped with cassava with no real focus on ascertaining the existence of necessary conditions for the expected increases. Production goals were set too high in relation to the then available resources for cassava production, processing and marketing. As a result, the official standards for selecting farmers and fields, as well as the technological recommendations, were frequently overlooked.

6. The Program's performance has led to the disillusionment and disenchantment of both farmers and rank-and-file staff.

Increasing numbers of farmers are opting for staying away from the Bank's sphere of influence. Some of them are no longer participating in the Program but continue to plant cassava with their own resources. Their cassava plots are understandably smaller and are often cultivated with a modified version of the Program's technological package. The perceived advantages are double: farmers gain flexibility not only in the production process but also in selling the crop. This suggests that farmers can find cassava production profitable provided that institutional conditions allow more freedom for producers to exercise economic initiative.

After six years of commercial operation the Program shows a general incremental trend regarding both the number of participating farmers and the area under cultivation (Table 5).

These figures on the development of the Program, however, conceal the disquieting fact that entire communities are dropping out of the program at a rapid pace. The only factor preventing more communities from withdrawing is the high turnover rate of the individual participants who live in these communities. In fact, roughly half of the communities joined the program for one agricultural cycle and three-fourths remained for two cycles (Table 6). The amount of change among farmers is even more pronounced. Under the program, 82% of the farmers produced cassava for only one agricultural

Table 5. Area under cultivation and number of Farmer Participants in the Cassava Program by cycle, 1981 to 1986.

Cycle	Hectares	Farmers
1981-82	104	20
1982-83	227	67
1983-84	852	92
1984-85	2,404	206
1985-86	667	92
1986-87	1,086	172

cycle and 94% joined the program for two years or less (Table 7). These statistics reveal that the social foundation of the program is extremely unstable. This is a disturbing finding because paradoxically the supposed main beneficiaries of the program are continuously pulling out of it.

As a result of these conditions, even though the Cassava Program in Huimanguillo is growing in terms of numbers of farmers and communities participating, it could soon reach a ceiling which would prevent its further growth. This maximum limit may well be determined by the rate of turnover among farmers and communities. (There are 39 communities in the savannah of Huimanguillo of which 23 are ejidos and the rest colonies). Needless to say, this may also hinder the expansion of the total area devoted to cassava production. Yet the program must develop a stable, experienced and committed mass of producers to be able to ensure its self-sustenance in the medium to long run.

Although farmers are aware that there are still problems with processing and selling cassava, the two most important factors that explains their high turnover are the Program's low profitability rates and the prevailing credit structure.

Table 6. Participation of communities in the Cassava Program by agricultural cycle, 1981-86.

Cycles	No. Communities	%
1	15	46.9
2	9	28.1
3	3	9.4
4	4	12.5
5	1	3.1
Total	32	100.0

Table 7. Participation of farmers in the Cassava Program by agricultural cycle, 1981-86.

Cycles	No. Farmers	%
1	532	82.0
2	76	11.7
3	36	5.5
4	4	0.6
5	1	0.2
Total	649	100.0

Conclusions and recommendations

In the ten years of activities, the cassava program has been able to establish a solid technological base for cassava production which has contributed to a large increase in the land area under cassava cultivation. From 1981 to 1986 during the commercial phase of the program, 5300 hectares have been planted in cassava. Several state and federal institutions as well as sundry farmer groups have participated in this effort. As a result many hopes and expectations have been raised both at the local and national levels.

There is a general awareness, however, that the Program's growth is fettered by certain factors. In this report these factors have been identified through the discussion of three symptons of underlying difficulties. These include the Program's relatively low cassava yields given its technological refinement and financial investment; the overstocking of cassava as illustrated by the fact that almost half of the cassava produced has not been harvested; and the Program's high level of participant turnover.

Behind these symptoms several elements have emerged which have fed into each other. Low yields are associated with limited use of improved production technology and lack of appropriate incentives to farmers caused by inadequate market integration. This has been further exacerbated by untimely delivery of inputs and credit. The common element to these shortcomings is that high-level program planners have relied too heavily on the Program's area expansion as its criteria for measuring success or failure of the program. This focus on crop expansion, unfortunately was not matched with the necessary preconditions for such growth. More importantly no commercial outlet for fresh or processed cassava was secured. Instead of seeking a steady market for cassava, the Program lowered its production standards maintaining a passive commercialization strategy. The Program also showed low earnings and symptons of unnecessary red tape. The low return rates were explained by the low volumes traded and general low yields. These low yields in turn increased the costs of production. The bureaucratic delays reinforced the farmers' sense of complete powerlessness vis-a-vis program staff and above all bank officials. These conditions fueled the participating farmers' frustrations and passive resistance to the Program policies.

Some recommendations to overcome these shortcomings and contribute to the Program's expansion into other areas besides Huimanguillo are given below.

1. The Program must carefully define explicit plans for cassava agroindustrial development. Its phasing should be stated. It should insure that production, processing and marketing are integrated, and that each of these components expands in a balanced manner. The goal will be for no component to ever be out of synchrony with the other two.

There are hundreds of possible uses for fresh and processed cassava. The Program must examine carefully which one of these product designs should be implemented given the available human, financial and technological resources. It must consider, then, which product designs are profitable, i.e. which ones have a good cost-benefit ratio <u>and</u> can be reasonally expected to be accepted in a particular market segment. The next step will not be full scale production of the selected designs, but rather their commercial and technical testing on a small scale. Pilot studies are essential in this process. According to experienced industrialists, out of every 100 concepts for new products, 33 are technically feasible, and only 3 will be commercially successful. Pilot testing is the only way to insure that the Program develops the right product for the right market. The Program should move forward to full scale commercial production only when the refining of the product and its technological requirements has been completed and the product has been successfully tested with a sample of the target market segment.

2. It is critical for the Cassava Programs' sustainability that the Program officials avoid centralizing processing as well as commercialization through only one channel. In processing, as in other functions, redundancy of organizations providing the same services is more efficient than concentrating functions in one organization. The co-existence of several organizations increases the likelihood that at least one of them covers services which may have been overlooked by one single organization. Extensive testing and refining is necessary before the processing plants will operate efficiently. Until that transpires and thereafter, it is important to keep open as many processing channels as possible.

3. The current emphasis on production has amply demonstrated that, all things being equal, it is much easier to produce cassava than to sell it. The technological success of the Cassava Program in Huimanguillo could lead to further research and eventually expansion of cassava production to other states of the country. However, a rapid increment in the supply of cassava would most likely create a glut, and frustration for all those involved in the Program, unless a commercial outlet is guaranteed.

4. The Program must formulate a new strategy for development. At the present time, it is critical that the program shift its primary emphasis

from producing fresh cassava to marketing processed cassava. Program officers should re-evaluate the goal of the Program not in terms of producing a crop but rather in creating a commodity. Until now, the Program has expanded both in terms of area under production and total production volume. Production goals and the characteristics of processed cassava have been defined independently of solid analysis of the market structure. The existence of a cassava demand has been taken as a given with no previous evidence based on research. As a result, large amounts of cassava have been produced but only a small fraction of that cassava has actually become a commodity. For cassava to impact the feed grain market, by reducing feed imports, helping to increase the availability of food for the population at large, and expanding the producers' family income, it must become a commodity, i.e. it must be sold.

5. It is essential to conduct market research before committing the Program's resources to producing a new product. This research will serve several purposes. It will help Program planners to make sure that there will be enough sales to cover the variable and contribute signficantly to meet fixed costs. It will help them to define different prices, different sales volumes, different advertising models, different sales and distribution programs according to different market segments. Finally, it will provide guidelines for the production of a commodity that will be accepted on the market. In other words, it will inform both the production process and the processing one as well. Technology development on these areas will be oriented according to the results of market research.

6. The new strategy should be extremely respectful regarding the producers. Farmers must be given an illimited period to reflect, compare, experiment with different agricultural methods. One must help them, technically and financially but not force them. The new strategy, them, should also tailor the product according to what farmers are willing to produce.

7. The Program should be administered by a group of staff each one with specific responsability for one of the Program's functions. In the past the Program has concentrated most of its institutional resources to tasks related to cassava production. Other program functions such as marketing and financial control, however, must receive careful consideration to facilitate the Program's harmonious development.

8. The Program administrators team should minimally include personnel familiar with and responsible for respectively the Program's technological aspect, marketing, production, and finances. The person in change of technology would be responsible for research and development. This person would be expected to generate solutions for specific problems, in addition to doing other research. The person with responsibility for marketing would devote his activities to coordination of cassava sales. The goal of establishing this separate position is to ensure that sales requests materialize. The staff person in change of production would be responsible for increasing production while decreasing time and cost investments. Finally, the staff in charge of finances would act as a comptroller, striving for high level economic performance on the Program as a whole.

9. In order to insure that all the Program's functions are equally represented there should be one person per function in the coordinating committee at the Programs's state level. All the people designated for these tasks should have the same hierarchical level, and cooperation from rank-and-file staff should be equally available for all. A clear mandate and support should be given to those designated from a selected groups of high-ranking authorities who would assume the coordination and general management of the Program. Presumably, the person in charge of research and development could be an INIFAP researcher. The positions for marketing and production could be filled by staff from any of the institutions which participate in the Program. The finance officer could be a Banrural or ANAGSA employee. Above all, it is critical that these people count with the full support of the institutions they work for, and that they are given enough power so that agreements signed by them are minimally binding on their institutions. It is expected that by assuming responsibility for one Program component, the organizations involved in the Program will be encouraged to participate more activity and constructively.

10. One of the most important tasks of this board of managers would be to jointly establish evaluation criteria for the Program and to define Program objectives at the state and local levels. Both the criteria and the objectives should be very explicit. For instance, the Program' managers should define the total maximum allowed investment for product engineering and marketing, the maximum time for development of a product concept or a technology. They should also define the minimum expected utility after a designated period, the product's growth rate, percentage of the product's market partipation up to a designated deadline, the lowest acceptable return on investment and sales, and the deadlines for sales requests. Objectives and criteria other than economic and financial should also be defined. Examples of this type include conditions for the Program to promote farmers' participation, and the Program's reputation and leadership to increase.

11. A considerable amount of energy and institutional resources should be invested to support the development of the administrative capacity of program staff. Creating and operating a successful cassava program is an extremely complex task, and a large part of the program's success rests on the cooperation of researchers and implementation program staff. Due to these reasons, it would be worthwhile to develop as soon as possible a training program for researchers and program staff which provides them with tools for improving their administrative and planning skills. The objectives of this program would be to familiarize the trainees with the theory and practice of methods and techniques of collecting marketing data over time and space, budgeting, design and implementation of market analysis, methods for monitoring the program's implementation, and techniques for program planning and evaluation. Such training program could include intensive short-term hands-on sessions oriented toward gathering data which would be useful to the program. This training could be sponsored by INIFAP. Staff and researchers from states in which cassava programs are currently functioning or about to begin should be required to participate in the training. To accompany this training, adequatelly qualified staff should be appointed as administrative trainers. Their task would include on-site follow up every six months, as well as provision of

on-site assistance for program start-up. While not on-site they should also be avaialable for consultation and evaluation.

12. Processing in no way guarantees that cassava will be sold. A new product must be introduced into the market that is competitive with and superior to customarily produced cassava. While there is little elasticity in the current market demand for cassava as it has been traditionally produced, processed cassava may offer new marketing opportunities. This is crucial as cassava is a highly perishable crop. With this in mind the creation of a new product would most likely benefit from explorations of processing options. Yet, while processing does offer additional possibilities, it does not solve the problem of selling cassava. The transformation of cassava into a non-perishable form which can be stored and transported more easily represents an extraordinary improvement. Processing expands the crops flexibility. Processed cassava, however, must also be sold. If a market outlet is not defined, processing only delays the crisis. Furthermore, there is not such thing as "all purpose" processing. Processing is not a blind activity carried out independently of a targeted market. One processes cassava into a particular form for a particular market. Thus, the market plays an important role by defining the parameters in which processing will take place. Similarly, the market specifications should determine the characteristics of the cassava to be produced. It is perfectly conceivable that if the Program were to process cassava into a form which is not accepted in the market, a new glut would be created.

13. Short term, yet sound studies should be conducted as soon as possible to ascertain the potential outlets for cassava. It is essential that one of the Program's priorities be to develop an informed marketing strategy. A marketing strategy does not mean creating plans on how to sell cassava. It means tailoring production and processing according to what customers are interested in buying. The Program strategy's starting point and constant reference will be the cassava consumer (and the producer, as it will be discussed below). It is essential to know the characteristics of the consumer. It is equally important to know the segments in which the market is divided and concentrate the Program efforts on one or two segments. It is my impression that the market segments have been prematurily defined around feed users only. A large share of the Program's cassava has been successfully marketed as a vegetable, flour or starch for human consumption. Rather than recommending that from now on the Program orients its production as to be used for human consumption, I suggest that the potential of these and other market outlets be examined and measured.

14. It would be a mistake to think that cassava consumption will significantly increase without an accompanying increase in consumer demand. Regarding cassava as feed, the Program strategy would have to target feed users who are not currently using cassava. The aim would be to substitute the feed they are now using with cassava. Some resistance to this change must be expected. The Program would have to design means whereby pig farmers for example have the opportunity to try cassava-based feed at no risks. This would require experimentation on the characteristics of cassava that best suit the needs of the feed users. Some of the variables which might be the focus of experimentation include modification of the

shape in which cassava is presented, its nutritional content, the product's compatibility with the tools used in the piggeries, and the product's price competitiveness vis a vis commercial feed. These adjustments could then help shape production and processing. Consumer tests could determine, for example, the required starch content of the cassava produced or the particular proportions of the ingredient in cassava-based mixes. Hence, the Program could produce cassava with well-defined commercial characteristics and in fact turn out a product with an already existing demand.

15. A similar approach should be used for cassava to be sold as a vegetable, when possible. In this case the Program's aim would be to enter the market with a type of cassava which fulfills the requirements that consumers associate with good cassava. Again, it would be essential to ascertain consumer's defined requirements and preferences. Since this would imply direct competition with other commercial varieties, the Program's cassava would have to adopt a brand name. Ideally, the consumers will associate this brand of cassava with a desirable product which is consistently superior to other varieties with regard to previously determined consumer preferences. Conceivably, the best quality roots could be traded for human consumption. The rest could be channelled through other outlets.

16. The Program's marketing strategy must be active. Until now, the transformation of cassava into commodities has been rather passive. Most of the Program's sales have been restricted to a handful of users. Intervention in the commercialization of cassava has been restricted to agreeing on a price for the roots themselves and then transporting. This situation has to change, and the Program has to take the initiative dynamically.

17. More emphasis should be placed on the identification of market segments, i.e. consumers of products other than cassava who could be commercially persuaded to shift to cassava, or cassava consumers who could be commercially persuaded to shift to the Program's cassava. These segments must be precisely defined. It is important to go beyond broad definitions of cassava's target market. Instead of defining feed users as its target market, the Program should identify smaller groups within that market who may be more open to switching to cassava. The criteria for the definition of such groups can not be determined independently of a careful analysis of the market characteristics. An analysis of the consumption patterns, buying process, and organization of production, for instance, will be required vis a vis users of products which could be substituted with cassava. The goal will be to obtain an extremely clear definition of cassava's competitive advantages in those situations.

18. When considering the crucial need to expand markets for dried cassava, the geographical narrowness of current strategies must be re-evaluated. In light of the fact that dried cassava can be more easily transported, it would most likely be beneficial to the Program and its participants if some promotion of processed cassava was done in several areas of the country, in particular in those areas where cattle feed is expensive or relatively unavialable. This approach would require the active and systemic

organization of demonstrations on cassava's potentials for direct consumers, commercial feed wholesalers and retailers as well as feed processing industries.

19. In the particular case of the Program, a marketing strategy will require in addition to an awareness of the consumers' interests, a concern for the producers', as well. In the past the Program has paid more attention to the availability of suitable fields for production than the interests and perceptions of farmers who produce in those fields. The pace of the Program's development has been set solely on the basis of potential for production increase. Such potential is equated with land agronomically suitable for cassava production. Hence, the Program has generally disregarded whether the farmers are interested and able to cultivate a relatively new and risky crop.

20. The perspective and opinion of the producers must be taken into account in the planning phase of the program, especially considering the risks involved. Those plans that have been handed down from high level officials without producer input should expect to be met with resistance and should be avoided at all costs. If producers are given more opportunities to be involved in decisions making, their committmment to the program and their willingness to experiment will likely increase.

21. It is essential for the Program's success to create a large institutional space for <u>real</u> farmer participation. The Program must accept pluralism so farmers can chose from a wide range of possibilities the form in which they would organize themselves and the extent of their involvement. The Program staff should not force farmers to form groups nor to merge into one single association. Farmers will join only those groups that are perceived to represent their interests. The Program should also recognize the producers' right to define the terms in which they will participate in the market. This means that farmers should be allowed and encouraged to decide who they sell product to. This is perfectly compatible with coordination among farmers and even agreement on a common bottom commercial price of cassava. The goal is for farmers to be the center of the economic decision-making process.

22. At the same time, farmers should decide what kind of product they will sell. There are farmers who are only interested in producing cassava, whereas there are others who also want to process the crop. In addition, there are those who do not produce cassava but only process it. All of these groups should be given the chance to operate at the same time. Farmers must be allowed to rent processing patios. They should also be allowed to sell their crop and obtain direct and immediate returns without having to vertically integrate into processing of any sort. Hence, the practice currently enforced that requires producers to advance cassava for processing in the industrial plants on promises that they will get a share once the processed cassava is sold should be discontinued.

23. Farmers should have the right to select the processing means and the market outlets that best serve their economic interests. Industrial processing plants and sundrying patios should be given an equal opportunity to succeed in terms of credit for operation, facilities for access to

cassava as a raw material, technical backup, etc. Likewise, future Program investments should be diversified to include several relatively inexpensive infrastructural facilities rather than concentrating investment in one single unit of the same total monetary value. Although several small units are less imposing than one large one, it is likely that many small units will greatly enhance the chance of their efficient utilization.

24. It should be stressed that organizing farmers for processing activities is even more important than providing them with infrastructure. Motivated farmers have dried cassava in small make-shift patios, whereas expensive patios have remained underutilized because there were no operators.

25. As for patios, their operators must be organized and motivated prior to initiating the construction of infrastructural facilities for cassava processing. In the past, the physical infrastructure of patios has been built by governmental agencies independently from the organization of farmers who are the target users. This practice has not been evenly efficient. There are patios that were built solely with the assumption that nearby farmers would produce cassava. Despite these farmers' good intentions, today they are not cultivating cassava, and nobody uses these patios. There are also several abandoned patios in cassava producing areas, where producers are not interested in the processing phase. At the same time, however, there are communities in which two or three groups of farmers or individuals compete with each other to obtain access to patio facilities. These communities authorize groups to sundry cassava for a fortnight to ensure access to all.

26. All patios must be equipped with all the necessary machinery for their independent operation and provisioned with technical back up for maintenance of motors and chippers' blades. This outfitting is likely to be achieved in 1988 because, as said before, in 1987 government agencies have provided patios with the most essential implements. However, more extensive training on the proper use and maintance of the motors by farmers is urgently required.

27. Credit must be available to patios operators for buying and processing cassava. Since 1986, Banrural has extended credit for the operation of some patios but disbursement has consistently taken place after the officially defined optimal drying period (March to May). Although, some patios continue to sundry cassava up to October, the late delivery of capital seriously undermines the commercial viability of the patios.

28. The price of dried cassava must be competitive vis-a-vis fresh cassava. Producers complain that the price of dried cassava generally is only slightly higher than the price of fresh cassava. Thus, they prefer to sell the crop fresh. The Program should refine its mechanisms for cassava price setting so as to respond not only to costs of production but also the commercial availability of sorghum in Southern Mexico.

29. Farmer organization is one of the most critical conditions for the sucessfull operation of patios. It is, however, difficult to fulfill. Over the years there have been 22 different groups of farmers participating

in the Program. Most of these groups have been organized after 1983. Although some of them have had a short life-span, the majority have operated for over two years. An association of producer groups (ARIC) was formed in 1986. ARIC was created as a means to encourage famer participation in the cassava commercialization process. Eventually, its aims were expanded to include the management of the industrial processing plants. Recent developments indicate that ARIC may be partaking in the administration of some drying patios, as well. One third of the farmer groups in the Program are part of ARIC. Because of being a new organization, however, ARIC has not been able to expand the pool of cassava buyers, especially insofar as dried cassava is concerned. The Program must provide specialized assistance to improve the performance of ARIC and any other farmer organization in the quest for new market outlets.

30. In the future, Program staff need to put more effort into the methodic and well conceived mobilization of farmers. This organization entails reinforcing training in the technology of patio operation and accounting procedures, which is a service already offered by Program staff. The organization of patio operators, however, should also include training that fosters skills for farmers in the identification of and direct participation in viable markets for their processed cassava. Whereas, today most of the fresh cassava sold through the Program is handled by ARIC, until very recently the most prevalent practice employed by both cassava producers and patio operators has been the commercialization of their products through Program functionnaires. The functionnaires contacted potential buyers, negotiated prices and the volume per transaction for the farmers and quite often without the producers' participation and approval. This practice was neither beneficial in the short nor long run. On the contrary, it reinforced farmer dependency on state interventions, and further inflated the program's operational expenses.

31. The Program must measure its progress from both the perspective of the nation as a whole and the local potential beneficiaries. Until now, the Program has concentrated above all on attempting to contribute to the solution of national problems. The emphasis on the role of cassava to alleviate the nation's relative sorghum and corn scarcity and decrease the amount of feed grain imports should be coupled with a concern for meeting other goals with a more local focus. The Program must spell out specific criteria to measure the benefits accrued from cassava commercial production by producers, their communities, the processing region and the state in which cassava is produced. In this vein, the Program should address specific local and regional problems. The Program should be conceived by its planners and perceived by the farmers in general as a solution to local problems.

32. It is especially critical that the Program's expansion begin with farmers who are already producing cassava. A potential area for cassava production should be defined on the basis of the existence of suitable land and institutions willing and able to lead in agricultural research and implementation. It should also be based, however, on the existence of farmers committed to cassava who want to overcome the crop's limitations. The Program will find strong supporters among farmers if they derive some

immediate benefits from their participation in it. The Program should provide the tools for making customary cassava production more versatile and efficient. Farmers who do not have a tradition of cassava production should be encouraged to partake in the Program not by means of promises but through the example of the actual success of those who joined the Program and benefited from it.

33. It is also important to expand the Program especially among customary producers because, if allowed, they will provide the feedback necessary for fine turning research activities on agronomy and improved variety development. Technology diffusion will be facilitated if farmers are allowed to intervene from very early stages on the design and evaluation of research experiments, and the definition of research priorities. In this way, researchers will contribute to generate technology which is useful to farmers.

34. INIFAP's Cassava Program was created under the assumption that the national program for cassava production could not operate without solid research component. Over the years the research program has become one of the most important elements for the program's development. Today, however, it faces new challenges which could seriously reduce its potential contributions in the near future. Limitations of the commercial production program have forced the research program to concentrate on short term interventions. Whereas ten years ago the program was conceived with a a national scope in mind, in practice it has operated almost exclusively within Huimanguillo. The program's research agenda has become subordinate to the strategy of the production program and its implementation. This is an admirable case of integration of research and operation components. Yet one must face the fact that as a result of this decision the production program is not as adequately prepared to expand to states other than Tabasco as had been originally intended. In this context, the research program has been forced to reliquish its role as a pioneer in the area of innovative planning for the expansion of the production program.

35. The research program should recover its original strength as a pathbreaking institution. More emphasis should be given to the development of the cassava program's capacity to administer and direct new research schedules. The program must define a clear development strategy for research activities with specific stages, goals and criteria of success, so as to prioritize certain areas of investigation. This should result in better integration of individual research projects into one common expected goal.

36. Because of INIFAP's current restructuring, the flow information and the movement of researchers from one state to another have become increasingly more difficult. The research program's activities have shifted from national to single state level. Yet, it is essential to guarantee that agricultural research is conducted as soon as possible in all those geographical areas targeted for potential expansion of the cassava production program. Also, specific channels should be created to ensure the regular flow of information among researchers and program staff working in different states. Intervention at a high level of INIFAP and, possibly, SARH is required to insure that the Tabasco-based cassava

research program not only continues to have a national mandate but also is given the resources to implement it.

37. It is especially crucial to encourage the growth of a permanent socio-economic unit within INIFAP which acts as liaison between farmers and researchers and betweeen researchers and extension agents. This unit's input should be given prior to the formation for the program's development, as well as during and after its implementation. Instead of acting primarily as an accountant for the program, the unit should be involved in and responsible for designing the program's operational strategy. After the creation of such a unit, support training for senior agricultural economists, anthropologists and sociologists should be consider as a priority in INIFAP.

Appendix 1.

The Institutional Interest and Support for the Cassava Program

The amount of institutional support both in terms of funding and staffing for the Cassava Program throughout time has been remarkably high and commendable. In its initial stages, the role of INIA researchers and administrators was extremely critical in laying the foundations for the Program. This involved a two pronged strategy: development of production technology for the specific characteristics of the Huimanguillo savannah; and public relation campaigns to increase the awareness of cassava's potential among officials of banks and trusts, high level administrators of the Ministry of Agriculture (SARH), extension agents and technology diffusors and politicans. INIA was also instrumental in creating a nucleus of permanent support for the crop among Banrural, SARH's District in Cardenas, and CSAT. When the commercial program was actually launched, the coincidence of enthusiam by INIA and the SARH's district's top administrators gave the Program additional impetus.

The state government of Tabasco joined the federal initiative early in the Program's development but has been especially active from the 1983 cycle onwards. At that time, it provided the Program with essential inputs, such as credit and access to tractors and technical assistance which, along with the inputs facilitated by the federal government, created a powerful enticement for farmers to join the Program. Over time, the state's involvement in the Cassava Program has increased to encompass the setting up of industrial organic fuel based processing plants.

In 1985, the Cassava Program received a very important boost from the federal government. The National Program for Rural Integrated Development (PRONADRI) for the years between 1985 and 1988 officially defined cassava as a strategic crop for the nation. The document also defined corn, rice (in the southeastern states), and oil seeds (in non-irrigated lands) as strategic crops. In reference to cassava, PRONADRI's goal was to support its cultivation, expansion and industrialization in order to use cassava as feed and thereby reduce importation of feed grains. The Program's scope was defined in the document as including Tabasco, Campeche, parts of Jalisco, Quintana Roo, Veracruz and Yucatan. The expected increase in production during the 1985-88 period is estimated to be from 6,000 hectares to 100,000 hectares (Poder Ejecutivo 1985:161).

Renewed institutional commitment to cassava ensued PRONADRI's strategic plans. An Institutional Coordination Task Group was established in the production area which integrated the representatives of SARH, the state's Secretary of Development (SEDES), Banrural, Anagsa, INIFAP, the state's Secretary of Industrial Promotion, Commerce and Tourism (SEFICOT), the federal Secretary of Agrarian Reform, and cassava producer organizations. Eventually, a society of farmers (ARIC) was formed that is in charge of the commercialization of cassava and the management of the industrial processing plants. ARIC, the Rural Association of Collective Interests, was composed of farmers from two colonies and two ejidos in 1986. Henceforth, it has expanded its memberhsip to include four more ejidos. At the federal level, the National Committee for Cassava Promotion took a stronger stance in the coordination of cassava production plans.

A clear indicator of the level of continuous commitment to the development of the Cassava Program on the part of federal and state agencies is found in the range of public investments that have been made up to the present in constant Mexican pesos.

1. Purchase of cassava seed for the Program's growth.
In 1982, SARH bought the stems of cassava produced by the farmers who first joined the commerical program. These cuttings were used for the 1982-83 agricultural cycle. SARH paid M$2,836,000 for them.

2. Road infrastructure in support of the Cassava Pogram.
SARH invested M$46,403,000 in improving access roads for the cassava producing colonies Pino Suarez, Martinez Gaitan, and Laguna del Rosario and the ejidos Chicoacan and Tierra Nueva. It also invested M$112,400,000 for paving such roads (Tabasco, Gobierno del Estado 1987:30).

3. Machinery for soil preparation, cassava cultivation and harvesting.
Since the inception of the agroindustrial phase of the Program in 1981, a total of 5,340 hectares have been prepared for cassava cultivation. In the period 1981-83, 1,985 hectares were put under cultivation with agricultural implements provided by SARH. Since 1984, SEDES implements operated by SARH personnel were used for the remaining 3,445 hectares. SEDES contribution to this operation was M$186,315,000 (Tabasco, Gobierno del Estado 1987:33). Also, SEDES built two sheds for machinery in the ejido Tierra Nueva and the colony Pino Suarez with an investment of M$28,383,000 (Tabasco, Gobierno del Estado 1987:34). SARH investment in this project is undetermined.

4. Removal of the forest cover and preparation of those plots for cassava cultivation.
In 1983 and 1984, SEDES cleared forested land as an incentive for farmers to join the Cassava Program. The clearing did not entail any cost for the producers but committed them to participate in the Program for at least four consecutive cycles. In 1983, 34 hectares were prepared under this arrangement, while 1,481 hectares were cleared in 1984. A total of M$220,353,000 were invested in those 1,515 hectares (Tabasco, Gobierno del Estado 1987:33).

5. Direct credit for cassava production.
Banrural and the state government provided M$353,383,000 and M$59,059,000 respectively for covering the costs of production incurred by farmers (Tabasco, Gobierno del Estado 1987:86).

6. Trucks for the transportation of agricultural inputs and machinery.
SEDES bought trucks in support for input distribution, which amounted to an investment of M$50,372,000 (Tabasco, Gobierno del Estado 1987:35).

7. Infrastructural support for cassava sun-drying in cement patios.

From 1982 to 1983, five patios ranging from 200 to 400 square meters each were built by SARH in the colony of Martinez Gaitan and the ejidos of Chicoacan, Tierra Nueva, La Nueva Esperanza and Tecominoacan. Since 1984, 17 additional patios of 2,000 square meters each have been built in 11 communities. The investment for the first ten patios was M$120,000,000. For its part, the state's office SEDES provided in 1987 operation equipment (motors and cutting disks for cassava chippers as well as scales and carts) for a total of M$130,000,000 (Tabasco, Gobierno del Estado 1987:31).

8. Credit for cassava drying operation

In 1986, the state granted M$2,400,000 in credit for the operation of eight patios, and in 1987, credit extension amounted to M$4,500,000 for nine patios.

9. Building of silos for cassava storage

There are today 10 silos with a storage capacity of 1,200 tons each. Seven of these were built by SEDES with the disbursement of M$153,135,000 (Tabasco, Gobierno del Estado 1987:35). Banrural's investment in the remaining three silos is undetermined.

10. Establishing industrial plants for cassava processing into flour.

INIA invested M$15,000,000 in the early 1980s to set up a small processing plant located in Guacamote. Eventually, SARH and SEDES contributed with a total of M$80,000,000 for the generation of an industrial plant in the ejido Tierra Nueva, which was to be the prototype for other industrial settings. The plant never developed beyond the experimental stage. In the last two years, two large scale cassava processing industrial plants were built. One is located in the colony of Martinez Gaitan, and was expected to process 90 tons of fresh cassava per day. The other one, located in the colony of Pino Suarez, was expected to process 120 tons of fresh cassava per day. These industrial plants were built by reconditioning a fish-drying and an alfalfa-drying plant respectively. The former plant was financed by SARH and SEFICOT and the latter one by Banrural and SEFICOT. The total investment for the setting up of these plants was M$500,000,000. These figures do not include expenditures for operating costs (Tabasco, Gobierno 1987:39).

11. Building pig pens to support commercial utilization of cassava.

SARH, the mayor's office of Huimanguillo, and the state's Secretary of Urban Development and Ecology (SEDUE) have invested over M$70,000,000 to build 14 pig farms in 11 communities of the Huimanguillo savannah. In these piggeries, 1,600 animals are fed with dried cassava (Tabasco, Gobierno del Estado 1987:38).

The above mentioned services represent only the main areas of intervention by the state. It is necessary to add to that list that PRONAMEX granted in April 1986 agricultural machinery at reduced prices and convenient payment arrangements for farmers engaged in the Cassava Program. The machinery included 5 International tractors of 70 HP each, 6 MF tractors of 70 HP each, and 3 International tractors of 120 HP each (Sanchez and Oliva 1986). Also, state and federal funds were used to cover the payment of salaries and the operational costs of both technical assistance personnel and research staff. Since 1983 extension agents from the state organization SEDES have joined with federal personnel from SARH to provide technical advice to farmers participating in the Cassava Program. Previously, only SARH personnel assisted farmers. Over time, the total number of the staff involved in these activities rose from 2 in the period 1981-84 to today's 16 technical assistants. Half of this support personnel works for SARH and the rest are SEDES employees. The number of vehicles used in support of this endeavor has also increased from 1 pickup truck in the period 1981-84 to 10 pickup trucks or other similar vehicles in 1987. INIFAP's cassava research team, however, decreased in number from 10 investigators in 1981 to 4 in 1988.

Keeping in mind that this list of state interventions is not exhaustive, we can conclude that the public investment in support of the cassava Program's development over the six year period 1981-87 amounts to at least 3 thousand million pesos.

Appendix 2

The Scope of the Program

While seeking to understand the Cassava Program's highlights and shortcomings, it is important to keep in mind that far from building upon relatively simple quantitative transformations in previously existing production and marketing systems, the program's design has required a radical shift into a qualitatively different system. The program's goals, unmodified since 1977, call for a sharp increase in the production area and productivity of cassava within a very short time period. Cassava production under the Program is intended to reduce or eliminate the need for feed imports which create a negative burden on the nation's balance of payment. In 1977, the program aimed at having 120,000 hectares under cassava production by 1983. At that time, however, Mexico had only an estimated 3,000 hectares in production of cassava. Thus, the Program's designers expected to achieve a forty-fold increase in the cassava hectarage planted in merely six years. When the Program moved from its research-only phase to its implementation phase in 1981, the target area for 1986 was sensibly reduced to 10,000 hectares. During the past four years, quoting specific production goals has become both unfashionable and politically unwise, but the dramatic change is still expected to occur.

Yet the Cassava Program's current design requires a new and considerably more intricate production system. This is revealed by comparing the customary and the agroindustrial systems. In the customary system, cassava production does not depend heavily on purchased inputs. Most cassava is produced in small quantities in tiny areas within the farmers' plots. Generally, farmers use either a team of horses or oxen to draw the plow or small tractors. The farmers own, hire, or borrow these instruments of land preparation. Manual weeding and harvesting are usually associated with this crop. Although chemical fertilizers are occasionally used, the norm is to use none. In general, cash requirements are low and production does not depend on the availability of credit. If investments are made, these tend to be short term. By and large, cultural practices are stable and well defined, even though there normally is room for an improvement in the mean net return.

The Mexican agroindustrial Cassava Program, on the other hand, relies heavily on purchased or capital intensive inputs. Soil preparation, planting, and harvesting are done mostly by machinery. The program introduces chemicals for stake treatment, weed control, fertilization, and sometimes for plague control when biological control has been ruled out due to the problem's severity. Cash requirements for cassava production in the Program are much higher than in the customary system. In addition to these variable costs, the program entails higher fixed set-up costs than the customary system for the tasks of learning and developing a new technology, creating and disseminating technology and market information, locating and developing product markets, obtaining credit, providing road infraestructure, and training labor. Admittedly, these fixed costs may decrease over time, but the Program requires a substantial financial, human and physical investment, especially in its initial period. As a consequence, the shift occurs towards favoring long term investments over short term ones, hence moving away from the low investment norm of the customary system.

In the agroindustrial Cassava Program, the mean net return is theoretically higher than in the customary system, but the risks and the level of requirements associated with production are also higher for the farmer. The Cassava Program treds on completely new ground by concentrating on producing cassava for feed, whereas the customary use of cassava has been and continues to be mainly for human consumption. Also, the production and processings technology continues to be in the process of being improved. It is now 10 years after the research aspect of the Program was initiated, but there is much more to be done in terms of technology development for mechanized planting and harvesting. The Program is at its earliest stage in terms of sound research on industrial processing of cassava into flour or starch. The use of trays, small tractors, and other technological devices in sun-drying patios has not been fully explored. Recommended diets for pigs and poultry using cassava and locally produced or commercially available protein sources remain on the agenda of pending research.

Major adjustments are implied by the Program on the part of the producer and the production process. By virtue of participating in the Cassava Program, the producer is vertically integrated into processing activities. This event has no parallel in customary cassava production regardless of the operation's size. This forward linkage with processing alters not only the nature of the farmer's final product but also the ability to realize profit. In order to effectively participate in the Program, processed cassava must be produced instead of fresh cassava. Under these conditions, access to reliable, efficient, and cost effective processing technology, transportation means, as well as timing and coordination are extremely critical. The combination of these circumstances renders cassava production riskier and thus less appealing to agriculturalists unless higher returns are guaranteed from these endeavors.

A further challenge of the Cassava Program consists of creating a new product which is marketable. This requires tailoring a product according to the specifications of a particular market. It also requires linking production with consumption through promotion and advertisement efforts. Because the use of processed cassava is contingent upon a whole range of new conditions, it cannot be assumed that a processed cassava market will develop spontaneously. On the contrary, an extremely careful adaptation of the final product's main characteristics in accordance with the requirements of the consumer is essential. The producers' and consumers' perceptions of cassava's potentials must be transformed. User training and demonstrations of the comparative advantages of using cassava rather than feed grains may be indispensible in breaking pig farmers' resistance to the new product. A pig farmer, for instance, may likely substitute cassava for the feed grains commonly used provided that cassava chips are consistently available; packaged in volumes appropriate for piggeries; and perceived as presenting low risks in terms of capital, time, and efficiency.

These transformations take place only through a slow and laborious process. All of these conditions spell a demand for increased levels of efficiency and complexity in the Program's planning and implementation. At the same time, new areas of expertise are required. The Program's boundaries cease to be defined around production concerns and are expanded to include processing and marketing issues. The input of agronomists, phytopathologists, breeders, and entomologists must be matched by that of utilization experts, marketing analysts, and social scientists with economic and behavioral expertise. Furthermore, the marketability takes pre-eminence over the crop's production and utilization, despite the apparent contradiction with a logic based on the chronological sequence of these events.

Finally, institutional arrangements also accentuate the risks of producing cassava in the Program. The success of the Program -- and the ability of the farmer to obtain economic benefit thereof -- depends on the skills for long term planning. Neither the farmer nor the average administrator necessarily possess these management skills. Specialized retraining becomes necessary.

The program is expected to run as a result of the concerted effort of heterogeneous institutions, but due to the nature of these organizations, institutional coordination is very hard to accomplish. This is particularly critical because the Program operation is based on the timely and efficient provision of goods and services before, during, and after the production process takes places. Agricultural know-how and inputs, extension service, credit, producer/consumer linkages as well as other services are furnished by a host of institutions with different resources, experience levels, ranges of activities, and commitment to the Cassava Program. Furthermore, these institutions differ in terms of the audiences that they are accountable to, whether to state or federal authorities, political forces, and/or farmer organizations. Although not all the goods and services are equally important, the untimely or careless provisioning of some of them can paralyze the Program as a whole.

It cannot be sufficiently stressed that the wide range of conditions that the Cassava Program requires to operate efficiently not only warrant but also prescribe the state's active intervention. The Cassava Program requires a far greater social investment than the customary production system. In fact, it requires political will and support at the national level, which were not necessary conditions for the operation of the commonly used system. Left to their own means, farmers are unable to respond successfully to the program's new challenges. Hence, the Program's strategy cannot be efficient without state intervention. Risks, however, are implicit in the state's involvement. By striving to make the Program's implementation smooth, farmers can be made too dependent on the state institutions. Today, the state defines how much cassava will be planted in an agricultural cycle; schedules the dates for planting, weeding, and harvesting; determines how much credit will be extended to farmers for production, and what activities the credit will cover; identifies to whom the farmers must sell their cassava, and establishes the farmgate price. The state also assumes the responsability of organizing farmers for cassava production and sun-drying, sets up industrial processing plants, and provides capital for their operation. As such, the Program's growth has increasingly become the exclusive responsibility of the state's administrators rather than the direct producers'. All of the state interventions have left farmers very little space to exercise initiative and creativity. This situation is pungently manifested by the farmers' reference to the cassava that they produce in their fields as "the bank's cassava." Yet, without the farmers' identification with the Cassava Program, the prospects of a strong and self-sustaining Program are bleak.

At the same time, the state's commitment to the development of the Program creates a series of political obligations on the part of the Program administrators. Even though some of these obligations reinforce and streamline program implementation, some others can be counter productive. An exaggerated concern for the Program's political ramifications has been conducive in the past to institutional impatience vis-a-vis farmers as well as rank-and-file support staff. Occasionally, high level authorities have demanded of Program implementation officials immediate and often urgent results rather than slower and more carefully planned actions. Sometimes, this pressure has induced Program expansion without first insuring the existence of viable conditions. In the past, the Program has been put into operation despite the fact that the delivery of some resources, such as fertilizers and credit, has consistently been untimely and factors, such as seeds or product market outlets, have been insufficient. In this respect, the advice of technical support staff was overlooked by higher-level program staff.

The Cassava Program's proposed radical transformations in the production system and the risks associated with these changes render implementation difficult. In turn, improper program implementation generates uncertainty among farmers, which frequently lowers both the morale of participants and the enthusiasm for the Program among those farmers who have not yet joined it. Although there is no way to completely eliminate all the risks involved in planning and implementing a program, the goal should be to insure that only the necessary ones remain and that the impact of these risks is minimized. It is only in this way that it will be possible for the Cassava Program to gain the widespread and active support of farmers, and establish its own status as a self-sustaining and efficient project.

LONG-TERM EFFECT OF CASSAVA CULTIVATION ON SOIL PRODUCTIVITY

R. H. Howeler[1]

Introduction.

Cassava (Manihot esculenta Crantz) is grown throughout the tropics on a great variety of soils, but it is generally found on Ultisols, Alfisols, Oxisols and Entisols, which are charaterized by low soil fertility. In many parts of the tropics it is grown on the poorest soils, such as on eroded slopes or extremely sandy soils, because under these unfavorable conditions the crop still produces something while other crops would perish. Because of this ability to grow on poor soils many people think that cassava does not require high soil fertility or does not respond to fertilization. On the other hand, farmers know that cassava extracts large amounts of nutrients from the soil and they generally prefer to grow it as the last crop in a rotation before turning the plot back to bush fallow (Ofori, 1973). In a more sedentary agricultural system they prefer to grow cassava intercropped or in rotation with other crops to prevent soils nutrient exhaustion. Also, being well adapted to grow on acid low-fertility soils and requiring relatively little land preparation, cassava is often grown on steep slopes. Under these conditions, cassava production may cause erosion, and drastically reduce soil productivity. However, in many cases, it is planted on already eroded slopes, where no other crop can still produce on the highly acid and infertile exposed subsoil. Thus, cassava production is sometimes the cause, but other times the result of soil erosion.

Whether it is justified or not, cassava has the reputation to be highly exhaustive of soil nutrients and to degrade soils by causing excessive erosion. The objective of this paper is to examine these presumptions, to compare cassava in this respect with other crops and to show possible solutions to overcome these negative attributes.

Nutrient absorption and removal.

In order to grow, plants absorb nutrients from the soil; at time of harvest part of these absorbed nutrients is removed with the harvested product and part is returned to the soils with the crop residues. Nitrogen (N), phosphorus (P) and potassium (K) are the plant nutrients absorbed in largest quantities; calcium (Ca), magnesium (Mg) and sulfur (S) are absorbed at intermediate levels, while the minor elements Fe, Mn, Cu, Zn and B are absorbed only in very small quantities. Thus, soil nutrient exhaustion is mainly due to excessive absorption and removal on N,P, or K.

Table 1 shows the nutrient content in cassava roots as compared with that in the harvested products of other tropical crops, as calculated by Prevott and Ollagnier (1958). According to this data, cassava extracts rather large amounts of N, and P, but by far the greatest amount of K

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among all crops compared; it also has the highest K/N ratio in the harvested product. Naturally, nutrient extraction depends on the level of productivity as well as on the fertility of the soil. Although Prevott (1958) does not mention the yields obtained with each crop, nor the level of fertility of the soil, it is clear from the data that cassava yields must have been very high and the soils must have been well-supplied with K.

Table 2 shows a similar comparison of nutrient absorption and removal by various crops grown in Sri Lanka (Amarasiri and Perera 1975). With an extremely high yield of 45 t/ha cassava absorbed more nutrients than any other crop. It removed similar amounts of N as the cereal crops but less than the legume crops, while it removed more P and K than any other crop. However, when the same data is recalculated in terms of nutrients removed per ton of dry matter (DM) produced (Table 3) we can see that cassava extracted less N and P than any other crop, while K removal was similar to that of sweet potato and less than soybean and cowpea. Thus, it is clear that when cassava produces high yields, it will extract large amounts of nutrients, but the nutrient removal per ton of DM produced is relatively low. This is indicated also by the data in Table 4, which shows nutrient uptake and removal in terms of Kg/ha as well as in Kg/t DM produced for various cassava trials having widely different yields. Nutrient absorption was extremely high when yields were high as indicated by the data from Nyholt (1935) and Howeler and Cadavid (1983). However, when yields were low, as in the case of unfertilized Rayong 1 grown in K-exhausted soil in Khon Kaen, Thailand, nutrient extraction was also low. Comparing the averaged cassava data with those reported for other crops in the literature (Table 5), it can be seen that cassava absorbed more nutrients than rice and wheat, but similar amounts as potato, maize and sorghum. The N and P uptake and removal, expressed per ton of DM produced, was much lower for cassava than for any other crop (except sugarcane), while the K removal was similar to that of the cereals, but much lower than the grain legumes, sweet potato or tobacco. It can also be seen that in case of cassava (and sweet potato) most of the absorbed K is removed by the root harvest while in case of the cereal crops usually less than 20% of absorbed K is removed in the grain. More detailed data, presented in Table 6, indicate that about 30% of absorbed N, 55% of P and 60% of K is removed in the cassava root harvest, while most of the N is returned to the soils as fallen leaves or with the incorporation of plant tops after harvest. Thus, it may be concluded that cassava removes large amounts of nutrients, especially K, because of the high root yields that may be obtained, but that the removal is moch lower than most other crops if it is expressed per ton of dry matter produced.

Long term effect on soil fertility.

When cassava is grown continuously without adequate fertilization and managed in a way that leads to erosion, soils productivity generally declines and cassava yields decrease. This is very well illustrated by data from Thailand (Sittibusaya et al, 1988), which show that cassava yields of unfertilzed plots in three different soils series declines to about 60-70% of the initial yields during 20-25 years of continuous cassava production (Figure 1). Without fertilization but with reasonably good crop management, yields declines from a initial level of 27-29 t/ha to about 16-18 t/ha. In Thailand, where cassava cultivation rapidly expanded into newly opened areas during the past 20 years, yield decreases experienced on the "old" land were partially off-set by high yields obtained in the newly-opened area, thus maintaining the country-wide average yield level of about 13-15 t/ha. Now that little new land is still available for further expansion, cassava yields in Thailand are likely to decline unless measures are taken to prevent further soils exhaustion and degradation.

To measure the effect of continuous cassava production on soil fertility, several long-term fertility trials have been conducted in Malaysia, India Thailand and Colombia. In Malaysia, Chan (1980) found that with high levels of fertilization the yield of cassava, grown for 9 consecutive years on the same plots, increased from about 30 to 55 t/ha, while without fertilization yields declined to about 20 t/ha. The yield decrease was found to be mainly due to K exhaustion, as yields could be maintained with annual applications of 156 kg K_2O/ha. Without K application, the available K content of the soils declined from 86 to 26 ppm between the 6th and the 9th crop, with a corresponding decline in yield. In India, Kabeerathumma et al (1988) also found that yields of 10 consecutive cassava crops could be maintained between 20 and 30 t/ha with the application of 100 kg/ha each of N, P_2O_5 and K_2O, while without K application the yield steadily declined to about 5 t/ha. The latter was associated with a decline of exchangeable K in the soils from an initial value of 68 to only 25 ppm after the 10th crop. Similarly, in Thailand, Sittibusaya (1988) and Hagens and Sittibusaya (1988) showed that soils K-exhaustion was the main cause of a yield decline in two of three long-term fertility trials. In the third trial no yield response to fertilizers was observed, even after 13 consecutive cassava crops, due to the extremely high initial K level of the soils.

In Colombia, in a long-term fertility trial cassava was grown for 8 consecutive years with three levels of N, P and K in all combinations, either applied annually or only initially with the first crop. Figure 2 shows that with adequate (100 kg N, 87 P, 125 K/ha) fertilization, yields increased from about 30 to 40 t/ha, while without K yields declined to 15-20 t/ha. Even when only K was applied, yields could be maintained around 30 t/ha, indicating that the soils could supply enough N and P to sustain this high yield. Figure 3 shows the effect of cropping on the exchangeable K content of the soil. Without K application the K level decreased in 2-3 years from 0.20 to 0.08 me/100g and remained at that level throughout the following 5 crops. With the application of either 125 or 250 kg k/ha the soil K level increased initially to 0.34 and 0.48 me/100g, respectively, and then decreased rapidly to about 0.10 me/100g with three consecutive cassava crops without further K applications. However, when 125 kg k/ha was applied annually the K level could be maintained at about 0.20 me/100g, while sustaining high yields of 30-40 t/ha every year. The annual application of 250 kg k/ha resulted in a build-up of soil K to about 0.4 me/100g, which did not further increase yields. Figure 4 shows that when treatments without N or P were excluded, the remaining treatments showed a good relation between yield and exchangeable K content of the soil, with a critical level (95% of maximum yield) of about 0.15-0.17 me/100g

(59-66 ppm). This is in agreement with critical levels of 0.17 and 0.18 me/100g reported by Howeler (1985), and that of 0.16 me/100g reported by CIAT (CIAT, 1988).

Thus, it may be concluded from these long-term fertility trials that continuous cassava production is most soils sooner or later leads to K exhaustion resulting in declining yields. N and P exhaustion have never been observed and, on the contrary, continuous applications of P wil gnerally result in a build-up of available P, which in extreme cases may lead to induced Zn-deficiency. While one-year fertilizer trials will often not show a significant K response, long-term fertility trials gnerally show K to be the main limiting nutrient, and yields of continuously grown cassava can only be maintained with the application of about 100-150 kg k_2O/ha/ Hagens and Sittibusaya (1988) have shown that in the case of Thailand, K applications become increasingly profitable the longer cassava was grown on the same soil.

Restoration of productivity of an exhausted soil.

In order to see whether the productivity of an exhaused soil can be restored, a simple NPK trial with three levels of each nutrient was conducted for 4 consecutive years on a soils that had been exhausted by 4 years of continuous cassava production without fertilization. For comparison, the same NPK trial was conducted on an adjacent field where 4 cassava crops had been grown previously with adequate fertilization. Figure 5 shows the yield response to N, P and K during 4 consecutive cassava plantings in both the "Exhausted" and the previously "Fertilized" plots.

During the first year there was little response to N, P or K, or to the combination of the 3 elements in the "Fertilizer Plot". In the "Exhausted Plots", however, there was a good response to all nutrients, but especially to K. The check yield was only 13.3 t/ha in the "Exhausted" and 34.4 t/ha in the "Fertilized Plot". However, application of 100 kg N, P and K/ha, increased these yields to 29.2 and 41.0 t/ha, respectively. Thus, in the first year fertilizer application could increase yields, but not completely restore the productivity of the soil in the "Exhausted Plot". In the subsequent 3 cassava croppings there was still little response to N and P in the "Fertilized Plot", but there was an increased response to K. Without K application yields dropped from 36.6 t/ha in the first year to about 20 t/ha in the fourth year. Even in the "Fertilized Plot" the application of 100 kg k/ha nearly doubled the yields in the 3rd and 4th crop. However, in the "Exhausted Plot" the already significant K response in the first year became even more pronounced in subsequent years. In the third year K application increased yields from 19.3 to 52.4 t/ha. While there was s significant response to N and P (at least in one of the two varieties), it is clear that the main response was to the application of K. The application of high levels of fertilization (mainly K) was able to restore the productivity of the exhaused soil in the second year and allowed yields of over 50 t/ha in the third year. Thus, there is no doubt that in most soils K exhaustion is the main cause of yield declines caused by continuous cassava production. A rate of at least 100 K/ha should be applied with every cassava crop to prevent soil exhaustion and maintain high yields. Farm yard manure and especially wood ash are also good sources of K.

Soil erosion.

Sittabusaya (1988) suggested that the yield decline shown in Figure 1, is only partly due to nutrient exhaustion and may also have resulted from a general fertility decline due to erosion. In Thailand most cassava soils are light textured (Duangpatra, 1988) and thus extremely susceptible to erosion. Moreover, cassava is mostly planted in the beginning of the rainy season (Tongglum et al, 1988), leaving much of the soil exposed to the impact of raindrops during the first 2-3 months of establishment.

Because cassava is widely-spaced when planted and has a slow initial growth rate, it usually requires more time for total canopy closure than other food crops (Aina et al, 1979). Thus, in this initial phase cassava may be more erosive than other crops. However, cassava is a long-cycle crop, which generally requires 10-12 months until harvest, so land is prepared and is exposed to severe erosion only once a year, compared with 2 or 3 times a year for short cycle crops like maize, soybean, peanut or sweet potato. Thus, comparing different crops, Shend (1982) found that cassava caused more erosion than long-cycle crops like pineapple or banana, but less erosion than those short-cycle crops like sweet potato, or a rotation of sorghum, peanut, sweet potato, soybean and maize. Roose (1977) calculated the crop factor "C" in the Universal Soil Loss Equation for various crops (Table 7). He found that the annual crops (except flooded rice) caused much more erosion than the perennial tree crops, which in turn were more erosive than pastures or forest. Of the annual crops cassava was found to be generally less erosive than groundnut, maize or sorghum, and when well-managed was less erosive than cotton or tobacco. Similarly, howeler (1988) showed that one 18-month crop of cassava produced only one-fourth the erosion as that caused by four consecutive crops of beans (*Phaseolus vulgaris*) grown during the same period in the same experiment on a 15% slope in Popayan, Colombia. Figure 6 shows that a bean crop produced severe erosion every time a new crop was planted. In case of cassava very little erosion occured once the canopy had closed (this took about 6 month at this high elevation, cool climate). After 17 months soils loss due to erosion in a manually (with hoe) prepared plot with cassava was only 6.3 t/ha compared with 44.7 t/ha for beans grown with the same treatment. When land was prepared only in 1m wide contour strips, alternated with unprepared strips, soils losses were slightly reduced for cassava and gretly reduced for beans. No soils preparation (zero tillage) was the most effective way to reduce erosion in this trial, while it had relatively little effect on cassava yields (CIAT, 1980). Thus, while cassava has a reputation to cause severe erosion, this is usually only true in the initial phase of plant establishment, while annual soils losses are generally lower than those caused by most short-cycle crops. Moreover, soils loss by erosion is more determined by the way the crops are managed than by the crop *per se*.

The effect of certain cultural practices on erosion is highly site-specific and some practices that are most effective in reducing erosion in one site may not be so at another location. This depends mainly on the soil type, the slope, the rainfall pattern, plant type, weeds etc. Thus simple erosion trial should be established in many locations (especially on representative cassava farms) to determine the effect of cultural practices on soils losses as well as on cassava yield. In many cases there is a trade-off, as certain practices may be very effective in reducing erosion but also cause a reduction in cassava yield. This is generally unacceptable to farmers. It is imperative for farmer acceptance that erosion control practices not be too expensive and not cause a reduction in yields. Ideally, they should increase his yields. Table 8 shows the results of a simple erosion trial conducted on a 45% slope in a farmer's field in Agua Blanca, Colombia. The land had been cleared from bush fallow and was prepared with one pass of a bullock-drawn plow, except in the last treatment in which cassava was planted without tillage. The farmer's practice of not fertilizing cassava caused the most severe erosion with 36 t/ha soils loss, as well as the lowest yield. Fertilizer application markedly increased plant growth and vigor resulting in better soil cover and a soil loss of only 23 t/ha. Moreover, cassava yields nearly doubled. Additional practices such as mulching, strip preparation with double-row planting or the planting of grass live barrier strips further reduced erosion while increasing yield. The best and cheapest practice, however, was zero tillage, which cused the least amount of erosion and resulted in the highest yield.

However, the results are not always so clear-cut nor always consistent. Depending on the soils texture and weed competition, minimum or zero tillage often results in a serious reduction in yield (Table 9A). In a few cases it may actually increase erosion (Jantawat <u>et al</u>, 1988). Similarly, the planting of live barriers may cause severe competition from the grass, and a decline in cassava yield. Less competitive grasses, or better yet, low-growing legumes, should be identified to serve as live barriers. The application of fertilizers to cassava grown on poor soils usually results in a marked reduction in erosion and a significat increase in yield (Table 9D). Contour ridging and subsoiling have also been found to reduce erosion and increase cassava yields in Thailand (Jantawat <u>et al</u>, 1988). Intercropping cassava with banana was found to reduce erosion while increasing cassava yields in India (Ghosh <u>et al</u>, 1987). The use of mulch is another practice that was found to be very effective in reducing erosion, but its application may be costly and yields are sometimes increased (Table 8) and sometimes decreased (Howeler, 1985). Thus, the best erosion control practices, which will reduce soils losses and increase cassava yields, should be determined locally, so as to be adapted to the edapho-climatic as well as socio-economic conditions of the area.

<u>Effect of erosion on soil productivity.</u>

To determine the effect of soils loss due to erosion on soil productivity, experiments have been conducted in which thin layers of top soils were artificially removed to various depths before planting. Thus, Mbagwu <u>et al</u> (1984), reported that topsoil removal to a depth of 5 cm (about 500 t/ha) reduced maize yields from 2.2 to 0.6 t/ha in an Alfisol in Ilora, and from 0.43 to 0.02 t/ha in an Ultisol in Onne, Nigeria. Fertilization with various levels on N and P could only partly off-set this loss of soil productivity.

Figure 7 shows the effect of erosion on the average yield of 18 cassava cultivars that were planted in adjacent fields of naturally eroded and non-eroded soil in Mondomo, Colombia. The average yield in the eroded soils was only 12.3 t/ha, compared with 24.2 t/ha in the non-eroded soil. However, one well-adapted local variety, called "Americana" grew very well even on eroded soil, where it produced 22.7 t/ha, compared with 26.6 t/ha on the non-eroded soil. It is clear that the effect of erosion on soils productivity depends greatly on the degree of erosion as well as on the crop and varieties grown. Some cassava varieties seem to be particularly well-adapted to grow on eroded slopes, but for many others yields may be drastically reduced by soil erosion.

Conclusions.

Continuous cassava production without adequate fertilization and poor management of crops grown on slopes will sooner or later result in a yield decline due to nutrient removal and/or soils losses due to erosion. Although cassava extracts large amounts of nutrients, especially K. from the soil, this is because of its high level of productivity. When expressed in terms of Kg of nutrients removed per ton of DM produced, cassava removes much less N and P and similar amount of K as many other crops.

Long-term fertility trials in several countries have shown that cassava may respond more significantly to applications of N and P in the first year, but that invariably K becomes the most limiting nutrient after several years of continuous cassava production. Thus, medium-high levels of K should be applied annually to cassava in all soils expect those that have an exceptionally high K supplying power, in order to prevent soils nutrient exhaustion and maintain high yields. Once exhausted a soil's productivity can generally be restored with high applications of K.

Poorly managed cassava can cause severe erosion when grown on steep slopes, but when well-managed the crop tends to be less erosive than manny short-cycle crops. Soil losses due to erosion can be minimized by several management practices such as minimum tillage, contour ridging, fertilization, strip cropping, intercropping and the application of mulch. However, the effect of these practices on erosion and cassava yield should be determined locally to identify those practices that are most suitable for the local edapho-climatic and socio-economic conditions. While somė casava varieties may still be quite productive when grown on eroded soils, in most cases yields are drastically reduced by a severe dgree of erosion.

Thus, soil productivity and high yeilds of cassava can be maintained as long as the nutrients removed by the crop, harvest are replaced and the crop is adequately managed to prevent excessive levels of erosion. In many countries cassava production sustains the lives of many small farmers. It should be managed to also sustain the productivity of the soil for the livelihood of future generations.

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Table 1. Exportation of nutrients and K/N relation in harvested product of tropical crops.

	N	P	K	K/N
	-----------kg/ha--------			
Cassava	124	46.0	485	3.91
Banana	56	3.5	161	2.88
African oilpalm	39	6.2	85	2.18
Pineapple	110	13.2	228	2.03
Coconut palm	35	6.6	71	2.03
Sugarcane	76	23.3	144	1.89
Tobacco	28	3.1	35	1.25
Sisal fiber	122	18.5	149	1.22
Soybean	58	16.2	65	1.12
Cocoa	19	4.4	21	1.10
Virginia tobacco	88	4.4	86	0.98
Coffee	32	2.6	30	0.94
Rice	21	4.8	9	0.43
Maize	103	16.7	85	0.82
Tea	5	0.3	2	0.41
Rubber	420	26.0	160	0.38
Cotton	66	11.4	22	0.33

Source: Prevot and Ollagnier, 1958.

Table 2. Yield and nutrient removal of several crops grown on an Alfisol in Sri Lanka.

Crop	Plant part	t/ha yield	Nutrients removed (kg/ha) N	P	K	Ca	Mg	S
Cassava	fresh roots	45	62	10	164	12	22	3
	total		202	32	286	131	108	15
Sweet potato	fresh tuber	15	31	6	51	10	4	3
	total		89	17	187	44	26	14
Rice	grain	5	58	12	10	2	7	3
	total		100	18	151	27	23	9
Sorghum	grain	4	68	8	16	3	6	2
	total		101	13	108	17	14	5
Maize	Grain	4	64	7	13	2	2	6
	total		118	11	155	32	25	13
Cotton	seed cotton	1.9	40	6	7	6	5	2
	total		77	14	68	34	21	19
Cowpea	grain	1.5	50	4	19	3	2	2
	total		60	5	36	11	6	4
Groundnut	grain	1.8	88	5	12	1	3	2
	total		101	6	34	12	8	4
Soybean	grain	1.2	103	10	34	6	4	3
	total		118	11	47	16	9	5

Source: Amarasiri and Perera, 1975.

Table 3. Yield and nutrient content of each ton of dry matter in the harvested product of several tropical crops grown in Sri Lanka.

Crop	Plant part harvested	Dry matter harvested 1/ t/ha	Nutrients in harvested product (kg/t DM) N	P	K
Cassava	roots	13.5	4.6	0.74	12.1
Sweet potato	tubers	4.5	6.9	1.33	11.3
Rice	grain	4.3	13.5	2.79	2.3
Maize	grain	3.4	18.6	2.03	3.8
Sorghum	grain	3.4	19.8	2.32	4.6
Cowpea	grain	1.3	38.7	3.10	14.7
Groundnut	grain	1.5	56.8	3.23	7.7
Soybean	grain	1.0	99.8	9.69	32.9

1/ Data estimated assuming 30% DM in roots and tubers and 86% in grain.

Source: Adapted from Amarasiri and Perera, 1975.

Table 4. Nutrient uptake and removal by cassava in kg/ha as well as in terms of kg per ton dry matter in the roots.

Variety-fertilization	Plant part	Root yield(t/ha) fresh	dry	---kg/ha--- N	P	K	kg/t dry roots N	P	K	Reference
Sao Pedro Preto	roots	64.7	26.6	45	28.2	317	1.70	1.06	11.9	Nyholt'35
	total		40.0	124	45.3	486	4.66	1.70	18.2	
M Col 22-fertilized	roots	59.0	21.7	152	22.0	162	7.01	1.01	7.5	Howeler and
	total		30.1	315	37.0	238	14.54	1.70	11.0	Cadavid'83
M Ven 77-fertilized	roots	37.5	13.97	67	17.0	102	4.79	1.22	7.30	Howeler'85
	total		22.74	198	30.5	183	14.17	2.18	13.10	
M Ven 77-unfertilized	roots	26.0	10.75	20	7.5	55	2.81	0.70	5.15	Howeler'85
	total		17.41	123	16.4	92	11.53	1.53	8.62	
Rayong 1-fertilized	roots	18.3	5.52	32	3.6	34	5.78	0.64	6.25	Sittibusaya
	total		9.01	95	9.9	64	17.15	1.80	11.68	pers. com.
Rayong 1-unfertilized	roots	8.7	2.68	13	0.9	4	4.92	0.35	1.63	Sittibusaya
	total		4.23	39	3.2	10	14.40	1.21	3.69	pers. com.
Average	roots	35.7	13.35	55	13.2	112	4.50	0.83	6.62	
	total		20.58	149	23.7	179	12.70	1.69	11.05	

Table 5. Average nutrient uptake and removal of cassava and various other crops in kg/ha as well as in terms of kg/t harvested product (dry grain, tuber or roots etc.) as reported in the literature.

Crop-plant part		Yield(t/ha) fresh	dry	---kg/ha--- N	P	K	kg/t DM produced[1/] N	P	K	Reference
Cassava	-roots	35.7	13.53	55	13.2	112	4.5	0.83	6.6	13,17,26
	total			149	23.7	179	12.7	1.69	11.0	
Sweet potato	-root	25.2	5.05	61	13.3	97	12.0	2.63	19.2	33
	total			117	20.1	199	23.2	3.98	39.3	
Potato	-tuber	23.3	4.67	-	-	-	-	-	-	21,23,31
	total			106	18.6	154	22.7	3.98	33.0	
Maize	-grain	6.47	5.56	96	17.4	26	17.3	3.13	4.7	3,~~24~~34,25
	-total			161	27.8	140	28.9	5.00	25.2	
Rice	-grain	4.62	3.97	60	7.5	13	17.1	2.40	4.1	10,30,34
	-total			87	12.3	75	25.9	4.00	22.9	
Wheat	-grain	2.70	2.32	56	12.0	13	24.1	5.17	5.6	34
	total			78	13.0	46	33.5	5.59	19.8	
Sorghum	-grain	3.60	3.10	134	29.0	29	43.3	9.40	9.4	34
	total			285	42.0	172	92.0	13.60	55.5	
Beans	-grain	1.09	0.94	37	3.6	22	39.6	3.83	23.4	8
	total			102	9.1	93	108.1	9.68	98.5	
Soya	-grain	1.0	0.86	60	15.3	67	69.8	17.80	77.9	19
Groundnut	-pod	1.5	1.29	105	6.5	35	81.4	5.04	27.1	5
Sugarcane	-cane	75.2	19.55	43	20.2	96	2.3	0.91	4.4	4,18,37
Tobacco	-leaves	2.5	2.10	52	6.1	105	24.8	2.90	50.0	32
	total			122	24.0	203	58.1	11.43	96.7	

1/ Assuming grain to have 86% DM, potato and sweet potato 20%, sugarcane 26%, dry tobacco leaves 84%.

Table 6. Dry matter and nutrient distribution of 12-month old cassava M Ven 77, grown with fertilization in Carimagua.

Plant part	Dry matter t/ha	N	P	K	Ca	Mg	S
		kg/ha					
Tops	6.9	100	12	74	55	15	10
Roots	14.0	67	17	102	15	8	7
Fallen leaves	1.9	30	2	7	32	5	3
Total plant	22.8	197	31	183	102	29	20

Table 7. Effect of crop cover on erosion factor "C" in the Universal Soil Loss Equation.

Crop cover	C
no cover (bare soil)	1.0
maize, sorghum	0.3-0.9
groundnut	0.4-0.8
cassava	0.2-0.8
cotton, tobacco	0.5
oil palm, coffee, cacao with cover crops	0.1-0.3
rice	0.1-0.2
rapidly growing cover crop	0.1
savannah or pasture (without grazing)	0.01
forest or crop with thick layer of mulch	0.001

Source: Roose, 1977.

Table 8. Cassava yield and soil loss due to erosion using various soil and crop management practices in Agua Blanca.

Treatment	Soil loss t/ha	Cassava yield t/ha
Without fertilizer	35.9	6.9
With fertilizer	22.9	13.6
With maize mulch	15.1	15.9
Strip preparation and double row cassava	14.1	15.6
Double row cassava + imperial grass	19.8	15.8
Double row cassava + Br. humidicola	9.8	13.3
Zero tillage	9.8	17.6

Table 9. Effect of agronomic practices on cassava yield and on soil losses due to erosion on 40% slope in Las Pilas farm, Mondomo, Cauca.

Agronomic practices	Cassava yield* t/ha	Dry soil loss* t/ha
A <u>Methods soil preparation</u>		
1. Without preparation	13.5	0.82
2. 1 meter strips plowed with oxen, alternated with 1 m unprepated strips	12.0	0.84
3. Large planting holes (30x60cm) for 2 stakes	18.7	1.15
4. 1 pass with oxen-drawn plow	31.7	1.82
B <u>Live barriers or intercrops</u>		
5. Without barriers or intercrops	31.7	1.82
6. Live barrier of Imperial grass	23.3	1.28
7. Live barrier of Elephant grass	7.3	2.52
8. Double row cassava intercropped with beans	26.4	2.00
C <u>Weed control</u>		
9. Weed control with hoe	31.7	1.82
10. Pre-emergent herbicides and machete	29.3	8.28
D <u>Fertilization</u>		
11. With fertilizers, 1 pass with plow	31.7	1.82
12. Without fertilizers, 1 pass with plow	10.5	6.45
13. With fertilizers, preparation planting holes	18.7	1.15
14. Without fertilizers, preparation planting holes	3.9	2.49

* Cassava fresh root yield, average two varieties, CMC 92 and Reg. Amarilla.
# Dry soil loss 12 months.

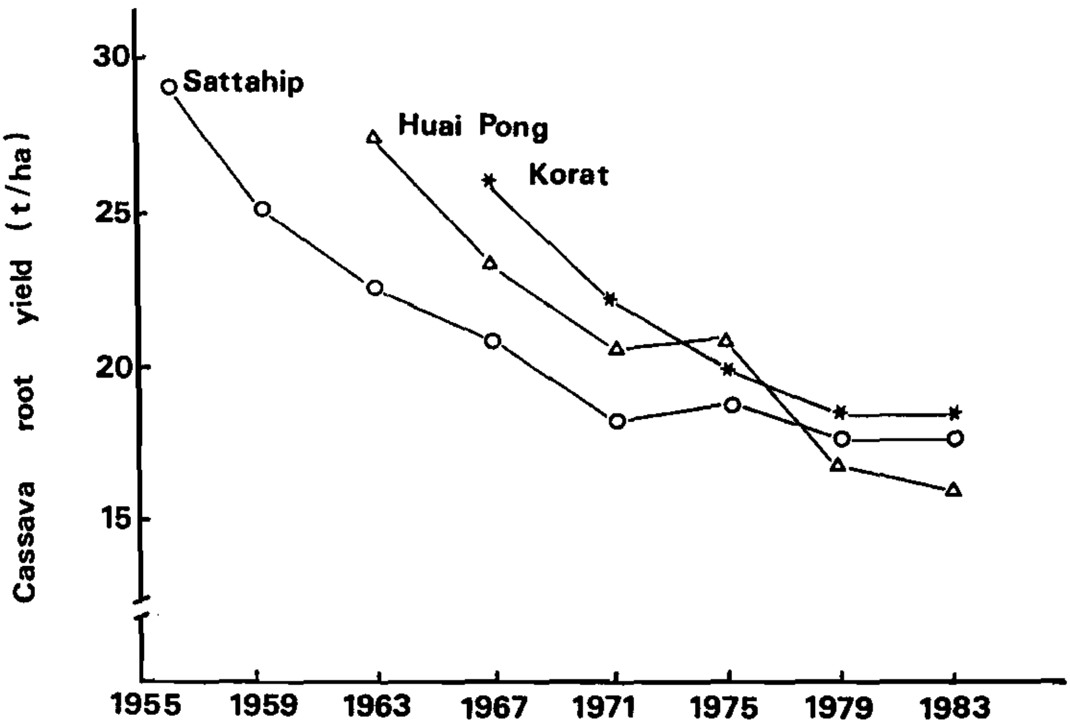

Figure 1: Yield decline due to continuous cassava production in unfertilized plots in three soil series in Thailand.

Source: Sittibusaya *et al*., 1988

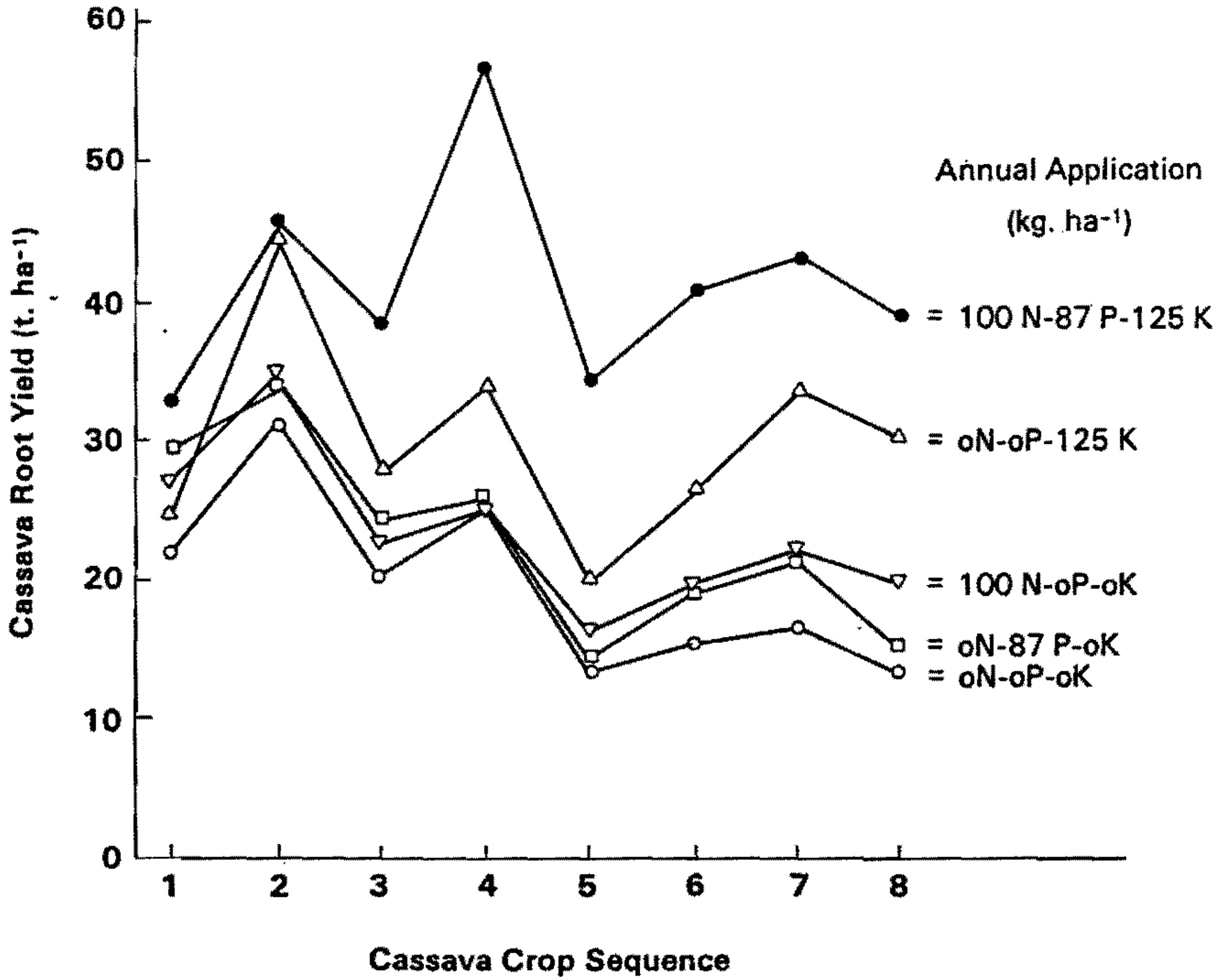

Figure 2: Effect of various levels of application of N,P and K on cassava root yield during 8 consecutive croppings in CIAT-Quilichao, Colombia.

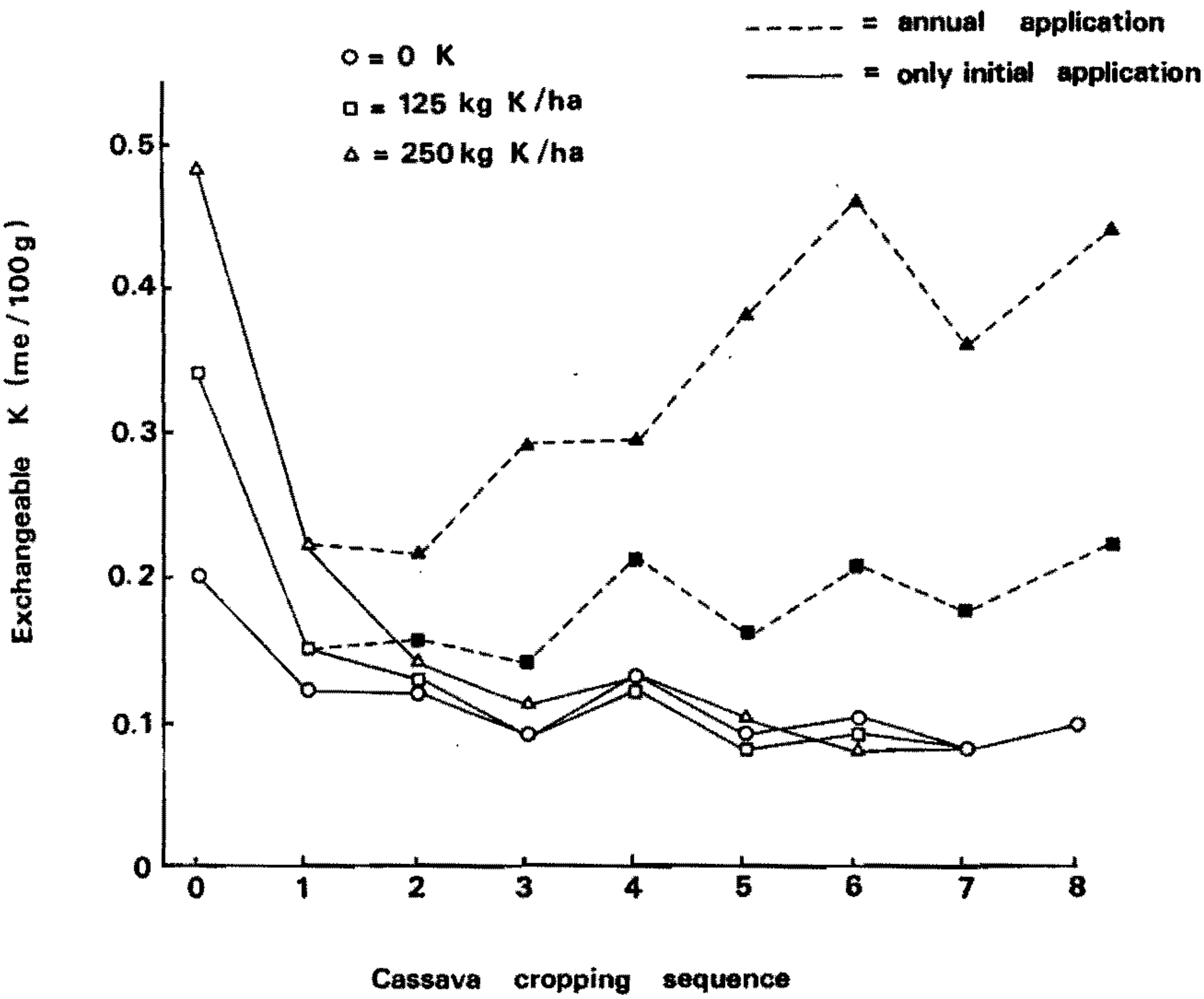

Figure 3: Effect of annual or only initial applications of two levels of K on the exchangeable K content of the soil during 8 consecutive cassava croppings in CIAT-Quilichao, Colombia.

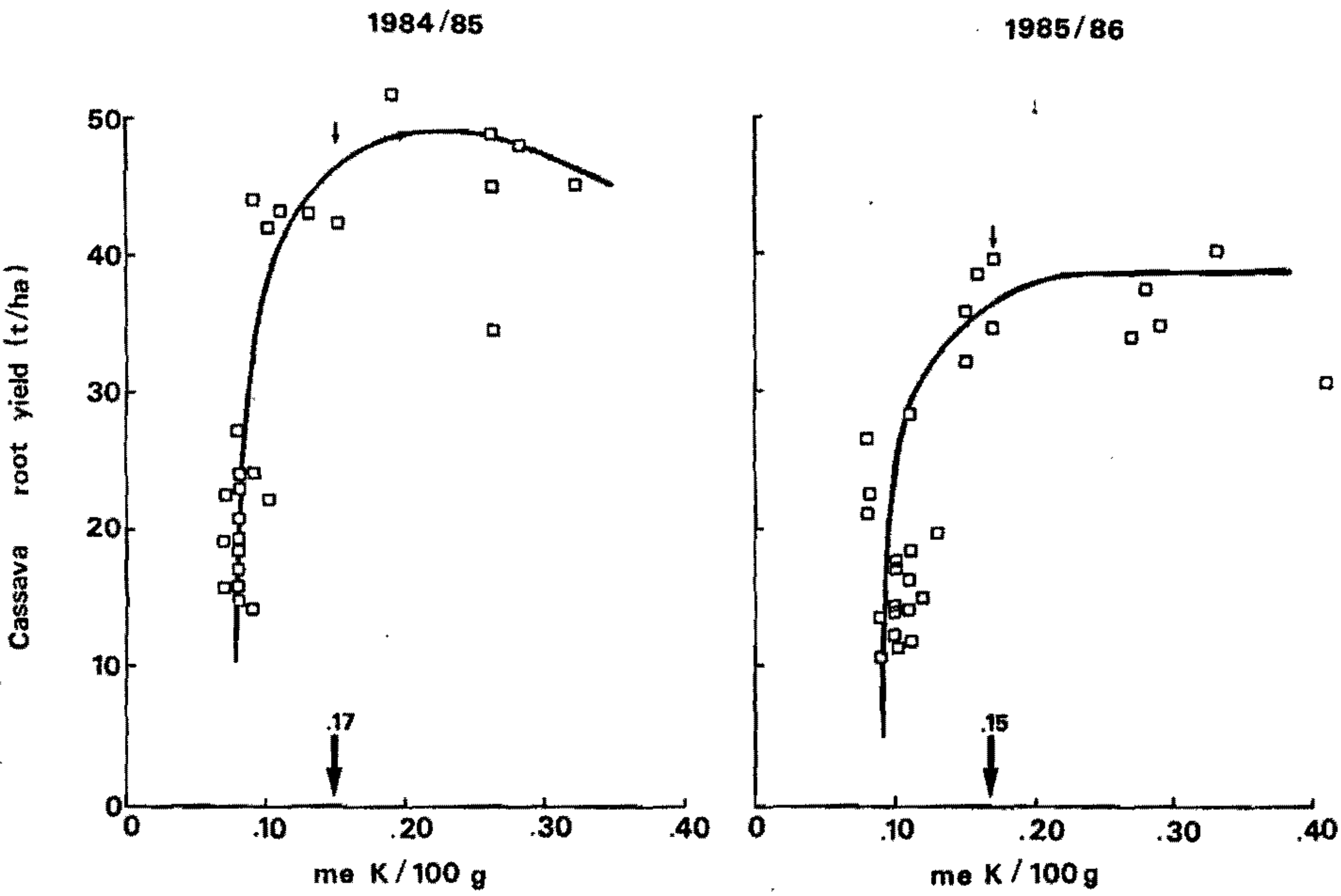

Figure 4: Relation between cassava root yield and the exchangeable K content of the soil in the two final years of a long-term NPK trial conducted in CIAT-Quilichao, Colombia. Arrows indicate the critical K content, corresponding to 95% of maximum yield.

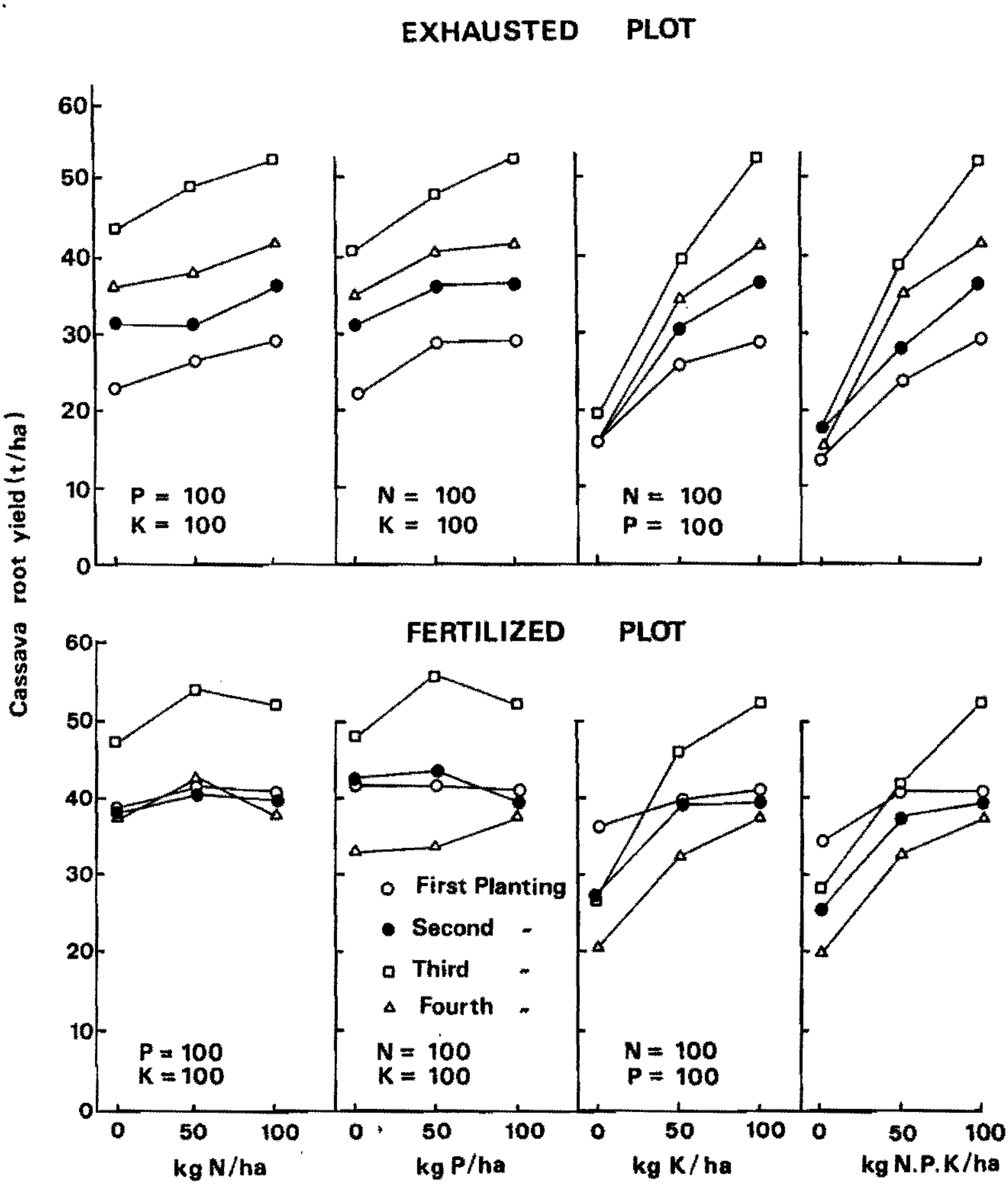

Figure 5: Effect of various levels of application of N,P and K on the yield of cassava grown for 4 consecutive years on a plot that was either exhausted due to 4 previous cassava croppings without fertilization or in a plot that had been similarly cropped with adequate fertilization in CIAT-Quilichao, Colombia.

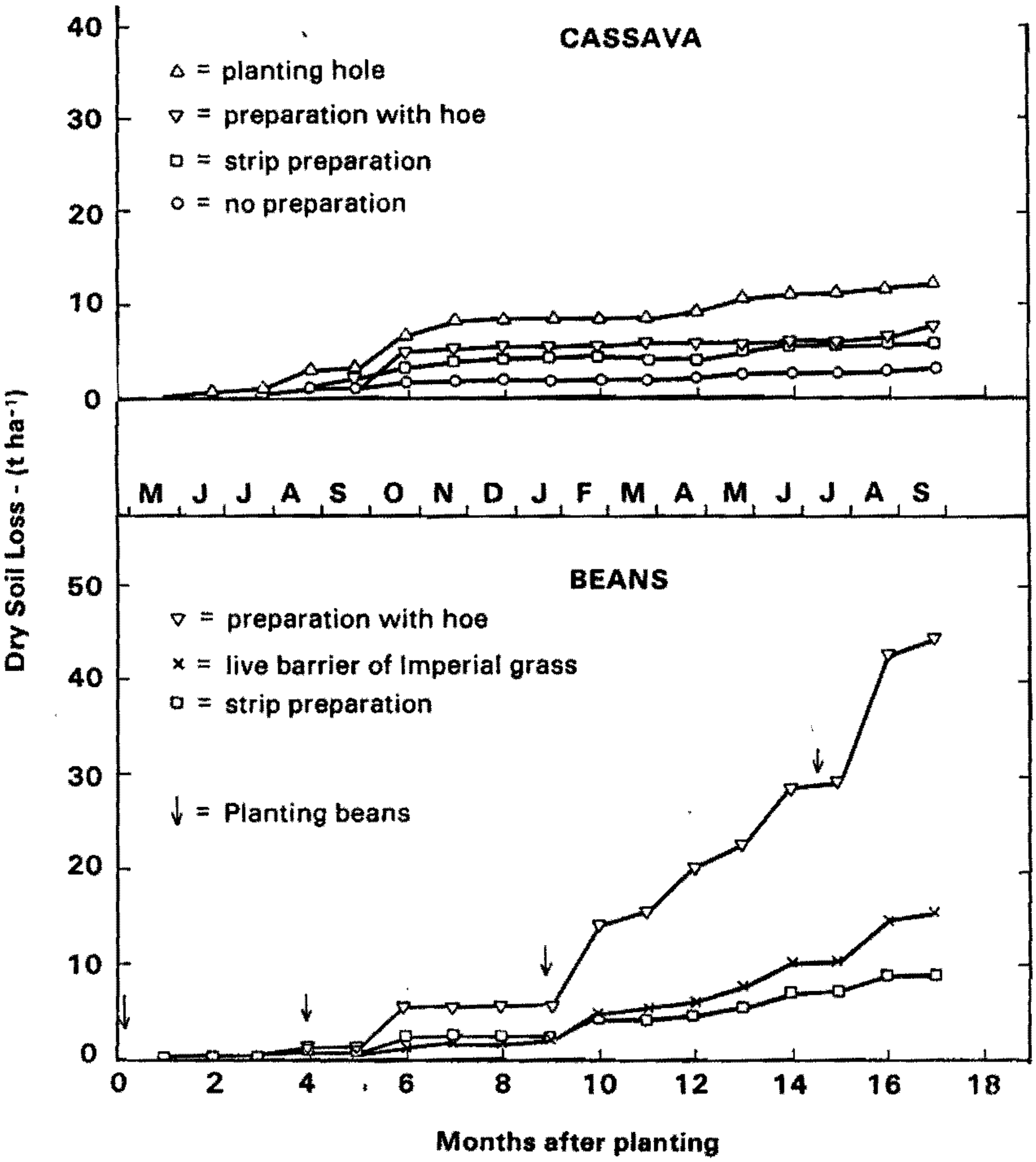

Figure 6: Effect of various methods of manual soil preparation on soil losses due to erosion in one crop of cassava and 4 consecutive crops of beans grown during 17 months on 30% slope in Popayan, Colombia.

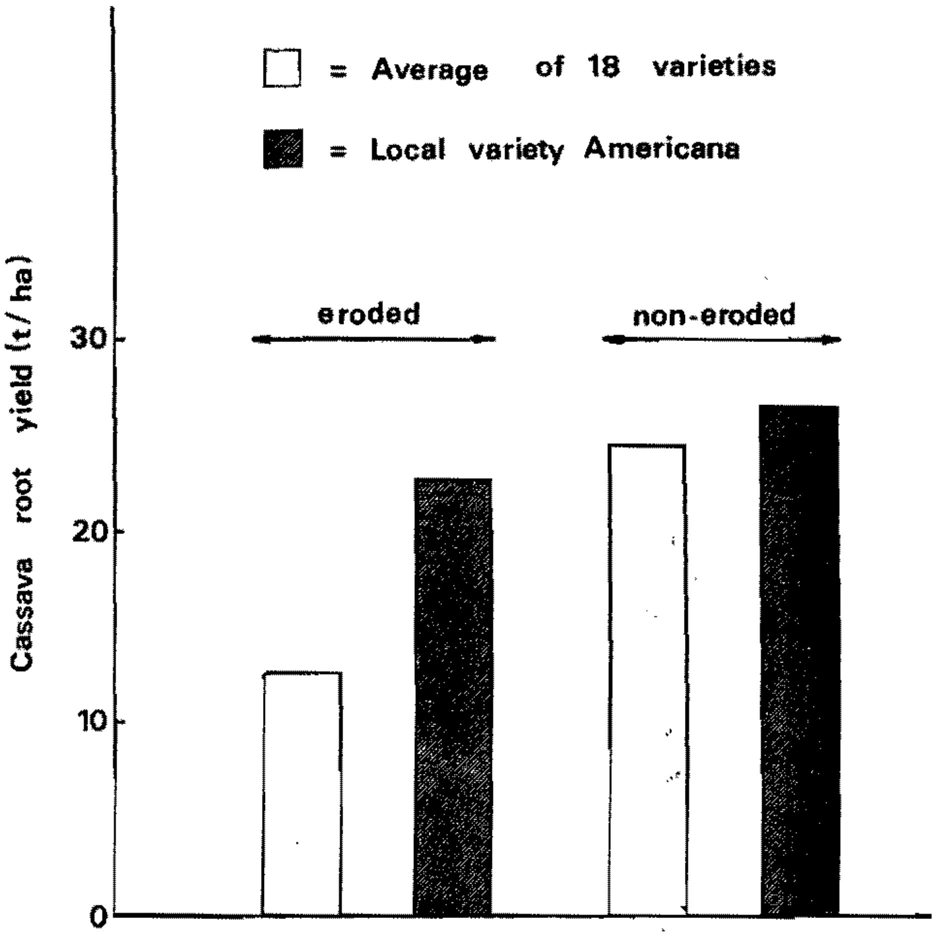

Figure 7: Cassava yield of 18 varieties as well as the yield of a local variety grown on both eroded and non-eroded soil in Mondomo, Colombia.

MAIZE/CASSAVA/YAMS INTERCROPS IN THE NORTH COAST OF COLOMBIA

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General Characteres of the North Coast of Colombia.

The Atlantic or North Coast of Colombia is one of the five major divisions of the country. The entire zone covers approximately 100.000 km^2 and it is characterized by large plains, rolling hills and a few mountainous areas. The Magdalena and Cauca are the most important of the several rivers that cross this region. Agriculture is its economic basis and approximately 50% of the total cattle population of Colombia grasses in this region.

Three main types of farming system are found: large farm holdings dedicated to low intensity cattle/pastures production systems; large to medium sized completely market-oriented farms that produce crops such as cotton, sorghum, rice and occasionally maize in a high input and more intensive type of agriculture; and the small farms sector that produces mainly annual crops such as cassava, yams, maize, cowpea and plantain for the internal market in a highly labor intensive rainfed type of agriculture.

The research sites reported in this paper correspond to a section of the North Coast, namely the Departments of Cordoba, Sucre, Bolivar and Atlantico, where most of the population and small farms are located. The four departments constitute an area of approximately 64.000 km^2.

Average annual temperature increases from Cordoba (27^{o}C) to Atlántico (28^{o}C) but total average annual precipitation decreases towards Atlantico, which is located closer to the Caribbean Sea. The rainy season normally begins in May and ends in November. During the rest of the year, evapotranspiration is higher than precipitation.

In Sucre, Bolivar and Atlántico the begining, duration, intensity and ends of a "short summer", normally occurring between June-August, strongly determines the success or failure of several crops, notably maize.

In general terms, the soils in the area present pH values ranging from 5.3 to 8.0; low to medium levels of organic matter; highly variable levels of P ranging from 2 to 270 ppm; medium to very high levels of K (0.05 to 1.33 meq/100 gr); no deficient levels of any microelement have been found in soil samples.

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The type of crops, cropping patterns, crops management practices and yields obtained by small farmers, are strongly influenced by the soil organic matter content and P level.

Small Farmers Cropping Systems.

Small farmers cultivate mainly cassava, yams, maize and plantain in a low input fallow-based type of agriculture. Yams (Dioscorea alata and D. rotundata) were introduced to the North Coast from the Caribbean Islands with the migrant slaves, probably around 1530. Once in the region and probably by trial and error, they were incorporated as important new components in the already existing maize/cassava crop combination.

The average size of a small farm is 5-6 ha. Usually more than 50% of the available land is dedicated to annual crops while the rest is on plantains or more commonly in natural pastures or fallow. Small animals and a few double-purpose ruminants complete this picture of a typical small farm in the North Coast of Colombia.

The cassava/maize intercop is predominant in the area. Both crops are planted at the onset of the rainy season. Only a few days (while cassava stakes are prepared for planting) elapse between the planting of maize and the planting of cassava. Planting distance is usually 1.2 x 1.2 m for both crops. Only in areas close to urban markets, maize population is reduced, to favor a more rapid growth of cassava roots so that they could reach the market early.

Maize/yams/cassava and yams/cassava cropping patterns are next to cassava/maize in terms of overall importance for the region. The three crops combination is a relay cropping system that begins with the planting of maize again in a 1.2 x 1.2 spatial arrangement. It is followed by the planting of yams (D. alata) at the base of each maize hill. Only after the field is completely planted with yams, approximately 20-30 days after the maize, the cassava stalks are prepared and planted.

The cassava/maize cropping system is planted in almost any type of soil but the maize/yam/cassava cropping pattern is planted only in soils with relatively high organic matter and P levels.

The yams/cassava cropping pattern is cultivated only in selected areas of the region in a slash and burn type of agriculture. It is based on D. rotundata and traditional varieties of both cassava and maize. Maize is a minor component of this crop combination. From the economic point of view this crop arrangement is very important for small farmers because it produces the first yams to reach the local market almost two months before the harvest of the D. alata yams.

From the ecological point of view, this crop combination is also very important. The constant search for new lands and the use of support stakes for yams that are obtained mainly from young secondary forest, are significantly contributing to the deforestation of the region. Moreover, since this crop combination is planted on 15 to 20% slopes, the onset and early part of the rainy season occurs when the soil is almost completely unprotected, causing severe soil erosion. Due to the scattered distribution of the plots with this crop combination in the region and the topographic characteristics of the areas where it is cultivated, the amount of available information about it was almost lacking until two years ago.

Technology and Rural Development Programs.

Since 1981, an integrated Cassava Production, Utilization and Commercialization Program is successfully operating in the North Cost of Colombia. The program began by testing the possibility of drying cassava chips for animal feeds on an experimental basis. Soon the drying of cassava took the form of a pilot project that operated on a semi-commercial scale, to become later one of the most successful Colombian rural development programs. At present there are 40 cassava drying plants in the region that during the last drying season produced 6.000 tons of dry cassava chips for the animal feed market.

CIAT has significantly contributed to the success of the Program mainly by developing and adjusting technological components, in coordination with national institutions.

Dry cassava constitute and excellent alternative market for fresh roots production and the most notorious consequence of the improved demand for cassava have been an increase in the demand for technology to improve its production. In the long range, one of the possible consequences of an improved market for cassava, could be a change in the current cropping patterns. Cassava as a sole crop could become an important cropping system in the future, but the actual demand is for technology to improve the existing multiple cropping patterns.
To cope with this high demand for improved production technology, both the national research institution (ICA) and CIAT are conducting on station as well as on farm research.

A regional network of approximately 20 researches from the four Departments have been organized to coordinate a regional effort to develop the necessary technology. This network is formed by members of ICA, ICAT, Regional Universities and the Regional Departments of Agriculture. The group meets at least twice a year to program and evaluate research results.

On-farm technology development with the active participation of farmers, is one of the most important activities of this network. CIAT's collaboration with the network consist mainly in on-farm research methodology; cassava germplasm testing and training in different aspects of cassava production as well as in other disciplines such as statistical analysis and use of microcomputers.

The experiments reported here were planned by the regional network and conducted by CIAT staff in close coordination with ICA in different farms throughout the region. The following results are presented as examples of the type of activities that are being conducted:

* Performance of improved and traditional maize varieties in association with the cassava var. "Venezolana".

Several improved maize varieties have been recently released by ICA in the North Coast, together with technical recommendations to increase yields. Most of these recommendations have been formulated for maize as sole crop in spite the fact that maize is more frequently intercropped than cultivated as sole crop. The use of these improved varieties is becoming more and more common among small farmers, although no always the rest of the recommended technology is applied. The influence of these new improved maize varieties on the performance of their traditional intercrops, particularly cassava and yams is not completely known. Conversely the effect of any new cassava variety on the improved and traditional maize varieties is not known either.

A set of experiments were designed to study the effect of three improved and one traditional maize variety on the performance of the most common cassava variety (Venezolana) cultivated in the North Coast. The improved maize varieties V-109; V-156 and SV-901 plus the traditional variety "Puya" were used for this experiment. These varieties were planted at 1.2 x 1.0 m (4 plants/hill) between rows (1.2 m apart) of the Venezolana cultivar. Plots of cassava as sole crop as well as each of the tested maize varieties in sole crop served as checks. The experiment was conducted in coordination with ICA in a total of 38 farms across the region. In this paper results from only 14 farms are reported. There were 18 reps in total, some farmers due to lack of land, only grew one rep, but in these cases two farmers with similar soil characteristics were considered a single locality for statistical analysis.

In addition to the trials described above, four farmers with similar soil characteristics planted four reps each of the same cassava/maize association plus the monocrops checks, using fertilizers in two of them (50-40-25 kg/ha NPK applied in bands to the maize 10 days after planting) while two reps remained as checks with no fertilizers applied.

Land clearing, soil preparation, weeding and the rest of the cultural practices that are common for the maize/cassava intercrop in the region, were conducted by the farmers. Only fertilizers dosis were calculated and applied by the researchers.

In spite of the logical differences in management, the calculated CV values of most of the analyzed variables was kept below 13% which is usually considered low, for on-farm research, even under researchers management.

Average cassava fresh roots yields considering both sole crop and intercrop varied from 4 to 14 ton/ha throughout the region. A maximum value of 28 ton/ha was obtained in single crop under favorable growing conditions while a minimum of 4 was obtained in association with maize under poor soil conditions and unfavorable rainfall distribution. Similarly, high yield of maize (3.7 ton/ha) in terms of dry grain (14% humidity) was obtained in maize sole crop with an improved variety while the minimum (0.6 ton/ha) was obtained in association with cassava growing in unfavorable conditions. Considering all the localities, cropping systems, fertilizations and maize varieties, the general average for maize yield was 2.2 ton/ha.

Both in sole crop and in association with cassava, the local maize variety "Puya" yielded significantly less than the improved varieties (Table 1).

Cassava monocrop yielded and average of 16.4 ton/ha of fresh roots while in association with maize yielded an average of 10.5 ton/ha; a 36% yield reduction due to the maize competition. Averaging the four varieties of maize used in this experiment, maize reduced its yield by 22% when it was associated with cassava.

The variety of maize with which cassava is associated does affect cassava yields in terms of total fresh roots. Cassava yielded an average of 11.7 ton/ha associated with the improved maize varieties but only 8.8 ton/ha associated with the traditional "Puya" variety (Table 2). These results indicate that maize breeding selection procedures selecting in favor of shorter types of maize that allocate more photosyntates to the reproductive rather than to the vegetative part of the plant is favoring both maize and cassava yields. These fact is particularly relevant for a region where maize residues are not intensively used as animal feed or incorporated in the soil.

The effect of fertilizers on the maize varieties and cassava both in association and in monocrop is shown in figures 1 and 2. For these figures, the yields of the three improved maize varieties were averaged. Considering both sole crop and association, there was a yield increase of approximately 1.1 ton/ha when fertilizers were applied to the improved maize varieties as compared with only 0.85 ton/ha yield increase when fertilizers were applied to the traditional variety. Cassava yields were not significantly affected by the fertilization applied to the maize when these crops were associated.

* Performance of different cassava varieties in association with maize variety V-156.

During the last years, several field experiments, mostly on farmers fields, have been conducted trying to identify cassava cultivars that could eventually replace the well adapted and widely cultivated variety "Venezolana". Most of these experiments have been conducted in monocrop in spite the fact that cassava sole crop is seldom cultivated in the region. Information about the effect of maize on the different cassava varieties when these species were intercropped was not available and an experiment was designed to provide the necessary information.

Based on their performance for high yields during the last five years of field trials, the cassava varieties CM-962; M Col 22; CM 681-2 and M Col 72 were selected for this experiment. The maize variety V-156 was selected based on farmers preference and good yields.

The experiment was planted in a split plot design arranged in four completely randomized blocks. The maize/cassava intercrop was planted at 1.2 x 1.2m for a population of 8.333 cassava plants/ha and 33K pl/ha of maize (1.2 x 0.4m at 4 pl/hill). Plant population for cassava monocrop was kept at the same 8.333 pl/ha but the maize population in sole crop was 49.333 pl/ha (0.9 x 0.9m at 4 pl/hill).

Table 3 summarizes the average yields of the different cassava varieties tested. The varieties M Col 22 and CM 962-4 reduced their yields more than the rest of the varieties when they were intercropped with maize. The variety M Col 72 yielded only 22% less in association with maize. The yields of maize were not significantly affected by the variety of cassava with which it was associated (Table 4).

According with these results if the farmer decision is to intercrop these species, from the point of view of maize production the type of cassava with which the maize is intercrop is not very important. From the cassava point of view in sole crop the cultivars M Col 22 and CM 962-4 outperformed the rest of the cultivars. Cultivar CM 962-4 reduced its yield by approximately 40% when intercropped (Table 3).

* Maize/yams cassava relay intercrop. On station research results.

In order to study this crop combination more closely before attempting future improvements in farmer's fields, and experiment was designed to simulate this crop combination on the experimental station. Sole crops as well as the combination of two and three species were planted to separate the effect of each crop on the overall performance of the three-crop combination.

Planting distance, varieties and cultural practices were kept as close as possible to the farmer's current agronomic practices. Since cassava's relative planting period varies across localities in the region, two planting dates for cassava were used: 30 and 60 days after the planting of maize.

The resulting treatments are presented in Table 5.

In this presentation the results obtained in a trial conducted during 1986-1987 are reported, although the same trial have been repeated for several cropping season to assess the effect of different environmental conditions.

Yield of maize were not significantly reduced by the treatments. In 1986-1987 they ranged from 1.4 to 2.0 ton/ha due to extremely dry conditions after planting. In the following cropping season average yield of maize were above 4.0 ton/ha but again with no differences between treatments. The tradition to plant the yams only after maize emergence; the time elapsed between yam planting and its 100% germination and the delay in cassava planting are probably the reasons for this free-of-competence initial maize growth.

As expected, the highest yield of yam (32.5 ton/ha) was obtained in sole crop. Significant differences (.01) were obtained between yams in monocrop and its intercrops. Maize alone caused a 44% yield reduction in yams yield during this trial. A 67% reduction was obtained the following cropping season and the literature inform of a 31% yield reduction in D. rotundata caused by the intercropped maize. Cassava reduced the yield of yams by 30% when it was planted 60 days after the maize. This reduction was higher when cassava was planted 30 days after the maize.

With regard to cassava yields and considering all treatments in which cassava was included, the average yield in terms of total fresh roots weight corresponding to cassava planted 30 days after maize was higher (24.5 ton/ha) than the yield obtained when cassava was planted 60 days after the maize (19.4 ton/ha).

Considering the results of this and other similar experiments, it seems that in this particular crop combination, cassava yields depends more on the environmental conditions prevalent after it was planted than on the level of competition exerted by the other crops with which cassava was intercropped.

In the cassava/yam crop combination, yams vines tend to climb on very young cassava plants particularly when cassava is planted late and maize growth is not vigorous. The results obtained in these experiments partially explain the relatively low yields for cassava that farmers are obtaining in the North Coast.

* Effect of yam population on cassava yields.

To further study the interacting between these two species in an intercrop situation, an experiment was designed to assess the effect of yam competition on cassava yields.

The cassava cultivar CMC-40 and the "criollo" cultivar of yam were used. Cassava population was kept constant at 8.333 pl/ha, while the yam population was 8.333 and 16.666 pl/ha to constitute five treatments including the respective monocrops. Treatments are shown on Table 6.

Total roots fresh weight of cassava was significantly reduced (0.1) by its intercrop with yam. The increase of yam population from 8.333 to 16.666 pl/ha further reduced cassava yield by 55% as compared with its yield in monocrop. The number and weight of the non commercial or small cassava roots was also significantly increased by the competition with yams in particular with the highest yam population.

The harvesting process of those treatments in which yam was planted at 16.666 pl/ha while cassava was still standing in the field, resulted in a significant (.01) increase in the number of rotten cassava roots.

Yam tuber weight resulted significantly different between treatments. Considering yam sole crop, doubling its plant density to 16.666 pl/ha increased yields by only 40%. A yield of 27.7 ton/ha/ton of seed used was obtained in the treatment with 8.333 pl/ha of yam. The treatment with 16.666 pl/ha resulted in a 20.7 ton/ha of yams/ton of seed used.

TABLE 1. Yields of different maize varieties as sole crop and associated with cassava variety "Venezolana". Colombia 1986-1987.

Maize variety	CROPPING PATTERNS Sole Crop	ton/ha Associated with Cassava	% of Sole Crop
V-156	2.60 a	1.95 a	75
V-109	2.45 a	2.01 a	82
SV-901	2.37 a	1.75 a	73
Regional "Puya"	1.56 b	1.27 b	81

TABLE 2. Total fresh roots weight of cassava intercropped with different maize varieties. Atlantic Coast of Colombia. 1986-1987.

Maize Variety	Total fresh roots weight (ton/ha)
V-156	11,3 a 1/
V-109	10,9 a
SV-901	11,0 a
Regional "Puya"	8,8 b

1/ Figures followed by the same letters are not significantly different according with the Duncan's Multiple Range Test (0.01).

TABLE 3. Total fresh roots weight (ton/ha) of different cassava varieties in sole crop and associated with V-156 Maize. 1987.

Cassava Variety	Cropping Pattern		% Reduction
	Sole Crop	Associated	
M Col 22	26.4	20.0	24
M Col 72	18.8	15.7	16
CM 681-2	17.4	13.6	22
CM 962-4	25.1	14.5	41
Venezolana	15.9	11.9	25

TABLE 4. Maize dry grain (14% moisture) yield (ton/ha) of cultivar V-156 as sole crop and in association with four different Cassava Cultivars. 1987.

Cassava	Cropping Pattern		%
Variety	Sole Crop	Associated	Reduction
M Col 22	2.6	2.0	23
M Col 72	2.5	2.0	20
CM 681-2	2.4	1.9	21
CM 962-4	2.6	1.7	35
Venezolana	2.7	1.8	33

TABLE 5. Yields of maize, yam and cassava in different cropping patterns. 1986-1987.

Cropping pattern [1/]	Maize	Yam	Cassava-30	Cassava-60	LER
	ton/ha				
M Y C-30	1.9 a [2/]	13.0 d	13.6 c		1.72
M C-30	1.9 a		25.8 b		1.63
M C-30		16.0 cd	22.5 b		1.14
C-30			36.0 a		1.00
C-60				25.0 a	1.00
M C-60	1.7 a			24.2 a	1.80
M C-60		21.7 b		16.4 b	1.30
M Y C-60	1.8 a	15.0 cd		12.2 b	1.80
M Y	1.4 a	18.3 bc			1.30
Y		32.5 a			1.00
M	2.0 a				1.00
Average	1.8	19.5	24.5	19.4	

1/ M = maize; Y = Yam; C-30 and C-60 cassava planted 30 and 60 days after maize.

2/ Figures followed by the same letters are not statistically different according with the Duncan's Multiple Range Test (0.05).

TABLE 6. Yields of cassava and yam in different cropping patterns. 1986.

Cropping patterns [1]	Cassava (ton/ha)	Yam (ton/ha)
Cassava sole crop	38.4 a	
Yam sole crop (8K)		35.4 b
Yam sole crop (16K)		51.4 a
Cassava/yam (8K)	27.0 b	14.6 c
Cassava/yam (16K)	18.0 c	22.0 c

[1] 8K and 16K = yam planted at 8.333 and 16.666 plants/ha respectively.

[2] Figures followed by the same letters are not significantly different according with the Duncan's Multiple Range Test (0.05).

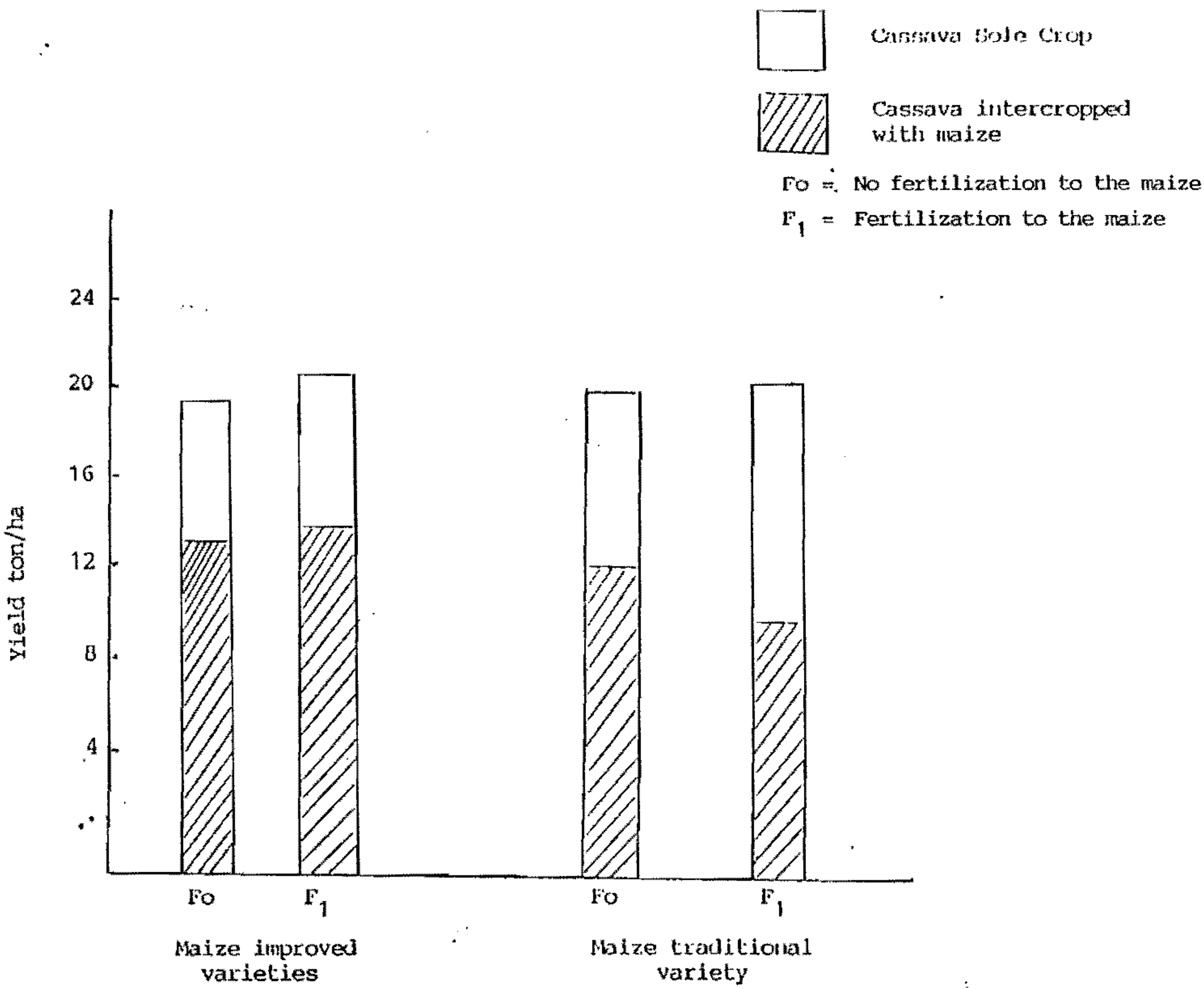

Fig. 1 Yields of cassava (total fresh roots weight) variety "Venezolana" in sole crop and associated with improved and traditional maize varieties with or without fertilization applied to the maize in intercrop.

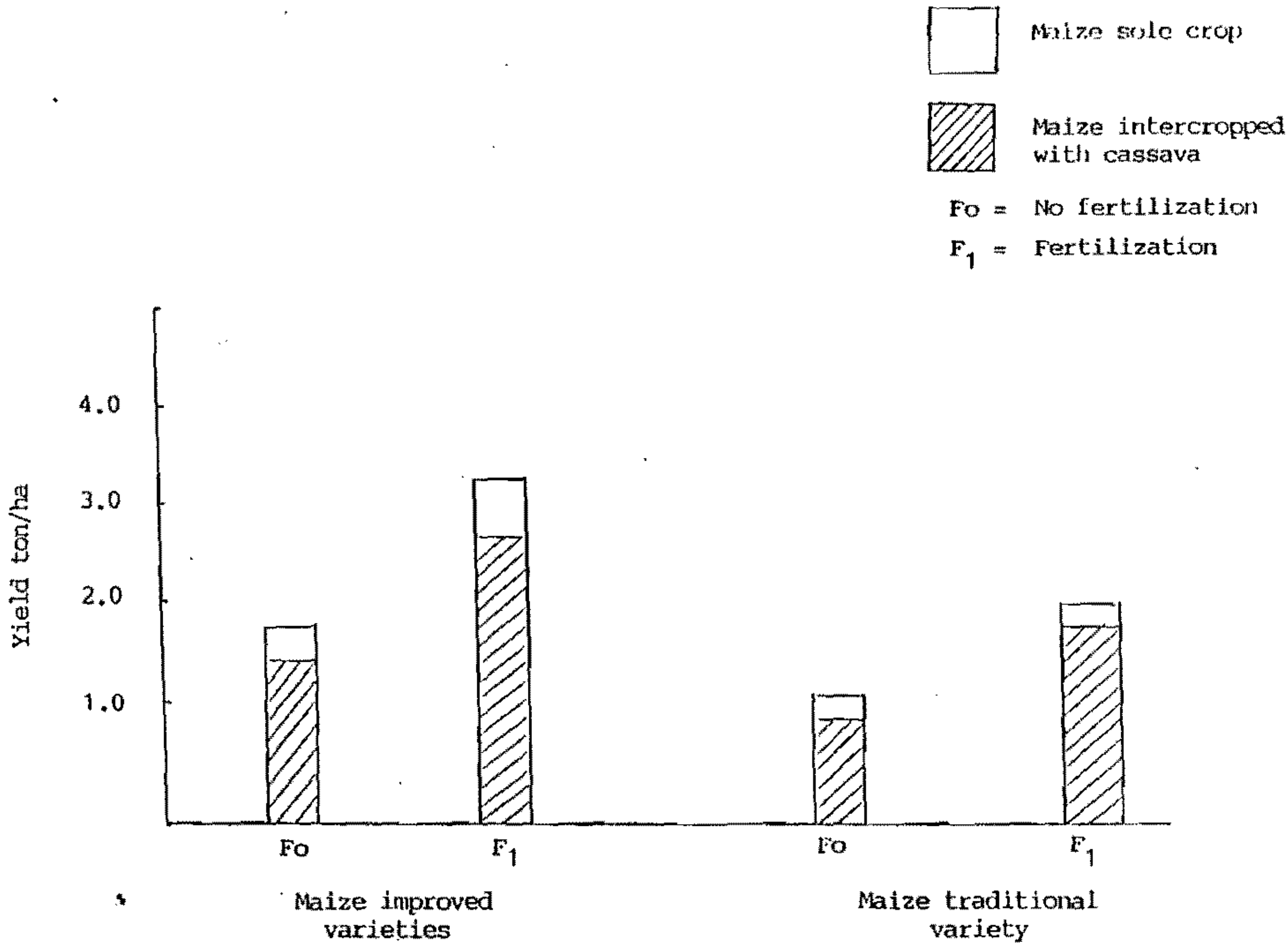

Figure 2. Effect of fertilizers applied to improved and traditional varieties on the yield of maize (14% moisture) cultivated as sole crop and in association with cassava.

CARACTERISTICAS AGRONOMICAS DE LA PRODUCCION DE RAICES Y TUBERCULOS: IMPLICACIONES PARA EL DIAGNOSTICO [1/]

Raúl A. Moreno [2/]

INTRODUCCION.

En esta presentación se intenta señalar algunos caracteres agronómicos importantes de los sistemas de producción de raíces y tubérculos, que son más comunes en el trópico. Se hace con el propósito de llamar la atención sobre algunos aspectos claves de estos sistemas, que deberían tenerse en consideración al intentar una descripción, con fines de diagnóstico.

Por razones prácticas se incluyen de preferencia características comunes de sistemas basados en yuca (Manihot esculenta), ñame (Dioscorea alata y D. rotundata), camote (Ipomoea batatas), y aroideas comestibles (Colocasia spp y Xanthosoma spp).

Existen varias razones para estudiar un sistema de producción. Estas van desde el puro interés académico, hasta el deseo de mejorar la producción y/o productividad de ese sistema con miras al desarrollo rural. En esta presentación, se supone que el interés se centra en el deseo de mejorar los sistemas existentes, para lo cual es necesario desarrollar mejor tecnología que la imperante y que para lograr esto, el punto de partida lógico, es un buen conocimiento de los problemas y potenciales de cada sistema.

La simple enumeración de características agronómicas comunes e importantes no es exactamente el propósito que se persigue con esta presentación. Se trata además de incluir comentarios breves acerca de cada aspecto tratado, con el propósito que ayuden en la correcta interpretación de la información que se obtiene durante el proceso de caracterización.

Las raíces y tubérculos en el trópico son producidas principalmente por pequeños agricultores. Es sabido que en este tipo de agricultura, los caracteres físico-biológicos de la producción, se confunden con los de naturaleza socio-económica y por ello es difícil cualquier intento por separar la agronomía de otras consideraciones. Sin embargo, a través de este artículo se intenta, con tal vez dudoso éxito, hacer esta separación.

1/ Trabajo presentado en el Taller de Trabajo para Mejorar la Capacidad de Diagnóstico de Sistemas de Producción de Raíces y Tubérculos, CIP-IITA-CIAT, Septiembre 12-17, 1988. Cartagena, Colombia.

2/ Agrónomo. Centro Internacional de Agricultura Tropical (CIAT), Apartado Aéreo 6713, Cali, Colombia.

MARCO CONCEPTUAL.

La producción agrícola puede verse como un ordenamiento jerárquico de sistemas que operan en el tiempo y en el espacio, transformando recursos del ambiente, en productos deseados por el hombre.

Los sistemas de producción de raíces y tubérculos son entonces una parte o el todo del sistema de producción de cultivos alimenticios, que a su vez se encuentra dentro de un sistema jerárquicamente superior, que es la unidad de producción o finca. Las fincas a su vez y en conjunto aportan una característica productiva especial a una región agrícola dada, que a su vez y como un todo, constituye un sistema de producción jerárquicamente superior a las fincas mismas (figura 1).

Mantener estas relaciones jerárquicas en mente, es el mecanismo más útil para comprender mejor las relaciones entre el sistema de interés (raíces y tubérculos) y su ambiente.

En el caso particular de las raíces, y a diferencia de muchas otras especies cultivadas, los procesos de transformación en productos derivados a nivel de finca y a nivel regional, son muy importantes y frecuentemente condicionan algunas prácticas agronómicas. Así entonces, las interacciones entre el sistema de producción de raíces y tubérculos y la unidad de producción y entre esta unidad y la comunidad que adquiere y transforma productos, puede ser más importante para las raíces, que para el caso de otras especies.

PRINCIPALES CARACTERISTICAS DE LOS SISTEMAS DE PRODUCCION DE RAICES Y TUBERCULOS.

Para analizar un sistema de producción, cuyos límites están ya más o menos definidos, es conveniente establecer primeramente su estructura y luego su función. Por estructura puede entenderse el o los arreglos entre las especies que lo integran.

El concepto de arreglo en este caso se refiere al patron temporal o cronológico (fechas de siembra y cosecha relativas) de las especies y el espacial en el sentido de la disposición de cada una con relación a las otras sobre la superficie del suelo (figura 2). Este mismo enfoque se aplica tanto para sistemas de cultivo que implican una especie cultivada en el año agrícola, como para varias en sistemas policulturales.

El funcionamiento de un sistema de producción de raíces y tubérculos puede verse desde varios puntos de vista. Entre ellos principalmente el de la interacción que existe entre las especies que integran este arreglo y entre éstas y el ambiente. Sin embargo, al tratarse de un sistema operado por el hombre y frente a la necesidad de caracterizarlo, lo que interesa en forma inmediata son las interacciones entre el arreglo y el hombre. Estas interacciones se conocen con el nombre de manejo y se puede afirmar que el funcionamiento de un sistema de producción de cultivos anuales es reflejo del manejo que da el agricultor. El manejo por parte del agricultor en su aspecto intelectual, revela su capacidad como empresario y resulta en decisiones que establecen el patrón general de producción de una finca y el arreglo entre las especies que integran el sistema de producción de raíces y tubérculos. El manejo en cuanto a la habilidad para ejecutar funciones, revela al agricultor en su capacidad como operador y comprende al conjunto de prácticas culturales que le permiten físicamente desde establecer una o un conjunto de especies en un espacio de terreno dado, hasta su cosecha o recolección.

El número de prácticas agronómicas varía en cada localidad, así como también varía la forma en que se ejecutan, pero por lo general, la mayor parte de estas prácticas, en una u otra forma, tratan de favorecer el uso por los cultivos, de los recursos de agua, nutrientes del suelo y radiación, a medida que se hacen disponibles en un ambiente dado.

Existe entonces una sucesión de prácticas que son específicas de cada especie o conjunto de ellas y que es necesario estudiar en serie lógica, si se desea caracterizar un sistema de producción con fines de mejoramiento.

Si se observa el resultado de un análisis económico de la producción de cualquiera de las especies señaladas anteriormente, se observa que hay tres actividades de manejo que usan la mayor parte de la energía gastada en producir. Estas prácticas son las de habilitación y preparación de terrenos; control de malas hierbas y cosecha. Así entonces para un proceso de caracterización, es necesario analizar estas tres prácticas con especial acento y por ello se discuten primero en esta presentación.

1- Habilitación y preparación de terrenos: La primera es una actividad particularmente importante en el caso de agricultura basada en el barbecho. En el caso específico de la producción de ñame, el correcto manejo de esta práctica, frecuentemente determina además la disponibilidad de soportes para su posterior desarrollo y existe relación entre el tipo de soporte y el rendimiento en raíces frescas. En el conjunto de prácticas necesarias para producir ñame, proveer de soportes es un aspecto crítico del manejo, que influye fuertemente en los costos de producción.

    La habilitación de terrenos se inicia en cualquier momento del año agrícola, pero el apilado y la quema, por lo general, se realizan en el período más seco. Esta labor de habilitación, puede prolongarse durante varias estaciones de cultivo, principalmente cuando la vegetación natural es de bosque secundario bien establecido, aunque con demanda decreciente por mano de obra, a medida que pasa el tiempo. También para el caso de ñame (D. rotundata), no solo parte de la habilitación de terrenos sino que la "ahoyada" anterior a la siembra, deben efectuarse en el período seco, lo que es otra característica que debe conocerse, principalmente en cuanto a la calidad y cantidad de mano de obra empleada y número de hoyos por unidad de superficie.

    Para fines de diagnóstico, y en el caso específico de agricultura con base en el barbecho, la observación de otros terrenos en descanso en la región, la temperatura promedio y la precipitación, pueden aportar una idea del volumen de la biomasa disponible para restaurar la fertilidad de los suelos y consecuentemente el largo del período de cultivo, en relación con el período de descanso.

Por el contrario, para el caso de agricultura de tipo estrictamente sedentaria, el manejo de los residuos durante la fase de habilitación de terrenos, debe caracterizarse bien desde el punto de vista sanitario y de recirculación y pérdida de nutrimentos.

En cuanto a la labor de preparación misma de terrenos, aparte del conocimiento general acerca del tipo de preparación frecuente en la región (manual, mecanizada o mixta) es necesario llegar a un buen entendimiento de la relación que existe entre los caracteres del suelo; tipo de energía de tracción e implementos disponibles; oportunidad en relación con la precipitación y/o temperatura, y finalmente intensidad de la operación en el sentido de la cantidad general de energía que se asigna a esta actividad de producción de raíces y tubérculos, en relación con las otras que se ejecutan en el año agrícola, para obtener una cosecha de raíces y tubérculos. Por lo general, la preparación del suelo en los sistemas de producción de raíces, es un aspecto crítico de todo el proceso productivo desde el punto de vista biológico, debido lógicamente a la naturaleza subterránea de crecimiento del producto deseado y desde el punto de vista socio-económico de manejo por el agricultor.

Es necesario relacionar este proceso de preparación y los implementos usados, con aspectos posteriores, tales como el ordenamiento espacial de la(s) especie en el campo y consecuentemente con la densidad de siembra y prácticas de control de malas hierbas.

La preparación de montículos en forma manual para sistemas de producción de ñame y/o yuca, la preparación de caballones en zonas de posibles inundaciones para yuca y principalmente ñame y la preparación del suelo del cultivo anterior para el caso de raíces que se siembran en sucesión con otras especies, son factores también importantes en este aspecto de caracterización.

En situaciones especiales de producción de Colocasia spp, el fangueo del suelo es probablemente una de las actividades más importantes de su producción, que necesita especial acento en una fase de caracterización.

2- Control de malas hierbas: Con excepción nuevamente del camote, la mayor parte de las especies tratadas, son altamente sensibles a la competencia por malas hierbas durante los estadios iniciales del crecimiento. Por ello, las prácticas de control de malas hierbas están directamente relacionadas con el rendimiento y deberían caracterizarse cuidadosamente en la descripción de un sistema de producción de raíces. Además, si se analizan los costos de producción de las raíces, frecuentemente el control de las malas hierbas es uno de los más altos después de la preparación del suelo y por esto esta práctica es de especial significado para los agricultores.

Para situaciones de intercultivo y en el caso de agricultura más tecnificada, los agricultores recurren frecuentemente a herbicidas de preemergencia. En estos casos, el ñame presenta problemas especiales debido a la desuniformidad en su germinación. Además, la existencia de soportes inertes, dificulta grandemente las labores de aplicación y cobertura del producto. Las araceas a su vez, principalmente Xanthosoma y Colocasia de secano, dificultan también la aplicación uniforme de los preemergentes sin dañar tejido, lo que afecta directamente la eficacia de estos. También, las especies que se establecen después de otras en el campo (generalmente más de 30 días), no siempre se benefician totalmente del afecto de estos herbicidas de preemergencia. Más aún, el pisoteo necesario para la siembra, afecta significativamente la eficacia de los preemergentes.

Un factor común que comparten las raíces es la relación directa que existe entre la buena preparación del suelo (o buena habilitación en el caso de no-labranza) y la eficacia de los preemergentes.

Aparte de estas consideraciones anteriores, la caracterización del factor malas hierbas no está completa en un sistema de producción de raíces, si no se conoce claramente el concepto de ingrediente activo que tiene el agricultor; la forma de medir dosis y el equipo (frecuentemente boquilla) con que cuenta; la calidad del agua y principalmente los métodos usados para calibrar el equipo.

En condiciones del trópico bajo húmedo de algunas regiones, la producción de raíces descansa fuertemente en el uso de glifosato en la habilitación del terreno y de paraquat con las especies ya establecidas.

El número e intensidad de las limpias a mano posteriores a la aplicación de los preemergentes, dependen básicamente de la calidad de la preparación inicial del suelo y de la correcta selección y aplicación de los herbicidas. El camote, por su cobertura, pocas veces presenta problemas serios de malas hierbas, después de su período de establecimiento.

Una de las prácticas comunes a varias raíces es el aporque, que guarda significancia para ñame, camote tecnificado y Xanthosoma y Colocasia de secano, principalmente cuando el cultivo es en caballones y se registra abundante precipitación. En su caracterización, es necesario relacionar esta práctica con el control de malas hierbas.

3- Cosecha y almacenamiento: Para caracterizar esta actividad, es necesario establecer primero si la época en que se efectúa está condicionada principalmente por factores agronómicos - mayor rendimiento por ejemplo - o únicamente por factores económicos. Es necesario además incluir dentro de esta actividad al método de ensacado y acarreo dentro de la finca.

En la mayoría de los casos, y nuevamente con la excepción del camote en agricultura más tecnificada, la cosecha de raíces se realiza con base en la mano de obra. Existe entonces una relación directa lógica entre el rendimiento y la cantidad de mano de obra gastada en cosecha.

El tipo de suelo, principalmente sus caracteres físicos y las prácticas de manejo tales como montículos, caballones, y aporques, deben tomarse en consideración al estudiar los factores que modifican la cosecha. Además, la posición en el terreno del material de siembra en algunos casos como el de la yuca, afectan a su vez el tipo de crecimiento de las raíces y consecuentemente la cosecha.

La cosecha parcial en casos de mercados poco estables es común para la mayor parte de las raíces y en el caso particular de D. rotundata, la doble cosecha de una parte (a los 5-6 meses) para el mercado de consumo y una segunda (a los 9-10 meses) más bien para semilla, complica todo tipo de estimaciones de rendimiento, y complica además, la caracterización de estos sistemas, para las personas sin experiencia.

A diferencia de otros cultivos, la cosecha de las raíces puede diferirse en el tiempo hasta ciertos límites, que en el caso de la yuca estan dados por la calidad de las raíces para el consumo fresco. Una situación similar se presenta en camote de consumo fresco, aunque la flexibilidad es menor que en el caso de la yuca. La posibilidad de espaciar la cosecha en el tiempo, dificulta frecuentemente las estimaciones de rendimiento, principalmente en el caso de yuca. Por el contrario, la posibilidad de adelantar la cosecha de D. rotundata afecta la calidad, frecuentemente por inmadurez del extremo distal. En estos últimos casos es interesante caracterizar los indicadores de madurez que usa el agricultor en una región dada, pues la literatura carece de información al respecto y solo informa de la correlación negativa entre la primera y la segunda cosecha de D. rotundata.

Aunque sea un aspecto puramente social, es necesario resaltar en esta oportunidad la dificultad frecuente que se encuentra al querer estimar el autoconsumo de raíces en sistemas de producción de pequeños agricultores. Mientras más pequeña la finca y menores los recursos del agricultor, este problema es cada vez mayor. La costumbre de comenzar a cosechar araceas y yuca principalmente a partir del comienzo del engrosamiento de la parte subterranea, agrega un factor adicional a este asunto de por sí complejo.

En el caso de yuca, la actividad de cosecha esta estrechamente relacionada con la disponibilidad de semilla para el año próximo. Si los precios son favorables, se tiende a vender toda la cosecha, incluso en pie, temprano en el año, lo que puede dejar al agricultor con serios problemas de disponibilidad de semilla para la próxima estación.

En el caso particular de ñame existe correlación entre tamaño del tubérculo desde donde se obtiene la pieza de semilla y el rendimiento posterior en el campo. Además existe correlación directa entre tamaño del tubérculo y su precio en el mercado. Esto hace que en años de buenos precios, tienda a venderse lo mejor (el ñame más grande y consecuentemente la mejor semilla) para almacenar entonces solo lo que reste. En ñame, tal como se mencionó, el valor relativo de la semilla es probablemente el más alto de todas las raíces (casi el 20% del valor total de la producción), y por ello se invierte una gran cantidad de mano de obra en construcción de almacenamientos y control de la brotación después de pasado el período de dormancia.

El almacenamiento de material de siembra de yuca es por lo general menos sofisticado que el de ñame, tanto en regiones con estaciones secas como en regiones con estaciones de temperaturas bajas en el año.

El almacenamiento de material de siembra de araceas y particularmente de camote, es menos crítico que en ñame, pero más tecnificado que en el caso de la yuca.

Solo en el caso de la yuca en la mayoría de los climas y del camote en el trópico húmedo, se practica con cierta frecuencia, el dejar plantas sin cosechar en el terreno con fines de semilla. La preservación del material de siembra del camote en agricultura de clima templado es una actividad importante que implica a veces la pre-germinación de tubérculos, con el propósito de obtener los brotes o bejucos de siembra.

4- Otras prácticas agronómicas: Después del análisis de los tres aspectos generalmente críticos de un sistema de producción de raíces y tubérculos, es conveniente completar la información del manejo con los siguientes aspectos:

- Preparación del material de siembra: Para la mayor parte de las especies que se tratan en esta presentación, se ha establecido relación entre el rendimiento y la calidad del material de siembra.

  En climas con estaciones secas prolongadas, la calidad del material de siembra de la yuca se afecta significativamente y es necesario caracterizar cuidadosamente todas las prácticas desarrolladas por los agricultores para obviar este problema y sus consecuencias.

  La preparación del material de siembra en ñame es una labor cuidadosa y metódica, que implica conocimiento por parte del agricultor del fenómeno de la dominancia apical. La protección ya sea química o por simple cicatrización, de la pieza de semilla del ñame es más importante que en el caso de otras raíces, pues el corte implica exposición al medio de tejido suculento.

En el caso de yuca y en regiones con tradición de producción, existiendo buena disponibilidad de semilla, los agricultores realizan una selección adecuada de ella y excepto en casos extremos, no se practica la protección química. En el caso de semilla en pie de yuca, es conveniente incluir en la caracterización de la preparación de semilla, el trabajo de obtenerla, pues es frecuente que esté ubicada lejos del lugar de siembra.

- Fecha de siembra: Tanto en una estación de crecimiento determinada por la temperatura como en una determinada por la precipitación, es necesario disponer de una noción de la importancia que tiene para el rendimiento, el hecho de modificar la fecha de siembra con relación al momento en que la variable ambiental determinante deja de ser limitante.

Para la mayoría de las raíces, tal vez con la excepción del camote, el crecimiento inicial lento de la parte aérea, tiene repercusiones de erosión y consecuentemente implicaciones para el mantenimiento de la fertilidad de los suelos. Este es otro factor que merece atención en un esfuerzo de caracterización.

En sistemas de producción de pequeños agricultores, el intercultivo es más bien la regla antes que la excepción y por ello, un buen conocimiento de las épocas relativas de siembra entre cada especie integrante de la asociación es vital para llegar a comprender el sistema. Es conveniente conocer si las épocas relativas de siembra se deben principalmente a consideraciones agronómicas tales como el maíz sirviendo de soporte al ñame, o de tipo socio-económicas, tal como sería el caso de la dispersión en el tiempo del uso de la mano de obra.

En una combinación de cultivos, además, cada uno de los integrantes cumple una función especial para el agricultor (proveedor de circulante, autoconsumo, protección al riego, etc.) que es necesario conocer para comprender mejor el arreglo temporal entre las especies.

Con excepción del camote, que por su período vegetativo puede cultivarse hasta dos veces en ciertos climas con temperatura constante y suficiente agua y/o capacidad de retención de humedad de los suelos, la mayoría de las especies que se consideran en estos comentarios ocupan la mayor parte de la estación de crecimiento. Por lo general entonces, el acento en el estudio de épocas relativas de siembra debe ejercerse solo en una parte del año.

- Intercultivo: Es necesario mantener en mente que para el caso de intercultivo, cualquier práctica que se efectue en un cultivo va a afectar a las raíces en alguna medida. El doblado del maíz; el número de vástagos a que se maneja el plátano; la aplicación de pesticidas al fríjol; etc, son ejemplos de estas prácticas propias de otros cultivos, pero que afectan en alguna medida a las raíces y tubérculos que se intercultivan.

- Aplicación de agroquímicos: La aplicación de productos químicos protectores no es frecuente en la producción de raíces, pero cuando se aplican, lo más probable es que se trate de control de antracnosis en ñame, o intentos por controlar Cylas formicarius en camote.

Finalmente, tampoco es frecuente la aplicación de fertilizantes para la producción de raíces y tubérculos, al menos para las especies mencionadas anteriormente y en condiciones de pequeños agricultores. Cuando esta práctica se efectúa, generalmente se refiere a ñame que es tal vez el más exigente en cuanto a fertilidad del suelo y responde principalmente a N y K, según el tipo de suelo. El aspecto que debe caracterizarse con especial cuidado es el de la época relativa de aplicación del fertilizante, y el fraccionamiento (si se practica) de la aplicación, pues en la mayor parte de las raíces, se conoce que cierto grado de desarrollo del sistema radicular, permite un mejor aprovechamiento del fertilizante aplicado inmediatamente después de la siembra.

CARACTERISTICAS DE LA UNIDAD DE PRODUCCION Y DEL SISTEMA DE PRODUCCION DE RAICES Y TUBERCULOS.

Como se mencionó antes, el sistema de producción de raíces y tubérculos, comunmente hace parte de un todo mayor que es la finca o unidad de producción. Es de esperar entonces que el primer nivel de interacciones de este sistema con su ambiente se presente a nivel de finca.

Como en el comienzo de todo análisis de un sistema, para una caracterización adecuada de una finca, es conveniente conocer la estructura y el funcionamiento de esta unidad de producción. Entendemos por estructura en este caso a la división física de la unidad de producción en lotes asignados a diferentes actividades productivas, que pueden ser cultivos alimenticios, cultivos perennes, producción agropecuaria etc, tal como se presenta en la figura 3.

Para caracterizar los cultivos alimenticios como componentes de la unidad de producción, nos interesa entonces conocer los criterios que fundamentan la asignación de lotes por parte del agricultor, tanto en su aspecto cualitativo como en el cuantitativo. Esta decisión aporta información preliminar acerca de la importancia relativa del sistema de producción de raíces dentro de la finca como un todo, cuando se le compara con el tipo y cantidad de terreno asignado para otros propósitos productivos.

Es necesario establecer además en forma clara, cuál es el factor determinante del tamaño de los lotes asignados a raíces y tubérculos. Este puede ser simplemente disponibilidad física de terreno; capacidad de trabajo de la mano de obra en cuanto a cobertura; cantidad de riesgo envuelto en la producción o una combinación de factores como los anteriores.

El patrón de rotación de estos lotes dentro de la unidad y los factores que lo condicionan, ya sea por necesidad de restitución de la fertilidad de los suelos o por razones de protección frente a malas hierbas, insectos o enfermedades, también debe conocerse. Como ejemplo puede citarse la frecuencia con que la yuca es el último cultivo en la sucesión de especies de un lote. Por el contrario, el caso en que el ñame es la primera especie en estas sucesiones en aquellas regiones en que es alimento preferido. Otro ejemplo es el del camote sembrado como segundo cultivo, siguiendo en el terreno a una especie hortícola de alto valor, con el propósito de aprovechar la fertilidad residual, y varios otros ejemplos de esta naturaleza.

La asignación de mano de obra que realiza el agricultor para los sistemas de producción de raíces en cuanto a cantidad, oportunidad y calidad de ella, en comparación con otros sistemas dentro de la unidad de producción, también es un indicador de la importancia relativa de las raíces y tubérculos. Esta información además proporciona conocimientos acerca del grado de complementaridad o competencia por este recurso, que existe entre las actividades productivas de la finca. Atendiendo al hecho que en el trópico la mayor parte de producción de las raíces y tubérculos se realiza con uso intenso de la mano de obra, la caracterización apropiada de la competencia por este recurso dentro de la unidad de producción, resulta de suma importancia.

Por último, dos recursos que frecuentemente se relacionan y que también proporcionan información acerca de la importancia relativa de las raíces y tubérculos dentro de la finca, son el uso de capital y de la tecnología de insumos en este sistema de producción, en comparación con las otras actividades de la unidad de producción. En forma más precisa aún, puede existir un uso diferente de tecnología para los integrantes del sistema de producción de cultivos alimenticios y en este caso, es necesario separar con mayor detalle aún el uso de este recurso tecnológico, para conocer mejor la importancia relativa de un componente con relación a los otros.

Aparte de la estructura de la finca y las razones detrás de este ordenamiento espacial decidido por el agricultor, es conveniente en una caracterización, conocer las relaciones entre las actividades de producción. Es decir, las bases del funcionamiento productivo de la finca.

Por lo general, una de las interacciones más importantes y que es necesario caracterizar, es la que se establece entre el sistema de producción animal y el de cultivos. Ya sea una relación de fuerza de trabajo animal aplicada a la producción de cultivos o de consumo significativo por parte de los animales de productos o subproductos del sistema de producción de cultivos.

La relación más frecuente que se establece entre los cultivos anuales y los perennes cuando estos últimos son fuente importante de circulante, es el de competencia por la mano de obra en períodos críticos como recolección de café, zafra o cosecha de algodón. Esta relación entre especies anuales y perennes no solo se restringe a los límites físicos de la finca, sino que es válida también en el caso de empleo de la mano de obra fuera de la unidad de producción.

Otra relación importante que se establece entre el sistema de plantas perennes y el de cultivos alimenticios, es de tipo tecnológico. Frecuentemente y debido a la rentabilidad mayor de las especies perennes, algunos productos químicos o prácticas culturales, comienzan por aplicarse a estas especies, para luego aplicarse al sistema de producción de cultivos alimenticios, según cambia el ambiente socio-económico. Así entonces, la racionalidad de algunas prácticas culturales que se empleen en la producción de raíces y tubérculos, hay que buscarlas a veces en las otras especies que integran la unidad de producción.

Finalmente, desde el punto de vista agronómico, siempre resulta interesante la caracterización de aquellos sistemas en los cuales las raíces son una parte de la sucesión de especies que se emplean para el establecimiento definitivo de las perennes. Es necesario en estos casos, conocer la(s) razones del uso de sucesiones, puede ser de protección de erosión; necesidad de sombreamiento; protección vegetal o simplemente mejor aprovechamiento del escaso recurso suelo, cuando es muy escaso.

CARACTERISTICAS REGIONALES IMPORTANTES QUE CONDICIONAN AGRONOMICAMENTE A LOS SISTEMAS DE PRODUCCION DE RAICES.

Así como a un nivel inmediato las interacciones entre el sistema de producción de raíces y tubérculos se producen a nivel de la finca, en un plano levemente más distante, las interacciones de este sistema con el ambiente se dan a nivel de región.

El conjunto de fincas de una región constituye frecuentemente una parte importante del sector primario de la economía regional. En los países económicamente subdesarrollados, la distribución de la tierra está condicionada por factores de tipo político y ello condiciona a su vez fuertemente el ordenamiento espacial de cualquier tipo de finca en una región. Aún así, a nivel regional, la consideración más importante para una caracterización de los sistemas de producción de raíces, es la distribución espacial de las unidades de producción que incluyen raíces a través de la región, en comparación con unidades dedicadas a otras actividades. Dentro de esta consideración, la calidad (frecuentemente fertilidad) del recurso suelo disponible para producir, condiciona fuertemente el tipo de especie cultivada, el arreglo entre especies, el manejo o conjunto de prácticas culturales, y principalmente la intensidad de las operaciones.

Otra consideración importante dentro del factor calidad del recurso suelo, son las condiciones topográficas en que se encuentran las fincas productoras de raíces. La topografía condiciona en forma frecuente el manejo de los suelos, principalmente en el aspecto habilitación y preparación de terrenos.

En climas que se caracterizan por la incertidumbre en cantidad y distribución de la precipitación, la capacidad de retención de agua de los suelos pasa a ser el factor determinante de la producción, aunque frecuentemente se relaciona estrechamente con las características anteriores y es necesario tomarla en consideración al estudiar la distribución espacial de las fincas.

Dentro del sector secundario de la economía de una región, los procesos de transformación de raíces interesan a una caracterización agronómica, principalmente desde el punto de vista de la calidad requerida de la materia prima (raíces), oportunidad en que se necesita y estacionalidad. Estos son por lo general los factores más estrechamente relacionados a la producción misma, especialmente en sistemas tradicionales de transformación.

Un ejemplo claro de influencia de procesos de transformación a nivel regional, que modifican a los sistemas de producción, lo constituyen las plantas de secado de yuca en rodajas para uso en alimentación animal.

Dentro del sector terciario de la economía de una región, los servicios importantes que es necesario caracterizar con más atención para llegar a un diagnóstico útil son: disponibilidad, cobertura, calidad y oportunidad de la asistencia técnica a los agricultores y el tipo de mercado que existe para insumos (principalmente químicos y semillas de especies que se cultivan con las raíces) y equipos.

MECANISMOS DE CAPTACION DE INFORMACION AGRONOMICA.

Aunque no calza exactamente dentro de los lineamientos de un trabajo de esta naturaleza, es conveniente, antes de finalizar, una breve mención acerca de los mecanismos que se pueden usar para captar la información agronómica. El método usado, puede hacer variar la información que se obtiene y consecuentemente la correcta interpretación de ella.

En resumen, algunos pasos prácticos de captación de información serían los siguientes:

- Revisión de información climática y de suelos existente acerca de la región de interés. Datos estadísticos de rubros agrícolas producidos.
- Recorrido por la región y entrevistas con técnicos y agricultores para conocer inicialmente la distribución regional de las unidades de producción.
- Separación, si es necesario, de diferentes tipos de fincas (o de agricultores) en dos o tres grandes grupos. Puede hacerse por grado de tecnología usado, tamaño de explotación, arreglo de cultivo usado, especie cultivada o cualquier otra característica, según la región.
- Entrevistas con algunos agricultores representativos de cada tipo de finca o solo de aquellas fincas de interés, para solicitarles una descripción de su sistema de producción de raíces.

  Es conveniente formular las preguntas siguiendo la sucesión cronológica de labores típica del área, tal como se ha intentado hacer en esta presentación. Es decir, comenzar por los criterios de selección de los lotes, seguir por habilitación de terrenos, preparación de ellos, siembra, etc. hasta llegar a cosecha almacenamiento y venta. Los problemas detectados por el agricultor en cada fase, deben describirse con especial atención.

Después es conveniente tratar de reconstruir, en forma teorica, el desarrollo fenológico de las especies del arreglo, según la marcha habitual del clima de la región y sobreponer esta información con el conjunto de prácticas agronómicas del agricultor.

Con base en la información anterior se formula un conjunto de preguntas en sucesión lógica que se pueden efectuar formalmente en una encuesta posterior, a fin de disponer de datos cuantificables.

- No siempre es necesario realizar una encuesta, pero si se decide hacerlo, tan importante como el tipo de pregunta es el entrenamiento correcto del encuestador en el conjunto de situaciones a las que se va a enfrentar. El correcto entrenamiento del encuestador solo se puede hacer con un buen conocimiento inicial de los sistemas de producción, que a su vez se consigue por interacción directa previa con agricultores representativos. La encuesta por más perfecta que sea, solo aporta un marco de referencia cuantificable que es necesario interpretar correctamente y más importante aún profundizar posteriormente en aspectos específicos por medio de estudios de casos o con las visitas frecuentes.

El concepto que debe quedar claro es que el diagnóstico de una situación de producción es de tipo dinámico, tal como lo es la producción agrícola misma. Los resultados de un estudio de caracterización con fines de diagnóstico, solo se van a sostener inalterados en su descripción de la estructura y funcionamiento de un sistema de producción, por un lapso de tiempo dado, según la situación.

La identificación de los factores ambientales que condicionan la posible variación de un sistema de producción en el tiempo, es clave para lograr suficiente capacidad de predicción y consecuentemente posibilidades de planeación agrícola inteligente, pero este es tema suficiente como para otro artículo.

ELITE CASSAVA GERMPLASM FROM CIAT

Through repeated evaluations in several locations, the CIAT Cassava Program is able to offer elite clones well adapted to diverse edapho-climatic conditions and suitable for various end uses. This pamphlet lists these clones, along with describing yield, quality, resistance, and morphological characteristics. Clones are available upon request as *in vitro* cultures or partially lignified stem pieces from virus-indexed mother plants. They may offer an opportunity for: 1) direct release as a cultivar following appropriate evaluation; and/or, 2) for use as cross parents in a breeding program.

In addition to clones sent as *in vitro* cultures, hybrid seeds from selected parents are also available. Seeds provide a high level of variability and good possibilities for local selection.

Clonal Material

Procedures for requesting cassava clones

Requests should normally be made by matching characteristics desired in a given selection/breeding program with the list of characteristics for each clone. CIAT has divided cassava-growing regions into six basic zones based on soil and climatic conditions. For each edaphoclimatic zone, major biological and physical yield constraints are also described (Annex 1).

The description of the cassava clones (Annex 2) is divided into five basic sections: 1) common name or cross parents; other remarks; 2) general adaptation in different edaphoclimatic zones; 3) yield and quality characters; 4) pest and disease resistance characters; and, 5) morphological triats.

For most of the quantitative traits (such as yield, quality and resistance) descriptions are given in terms of a scale designating high to low trait expression. Because expression of these traits varies considerably according to environmental conditions, reporting of exact numerical data can be misleading unless details of environmental conditions are also given for each trial. More extensive data for some of the yield, quality and resistance characters can be found in CIAT Annual Reports. A description of the variables is found at the end of Annex 2.

As the preparation and shipment of each clone involves considerable expense, CIAT expects that only clones would be requested which have potential usefulness in the country where they will be introduced.

Each recipient is advised to include with the request an import permit from the national quarantine authorities, if it is required. Requests should be sent with the attached form, or with a letter specifying the same information.

Phytosanitary certificate and phytosanitary statement

All the source materials for preparing *in vitro* cultures are taken as meristem tips from plants grown at the CIAT-Palmira station. All shipments are inspected by Colombian quarantine authorities, and a phytosanitary certificate issued by them is included with the consignment. CIAT includes an additional phytosanitary statement, which reads as follows:

"This statement is meant to provide supplementary information, but not to substitute the Phytosanitary Certificate issued by the Colombian authorities.

The in vitro meristem cultures of cassava (Manihot esculenta Crantz) contained in this package are vegetative samples. They were aseptically prepared from terminal buds of sprouted stakes, which were under heat therapy for 4 weeks.

The stakes were taken from visually healthy plants, free of symptoms of cassava bacterial blight, superelongation, and Diplodia spp. stem rot. These plants were also indexed using the latest available techniques for cassava viral diseases and found negative for the following: Common and Caribbean mosaics, latent viruses affecting differential clones, and frog skin disease.

The cultures were free of cassava insects and mites and from the eggs of these pests. To the best of our knowledge this plant material was free of cassava diseases and pestu at the time of dispatch."

Form of Shipment

In Vitro. Normally, five to ten test tubes are shipped for each clone requested, but more could be shipped in special cases. Each plantlet is individually cultured in a test tube with sterile media. Test tubes are placed in protective packaging to minimize possibility of breakage during transit. Unless otherwise requested, packages will be sent via airmail to most destinations.

Stakes. Immature, partially lignified stakes are cut from virus-free plants maintained under controlled conditions. Stakes are treated with fungicides, protected against rapid dehydration, and shipped in cardboard containers. This method permits more rapid recovery of plants as compared to in vitro cultures.

Post-receipt handling procedures

CIAT will inform by telex or cable of the details of shipment so that the recipient can be prepared as necessary. This will be especially important for those cases where the consignment will be held by quarantine authorities, so that undue delays and possible losses of material do not occur. Detailed instructions for post- receipt handling and propagation will be included on request.

Other clonal material available

Though elite clones or hybrid seed should provide possibilities for promising selections for most regions, special requests for other germplasm bank accessions or hybrid clones will also be considered. Other clones available include a germplasm collection of approximately 4500 accessions.

Botanical Seed

Up to several thousand seeds can be made available according to needs and selection capabilities of the requesting institution. Cross parents used and quantities of reserve seed available change constantly, so each request for seeds will be considered individually on the basis of material at the time of the request.

Evaluation of Introduced Germplasm

In order to continually improve the cassava clones or crosses we have available, CIAT requires information on the performance of the materials we distribute internationally. Further details can be provided on evaluation procedures for programs who desire them.

Annex 1. Description of edaphoclimatic zones and production constraints.

Zone	Description	Major yield constraints
1	Lowland tropics with prolonged dry season	Drought, mites, thrips, mealybugs, termites, bacteriosis, root rots, viruses.
2	Acid soil savanna	Low soil fertility, drought, bacteriosis, superelongation, anthracnose, Cercospora leaf spot, mites, mealybugs, lace bugs.
3	Tropical rainforest without pronounced dry season	Low soil fertility, root rots, Cercospora leaf spot.
4	Intermediate altitude tropics (800-1400 m.a.s.l.)	Thrips, mites, mealybugs, bacteriosis, mycoplasma, anthracnose, root rots, and viruses.
5	Highland tropics (1400-2000 masl)	Low temperature, phoma leaf spot, anthracnose, mites.
6	Subtropics	Low winter temperature, bacteriosis, superelongation, antracnose.

Annex 2. Description of CIAT's elite cassava clones.

CLONE	COMMON NAME OR CROSS PARENTS	ZONE PRPL	ZONE SCND	YLD	DM	HCN	CUL QLT	TRP	MON	CBB	SED	DPL	ROOT COLR	FLSH COLR	PGMN CRTX	BRN-CHNG	PLNT HGHT
CG 915-1	MBRA 12 X MCOL 1643	1	4	5	4	3	2	3	2	2	4	5	3	1	1	2	3
CG 917-5	MBRA 12 X MCOL 1818	1	4	4	4	3	2	2	2	3	5	1	3	1	Y	1	4
CG 1141-1	MMEX 11 X MCOL 65	1	4 2	5	5	3	1	2		3	3	1	3	1	0	2	3
CG 1220-2	MCOL 976 X MVEN 77	1		4	3	3		2				5	3	2	0	2	4
CG 1355-2	CM 922-2 X MMAL 3	1		5	3	3		3		3	4		3	1		2	4
CG 1372-5	*MBRA 12 X MMAL 3	1		5	4	2		3		2	5		3	1	0	2	5
CG 1413-3	MCOL 976 X CM 507-37	1		5	3	4	4	2		4	2		2	1	0	2	3
CM 962-4	CM 309-93 X MPAN 70	1	4	5	3	4	4	3	2	3	3	5	3	1	1	3	2
CM 1014-2	MCOL 22 X MCOL 655A	1	4	4	3	4	3	3		5	4	4	3	1	1	2	4
CM 1442-204	MBRA 12 X MCOL 1684	1		5	3	5	5	2	3	4	5		3	1	Y	1	3
CM 3281-4	MBRA 12 X MCOL 22	1	4	5	4	3	2	2		4	5		1	1	0	2	3
CM 3299-4	CM 849-1 X MCOL 22	1	4	4	4	3	2	2		3	4	2	1	1	Y	3	4
CM 3306- 4	MCOL 22 X CM 523-7	1	4	4	5	2	2	2		4	3	5	3	1	0	2	3
CM 3306- 9	MCOL 22 X CM 523-7	1		4	5	2	2	2		3	5	5	2	1	0	2	2
CM 3320-4	MBRA 20 X CM 523-7	1		4	3	3	3	3		3	4		3	1		3	3
CM 3372-4	CM 517-1 X CM 840-31	1	4 2	4	3	2	2	3		2	2	5	3	1	0	3	3
CM 3555-6	CM 841-106 X MCOL 22	1		4	4	2	3	1		3	4	1	3	1	0	2	3
CM 3750-5	CM 1117-3 X MCOL 22	1		4	4	4	3	1		3	4	1	2	2	2	2	2
CM 3997-1	CM 681-2 X CM 849-1	1	4	4	4	3	3	3		4	4		3	2	Y	3	4
CM 4042-4	CM 1015-13 X CM 180-5	1		5	4	4	3	2		4	3		1	2	Y	2	3
CM 4181-1	CM 847-1 X MCR 2	1		4	4	5				3	3		3	1	Y	3	4
M BRA 191	AMARELA CASCA ROXA	1		4	4	2	2	1		4	4	1	3	3	Y	2	4
M COL 1505	MANIHOICA P-12	1	4	4	3	2	2	3	3	3	3	2	2	1	2	2	3
M COL 2215	VENEZOLANA	1	4	4	5	2	1	3	4	4	5	5	3	1	0	3	3
M TAI 1	RAYONG 1	1	4	4	4	4	4	2	3	4	4	3	1	1	0	2	5
SG 455-1	MCOL 1684	1		4	5	4	5	2		3	5	5	3	1	0	4	4
CG 32-22	MBRA 20 X MPAN 97	2	4	4	3	3	3	3	2	2	2	1	3	1	0	2	3
CG 35-3	MBRA 20 X MVEN 77	2		5	3	4	3	5		2	2		3	1	0	2	3
CG 165-7	MCOL 1495 X MPAN 90	2	4	5	3	4	5	3		2	2	5	3	1	0	2	4
CG 1139-2	MBRA 5 X MECU 82	2	4	4	3	4	2	2		3	2		3	1	Y	2	4
CM 523-7	MCOL 655A X MCOL 1515	2	3 4 1	4	5	2	2	3	3	2	2	5	3	1	1	3	4
CM 2166-6	CM 430-37 X MVEN 218	2	1	5	3	2	2	2	2	2	1	5	3	1	Y	3	3
CM 2177-2	CM 430-37 X CM 840-138	2	4	5	3	2	1	2	2	2	2	2	3	1	0	3	3
CM 2600-2	MVEN 77 X CM 523-7	2	4 1	4	4	2	3	3		2	3	4	3	1	3	4	4
CM 2766-3	CM 723-3 X CM 523-7	2	3 1	4	4	3	3	3		2	1	5	3	1	3	3	4
CM 2766-5	CM 723-3 X CM 523-7	2	4	5	4	3	1	3		2	1	5	3	1	2	3	4
CM 2770-7	CM 727-14 X MVEN 77	2		4	2	3	3	3		2	2	5	2	2	2	3	4
CM 2772-3	CM 727-14 X MPAN 128	2	3	4	3	2	2	3		2	3	5	3	3	Y	2	5
CM 2909-36	CM 1011-4 X CM 523-7	2		4	4	3		3		2	2	3	3	1	0	4	5
CM 2952-1	CM 1145-1 X MPAN 128	2		5	2	2	2	3		2	1		3	1	0	3	5
CM 2952-3	CM 1145-1 X MPAN 128	2		4	3	3	2	3		2	3	4	3	1	0	2	4

(Continued)

Annex 2. (Continued)

CLONE	COMMON NAME OR CROSS PARENTS	ZONE PRPL	ZONE SCND	YIELD AND QUALITY YLD	DM	HCN	CUL QLT	PEST AND DISEASE RESISTANCE TRP	MON	CBB	SED	DPL	MORPHOLOGICAL TRAITS ROOT COLR	FLSH COLR	PGMN CRTX	BRN-CHNG	PLNT HGHT
CM 3064-4	CM 1326-5 X MVEN 77	2		4	4	2	1	2		3	1	5	3	1	2	3	4
CM 3380-7	CM 586-1 X CM 523-7	2		4	4	3		2		2	3	4	3	1	1	3	3
CM 3401-2	CM 621-169 X CM 523-7	2		4	3	4	3	3		3	2	3	3	2	Y	1	3
CM 3544-9	CM 840-138 X CM 523-7	2			3	4		3		2	2						
CM 3894-1	CM 1307-3 X CM 523-7	2		4	3	4		2		1	3		2	1		3	2
CM 4157-34	CM 586-1 X MBRA 12	2		5	3	3	2	2		2	2		3	1	0	3	4
M PAN 51	BRASILENA	2		3	3	2	2	3	3	3	2		3	1	2	4	5
SG 104-264	VAR 2	2	3 4	5	3	4	5	3	2	1	1	2	2	1	1	2	4
SG 104-284	VAR 2	2	4	4	3	3	1	3		2	2	4	3	1	0	4	4
SG 107- 35	VAR 5	2	3 4	4	3	2	1	4	3	1	2	1	3	1	0	3	4
SG 250-3	MCOL 1912	2		4	3	4	2	3		2	2	5	3	1	2	3	4
SG 695-1	CM 723-3	2		4	3	2	1	2		2	2		3	1	0	3	4
CM 507-37	MCOL 1438 X MCOL 1684	3	2 4	5	2	4	4	4	4	2	3	5	3	2	1	5	2
CM 1999-5	CM 516-15 X CM 517-1	3	4	5	4	3	4	3	3	4	4	4	3	3	2	3	4
M MAL 2	BLACK TWIG	3	1	4	4	3	4	4	4	3	5	1	3	1	1	3	5
CG 1-37	MBRA 12 X MCOL 22	4	1	5	3	3	4	1	3	4	5	3	1	1	0	2	4
CG 5-79	MCOL 22 X MCOL 414	4		4	4	2	3	1	1	5	5	5	1	1	0	2	4
CG 996-6	MCOL 1413 X MPTR 19	4	1 2	5	4	2		2		2	2	5	3	1	0	2	4
CG 1534-10	M MEX 1 X CM 922-2	4		5	4	2		2		3	3		3	1	1	3	4
CM 321-188	MCOL 22 X MVEN 270	4	6	4	3	3		2	3	3	5		1			2	4
CM 489-1	MCOL 882 X MVEN 270	4		5	2	3	4	3	3	4	5	5	2	2	1	3	5
CM 849-1	SM 76-66 X MVEN 218	4	2	5	2	4	4	3	3	3	3	4	3	1	Y	2	5
CM 922-2	MPTR 19 X CM 314-20	4	1	4	5	2	2	2	3	4	4	4	3	1	3	2	3
CM 955-2	CM 309-37 X MVEN 218	4	1	5	4	2	3	2	2	4	4	3	3	1	Y	2	4
CM 1305-3	CM 446-22 X MCOL 1684	4	3	5	2	5	5	3	3	5	5	4	3	1	2	4	4
HMC 1	MANIHOICA P-13	4	3 2	3	4	2	1	3	3	2	4	3	3	1	2	3	4
M BRA 383	VASSOURAO	4	1	4	4	4		1		3	4		3	1	I	1	4
M COL 1468	MANTIQUEIRA; MANIHOICA P-11	4	6 1	4	2	3	2	5	4	3	3	5	3	1	3	3	3
M CUB 74	SENORITA	4	6	4	4	2	1	2	2	5	2	5	3	1	2	2	4
CG 354-2	MCOL 309 X MCOL 1468	5		4	4	2		2	2	4	5	4	3	1	0	3	3
CG 358-3	MCOL 335 X MCOL 2060	5		4	3	1		2	3	3	5	3	3	1	0	3	3
CG 401-3	MCOL 1522 X MCOL 340	5		5	4	3		2	2	4	4	2	3	1	0	3	4
CG 402-11	MCOL 1522 X MCOL 647	5		4	3	3		1				3	3	1	0	3	4
CG 406-6	MCOL 1522 X MECU 169	5		5	4	3		1	3	4	5	5	1	2	0	3	3
CG 481-3	MCOL 2060 X MECU 169	5		5	4	3						3	2	1		3	3
CG 501- 2	MECU 169 X MCOL 2060	5		5	4	2		1					1	1	0	3	3
CG 501-18	MECU 169 X MCOL 2060	5		4	4	2							1	1		3	3
CG 1118-32	MCOL 2017 X MCOL 2060	5		4	3	3							2	1		3	4
CG 1255-1	MCOL 2006 X MCOL 2019	5		4	4	1		1					2	1	0	4	4
M COL 1522	ALGODONERA AMARILLA	5		4	4	2		1	2	4	5	5	3	1	0	3	3
SG 350-23	MCOL 1522	5		5	4	1							3	1		2	5
SG 350-42	MCOL 1522	5		5	4	2							2	1		3	3

(Continued)

Annex 2. (Continued)

DESCRIPTION OF CODES FOR ELITE CLONES

ZONE = EDAPHOCLIMATIC ZONE OF ADAPTATION
PRPL = PRINCIPAL ZONE OF ADAPTATION
SCND = SECONDARY ZONE(S) OF ADAPTATION

1: TROPICAL LOWLANDS; LONG DRY SEASON
2: ACID SOIL SAVANNAS
3: HUMID TROPICS
4: MIDDLE ALTITUDE TROPICS
5: HIGHLAND TROPICS
6: SUBTROPICS

YIELD AND QUALITY
(1 = LOW; 5 = HIGH)

YLD = YIELD POTENTIAL IN ZONE(S) OF ADAPTATION
DM = ROOT DRY MATTER CONTENT
HCN = ROOT HCN CONTENT
CUL QLT = CULINARY QUALITY (1 = GOOD; 5 = POOR)

PEST AND DISEASE RESISTANCE
(1 = RESISTANT; 5 = SUSCEPTIBLE)

TRP = THRIPS
MON = MONONYCHELLUS TANAJOA
CBB = CASSAVA BACTERIAL BLIGHT
SED = SUPERELONGATION DISEASE
DPL = DIPLODIA ROOT ROT; GREENHOUSE EVAL.

MORPHOLOGICAL TRAITS

ROOT COLR = ROOT SURFACE COLOR
1 = LIGHT
2 = MEDIUM BROWN
3 = DARK BROWN

FLSH COLR = ROOT FLESH COLOR
1 = WHITE
2 = CREAM
3 = YELLOW

PGMN CRTX = PIGMENTATION OF ROOT CORTEX
0 = ABSENT
1 = SLIGHT PINK
2 = LIGHT PURPLE
3 = PURPLE
Y = YELLOW

BRNCHNG = BRANCHING HABIT
1 = VERY LITTLE BRANCHING
5 = VERY HIGHLY BRANCHED

PLNT HGHT = PLANT HEIGHT
1 = VERY SHORT
5 = VERY TALL

REQUEST FOR CASSAVA GERMPLASM

Name: ______________________________

Position: ______________________________

Institution: ______________________________

Address: ______________________________

Clones desired:

________	________	________
________	________	________
________	________	________
________	________	________
________	________	________
________	________	________
________	________	________

Desired form of shipment: In vitro ______ Indexed stakes ______

Approximate number of botanical seeds desired: ____________

Approximate date desired: ____________________

Description of target region and expected uses of new varieties:

____

____

____

Mail request form to:

Dr. Clair Hershey
Cassava Breeder
CIAT
Apartado Aereo 67-13
Cali, COLOMBIA

RELATIONSHIP BETWEEN BIOMASS, ROOT YIELD AND SINGLE LEAF PHOTOSYNTHESIS IN FIELD GROWN CASSAVA

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ABSTRACT

The present study was conducted to determine the relationship of single leaf photosynthesis to root yield and biomass of field grown cassava. More than 100 genetically diverse cassava lines were grown in a clay loam soil, which was previously under pasture grasses, at the Patia Valley, Cauca, Colombia, South America, during the 1986/1987 growing season. The plants were adequately fertilized at the rate of 75, 65 and 125 kg ha^{-1} N, P and K, respectively. From planting (23 October, 1986) to harvest (26-27 August, 1987), the cassava crop received about 700 mm of rain, the majority of which occurred during October-November 1986 and April-May, 1987. Gas exchange (CO_2 uptake and H_2O loss) of single attached upper canopy leaves was monitored using the LI-6000 portable photosynthesis system on 24 February to 6 March (4 leaves per cultivar), on 4-14 April (4 leaves per cultivar), and on 3-7 June, 1987 (2 leaves per cultivar). There were large variations among cultivars in the average leaf photosynthetic rates, total biomass, top weight, and storage root yield. Across all cultivars, there was a highly significant and positive correlation between leaf photosynthetic rates and both total biomass (r = 0.37, df 125) and dry root yield (r = 0.4, df 125). When the cultivars were grouped on the basis of top weight (as a proxy for leaf area), the correlations were not significant in the low top weight group (r = 0.22 and 0.09, df 45, for root yield and total biomass with leaf photosynthesis, respectively), and highly significant in the average and high top weight groups (r = 0.5 and 0.53, df 38, for root yield, and 0.49 and 0.5 for total biomass). The same trends were observed for the correlations between mesophyll conductance and both root yield and total biomass. There were no significant correlations between these traits and leaf conductance. Leaf photosynthesis was not significantly correlated with either leaf conductance or with leaf N P K contents. These results indicate that when light interception is not limiting (e.g. with average and high top weight) selection for high photosynthetic capacity is likely to lead to increases in yield and total biomass. It is suggested that screening for high leaf photosynthetic rate under field conditions could be used as a selection criteria for parental materials to obtain progeny with high yield potential.

Additional index words: Gas exchange, leaf conductance, mesophyll conductance, harvest index, light interception, Manihot esculenta Crantz, leaf N P K.

There is an emerging consesus that traditional means of increasing crop productivity, at least in developed countries, have reached their limits and new means are required for future improvements in crop yields (Beadle et al, 1985). These traditional approaches have principally relied on major improvements in harvest index and the supporting changes in cultural practices, plant nutrition, and pest and disease control that allowed the yield expression in these more efficient plant types. A principal area of focus in the search for new sources of yield increases has been through enhancing the photosynthetic efficiency of crop plants (Hesketh et al, 1982). Nevertheless, after a substantial body of research oriented toward a more basic understanding of plant photosynthesis, there has, to date, been extremely limited progress in translating this knowledge into crop productivity gains (Nasyrov, 1978; Gifford and Jenkins, 1982). The movement from basic laboratory results on photosynthesis to an understanding of the ramifications on yield at a field level have been limited by the ability to control for other factors governing yield, and, until relatively recently, by the lack of field measurement techniques suitable for screening applications (Boerma and Ashley, 1988; Bunce, 1986; Sestak et al, 1971).

This paper addresses the problem the other way around, namely by measuring field level differences in photosynthetic efficiency across a wide range of genotypes, and evaluating any systematic effect of variation in photosynthesis on yield. Furthermore, we attempt to characterize the physiological basis for any relationship between yield and photosynthetic efficiency. The approach coincides to a significant extent with the decision process for a crop breeder interested in utilizing differences in photosynthetic efficiency as a basis for development of a breeding population. Namely, the breeder must demonstrate a relationship between yield and photosynthesis with measurable field techniques, recognizing that the relationship will probably be conditioned on other factors contributing to yield and that selection based on photosynthetic efficiency (especially if measured in terms of unit leaf area) will have to be simultaneously combined with other yield determinants.

Nevertheless, the association between the yield of crop plants and photosynthetic efficiency has been elusive (Buttery et al, 1981; Elmore 1980; Gifford and Evans, 1981). In fact, in the case of rice (Yoshida, 1972, 1983) and wheat (Evans and Dunstone, 1970; Khan and Tsunoda, 1970), two crops where large gains in productivity have been made, through change in harvest index, there appears to be a negative relation between the level of improvement of the crop and the photosynthetic rate. The authors feel that the lack of a direct and simple relation between yield and photosynthetic rate of leaves as normally measured is not surprising. Yield is so dependent on harvest index for crops that have not been subject to improvement for high-input agricultural systems, that factors such as photosynthetic efficiency may be masked. Secondly, total biomass production is so dependent on the leaf area index (LAI) and hence light interception under sub-optimal conditions that it will be difficult to detect differences caused by variation in photosynthetic efficiency alone. Furthermore, until recently, photosynthetic efficiency has in general been measured on leaves when they are performing at their maximum rates, rather than their average performance in the field or perhaps more important their efficiency during the period of yield formation (El-Sharkawy et al, 1965; Sinclair, 1980; Buttery et al, 1981; Bunce, 1986). All these factors will tend to make any direct relation between yield and photosynthesis tenuous.

The cassava crop offers a good model for searching for a direct relation between yield and photosynthesis. In general, sink does not appear to limit yield and increased carbohydrate supply will be reflected in increased yield rather than growth of other organs (Tan and Cock 1979; Cock et al 1979; Cock 1984; Cock and El-Sharkawy, 1988). Furthermore, the photosynthetic rate of individual leaves does not show marked variation with leaf age during a long portion of their life (Cock, 1984). In addition, the crop is not characterized by a critical yield formation period in which leaves are senescing and rapidly changing their photosynhthetic capacity. Thus, a significant relationship between photosynthetic rate and yield would be more probable in cassava than in grain crops.

In addition to the choice of crop in evaluating such a relationship, there is also the choice of environment. Most attempts in the past have assumed that such expression of differences in yield due to variation in photosynthetic efficiency would occur under optimal or non-limiting conditions (See Bunce, 1986). Such an assumption usually severs the linkage with breeding programs since in crop production plants must be assumed to be subject to periodic or continued stresses. In cassava, the breeding approach has been based on selection under a range of relevant stresses. In addition, recent research suggests that cassava is a C_3 - C_4 intermediate, that there is variation between varieties in activity of the C_4 enzyme phosphoenolpyruvate carboxylase, and that the role of the C_4 enzyme may be particularly advantageous under water stress conditions (El-Sharkawy and Cock, 1987; Cock et al 1987; CIAT, 1987). All of this points to evaluation of the genotypes under relevant environmental stresses in order to get sufficient variation in photosynthetic efficiency and relate it to yield. However, this does raise a conceptual problem of how photosynthetic efficiency is being defined, especially given the shared pathway between transpiration and CO2 exchange. This issue is also addressed in the analysis.

MATERIALS AND METHODS

The experiment was conducted on a private farm located in the Patia Valley, Cauca, Colombia, South America (altitude 600 m, latitude 2^{o} 09' N, longitude 77^{o} 04' W, mean annual temperature 28^{o}C). The farm was under continuous pasture grasses, mainly *Panicum maximum*, for the last 25 years. Table 1 summarizes some physical and chemical properties of the surface soil of the experimental site after it was closely grazed before being disked twice to 0.15 - 0.20 m deep.

More than 100 cassava cultivars and lines (*Manihot esculenta* Crantz), representing the major ecological zones where cassava is grown, were selected as test materials (Table 3). On October 23, 1986, the experimental area of about 2600 m^2 was planted on the flat. A single 4 m x 4 m plot was assigned, randomly, to each cultivar. Twenty five healthy woody stakes, 0.2 m long, were selected from the CIAT cassava germplasm bank at the Palmira Experimental Station, Valle, Colombia. The stakes were pretreated with fungicides and immersed briefly in a diluted solution of zinc sulfate as a standard treatment before planting. The stakes were vertically planted at 0.8 m x 0.8 m arrangement to give a population density of 15625 plants ha^{-1}. At 30 days after planting, the few stakes which failed to germinate were replaced with germinating stakes that were previously planted in plastic bags filled with the same soil and were kept in the field since the day of planting the whole experiment. Forty days after planting, 10-20-20 NPK compound fertilizer was applied in bands 0.05 m away from the plants at the rate of 75, 65, and 125 kg ha^{-1} N, P and K, respectively. The plots were hand-weeded whenever needed before full canopy closure. From planting to the final harvest (309 days), the cassava crop received about 700 mm of rain (Table 2) as was recorded by a rain gauge installed at the experimental plot. From December 1986 to April 1987, the rainfall was less than the potential evaporation of the region (greater than 5 mm day^{-1}). The Patia Valley, lying between the central and the western Andes mountains, is characterized by two wet periods (October-December, and March-June) and two dry periods (December-March, and June-September). The 1986/1987 season was particularly dry with no recorded rainfall from June to August 1987.

Measurements of single leaf gas-exchanges (CO_2 uptake and H_2O loss) were made with a LI-6000 portable infrared gas analyzer (LI-COR, inc., Lincoln, Nebraska, U.S.A.) on 24 February to 6 March (4 leaves per cultivar), on 4-14 April (4 leaves per cultivar), and on 3-7 June 1987 (2 leaves per cultivar). Measurements were always made during 4 h daily from 900 h to 1300 h when the solar irradiance exceeded 1000 μmol m^{-2} s^{-1} of photosynthetic photon flux density (PPFD). Across cultivars and measurement dates, the PPFD ranged from 1070 to 2200 (1700 + 227, mean + s.d.) μmol m^{-2} s^{-1}. The central lobe of the attached upper canopy leaves, 4th to 6th from top, was enclosed in a ventilated 4 L chamber (LI-COR) held toward the sun for one minute gas exchange measurement. The CO_2 depletion during measurement ranged from 20 to 45 μ LL^{-1}. The leaf temperature inside the chamber ranged from 27C to 38C (35 + 1.7, mean + s.d.) across cultivars and measurement dates. This range of leaf temperature coincided with the broad optimum known for cassava leaf photosynthesis determined under controlled laboratory conditions (El-Sharkawy et al, 1984a). A lateral lobe was cut from the measured leaves prior to enclosing in the chamber, and the bulk leaf water potential (Ψ L) was determined with the pressure chamber technique (Scholander et al, 1965). The Ψ L ranged from -1.0 to -1.5 MPa (-1.2 + 0.12, mean + s.d.) across cultivars and measurement dates. During the measurements of gas exchange, the zero and span of the CO_2 gas analyzer were always checked using a cylinder of a standard gas of approximately 657 μ LL^{-1} CO_2. The zero was reset every 20 minutes and the span was reset every two hours. Due to the high humidity in the air, the desiccant (magnesium perchlorate) was replaced at least every two hours.

Since the great majority of the cassava cultivars possess hypostomatus leaves (El-Sharkawy et al 1984b) with stomatal density of about 500 mm^{-2} on the lower surface, calculations of leaf conductance to water vapor were made for one surface only. The measured boundary layer resistance to water vapor of wet leaf-replicas made of filter papers that were placed in the ventilated 4 L chamber was about 0.12 s cm^{-1}. Using the apparent leaf CO_2 uptake rates (AP) and the calculated intercellular CO_2 (C_i), the mesophyll conductance to CO_2 transfer was calculated from the following relation:

$$\text{Mesophyll conductance} = \frac{AP}{(C_i - C_{chl})}$$

Where C_{chl} is the concentration of CO2 within the chloroplast and was assumed to be equivalent to the CO_2 compensation point of about 25 μLL^{-1} CO_2 for cassava (El-Sharkawy and Cock, 1987).

At 160 days after planting, five upper canopy leaves were harvested per cultivar for N, P and K analysis.

On 26-27 August 1987 (309 days after planting), the six central plants of each cultivar were harvested for the determination of yield and standing biomass (excluding the fallen leaves). The fresh weight of the storage roots and the stems + attached leaves were determined in the field immediately after harvest.

Five kg of fresh roots per cultivar were cut into small pieces and were oven-dried at 75°C for 75h for the determination of dry root yield. The average dry matter content across cultivars was 30.9 $\pm$ 4.5% (mean $\pm$ s.d.) with the cv. MCol 2019 possessing the lowest level (16.1%) and cv. MCol 2215 the highest level (40.5%).

RESULTS AND DISCUSSION

There were large variations in the average measured leaf photosynthetic rates, total biomass, top weight and yield (Table 3). There was a loose but highly significant correlation (r = 0.37, 125df) between total biomass and the average leaf photosynthetic rate (Table 4).

In general terms total biomass should be described by the product of total light interception and efficiency with which that light is used in photosynthesis. The total light interception of the crop will in turn be loosely related to the leaf area duration of the crop. Furthermore, the leaf area duration will be related to the total leaf production and other factors such as leaf life and the pattern of leaf formation over time. In cassava, the nodal units that form the aerial part of the plant each sustain one leaf. Hence, in very broad terms total top weight at harvest can be used as an indirect measure for the integral of leaf area index with time, that is leaf area duration. Light interception is however asymptotically related to total leaf area index at any given time. Hence, above a certain level of LAI light interception will vary little with changes in LAI. Applying this argument to the assumption that top weight can be used as a proxy for leaf area duration leads to the assumption that at high values of top weight light interception should be relatively constant over a range of top weights. If this is true then there should be a close relation between average photosynthetic rate of leaves and total biomass at high values of top weight. This relation would also be expected to be weaker at lower values of top weights as the total biomass would be determined by both photosynthetic capacity of the leaves and the light interception.

The data were divided into three sets: high values of top weight (more than 31 t ha^{-1}), medium values (between 23 and 31 t ha^{-1}) and low values (less than 23 t ha^{-1}). At the high values of top weight, total biomass was closely correlated with photosynthesis (r = 0.50, 38df) (Table 4). There was no significant relation between total biomass and top weight indicating that light interception was probably not a limiting factor. It would be expected that the dominant factor at low levels of light interception would be the ability to intercept light. There was a highly significant correlation between total biomass and top weight at low top weight (This correlation should be treated with care as top weight is also used in the determination of total biomass and as such is not an independent variable). However, the correlation between average photosynthetic rate of leaves and total biomass at low levels of top weight was not significant (r = 0.09, 45 df). The tendency of these relations is in the directions dictated by our hypotheses. The medium levels of top weight gave similar results to those for high top weights suggesting that light interception was not limiting.

These results indicate that, at high levels of light interception, there was a direct and readily measurable relationship between total biomass and average photosynthetic rate of leaves. At lower levels this relation was lost and light interception itself appears to be the most significant factor in determining biomass production.

Under the conditions in which the experiments were carried out there were long dry periods and potential evapotranspiration certainly exceeded precipitation. Unfortunately, due to the primitive conditions under which we carried out these trials we do not have data on potential evapotranspiration, however the rainfall pattern shown in Table 2 in an area with an average temperature greater than 25°C are sufficient to substantiate this conclusion. In these circumstances stomatal conductance could be a major factor influencing photosythesis and hence total biomass production at high leaf area indices. The correlation between total biomass and leaf conductance was low and not significant in the high top weight group, negative in the average and non existent in the low top weight group (Table 4). The overall analysis showed no correlation between leaf conductance and total biomass. The same trend was found between photosynthesis and leaf conductance (r = 0.08, df 125). These data indicate that differences in leaf conductance cannot account for the relation between the total biomass and photosynthesis.

Furthermore, variations in leaf photosynthesis cannot be attributed to variations in leaf N P K contents since the correlation coefficients were not significant (r values for leaf photosynthesis with N, P and K are 0.02, -0.08 and -0.019, df 125, respectively).

On the other hand, total biomass was positively correlated with mesophyll conductance for the whole sample (r = 0.33, df 125). The correlation was not significant in the low top weight group (r = 0.09, df 45) and was significant at the 1% level in the average and high top weight groups (r = 0.43 and 0.47, df 38, respectively). This indicates that the primary effect of differences in photosynthesis on total biomass is related to differences in the mesophyll conductance. This suggests either biochemical or anatomical differences in the varieties tested as being the major cause of variation rather than stomatal factors. The possibility of screening directly for these factors should not be overlooked.

Yield in a crop such as cassava is not synonymous with total biomass. In fact there is considerable evidence to indicate that optimal yields of cassava will be obtained when the distribution of photosynthate to the roots is such that light interception is incomplete (Cock, 1984). Harvest index is closely related to yield, as indicated in Table 5 and is critical in determining yield (Cock and El-Sharkawy, 1988).

Nevertheless, in each of the classes of top weight there was a positive correlation between yield and average leaf photosynthetic rate (Table 5). The highest correlations were once again in the highest top weight classes, and lowest in the lowest class. The same trends were observed in the correlations between yield and mesophyll conductance. These data indicate that when insufficient light interception or leaf area is a problem in cassava growing then the use of selection based on leaf photosynthetic rates will not be effective, however where light interception is already at high levels then selection for photosynthetic rate is likely to lead to yield increases. It is also interesting to note that in the higher top weight classes the photosynthesis and harvest index are highly significantly correlated (r = 0.62 and 0.47, df38, for high and average top weights, respectively). On the other hand, there was not significant correlation between photosynthesis and harvest index in the low top weight group (r= 0.18, df45). Cock (1984) and Cock and El-Sharkawy (1988) have indicated that other things being equal increased photosynthesis will lead to increased harvest index.

The possibility exists that the relation between yield and biomass and photosynthetic rate is not causal. It has been shown that photosynthetic rate may be influenced by the sink or the capacity of the plant to absorb carbohydrates (Neales and Incoll, 1968). This seems to be unlikely in the case of cassava. Tan and Cock (1979) showed that reducing the aerial sink by pruning did not decrease the net assimilation rate and that the excess carbohydrate was effectively utilized by the roots. Similarly Cock et al (1979) showed that severe reductions in root number, and hence sink were required to decrease total biomass production. The authors do however concede that this is still an open question. Nevertheless, field selection for average leaf photosynthetic rate would select for plants that were not sink limited which is in itself a desirable character.

Considerable progress has been made in the last two decades on the use of visual characteristics and harvest index as tools for breeders to use in the selection process (see Cock and El-Sharkawy, 1988). It is suggested that field selection for photosynthetic rate can now be added as an effective tool for plant breeders. It may be too complicated for routine screening of large populations of progeny but can certainly be used for parental selection.

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Table 1. Some physical and chemical properties of the surface soil (upper 0.2 m) at the experimental site, the Patia Valley, Cauca, Colombia. Values are means of 12 profiles ± s.d. The site was closely grazed and then disked twice before sampling the soil.

Clay	Silt	Sand	Organic Matter	Conductivity	pH	Al	Ca	Mg	K
	$g\ kg^{-1}$			$S\ m^{-1}$			$c\ mol\ kg^{-1}$		
303 ± 55	232 ± 37	465 ± 31	20 ± 9	0.013 ± 0.003	5.8 ± 0.3	0.6 ± 0.3	3.4 ± 0.7	1.4 ± 0.6	0.13 ± 0.07

P(Bray II)	$N-NH_4$	$N-NO_3$	B	Zn	Mn	Cu	Fe
				$mg\ Kg^{-1}$			
3.2 ± 1.9	7.0 ± 5	3.3 ± 2.1	0.42 ± 0.12	0.56 ± 0.11	15.1 ± 5.1	0.75 ± 0.39	29.5 ± 21.4

Table 2. Rainfall record during the growing season 1986/1987 at the experimental site, the Patia Valley, Cauca, Colombia.

Month/year	Day	Rainfall (mm)	Month/year	Day	Rainfall (mm)
October, 1986	20-31	35	March, 1987	4	14
				8	8
November, 1986	9	16		16	15
	10	54			37
	19	18			
	20	32	April, 1987	2	20
	22	26		3	56
	28	22		16	4
		168		28	8
				30	4
					92
December, 1986	3	8			
	14	6	May, 1987	1	3
		14		3	23
				4	17
January, 1987	6	24		5	24
	7	16		16	40
	8	19		19	36
		59		24	40
					193
February, 1987	12	22			
	13	34			
	14	32			
	19	10			
		98			

Table 3. Data of yield, biomass, gas exchange and leaf nutrient concentrations of the cassava cultivars grown in the Patia Valley, Cauca, Colombia.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf Content N	P	K
	Mg ha^{-1}			%	μmol $CO_2 m^{-2} s^{-1}$	mmol $m^{-2} s^{-1}$		g kg^{-1}		
MBra 12	11.5	33.1	72.2	54	27.4	111	1311	37.2	2.6	7.7
MCol 22	12.7	19.3	58.4	67	22.0	95	947	45.4	2.3	8.6
MCol 72	4.6	21.6	37.5	42	24.4	101	843	43.7	2.4	6.2
MCol 638	5.1	33.6	50.3	33	23.3	93	908	40.9	2.4	8.8
MCol 1468	9.7	30.2	62.2	51	24.3	103	1263	40.9	2.2	6.8
MCol 1522	0.9	42.7	45.3	6	17.5	75	1201	48.2	3.0	11.9
MCol 1684	11.0	17.2	49.0	65	23.7	93	1493	46.8	2.5	8.9
MCol 1823	9.6	18.2	45.3	60	25.7	104	1061	41.4	2.7	9.5
MCol 1894	5.4	26.6	46.4	43	23.4	108	988	41.4	2.3	9.5
MBra 12	6.9	26.0	49.4	47	28.4	117	1406	45.5	3.2	10.1
MCol 1964	6.4	22.1	39.0	43	23.5	96	1003	44.0	2.8	9.8
MCol 2017	0.9	37.2	39.8	7	21.7	97	850	47.0	3.3	11.2
MCol 2019	2.3	10.9	25.2	57	19.5	79	956	50.4	3.1	12.6
MCol 2032	7.6	10.7	37.8	72	25.6	111	930	44.0	3.0	9.6
MCol 2054	9.3	15.9	39.6	60	26.1	114	1046	44.5	2.9	8.5
MCol 2057	9.3	46.1	72.7	37	27.8	122	948	49.0	3.0	9.5
MCol 2059	1.0	46.1	49.7	7	23.8	104	503	45.6	3.0	11.8
MCol 2215	12.2	10.9	41.1	73	23.7	95	923	50.1	2.9	9.8
MCub 49	6.2	34.6	50.2	31	29.0	117	1388	49.8	2.7	12.8
MCol 22	11.3	26.3	60.4	56	25.6	106	1056	56.3	2.9	12.4
MCub 74	10.2	28.6	64.3	56	26.5	106	1153	47.3	2.9	12.4
M Ecu 72	4.2	39.1	58.1	33	25.6	103	1351	50.7	3.1	12.7
M Mal 2	8.5	41.9	64.8	35	26.4	100	999	41.2	2.6	16.0
MMex 59	9.5	31.3	61.0	49	29.1	117	1182	38.1	2.4	11.6

Table 3. Cont.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf content N	P	K
	Mg ha^{-1}			%	$\mu mol\ CO_2 m^{-2} s^{-1}$	mmol $m^{-2} s^{-1}$		g kg^{-1}		
MPan 70	7.8	32.0	54.7	41	28.3	104	1262	39.2	2.7	15.4
M Per 245	8.1	43.5	67.7	36	21.5	80	622	44.2	2.7	13.7
MTai 1	11.9	45.3	84.1	46	27.9	106	1259	42.0	2.6	16.5
MVen 25	13.9	38.8	74.5	48	25.8	97	1245	40.6	2.4	11.8
MVen 77	10.8	28.6	59.1	52	21.8	87	1469	37.0	2.8	16.1
MCol 113	4.3	28.6	45.3	37	22.1	88	888	47.0	2.0	13.1
MVen 156	13.2	26.3	61.2	57	24.4	100	1032	41.4	2.7	10.2
HMC 1	5.0	16.4	31.8	48	25.7	102	1182	45.8	2.9	11.8
HMC 2	3.7	35.4	46.6	24	21.2	79	1377	46.2	3.0	10.1
CG1-37	7.9	12.0	39.6	70	23.6	93	1384	45.1	2.8	10.2
CG1-48	11.1	14.6	53.7	72	25.3	102	1445	47.6	3.0	9.9
CG4-27	10.1	14.8	57.2	74	25.4	102	1010	47.0	2.5	10.3
CG5-95	8.0	18.7	44.5	58	24.2	100	898	48.2	2.5	10.1
CG6-18	10.4	12.0	43.0	72	22.8	100	771	45.5	2.6	9.1
CG7-64	7.7	17.4	49.7	65	23.1	91	993	45.2	2.6	10.8
MCol 1468	10.3	21.1	55.0	62	24.0	100	1124	43.4	2.6	8.9
CG32-22	8.8	24.0	46.9	49	24.4	99	1223	40.3	2.9	11.8
CG354-2	5.9	35.7	53.7	34	23.6	94	1145	44.8	3.0	10.5
CG358-3	0.1	29.2	29.7	2	18.1	67	1217	45.8	3.1	12.2
CG401-3	4.0	36.2	49.0	26	18.4	78	740	42.0	2.8	13.9
CG401-6	1.1	25.3	29.2	13	19.4	81	1048	48.2	3.2	13.8
CG403-18	4.1	46.9	60.7	23	23.0	94	904	44.8	2.6	13.2
CG406-5	5.2	50.3	70.4	29	25.2	104	1027	45.4	2.8	17.6
CG406-6	2.7	47.1	56.2	16	23.5	101	868	35.0	2.7	14.8
CG487-2	5.3	46.1	66.4	31	19.8	83	1133	37.8	2.2	13.5

Table 3. Cont.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf content N	P	K
	Mg ha^{-1}			%	μmol $CO_2 m^{-2} s^{-1}$	mmol $m^{-2} s^{-1}$		g kg^{-1}		
MCol 1684	11.2	39.3	75.8	48	24.5	112	1148	38.4	2.4	13.7
CM 91-3	10.9	37.5	81.0	54	22.6	89	1051	35.4	2.4	14.0
CM305-41	13.4	32.0	74.2	57	26.2	106	1012	39.8	2.3	13.3
CM308-197	15.5	12.0	63.8	81	23.4	99	1079	39.8	2.4	10.9
CM342-170	17.1	17.7	67.2	74	24.2	102	857	37.5	2.3	7.3
CM344-71	7.7	26.0	51.8	50	22.4	95	1176	40.6	2.8	8.4
CM430-37	11.1	32.0	65.1	51	20.9	88	1343	34.4	2.7	9.7
CM489-1	10.6	23.4	70.0	67	22.6	96	1410	39.8	2.4	10.1
CM507-37	4.7	22.4	39.1	43	20.0	87	1310	37.8	2.4	10.4
CM523-7	10.0	15.4	46.9	67	21.0	96	1052	44.5	2.4	10.2
MVen 77	11.8	15.1	66.1	77	17.7	76	1064	44.0	2.6	8.8
CM681-2	6.8	22.4	41.9	47	18.8	90	1167	37.0	2.4	9.5
CM696-1	10.7	15.9	57.9	72	20.3	93	1079	43.1	2.3	14.4
CM847-11	11.7	22.1	60.1	63	23.1	97	795	43.4	2.7	12.3
CM849-1	13.8	48.4	86.2	44	25.4	109	875	41.2	2.6	11.8
CM854-21	6.8	58.1	77.4	25	25.0	105	1033	41.7	2.6	12.6
CM922-2	14.4	24.5	67.5	64	24.9	102	1270	45.9	2.8	10.7
CM955-2	5.9	26.0	44.8	42	23.0	101	849	41.7	2.8	11.9
CM962-4	13.4	27.6	68.5	60	25.0	109	1028	34.7	2.3	9.8
CM975-1	13.1	46.1	83.6	45	21.2	91	818	35.6	2.7	13.6
MBra 12	11.6	39.8	77.0	48	27.5	107	1134	40.5	2.8	11.8
CM975-5	14.0	25.5	69.3	63	21.7	94	1215	38.9	2.5	10.2
CM976-15	11.5	22.9	58.1	61	21.1	93	1029	45.1	2.7	13.3
CM981-8	11.5	20.8	52.6	60	24.2	103	970	38.5	2.4	9.7
CM982-20	7.5	20.3	55.2	63	20.9	87	1143	34.7	1.9	8.6

Table 3. Cont.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf content N	P	K
	Mg ha^{-1}			%	$\mu mol\ CO_2 m^{-2} s^{-1}$	$mmol\ m^{-2} s^{-1}$		g kg^{-1}		
CM996-6	6.3	29.9	66.1	55	22.3	91	1009	38.9	2.3	11.4
CM1014-2	9.7	19.0	50.5	62	28.3	116	1113	42.5	2.2	9.7
CM1015-16	17.5	22.4	72.1	69	25.6	101	1172	42.3	2.4	10.5
CM1015-34	14.3	24.5	69.6	65	25.1	104	787	41.4	2.2	9.4
CM1015-42	13.1	16.4	56.8	71	25.4	102	1034	44.0	2.5	11.1
MCol22	17.3	43.8	93.3	53	27.4	108	1361	41.2	2.2	12.2
CM1016-34	18.3	39.6	97.2	59	29.1	113	1301	40.3	2.1	9.1
CM1022-34	17.9	24.5	74.5	67	28.1	112	1235	41.7	2.2	8.8
CM1223-11	16.0	23.7	72.1	67	24.1	98	1145	41.7	2.0	10.4
CM1286-7	13.8	14.8	51.0	71	26.5	112	1349	44.5	2.6	8.8
CM1288-17	12.3	30.5	65.1	53	21.8	84	719	42.0	2.5	10.3
CM1297-9	15.6	31.8	77.1	59	27.5	110	879	40.9	2.4	11.3
CM1299-2	14.0	21.4	59.9	64	30.6	126	1043	37.8	2.1	7.8
CM1305-3	17.4	22.9	82.8	72	25.4	99	1330	35.0	2.0	10.5
CM1335-4	10.6	23.7	55.0	57	25.2	95	1172	43.1	2.7	9.8
MCol 113	5.8	24.5	50.5	51	27.3	105	1026	42.0	2.6	14.8
CM1491-5	11.2	25.8	65.8	61	25.6	96	1107	42.6	2.7	10.5
CM1533-19	9.8	22.7	62.3	64	25.7	98	1035	40.5	2.7	10.8
CM1585-13	11.5	18.8	58.9	68	23.8	93	804	45.9	2.7	8.4
CM1785-6	9.1	24.2	57.3	58	25.6	98	1159	42.6	2.7	13.1
CM1797-4	21.8	27.6	106.8	74	25.6	97	801	42.5	2.5	12.5
CM1797-8	13.4	13.3	55.0	76	24.7	96	1143	48.2	2.5	9.6
CM1918-3	6.4	15.1	32.8	54	23.0	88	1202	41.2	2.7	10.3
CM1999-5	8.0	30.2	53.1	43	23.2	89	1250	42.8	3.0	15.1
CM2086-16	7.2	27.1	48.7	44	25.6	98	1317	42.5	2.8	11.8

Table 3. Cont.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf content N	P	K
	$Mg\ ha^{-1}$			%	$\mu mol\ CO_2 m^{-2} s^{-1}$	$mmol\ m^{-2} s^{-1}$		$g\ kg^{-1}$		
MCol1468	10.0	24.7	58.6	58	25.0	100	911	44.5	2.7	9.9
CM2087-101	6.5	15.9	40.9	61	26.5	106	1465	45.9	3.2	15.9
CM2088-1	4.9	27.6	44.3	38	24.4	96	1150	43.4	3.2	17.5
CM2109-1	9.3	29.4	58.8	50	24.6	99	1171	40.0	2.7	19.3
CM2133-5	11.8	37.5	80.7	54	27.6	110	1260	41.2	3.1	18.2
CM2136-2	12.0	27.1	77.4	65	28.7	113	1189	45.6	2.5	12.6
CM2146-3	9.2	31.0	64.9	52	24.9	101	825	42.0	3.2	15.5
CM2156-3	7.8	28.6	55.2	48	21.1	84	1012	47.6	2.1	12.9
CM2157-1	13.6	18.2	69.0	74	25.4	107	1030	39.2	2.6	12.8
CM2166-6	10.0	23.4	57.3	59	24.3	107	1103	38.1	2.6	14.6
MCol 1684	9.5	21.6	53.6	60	23.6	99	1330	45.1	2.6	14.2
CM2174-7	6.4	22.1	44.8	51	22.5	94	1140	38.1	3.0	12.3
CM2177-2	5.3	30.2	49.2	39	21.7	91	1409	41.2	2.9	13.1
CM2298-3	6.3	26.0	46.8	44	22.9	92	1066	41.7	2.9	14.4
CM2306-7	6.5	34.6	58.0	40	21.3	89	1080	40.0	3.0	17.4
CM2452-5	5.4	35.2	56.3	37	20.3	79	1603	44.0	3.2	13.2
CM2481-2	11.7	34.9	81.0	57	25.2	103	1486	45.4	3.2	18.1
CM2952-3	10.0	32.0	62.7	49	20.5	90	1439	40.3	2.8	15.5
CM2962-4	11.2	20.3	56.5	64	22.2	93	933	40.6	3.0	13.7
CM3110-8	10.4	14.8	52.6	72	22.8	95	905	41.2	2.8	12.2
MVen 77	11.0	23.7	55.7	57	22.5	97	575	39.5	2.4	12.5
CM3168-15	9.6	20.8	48.7	57	17.9	75	1122	42.8	2.4	9.3
SG104-13	13.6	21.9	58.4	63	19.6	84	1127	43.4	2.5	9.4
SG104-74	11.9	35.7	71.6	50	21.7	94	1254	40.9	2.7	12.6
SG104-164	3.8	33.6	44.8	25	19.6	83	1260	45.4	2.8	11.1

Table 3. Cont.

Cultivar	Dry Root Yield	(1) Standing top Biomass	(1) Standing total Biomass	(2) Harvest Index	(3) Leaf Photo-synthesis	(3) Mesophyll Conductance to (CO_2)	(3) Leaf Conductance to water Vapor	(4) Leaf content N	P	K
	Mg ha^{-1}			%	μmol $CO_2 m^{-2} s^{-1}$	mmol $m^{-2} s^{-1}$		g kg^{-1}		
SG104-264	10.9	29.9	65.3	54	24.0	101	1632	41.7	2.8	13.2
SG104-283	13.9	22.4	63.5	65	21.5	97	1302	44.8	3.0	9.4
SM301-3	4.2	24.7	39.5	37	19.1	78	1496	37.5	2.2	13.3

(1) On fresh weight basis without including fallen leaves.

(2) Harvest Index = $\frac{\text{Fresh root wt.}}{\text{Total fresh wt.}} \times 100$

(3) Average of ten leaves

(4) Blended samples of five leaves.

Table 4. Correlation between total biomass and: top weight, average leaf photosynthesis, leaf conductance to water vapor and mesophyll conductance to CO_2.

Sample strata	Number of cultivars	Correlation coefficients of total biomass with			
		Top weight	Leaf photosynthesis	Leaf conductance to H_2O	Mesophyll conductance to CO_2
Overall sample	127	0.48**	0.37**	0.014 NS	0.33**
Low top weight (less than 23 t ha^{-1})	47	0.37**	0.09 NS	0.003 NS	0.09 NS
Average top weight (23 to 31 t ha^{-1})	40	- 0.01 NS	0.49 **	- 0.14 NS	0.43 **
High top weight (greater than 31 t ha^{-1})	40	0.28 NS	0.50 **	0.11 NS	0.47 **

(*) Significant at 5% level

(**) Significant at 1% level

(NS) Not significant at 5% level

Table 5. Correlation between dry root yield and: top weight, average leaf photosynthesis, leaf conductance to water vapor, mesophyll conductance to CO_2 and harvest index.

Sample strata	Number of cultivars	Correlation coefficients of dry root yield with: Top weight	Leaf photosynthesis	Leaf conductance to H_2O	Mesophyll conductance to CO_2	Harvest index
Overall sample	127	- 0.19 *	0.40 **	0.03 NS	0.39 **	0.75 **
Low top weight (less than 23 t ha^{-1})	47	0.10 NS	0.22 NS	- 0.01 NS	0.25 NS	0.71 **
Average top weight (23 to 31 t ha^{-1})	40	- 0.21 NS	0.50 **	- 0.16 NS	0.47 **	0.88 **
High top weight (greater than 31 t ha^{-1})	40	- 0.13 NS	0.53 **	0.23 NS	0.47 **	0.90 **

(*) Significant at 5% level

(**) Significant at 1% level

(NS) Not significant at 5% level

BIOLOGICAL CONTROL OF THE CASSAVA HORNWORM, *Erinnyis ello* (Lepidoptera: Sphingidae) WITH EMPHASIS ON THE HORNWORM VIRUS.

Anthony C. Bellotti*
Bernardo Arias V.

INTRODUCTION

The cassava hornworm *Erinnyis ello* is one of the most serious pests of cassava in the neotropics. Hornworm attacks often cause complete defoliation of cassava fields, resulting in losses of bulk root production and inferior root quality. Farmers often react to attacks by mainly excessive, ill-timed applications of toxic pesticides. This has often resulted in repeated and more severe attacks (Bellotti and Schoonhoven, 1978).

Cassava is a perennial shrub of the Euphorbiaceae but for commercial purposes is usually grown as a biennial. Its long vegetative cycle makes it particularly vulnerable to pest attack. Pesticides are rarely important in the traditional cropping systems where cassava is usually grown and its long production cycle makes their repeated use uneconomical (Bellotti et.al, 1988). In addition pesticide use is discouraged since it often leads to outbreaks of other pests such as mites.

Adequate host plant resistance to the cassava hornworm does not exist although some ovipositional preference has been detected (Bellotti & Arias, 1988).

There is extensive complex of natural enemies associated with the cassava hornworm in the neotropics; however, sporadic and unpredictable attacks of the hornworm, often occur when populations of natural enemies are low and therefore, unable to prevent severe outbreaks. Careful monotoring of the hornworm population together with manipulation and management of certain natural enemies is the key to successful control of the cassava hornworm.

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Crop Damage

Hornworm larvae will feed on all cassava leaves and on the young tender growing stem and leaf buds. Attacks can occur at any plant age but young plantations (2 to 5 months) are preferred. Research has shown that losses in root production due to hornworm attack are influenced by plant age, soil fertility, environmental factors (especially rainfall) and frequency of attacks. Yield losses in fertile soils ranged from 0 to 25% for one attack and up to 47% after two consecutive attacks. Losses on less fertile soils were from 15 to 46% for one attack and up to 64% after two attacks. After plants have reached 6 months of age, losses are less severe although root quality may be adversely affected.

Biology and Ecology

Hornworm adults oviposit small (1 to 1.5 mm) round, light green to yellow eggs, individually on the upper surface of cassava leaves. In field cage studies female oviposited an average of 440 eggs, although as many as 1850 eggs per female have been observed. Eclosion occurs 3 to 5 days after oviposition.

There are five larval instars. Duration of the larval period is influenced by temperature. At 15, 20, 25 and 30°C, larval duration averages 105, 52, 29 and 23 days respectively (Table 1). Fifth instar larvae are 10 to 12 cm in length and are responsible for up to 75% of total foliage consumption. Each larvae is capable of consuming 1100 cm^2 of leaf during its larval cycle.
Pupae are dark brown in color and about 45 mm long. Pupation occurs in plant debris or within the first 5 to 8 cm of soil surface. The pupal stage lasts from 10 (at 30°C) to 41 (at 15°C) days.

In large field cages (3 x 2 x 2 m) adult females live an average 9 days while males averaged 7 days. Copulation usually occurs at night and during the first 24 hours after emergence. Oviposition is initiated three days after copulation.

Adult Migration.

The genus Erinnyis (Sphingidae) is principally found in the neotropics. E. ello is the most common species and is distributed throughout South, Central and North America, up to Canada. This wide distribution derives from strong flight abilities (Wolda, 1979), broad climatic adaptation and wide host range (Winder, 1976; Janzen, 1985). Larvae have been reported feeding on 35 different hosts in 10 families including papaya, tomato, tobacco, and cotton.

The migratory and flight capacity of E. ello is well documented (Winder and Abreu, 1976, Janzen, 1986, 1987). It has been found on the Galapagos Islands, 600 miles from the mainland. From field observations in Costa Rica, Janzen (1987, Pers. Com.), concludes that adults migrate from the Pacific side of Costa Rica to the Atlantic rainforest and that this migration is synchronized to the onset of the rainy seasons.

In the subtropical zone of Santa Catarinha in southern Brazil, E. ello is absent during the winter months of June through September. However populations begin to appear in October with attacks occurring from November through April. It is possible that E. ello is overwintering in the pupal stage but no evidence of this has been recorded in this region where temperatures can fall to 0°C. It is suspected, but not proven, that E. ello adults migrate from the warmer northern regions and pass several generations moving from one cassava-growing area to another within the southern region of Brazil (Pers. Obs.). Migration patterns are also suspected in Cuba where E. ello populations appear to be absent from the island during the colder months. This type of ecological migration is an escape from inhospitable environmental conditions (Danthanarayana, 1986).

Johnson (1960) states that "migration is an evolved adaptation for survival and reproduction, so promoting genetic fitness". Wallner (1987) attributes migration to several factors including food availability, insect density, environmental conditions and natural enemies. He further states that "evidence suggests that natural enemies may have a minor role in population dynamics of rare, endemic, and gradient insects but a major role in those of cyclic and irruptive pests". Andrewartha and Birch (1982) attribute insect irruptions to an unusual increase in food quality, reduced natural enemy pressure, or an extended period of favorable weather. They also state that "natural enemies are a more important factor in complex perennial systems". Janzen (Pers. Com.) speculates that E. ello probably evolved in the complex perennial rainforest of the neotropics.
The role of these factors in hornworm outbreaks will be discussed later in this paper.

The Natural Enemy Complex

A large complex of natural enemies is associated with cassava hornworm pupulations in the Americas. Winder (1976) describes more than 30 species of parasites and predators attacking E. ello. Recent studies at Centro Internacional de Agricultura Tropical (CIAT) have recorded 34 species of parasites and predators of the egg, larval and pupal stages and three species of microorganisms associated with the hornworm (Bellotti and Arias 1988).

Eight microhymenopteran species of the families Trichogrammatidae, Scelionidae and Encyrtidae are egg parasites. Of these, Trichogramma and Telenomus are the most important. Several species of Trichogramma parasitize hornworm eggs (Winder 1976, Bellotti and Arias, 1988). A three year study in the Cauca Valley of Colombia measured egg parasitism at between 53 and 57% (Bellotti and Arias, 1988). Release of Trichogramma during hornworm adult oviposition significantly increases levels of egg parasitism. One parasitized hornworm egg yields an average of 23 Trichogramma offspring, making it an effective parasite during high hornworm densities.

The Telenomus egg parasite is considerably larger than Trichogramma and appears to be a better "searcher". Each Telenomus can parasitize an average of 32 hornworm eggs and approximately 3 Telenomus adults emerge from each parasitized egg (Bellotti etal. 1983).
Numerous dipteran and hymenopteran parasites attack hornworm larvae (Winder 1976, Bellotti and Aris, 1988). Tachinid flies are the most important

group of dipteran parasites, especially in Brazil where 8 species have been identified. Of the hymenopteran parasites, the Braconidae, particularly those of the genus *Apanteles* are the most important, especially in Colombia. Adult *Apanteles* females oviposit within hornworm larvae; after 14 to 16 days parasite larvae emerge and form a white cottony web, which contains up to 500 pupal cocoons, around the parasitized hornworm larvae. In 5 to 6 days the adult parasites emerge (Bellotti and Arias, 1988). Studies at CIAT (1978) showed that *Apanteles* releases increased field parasitism levels to 27%, however, high levels of hyperparasitism associated with the *Apanteles* reduces the effectiveness of this parasite in the field.

A large group of predators attacks hornworm eggs, larvae and pupae. The most common egg predators are *Chrysopa* spp., which feed by sucking out egg contents. Laboratory studies showed that one chrysopid can consume 17 hornworm eggs per day.

The most important larval predators are *Polistes* spp. (Hymenoptera: Vespidae) and the *Podisus* spp. (Hemipteran: Pentatomidae). *Polistes erythrocephalus* generally lives in small colonies in or around cassava fields. Their sting paralyzes hornworm larvae which are then carried to the nest to feed developing wasp larvae. Those hornworm larvae that are too large to transport are sectioned into strips, rolled up, and carried to the nest. *Polistes* predation levels are primarily determined by the number of wasp larvae contained in the nest. Each *Polistes* larva will consume about 0.5 hornworm larvae daily (Bellotti and Arias, 1988). *Polistes* wasp populations can be maintained in cassava fields by constructing roofed, open-sided, huts to protect wasp colonies. Wasp nests, preferably with less than 50 cells can be attached to beams under the protective covering.

The bacterial pesticide, *Bacillus thuringiensis* has been shown to be effective in controlling hornworm larvae. Larval mortality reached 68% in field studies 3 days after *Bacillus* application. The bacteria is most successful against the first 3 hornworm larval instars.

Cordiceps sp. (Ascomycetes: Clavicipitaceae) is a soil fungus, the mycelium of which invades the pupal stage of the hornworm. In some cassava-growing regions of Colombia, natural field populations of the fungus cause considerable pupal mortality. The fungus can be cultured in the laboratory on a oat-agar media. In controlled experiments, soils innoculated with the cultured fungus resulted in 80% mortality to hornworm pupae (Bellotti and Arias, 1988).

The Cassava Hornworm Virus.

In 1980 field populations of hornworm larvae were found to be infested with a disease that cause considerable larvae mortality in CIAT fields. Samples sent to Boyce Thompson Institute (Cornell University, Ithaca, N.Y.) identified it as a granulosis virus of the family Baculoviriidae (Granados, Personal Communication). Subsequent studies have evaluated the potential of this virus for the control of *E. ello* (Arias and Bellotti, in press, Bellotti and Arias, 1988).

Virus infected larvae collected from the field were liquified in a blender and the mixture filtered through cheesecloth to remove large particles. The resulting liquid was diluted with water to a 30% concentration. Five and 10 cc of this solution were mixed with 1 liter of water and applied to cassava fields. Hornworm larvae fed in the virus-infected fields for 24 hours. Fifty larvae were collected from plots where the virus was applied as well as from control fields where no virus was applied. Collected larvae were maintained separately in the laboratory and fed only non-virus infected larvae.

Larval mortality was observed 48 hours after application; at the 10 cc dose larval mortality was 82% after 48 hours and 100% at 72 hours (Figure 1). At the 5 cc dose, larval mortality reached 45% at 48 hours, 88% at 72 hours and 100% at 96 hours. Due to contamination of the control larvae, mortality was 32% after 96 hours.

A second trial was carried out in the field in El Patia (Cauca, Col.). Freshly collected virus prepared at a dosis of 70 gr. in 200 liters of water was applied to hornworm infested fields. Hornworm populations were monitored on 50 plants in the treated and non treated plots before application and 48 hours post application. Mortality at 48 hours was 99.75% (Table 2).

Production of Hornworm Baculovirus.

A laboratory procedure was established to produce a powdered form of the virus. This procedure begins with the liquification of virus-infested hornworm larvae from the field followed by separation of residual skins through a sieve and then by filtration. Impurities are decanted and the virus inclusions are separated by centrifuging. Virus inclusions are mixed with water and chloroform and eventually vacuum dried a powdered form (Figure 2).

Evaluation of Virus Sources:

A field experiment was conducted at CIAT to evaluate the source and storage of virus on hornworm mortality. Two-year stored powdered virus, virus-infected hornworm larvae stored frozen for four years, and recently collected virus-infected hornworms were compared The following solutions were used:

1) Virus powder: stock solution of 0.26% (2.6 grams/liter distilled water).

2) Frozen larvae (4 years): stock solution of 6% (60 grams of infested larvae in 1 liter/distilled water).

3) Recently collected larvae: stock solution of 6%.

Treatments were made in 15-plant plots separated by 20 rows of cassava plants. The number of hornworm eggs and larvae were evaluated in each plot prior to application. A 10% solution of the previously described stock solutions were applied to their respective plots. Evaluations were made at 41, 89, 113 and 161 hours after virus application.

Virus extracted from recently collected Infected hornworms resulted in 100% hornworm mortality within 161 hours after appplication (Figure 3). The virus from four-year frozen hornworms resulted in 67% control while virus in powdered form reached only 27% mortality. These results indicate that virus storage for long periods of time is very feasible and further research needs to be done in this area.

Farmer Application of the Hornworm Virus:

A hornworm virus, Baculovirus erinnyis, has been found naturally infesting cassava hornworms in Brazil, in the Santa Catarinha area. By using the frozen hornworm/virus technique, the virus is available on a semi-commercial basis (EMPASC, the Santa Catarinha State Research Institute, prepares and stores the frozen virus which is available to scientists, extension workers, farmers, etc. upon request). Through printed material, newspapers, audiotutorial units, radio and television, farmers are instructed on the collection, preparation storage, and application of diseased larvae. The hornworm virus is being used effectively by farmers in several areas of Brazil (Schmidt, 1988).

DISCUSSION

In spite of the large complex of natural enemies previously described and their apparent success in causing hornworm mortality, hornworm outbreaks continue to occur periodically in cassava plantations throughout the neotropics. In certain areas, these outbreaks occur almost annually. In other areas cyclic outbreaks may occur every 3, 4 or 5 years. Light trapping data (Bellotti et. al. 1983) shows that these outbreaks are characterized by an "invasion" of migrating adults resulting in considerable oviposition. Several hundred eggs per plant have been observed. The natural enemy population present in the field is not adequate to control larval populations, resulting in severe defoliations and yield losses.

A probable explanation for this phenomenon is based on the migratory behavior of the adults. Migration is a possible defense against the large complex of natural enemies associated with E. ello. Wallner (1987) states that "the equilibrium population size and dynamic behavior of many phytophagous insects is largely determined by their predators and host food" and "natural enemies are key factors in keeping many phytopghagous insects rare". Migrating E. ello adults oviposit in cassava fields where natural enemy populations are low and perhaps in equilibrium with the low native hornworm populations. Because their rate of reproduction is limited, predators and parasites usually cannot compensate quickly enough to suppress dramatic pest irruption of certain migratory lepidoptera (Wallner, 1987).

After one or possibly two generations of hornworm feeding, populations of natural enemies increase and food supply decreases due to severe host plant defoliation. E. ello adults are forced to migrate to other cassava fields or forests to seek a more favorable habitat. Janzen (Pers. Com.) supports this possibility and has indicated that in Costa Rican rainforests the first generation of sphingids (as well as other moths), produces an enormous pulse of carnivores (parasites and predators) that would make it almost suicidal to attempt another generation. This factor also helps explain why there seldom occurs more than one, or possibly two consecutive hornworm outbreaks in the same cassava field.

It has also been observed that hornworm outbreaks occur more frequently in areas of intensified cassava production. This has occurred in souhern Brazil, the middle altitude highland (1000 to 1400 m.a.s.l.) and the Atlantic Coast of Colombia, in Tabasco and Veracruz States of Mexico and in several areas of Cuba. The increased food supply combined with low carnivore populations make hornworm outbreaks a more frequent occurrance. Light trapping data in Colombia as well as other regions (Janzen, 1987) show that E. ello outbreaks usually commence at the onset of the rainy season. In subtropical areas such as southern Brazil and Cuba, outbreaks are timed to the onset of warm weather and rains. The food supply at this time, especially the young tender cassava growth that hornworm larvae prefer, is optimal as the rains stimulate considerable new growth. Undoubtedly, climatic conditions also play an important role in hornworm migration and population dynamics. Janzen has observed similar behavior with E. ello populations in Costa Rican rainforests.

A combination of factors including food supply, natural enemies and environmental conditions probably influence the migration of E. ello adults. This movement makes control of E. ello in cassava agroecosystems especially difficult. The application of pesticides is often unecomical and may destroy the natural enemy complex (Urias and Bellotti, 1987) resulting in more frequent attacks.
The rearing of parasites and predators is costly and the timing of releases difficult due to the migratory and cyclic habits of the adults. The use of light traps in cassava fields allow prediction of hornworm outbreaks and consequently more timely applications of pesticides or releases of natural enemies. However, cultures of parasites and predators would have to be continually maintained, at a high cost, to have available when outbreaks occur.

The hornworm virus offers a natural enemy that can be manipulated, maintained and managed at a relatively low cost. The virus can be easily stored in refrigerated form until required for application. The need to maintain a perpetual culture of parasites or predators is avoided. The application of the virus with a back-pack sprayer is easily achieved and the farmer or technician can maintain the culture by collecting infested larvae from the field for storage. This avoids the use of expensive pesticides or the maintenance of carnivore colonies. The E. ello virus combined with timely detection of hornworm outbreaks offers an effective and economical control of this pest.

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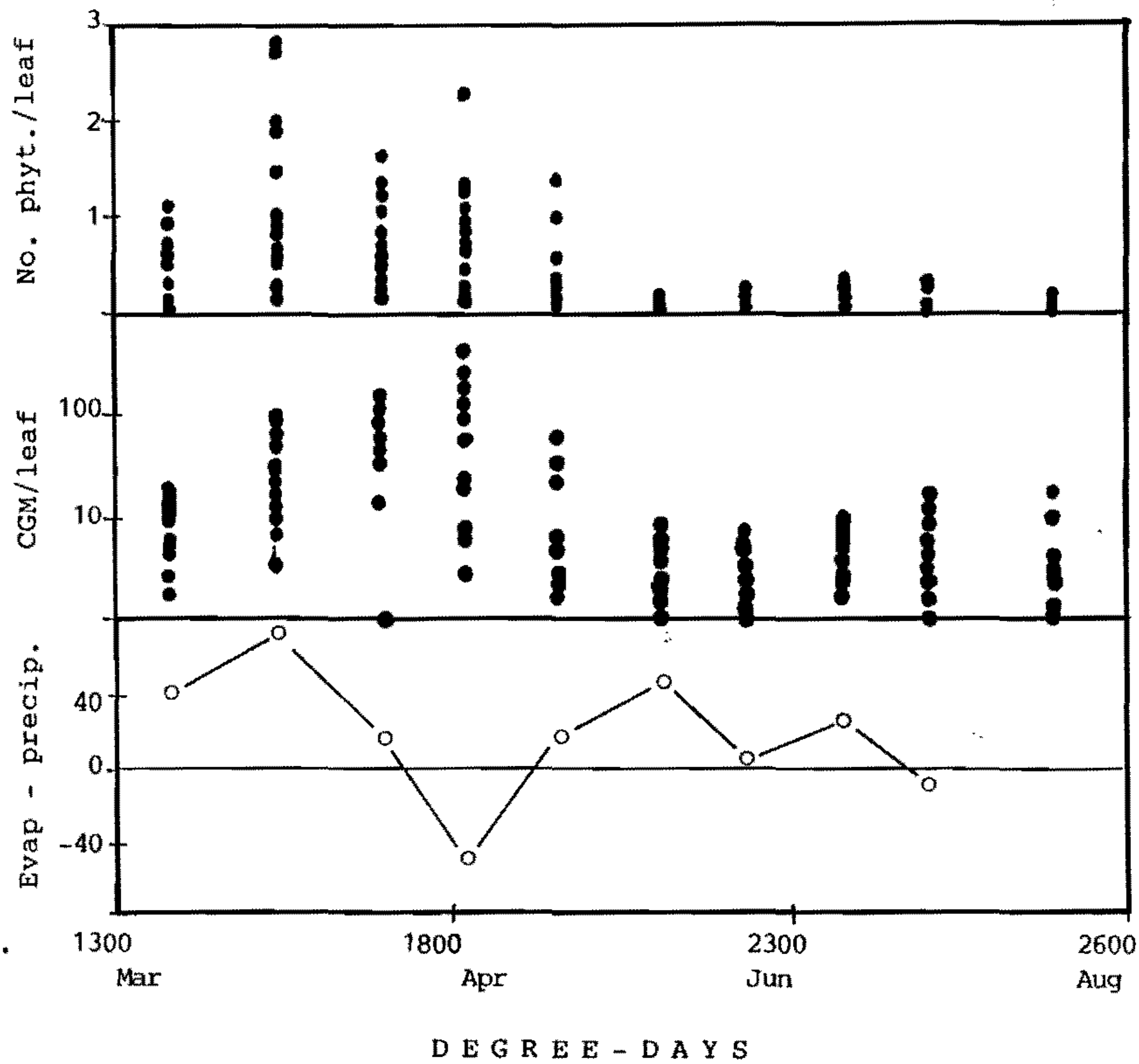

FIGURE 1. Phenology of CGM and phytoseiid predator densities in 20 cassava clones. Top panel: No. phytoseiids/leaf (n=30 leaves/clones); Center panel: No. CGM/leaf (n=30 leaves/ Clones); Bottom panel: Evaporation-precipitation (mm , summed over two week interval preceeding each sampling date).

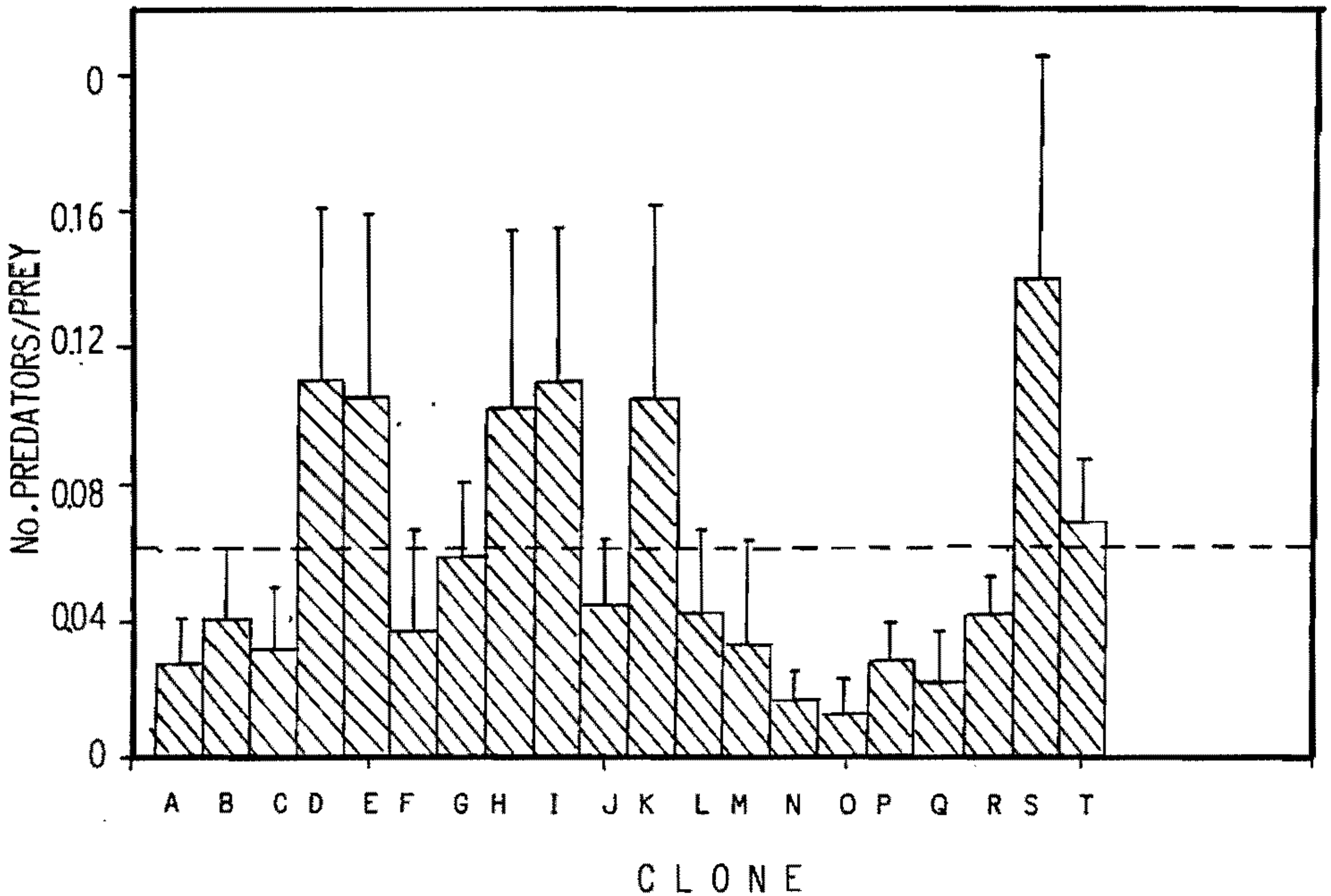

FIGURE 2. PREDATOR-PREY RATIOS (TOTAL PHYTOSEIIDS; CGM) IN 20 CASSAVA CLONES. BARS ARE STANDARD DEVIATION. DOTTED LINE IS THE MEAN RATIO (0.059).

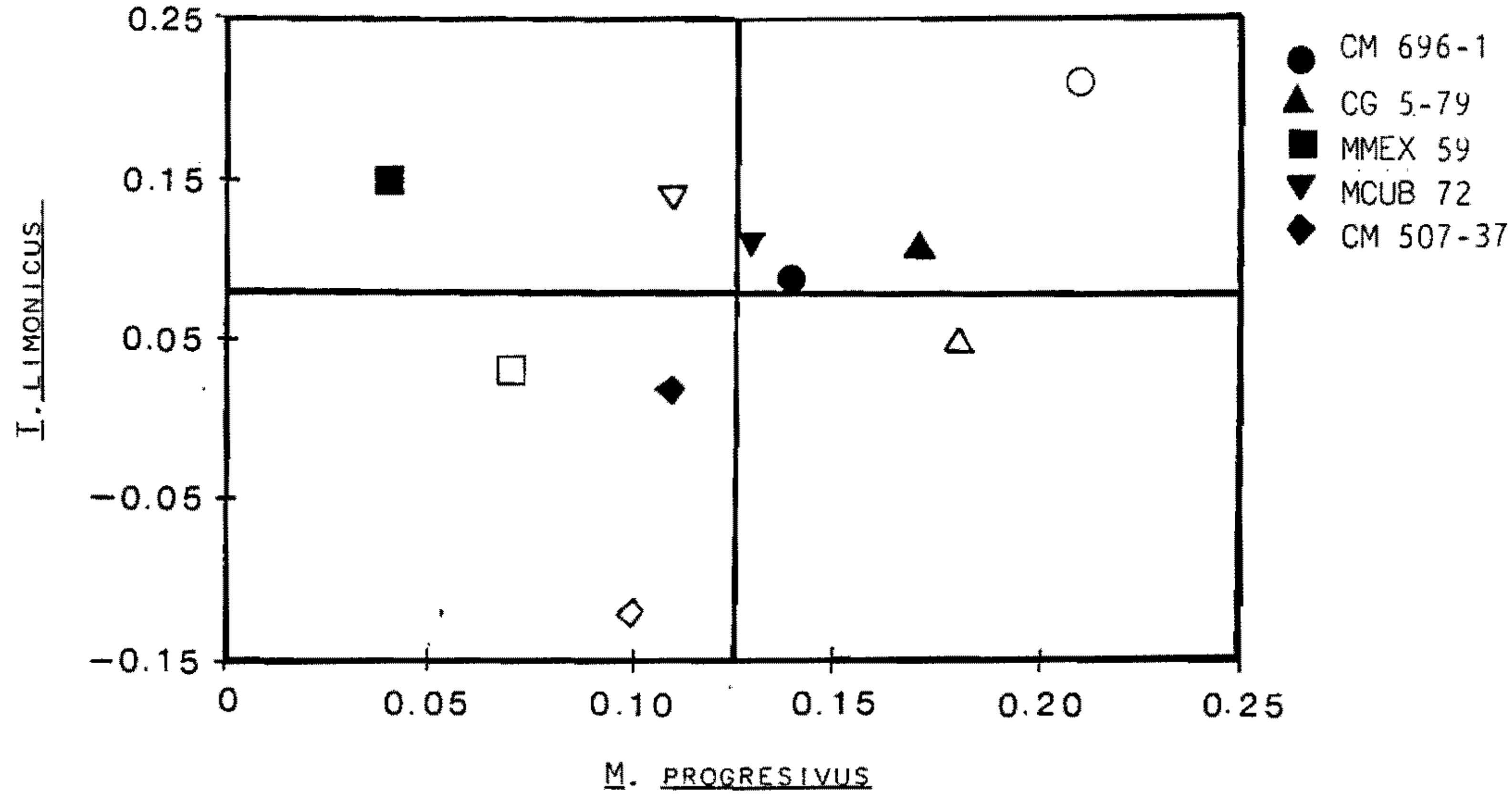

FIGURE 3. INTRINSIC RATE OF INCREASE, R_M OF M. PROGRESIVUS AND ITS PREDATOR T. LIMONICUS IN CASSAVA CLONES. (FILLED SYMBOLS ARE VALUES FROM PARENTAL GENERATION ON EACH CLONE; OPEN SYMBOLS ARE FROM THE F1.; THE PARENTEL GENERATION ORIGINATED FROM PARENTS TAKEN FROM A COLONY ON CLONE CMC-40 ; SOLID LINES ARE MEAN R_M VALUES).

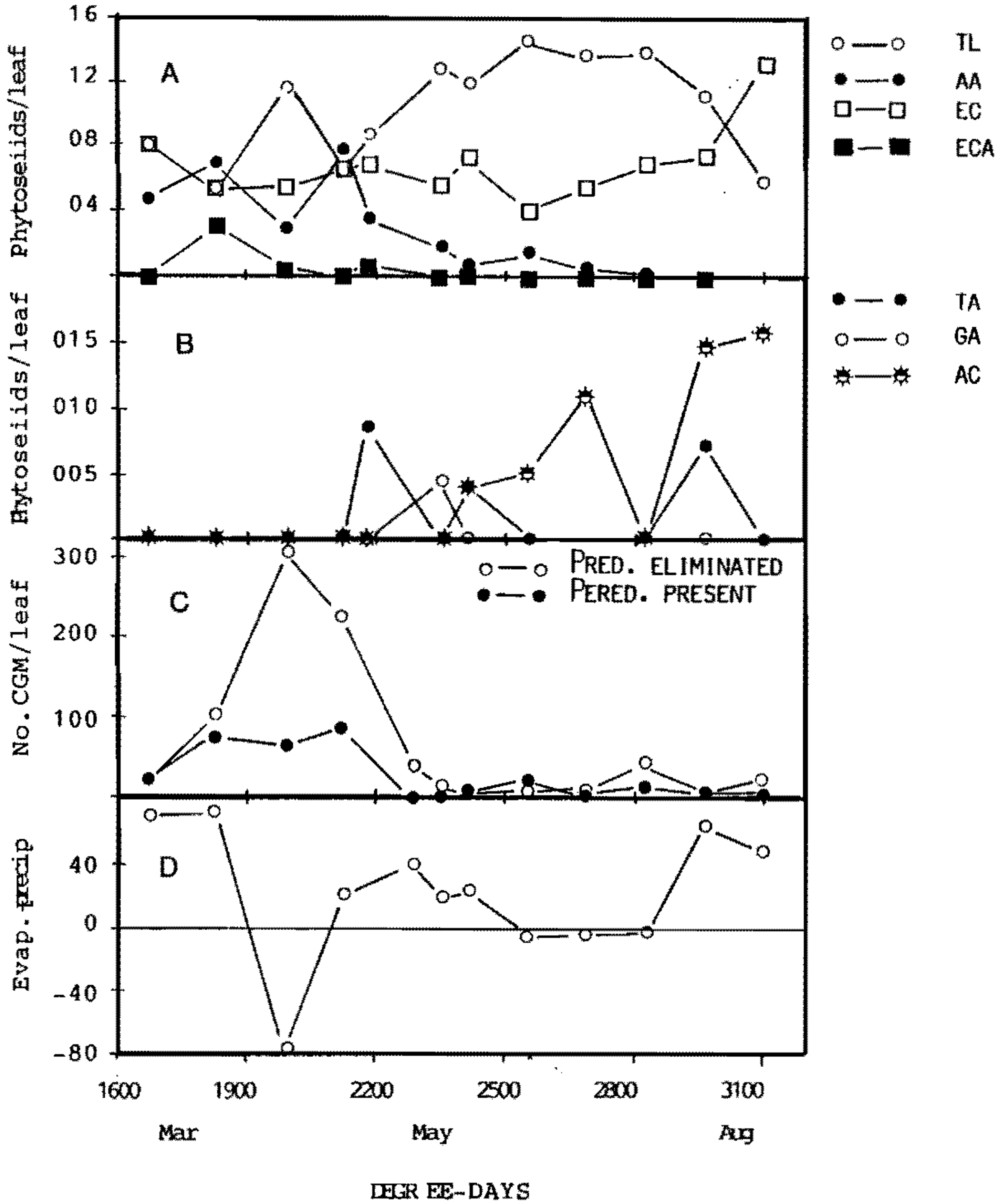

FIGURE 4. THE PHENOLOGY OF CGM AND PHYTOSEIID PREDATORS AT CIAT, CALI COLOMBIA. PANEL A, NO. OF T. LIMONICUS(TL), A. ANONYMUS(AA) E. CONCORDIS(EC) AND E. CASEARIAE(ECA) PER LEAF; PANEL B: NO. OF T. ARIPO(TA), G. ANNECTENS(GA) AND A. CALIFORNICUS(AC) PER LEAF, (DATA FOR PANELS A AND B ARE FROM UNSPRAYED PLOTS); PANEL C: NO. CGM/ LEAF IN UNSPRAYED AND PERMETHRIN-TREATED PLOTS(PREDATORS ELIMINATED); (EACH DATA POINT IN PANELS A,B AND C REPRESENTS THE MEAN OF 60 LEAF SAMPLES); PANEL D: EVAPORATION PRECIPITATION(MM) SUMMED OVER THE 15 DAY INTERVAL PRECEEDING EACH SAMPLING DATE.

OUTBREAKS OF CASSAVA DISEASES AND LOSSES INDUCED

J. CARLOS LOZANO

Cassava, *Manihot esculenta* Crantz (Euphorbiaceae), is a starchy root crop that is among the most important tropical foods. World production is estimated to be 120 million tons annually. Because the roots are 65% water, annual production is 42 million tons of dry matter, or the calorie equivalent to 40-50 million tons of grain. About 80% of the cassava produced is for human consumption and constitutes the principal carbohydrate source for more than 500 million people in many developing countries. In countries of tropical Africa, for example, cassava provides an average of 230 calories/person/day; in Zaire, the average daily intake is over 1,000 calories/day. The remaining 20% of production is used for animal feed and industrial purposes (Cock, 1985).

Cassava is grown between 30° north and south latitude under very broad climatic and edaphic conditions. The plant is completely domesticated and shows a high degree of local adaptation. Cassava is a perennial plant and is multiplied by cuttings from the woody stem. The large, swollen, true roots, resembling sweet potatoes, may be harvested seven months after planting in warm areas; however where temperatures are low, harvest may be delayed for 18 months or longer. The world average yield is 9 t/ha, but yields of only 4-7 t/ha are common in many areas. Under favorable, semi- commercial conditions, yields of 40 t/ha can be obtained (Cock, 1985).

Many cultivation systems have been developed, including mixed-cropping, that generally maintain stable, although low yields. Recent economic difficulties in most developing countries, have stimulated policy makers to reevaluate the potential of native crops as substitutes for foreign food imports (Horton *et al*, 1984). Partly as a result of this, cassava cultivation has been expanding rapidly, with concurrent increases in international exchange of planting material over the past 20 years. New areas with large monocrop cassava plantations are being established, and with this change, pathological and entomological problems are flourishing and causing heavy losses in many countries.

Importance of diseases on cassava

Cassava has been considered a species tolerant to adverse edaphic and climatic conditions as well as to the attack of pathogens and pests. This is correct when comparing production stability of native cassava clones with that of other crop species in a given region. A total crop failure is rare. Similarly, cassava produces satisfactory yields in areas where other crop species often fail (Cock, 1985; R. Moreno, CIAT, unpublished). However, when yields obtained by traditional cassava growers, or average yields in regions, countries or even continents, are compared with those obtained in experimental centers or by progressive cassava growers, differences are striking. A high percentage of this is due to the stress exerted by pathogens on the crop, even though other abiotic stresses also reduce yields simultaneously and severely.

Severe outbreaks of cassava diseases have been reported during the 1970's and 80's. The cassava bacterial blight (CBB) epidemic in Central Africa induced losses of around 80% (Persley, 1976) and in Zaire, where the plant leaves are an important source of protein for human food, the CBB-epiphytotic from 1970 to 1975 resulted in starvation (R. Zeigler, personal communication; Persley, 1976). In 1974 an epiphytotic, caused by a complex of pathogens reduced yields by approximately 50% in large plantations of Minas Gerais, Brasil as a result of the introduction of cuttings from infested plantations located several hundred miles away. Yields of cassava plantations along the Amazon River have decreased more than 30% due to a root rot induced by Phytophthora drechsleri. More than 70% of the plantations in the states of the Amazonas and Para are affected. The price of fresh cassava roots and farinha (a processed cassava flour used as food in Brasil) have increased 5 to 10 fold during 1988.

Several years of research in locations with diverse ecological conditions have demonstrated that cassava diseases are not universal. Pathogen distribution and incidence are limited by specific climatic and/or edaphic factors that restrict them to ecological zones (Table 1) (Lozano et al., 1984). Susceptible clones may not survive in areas of high disease pressure; however the performance and yield of the same clones may be very good in other locations (with different edaphoclimatic characteristics) where these diseases are not present (Table 2) (Lozano, et al., 1978). Disease constitutes an important factor that determines the stability of a clone in a given region (Lozano et al, 1984).

Yield losses due to diseases of cassava

Diseases of cassava can be arranged in four groups based on their effect on fresh root yield or root deterioration.

1. Wind blown pathogens. These agents are wind disseminated, and establish most readily during rainy periods. Leaf blight (Cercospora vicosae), brown leaf spot (Cercosporidium henningsii), superelongation (Elsinoe brasiliensis) and Phoma leaf spot (Phoma manihotis) are the most serious diseases of cassava belonging to this group. Losses have been evaluated by comparing yield (tons of fresh roots and/or starch/ha) of untreated controls with fungicide treated plots of clones with various degrees of resistance to these diseases (Teri, et al,, 1977; Zeigler, et al., 1984) (CIAT, 1974). Yield losses induced by these diseases are mostly due to the effect of defoliation and, in the case of superelongation and phoma leaf spot, by dieback (Zeigler, et al., 1984; CIAT, 1974); losses range from 18.8 to 92%, or from 9,5 to 12,5% loss of starch content (Table 3).
2. Stem borne pathogens. Pathogens of this group systemically infect stems, decreasing the sanitary quality of planting material. Dissemination to other locations is mostly via infected vegetative planting material. Invasion of stem tissue is relatively slow, particularly for pathogenic fungi and bacteria invading lignified stems of intermediate resistant or resistant clones (Lozano, 1986). The most important diseases of this group are: cassava bacterial blight (Xanthomonas campestris pv. manihotis), viruses, diplodia (D. manihotis) and fusarium (Fusarium spp.) stem and root rots.
   Losses induced by pathogens in this group are related to the degree of cutting infection and the percentage of infected cuttings planted in a given plantation. The degree of cutting infection increases by successive planting of cuttings from affected plants. The percentage of infected cuttings planted

is related to the number of infected mother plants at the time of cutting preparation. Mechanical transmission of some viruses and bacteria may increase if contaminated tools are not disinfested.

Losses induced by this group of diseases can be large (Table 3), particularly if a high percentage of severely affected cuttings are planted during a period of favorable climatic conditions for diseases. This results in epiphytotics, such as those reported for CBB in Africa and several regions of the Americas (Lozano, 1986).

3. Soil-borne pathogens. The continuous planting of cassava or other crop species increases the inoculum potential of soil-borne pathogens following introduction via infected planting material, plant debris, machinery, water, etc. They generally affect plants by inducing sudden wilting. Damage can be much more evident at harvesting when roots appear rotted. The degree of root infection depends on the soil infestation at planting which is generally several times higher than the incidence of root rot in the preceding harvest. Soil infestation increases during soil preparation, due to mechanical distribution of infected plant debris (especially by tractors) before planting. If non-lignified cuttings less than 10 cm in length are planted, a high percentage of plants will die before harvest or root rot severity is higher. Losses are generally evaluated by comparing amended plots where soil-borne pathogens are controlled through crop rotation, drainage, planting on ridges, etc. with unamended controls. Losses can reach 100% in some affected regions (Table 3), causing a considerable increase in the price of fresh cassava or byproducts.

4 Post harvest root rot. The usually great difference in the price of fresh cassava roots between producers and retailers is due to the high susceptibility of roots to both microbial and physiological deterioration after harvest (Wheatley, et al.). If roots are injured at harvesting, microorganisms belonging to various genera of fungi and bacteria penetrate and invade root tissues inducing rots a few hours after establishment. Affected roots are not edible; losses due to this are frequently high and generally represent more than 10% of all cassava roots produced around the world.

Due to the high percentage of starch in cassava roots (around 70%) many fungal and bacterial species, both saprophyte or pathogenic, are able to induce root rots after harvesting. The severity of deterioration is related to the damage induced at harvest and the length of time roots are stored before consumption or processing. Roots produced in highly pathogen-infested soils or in soils with high organic matter content may deteriorate more than those produced in pathogen-free or low organic matter soils. A simple record of percentage of rotted tissue/root after a given period of storage is used for the evaluation of post-harvest deterioration (Wheatley, et al., 1984).

Yield loss due to cassava bacterial blight

Losses induced by CBB vary throughout the world although they may be very high. Losses can reach 30% when cuttings taken from an infected plantation are planted in a clean plot (Lozano, 1986). If environmental conditions are favorable and no control measures adopted, losses can reach 80% within three successive cropping cycles by using planting material from the previous crop (CIAT, 1975; Lozano and Sequeira, 1974). Generally, losses due to CBB, for susceptible clones, are correlated with the number of infected cuttings (Table 4). The sprouting of buds from CBB-infected cuttings is low. Shoots that do emerge are foci of infection, increasing the incidence and severity of disease. Rain splash and high relative humidity favor bacterial establishment and invasion. Fresh root yield and number of marketable roots decrease, but starch and dry matter contents of roots are not affected (Otim-Nape, 1985). When weak pathogens such as *Colletotrichum* spp. and *Choanephora cucurbitarum* invade CBB-infected tissues, disease severity is higher due to the synergetic effect of the pathogens (Lozano, 1986). In an area where cassava anthracnose was present, losses exceeded 90% during the first cycle (Lozano, unpublished).

The evaluation of root yield losses due to CBB have been calculated based on plots planted with cuttings from affected plants or with CBB-free cuttings artificially dip-inoculated with a bacterial suspension (1 X 10^8 cfu/ml). For the calculation of losses due to CBB, anthracnose, and their synergetic effect, a strain of *Pseudomonas putida* was used to control *X. campestris* pv. *manihotis* and benomyl (Benlate, 2g/l) applied to control *Colletotrichum* spp. Around 7 spray applications of each was used to obtain a satisfactory control of each pathogen.

General conclusions

There are several diseases of cassava able to induce severe losses in areas where climatic and edaphic conditions favor spread. The severity of most diseases of cassava on susceptible clones is related to the sanitary quality of the planting material used for planting and the cultural practices applied to reduce the inoculum potential of cassava pathogens during its long growing cycles. Post harvest losses in cassava are so important that they have a profound impact on consumer preference.

Table 1. Damage induced by cassava diseases identified and evaluated in four ecosystems (edapho-climatic zones, ecz; see Lozano et al., 1984, for more complete description) in Colombia during 1979 through 1982.

	ECZ number and description			
Diseases	I Low rainfall lowland tropics	II Acid soil savanas, high rainfall	IV Mid-altitude tropics	V Highland tropics
Frog skin	-[a]	-	++	-
Cassava common mosaic	++	-	++	++
Bacterial blight	++	+++	-	-
Bacterial stem rot	-	-	++	-
Cassava ash	+	-	++	++
Brown leaf spot	++	++	++	-
Brown leaf blight	++	-	++	-
White leaf spot	++	-	+	++
Concentric ring-leaf spot	-	-	-	+++
Anthracnose	+	+++	+	+++
Superelongation	+	+++	+	-
Choanephora leaf blight	++	++	-	-
Root rots	+	+	+++	+
Diplodia stem and root rot	+++	-	++	-

[a] +++=Severe damage (yields were reduced at significant levels during the years of evaluation); ++= Moderate damage (yields were reduced at significant levels during one or two years of evaluation); += Light damage (yields were not reduced); -= Not observed (CIAT, 1981; Lozano, unpublished).

Table 2. Fresh root yield (t/ha) of different clones with different reactions to negative production factors (NPFs) existing in Popayán, Darién and CIAT ecosystems.

Clone	Popayán	Darién	CIAT
CMC 92	22.3[a]	26.6	8.2
Morada	16.5	18.3	
M Col 80	13.7	15.3	
M Col 235	14.5	11.5	
M Col 230	11.3	10.3	
M Col 307	6.5	6.7	
CMC 39	8.6	8.8	13.0
M Col 22	0.3	0.0	39.4
M Mex 59	0.9	2.4	33.1
CMC 40	3.8	5.3	42.2
CMC 84	1.0	4.0	40.3
CMC 76	0.5	1.4	36.0
M Col 113	5.0	2.5	26.8
CMC 9	0.5	0.1	31.7
M Mex 23	1.0	1.0	34.3

[a] Data taken during 1974-1975 by the Agronomy and Pathology sections of the Cassava Production Program at CIAT (Lozano, Byrne and Bellotti, 1980).

Table 3. Yield losses induced by cassava diseases on susceptible clones planted in locations where edapho-climatic conditions favored disease incidence.

Disease group according to pathogen dissemination	Yield reduction (%) Fresh roots	Starch content	Reference
Wind blown pathogens:			
Leaf blight	26.9	9.5	Teri *et al*, 1977
Brown leaf spot	18.8	12.5	Teri *et al*, 1977
Phoma leaf spot	92.0	-	CIAT, 1975
Superelongation	80.0	-	Zeigler *et al*, 1984
Stem borne pathogens:			
CBB	49.8 to 70.0	0.0	CIAT, 1974; Otim-Nape, 1985
Cassava bacterial stem rot	33.1	-	Lozano & Bellotti, 1978
Common mosaic virus	10.0-20.0	-	Costa *et al*, 1970
The frog skin	80.5	-	CIAT, 1981
The caribbean mosaic virus	69.5	-	Lozano *et al*, 1984
African mosaic virus	78.0-86.0	-	Bock, 1984
Diplodia and stem root rot	30.3	-	CIAT, 1986
Fusarium stem and root rot	20.0-100.0	-	Lozano, unpublished
Soil born patoghogens:			
Fusarium root rot	69.9	-	Lozano, 1988
Phytophthora root rot	69.9	-	Lozano, 1988
Rosellinia root rot	41.0	-	CIAT, 1973
Smallpox disease	62.3	-	Castaño *et al.*, 1975
Post-harvest root rots	100.00	-	Wheatley et al, 1984

Table 4. Yield reduction due to the use of cassava bacterial blight (CBB)-infected cuttings for planting a susceptible clone in a CBB-favorable location.

% of CBB-infected cuttings planted	Yield (t/ha)	Yield reduction (%)
0	28.9[a]	-
25	20.4	29.4
50	15.8	45.3
75	17.9	38.1
100	8.1	72.0

[a] Average data taken from six replicates of 30 plants/plot one year after planting.

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FIGURE 1. Effect of <u>Baculovirus</u> treatment on cassava hornworm mortality.

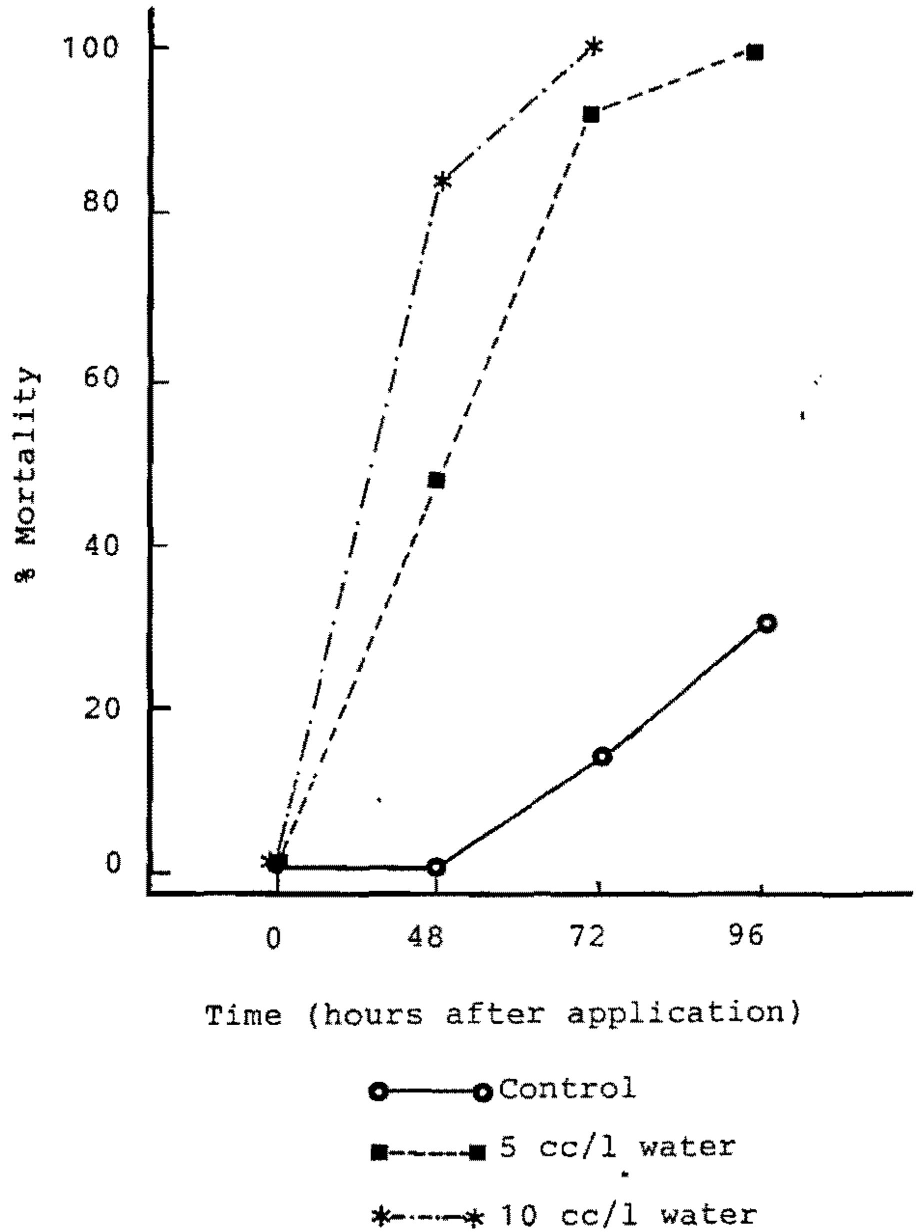


Figure 2 . Procedure for production of cassava hornworn Baculovirus.

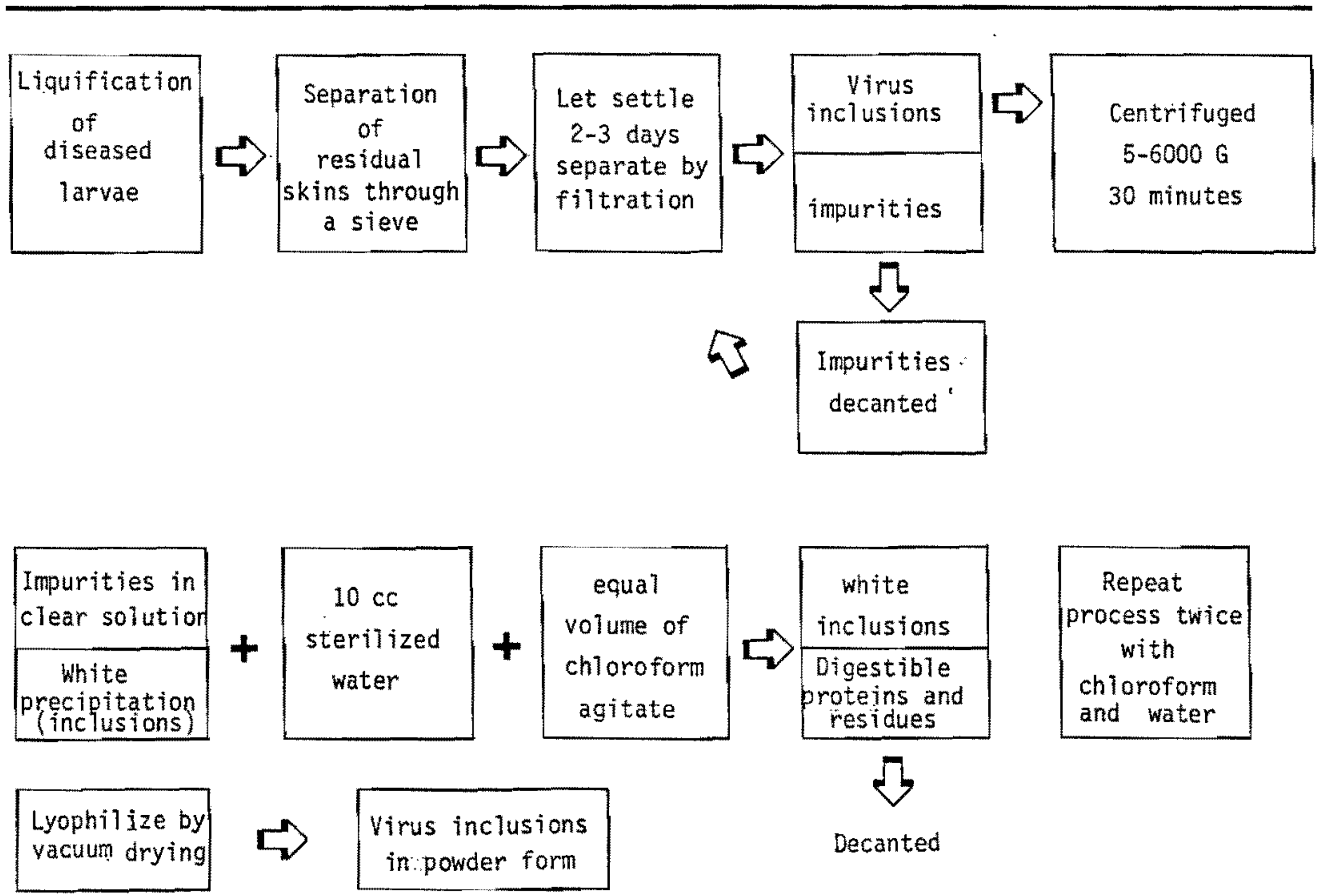
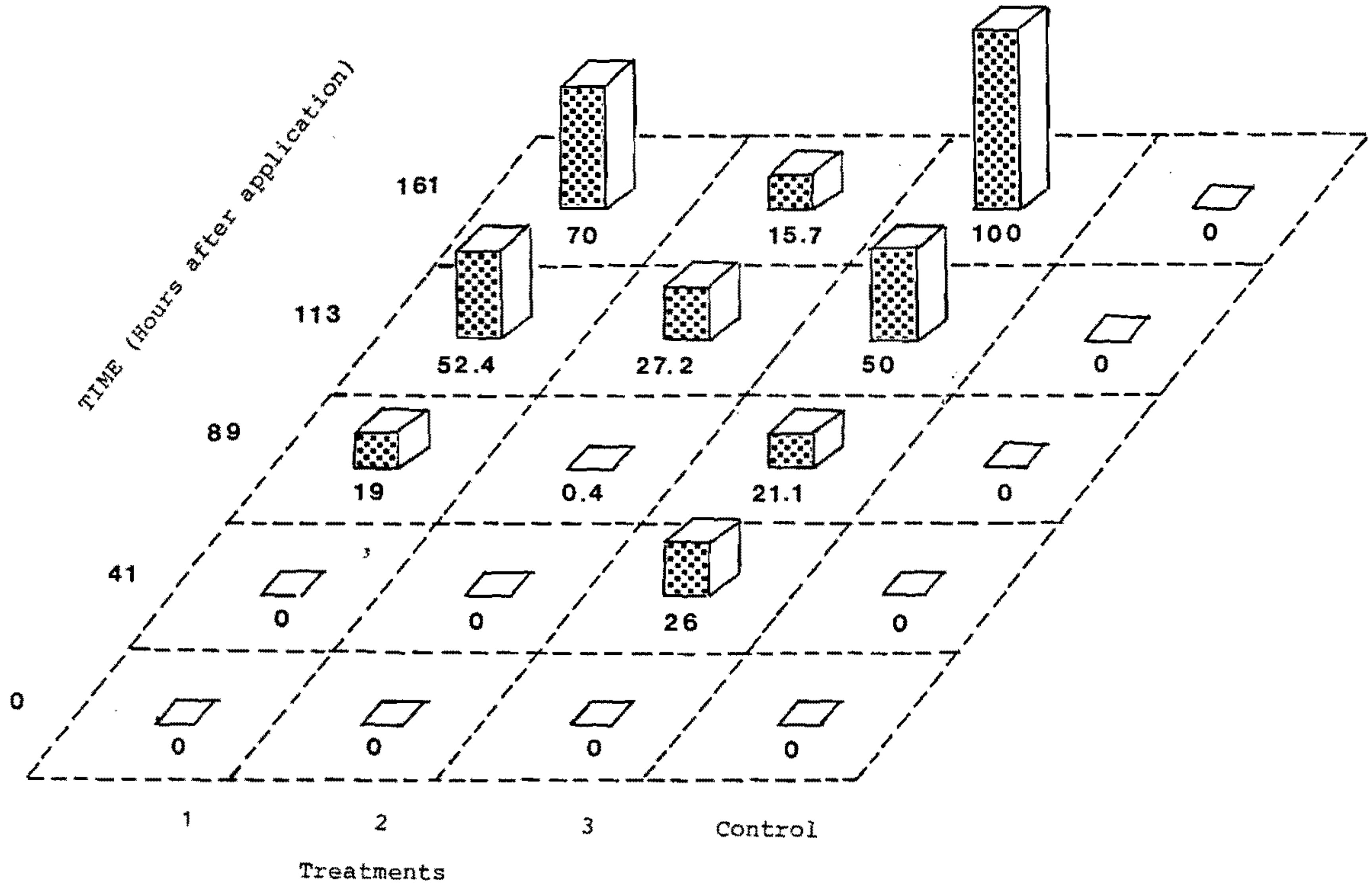


FIGURE 3. Effect of storage of the hornworm <u>Baculovirus</u> on % field mortality of cassava hornworm.



(Treat. 1 = stock solution prepared from 60 g larvae frozen for 4 years/l destiled water; treat. 2 = 2.6 g virus powder stored for 2 years/l destile water; treat. 3 = 60 g recently collected virus-infected larvae/l water; control = no application).

TABLE 1. THE EFFECT OF TEMPERATURE ON THE DEVELOPMENT CYCLE OF *Erinnyis ello*

TEMPERATURE °C	DEVELOPMENT STAGE (Days)				
	Egg	Larvae	Pre-Pupae	Pupae	TOTAL
15	8.0	44.0	11.3	41.4	104.7
20	5.0	19.6	3.7	23.7	52.0
25	3.0	10.4	1.8	13.7	28.9
30	1.9	9.6	1.2	10.0	22.7

TABLE 2. The effect of cassava hornworm virus on *Erinnyis ello* populations in El Patía (Cauca, Colombia).

INSTAR	1st Evaluation[1] (0 hours[2])		2nd Evaluation (48 hours)	
	No. healthy larvae	% healthy larvae	No. live larvae	% Mortality
I	136	34.00	1	33.75
II	217	54.25	0	54.25
III	46	11.50	0	11.50
IV	1	0.25	0	0.25

[1] 50 plants per plot evaluated

[2] After application