PD-AAQ-806
ISN: 32558

Annual Reports for 1982 and 1983

Grain Program

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The government of Colombia provides support as a host country for CIAT and furnishes a 522-hectare site near Cali for CIAT's headquarters. In addition, the Colombian Foundation for Higher Education (FES) makes available to CIAT a 184-hectare substation in Quilichao and a 73-hectare substation near Popayán; the Colombian Rice Federation (FEDEARROZ) also makes available to CIAT a 30-hectare farm—Santa Rosa substation—near Villavicencio. CIAT co-manages with the Colombian Agricultural Institute (ICA) the 22,000-hectare Carimagua Research Center in the Colombian Eastern Plains and carries out collaborative work on several other ICA experimental stations in Colombia; similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors, most of which are represented in the Consultative Group for International Agricultural Research (CGIAR). During 1984 these CIAT donors are the governments of Australia, Belgium, Canada, France, the Federal Republic of Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America; the European Economic Community (EEC); the Ford Foundation; the German Agency for Technical Cooperation (GTZ); the Inter-American Development Bank (IDB); the International Development Research Centre (IDRC); the International Fund for Agricultural Development (IFAD); the OPEC Fund for International Development; the Rockefeller Foundation; the United Nations Development Programme (UNDP); the United Nations Food and Agriculture Organization (FAO); the World Bank; and the W. K. Kellogg Foundation.

Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned entities.

Annual Reports for 1982 and 1983

Cassava Program

Centro Internacional de Agricultura Tropical

Contents

CASSAVA ANNUAL REPORT FOR 1982

Physiology 5

Soils and Plant Nutrition 25

Mycorrhiza Project 59

Entomology 71

Pathology 97

Germplasm Development 119

Varietal Improvement 133

Cultural Practices 145

Regional Trials 165

Cassava Utilization 171

Economics 181

Scientific Training 197

International Cooperation 209

Tissue Culture 213

Personnel (as of December 1982) 229

CASSAVA ANNUAL REPORT FOR 1983

Agroecological Studies 233

Physiology 239

Soils and Plant Nutrition 275

Mycorrhiza Project 301

Entomology 325

Pathology 371

Germplasm and Breeding 401

Tissue Culture 433

Cultural Practices 445

Cassava Utilization 477

Economics 487

Scientific Training and Conferences 511

Personnel (as of December 1983) 521

Physiology

The physiology section has continued to describe the growth and development of cassava under stress conditions to determine these characters associated with high yield under marginal conditions.

This year's work has concentrated on the effects of long days on different periods in the growth cycle, the efficiency with which absorbed minerals are utilized for root production, the control of stomatal aperture and its relevance to water use efficiency as well as the study of source sink relationship.

Photoperiod Response

Last year it was conclusively shown that long days, under field conditions, decrease root yield of cassava (Cassava Annual Report, 1981). Earlier work had also suggested that the main effect of long days occurred in the first three months after planting, however, these trials were done with M Col 22 and Llanera which are relatively insensitive to long days (Cassava Annual Report, 1976). M Col 1684, the most sensitive clone in last year's trial, was planted at three month intervals and long days (16 hrs.) simulated with artificial light for a period of three months so that plots received long days from 6-9, 3-6, 0-3 months after planting.

Long days from 6-9 months after planting had no significant effect on final root yield nine months after planting (Figure 1). Long days in last year's trial increased branching and hence final apex number per plant leading to increased stem growth and reduced root growth. The 6-9 month treatment had no effect on final apex number per plant, thus reinforcing the hypothesis that photoperiod has little effect on cassava growth and development after six months.

Long days from 3-6 months decreased yields markedly (Figure 1). Root growth rate was decreased by long days during the treatment period and the effect continued when natural day length was restored. (Figure 1). The daylength treatment had no marked effect on apex number per plant but markedly increased total node number per plant (Figure 2) due to an increase in rate of leaf formation per apex (Figure 3). The increased node number resulted in greater stem weight under long days and a reduced harvest index with no change in total dry matter produced (Table 1).

The final harvest data of the 0-3 month long day treatment has yet to be obtained. Nevertheless, certain conclusions can be drawn from the growth up to six months after planting. Total dry matter production was similar in both treatments however the harvest index at six months was much greater in the natural day plants (0.50) than the 16 hr. day plants (0.22). The accumulation of dry matter in the storage roots was minimal when the long day treatment ended three months after planting (Figure 1), however, the effect on the distribution of dry matter was marked in the next three month period.

These data suggest that cassava is sensitive to changes in photoperiod during at least the first six months of its growth. Long days stimulate top growth at the expense of root growth. The effects of long days may carry over beyond the period during which they occur, thus long days in the establishment phase may adversely affect root bulking even though this occurs under shorter day lengths.

Mineral Nutrition

Cassava is known as a crop that grows well and gives good yields on poor soils. The growth of cassava and nutrient absorption were measured under the fertile conditions of CIAT, Palmira in four clones. Data were generally similar for all four clones and so only those for M Col 1684 are presented except for cases where differences were notable. The final yield of M Col 1684 was 14.9 t dry roots/ha (41.9 t fresh roots/ha). The absorption of N, P, K over the growth of the crop and its distribution are shown in Figure 4 Total uptake 362 days after planting was 294 kg N/ha, 34.4 kg P/ha and 202 kg/K/ha. Absorption of all three major nutrients was greatest between 60-180 days, however, absorption continued until final harvest 362 days after planting. The nitrogen absorbed was distributed fairly uniformly between leaves, stems and roots; phosphorous was mainly distributed to the stems and potassium to the roots (Figure 4).

The weight of roots throughout the experiment was linearily related to the nutrient absorbed by the plant. In each case there was a threshold value below which no roots were formed, the threshold values were 85 kg N/Ha, 9.1 kg P/ha and 69 kg K/ha (Fig. 5). Above the threshold value the dry weight of roots produced were 67 kg roots/kg N, 555 kg roots/kg P, and 103 kg roots/kg K in M Col 1684. M Col 1684 was more efficient in terms of root production per kg absorbed above the threshold value than the other clones (Table 2) with this tendency most marked in the case of phosphorus. In order to produce a yield of 15 t dry roots/ha M Col 1684 needs to absorb 36 kg P/ha whereas M Ven 77 requires 52 kg P/ha, an increase of 44% in phosphorus requirement. This type of response might be expected when large differences in real harvest index (includes fallen leaves in total biomass) occur. M Ven 77 does indeed have a lower harvest index (0.40) than M Col 1684 (0.53). Nevertheless, M Ptr 26, with a harvest index of 0.52, still requires 27% more phosphorus absorbed than M Col 1684 to yield 15 t dry roots/ha. This suggests that it may be possible to select clones that are more efficient at producing roots in terms of nutrients absorbed.

The nutrient content of young leaves of plants 3 1/2 months old was high (Figure 6) but declined rapidly, stabilized at an intermediate value and then further declined immediately before leaf abscission. The final decline before leaf fall suggests that nutrients are translocated from the old leaves immediately before the leaves fall, thus conserving nutrients within the plant.

Most plant species under nutrient stress show a decrease in nutrient content of the leaves. Cassava tends to reduce LAI and maintains the nutrient content of the leaves (CIAT 1978). When corn and beans were grown in pots in a low nitrogen status soil the leaf nitrogen

content of the leaves was markedly reduced and photosynthetic rate of leaves was also reduced (Table 3). In corn and beans, a close relationship was found between photosynthetic rate of leaves and their nitrogen content (Figure 7). In cassava nitrogen status of the leaves was not reduced by low levels of soil nitrogen and leaf photosynthetic rate was also minimally affected although it showed marked differences between the two measurement dates. A canopy photosynthesis model was used to demonstrate that a plant that reduces LAI but maintains its photosynthetic rate of individual leaves will have greater primary production potential under nutrient stress than a plant that produces more LAI but reduces leaf photosynthesis (Figure 8). In cassava, this strategy is doubly effective as with reduced leaf area, the harvest also increases. The data and hypothesis demonstrate the physiological mechanisms that enable cassava to yield relatively well under nutrient stress conditions.

Stomatal Response in Cassava to Air Humidity

Last year it was shown that cassava stomata respond directly to changes in the leaf to air vapor pressure deficit (VPD). The response of cassava to changes in VPD was compared to that of several other plants. All the species tested showed a decrease in leaf conductance (i.e. stomatal closure) when the leaves were exposed to large VPDs (Figure 9), however, the response of cassava (as indicated by the slope of the regression line and also the correlation coefficient) was most marked in cassava. The stomatal response in cassava, siratro, amaranthus, beans and eucalyptus was such that only small changes in leaf water potential occurred (Table 4) suggesting that in these species a "feed forward" stomatal response occurred and that this was directly related to VPD. In rice, sorghum and andropogon the stomata remained open and transpiration increased with increased VPD leading to a change in bulk leaf water potential and probably a "feed back" stomatal response.

The "feed forward" response of cassava leads to a decrease in transpiration at high levels of VPD in contrast to a continued increase found in non-sensitive species (Figure 10). Thus, the closure of stomata in cassava at high VPDs tends to conserve water.

Stomatal closure does, however, lead to a reduction in photosynthesis as well as transpiration as photosynthesis under non-light limiting conditions is closely related to leaf conductance. Nevertheless, water use efficiency (WUE) is greater when leaf conductance is lower. Thus cassava has a greater WUE at any given VPD than the other C3 species tested, with the exception of siratro which is also sensitive, but has a lower WUE than the C-4 plants (Figure 11).

The real advantage of the feed forward stomatal reaction to changes in air humidity is, however, not seen by observing WUE at any given VPD but rather by looking at the average daily WUE. Sensitive and insensitive horizontally disposed C-3 leaves were simulated for daily total photosynthesis, transpiration and WUE using a very crude model. (Figure 12). It can be seen that the WUE is greatly increased by the direct response to air humidity, however, photosynthesis is also greatly

reduced by this response, nevertheless under the conditions used for the simulation model stomatal response to changes in VPD increased daily WUE by 40%.

This indicates that under conditions where soil water may be limiting, stomatal closure in response to increased VPD is an optimal strategy as dry matter production per unit of available water should be maximized. On the other hand when soil water is not limiting the stomatal closure will reduce total photosynthesis and hence growth and will not be an efficient strategy. Varietal differences in the stomatal response have been found and may be exploited to breed clones for the two situations described above.

M Col 1684 was grown at CIAT and half the field was artificially misted from 08:00 to 16:00 hours. The misting treatment increased the relative humidity of the air at 13:30 hours from an average of 44% to 58%. The field was irrigated at weekly intervals (unless it rained) so that the soil was kept close to field capacity and differences in soil water status were minimized. The photosynthetic rate of leaves when the photon flux density was greater than 700 N moles m^{-2} sec^{-1} showed a close relation to the relative humidity (Figure 13). Crop growth rate was measured over three week intervals. In the first two intervals crop growth rate was increased in the misting treatment when LAI was similar in both treatments (Table 5) indicating that the greater photosynthesis recorded at higher air humidity manifested itself in greater dry matter production. In the third interval crop growth rate was less in the misting treatment, this was probably due to decreased LAI in the misting treatment and heavy leaf fall. The loss in dry weight expected from a decrease in LAI from 3.0 to 2.4 about 15 g m^{-2} wk^{-1} accounts for the decreased CGR in the misting treatment in the third interval. These data reinforce the hypothesis that the stomatal response of cassava to changes in air humidity may be detrimental when soil water is not limiting.

In previous reports it has been suggested that top growth has preference over root growth and that photosynthate in excess of the needs of the tops is used for storage root growth. This increased photosynthate supply due to misting should lead to large increases in the root yield and these were observed (Figure 14).

Growth and Development

Four cassava clones M Col 1684, M Ven 77, M Ptr 26 and M Col 22 were grown at the CIAT station. There was a close relationship between the total dry matter produced and the photosynthetically active radiation (PAR) intercepted. There were no notable differences between varieties and dry matter was produced at 1.35 - 1.47 g/MJ. This corresponds to an efficiency of 2.3 - 2.5% in the conversion of intercepted PAR to biomass.

The efficiency of the conversion tended to decrease in plants over 185 days old. This tendency was observed in all clones and the reason why it occurs is not clear. Nevertheless, it appears to warrant further study as this phenomenon will limit potential productivity of cassava.

Four cassava clones were grown at CIAT, Palmira in two separate experiments. Data for M Ptr 26 are shown here but the other varieties behaved in a similar manner. Stem weight was a constant proportion of total dry weight irrespective of growth stage (Figure 15). Leaf weight (including dead leaves) initially comprised a high proportion of total dry weight but once the plants started to produce thickened roots this proportion decreased but was thereafter maintained at a constant value (Figure 15). No thick roots were formed until plants produced about two t/ha of total dry weight. The threshold weight, however, from this point on root weight was a constant proportion (root distribution index) of the new dry weight produced (Figure 15). These data are not completely in accordance with the hypothesis that root growth occurs only when there is excess of carbohydrates over top growth requirement and indicate a distinct physiological change in the plant at the time when roots to thicken. This would then suggest that root factors may influence top growth directly rather than root growth being dependent only on top growth.

When various combinations of grafts were made it was found that stock effects had a small but significant effect on LAI six months after planting, while differences between scions-were large irrespective of which stock was used with no scion stock interaction. Thus, top growth was largely determined by the scion but the stock had a limited effect.

There was no significant effect of either scion or stock on the dry matter produced per unit PAR absorbed. This indicates that no basic differences in photosynthetic efficiency existed in the cultivars used and also that stock sink limitations did not reduce photosynthesis by a feedback mechanism.

The stock did nevertheless markedly affect dry matter distribution to the roots. M Col 1684 stocks, irrespective of the scion, had high root distribution indices when compared to M Mex 59 or M Col 638 as a stock (Table 6). M Ptr 26 as a stock behaved as would be expected if distribution depended on excess of carbohydrate for shoot growth passing to the roots and shoot growth independent of the stock. Thus, the values of the root distribution index with M Ptr 26 as a stock are very close to those of the autografts of the scion - 0.61 and 0.56 for M Col 1684; 0.39 and 0.41 for Mex 59; and 0.34 and 0.39 for M Col 638. These data show that although the top growth preference seems to hold true in some cases it is not universally true where distribution of dry matter is concerned. On the other hand, the scion does seem to determine the threshold value above which root growth occurs. (Table 6).

Table 1. Effects of 16 hr days from 3-6 months on cassava nine months after planting.

	Dry root yield (t/ha)	Total dry weight (t/ha)	Shoot weight (t/ha)	Harvest index (%)
Control	6.2	16.7	10.5	37
16 hr days	3.0	16.4	13.4	18

Table 2. Threshold value for nutrient absorption and root weight per unit weight of nutrient absorbed above the threshold value.

Nutrient	Clone	Threshold value kg/ha	Root weight per unit/ weight of nutrient absorbed kg roots/kg nutrient
Nitrogen	M Col 1684	85	67
	M Ven 77	83	56
	M Ptr 26	92	65
	M Col 22	64	44
Phosphorus	M Col 1684	9.1	556
	M Ven 77	7.0	336
	M Ptr 26	9.6	417
	M Col 22	4.7	333
Potassium	M Col 1684	69	103
	M Ven 77	56	74
	M Ptr 26	37	89
	M Col 22	21	65

Table 3. Photosynthetic rate and nitrogen content of corn, bean and cassava leaves of plants grown in a low nitrogen status soil planted on 27 August 1982.

	Date	N (% dry weight)	N (mg dm^{-2} leaf)	Pn mg $CO_2 dm^{-2} hr^{-1}$
Corn no	21 Sept.	2.99	12.2	65
N_1	21 Sept.	3.72	14.5	67
Beans no	21 Sept.	4.81	17.5	52
N_1	21 Sept.	5.42	23.5	43
Cassava no	21 Sept.	4.62	21.5	42
N_1	21 Sept.	4.62	19.2	42
Corn no	6 Oct.	1.85	7.9	43
N_1	6 Oct.	3.43	14.9	57
Beans no	6 Oct.	3.38	11.7	26
N_1	6 Oct.	5.00	21.2	40
Cassava no	6 Oct.	4.44	22.7	28
N_1	6 Oct.	4.56	20.3	27

Table 4. Net photosynthesis, leaf conductance and leaf water potential of diffent C_3 and C_4 species.

Species	Net maximum photosynthetic rate (mg CO_2 $dm^{-2}hr^{-1}$) mean + s.d.	Leaf conductance to water vapor at VPD of 10 mb cms	% reduction in leaf conductance at VPD of 40 mb	Leaf water potential Ψ_L (-bar) Initial	Final
C_3 Species					
Cassava	41 ± 2.6	0.669	69	-/.5	-/.0
Siratro	51 ± 7.7	0.843	54	-5.0	-6.0
Beans	31 ± 1.4	0.697	57	-5.5	-7.5
Paddy rice	36 ± 9.0	0.614	32	-8.0	-17.0
Eucalyptus	29 ± 3.2	0.440	52	-6.0	-/.5
C_4 Species					
Grain sorghum	74 ± 8.2	0.607	36	-2.0	-12.0
Andropogon	50 ± 2.0	0.480	31	-6.5	-15.0
Amaranthus	57 + 2.7	0.600	50	-5.0	-6.0

Table 5. Growth of M Col 1684 under natural conditions and with an artificial misting treatment. Crop growth rate (CGR) gm^{-2} wk^{-1}.

	Period I		Period II		Period III		
Treatment	LAI	CGR	LAI	CGR	LAI	CGR	LAI
Control	2.1	70	2.0	70	3.0	42	2.8
Misting	2.2	83	2.2	50	3.1	60	2.4

Table 6. Threshold dry matter for root production and root distribution index of various graft combination. Root distribution index outside brackets, threshold value (t/ha) in brackets.

Scion \ Stock	Stock			
	M Col 1684	M Mex 59	M Col 638	M Ptr 26
M Col 1684	0.56 (3.2)	0.44 (4.1)	0.40 (2.2)	0.61 (2.6)
M Mex 59	0.56 (9.3)	0.41 (8.0)	0.30 (5.6)	0.39 (5.0)
M Col 638	0.53 (5.6)	0.39 (5.2)	0.34 (3.0)	0.34 (3.0)
M Ptr. 26	0.53 (2.5)	0.41 (3.7)	0.40 (2.7)	0.64 (4.2)

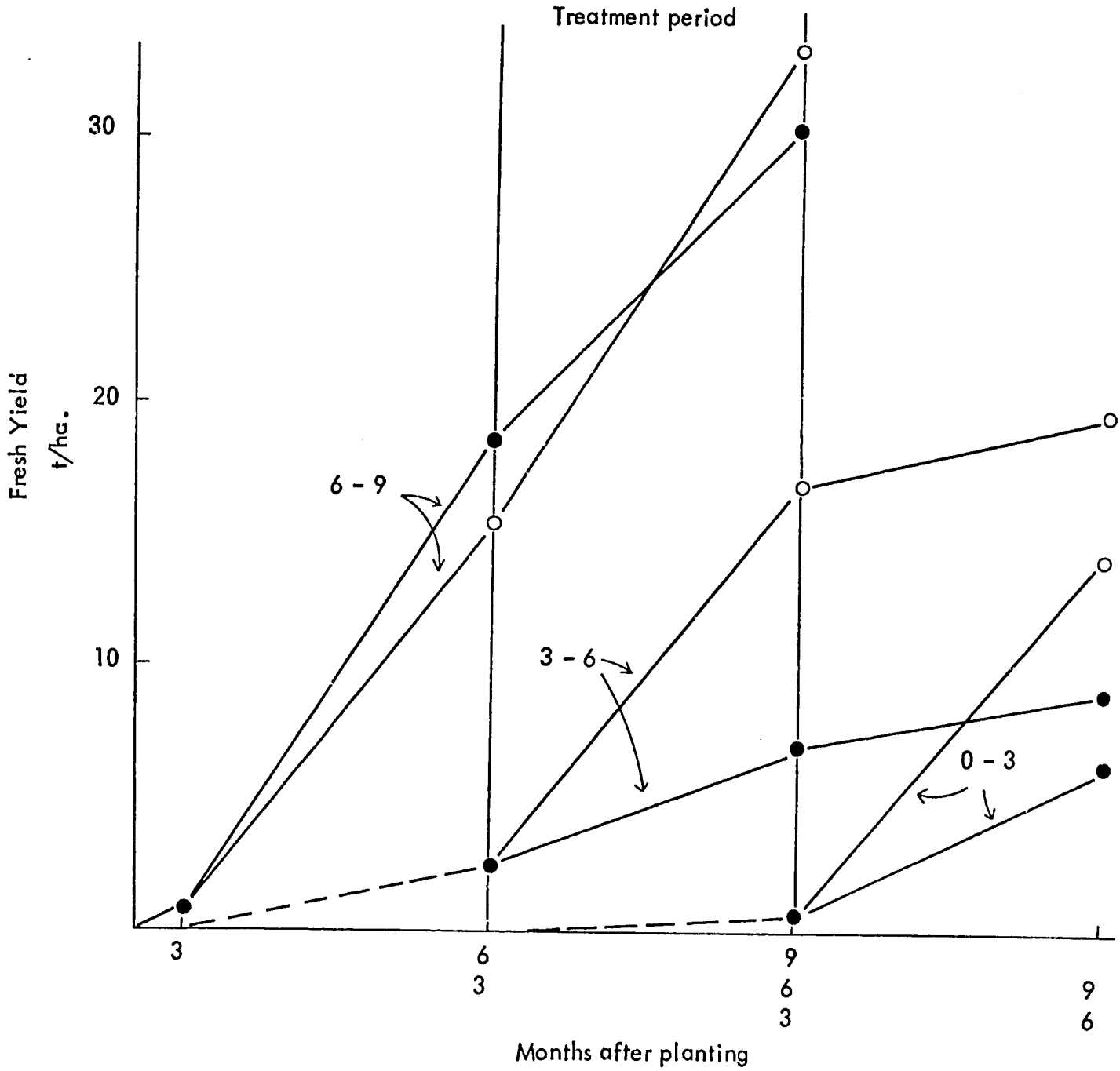


Figure 1. Yield of cassava (clone M Col 1684) under natural days (o) and with a 3 month 16 hr day treatment (•) from 0 - 3, 3 - 6, 6 - 9, months after planting

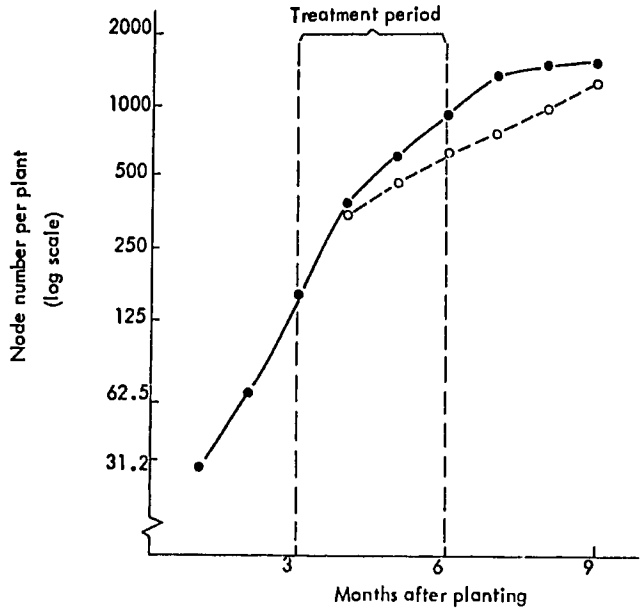


Figure 2. Total number of nodes per plant of M Col 1684 grown under natural (o) and 16 hr days from 3 - 6 months after planting (•).

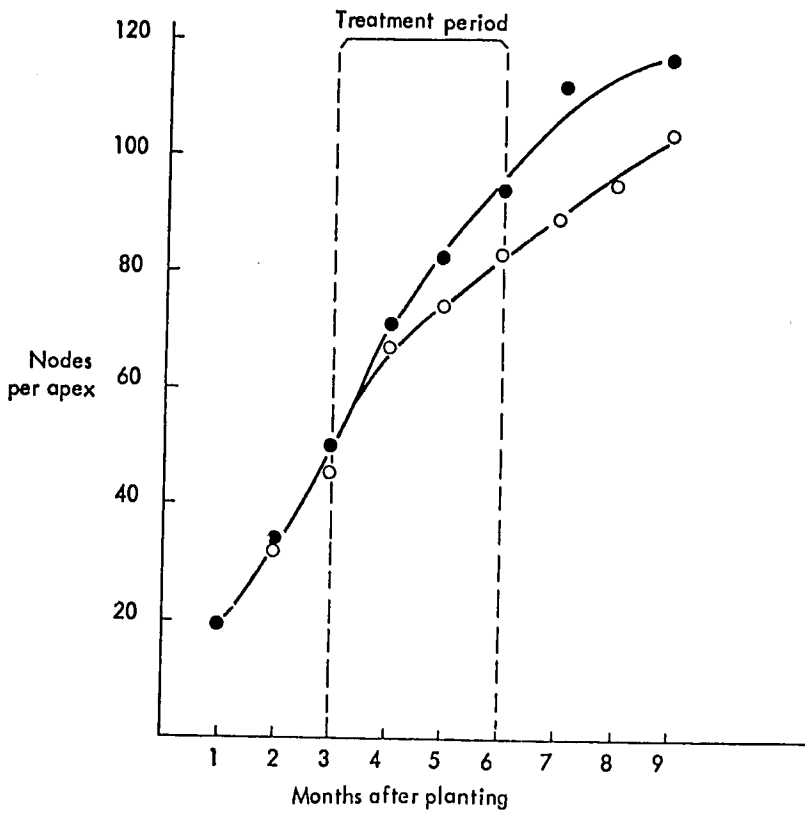


Figure 3. Cumulative number of nodes per apex of M Col 1684 grown under natural days (o) and long days from 3 - 6 months after planting (•).

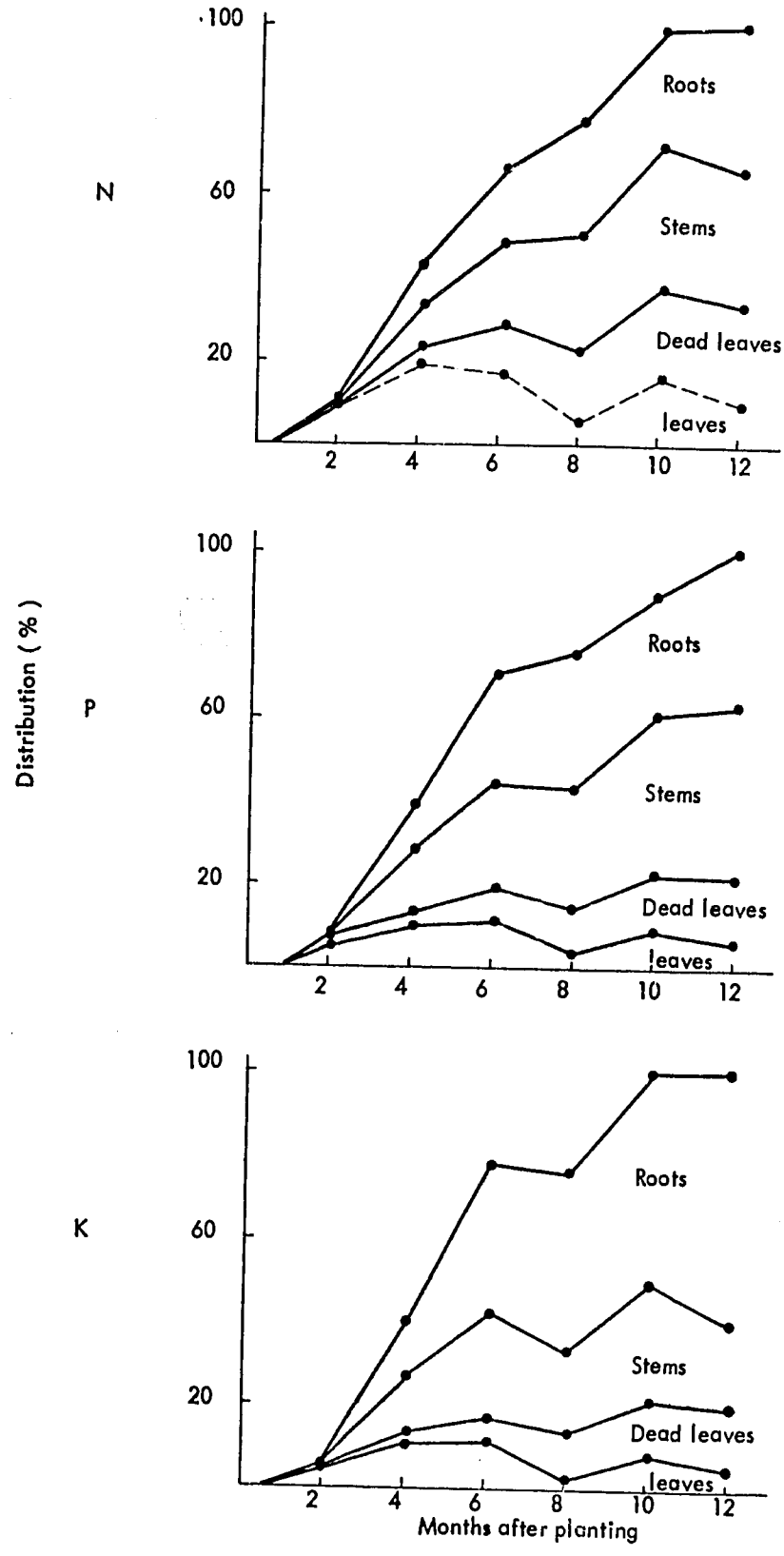


Figure 4. Distribution of nutrients to different plant parts in M Col 1684.

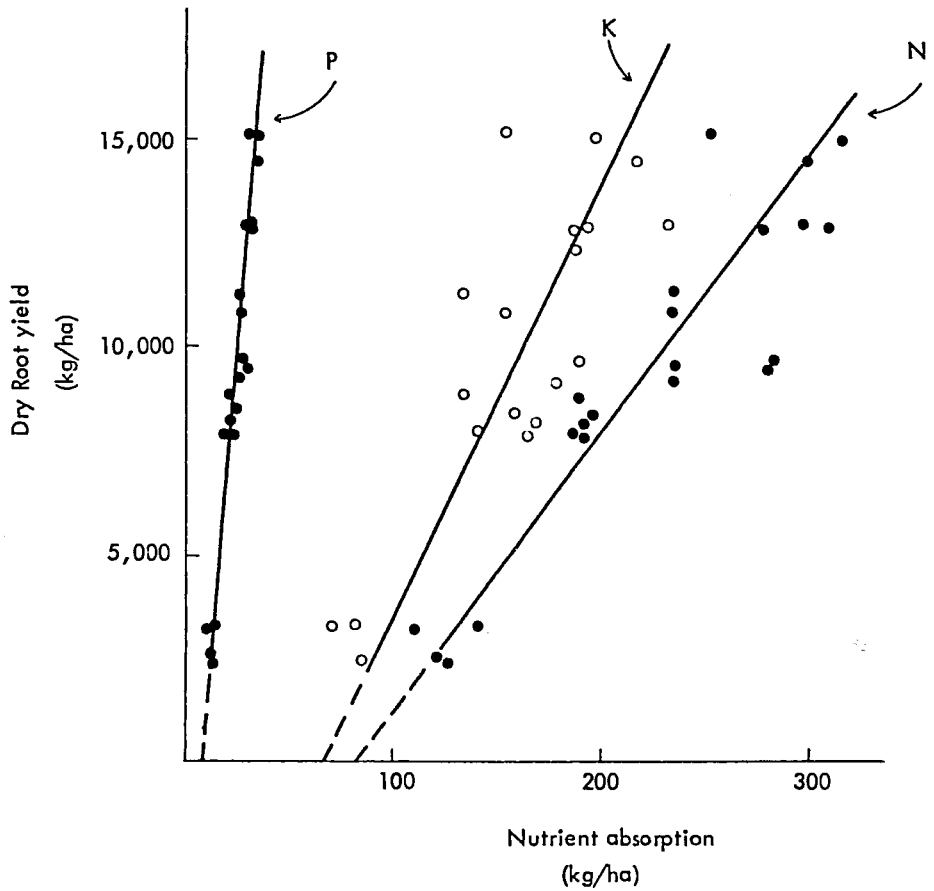


Figure 5. Dry root yield as related to total nutrient absorption (N, P and K) of the clone M Col 1684.

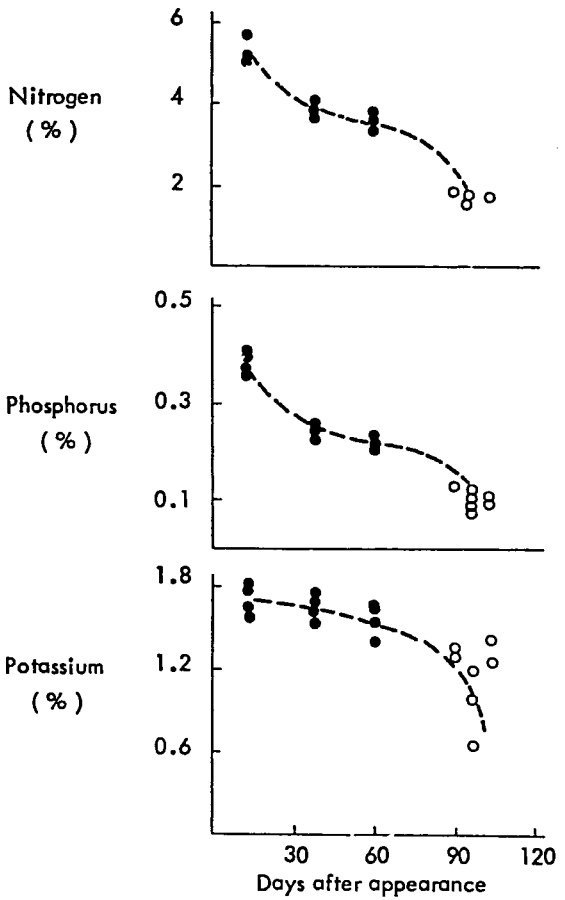


Figure 6. Nutrient content of leaves as they age on a cassava plant (•) and when they fall (o).

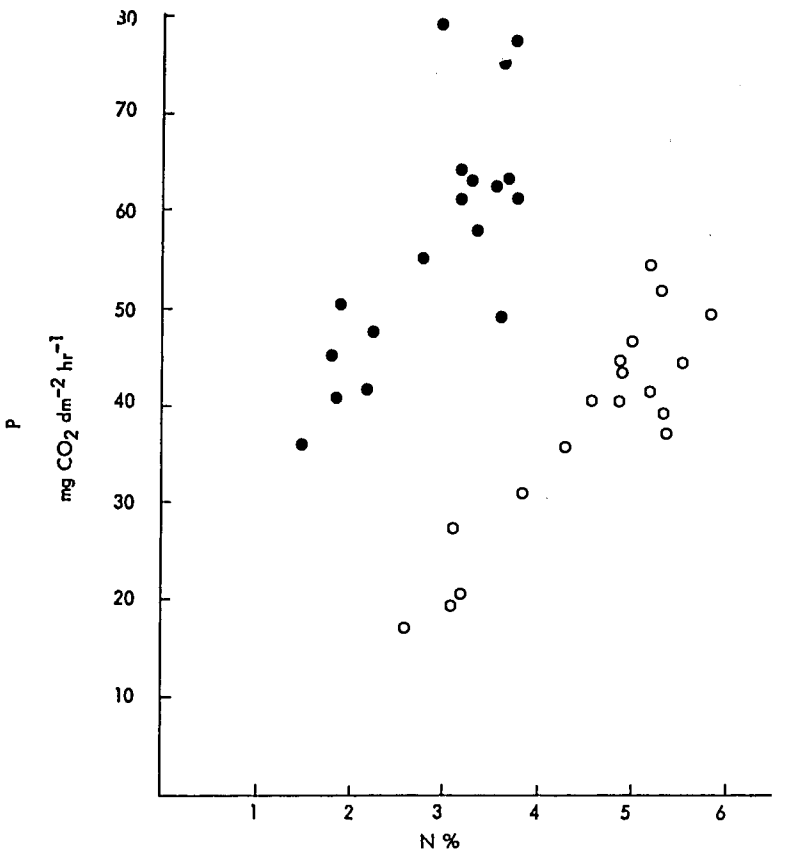


Figure 7. Photosynthetic rate of corn (•) and beans (o) as related to leaf nitrogen content.

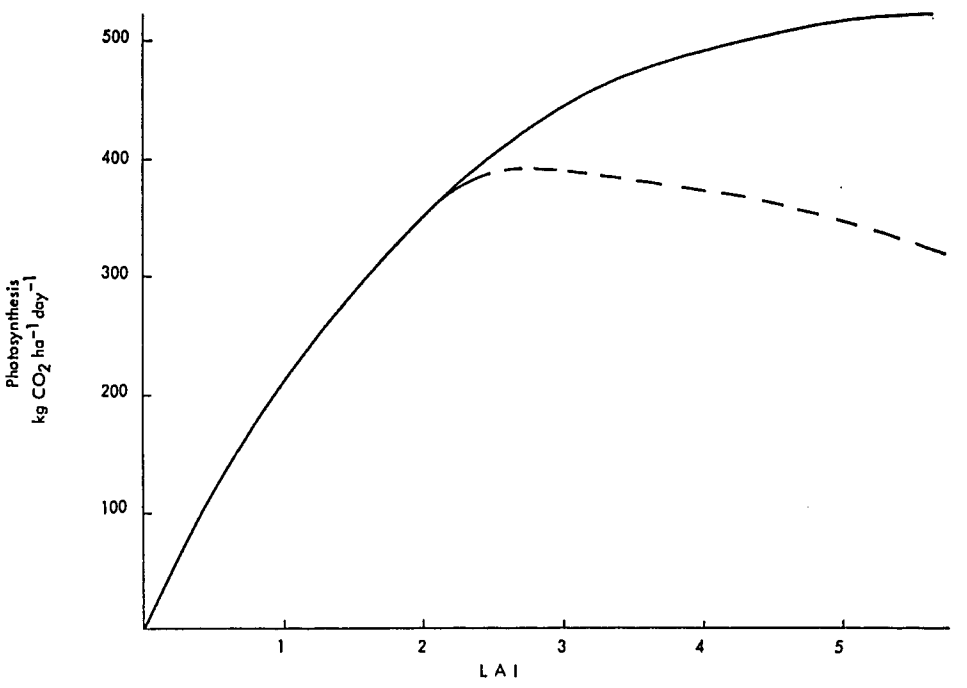


Figure 8. Simulated photosynthesis of a crop canopy with unlimited nitrogen supply and a maximum of 50 kg leaf N/ha (— — — —).

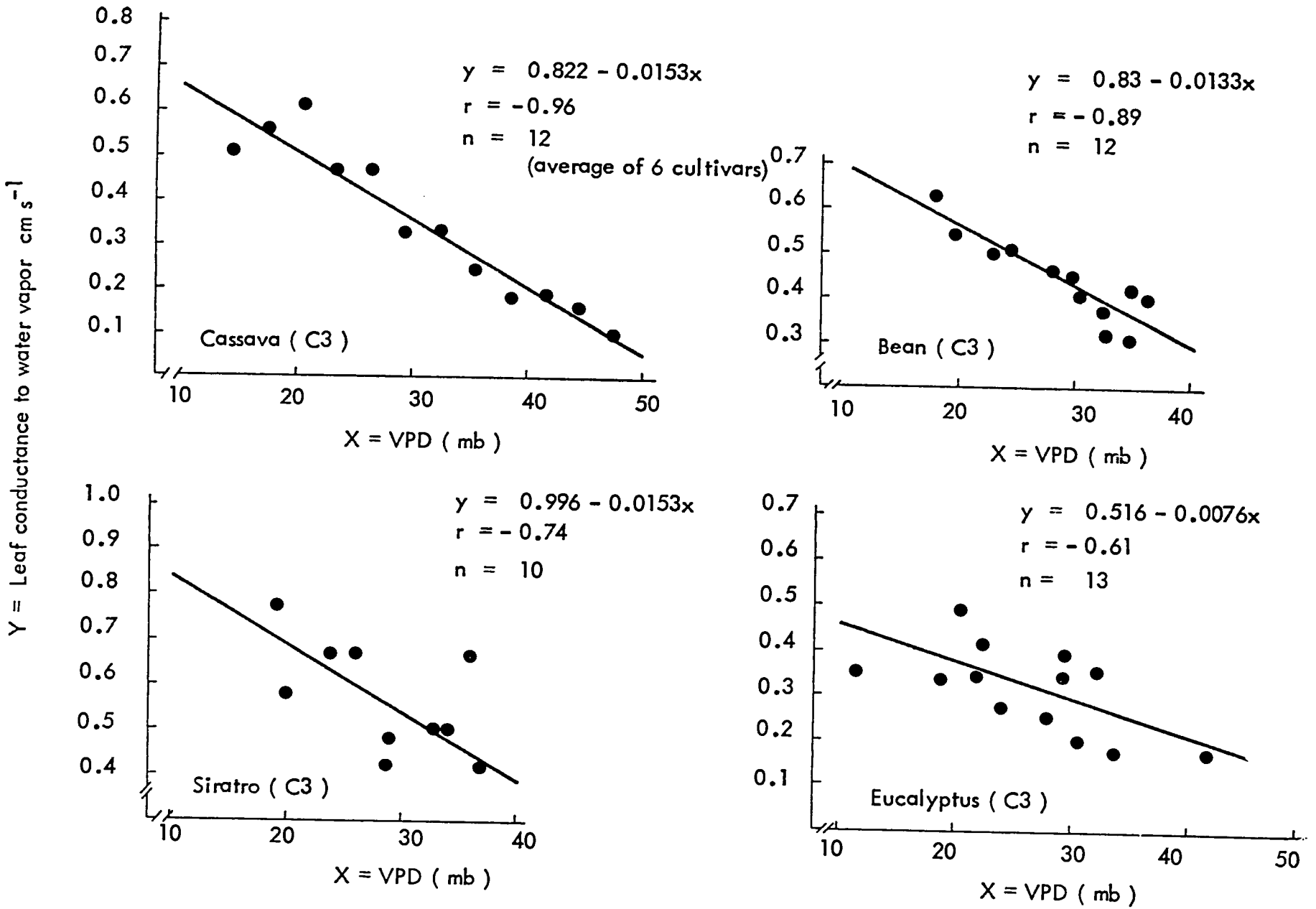


Figure 9. Response of stomata to differences in VPD in various species.

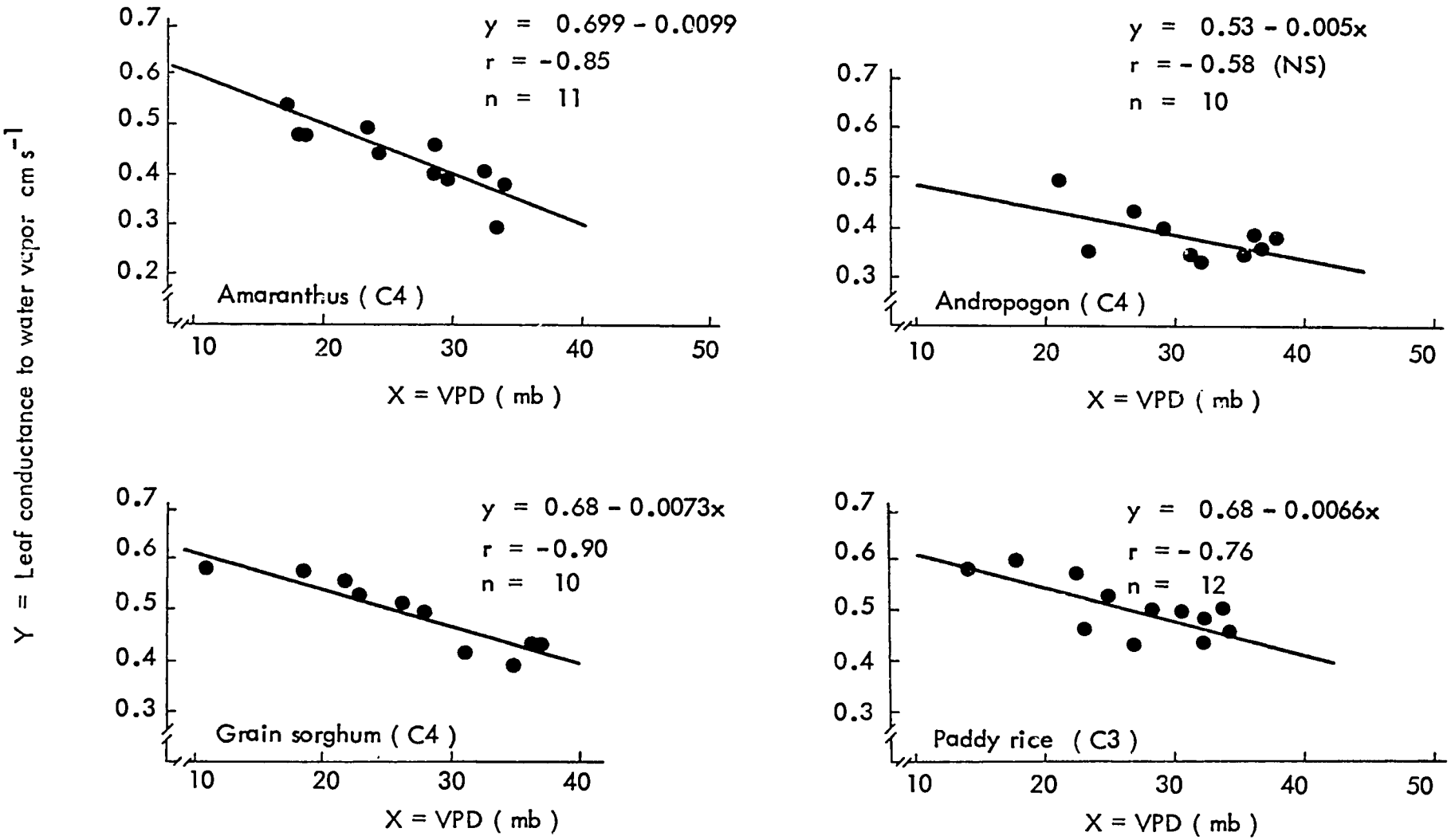


Figure 9. Continued

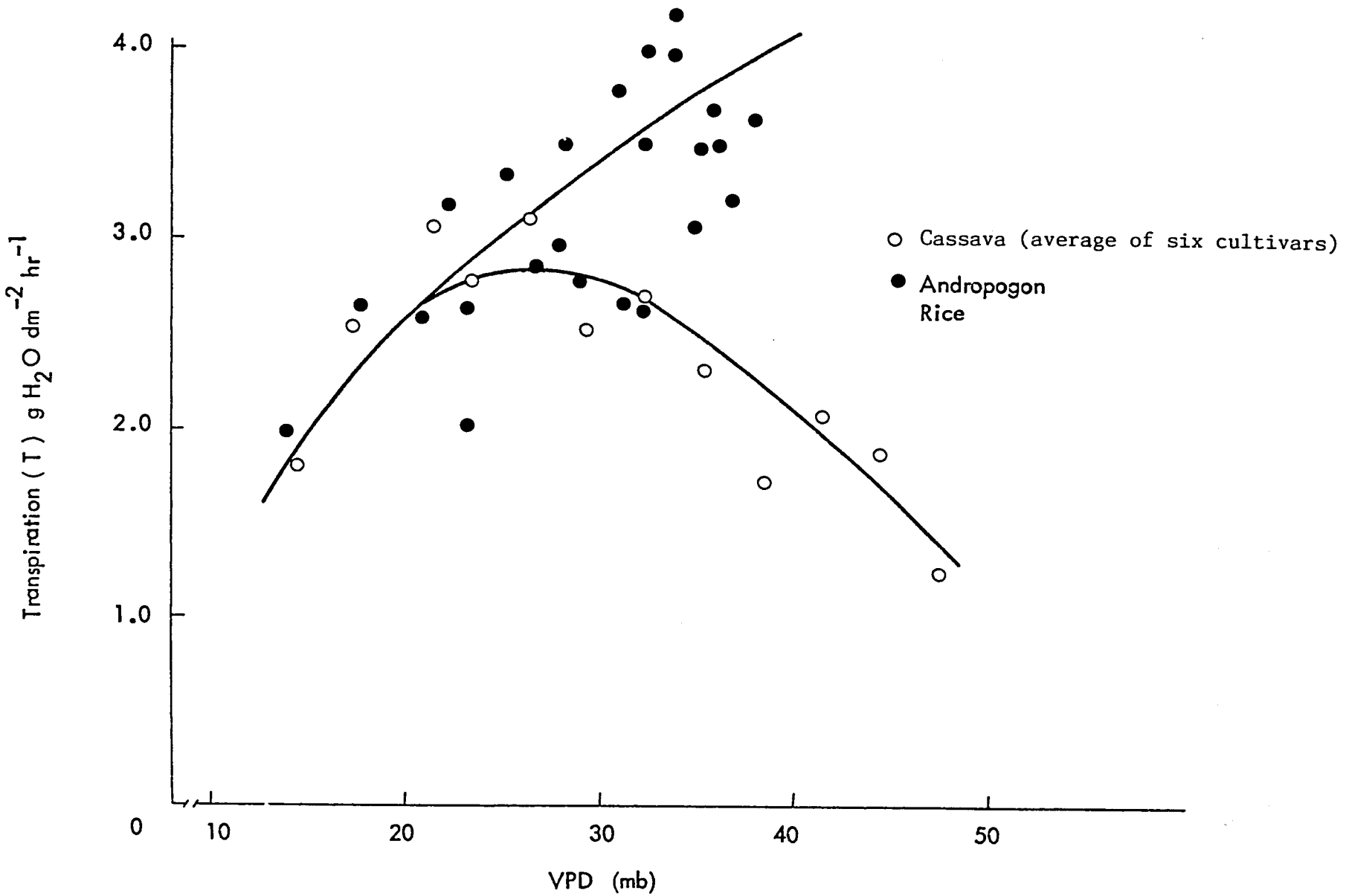


Figure 10. Transpiration of cassava and less sensitive species at different VPDs.

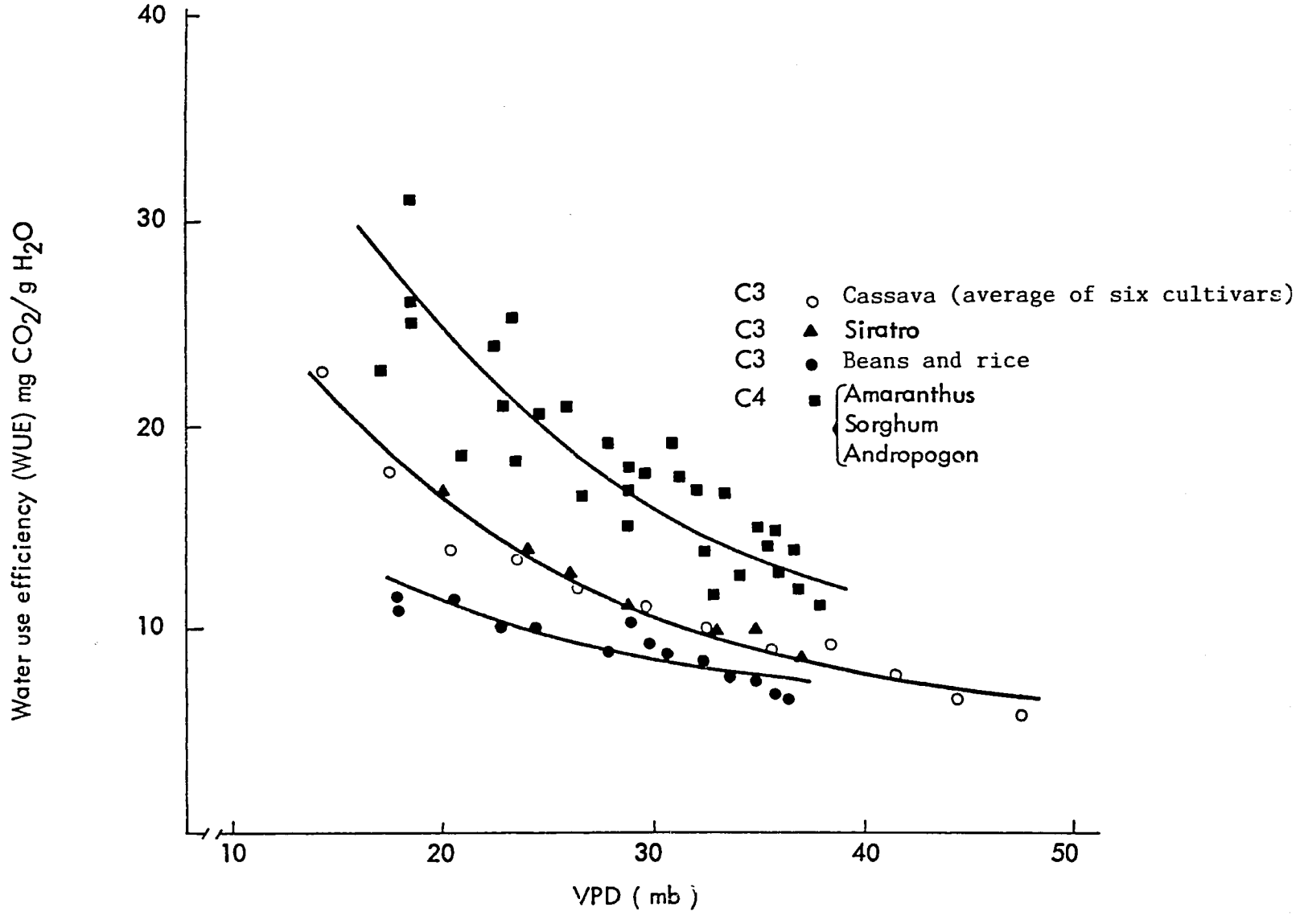


Figure 1.1. Water use efficiency of cassava compared to various C 3 and C 4 species at different VPDs.

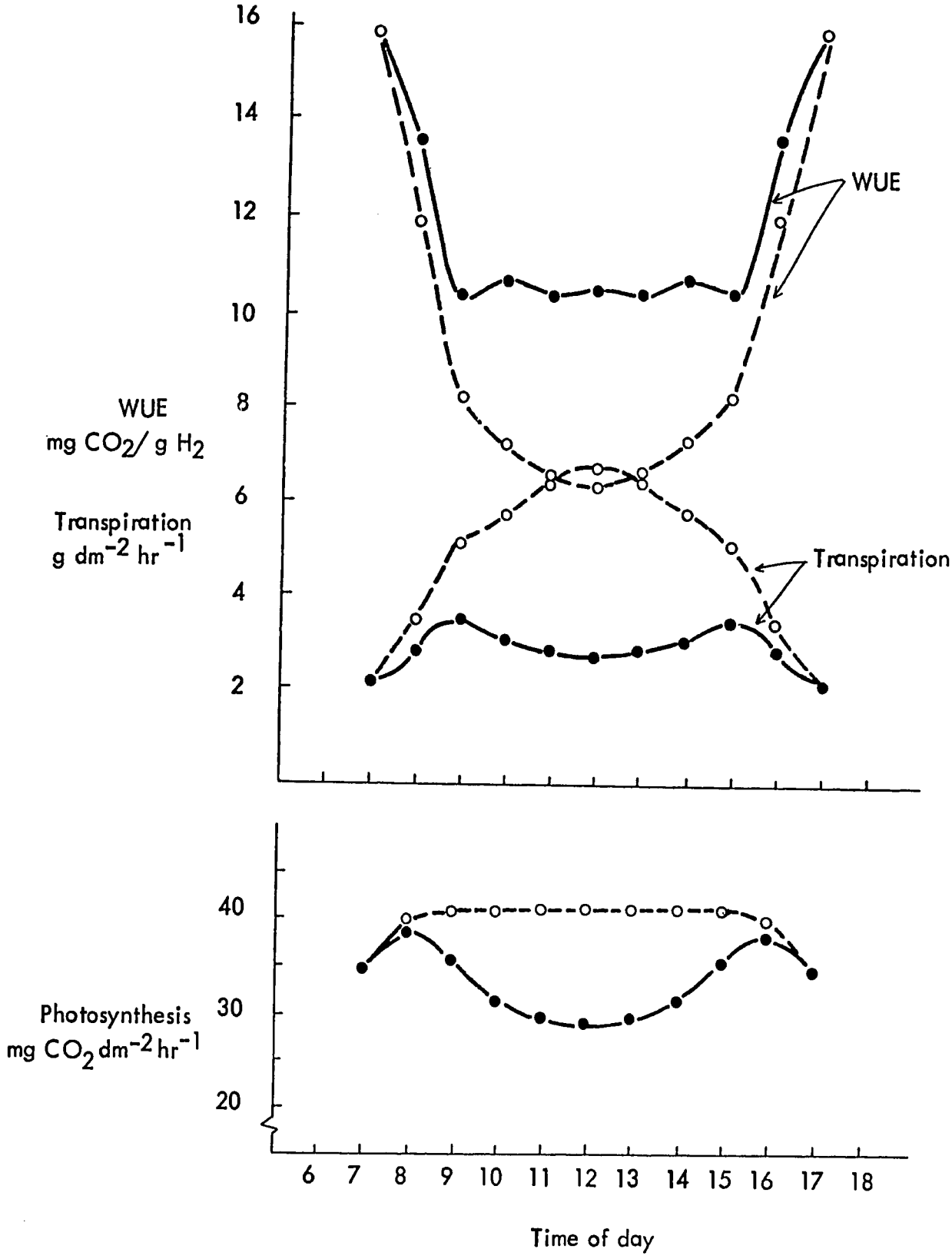


Figure 12. Simulated daily course of transpiration, photosynthesis and WUE of horizontal leaves either insensitive to changes in VPD (o) or with stomata sensitive to changes in VPD (•).

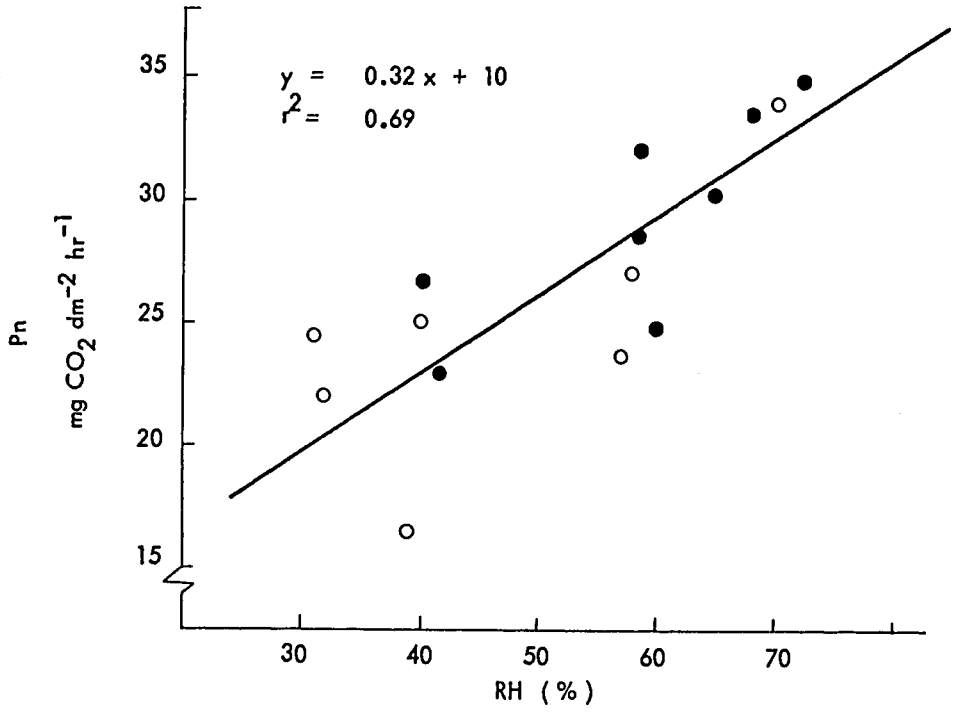


Figure 13. The relation between photosynthesis of individual leaves of M Col 1684 grown in the field and the relative humidity of the air.

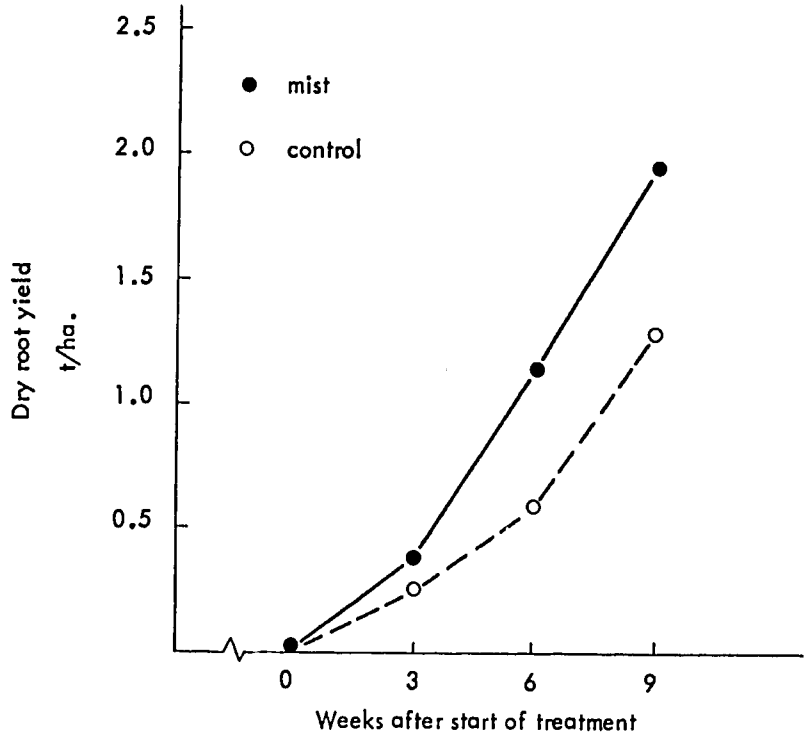


Figure 14. Root dry weight of M Col 1684 grown under natural conditions and with mist.

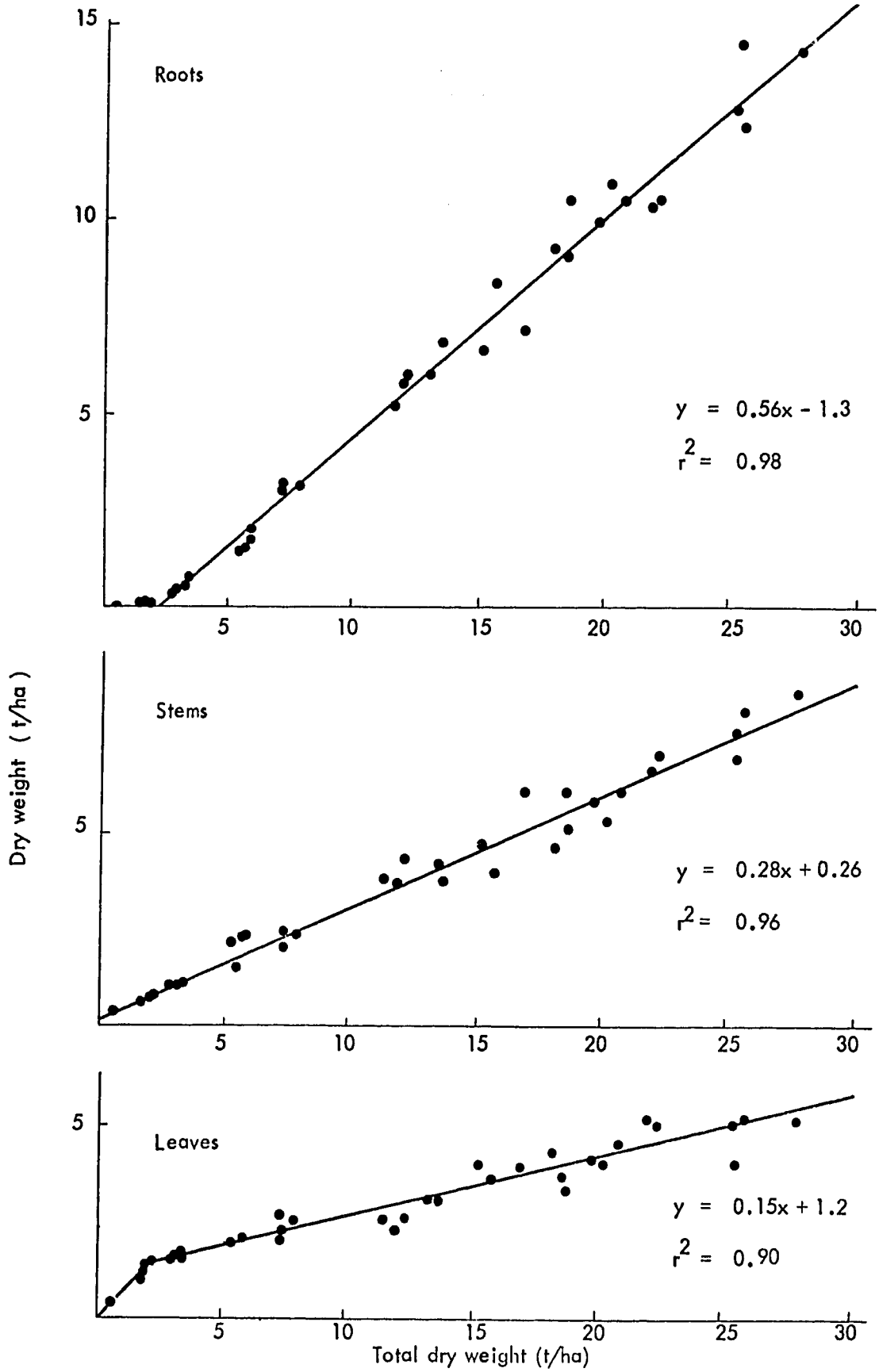


Figure 15. Relation between dry weight of roots, stems and leaves and the total dry weight of M Ptr 26 grown at CIAT Palmira.

Soils and Plant Nutrition

During 1982 research continued with the following objectives:

(1) To select cassava germplasm with special adaptation for acid soils low in P.

(2) To define symptoms of nutritional disorders and determine critical levels of nutrients in soil and plant tissue.

(3) To determine the effect of continuous cassava production on soil fertility and test management practices that reduce soil erosion on hillside cassava.

(4) To determine which sources, levels, methods and times of application of fertilizers are most efficient in supplying cassava with nutrients.

(5) To determine the most effective methods of mycorrhizal inoculation and establish which management practices enhance or inhibit an efficient mycorrhizal association.

Germplasm Screening for Adaptation to High Acidity and Low P.

In CIAT-Quilichao another 688 accessions from the germplasm bank were evaluated for low P tolerance by planting in single rows in two large plots to which 0 and 75 kg P/ha as triple superphosphate (TSP) was band-applied. The same plots had received 0 and 150 kg P/ha in 1979 for the first screening, reported in last year's annual report. At planting these plots had available P levels of 2.0 and 2.3 ppm P (Bray II).

Due to good weather and timely control of thrips, plant growth of most cultivars was exuberant even without applied P. Table 1 shows the root yield and the low-P adaptation index of the best 20 cultivars. The adaptation index is the product of the yield at 0 and 75 kg P/ha, divided by the product of the average yields at these P levels. Thus, those cultivars that tolerate low levels of soil P and also make efficient use of applied P will have high yields at both levels and thus have a high adaptation index. The first 11 cultivars are considered highly adapted, having an adaptation index above that corresponding to the average yields plus two standard deviations.

In addition, 77 of the most adapted cultivars, selected in the 1979 screening, were reevaluated in small plots of 30 plants to which 0 or 150 kg P/ha had been applied. Half of the P was broadcast and incorporated as Huila rock phosphate, and half was band-applied as TSP. Lime, N, K, Zn and B were applied uniformly to all plots. Plant growth was less vigorous than in the first screening and some cultivars were severely affected by CBB, anthracnose or superelongation. Table 2 shows the root yields at 12 months as well as the P content of the leaves and the mycorrhizal infection of roots at four months. The low P adaptation index was calculated as indicated above. Root yields were generally low with an average of 16.7 t/ha without P and 22.2 t/ha with applied P. The best adapted cultivars were M Ecu 56, M Ecu 154, M Col 1513 (CMC 84), M

Col 1185, and M Col 1684. At four months the P contents of the indicator tissue as well as the mycorrhizal infection of roots were low and these characteristics were not related to final root yields. Thus, cultivars cannot be selected on the basis of high internal P concentrations or high levels of mycorrhizal infection. Their adaptation to low P soils may be due to efficient use of a limited amount of P absorbed, as well as having a high harvest index.

Critical Levels of Ca and Mg in Plant Tissue

The response to Ca and Mg applications in the fields is often obscured by concommitant changes in Al and K availability. To prevent these difficulties the response to Ca and Mg were determined in nutrient solutions in the absence of Al and the presence of adequate levels of K. Rooted plantlets of M Ven 77 were grown for 1½ months in aerated solutions, using the "programmed nutrient addition" technique, in which nutrients are added according to the rate of plant growth. In two separate trials Ca and Mg concentrations were varied over eight levels ranging from 0.01 to 1000% of the optimum concentration. Calcium was applied as $Ca(NO_3)_2.4H_2O$ and $MgSO_4.7H_2O$. The differential amounts of N applied with the Ca were corrected with the additional application of NH_4NO_3. The first symptoms of Mg deficiency were observed after four weeks as a light intervenal chlorosis of bottom leaves in levels 1 and 2 of the Mg trial. These symptoms became more severe with time, producing severe intervenal chlorosis and border necrosis in levels 1 and 2 and only chlorosis in level 3. Plant height was severely reduced, being 30 cm at level 1 and 234 cm at level 5 at the time of harvest. The root system was small but not necrotic due to Mg deficiency.

The first symptoms of Ca deficiency were observed after six weeks as a slight chlorosis of middle leaves and a downward curling of the tips of upper leaves. These became more severe with time; eventually many lower leaves became necrotic and fell off. Plant height was markedly reduced and root growth was very stubby and excessively branched due to death of root tips. At the time of harvest plant height varied from 37 cm at low Ca to 230 cm at level 5. Higher concentrations did not significantly change plant height or dry matter (DM) production. Figure 1 shows the relation between DM production and the Ca and Mg concentrations in the youngest fully expanded leaf (YFEL) blades. Although DM production was highly variable at high concentrations of Ca and Mg, critical levels corresponding to 95% of maximum yield were estimated to be 0.24% Mg and about 0.46% Ca. These values are slightly below the critical levels of 0.29% Mg determined in 1976 for CMC 40 and 0.8% Ca estimated in 1980 for M Col 638 in Carimagua, but close to other values reported in the literature. Critical levels in the petioles were 0.32% Mg and 0.48% Ca, slightly higher than in the leaf blades. It was observed that Ca and Mg concentrations were always higher in the petioles than in the corresponding leaf blades, especially when high levels of these nutrients were applied. While Mg concentrations were highest in the upper leaves and petioles, those of Ca were highest in the lower leaves, reflecting the poor phloem mobility of the latter.

Levels, Sources, and Times of Application of K

Since cassava extracts large amounts of K from the soil, the response to application of this element tends to increase with time. Therefore, a K trial to determine the best level and time of application, established in 1979 was replanted for the third consecutive year in Carimagua. Due to increasing disease and insect pressure, yields of M Ven 77 and CMC 40 were low (Figure 2), but there was still a significant response to K application, which nearly doubled yields from 6 to 11 t/ha with the application of 84 kg K/ha. There were no significant differences between different times of application, but the application of all K at 30 days after planting gave higher yields at low rates of K than any fractioned application. Thus, even though precipitation was very high and soils are well drained, it appeared that a fractionated application had no advantage over a single basal application, either at planting or after one month.

In another trial on a sandier soil in Carimagua, cassava yields in the first year of cropping increased from 5 to 13 t/ha with the application of 100 kg K/ha while the application of 200 kg K/ha slightly decreased yields (Figure 3). Although S deficiency symptoms have been observed on this soil, there were no significant differences between the application of KCl, KCl + S, K_2SO_4, or sulpomag (potassium-magnesium sulfate). The beneficial effects of K-sources containing S have been observed previously in planting shortly before the dry season, when S deficiency tends to be most pronounced. Relating root yield with K contents in YFEL blades at four months after planting, a critical K level of 1.7% was determined, which is only slightly higher than the levels of 1.4 and 1.5% reported in last year's annual report.

Response to NPK Fertilization in Different Soils

With the objective to determine critical levels of NPK both in plant tissue and in soils over a range of varieties and environments, simple NPK trials were planted in another 10 locations ranging from the hot climate on the Colombian North Coast to the high altitude cold climate in Popayan. Table 3 shows the sites and the principal soil characteristics as well as the fertilizer responses obtained. As observed last year, the greatest responses were obtained to the application of P, especially in the low-P volcanic ash soils of the Quilichao-Mondomo-Popayan area and the Oxisols of the Llanos. A significant K response was obtained only in Carimagua, while in the equally infertile soils of La Colorada on the North Coast no such responses were obtained. Leaf contents of P and K were much higher in La Colorada than in Carimagua, possibly because of a higher pH and higher concentrations of Ca and Mg in the Colorada soils, cassava plants absorbed more efficiently the low amounts of P and K in the soil. Figure 4 shows the reaction between the relative yields and the P and K levels in the soil, extracted with Bray II. Although considerable variation exists between sites and between cultivars in the same site, a critical level of about 6 ppm P and 0.15 me K/100 g were estimated. Thus, it appears that cassava has a soil K requirement similar to those of other crops, but a P requirement which is much lower, probably due to an effective mycorrhizal association (See "Mycorrhizal Effects in Cassava" in this section).

Figure 5 shows the relation between the relative root yield and the P concentration of YFEL blades obtained in the 20 different sites, each with two cultivars. It is clear the large differences exist between sites and between cultivars, but that near-maximum yields are generally obtained with a P content of about 0.4%. Similarly, relating yield with K in YFEL blades a critical K content of about 1.5% was estimated. Although each cultivar may have a slightly different critical value in each location, these values can serve as a general guide in the interpretation of plant analyses results. Critical N contents in YFEL blades could not be determined because of a low N response. However, even in the most infertile soils cassava leaves had N contents above 4% and in some sites even up to 6.5%, indicating that upper cassava leaves are extremely high in crude protein.

Response to Zinc Application

In both acid and alkaline soils cassava yields can be seriously affected by Zn deficiency. To study the response to Zn in an acid soil, four levels of $ZnSO_4.7H_2O$ were band-applied in Alegria-Carimagua. Figure 6 shows the Zn response in M Ven 77 and CM 91-3. Yields of CM 91-3 were zero without Zn application, while the application of Zn to M Ven 77 tripled yields from 5 to 15 t/ha. Thus, in these extremely acid infertile Llanos soils, with the application of two t/ha of lime, deficiency of Zn was as limiting as that of any of the major elements. Application of B, Mn, or Cu had no significant effect. Figure 7 shows the relation between root yield and Zn content of YFEL blades at four months and indicates a critical level of 33 ppm Zn. This falls within the range of 30-50 ppm determined previously for a range of different cultivars.

In alkaline soils, applications of Zn to the soil are often not very effective because of precipitation of Zn at high pH. In that case treatment of the planting stakes may be more efficient. Thus, in a high-pH (8.2), low-Zn soil in CIAT-Palmira, 20 cultivars were planted with and without treatment of stakes with a 4% $ZnSO_4.7H_2O$ solution. The beneficial effect of the stake treatment was already apparent one month after planting; many plants without the treatment were showing severe salinity and Zn deficiency symptoms, while those treated with Zn generally germinated better and produced healthier plants. In many susceptible cultivars, plants not treated with Zn died, while those treated survived and more or less prospered, although often with severe Zn deficiency symptoms. Table 4 shows the Zn content of YFEL blades at 4½ months as well as root yields at 12 months. Zinc levels in YFEL blades varied from 17 to 26 ppm with or without stake treatments, i.e., considerably below the critical levels of 30-50 ppm. Average yields with stake treatment were 25.0 t/ha and without treatment 11.5 t/ha. Thus, this simple stake treatment, which costs less than US$1.0/ha increased yields 13.5 t/ha with a present value of about US$2.000. It is clear that some cultivars, like M Per 245, are not adapted to alkaline soils and did not grow well with or without Zn (this same cultivar is among the best adapted to acid soils in Carimagua) but most of the adapted cultivars either doubled or tripled yield by the stake treatment. Only M Per 247 and the two hybrids can be considered tolerant of Zn deficiency

as they produced high yields (more than 20 t/ha) even without Zn application.

Long-Term Fertility Trial

To study the effect of continuous cassava production on soil fertility and yield a long-term fertility trial was established in 1977 in CIAT-Quilichao, which this year completed its fourth cycle. Most plots had received three levels of N, P, and K in all possible combinations at the start of the trial and thus the effect of these applications is a residual one. In eight additional treatments fertilizers were applied annually.

Figure 8 shows the average response to the residual effect of N, P, and K in terms of root yield at 12 months and nutrient content at three months. The initial application of N had little effect on yield or N content, while that of P only increased the P content of leaves without having much effect on yield, and that of K increased both yield and K content. Since fertilizers had been applied only once, four years prior to planting, plant growth was not vigorous and nutrient content of leaves was below the critical levels. Still yields of up to 30 t/ha were obtained. As expected after four years of continuous cassava cropping, greatest responses were obtained to K, as this element is removed in largest quantities with each root harvest. Lowest yields of 15 t/ha were obtained in plots with high levels of N and P but without K, which had produced high yields in previous years that exhausted the soil K content. Also, for this reason there was a negative response to P in M Col 1684 but not in CMC 40, as the former appeared to be more susceptible to K deficiency than the latter. Figure 9 shows the relative yield increases obtained by the initial application of N, P, and K during four consecutive cassava crops. Responses to N were small and fairly stable over time; responses to P were most marked during the first year, but this element became less important over time, while responses to K were small initially but increased over time.

Figure 10 shows that while the residual effect of fertilizer application was small, the effect of annual applications was most dramatic, resulting in yields of 71 t/ha with M Col 1684 and 55 t/ha with CMC 40. While this high fertilizer level would cost about US$575, the value of the yield increase obtained would be US$7300 for M Col 1684 and $4500 for CMC 40 at present fertilizer and cassava prices. These high value cost ratios could make fertilization of cassava extremely profitable.

Soil Management for Erosion Control

Since cassava is a crop that tends to enhance erosion it is recommended only for land with less than a 10% slope. However, many small farmers that are located on steep and already eroded land, often do not have another alternative, since cassava is one of the few crops that can be economically grown with little purchased inputs on these acid infertile soils. To help these farmers to at least reduce erosion to a minimum, some limited research was started on soil and crop management on steep slopes. Since land preparation can be costly and very time

consuming under these topographic conditions, and can also have a significant effect on soil erosion, a trial was planted to observe the effect of different preparation techniques on a farmer's field near Mondomo with 15% slope. A similar trial, with treatments adapted to the gentler slopes in the Llanos, was planted in Carimagua.

Table 5 shows that in the very friable volcanic ash soils of Mondomo, land preparation can be reduced to a minimum, but cannot be entirely eliminated. Planting without any land preparation, but with adequate weed control, reduced yields significantly. There were no significant differences in yields between localized preparation of planting holes or complete preparation with oxen or mini-tractor with a rotavator. Planting on ridges along contours had no beneficial effect on yield, while double-row planting of cassava in one meter prepared strips reduced yields significantly. Thus, the traditional practice of land preparation with oxen or localized preparation of planting holes is not only necessary but also adequate.

In the rather friable soils of Carimagua (Table 6) there were no significant differences in root yield between the various land preparation alternatives, although in M Ven 77 the use of a disk harrow followed by ridging was significantly better than no preparation at all. The absence of soil preparation did not have much effect on yield, but greatly enhanced the difficulty of root harvest. Disking and ridging is the minimum amount of tillage required to control weeds and facilitate both planting and harvesting, while preventing root rot during periods of heavy rain.

In another farmer's field with 26% slope near Mondomo cassava was planted under six soil and crop management systems and the amount of soil eroded was collected in plastic covered channels below each plot and weighed periodically to determine soil erosion. Figure 11 shows the effect of the various treatments on soil loss over time. Erosion was most severe during the two rainy seasons from April to June and from October to December. Intercropping with either cowpea within a normal stand of cassava or strip cropping of four rows of cowpea alternated with double rows of cassava greatly increased erosion due to the poor performance of the cowpea and the extra soil preparation required for its planting. The traditional method of soil preparation with oxen either with or without ridging resulted in a loss of about 40 t/ha in 10 months. Application of maize stalks as a mulch between cassava plants reduced erosion to more acceptable level of 12 t/ha, while alternating rows of cassava with a one-meter strip of Brachiaria humidicola was nearly as effective in reducing soil erosion. However, at the time of harvest it became clear that those treatments most effective for erosion control reduced cassava yields either due to poor stands of cassava in the mulch or excessive competition from the Brachiaria. Research is presently underway to test other alternative systems, before practices can be recommended that not only control erosion but also give acceptable cassava yields.

Mycorrhizal Effects in Cassava

Since the importance of an effective mycorrhizal association in cassava grown on low P soils has been amply demonstrated (Cassava Annual Reports, 1979, 1980, 1981), research on the factors that determine the effectiveness of the association were continued, both in greenhouse and field experiments.

Greenhouse experiments were conducted generally with steam sterilized or unsterilized soil from CIAT-Quilichao or Carimagua, to which various levels of P were incorporated as powdered triple superphosphate, while 200 kg N, 200 kg K and 10 kg Zn per hectare were applied as NH_4NO_3, KCl and $ZnSO_4.7H_2O$ in solution. Planting material consisted of either short stakes (10 cm) or rooted plantlets. Plants were inoculated with 100 g of infected soil with maize roots, placed directly under the plant or stake at time of planting.

Effect of stake treatments of soil or foliar-applied agrochemicals

Stakes of CMC 40 were submerged for 15 minutes in solutions of various fungicides, insecticides, or nutrients, either separately or in combinations recommended by the Cassava Program for stake treatment. These stakes were planted in sterilized Quilichao soil, fertilized with 100 kg P/ha. Table 7 shows the effect of treatments on DM production at three months, root infection, P content of tops and number of spores in the soil. Incoculation increased DM production 3-4 fold over the non-inoculated treatment, increased the percentage of P in the tops, the infection of roots, and numbers of spores in the soil. All stake treatments had a positive effect on DM production with little or no detrimental effect on root infection or spore numbers. Stake treatment with Dithane actually increased root infection and spore formation, as was the case with TSP. Thus, it appears that none of the recommended stake treatments have any long term detrimental effect on the mycorrhizal association. The result also points to the possible beneficial effect of stake treatments with P solutions of rather high concentration.

A similar trial with soil or foliar applications of insecticides and herbicides indicated that there was no detrimental effect on the mycorrhizal association by application of recommended doses of Furadan, Temik, Sistemin, Dipterex, Lebaycid, Karmex, Goal, or Round-up, but that the herbicide Lazo decreased root infection and DM production. This effect is presently being verified.

Effect of fertilizer application

On most low P soils where mycorrhiza play an important role it is essential to use chemical fertilizers to produce high yields of cassava and the method of application can affect the mycorrhizal association, as band or spot application produce extremely high concentrations of nutrients at the site of placement. To verify this, stakes of M Ven 77 were planted in sterilized soil from Quilichao, inoculated with infected soil and maize roots, and fertilized with 2000 kg/ha of 10-30-10 alone or in combination with 20 kg Zn or 2 kg B/ha as $ZnSO_4.7H_2O$ and Borax, respectively. These fertilizers were either mixed with the whole soil or

band or spot placed to the side or under the stake. Table 8 shows that fertilizer application increased DM production up six fold and that band or spot placement was significantly more effective than the incorporated application. The addition of Zn increased DM production consistently, while the response to B was variable. Neither source or method of fertilizer application had a significant effect on root infection.

Mycorrhizal Infectivity of Different Soils

Although responses to mycorrhizal inoculation in cassava are often quite dramatic in sterilized soil this is not necessarily the case in unsterilized soil due to the presence of effective native mycorrhiza. Before testing new species and strains in the field, it is useful to test them first under greenhouse conditions to determine whether the new strains are actually more effective than native strains and whether they are adapted to the soil and can compete with other microorganisms present. For that reason five unsterilized soils were mixed with TSP at the rate of 0, 100, and 500 kg P/ha. Rooted plantlets of CM 91-3 were planted and half of the plants were inoculated. The effect of inoculation on plant dry weight at three months decreased with increasing P application and was only significant without applied P, as shown in Figure 12. Inoculation was most effective in Carimagua-Alegria followed by Carimagua-Reserva, Popayan, Quilichao, and CIAT-Ql. Although the first four soils are very similar in available P content (2.6-3.4 ppm) and all showed a marked response to applied P, the native mycorrhizal population in Quilichao was more effective than in Carimagua, resulting in larger responses to inoculation in the latter. This was corroborated by results of fields trials (see below). Figure 13 shows the relation between DM production and available (Bray II) P content of soil. In general, yields were higher in inoculated plants, resulting in a lower critical P content for inoculated plants with a more effective mycorrhizal association. Thus, some of the variations observed in the determination of critical P concentrations in cassava are due to differences in the effectiveness of the mycorrhizal association, as was also reported in the Cassava Annual Report, 1980.

Field trials on the effect of mycorrhizal inoculation were conducted in CIAT-Quilichao and Carimagua-Yopare. In these trials cassava stakes were planted and inoculated with either infected roots or a soil-root mixture, placed directly under the stake at planting.

Methods of Inoculation in Quilichao

Different levels, sources and methods of inoculation were evaluated in CIAT-Quilichao, using M Col 1684 and M Col 638 as test cultivars. Huila rock phosphate was uniformly applied at 100 kg P/ha and incorporated together with 500 kg/ha of dolomitic lime; N and K were band applied at 100 kg N and 75 kg K/ha, respectively. In one treatment the soil was sterilized with methyl bromide two weeks before planting, but all other treatments were applied to non-sterilized soil.

In the sterilized treatment plants remained extremely small and P deficient for the first five months; some died during the dry season. However, at five months border rows started to recuperate as roots

penetrated into neighboring unsterilized plots and became infected; after seven months nearly all plants started to recuperate from the P deficiency as their roots penetrated into unsterilized subsoil. However, these plants were physiologically immature at harvest at 12 months and produced only about 50% of the yield of cassava grown in unsterilized soil. Figure 14 shows the effect of different sources and levels of inoculum on the yield of M Col 638. None of the inoculation procedures resulted in significant yield increases over the non-inoculated control, except the use of two g of infected maize roots in the case of M Col 638. With M Col 1684 there were no significant responses to inoculation, but an extremely high yield of 53 t/ha was obtained without inoculation, using only a cheap local rock phosphate as the P source. Thus, it appears that in Quilichao the native mycorrhizal population is extremely efficient, so that inoculation has no beneficial effect, while elimination of this population by sterilization has a most dramatic negative effect.

Effect of inoculation in sterilized and unsterilized soil in Carimagua

To determine the importance of, both native and introduced mycorrhiza, a trial was planted in a soil with 2 ppm available P in Carimagua-Yopare. Phosphorus was applied at 0 and 100 kg P/ha as Huila rock phosphate. After incorporation, together with 1 t/ha of lime, half of the plots were sterilized by injecting 1 kg methyl bromide/10 m^2 under plastic. In sub-subplots stakes of M Ven 77 were either non-inoculated or inoculated with a mixture of 2 g infected cassava roots and 100 g infected soil, placed directly under the stake. The inoculum consisted mainly of *Glomus manihotis* (C-1-1) from Quilichao.

After one month there was a clear positive response to sterilization, possibly due to elimination of soil pathogens or liberation of soil N. After three months there was a marked positive visual response to inoculation in the sterilized soil; the non-inoculated plants remained extremely small and P deficient, while the inoculated plants grew more vigorously than those inoculated or non-inoculated in the unsterilized soil. These differences increased until about nine months, after which the non-inoculated plants in sterilized soil slowly started to recuperate due to re-infection from the unsterilized subsoil. Figure 15 shows the root yield response at 12 months. The initial elimination of mycorrhiza by sterilization decreased yields 34% at both levels of applied P. However, inoculation increased yield nearly 200% in the sterilized and 21% in the unsterilized soil when no P was applied, and 164% and 37%, respectively, when 100 kg P/ha had been applied. Although responses to inoculation were much more marked in sterilized than unsterilized soil, even in the latter the effect of inoculation was highly significant, especially when some P had been applied. As observed in other greenhouse and field trials (Cassava Annual Report 1981) the highest yields were obtained with inoculated plants in sterilized soil, probably due to elimination of pathogens or competing microorganisms in the soil.

Effect of P sources and levels on mycorrhizal efficiency

Greenhouse trials with rooted plantlets have shown that the mycorrhizal infection increases with increasing P levels until a maximum is reached above which infection decreases. To study this effect on the field, five sources of P were incorporated at levels of 0, 50, 100, and 200 kg P/ha in Carimagua-Yopare. In sub-subplots plants were either non-inoculated or inoculated with a mixture of 2 g infected maize roots and 100 g infected soil, placed under the stake. Visual responses to inoculation in this unsterilized soil were minimal. However, Figure 16 shows that root yields were increased significantly by inoculation with a maximum response at 100 kg P/ha and no response without P application. There were no significant differences between P sources, but mycorrhizal responses were greatest with the more soluble sources of TSP and Reno-rock phosphate; when TSP was applied at 100 kg P/ha, inoculation increased yield 51%. This result indicates that in a soil with low effectivity of the native mycorrhiza, inoculation can either increase yields at a given level of applied P or maintained high yields with a much lower level of P application.

Effect of inoculation source and strain

Once inoculation has been shown to be effective under field conditions, it is important to determine the most economical source of inoculum and most effective method of inoculation. Both aspects were studied in Carimagua-Yopare in a soil with 1.5 ppm available (Bray II) P, to which 100 kg P/ha was applied as broadcast and incorporated Huila rock phosphate. There were no significant responses to inoculation when different quantities of either infected maize roots or soil were used as inoculum. However, when 2 g fresh roots of different species, infected with either a Quilichao strain (mainly C-1-1) or with native Carimagua strains, were used, there were significant responses to inoculation. Figure 17 shows that best responses were obtained with cassava roots infected with Quilichao strains, which increased yield 65%. Significant responses were also obtained with roots of *Panicum maximum*, while those with *Stylosanthes capitata* and *Brachiaria decumbens* were marked but not statistically significant. Averaged over all species, yields increased 37% with the Quilichao strains and 21% with Carimagua strains, indicating that the efficiency of the strain is also of utmost importance. This aspect is being investigated in more detail by the Mycorrhiza Project.

Though much remains to be learned about strain effectiveness and competitiveness, about efficient sources, levels, time and method of application, as well as factors that optimize the cassava-mycorrhizal association, it is very promising that highly significant yield responses have been obtained under natural field conditions, such that mycorrhizal inoculation does not only appear agronomically possible but also economically feasible.

Table 1. Cassava cultivars with highest adaptation index for low P soils, as selected from a screening of 688 cultivars in Quilichao, in which the adaptation index is the product of the root yield at 0 and 75 kg P/ha divided by the product of the average yields at these levels.

Cultivar	Root yield (t/ha)[a]		Adaptation index
	0 P	75 K of P/ha	
M Col 628	89.6	130.5	20.27
M Col 463	75.9	86.6	11.40
M Col 1771	62.9	89.2	9.73
M Bra 41	63.9	82.9	9.19
M Col 1524	72.3	58.6	7.35
M Col 799	69.6	59.9	7.23
M Col 1778	63.6	57.7	6.23
M Col 1880	43.3	80.9	6.07
M Col 1927	63.3	51.6	5.69
M Col 1514	50.6	60.9	5.34
M Col 1891	54.3	53.9	5.07
M Col 751	51.6	53.6	4.80
M Col 802	34.0	80.6	4.75
M Cub 18	45.0	60.3	4.70
M Cub 10	51.6	52.3	4.68
M Bra 50	46.0	57.9	4.62
M Col 2022	45.6	58.3	4.61
M Col 511	49.3	53.9	4.61
M Col 848-B	56.3	46.3	4.52
M Col 1612	40.3	64.3	4.49

a. Based on four plants in single row trial.

Table 2. Cassava cultivars with highest adaptation index for low P soils, as selected from a yield trial of 77 cultivars at two levels of applied P in Quilichao.

Cultivar	P in leaves[a] (%)		Root infection[b]		Root yield (t/ha)		Harvest index		Adaptation index
	Po	P 150	Po	P 150	Po	P 150	Po	P 150	
M Ecu 56	.28	.37	2	2	30.9	37.4	.78	.77	3.12
M Ecu 154	.28	.28	1	2	27.8	37.6	.75	.75	2.82
M Col 1513	.28	.34	1	3	27.7	37.0	.62	.74	2.77
M Col 1185	.24	.30	1	2	24.6	35.9	.60	.71	2.39
M Ven 310	.22	.28	0	2	24.4	35.1	.72	.74	2.31
M Col 1684	.21	.38	0	2	22.4	35.2	.82	.84	2.13
M Ven 295	.31	.40	0	0	24.4	31.2	.57	.67	2.05
M Col 110	.35	.35	2	2	21.6	34.9	.76	.75	2.04
M Col 131	.30	.36	2	2	25.8	27.9	.74	.75	1.94
CM 91-3	.29	.33	0	2	24.1	28.9	.80	.73	1.88
M Bra 13	.37	.37	1	1	26.3	24.5	.63	.67	1.74
M Ecu 69	.23	.38	2	3	17.8	36.2	.67	.68	1.74

a. P content of leaves and root infection determined at four months, root yield at 12 months.

b. Root infection on scale of 0 to 6.

Table 3. Response of cassava to NPK fertilization in ten different locations in Colombia, 1981.

Location	Soil characteristics M.O. (%)	P (ppm)	K (meg/100 g)	Cultivar	Fertilizer response N	P	K
					Relative yield[a] (%)		
1. CIAT-Palmira	4.1	16.3	0.58	CMC 40	96	97	84
				CMC 723-23	100	88	94
2. CIAT-Quilichao	7.1	1.8	0.18	CM 40	72	45**	67*
				Llanera	53**	34**	50**
3. San Julian	6.8	1.5	0.20	CMC 40	100	78	95
				M Col 1684	100	85	91
4. Mondomo	5.6	0.4	0.12	CMC 92	95	59**	85
				Algodona	85	61**	97
5. Tres Quebradas	8.0	0.9	0.13	Barranquena	83	41*	76
6. CIAT-Popayan	35.0	1.5	0.40	Algodona	80	39**	74
				X 4 cultivars	97	46	92
7. La Idea	0.9	5.1	0.04	Secundina	80	100	92
				Venezolana	86	91	69
8. La Colorada	0.6	2.6	0.05	Secundina	100	100	100
				Venezolana	100	79	85
9. Valledupar	1.5	31.3	0.31	M Col 1684	85	90	100
				M Col 22	95	100	97
10. Alegria-Carimagua	1.8	2.4	0.05	M Ven 77	86	12**	28**
				M Col 1684	63	1**	17**

a. Yield without nutrient compared to highest yield obtained with the nutrient applied.

* Significant at 5% over all levels of the nutrient under study.

** Significant at 1% over all levels of the nutrient under study.

Table 4. Zinc content of youngest fully expanded leaf (YFEL) blades at 4½ months and root yield at 12 months of 20 cassava cultivars planted with and without stake treatment of Zn at CIAT-Palmira.

Cultivar	Zn in leaves (ppm) with Zn	Root yield (t/ha)	
		With Zn	Without Zn
M Per 176	22	3.9	0
M Per 193	19	24.9	10.7
M Per 196	17	30.5	13.8
M Per 200	22	35.4	15.0
M Per 206	20	31.1	9.0
M Per 211	20	21.9	9.2
M Per 239	20	25.9	13.0
M Per 243	24	7.6	6.5
M Per 244	25	18.0	14.1
M Per 245	23	1.0	0.6
M Per 247	22	48.7	31.3
M Per 252	26	22.8	17.2
M Per 253	20	44.9	10.7
M Per 266	20	20.4	8.1
M Col 22	21	23.3	11.2
M Col 113	25	35.3	9.4
M Col 1438	22	3.7	2.3
M Ven 290	20	8.8	3.4
CM 231-188	21	47.6	23.5
CM 498-1	18	44.8	21.2
Mean		25.0	11.5

Table 5. Effect of different soil preparation techniques on root yield of two cassava cultivars in Mondomo, Cauca.

Treatment[a]	CMC 92	M Col 13	Mean
Without preparation	10.8	10.4	10.6
Localized preparation of planting holes	17.9	12.3	15.1
Two passes with oxen	16.0	11.6	13.8
Two passes with oxen plus hand ridging	15.0	10.0	12.5
Two passes with rotavator	15.7	14.1	14.9
Two passes with rotavator plus hand ridging	16.8	10.9	13.9
One-meter strips prepared with pick	12.2	9.7	10.9
One-meter strips prepared with rotavator	13.5	9.5	11.5
LSD treatment at 5%	3.97	1.77	

a. Cassava planted 80 x 80 cm except in treatments 7 and 8 in which double rows of cassava were planted at same population in one-meter prepared strips alternated by one-meter unprepared strips.

Table 6. Effect of various soil preparation techniques on root yield of two cassava cultivars in Carimagua.

Treatments	Cassava root yield (t/ha)		
	M Ven 77	CM 91-3	Mean
1 Without preparation	10.3	14.8	12.5
2 Localized preparation of planting holes	12.6	12.7	12.6
3 1 chisel per cassava row	11.7	13.4	12.5
4 3 chisels per cassava row	10.1	14.2	12.1
5 5 chisels per double row of cassava	11.4	11.1	11.2
6 Preparation with cassava harvester	11.5	14.4	12.9
7 Preparation with disk harrow	14.3	12.7	13.5
8 Disking + ridging	16.7	14.9	15.8
9 Disking + plowing + disking	14.6	12.2	13.4
10 Disking + plowing + disking + ridging	14.4	13.6	14.0

Table 7. Effect of various stake treatments on dry matter production, P content of top growth and mycorrhizal root infection and spores in CMC 40 grown in sterilized Quilichao soil.

Treatment	DM (g/plant)	P in top (%)	Root[a] infection	Spores/ g soil
Without inoculation, without stake treatment	8.25	.07	0	1.6
Inoculated, without stake treatment	22.71	.09	3.7	11.0
Inoculated, stake treatment, Dithane M-45 4.4 g/l	29.67	.09	5.9	23.0
Inoculated, stake treatment, Manzate 80 2.5 g/l	26.35	.09	3.9	15.2
Inoculated, stake treatment, Vitigran 35% 4 g/l	26.50	.09	4.5	12.9
Inoculated, stake treatment, Malathion 4% 10 g/l	22.26	.09	4.4	13.7
Inoculated, Dithane + Manzate + Vitigran + Malathion ½ dose above	29.43	.09	2.7	24.1
Inoculated, stake treatment, Bavistin 12 g/l	30.15	.09	3.7	8.6
Inoculated, stake treatment, Orthocide, 12 g/l	23.11	.08	3.4	11.8
Inoculated, stake treatment, Aldrin, 1 g/stake	29.74	.10	2.5	17.3
Inoculated, Bavistin + Orthocide + Aldrin at ½ dose above	27.77	.09	3.7	17.0
Inoculated, stake treatment, 5% KH_2PO_4	30.43	.09	4.0	20.0
Inoculated, stake treatment, 10% KH_2PO_4	32.98	.09	2.2	14.0
Inoculated, stake treatment, 5% polyphosphate	25.18	.08	3.7	12.7
Inoculated, stake treatment, 10% polyphosphate	30.67	.09	3.4	12.0
Inoculated, stake treatment, 5% triple superphosphate	29.62	.09	4.2	17.6
Inoculated, stake treatment, 10% triple superphosphate	36.61	.08	5.0	19.8
Inoculated, stake treatment, 5% suspension of basic slag	28.64	.09	3.4	17.6
Inoculated, stake treatment, 10% suspension of basic slag	31.42	.09	4.2	16.2
Inoculated, stake treatment, 2% Zn SO_4 $7H_2O$	32.45	.08	4.7	9.8

a. Rating from 0 to 10 in terms of presence of vesicles and/or hyphae.

Table 8. Effect of three sources and four methods of fertilizer application on DM production and nutrient content of tops, as well as root infection to two month old inoculated M Ven 77 grown in sterilized Quilichao soil.

Treatment[a]	DM tops (g/plant)	Nutrient content of tops (% N)	(% P)	(% K)	(ppm Zn)	(ppm B)	Degree of root infection[b]
No fertilizers	8.68	2.32	.11	.90	75	8.0	2.5
10-30-10, method 1	24.02	1.65	.20	1.11	73	10.4	2.7
10-30-10, method 2	35.90	1.51	.14	.90	57	8.8	2.0
10-30-10, method 3	42.58	1.40	.12	.89	72	9.2	2.2
10-30-10, method 4	38.49	1.48	.12	.99	72	8.9	1.5
10-30-10 + Zn method 1	29.84	1.48	.16	.96	165	10.2	2.0
10-30-10 + Zn method 2	40.63	1.43	.13	.88	140	8.8	3.0
10-30-10 + Zn method 3	47.11	2.02	.14	.80	125	7.3	2.2
10-30-10 + Zn method 4	48.39	1.46	.13	.81	120	8.0	2.2
10-30-10 + B method 1	23.92	1.60	.15	.93	72	24.0	3.7
10-30-10 + B method 2	52.96	1.37	.12	.84	77	23.4	2.2
10-30-10 + B method 3	40.98	1.71	.14	1.03	84	25.0	2.0
10-30-10 + B method 4	45.48	1.34	.14	1.05	43	25.7	2.2

a. Fertilization: 2000 kg/ha 10-30-10
20 kg/ha Zn as Zn SO_4 $7H_2O$
2 kg/ha B as Borax

Method 1 = incorporated with all the soil.
Method 2 = band applied five cm to side of stake.
Method 3 = band applied five cm below the stake.
Method 4 = spot applied below the stake.

b. Degree of root infection: 0 = no infection, 5 = highly infected.

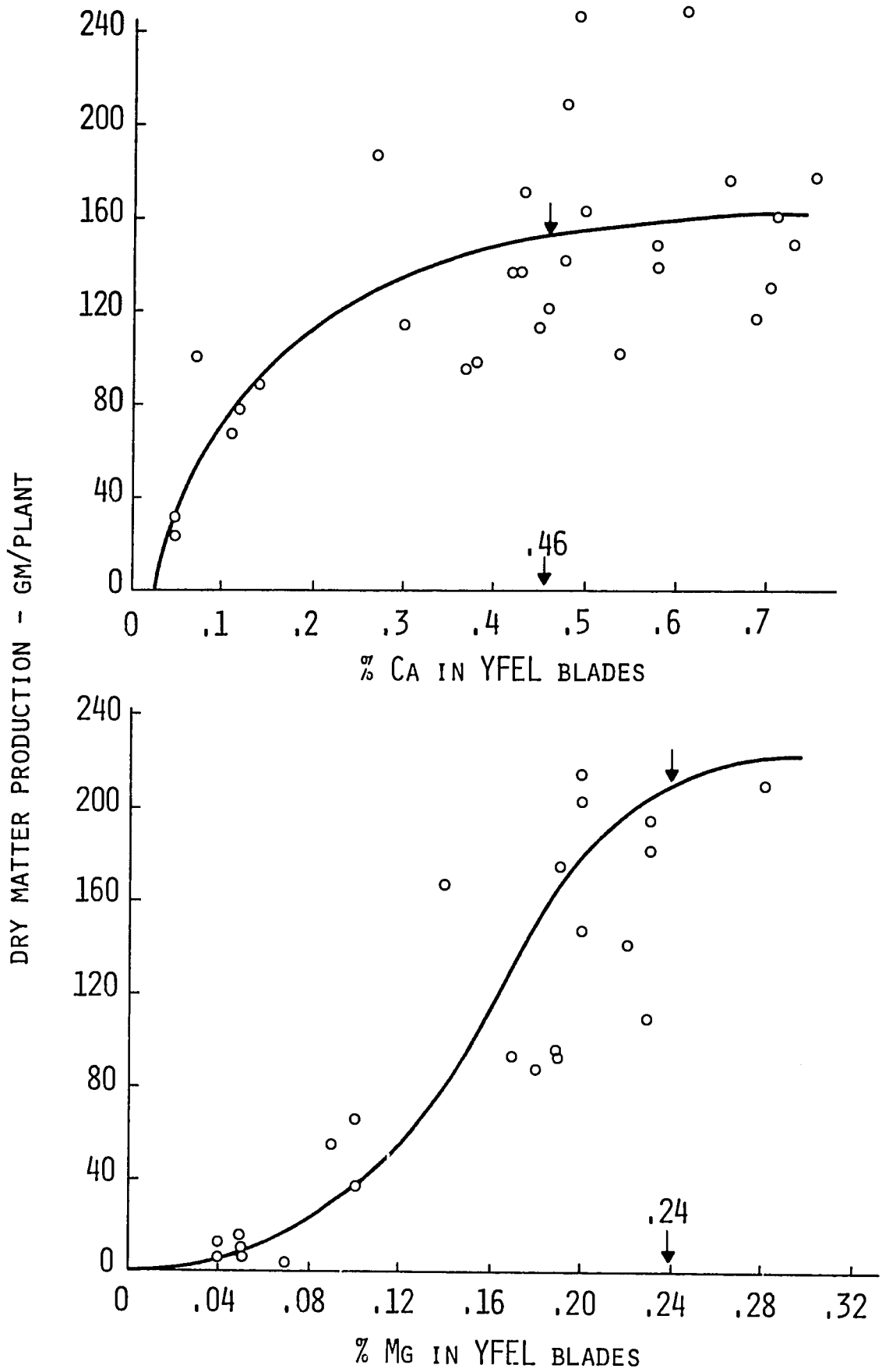


Figure 1. Relation between total dry matter production and the Ca or Mg concentration in youngest fully expanded leaf (YFEL) blades of cassava, M Ven 77, grown for 2-1/2 months in nutrient solutions with various levels of Ca and Mg. Arrows indicate the critical levels.

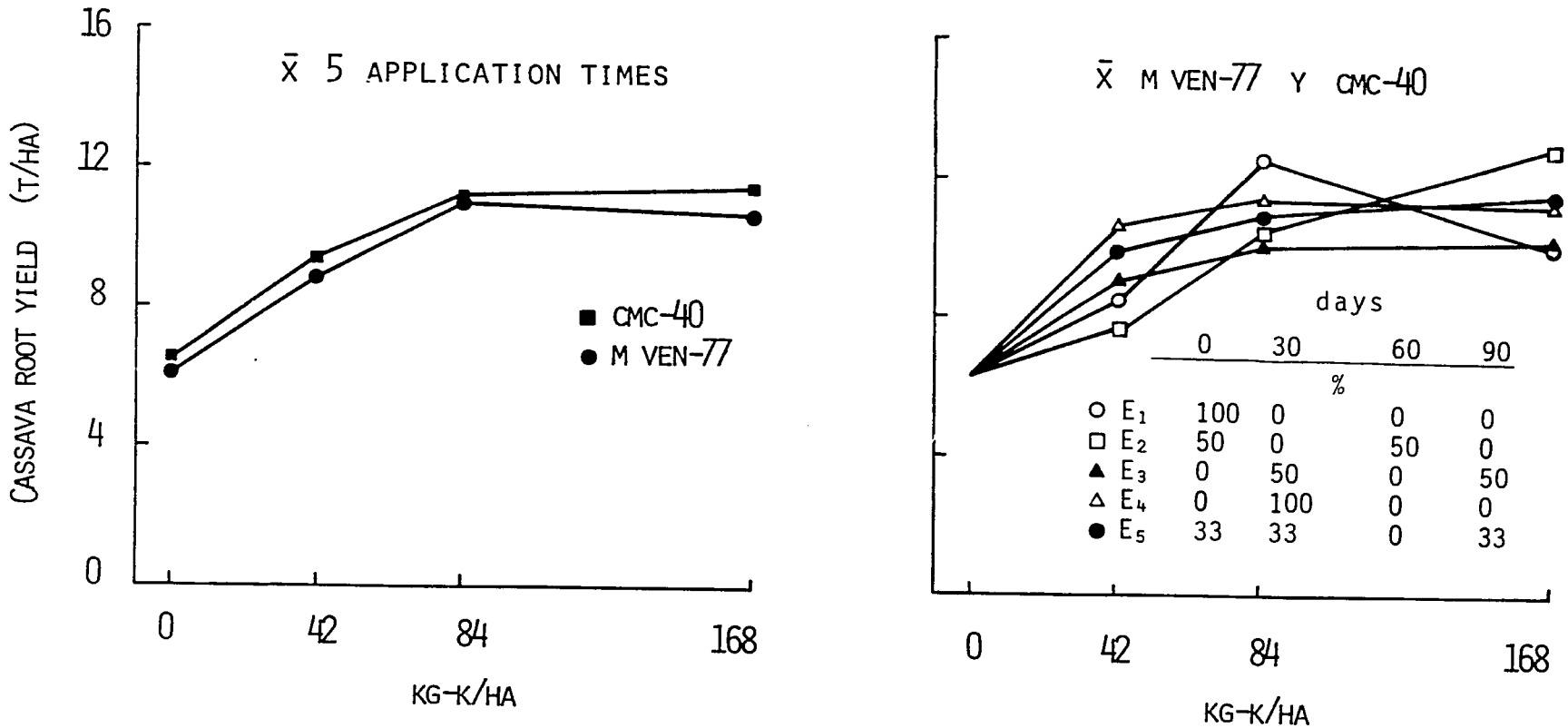


Figure 2. Root yield response of two cassava cultivars to various levels and times of application of K in Yopare-Carimagua.

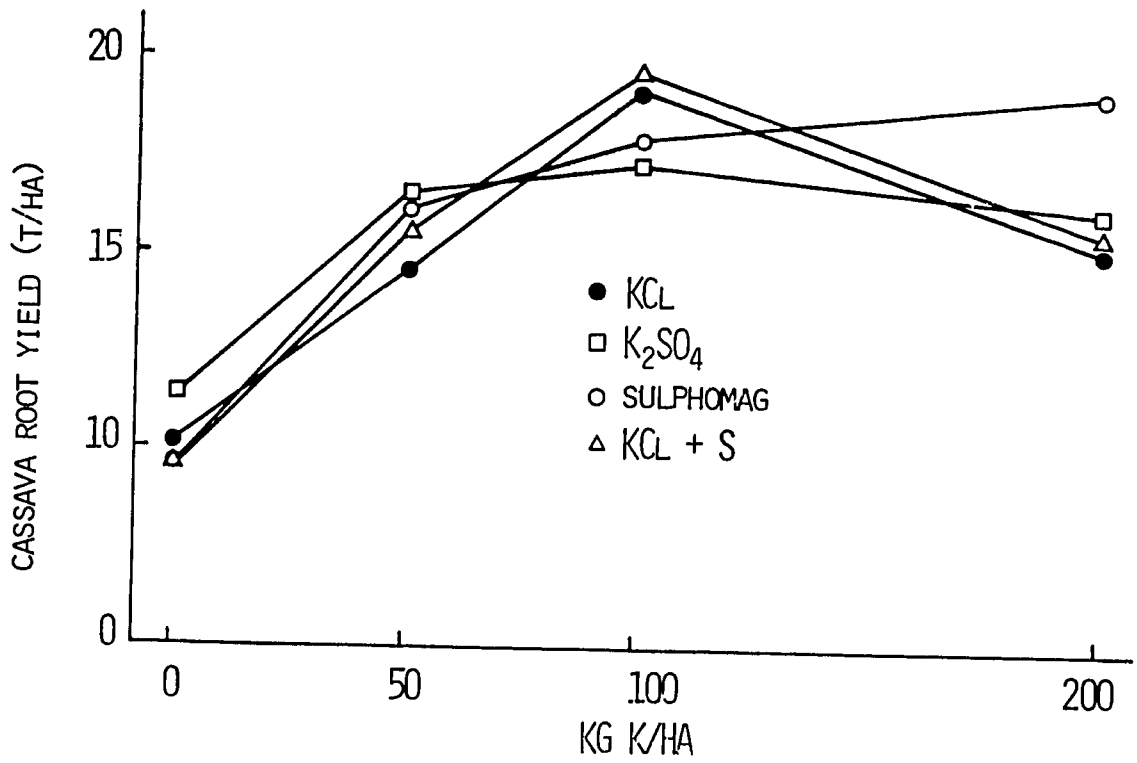


Figure 3. Root yield response of M Ven 77 to various levels and sources of K in Alegria-Carimagua.

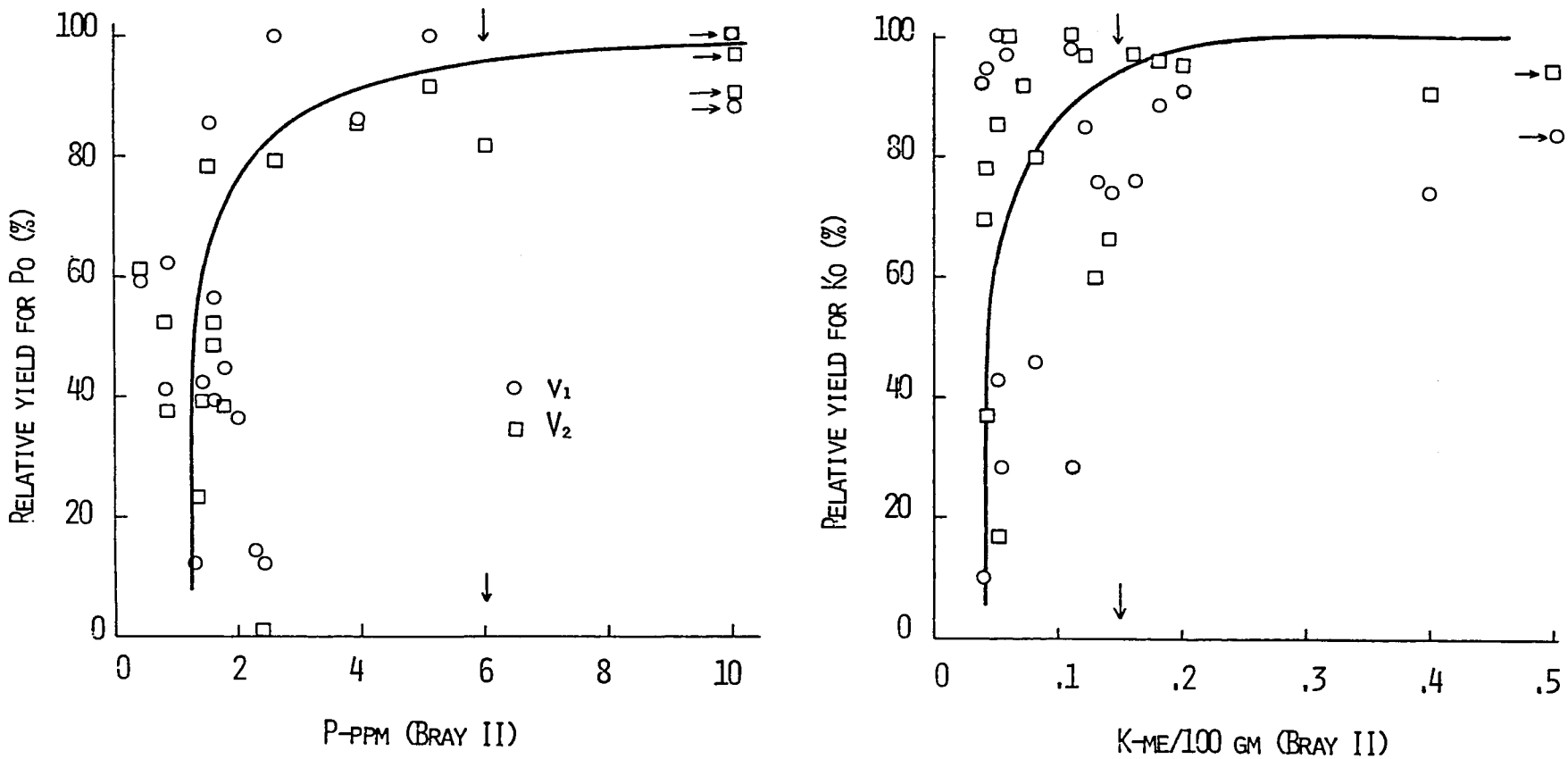


Figure 4. Relation between relative yield of several cassava cultivars and the available P or exchangeable K content of the soil. Vertical arrows indicate the critical levels.

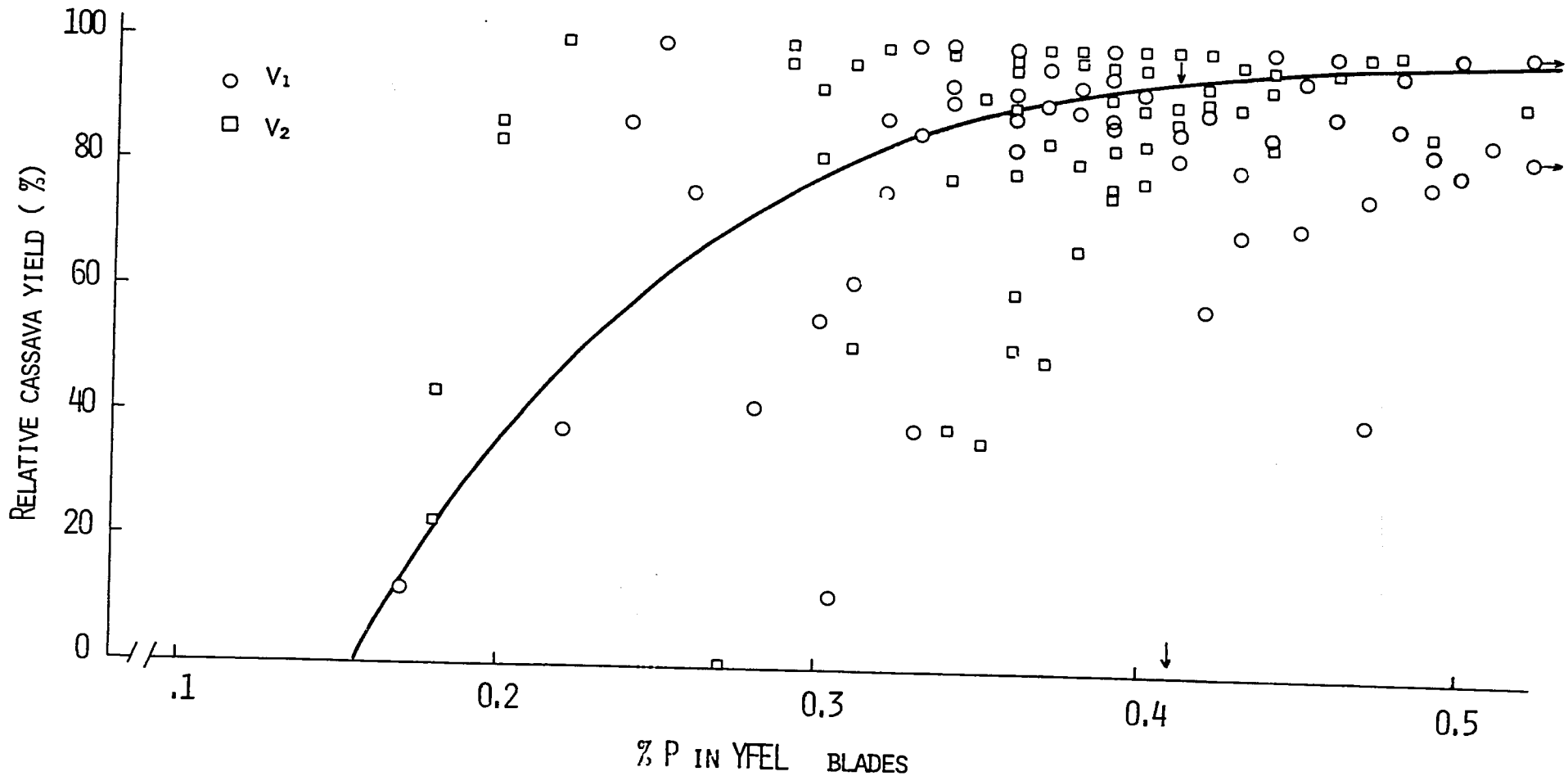


Figure 5. Relation between relative root yield of several cassava cultivars, grown with 4 levels of applied P in 20 locations, and the P concentration in youngest fully expanded leaf (YFEL) blades of 3-5 months old plants. Vertical arrows indicate the estimated critical level.

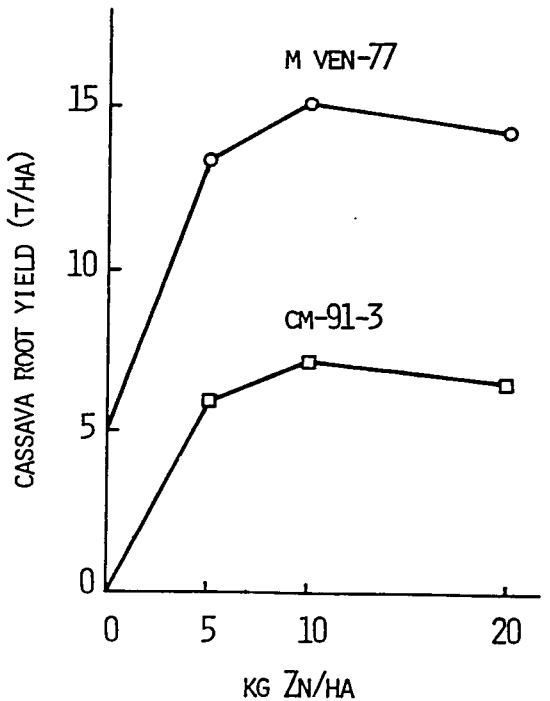


Figure 6. Root yield response of tuwo cassava cultivars to various levels of applied Zn in Alegria- Carimagua.

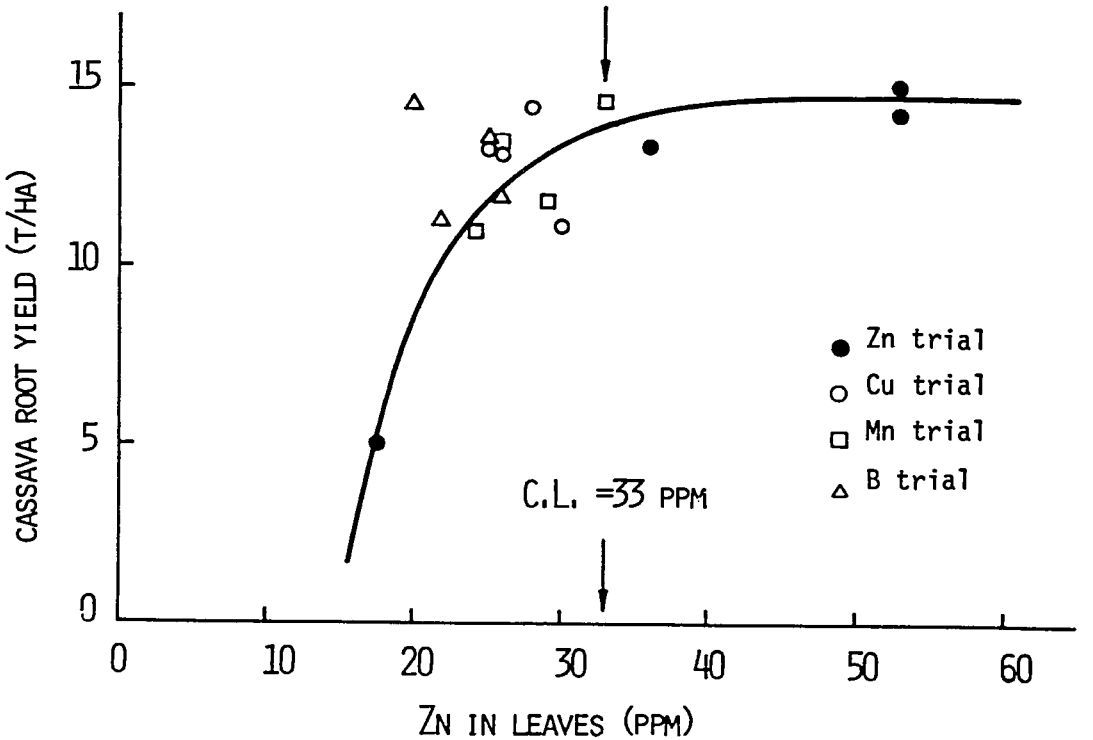


Figure 7. Rlation between root yield of cassava, M Ven 77, and the Zn concentration in youngest fully expanded leafblades at four months in Alegria- Carimaua. Arrows indicate the critical level.

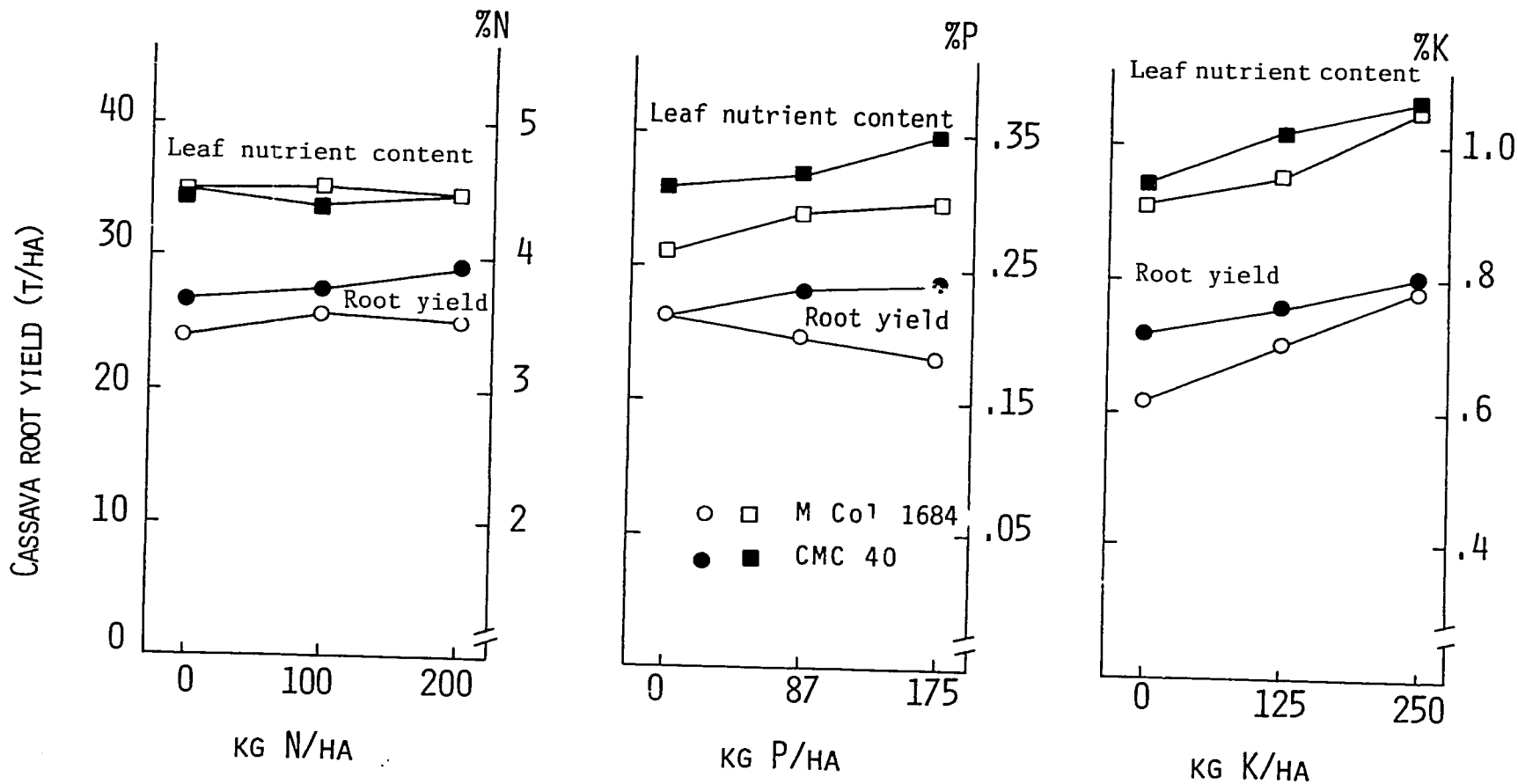


Figure 8. Residual effect of various N, P, and K levels, applied in 1977 on cassava root yield at 12 months, and the N, P and K concentrations in youngest fully expanded (YFEL) blades at three months of two cassava cultivars planted in Quilichao in 1981.

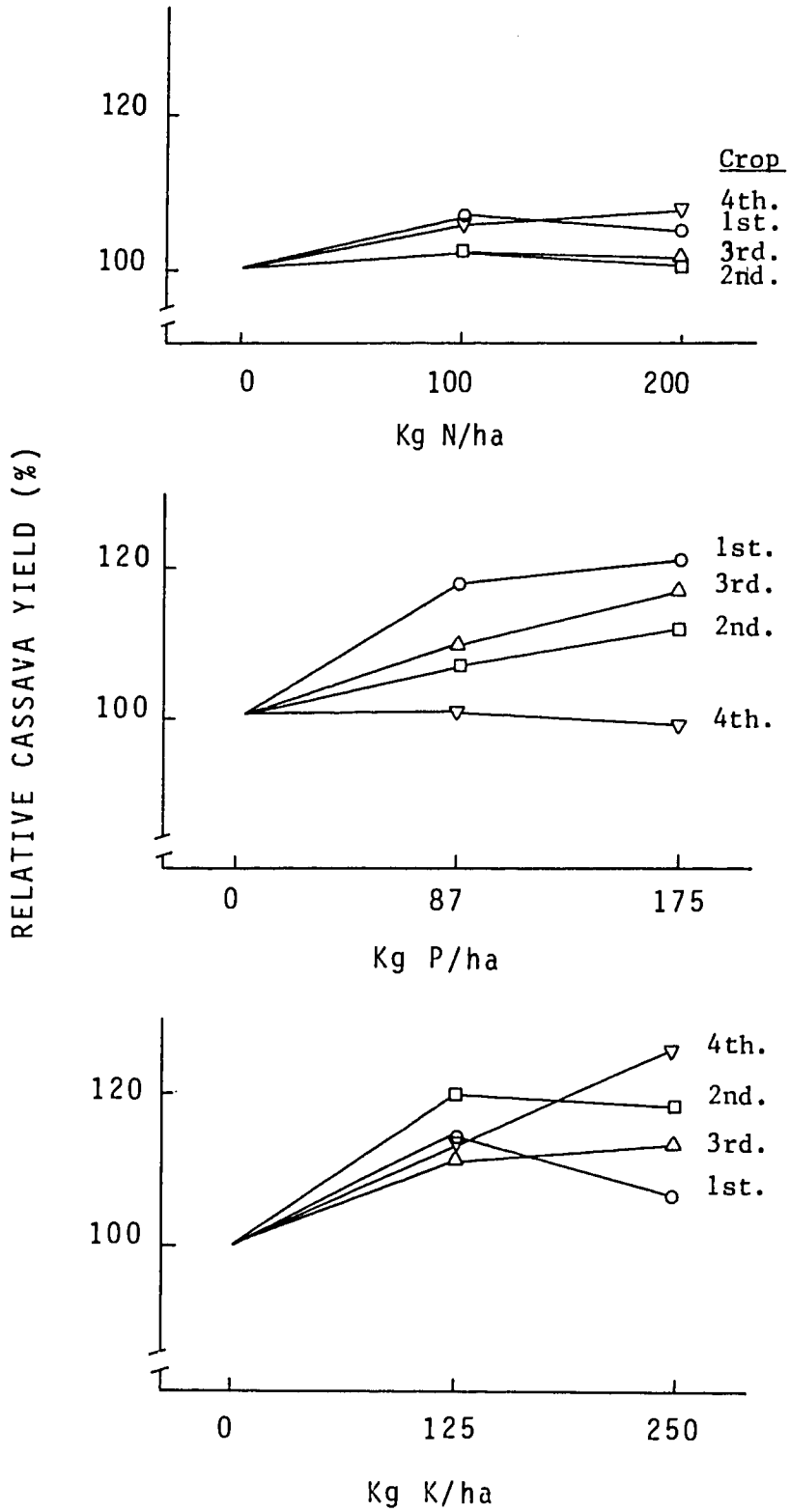


Figure 9. Effect of various N, P and K levels on the relative cassava yield of four consecutive cassava crops grown subsequent to the initial application in 1977.

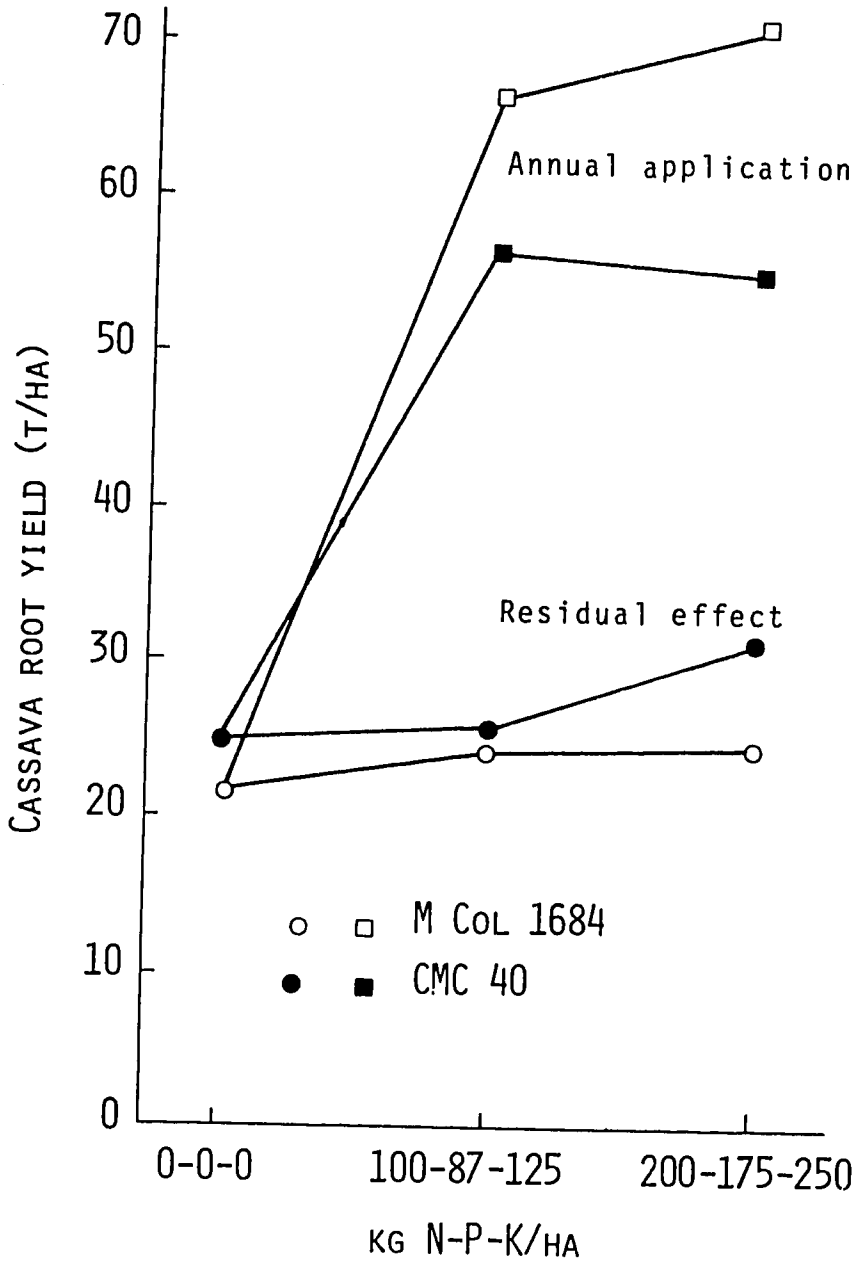
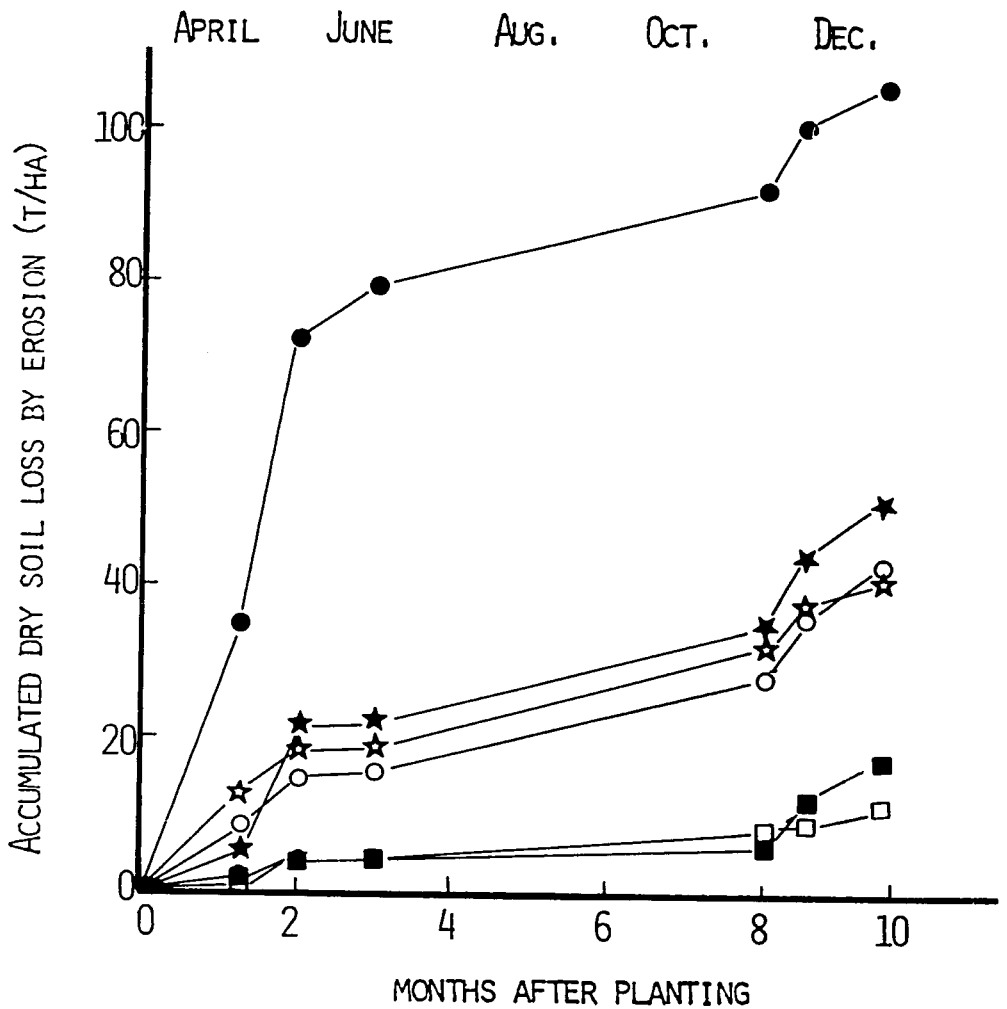


Figure 10. Response of two cassava cultivars to the initial (1977) and annual application of various levels of N, P and K in Quilichao.



● Double row cassava with four rows cowpea

★ Cassava intercropped with one row cowpea

○ Coventional preparation with oxen

☆ Preparation with oxen and hand ridging

■ Double row cassava with strips of Brachiaria humidicola

□ Cassava with maize mulch

Figure 11. Accumulated soil loss due to erosion in various planting systems of cassava in Mondomo.

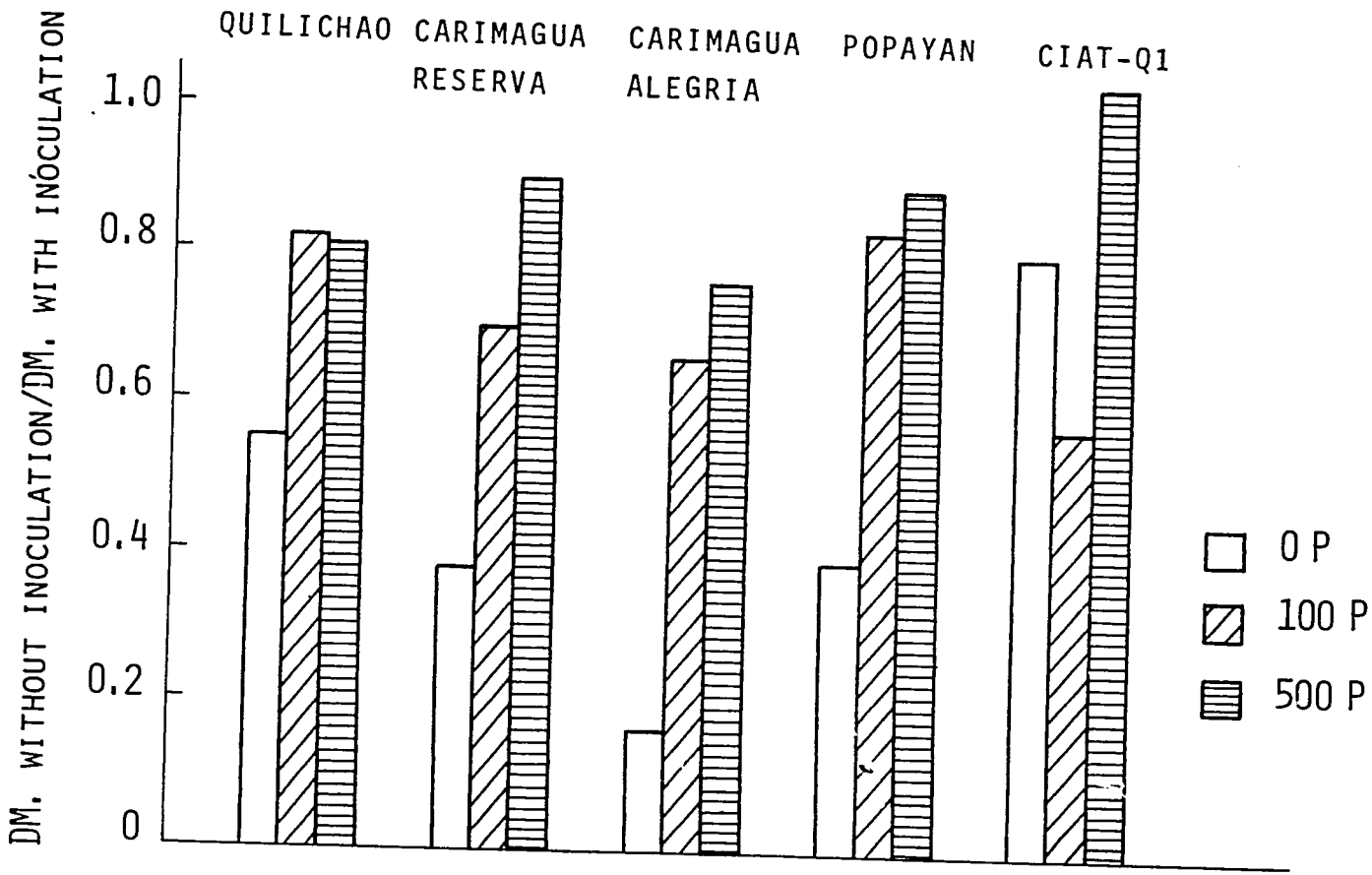


Figure 12. Relative response of CM-91-3 to inoculation in five unsterilized soils with three levels of applied P under greenhouse conditions.

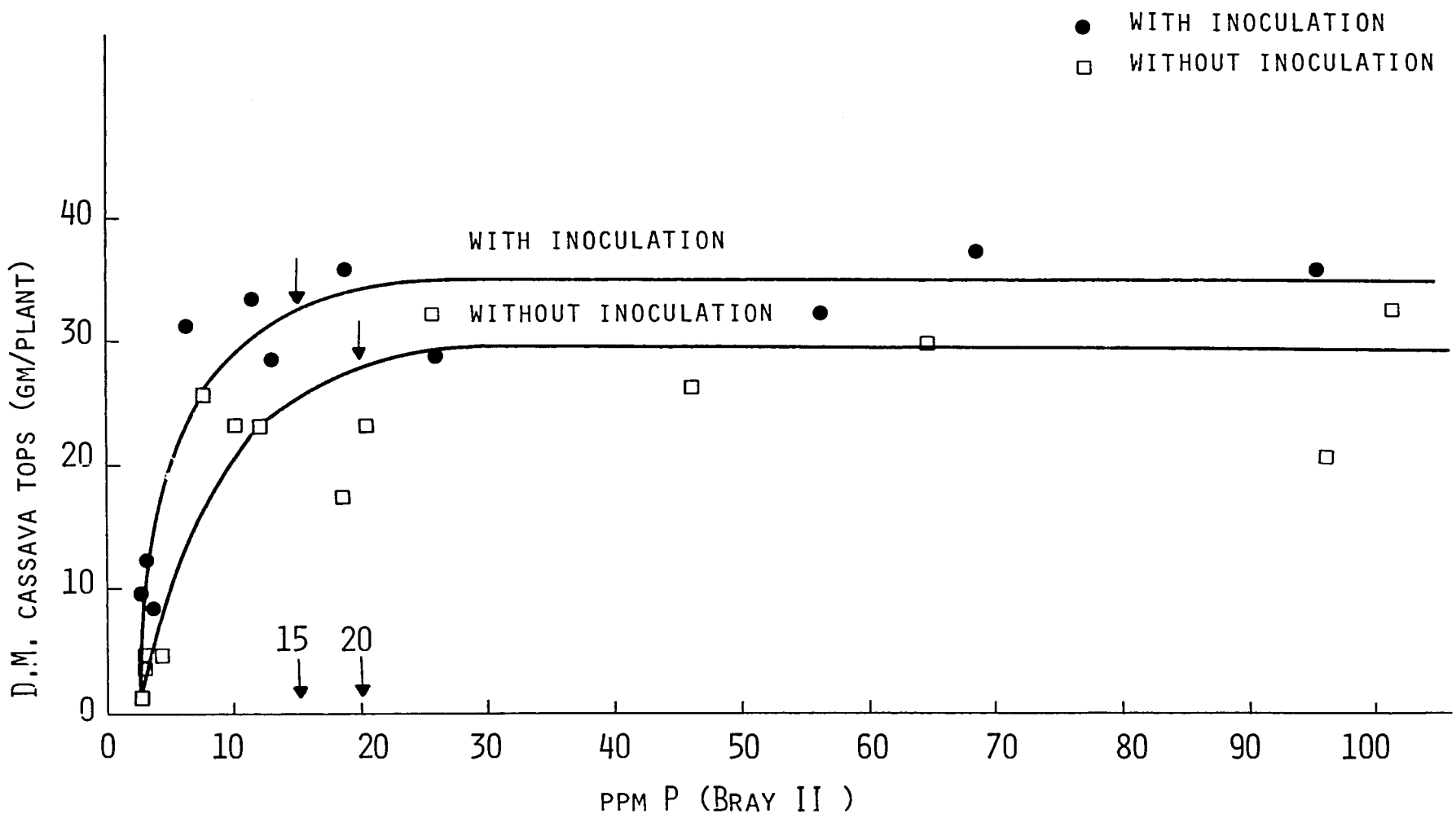


Figure 13. Relation between dry matter production of inoculated and non-inoculated plantlets of CM 91-3 and the available P content of various soils. Arrows indicate critical levels with and without inoculation.

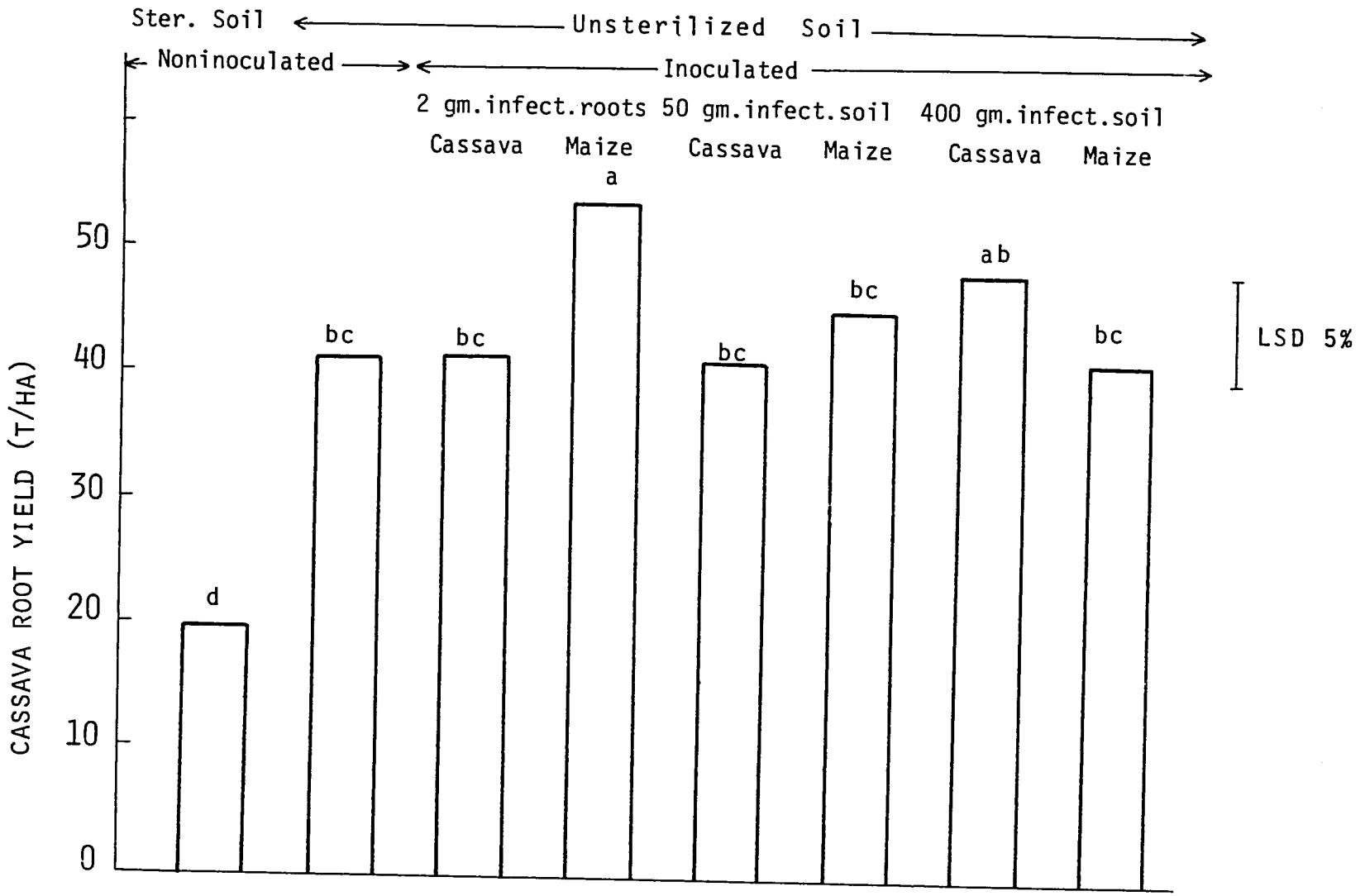


Figure 14. Root yield of M Col 638 grown in sterilized or unsterilized soil in CIAT-Quilichao, without or with inoculation and with various levels and sources of inoculum. Bars indicated by different letters are significantly different at 5% levels.

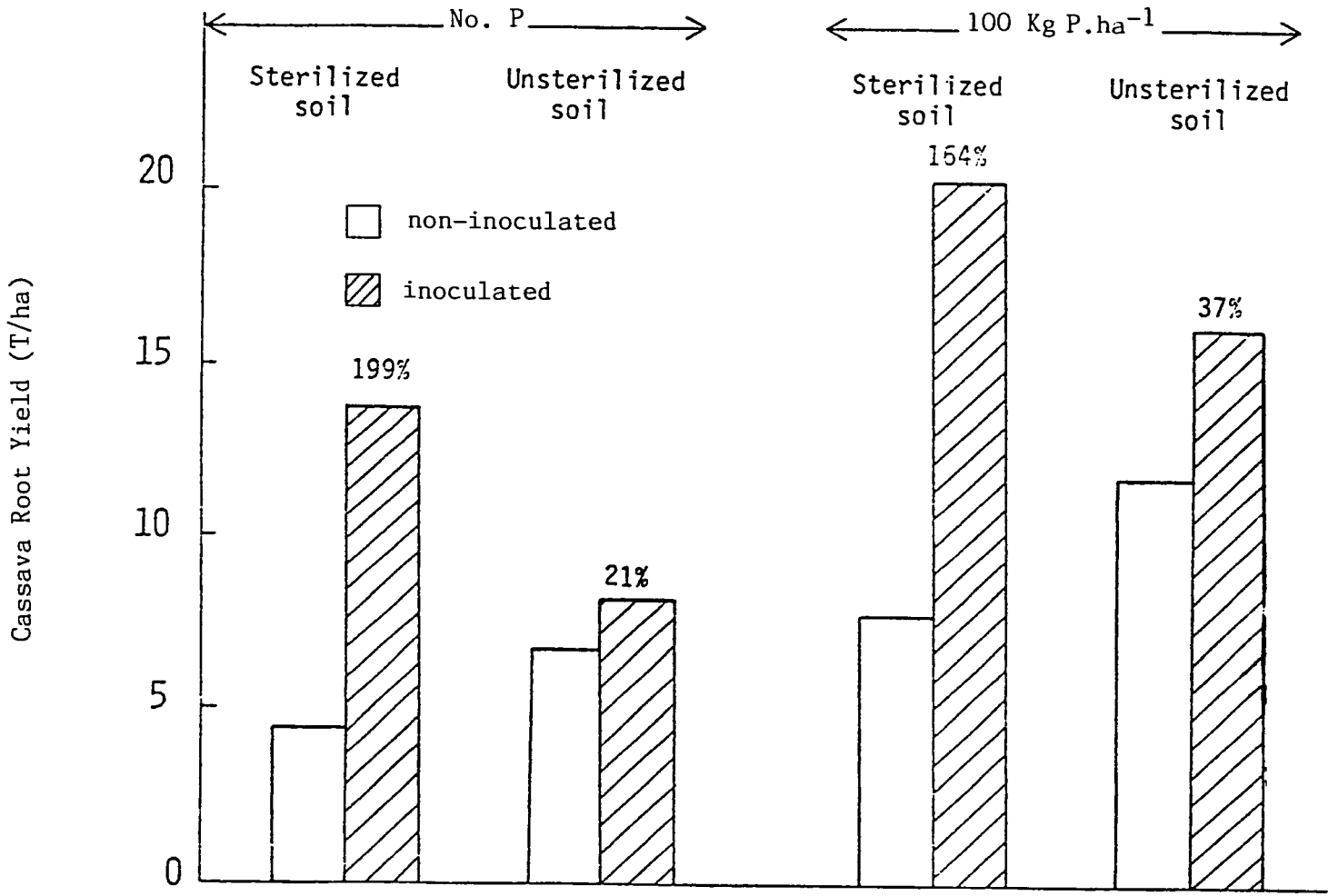
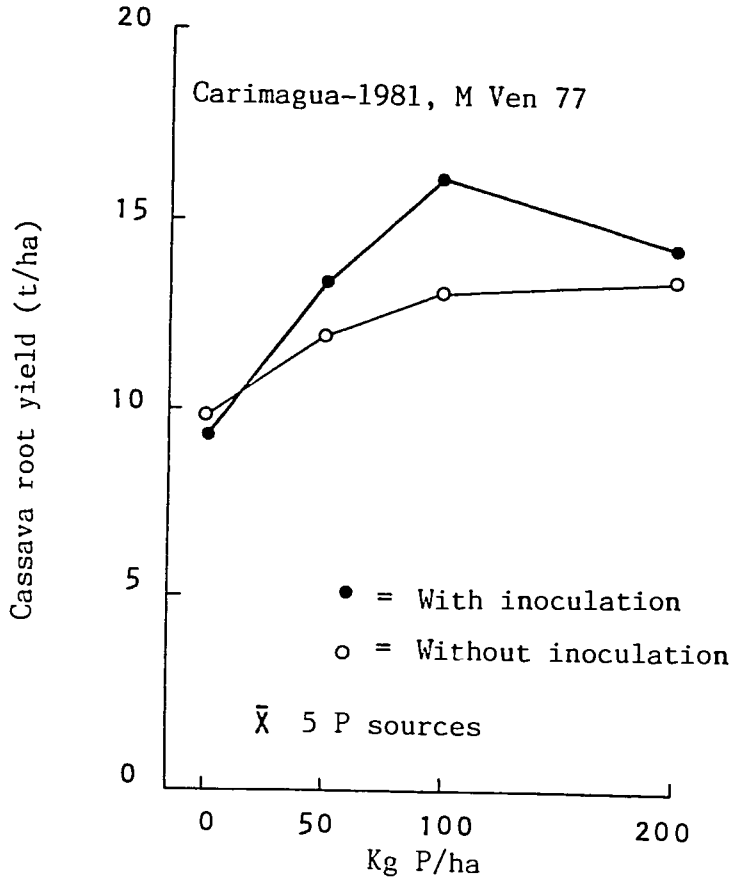


Figure 15. Effect of soil sterilization, P application and mycorrhizal inoculation on the root yield of cassava, M Ven-77, grown in Yopare, Carimagua. Numbers on bars indicate the percentage response to inoculation.



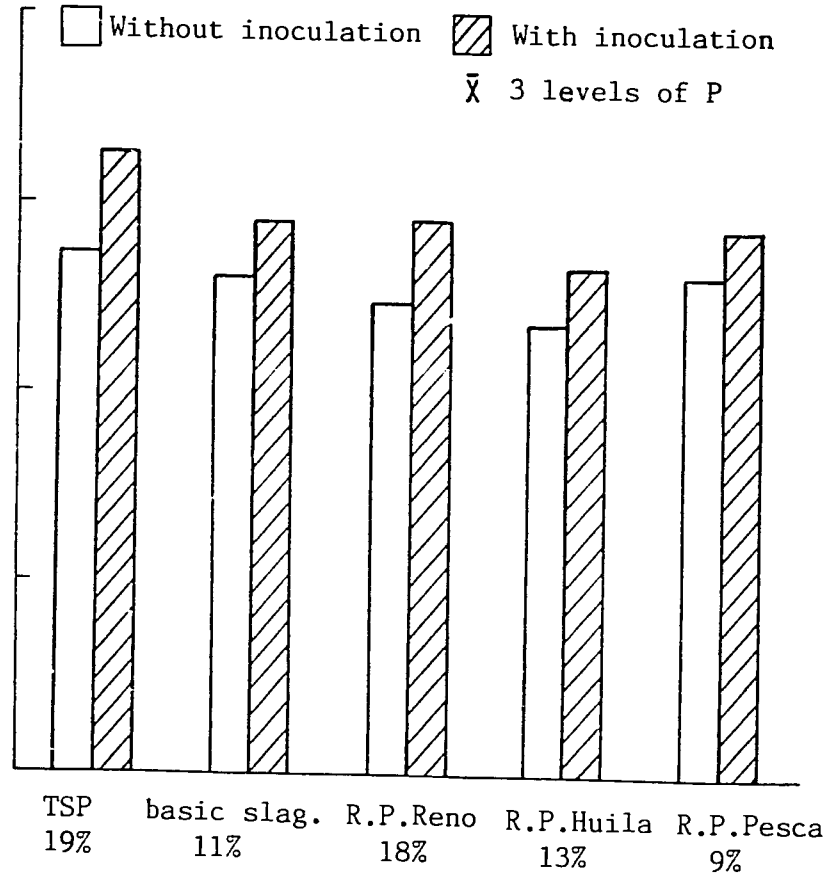


Figure 16. Effect of various levels (left) and sources (right) of P as well as mycorrhizal inoculation on root yield of cassava, M Ven-77 in Carimagua. Numbers below the sources indicate the percentage response to inoculation.

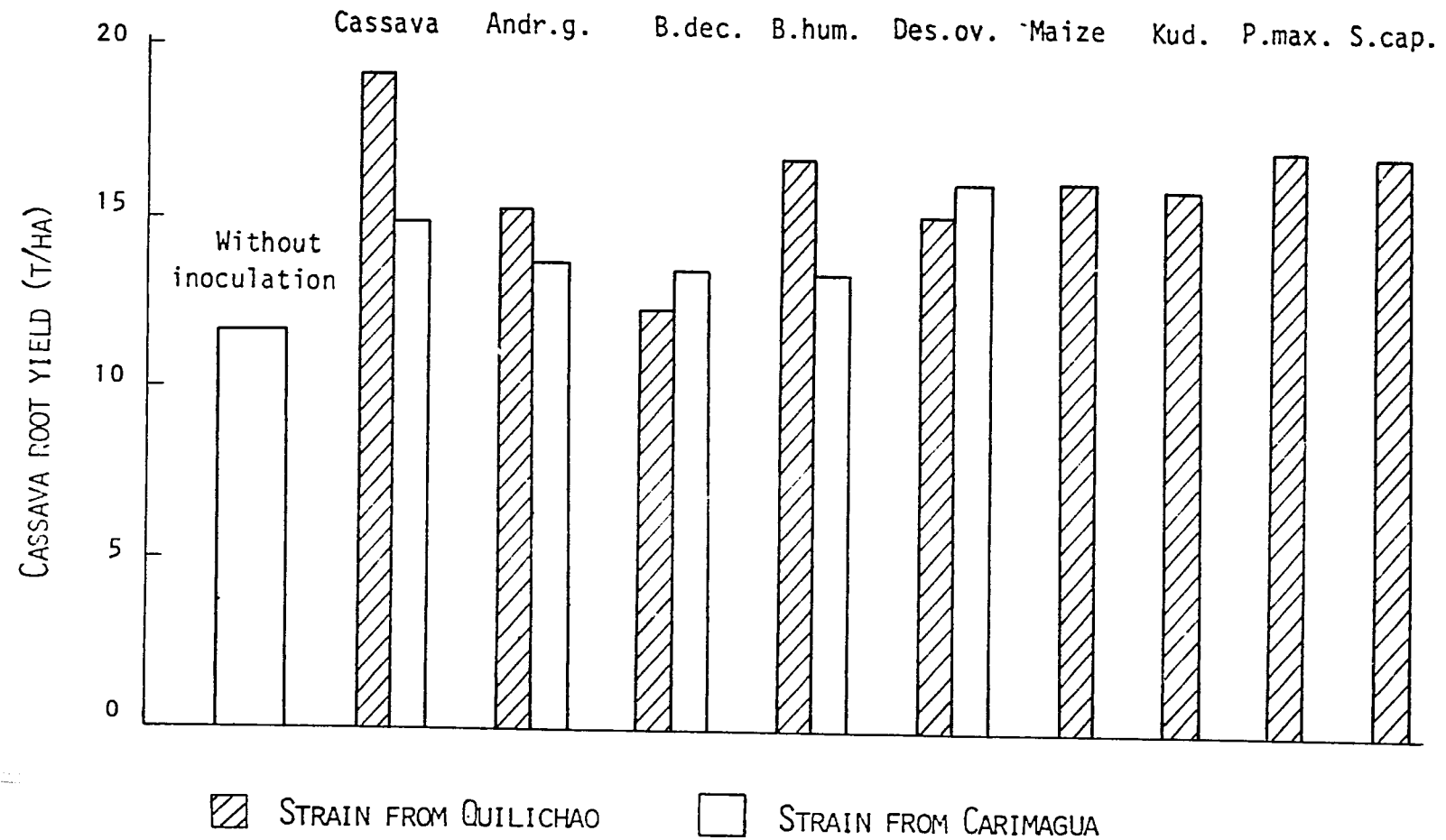


Figure 17. Effect of inoculation with roots of various plant species, infected with mycorrhizal strain from Quilichao or Carimagua, on root yield of cassava, M Ven 77, in Carimagua.

Mycorrhiza Project

The objectives of the Mycorrhiza Project are:

(1) collection and maintenance of pure mycorrhizal strains;

(2) evaluations of effectiveness of mycorrhizal strains; and

(3) determination of favorable cultural practices for maintaining a highly effective mycorrhizal association during the entire growth period of cassava, and to preserve a high mycorrhizal spore population in the soil. An additional objective is to evaluate the conditions under which a field inoculation of cassava could be considered economically useful. In 1982, most emphasis was placed on strain collection and purification and the determination of the influence of cultural practices.

Collection

Isolation procedures of VA mycorrhizal fungi were standardized. Two methods of isolation are possible as shown in Figure 1. Direct isolation from soil samples is done if soil can be collected easily. Multiplication of native mycorrhizal population and re-isolation from pot cultures is done if samples are small, which is generally the case when taken on collection trips. Multiplying native mycorrhiza first in pots is also recommended due to absence of sporelation of some strains in the field. Collection numbers are now sub-divided. The first number (for example C-17-2) indicates origin of soil sample with climatic and soil data of collection site. Each subnumber corresponds with a mycorrhizal spore type at the location. Taxonomy of mycorrhizal spores now is done in cooperation with Dr. Schenck, of the University of Florida, Gainesville, Florida.

Total preliminary type collection was increased to about 250 strains. Pot culture purification of strains and multiplication of native mycorrhiza spores was done exclusively with tropical Kudzu (*Pueraria phaseoloides*. This is because Kudzu is an obligate mycorrhizal plant, adapted to a broad range of soil conditions, and the seed is easy to handle and available in most parts of the tropics. Tropical Kudzu is also known as a good host plant for mycorrhizal spore production at several P fertilizer levels. Other pasture legumes can also be used for spore production; however, plant establishment in pots is easier with Kudzu. Rhizobium are applied to the plants to assure adequate N fixation. In the total multiplication process only 25 kg P/ha are applied. All strains from soil samples with a pH lower than 5 and available P below 20 ppm (Bray II) are multiplied and maintained in soil from Quilichao mixed with river sand. Strains from samples with a higher pH or P content are multiplied in a Palmira soil/river sand mixture.

Strain evaluation

The procedure for strain evaluation was also standardized

(Figure 1). For the first test of effectivity (Test I) a sterilized loamy, acid and low P soil from Quilichao is used. Tip cuttings of the cassava line CM 91-3 will be used in all strain evaluations.

For competitive ability studies (Test II) in unsterilized Quilichao soil, only those mycorrhizal strains will be evaluated which were most effective in Test I. In Test II, 50 kg P/ha as Huila rock phosphate as well as low levels of N, K and Mg are applied. The cassava line CM 91-3 is again used as the test plant. The infectability and competitive ability of the native mycorrhiza is determined by the "most probable numbers" method for every trial so as to compare Test II trials done at different times.

All strains not effective in Test I, nor able to compete with native mycorrhizal fungi in Test II, are stored. Storage in plastic bags in the cold room is done after sun drying of soil with a high spore content.

Because multiplication of isolated spores is a time consuming process (about six months from isolation to initiation of Test I) only some isolated strains could be tested. Two newly named species, Glomus manihotis Howeler, Sieverding et Schenck (C-1-1, C-2-2, C-17- 1) and Entrophospora colombiana Spain et Schenck (C-1-4 and C-10) are the most effective species evaluated so far. These strains are now being tested in field trials.

Evaluation of cultural practices.

A. Fertilization. The effect of P application on mycorrhizal root infection was determined. Figure 2 shows the effect of increasing levels of applied P on cassava root and shoot yield as well as on mycorrhizal root infection at four different sites. Observations of root infection were made twice during the growth cycle, as indicated in Figure 2.

At all sites, a good root yield response was obtained with 50 kg P/ha. However, responses to higher P levels were found only at Quilichao and Carimagua-La Reserva. At these sites, increasing P levels caused a marked increase in vesicle formation in relation to the total infection, indicating that mycorrhizal species which produced vesicles in the roots (i.e. species of the genus Glomus) were favored by increasing P levels. However, also at Agua Blanca, Glomus spp. were present but no increase in vesicle formation was observed at high P levels. Morphological observations of the native spore population showed absence of Glomus manihotis at Agua Blanca, indicating that G. manihotis was probably the mycorrhizal species which was favored by higher P levels, and which was responsible for increasing yields at higher levels of P fertilization. However, no favorable response to higher than 50 kg of applied P/ha was found at Carimagua-La Alegria, where infection by vesicles increased similarly as total infection did where G. manihotis was present. This may be due to a more sandy soil type in Carimagua-La Alegria, which results in leaching of nutrients, especially potasium, which in turn affects the plant growth response to P application. Furthermore, at Carimagua-La Alegria, phosphate was the limiting factor, not only for plant growth but also for root infection, indicating that

in these extremely low-P soils, some P application is required to stimulate the native mycorrhizal population.

The first sampling for observation of mycorrhizal root infection was done in November at the end of the rainy season in all sites. The plant harvest (and second root observation) at Quilichao was done at the end of the dry season in March; at this time a lower root infection was found, including very poor infection with vesicles. At other sites, plants were harvested during the rainy season, and no marked differences in root infection were observed between the two root observation times. It may be concluded that root infection decreases when the plant is under water stress. This is especially true for those mycorrhizal species which produce vesicles inside the roots since they are sensitive to drought because the carbohydrate exchange from host to fungi is diminished during the dry season.

B. Mulching. At the CIAT-Quilichao Station a trial was initiated to test the effect of field inoculation with *G. manihotis* (strain C-1-1) and of mulching with 15 t/ha of *Brachiaria decumbens* straw (10-15 cm layer) on yields of two cassava cultivars (Figure 3). In the first three months of growth, mulching reduced soil temperature (measured at 4 P.M.) from about 30°-32°C to 25-26°C at a 10-20 cm depth. Under mulch, the daily soil temperature only fluctuated between 24 and 26°C, while without mulch it varied from 25°C - 35°C at a 10 cm depth. Also without mulch, temperatures varied strongly from a maximum of 42°C at the soil surface to a minimum of 25°C at 20 cm depth. Soil water content at the 0-15 cm soil depth was 3.5% higher under mulch (on dry weight basis).

Figure 3 shows that fresh root yield of M Col 638 was lower than that of M Ven 77 without the use of mulch; however, mulching increased yields significantly and both cultivars produced equal yields with mulch. Inoculation with mycorrhizal strain C-1-1 (*Glomus manihotis*) increased root yields consistently, but not significantly. However, the coefficient of variance of four replications was reduced from 22.4% to 13.6% by field inoculation, indicating that more stable yields may be possible by inoculating each plant with effective mycorrhizal strains. The introduced strain came originally from Quilichao so that the native population was as effective as the introduced one. Mulching decreased root infection of M Ven 77 in the first six months of growth of both inoculated and noninoculated plants, which may be due to lower soil temperatures under mulch. This reduction in infection was not found with M Col 638. As differences in root infection between inoculation treatments were generally small (only under mulch with M Ven 77 was root infection by inoculation constantly increased over the entire vegetation period) the mean growth response to mulching has to be explained by lower soil temperatures or better water relations under mulch.

C. Herbicides. On a field at CIAT-Quilichao which was free of plants for over three months before planting, a trial with M Col 638 was initiated to determine the effect of herbicide applications on cassava yield and mycorrhizal infection. Check plots were hand weeded twice at 8 and 28 weeks after planting (WAP) and herbicides were applied three days after planting. Oxifluorfen was most effective in controlling weeds

(95%), followed by oxadiazon (90%) during the first 27 weeks of growth. With a diuron/alaclor mixture, 52% of weeds were controlled at 8 WAP and 35% at 27 WAP. In the second half of the growth cycle, development of weeds was slow and independent of the treatments so that at harvest no marked differences in weed incidence between the treatments were observed. No significant differences in yields, nor in root starch content, were found between the treatments. Mycorrhizal root infection of cassava was very high in the first three months and decreased markedly during the last six months of growth (Figure 4). Although there appeared to be a consistent negative influence of oxifluorfen application on root infection, these differences were not significant statistically but indicates that the presence of weeds may actually increase root infection of cassava. Mycorrhizal spore population in the hand weeded check increased strongly up to 27 WAP and remained constant at a high level from that date on (Figure 5). The reason for the lower spore production at 27 and 41 WAP with herbicide applications may be: (a) absence of weeds that act as a host for mycorrhizal production (this appeared to be the case for oxifluorfen and oxadiazon at 27 WAP; with the reinfestation of weeds, the spore production increased through to the end of the growth cycle); (b) a direct negative chemical influence of the product as was the case with the diuron/alaclor mixture). In greenhouse trials (see Cassava Annual Report, 1981) this herbicide mixture also had the strongest negative influence on spore production in sterilized soils. While in another trial, reported in the Plant Soils and Nutrition Section of the report, the herbicide Lazo was also found to have a negative effect on root infection and DM production. At the end of the growth cycle spore populations in herbicide-treated plots were as high as in the hand weeded check. This was due to a normal increase of the mycorrhizal population to a constant level with plant maturity and due to re-invasion of weeds; the presence of weeds was correlated positively with numbers of mycorrhizal spores (Figure 6). From this trial it can be concluded that herbicide applications had only a small effect on the mycorrhizal root infection. However, this may vary with different soil conditions. Radical weed control by herbicides may be more detrimental for mycorrhizal spore production in crops with a shorter growth cycle than cassava.

Cultivar Differences

In a field trial at Quilichao the cultivars M Ven 77, M Col 638, M Col 1684 and CM 91-3 were planted and inoculated with either a soil root mixture from corn containing mycorrhizal strain C-1-1 (G.manihotis) or with highly infected soil and roots taken from Panicum maximum plots from the CIAT Quilichao Station. Some 500 g of inoculum was placed under each cassava stake. Root yields were high without additional field inoculation and varied between 27.1 t/ha (M Col 638) and 41.4 t/ha (M Col 1684), although only 50 kg P/ha were applied as Huila rock phosphate. The change in yield by inoculation was not significant. As was the case in the mulch trial, the coefficient of variance between the four replications was decreased from 18.2% to 9.5% by inoculation with strain C-1-1. This effect as more pronounced with vigorous growing cultivars like M Col 638 and CM 91-3 than with the less vigorous ones (from 23% to 10.9% VS. 13.9% to 8%, respectively). The reduction in the coefficient of variance by inoculation with infected soil from the

CIAT-Quilichao station was small. Results from both the mulching and cultivar trials indicate that the native mycorrhizal population was highly effective for cassava production. The introduction of effective mycorrhizal strains seems only worthwhile in areas where the quantity and the quality of the native mycorrhizal population is low. Trials are now underway at these locations.

Spread of Mycorrhizal Infection in the Field

At the CIAT-Quilichao station M Col 1684 was planted in ridges and inoculated with 500g inoculum of C-32-1, Glomus manihotis per stake. This was applied either directly under each stake or banded near the surface on both sides of stake. These two methods of inoculation were compared with an uninoculated control (Figure 7). Before planting, 50 kg P/ha as Huila rock phosphate were incorporated; 100 kg N/ha and 100 kg K/ha were band-applied, 15-20 cm on either side of the stakes, half at planting and half five months after planting. Fine roots were taken for observation from four plants of each treatment at the end of the rainy season (8 WAP), in the dry season (13 WAP), and in the following rainy season (29 WAP) at several distances from the plant and at three soil depths as shown in Figure 8. Root sampling was done in a band of about 2.5 cm within a half circle around the stake. The mycorrhizal species Glomus manihotis is characterized by forming spores and vesicles inside the roots. Observations of the percentage of infected root length by either hyphae, arbuscles or vesicles, and separately, of infected root length by vesicles indicate the spread of the infection caused by the introduced mycorrhizal strain. Figure 8 shows that roots were generally more infected at a deeper depth (20-30 cm) during the dry season. In the rainy season root infection was greatest at the intermediate soil depth (10-20 cm). (At the intermediate soil depth a slight increase of infection with plant age was observed). Root infection decreased with the distance from the stake, especially in the first 13 weeks of growth in the upper 20 cm. Placement of inoculum under the stakes favored root infection in and under the zone of placement in comparison to treatment without inoculum application.

With treatment A, the presence of vesicles in more than 10% of root length was found only in the dry season at 20-30 cm soil depth. Vesicle infection in treatment B indicated clearly that the infection with Glomus manihotis had spread into deeper soil zones because the initial fine roots had passed through the inoculum. However, the lateral spread of infection was very low. When inoculum was placed in side bands, root infection with vesicles was low and almost the same as in non-inoculated plants six weeks after planting. However, at 13 WAP the infection had already spread into the 10-30 cm soil depth and in that case more infection was observed at 20 cm distance than with treatment A or B. At 29 WAP band-applied inoculum resulted in the best lateral spread of the introduced mycorrhizal strain. This is because at the start of the rainy season a growth of fine cassava roots occurs in the upper soil horizon and these roots pass through the banded inoculum; this also indicates that inoculum seems to survive the dry season. A lateral spread of introduced mycorrhizal strains is thought to be most important when P fertilizers are broadcast and incorporated in the upper soil horizon. It can be concluded that it may be favorable to place inoculum

at planting under the stakes and reinoculate in side bands after the dry season. However, other mycorrhizal strains may be better able to establish themselves in the field with only one inoculation at planting.

Prediction of Need for Field Inoculation of Cassava

It is well known that the success of any field crop inoculation with mycorrhizal fungi depends on five points: (1) the nutrient content of the soil must be low or adapted to the introduced mycorrhizal strain; (2) the crop must be obligate mycorrhizal under the given field conditions; (3) the population and/or the quality of the indigenous mycorrhiza must be low; (4) the introduced mycorrhizal strain needs to be effective with the host, must be highly competitive with native mycorrhiza, and the inoculum must be free of pathogenic organisms; (5) the cultural practices before and during the entire crop growth cycle have to be beneficial to the plant as well as the introduced mycorrhizal strain.

Assuming that conditions 1, 2, 4, and 5 can be met in the major cassava growing areas, point 3 is the most important and difficult to predict. The following procedures may be used to predict the effectivity of the native mycorrhizal population:

- Mycorrhizal spore counting in the soil to determine the quantity of the population. However, as it is known that some mycorrhizal strains do not sporulate in the field, and that fungal structures like mycelium inside or outside of native growing plant roots can serve as inoculation material for new roots, it is better to determine the infective propagules in the soil using the "most probable number" method.

- Observations of root infection in native plants also give some indications of infectability of the indigenous mycorrhiza.

- Quality of native mycorrhizal strains can only be determined after isolation of spores from the field soil, and by morphological comparison of these strains with isolated strains in the collection. From comparisons with data in the collection catalogue it can be concluded whether native strains may be effective or not.

- Quality of native mycorrhizal strains may also be indicated by the cassava growth response to phosphate application. If the response is low this may indicate the lack of adapted mycorrhizal strains.

- A still unconfirmed method to define the quantity and quality of the native mycorrhizae is the observation of the native plant or weed succession in the field. High presence of obligate mycotrophic plants such as native legumes or non-mycorrhizal plants can indicate the presence or absence of effective mycorrhizal strains because obligate mycotrophic plants cannot survive without effective mycorrhiza.

All mentioned points will be evaluated and taken into consideration for the field inoculation trials.

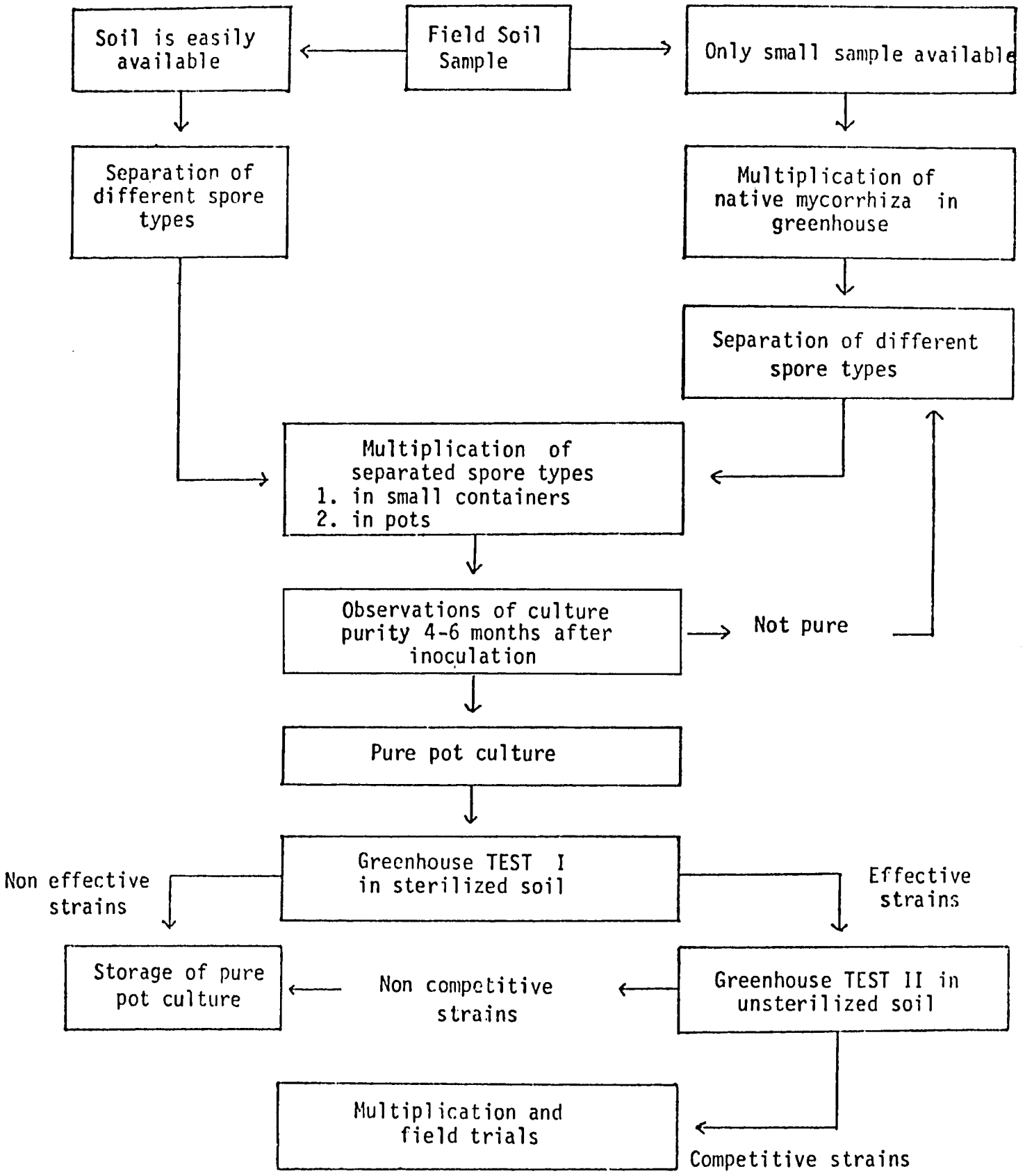


Figure 1. Flow chart of mycorrhizal strain isolation ahd testing procedures.

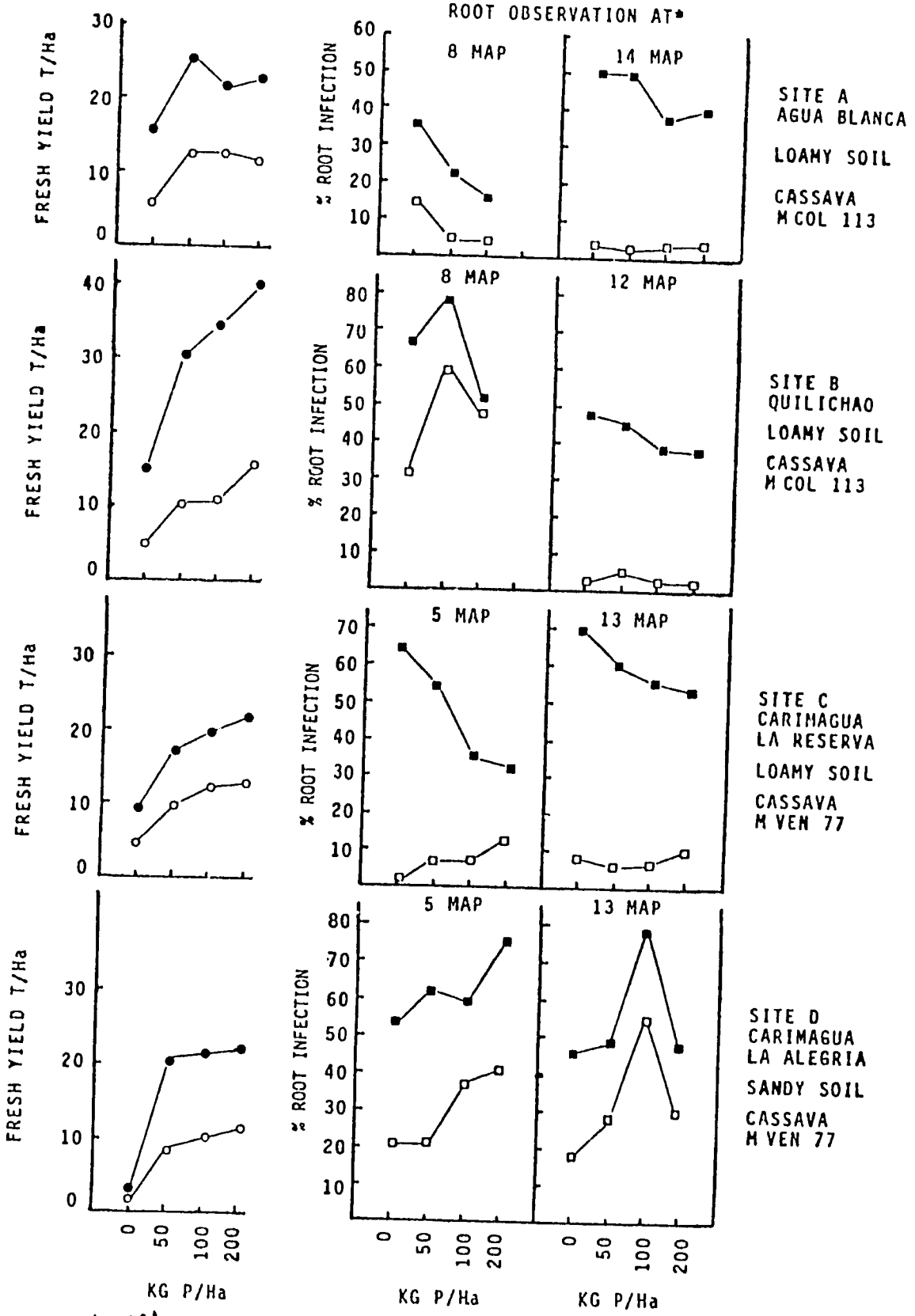


Figure 2. Effect of P application levels on yields (● Root yield; o shoot yield) and micorrhizal root infection (■ Root infection by either hyphae, arbuscles or vesicles; □ Root infection by vesicles) of cassava cultivars at four locations.

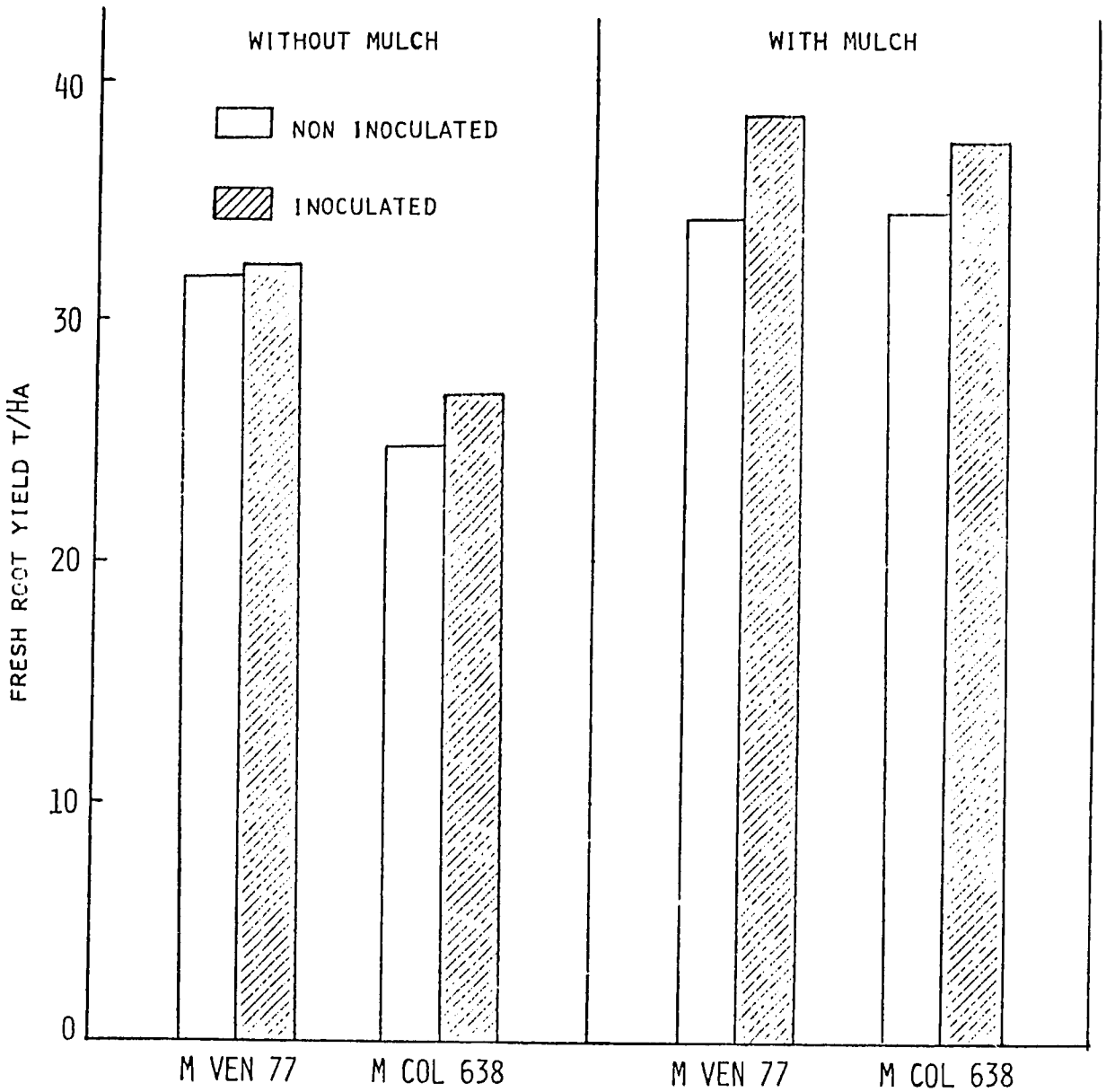


Figure 3. Effect of field inoculation with Glomus manihotis (Strain C-1-1) of cassava M VEN 77 an M COL 638 grown with and without mulching of soil.

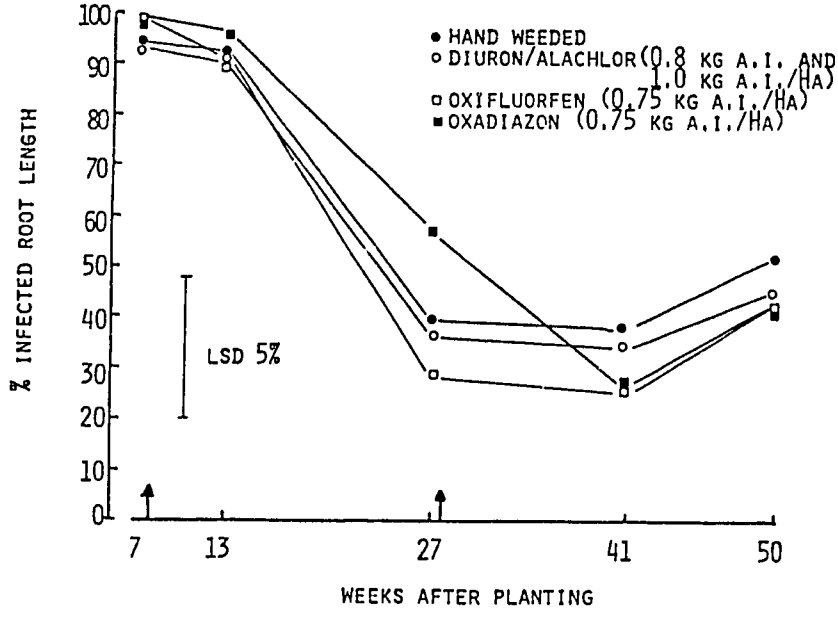


Figure 4. Effect of hand weeding and herbicide applications on mycorrhizal root infection of cassava M Col 638 at CIAT-Quilichao.
(Arrows indicate dates of hand weeding for plots without herbicide application).

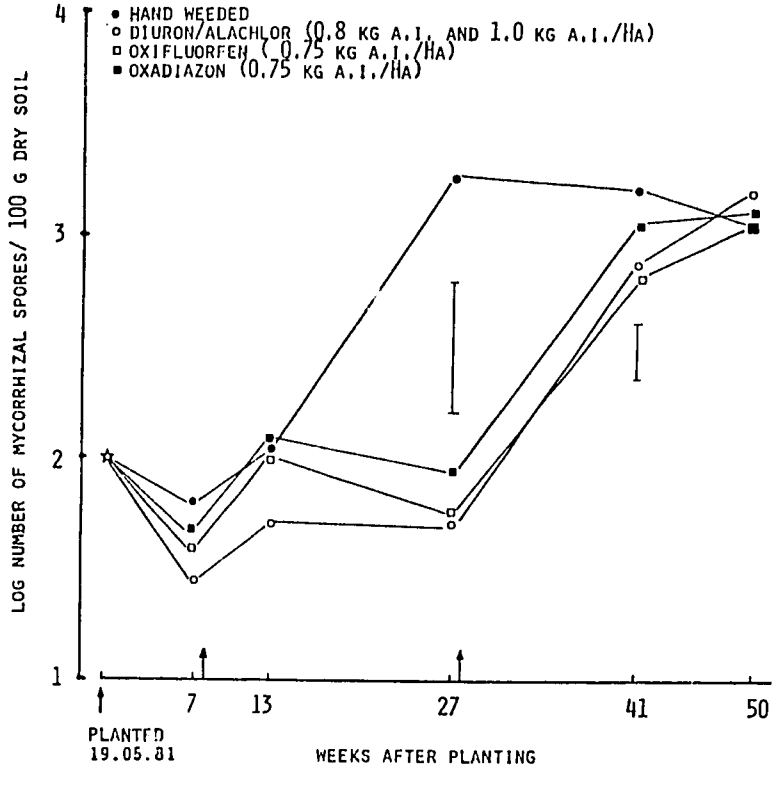


Figure 5. Effect of hand weeding and herbicides on native mycorrhizal production in a cassava field with M COL 638 at CIAT- Quilichao. (Bars indicate LSD 5%. Arrows indicate dates of hand weeding for checks without herbicide application).

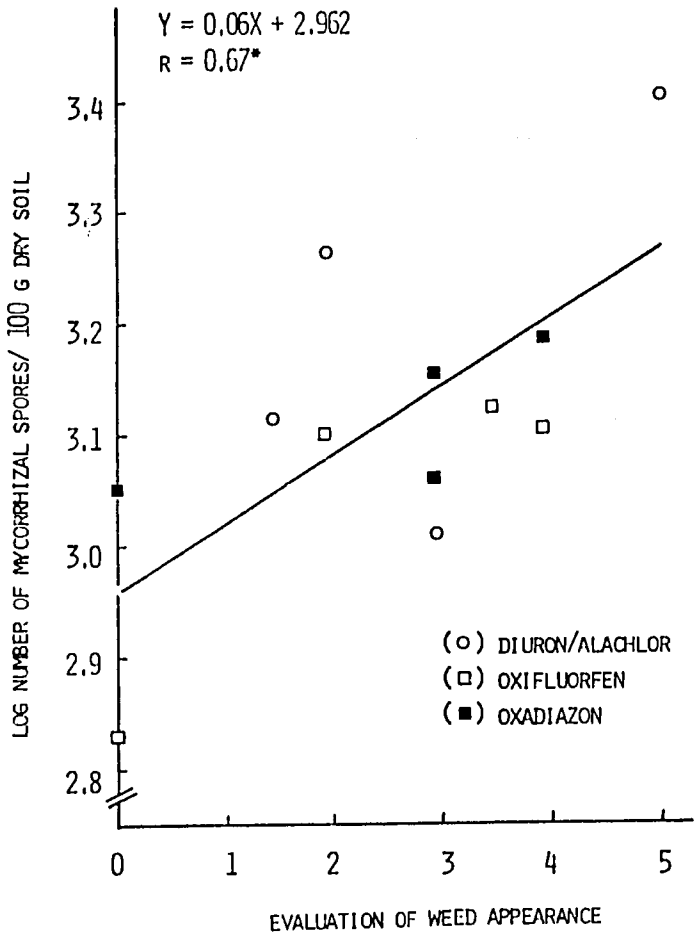


Figure 6. Correlation between weed appearance and mycorrhizal spore production at harvest in a cassava field at CIAT-Quilichao. Herbicides were applied at planting time.

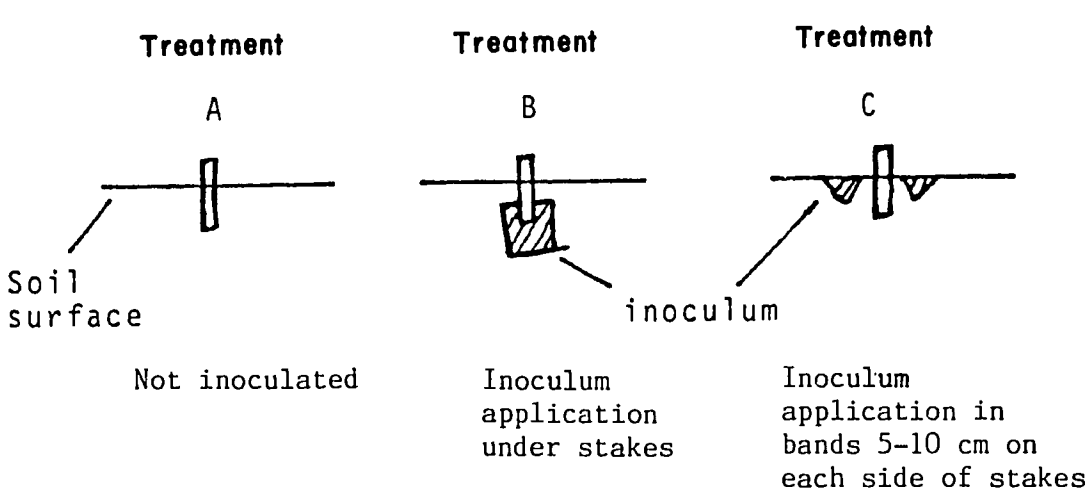


Figure 7. Inoculum application method

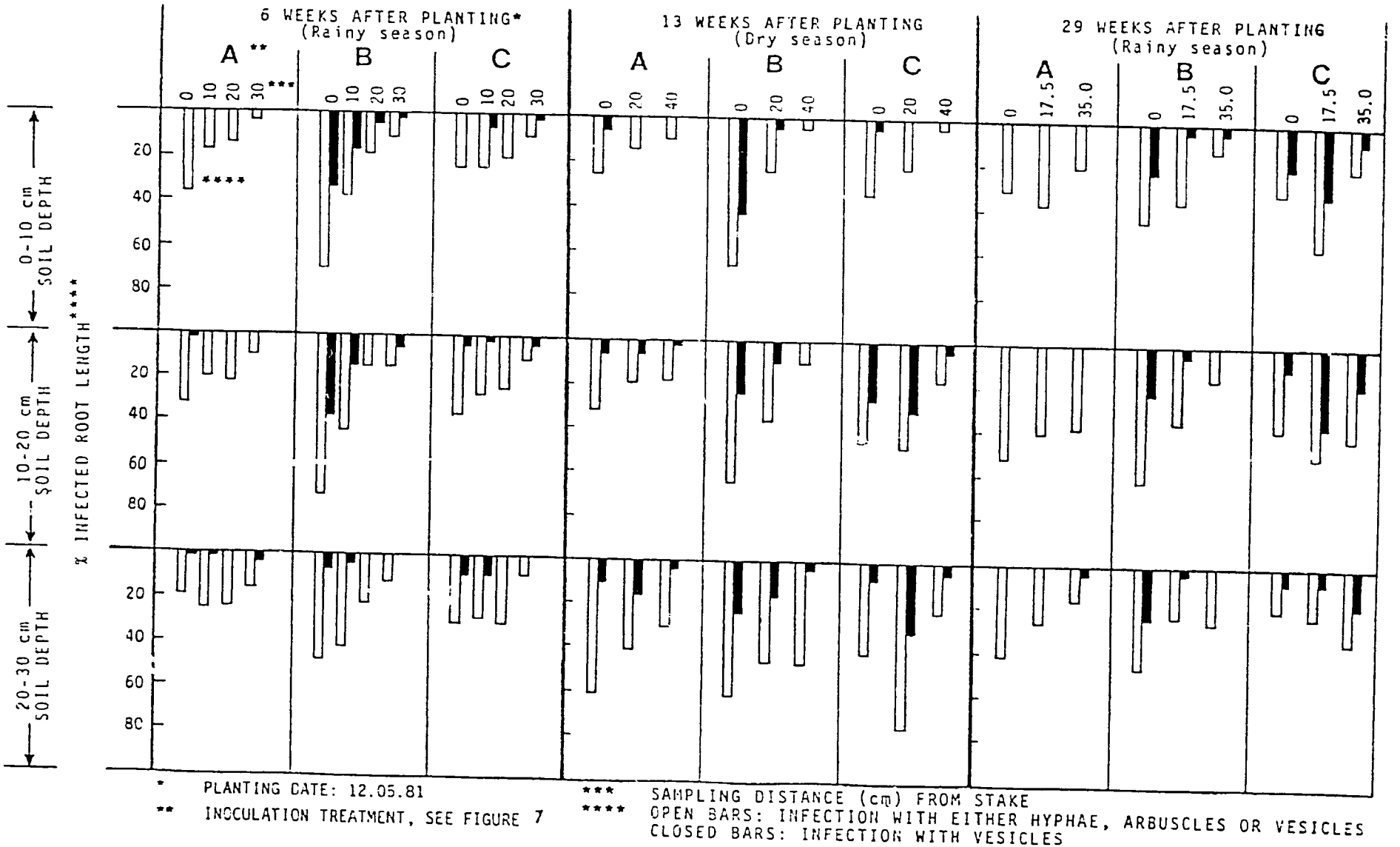


Figure 8. Spread of mycorrhizal root infection of cassava. M COL 1684 at three sampling dates and with three methods of inoculation.

Entomology

Research in cassava entomology during 1982 emphasized evaluation of CIAT germplasm for resistance to the mealybug, Phenacoccus herreni, a pest of major importance in certain areas of South America. Natural enemies of this pest were identified and are being evaluated. The biology of the whitefly Aleurotrachelus socialis and the "tiger insect" Phoenicoprocta sanguinea were studied. Plant damage due to stemborers, termites, whiteflies and P. sanguinea were investigated; losses of dried cassava chips due to Araecerus fasciculatus and Lasioderma servicorne were measured. Ovipositional and feeding preference studies were continued with whitefies and the subterrean hemipteran, Cyrtomenus bergi. Several aspects of lace bug (Vatiga manihotae) behavior and ecology were investigated.

Mealybugs

Populations of the mealybug, Phenacoccus herreni were studied in the Colombian llanos and at CIAT.

Varietal resistance

A program was initiated to evaluate the CIAT cassava germplasm bank for resistance to the mealybug. Initial screenings were done in the greenhouse (average temperature 24°C and 70% RH). Two 4 - 5 week old plants of each variety grown from stem cuttings were inoculated by placing two mealybug ovisacs on the growing point. Evaluations were made 2-4 weeks later and mealybug counts as well as damage symptoms recorded.

Four hundred varieties have been evaluated; results show that a range of population reactions and damage symptoms exist in cassava germplasm. About 3% of the varieties evaluated displayed light damage symptoms (1-2 on a 0-5 damage scale) although several of these had a high population (Table 1). This preliminary screening will be complemented by field screening of varieties selected as promising for resistance or tolerance.

Preliminary studies on the methodology of artificial field infestations indicate that high populations of natural enemies can greatly reduce mealybug populations, complicating field resistance studies. Three methods were tested: (a) second instar nymphs were placed on growing points; (b) ovisacs were placed on growing points; (c) ovisacs were protected within miniature cages and attached to leaves closest to the growing point. The first method resulted in only a 10% efficiency, the second in a 50% efficiency, while the third resulted in a 100% infestation efficiency rate.

Biological control

The presence of a fungus Cladosporium sp. has been observed on mealybug populations in the greenhouse and field. High levels of parasitism by this fungus were also observed in field populations of the

mealybug in Pernambuco, Brazil. Fungus parasitism has been observed on all biological stages of the mealybug with the exception of the male adult. Nymphs of the 1st and 2nd instar are primarily attacked. Parasitized nymphs take on a gray to black color and become momified.

Natural populations of the mealybug were studied at CIAT for the presence of natural enemies. Systematic collections were made during September (50 growing points per collection) when mealybug populations were high. Numerous parasites and predators were observed (Table 2). The most predominant species was the hymenopteran parasite Acerophaga coccois (Encyrtidae). This parasite occurred in all collection sites and comprised 80% and 92% of the parasites observed during two collecting dates, respectively. This parasite appeared to be reducing mealybug populations in the fields. Other parasites and hyperparasites were also observed but in very reduced numbers.

Numerous predators were also observed; Ocyptamus (Diptera; Syrphidae) whose larvae had been previously reported as a good mealybug predator (Cassava Annual Report, 1981) was only found in low populations and very heavily hyperparasitized. High populations of the dipteran predator Kalodiplosis coccidarum were collected during one evaluation (Table 2). This predator has been highly successful on greenhouse colonies of the mealybug but had not been observed in high numbers in field populations. This parasite was released in a CIAT cassava field three years ago and may finally be taking hold in field populations of the mealybug. K. coccidarum is a very efficient predator of mealybug eggs.

A laboratory colony of the parasite A. coccois has been established and its role in controlling mealybug populations is being studied.

Whiteflies

Previous studies have shown that a high infestation of the whitefly, Aleurotrachelus sociales B. causes considerable yield losses in cassava (Cassava Annual Reports, 1978, 1979, 1980, and 1981). These studies show that losses occur only during a prolonged attack; a one month attack resulted in no root yield losses (Cassava Annual Report, 1980). A trial was conducted at the Nataima Station of the Instituto Colombiano Agropecuario (ICA), Tolima to study the effect of three month attacks of the whitefly on root production.

Three month attacks by whiteflies were permitted over a 10 month growing cycle of the crop with plants protected by applications of dimethoate at 15 day intervals during all other times. Three month long whitefly attacks during any stage of plant growth did not significantly reduce root yield (Table 3). However, when whiteflies were not controlled, average yields decreased from 52 to 28.5 t/ha, a decrease of 55%. Starch content did not differ significantly between controlled and non-controlled plots.

These results support previous studies which indicated that whitefly attacks in excess of three months are needed to cause

significant yield reductions (Cassava Annual Report, 1980) and that spray applications every three months may be sufficient to reduce whitefly attacks below the economic injury level.

Biological studies

Development studies of the whitefly A. socialis on cassava were done under field conditions at CIAT. Recently oviposited eggs were isolated with small individual leaf cages and daily observations were made.

Eggs are small, banana-shaped, oviposited only on the leaf underside and joined to the leaf by a pedicel at the widest end of the egg. Eggs are oviposited individually or in groups only on the apical leaves. They are initially white in color surrounded by a white dust which comes from the wings of the adults. After the second day the egg color changes to light brown and darkens with the egg age; the duration of the egg stage is 11.3 days.

There are four nymphal instars of 6.6, 4.3, 5.6, and 11.2 days, respectively (Table 4). The last instar is the pupal stage. The first instar is translucent and mobile, although its displacement is limited. On the second day the nymph begins to secrete a white waxy substance through its eight dorsal pores. During the second instar the nymph begins to acquire a black, chitinized color; the third instar nymph is completely black and a white waxy substance is secreted through lateral pores. This gives the third and fourth instars (pupal stage) its characteristic black color surrounded by the white waxy secretion. The adults are small, with two pairs of wings and covered with a white waxy dust.

Varietal resistance

The cassava varieties M Ecu 72, M Col 336, M Pan 70, M Bra 12, and M Col 339 had been previously selected as resistant or tolerant to whitefly attack.

Crosses were made between M Ecu 72 and M Bra 12, and between M Bra 12 and M Col 511, a susceptible variety. Progeny of these crosses were evaluated under high whitefly populations at the Nataima, Tolima ICA station. Whitefly infestation and damage symptoms were lower on the M Ecu 72 x M Bra 12 F_1 (Resistant x Resistant) crosses than on the M Bra 12 x M Col 511 (Resistant x Susceptible) crosses (Table 5). M Bra 12 is a variety which normally has high whitefly populations but does not display severe damage symptoms; M Ecu 72 normally does not have very high whitefly populations nor does it display very severe damage symptoms; M Ecu 72 normally does not have very high whitefly populations nor does it display very severe damage symptoms. The result of these crosses shows high levels of whitefly populations for progeny of the R x S cross but only a moderate level of damage symptoms. The R x R progeny show a moderate whitefly population but a very low level of damage symptoms.

Complementary to these evaluations, preliminary studies on whitefly ovipositional preferences were evaluated under CIAT greenhouse conditions. The resistant varieties M Ecu 72, M Col 336, M Pan 70, M Bra 12, were grown in pots and two month old plants were exposed to high adult whitefly populations. Periodic counts were made of oviposition on the 4th leaf. The results indicate high whitefly infestations (% of leaves infested with one or more whitefly stages) but there was a marked difference in oviposition, pupal levels and damage symptoms between the varieties. M Ecu 72 had the lowest numbers of eggs, 50.5% less than on M Bra 12 which had the highest (Table 6). Pupal counts were moderate on varieties M Col 336, M Pan 70, and M Bra 12 but there was no pupal development on M Ecu 72. Damage symptoms were low on M Ecu 72 and M Col 336 and slightly higher on M Pan 70 and M Bra 12. These results indicate than an ovipositional preference resistance mechanism as well as an antibiosis mechanism may be responsible for whitefly resistance. Further studies on this phenomenon are planned.

Stemborers

Lagocheirus araeniformis (L).

Populations of L. aranieformis have increased in recent years at CIAT. Dissemination of the borer between areas, fields or from one planting cycle to the next is through infestated planting material and the movement of the adults. Clean sanitary conditions, destruction of unused plants and older plants, will reduce populations. The treatment of planting material after cutting and before storage or prior to planting will considerably reduce the damage caused by this insect.

A series of experiments were designed to study the control of this pest. These consisted of: (a) the most efficient insecticides to be used as a stake treatment and the time of immersion required for effective control; (b) determine at how many days after stemborer oviposition is insecticidal control still effective; (c) is there a preference for stemborer oviposition on bitter or sweet cassava varieties.

A. Insecticide efficiency as stake treatment.

Aldrex 2 was tested at the immersion times of 5 and 10 minutes. Cut stakes were infested by placing bundles of 20 stakes in the field for eight days. Stakes were treated with Aldrex 2 and placed in cages for 60 days (developmental life cycle of this stemborer is about 60 days). See Cassava Annual Report, 1981. Results show that Aldrex 2 gave equally efficient control at both the 5 and 10 minute immersion times. Of 80 stakes for each treatment only one stake was infested while 62.5% of the control stakes (no treatment) were infested (Table 7).

In a second trial, Aldrex 2 was compared with Furadan PF and Malathion for stemborer control using the same procedure as in the first trial. Results show that all three insecticides will give stemborer control. However, Aldrex 2 was far superior to the other two insecticides (Table 8). There was no infestation in stakes treated with

Aldrex 2 at either the 5 or 10 minute immersion time; 20.5% of the Furadan PF-treated stakes and 15% of the Malathion treated stakes were infested. There was no significant difference in immersion time.

In a third trial, stakes were treated with Aldrex 2 immediately after cutting and were placed in the field at both CIAT-Quilichao and CIAT-Palmira for eight days and compared to untreated stakes. Observations after 60 days showed no infestation in treated stakes and a 29% and a 65% infestation for untreated stakes at CIAT-Palmira and CIAT-Quilichao, respectively.

B. Effectivity of insecticidal control over time.

Several insecticides were compared for effectiveness of stemborer control at 8 and 14 days after infestation. At the eight day interval most stemborers would be in the egg stage with a few recently emerged larvae. At the 14 day interval, most would be in the larval stage and boring into the stems. Stem cuttings were infested in the laboratory by releasing about 50 pairs of adults into large cages containing stem cuttings for eight days. Half of the stem cuttings were immediately treated while half were stored without stemborer adults for seven additional days before treatment. The insecticides used were: Aldrex 2, Furadan PF, Fifanon, Sevin, Systemin and Dipterex.

Aldrex 2 effectively controlled stemborers in both experiments; there was a 2% infestation in the first experiment and no infestation in the second (Tables 9 and 10). Sistemin also gave effective control in both experiments with a 12% and 8.5% infestation, respectively. There was no significant difference in infestations between the 7 and 14 day treatments. From the proceeding results the following recommendations can be made:

(1) Insecticide stake treatments can be made at least two weeks after cutting and still effectively control stemborers.

(2) Sistemin should be used instead of Aldrex 2 for effective control since this is a less persistant insecticide.

(3) If stem cuttings are to be stored in the field before planting in areas of stemborer attack they should be treated with an insecticide.

C. Ovipositional preference studies.

Previous observations have indicated that not all cassava varieties were equally attacked by *L. araeniformis* in the germplasm bank. Ten varieties, five with a high cyanide (HCN) content, M Bra 12, HMC 7, CM 894-1, CMC 84, and M Col 1684 were compared to five varieties with a low HCN content, CM 342-55, M PTR 26, M Col 22, CM 391-2 and CMC 40, for stemborer ovipositional preference. Four bundles of 20 stakes of each variety were left in the field for eight days. Simultaneously, the same number of stakes were exposed to 50 pairs of adults in large laboratory cages for eight days. Stakes from both treatments were evaluated after 60 days for stemborer infestation.

There was no significant difference in number of infested stakes between the high and low HCN varieties under both field and laboratory conditions. In the field 50.2% of the high HCN varieties were infested and 45% of the low HCN; in the laboratory the results were 71.9 and 68.1%, respectively. However, the number of biological stages that developed on high HCN varieties in the field was much higher than on the low HCN varieties 298 vs. 206, respectively (Tables 11 and 12). This indicates that about 31% more eggs were oviposited on the high HCN varieties. The low HCN variety CM 391-2 displayed a low oviposition and larval development rate under both field and laboratory conditions.

Additionally, a new species of Cerambicidae stemborer identified as Lepturges sp. has been found attacking cassava stakes. At present populations are low. The egg to adult period is approximately 60 days. This species has also been identified attacking cassava is the state of Parana in Brazil.

Cassava Lacebug

The cassava lacebug (Vatiga manihotae and V. illudens) is often found in high populations in many cassava growing regions, especially where a prolonged dry season exists. As part of a doctoral thesis several aspects of lacebug behavior were investigated. These included: (a) the effect of polyculture vs. monoculture on lacebug populations; (b) the effect of cassava fertilization on lacebug populations; (c) the effect of dry season irrigation on lacebug populations; (d) lacebug populations in weedy vs. non-weedy plots; (e) populations of lacebug predators in cassava monoculture vs. polyculture; (f) the effect of plant density on lacebug populations; (g) the concentration of lacebug population in relation to leaf age.

Lacebug populations were recorded weekly on cassava intercropped with maize; resistant and susceptible cassava cultivars were intercropped with tall and short maize varieties. Lacebug populations were consistently higher in the polyculture association than in monoculture (Figure 1). Similar results were obtained for multiclonal plots, where there were more lacebugs than in monoclones. There was no significant difference in the ratio of lacebug populations in polyculture/monoculture with variation in maize height. Cassava competition for sunlight does not appear to be an important factor in determining lacebug populations.

The effect of fertilizer on lacebug populations were studied with potted plants in the greenhouse and in field experiments with varying levels of triple phosphate. No significant differences ($P = 0.05$) were found between fertilized cassava and controls either in pot/greenhouse or field experiments.

The assessment of competition for water by free choice of the lacebugs in field experiments was done by applying and withholding irrigation during the dry season when insect attack is highest. Significantly more lacebugs were found in cassava irrigated during the dry season than in controls with no water added.

The association of cassava with weeds had significantly fewer lacebugs when weeds were present than the non-weedy plots (Figure 2). There was no significant difference in lacebug populations when cassava was intercropped with beans.

Cassava monoculture plots and polyculture plots associated with maize were periodically surveyed for natural enemies of the lacebug. Predators sampled and analyzed included: Coccinellidae, Neuroptera, Chrysopa sp., Sympherobius sp. and Reduvidae Zelus nugax. Chrysopa sp. and Z. nugax were the dominant species present. No significant differences (P = 0.05) were found in populations of predators in monoculture of cassava compared to cassava in association with maize. No parasites were reared from caged lacebugs of any life stage.

There were significant negative regressions between plant density and the number of lacebugs per leaf. Additionally, as lacebug populations changed over time the intercept changed accordingly; however, the slope or relationship between density and relative lacebug population remained exactly the same (slope = -0.40). Therefore, the effect of plant density on lacebug population remained constant regardless of gross population parameter changes.

The original intercropping experimental design held constant density of cassava plants in association and monocultures. However, significantly fewer leaves were present in association with maize (P = 0.05). In cassava/bean associations, the number of leaves per cassava plant was not significantly different from monoculture cassava. With long range, random dispersal and short range host selection, lacebugs would tend to concentrate on the fewer cassava leaves present in maize association. In an experimental design varying both density and association while monitoring both number of leaves per plant and lacebugs per leaf, the data displayed a significant regression (r = -.81) of the number of lacebugs per leaf on cassava leaf density per area regardless of monoculture or association.

Measurements of lacebug population distribution over plant surface indicate that adults are evenly dispersed through the plant while nymphal populations tend to be concentrated on the lower leaves (Figure 3).

The "Tiger Insect" (Phoenicoprocta sanguinea)

Phoenicoprocta sanguinea Wlk. (lepidoptera: Tnuchidae = Amatidae) is a consumer of cassava foliage during its larval stage. This pest is commonly known as the "tiger insect". The male adults are of medium size with the head, thorax, and abdomen of metallic coloration (blues, reds, and yellows); the wings are transparent with black veination. Females are less colorful. The larva is hairy and during its development its coloration varies from light cream, gray and red until the pupal stage. The larva is usually found feeding on the leaf underside; damage is first manifested by circular holes in the leaf, eventually leaving only the leaf veins. Plant damage is usually not severe.

The life stages and foliar consumption were studied under laboratory conditions. The egg stage is an average of 5.7 days; there are five instars with an average total of 14 days; the pre-pupal and pupal stages are approximately 16 days and adults live about 5.5 days; the total life cycle is about 41 days (Table 13). During the larval period about 77.8 cm^2 of leaf surface is consumed; 67.2% of this consumption occurs during the fifth instar (Table 14).

Additional observations indicate that the larval stage is parasitized by the hymenopteran Apanteles sp. An average of 22 Apanteles parasites will emerge from one Phoenicoprocta larva with a sex ratio of 2.5 females to 1 male. Eggs are parasitized by Trichograma sp.; an average of 6.5 adult Trichogramma will emerge from one egg with a sex ratio of 1.2 female to 1 male.

The Chinch bug (Cyrtomenus bergi).

Nymphs and adults of this subterranean sucking insect feed on cassava roots by means of a thin and strong stylet. Insect feeding combined with soil pathogens induce the appearance of brown to black spots on the white fleshy root, rendering it commercially unacceptable. During 1982, life cycle studies were completed; adult longevity was measured at an average of 293.4 days (see Cassava Annual Report, 1981 for additional life cycle data). Adults of C. bergi were found to be attacked by the fungus Metarhyzium sp.

Studies were initiated to determine if a feeding preference exists for high HCN vs. low HCN varieties. A laboratory colony of 20 adults and 30 nymphs was placed in plastic trays containing sweet and bitter cassava roots set in a shallow layer of soil. In one treatment three roots of CMC 40, a sweet variety was compared to one root of M Col 1684, a bitter variety. The second treatment compared one root of CMC 40 to three roots of M Col 1684. Roots were replaced every six days and feeding preference observations were made every three days. Data was taken on the number of nymphs of adults attacking roots as well as those resting in the soil around the root but not feeding. Results show a strong feeding preference for sweet (low HCN) roots over bitter (high HCN) roots (Figures 4 and 5).

Approximately 80% of the nymphs and adults were consistently found feeding on or under the variety CMC 40 while only 20% were found on or under the M Col 1684 roots, when there was a choice of three sweet vs. one bitter root. Given a three bitter vs. one sweet choice feeding behavior was more erratic but an average of 75% of the chinch bug population fed on or were under the CMC 40 root. When not given a choice, the insect will feed on and cause damage to bitter roots.

A preliminary experiment using 20 nymphs tested the preference of C. bergi for feeding on cassava vs. the alternate hosts corn and crotalaria. There is no strong feeding preference observed between corn and cassava; however, nymphs preferred to feed on cassava over crotalaria (15 vs. 5 after eight days). The use of an alternate non-preferred host in rotation with cassava offers a feasible means of controlling this pest. Given the type of damage it causes and its

ability to survive long periods in the soil, C. bergi has the potential to become a serious cassava pest.

Cassava Fruitfly

Cassava fruitflies (Anastrepha manihoti and A. pickeli) can reduce the quantity and quality of planting material. The stemboring larvae transmit the bacterial disease Erwinia carotovora (Cassava Annual Report, 1977) which causes rotting of the pith region of cassava stems. The critical period of plant growth in relation to fruitfly attack was determined as the first three months of plant growth (Cassava Annual Report, 1980). An experiment was designed to corroborate these previous findings. Plants were protected with bi-monthly applications of dimethoate beginning at the 1st to 10th months, the 2nd to 10th month, the 3rd to 10th month, etc.

Results show that plants protected from the first month of growth, yield 100% damage-free stakes; beginning with the second month 95% of the stakes are damage-free and beginning with the third month 75% are damage-free (Figure 6). If protection is not initiated until the fourth month, production of healthy stakes drops sharply to 45% and progressively lower if protection is initiated at later stages in plant development. These results support the previous findings that the first three months of plant growth are most critical for production of damage-free planting material in the presence of heavy fruitfly attack.

The Cassava Hornworm

Populations of the cassava hornworm (Erinnyis ello) were monitored by black light capture at the CIAT-Quilichao station. Simultaneous to adult capture, egg and larval populations on cassava were recorded in several surrounding cassava fields. Adult populations were low throughout the year and no severe field crop damage was reported. The highest adult capture was during January and February with 46 and 28, respectively (Table 15). A corresponding increase in oviposition was recorded during this period. These data indicate that light trapping of hornworm adults can be useful in predicting an increase in oviposition, an important tool in a biological control program.

Termites

Termites have been found attacking cassava in the tropical lowlands. They feed on propagation material (cuttings), on roots or lower stems. They are primarily a problem in Media Luna, ecosystem 1 (see Ecosystem Studies section of this report). At the harvest of the Media Luna ecosystem trial during 1982, all plants were evaluated for termite damage. Results show that 9.8% of the harvestable roots were damaged by termites and 90.8% of the lower stems (Table 16).

A total of 41 varieties were evaluated; these were divided into five groups: (1) regional varieties from the coast; (2) regional high altitude varieties (ecosystem 5); (3) other Colombian varieties; (4) hybrids; and (5) non-Colombian varieties. Regional varieties from the coast had the lowest termite damage, 2.7% while the regional high

altitude varieties and hybrids had the highest damage, 16.2 and 16.5%, respectively (Table 16). These results indicate that the regional coastal varieties may have undergone a selection pressure against termite damage while varieties and hybrids from other ecosystems have not had this selection pressure.

Pests of Dried, Stored Cassava

Araecerus fasciculatus and *Lasioderma servicorne* are two of the most frequent pests of dried cassava, especially when it is stored in chip form. Experiments were designed to measure the losses incurred on stored cassava chips by these pests. Jars containing 100 g of cassava chips were infested with 20 adults of *L. servicorne* or *A. fasciculatus*. They were allowed to feed and multiply for five months at which time the pest population was recorded and the weight of the fine flour waste from pest feeding was recorded.

Results show that both species can cause considerable losses. Losses due to *L. servicorne* feeding were 28.5% on the high HCN variety M Col 1684 and 49.3% on the low HCN variety CMC 40 (Table 17). The total population (adults, pupa, and larvae) was also considerably higher on CMC 40 on M Col 1684; the population on M Col 1684 was 538.5 per replicate while on CMC 40 it was nearly double at 1041.7 per replicate or a 48.3% increase. These results indicate that *L. servicorne* is more successful feeding on the low HCN variety.

Losses due to *A. fasciculatus* feeding were similar but population increases were greatly reduced when compared to *L. servicorne*. Losses were 39.5% for M Col 1684 and 49.5% for CMC 40. Pest populations however, were slightly higher on M Col 1684 than on CMC 40; populations on the former averaged 288.5 per replicate while on the latter it averaged 242.5, a 16% difference.

Table 1. Selections from an evaluation of 400 cassava varieties for resistance to Phenacoccus herreni under greenhouse conditions (average temp. 24°C and 70% RH).

Variety	Population[a] grade	Damage[b] grade
M Col 2	5	2
M Col 181	4	2
M Col 214	4	2
M Col 233	5	2
M Col 253	3	2
M Col 263	5	1
M Col 270	5	2
M Col 279	5	2
M Col 286	5	2
M Col 296	3	2
M Col 299	4	2
M Col 310	5	2

a. 0 = no mealybug biological stages; 1 = presence of numphs on the growing point; 2 = presence of nymphs and adults on growing point; 3 = presence of ovisacs and biological stages on growing points; 4 = presence of ovisacs and biological stages in growing point and middle leaves; 5 = presence of nymphs, adults, and ovisacs on all leaves.

b. Damage grade on a scale of 0-5.

Table 2. Parasites and predators collected on a high field population of Phenacoccus herreni at CIAT-Palmira.

	September 2, 1982[a]			September 14, 1982[a]		
	Species (no.)	Individual (no.)	(%) of total	Species (no.)	Individual (no.)	(%) of total
Parasites						
Hymenoptera						
Acerophaga	1	288	86	1	377	92
Other hymen.	6[b]	19	14	1[b]	32	.08
Subtotal						
Predators						
Coleoptera	7	26	37	5	9	9
Neuroptera	2	5	7	1	1	1
Diptera	2	30	43	1[c]	106	84
Lepidoptera	2	9	13	3	8	6
Psocoptera				1	1	1
Hemiptera				1	1	1

a. Total of 50 growing points collected.

b. Probably contains hyperparasites.

c. Kalodiplosis coccidarum.

Table 3. The effect of a three month whitefly attack (*Aleurotrachelus socialis*), occurring at different stages of plant growth, on yield of cassava.

Months of attack	Yield (t/ha)	Starch (%)
0	54.3	25.4
1, 2, 3	48.4	26.1
2, 3, 4	55.5	25.8
3, 4, 5	48.7	24.9
4, 5, 6	49.0	25.0
5, 6, 7	49.7	25.0
6, 7, 8	52.9	27.2
7, 8, 9	53.0	25.2
8, 9, 10	58.3	25.4
9, 10, 11	49.4	27.0
10, 11, 12	53.8	26.3
11 (control)	28.5	23.4

Table 4. Egg and nymphal development and size of the whitefly *Aleurotrachelus socialis* Bondar, on cassava (M Col 12) under CIAT field conditions.

Life stage	Observations	Average duration	Range (days)	Area (mm)	L/W
Egg	30	11.3	10-12		
Nymphal instars					
I	66	6.6	6-8	0.0145	2.2
II	59	4.3	3-6	0.0455	1.93
III	37	5.6	5-8	0.1054	1.73
IV (pupa)	32	11.2	10-13	0.263	1.80
TOTAL		39.0	34-47		

a. Temperature minimum, 18°C; maximum, 34°C.
RH minimum, 19%; maximum, 72%.

Table 5. Reaction of F_1 progeny of crosses between whitefly (Aleurotrachelus socialis) resistant and susceptible varieties to heavy attack at Nataima, Tolima, ICA station.

Cross	F_1 (no.)	Evaluations: Infestation[a] level	Pupal[b] level	Damage[c] grade
M Col 511 x M Bra 12 (suscept. x resist.)	9	4.6	4.2	2.0
M Ecu 72 x M Bra 12 (resist. x resist.)	73	3.2	2.0	0.5

a. 0-5 scale based on percent of leaves infested with whitefly stages.

b. Pupal level = 0-5 scale based on number of pupae per leaf: 1 = 1-50; 2 = 51-100; 3 = 101-250; 4 = 251-500; 5 = 500.

c. 0-5 scale: 1 = no damage, 5 = severe plant wilting; defoliation and heavy sooty mold.

Table 6. Whitefly (Aleurotrachelus socialis) ovipositional preference and population development on four resistant cassava varieties under greenhouse conditions[a].

Variety	Eggs[b] 4th leaf	% of maximum	Population	Pupae	Damage symptoms
M Col 72	909	495	5	0	1.0
M Col 336	1436	79.7	5	3	1.5
M Pan 70	1686	90.5	5	3	2.0
M Bra 12	1836		5	3	2.0

a. Average temperature 24°C and 70% RH.

b. Average of four replications.

Table 7. The effect of Aldrex as a cassava stake treatment for the control of the stemborer *Lagochierus araeniformis*.

Treatment	Clean[a] stakes (no.)	Infested stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adult (no.)	Total[b] biological stages
Absolute control[c]	80	0	0	0	0	0	0
Untreated	30	50	62.5	42	17	3	62
Aldrex[d] 5-minute immersion	79	1	1.25	1	0	0	1
Aldrex 10-minute immersion	79	1	1.25	1	0	0	1

a. Total of 80 stakes; four replications of 20 stakes.

b. Observations made 60 days after infestation.

c. Absolute control; stakes cut from growing plants and brought into laboratory for protection.

d. Aldrex 2, 1 cc/liter of water.

Table 8. The effect of Aldrex, Furadan and Malathion as cassava stake treatments for the control of the stemborer *Lagochierus araeniformis*.

Treatment[a]	Clean[b] stakes (no.)	Infeated stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adult (no.)	Total[c] biological stages
Absolute control[d]	80	0	0	0	0	0	0
Untreated	44	36	45	21	17	1	39
Aldrex 5-minute immersion	80	0	0	0	0	0	0
Aldrex 10-minute immersion	80	0	0	0	0	0	0
Furadan 5-minute immersion	64	16	20	13	7	2	22
Furadan 10-minute immersion	63	17	21	5	5	3	13
Malathion 5-minute immersion	67	13	16.3	8	5	1	14
Malathion 10-minute immersion	69	11	13.8	5	4	1	10

a. Aldrex 2, 1 cc/liter of water.
Furadan P.F. 1 cc/liter of water.
Malathion 1 cc/liter of water.
b. Total of 80 stakes, four replications of 20 stakes.
c. Observations made 60 days after infestation.
d. Absolute control; stakes cut from growing plants and brought into laboratory for protection.

Table 9. The effect of several insecticides on stemborer (*Lagochierus araeniformis*) populations seven days after infestation on cassava stem cuttings.

Treatment[a]	Clean[b] stakes (no.)	Infested stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adult (no.)	Total[c] biological stages
Absolute control[d]	120	0	0	0	0	0	0
Untreated	64	56	46.5	6	13	66	85
Aldrex 2	59	1	2.0	1	0	1	2
Furadan P.F.	47	13	21.5	7	1	6	14
Fifanon	40	20	33.5	1	5	13	19
Sevin	46	14	23.5	2	1	13	16
Sistemin	53	7	12.0	0	0	5	5
Dipterex	42	18	30.0	3	3	16	22

a. Aldrex 2, 1 cc/liter of water; Furadan P.F. 1 cc/liter of water; Fifanon, 1 cc/liter of water; Sevin, 5 g/liter of water; Sistemin 1 cc/liter of water; Dipterex, 1 g/liter of water.

b. Absolute control and untreated; 120 stakes; 6 replications of 20 stakes. Insecticide treatments; 60 stakes; three replications of 20 stakes.

c. Observations made 60 days after infestation.

d. Absolute control: stakes cut from growing plants and brought into laboratory for protection.

Table 10. The effect of several insecticides on stemborer (*Lagochierus araeniformis*) larval populations 14 days after infestation on cassava stem cuttings.

Treatment[a]	Clean[b] stakes (no.)	Infested stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adult (no.)	Total[c] biological stages
Absolute control[d]	120	0	0	0	0	0	0
Untreated	64	56	46.5	6	13	66	85
Aldrex 2	60	0	0	0	0	0	0
Furadan F.P.	46	14	23.5	2	3	9	14
Fifanon	41	19	31.5	1	3	15	19
Sevin	50	10	17.0	2	4	7	13
Sistemin	55	5	8.5	0	1	4	5
Dipterex	49	11	20.0	0	4	7	11

a. Aldrex 2, 1 cc/liter of water; Furadan P.F., 1 cc/liter of water; Fifanon, 1 cc/liter of water; Sevin, 5 g/liter of water; Sistemin 1 cc/liter of water; Dipterex, 1 g/liter of water.

b. Absolute control and untreated; 120 stakes, 6 replications of 20 stakes. Insecticide treatments; 60 stakes; three replications of 20 stakes.

c. Observations made 60 days after planting.

d. Absolute control: stakes cut from growing plants and brought into laboratory for protection.

Table 11. Stemborer (*Lagochierus araeniformis*) ovipositional preferences studies for five low and five high cyanide (HCN) cassava varieties under field conditions.

Varieties	HCN content	Clean[a] stakes (no.)	Infested stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adults (no.)	Total[b] biological stages
M Bra 12	H	29	51	63.7	39	46	19	104
HMC 7	H	49	31	37.5	34	11	5	50
CM 894-1	H	42	38	47.5	40	4	1	45
CMC 84	H	31	49	61.3	52	14	2	68
M Col 1684	H	47	33	41.3	30	0	1	31
Total		198	202	50.3	195	75	28	298
CM 342-55	L	49	31	38.7	31	5	1	37
M PTR 26	L	48	32	40.0	28	9	1	38
M Col 22	L	30	50	62.5	49	11	1	61
CM 391-2	L	60	20	25.0	16	5	0	21
CMC 40	L	32	48	60.0	39	9	1	49
Total		219	181	45.2	163	39	4	206

a. Total of 80 stakes, four replications of 20 stakes.
b. Observations made 60 days after infestation.

Table 12. Stemborer (*Lagochierus araeniformis*) ovipositional preference studies for four low and four high cyanide (HCN) cassava varieties under caged insectary conditions.

Varieties	HCN content	Clean[a] stakes (no.)	Infested stakes (no.)	Infested stakes (%)	Larvae (no.)	Pupae (no.)	Adults (no.)	Total[b] biological stages
M Bra 12	H	9	31	77.5	11	7	12	30
CM 849-1	H	9	31	77.5	10	11	30	51
CMC 84	H	11	29	72.5	15	7	14	36
M Col 1684	H	16	24	60	11	5	14	30
Total		45	115	71.9	47	30	70	147
CM 342-55	L	8	32	80	26	18	18	62
M Col 22	L	8	32	80	17	7	16	40
CM 391-2	L	28	12	30	1	6	5	12
CMC 40	L	7	33	8.25	12	8	19	39
Total		51	109	49.6	56	39	58	153

a. Total of 40 stakes, four replications of 10 stakes.
b. Observations made 60 days after infestation.

Table 13. The life stages of Phoenicoprocta sanguinea Wlk. (Lepidoptera: Tnuchidae = Amatidae) on cassava leaves.

Life atage	Observations	Duration in days Minimum	Maximum	Average
Egg	65	5	6	5.7
Inatar				
I	28	2	3	2.5
II	28	2	4	2.6
III	28	2	4	3.1
IV	28	2	4	2.5
V	28	2	4	3.3
Total	28	10	19	14.0
Prepupa	28	1	2	1.9
Pupa	28	12	16	14.0
Adult	28	4	7	5.5
Total		32	50	41.1

Table 14. Consumption of cassava foliage by five larval instars of Phoenicoprocta sanguinea Wlk. under laboratory conditions.

Instar[a]	Consumption (CM^2)	Consumption (%)
I	0.30	0.39
II	2.58	3.28
III	4.74	6.03
IV	18.12	23.07
V	52.08	67.23
Total	77.82	100.00

a. Mean of 10 larvae.

Table 15. Population fluctuation of adult cassava hornworm (Erinnyis ello) captured in black light traps and oviposition in cassava fields.

Month of evaluation	Adults captured in light traps CIAT-Palmira	CIAT-Quilichao	Total	Mean egg/plant[a]	Parasitism (%)	Larvae/plant
January	23	23	46	2.3	42.5	0.1
February	14	14	28	1.54	59.7	0.06
March	4	14	18	0.46	42.0	0.06
April	5	12	17	0.1	71.0	0.01
May	0	0	0	0.08	70.0	0.01
June	3	1	4	0.06	67.0	0
July	7	18	25	0.03	75.0	0
August	1	5	6	0	0	0
September	1	4	5	0.06	0	0

[a] 50 plants evaluated.

Table 16. Varietal reaction to termite attack in cassava roots and lower stems at Media Luna (Magdalena), Colombia (Ecosystem 1).

Varietal group	Variety (no.)	Root attacks (%)			Lower stem attacks (%)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Regional	8	0.0	5.6	2.7	77.0	94.2	85.6
Coastal varieties (Ecosystem 1)							
Regional upland varieties (Ecosystem 5)	3	15.1	18.0	16.2	91.0	100	93.1
Other Colombian varieties	9	0.6	18.7	8.1	66.0	100	90.8
Hybrids	11	3.9	43.1	16.5	68.4	94.2	89.0
Non-Colombian varieties	10	1.3	16.2	5.74	74.0	100	95.5
Totals	41			9.8			90.8

Table 17. Losses in stored cassava chips due to feeding by *Lasioderma servicorne* and *Araecerus fasciculatus* on high HCN (M Col 1684) and low HCN (CMC 40) varieties under laboratory conditions[a].

Pest species	Variety	Replication	Duration of attack (months)	Initial weight (g)	Flour weight (g)	Loss (%)	Total[b] population
L. servicorne[c]	M Col 1684	1	5	100	37	37	719
		2	5	100	20	20	358
	Total	2	5	200	57	28.5	1077
	CMC 40	1	5	100	49	49	1351
		2	5	100	62	62	1050
		3	5	100	37	37	724
	Total	3	5	300	148	49.3	3125
A. fasciculatus[c]	M Col 1684	1	5	100	36	36	217
		2	5	100	43	43	360
	Total	2	5	200	79	39.5	577
	CMC 40	1	5	100	56	56	280
		2	5	100	43	43	215
	Total	2	5	200	99	49.5	485

a. Temperature 25-26°C; RH, 65-70%.
b. Population consists of adults, pupae, and larvae.
c. Each replication was infested with 20 adults.

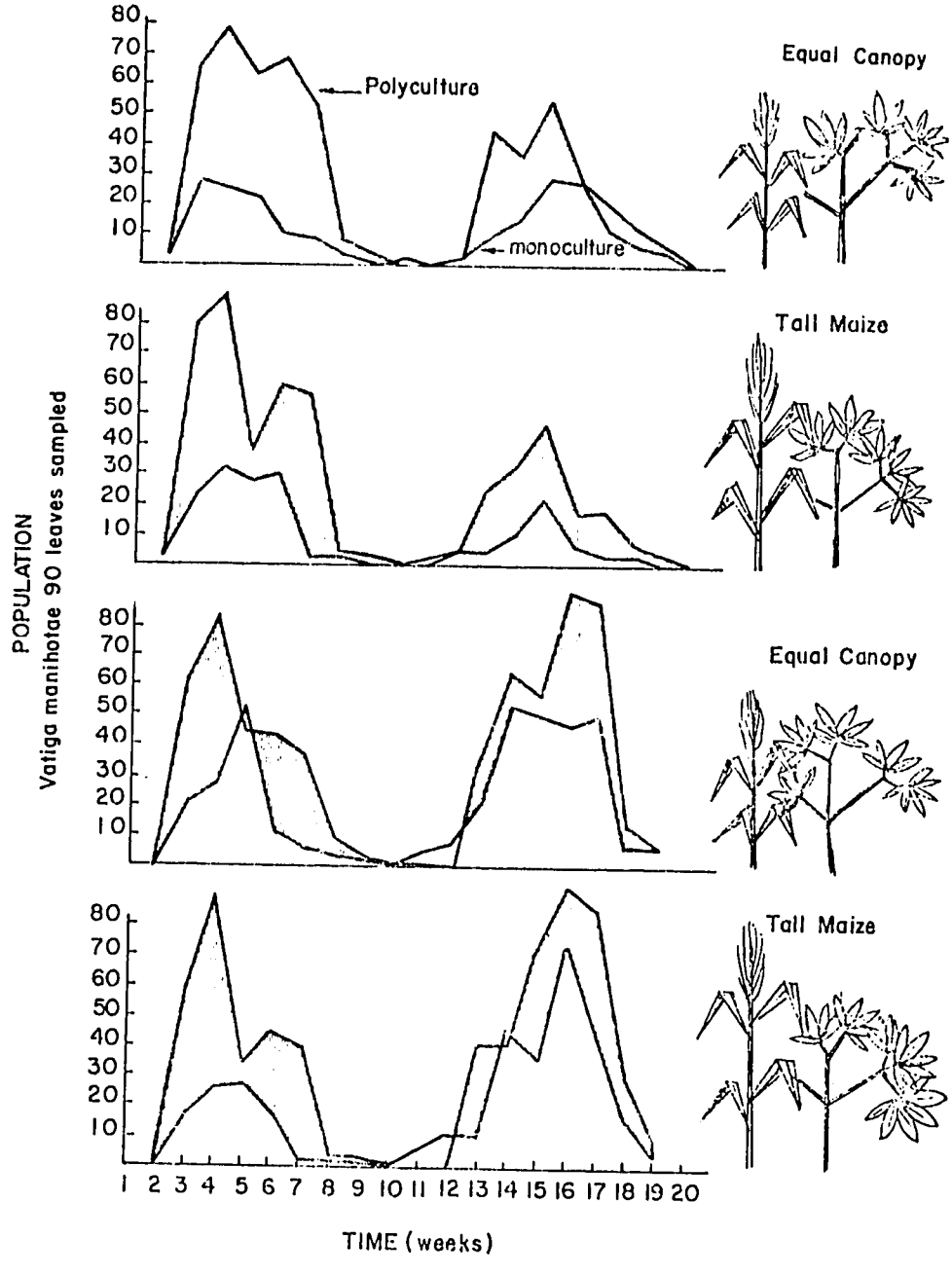


Figure 1. Lacebug (Vatiga manihotae) populations on cassava intercropped with short and tall maize.

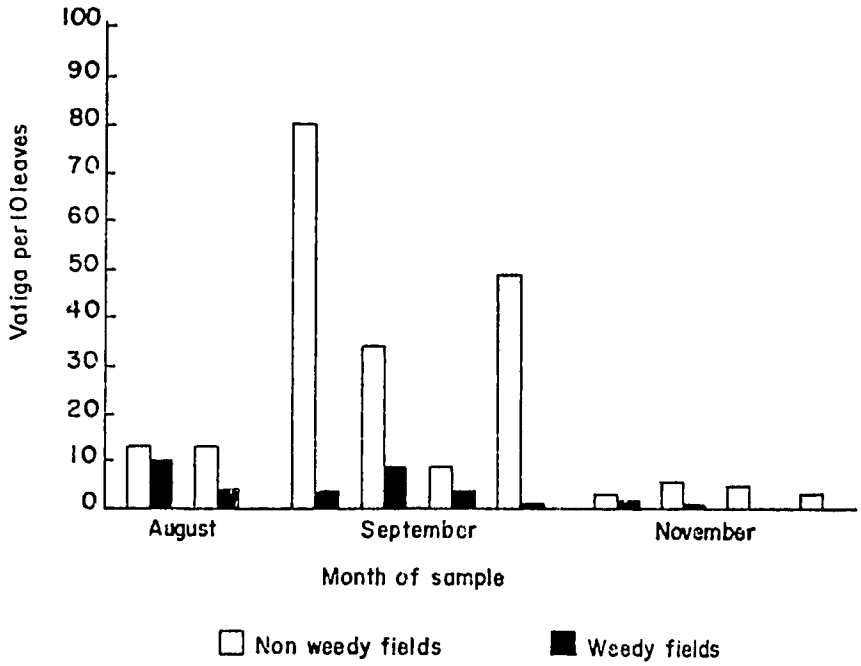


Figure 2. Lacebug (Vatiga manihotae) populations in weedy vs. non-weedy cassava fields.

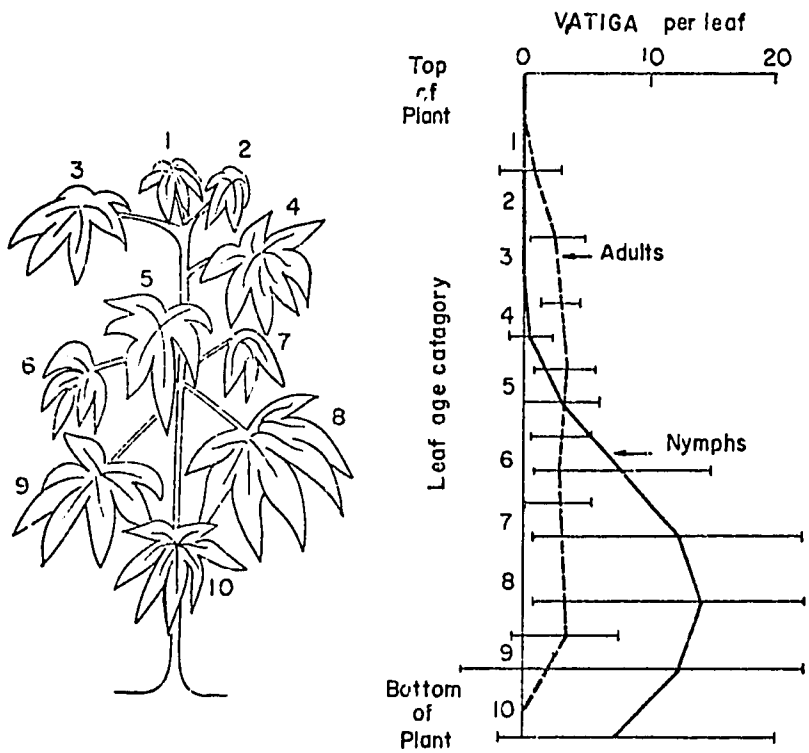


Figure 3. Distribution of lacebug (Vatiga manihotae) populations over the cassava plant surface.

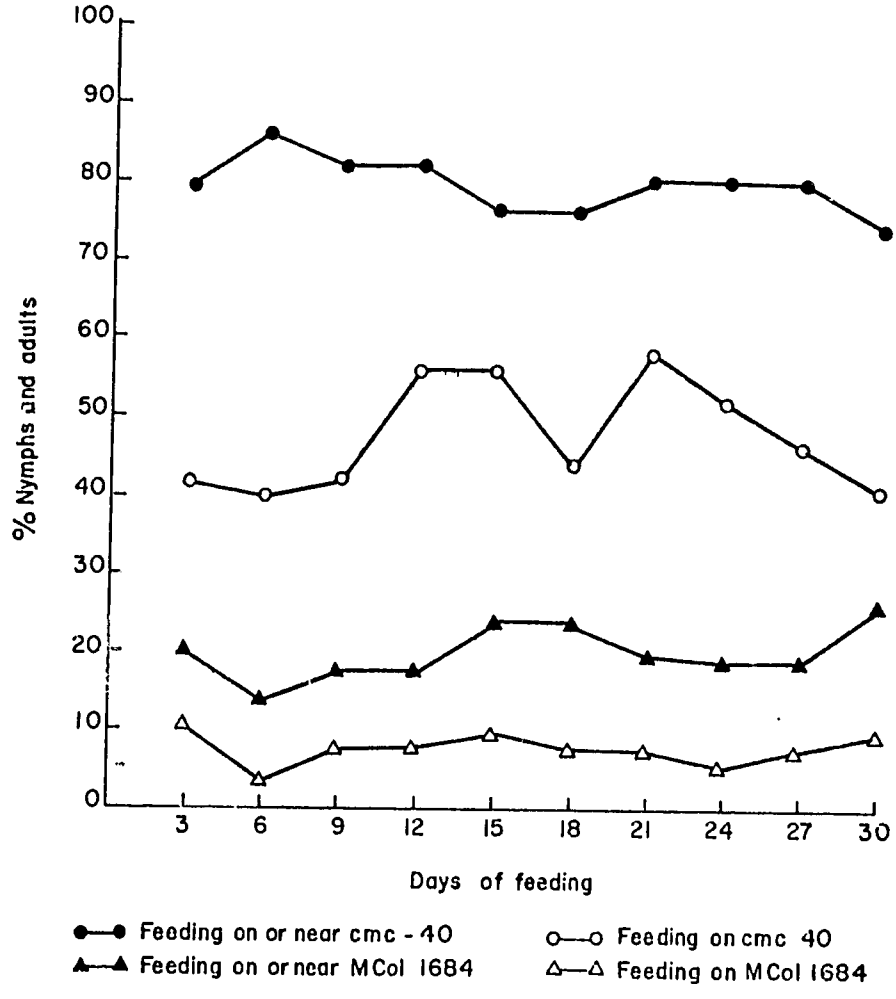


Figure 4. Feeding behavior of Cyrtomenus bergi (Hemiptera : Cydnidae) on bitter (1 root of M Col 1684) and sweet (3 roots of CMC 40) cassava roots during laboratory preference tests.

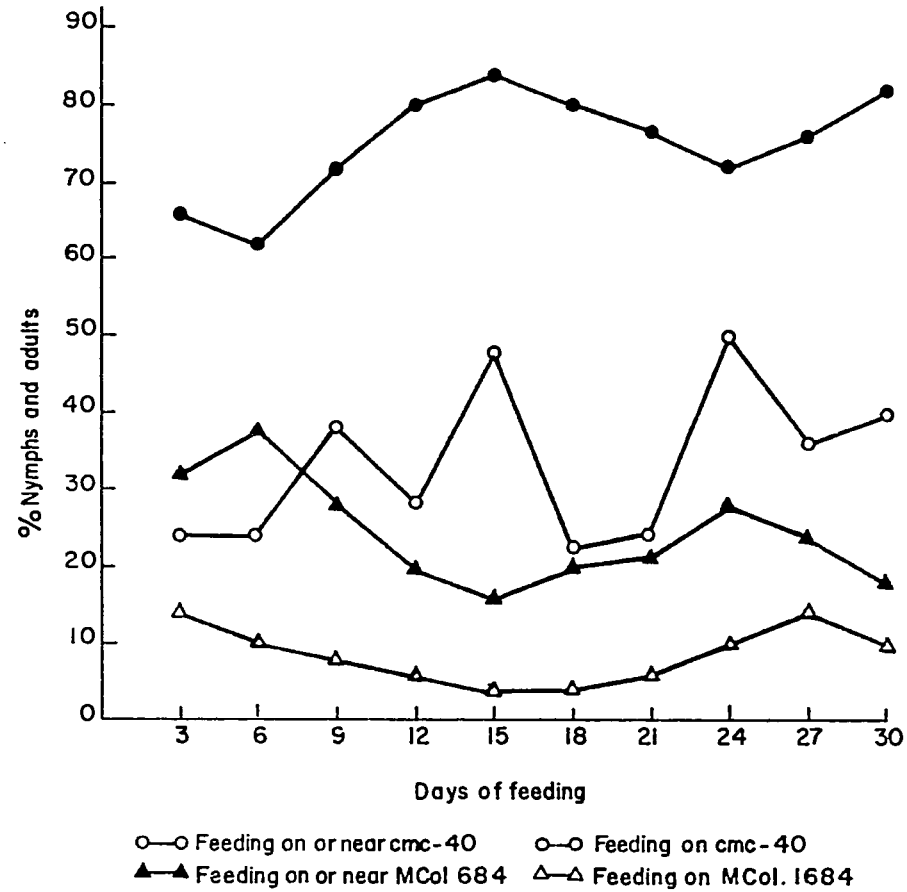


Figure 5. Feed behavior of Cyrtomenus bergi (Hemiptera : Cydnidae) on bitter (3 roots of M Col 1684) and sweet (1 root of CMC 40) cassava roots during laboratory preference tests.

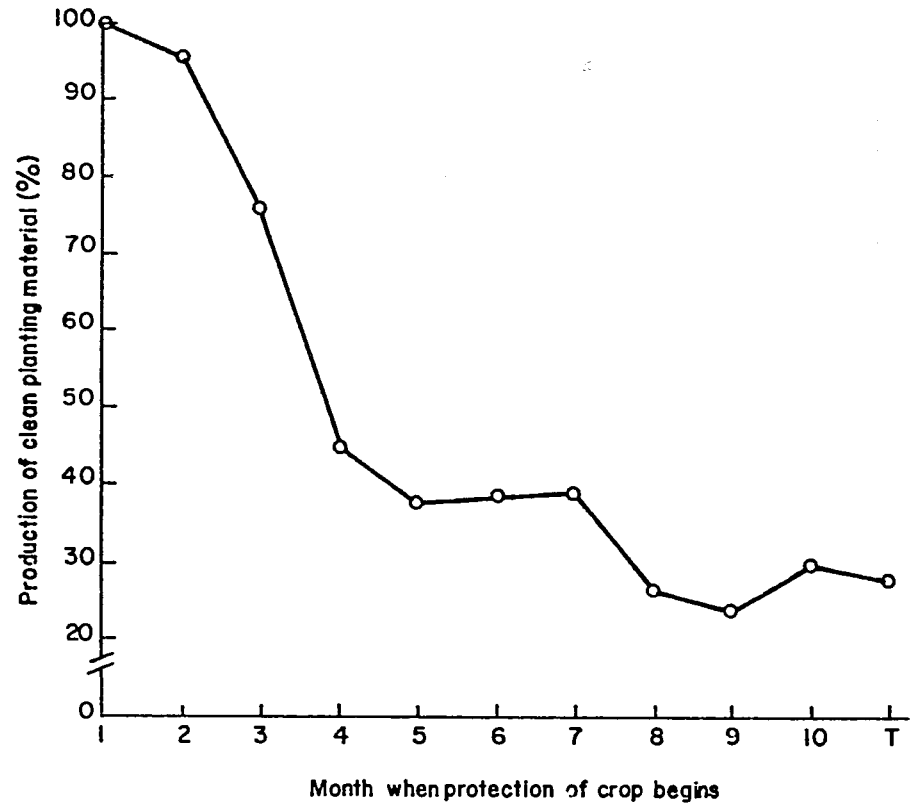


Figure 6. Production of planting material free of fruitfly (Anastrepha manihoti) damage by periodic applications of the insecticide dimethoate.

Pathology

This year, emphasis was placed on defining the taxonomic characters of the causal agents of superelongation, choanephora leaf blight and diplodia stem rot, and also on pathological problems disseminated in or on both vegetative cuttings and botanical seed. Tests for detecting these problems and suitable control measures have been developed for use by seed certification programs. In depth investigations of viral and mycoplasmal problems were carried out including their characterization, detection and recognition in the field as well as their effect on general clonal performance.

Superelongation Disease

Taxonomic investigations of conidial morphology and dimensions, examinations of living, herbarium and type specimens and of pathogenicity and symptomatology led to the identification of the sexual stage of the causal agent as *Elsinoe brasiliensis* and its asexual stage as *Sphaceloma manihotis*, synonymous with *Elsinoe jatrophae*. The known hosts of this species are: *Euphorbia brasiliensis* L., *E. hyperecifolia* L., *Jatropha aconitifolia* Muell. var. *papaya* Arbelaez, *J. curcas* L., *Manihot carthaginensis* Muell., *M. esculenta* Crantz and *M. glaziovii* Muell. Arg. Similarly, this investigation also established that *Sphaceloma poinsettiae* can be considered as a different species synomymous with *S. krugii* whose known hosts are *Euphorbia heterophylla* L., *E. prunifolia* L. and *E. pulcherrima* L.

The results of these taxonomic studies are relevant to the epidemiology and control of the superelongation disease of cassava. Alternative hosts of *E. brasiliensis* are cosmopolitan weeds and widely grown ornamentals. If the pathogens were introduced to cassava producing areas of Africa or Asia it probably would be impossible to eradicate them, when alternative euphorbiaceous hosts are present. Many regions of Africa and Asia where cassava is the staple crop are climatologically very similar to regions of America where the pathogen causes extreme losses under local conditions. There is a danger of introducing this pathogen on ornamental *Jatropha* or other so far unreported host(s) which may not be subject to the same stringent quarantine regulations as those restricting the movement of cassava. Because of the wide host range, inoculum will probably be present year-round. Furthermore, the high genetic variability of the hosts (*i.e.* several genera) may assist the maintenance of a genetically variable pathogen population.

Investigations on host-pathogen relationships revealed that:

(a) disruption of the stem cuticle significantly increased the severity of stem disease symptoms on clones both resistant and susceptible in the field;

(b) conidia and hyphae of morphologically variable isolates were monokaryotic;

(c) cross inoculations of selected cultivars of diverse origins and

characteristics with isolates of diverse origins yielded significant cultivar/isolate interactions suggestive of pathogenic specialization. These interactions were weak, not always reproducible and none were characterized by a hypersensitive-like component. It appears that the observed specific host-isolate incompatibility is only part of a complex of resistance mechanisms in field-resistant cultivars;

(d) no differences in response to Gibberellin A_4- (GA_4) (a hormone produced by the fungus) were detected between resistant and susceptible cultivars. It appears that hormone production confers an advantage to the pathogen by inducing growth and increasing the amount of susceptible juvenile tissue. GA_4 does not appear to have much potential as a screening tool for identifying field resistant cultivars.

In an experiment using 16 replicates for both multi-and monoclonal plots of four clones with different levels of resistance to the superelongation disease, the disease severity was higher in all clones planted in the monoclonal system than in the multiclonal plots. Yields also decreased under the monoclonal system by approximately 33%. However, the yield of cuttings produced by all clones in the monoclonal system was significantly higher ($P = 0.05$); this could be the result of plant competition effects among clones under the multiclonal system. The above results were not in accordance with last year's results (Cassava Annual Report, 1981), possibly due to the previous planting system used in the multiclonal plots. (The 1981 multiclonal planting was of single plants per clone randomly planted with a 1 x 1m spacing; this year, groups of four plants per clone were planted in a random arrangement in plots of 64 plants replicated four times). In 1982 there was a highly significant negative ($P = 0.01$) correlation between the yield of cuttings produced by all clones and the disease severity recorded for each clone under both mono and multiclonal planting systems (Figure 1). These results demonstrate the importance of the superelongation disease in determining yields of both roots and cuttings.

Choanephora Leaf Blight

The maximum production of structures characteristic of the causal agent was found in the following media: PDA, for profuse mycelia; PDA + high relative humidity, for sporangiophores; water-agar (1% w/v), for zygospores; water-PDA (1% w/v), water-agar + sterile soil or PDA + anthracol (Zn-propylene-bis-dithiocarbonate; 100 to 220ppm) for conidiophores; and PDA + coconut milk for mycelia and sporangiophores. The highest amounts of sporangial and conidial production occurred at 20°C, respectively.

Choanephora curcubitarum isolated from cassava profusely formed two kinds of asexual reproductive structures; (a) nodding columellate sporangia with brown, faintly striated spores which usually bear bristle-like appendages; and (b) compound conidiophores bearing one-celled, brown striated ellipsoid conidia without appendages (Figure 2).

Artificial inoculations showed that penetration occurs only through foliar wounds. This agrees with observations of natural infections under field conditions. Infections occurred on damaged leaves and their severity was related to the presence of strong wind and rain or of infections caused by pathogens (Xanthomonas campestris pv. manihotis, Colletotrichum spp., for example) or insects (leaf cutters or suckers) capable of inducing leaf injuries. Consequently, the damage induced by this pathogen can be additive to that caused by other foliar pathogens, insects or physical inducers. The quantification of this is under investigation.

The disease was particularly severe this year in Caribia and Carimagua, but was less so in Media Luna (see Table 1 and Cassava Annual Report, 1981). This is related to the prolonged periods of rainfall of high relative humidities occurring at each site during the cassava growing cycles.

Diplodia Root Rot

The presence of this disease during the current year was much more noticeable in the Media Luna area than in the other five areas where the program is working (Table 1). In Media Luna, the germination and establishment (% of plants surviving two months after planting) was reduced by 59% when using diseased planting material of the native cultivar Secundina. This may be one of the factors that reduces the number of plants/cutting obtained in the fields of traditional farmers in this area. By using visually selected cuttings from plants produced by meristem culture techniques and also from treated cuttings (Captan/BCM, 3000 ppm each) germination and establishment increased to 87%.

The causal agent of this disease can be differentiated from that of anthracnose by the characteristic production of profused, randomly distributed black-brown pigniostroma borne on epidermal tissues. Pignidia produce brown-dark two-celled pigniospores (Figure 3). Infected plants commonly show brown streaking due to vascular necrosis beneath the epidermal tissues.

Viral and Mycoplasmal Diseases

Frog skin disease (FSD)

As reported last year, the investigations on the etiology and control of FSD were hindered by the presence of a latent virus in cassava (Cassava Annual Report 1981). All control plants of the clones M Col 33 and QPR used for FSD studies proved to be infected with a latent virus. This virus could only be detected by grafting tests using the cassava clone Secundina as scion. The mosaic symptoms observed on Secundina grafted to diseased and symptomless M Col 33 plants did not exhibit noticeable differences. To overcome this problem a redefinition of the FSD symptoms was undertaken. The following symptom description is based on observations of both field and glasshouse-grown M Col 33 plants affected by FSD. The earliest symptoms of the disease can be detected in rootlets developing from diseased cuttings planted 60 days earlier. The characteristic symptom of FSD at

this stage, is a small, longitudinal, deep fissure resulting in a lip-shaded lesion. As the root matures the lesions also increase in size inducing the formation of scales on the epidermis (Figure 4). Some infected roots remain thin and fibrous while others develop normally in the same plant. Sometimes, the above symptoms are present on the whole length of the root but occasionally they are restricted to a portion of the root while the rest remains normal. In certain clones such as Secundina the disease does not induce symptoms on roots except for lip-shaped lesions with very little cork tissue. Occasionally, the lip-shaped lesions can also be seen on any stem which is underground. No symptoms are present in the above-ground parts of affected plants. The above-ground parts of diseased plants under field conditions look apparently vigorous and healthy. FSD symptoms can only be observed on freshly-harvested roots and rootlets. Under glasshouse conditions, transmission of the causal agent to healthy cassava plants has been achieved only by grafting. Grafting tests between FSD-affected cassava and other plant species such as Euphrobia prunifolia, Nicandra sp., Chenopodium amaranticolor, C. quinoa, Nicotiana benthamiana, N. tabacum "Samsun", N. glutinosa, N. clevelandii and Gomphrena globosa did not lead to the transmission of the pathogen.

Transmission experiments conducted in insect-proof cages using whiteflies collected in FSD-affected fields led to the transmission of the disease to 17% of the cassava test plants, using 50 whiteflies per plant. When the number of the whiteflies was increased to approximately 500 per plant, 100% transmission occurred. This result suggests that among the whitefly population the number of vectors is rather low. Aleurotrachelus socialis, the most abundant whitefly species in cassava at Quilicase (Cauca), failed to transmit the disease when tested, individually, indicating the existence of different species of whiteflies in the affected fields surveyed.

The electrophoretic technique (Cassava Annual Report, 1981) developed for the detection of FSD is currently being tested using plants regenerated after meristem culture.

Electron microscopy of dip preparations from roots infected with FSD showed the presence of spherical particles, approximately 30nm in diameter. Similar particles could also be seen in preparations obtained from mosaic-affected leaves of Secundina scion grafted onto M Col 33 infected with FSD. Ultrathin sections of infected Secundina leaves showed the nucleus and nucleolus to be greatly enlarged, and in certain cases complete degradation of the nuclear material. In some samples, randomly distributed 30nm spherical particles could be observed within the nucleus. No such nuclear malformation could be detected in healthy controls. Ultrathin sections of infected root tissue showed the complete degradation of the phloem cell contents. In such cells, in addition to the degraded cell components, spherical particles of approximately 30nm were observed (Figure 4).

Caribbean mosaic virus

The disease referred to as Caribbean Mosaic, herein, was first observed in Media Luna, affecting the plants of the cassava variety

Secundina. Field experiments conducted in Media Luna showed that the disease caused a yield reduction of approximately 38.5% in Secundina (see Table 2 in seed pathology section).

Dip preparations obtained from infected cassava leaves showed the presence of flexous virus-like particles when examined with the aid of the electron microscope (Figure 5). The causal agent induced local lesions on Chenopodium quinoa, C. amaranticolor, C. murale and C. album when mechanically inoculated using sterile distilled water containing 0.2M Na_2SO_3 and 0.85% (w/v) as the extracting medium. It did not infect Euphorbia prunifolia, Datura stramonium, Gossypium hirsitum, Nicotiana glutinosa, N.benthamiana, N. tabacum 'Samsun NN' and Nicandra physaloides when inoculated mechanically. The virus has a dilution end point between 10^{-5} - 10^{-6}, and a thermal inactivation point between 50-60°C. Infection of healthy cassava with the isolated virus has not been achieved to date.

The virus can be easily purified using local lesions on C. quinoa leaves inoculated 4-5 days earlier. Yields average one gram of virus per kilogram of leaf tissue.

The purified virus solution shows infectivity when tested on C. quinoa. The UV absorption spectrum of the purified virus shows a typical nucleoprotein curve with a distinct trytophan shoulder at 289nm. The 260/280 ratio of the purified virus is 1.39 (uncorrected for light scattering).

Ultrathin sections of the infected C. quinoa leaves showed the presence of inclusions made up of virus particles in the cytoplasm (Figure 5).

Specific antiserum to this virus has been produced and is currently being used for serological detection of the virus in infected plants (Figure 5).

Antholysis - previously unreported disease in cassava

For the past three years a metamorphosis of floral parts into vegetative leafy structures (antholysis) has been observed in certain field-grown cassava plants. This abnormal development of floral parts has been observed both at CIAT-Palmira and Santander de Quilichao.

Recent experiments have demonstrated that cuttings obtained from affected plants perpetuate the disease in the following generation, suggesting the presence of a transmissible pathogen. As observed in the clone Secundina, antholysis starts with virescence (greening) of the normally pinkish-cream tepals followed by hypertrophy and phyllody (Figure 7). Apostasis (development of internodes in the floral receptacle) is rather common in such flowers when there is considerable protuberance of the gynophore from which central prolification occurs. Such deformed flowers are completely sterile and premature abortion results. In certain cases, however, it has been observed that instead of premature abortion the malformed flowers become necrotic but remain attached to the plant for prolonged periods of time. Necrosis, however,

is restricted to the floral parts. A similar situation also occurs in male flowers. Affected plants do not produce any normal flowers, thus causing a major problem for breeding programs.

Attempts to isolate pathogenic bacteria or fungi from diseased tissues in a PDA medium failed. An experiment conducted under glasshouse conditions showed that the development of symptoms can be arrested by the application of tetracycline to plant cuttings at 100 ppm, twice weekly for two months. Streptomycine sulphate at this concentration had no effect. The diseased plants show a slight stunting in comparison to the controls but under field conditions no such differences could be observed.

Hand cut sections of fresh tissues stained with Dienes' stain showed the presence of darkly stained mycoplasma-like material in the phloem of the diseased penducle but not in healthy controls. Ultrathin sections of the same tissues showed pleomorphic mycoplasma-like organisms (MLO) in the diseased phloem elements (Figure 6).

These MLO are predominantly spherical but ovoid and elongated forms are also present. The numbers of MLO in sieve elements varied from many to none. No such bodies were found in healthy controls.

Seed Pathology

Investigations concerning the effect of biotic stresses on the establishment and general plant performance of propagative material is being undertaken.

Vegetative material

The effect of the planting material source on the general performance (measured by root, starch and cutting yields; plant height; root rot resistance; and root cutting quality) of a native cultivar traditionally used by small farmers and a recently selected hybrid was investigated. Results showed that by using cuttings derived from plants regenerated after meristem culture, greater root and starch yield were obtained than with traditional planting materials (Table 2). Plant height was significantly higher ($P = 0.05$), as was the quantity of good quality planting material (Table 2). There were no differences in yield (fresh roots) between the native cultivar and the selected hybrid if "clean" cuttings were used. However, significant differences in cutting production between the native and the hybrid genotypes were found. When "traditional" planting material was used, the hybrid produced 3.2 times more than the native cultivar (Table 3).

These findings indicate a continuous decrease in the performance of cassava cultivars over time due to the effect of the biotic and possible abiotic stresses present during each growth cycle.
It is therefore necessary that: (a) the selection process for the evaluation of genotypes should use planting material of equal quality, and (b) "clean" planting material should be used to obtain a high yield performance. Yields could be increased simply by visual selection of the most vigorous and healthy plants from plantations, by careful

selection of mature-lignified stem portions (free from cankers and mechanical damages), and treatment with appropriate fungicide/ insecticides. Devoting a plot of each farm exclusively to the production of planting material will greatly assist growers in obtaining high quality cuttings. Appropriate cultural practices related to soil preparation, fertilization, weed control, insect-disease control, etc., must, however, be applied to these plantations.

Botanical seed

Isolations under laboratory conditions have shown that besides the causal agent of CBB and anthracnose, previously reported as seed born pathogens (Cassava Annual Report, 1978 and 1980), species of Fusarium, Rhizopus, Penicillium, Cladosporium, Diplodia and Aspergillus as well as profuse bacterial growth are both infecting or infesting the cassava seeds. Reduction of germination and damping off infections were commonly observed on growth chamber seed beds after one month of planting untreated visually selected seeds. These organisms may also represent a serious threat if diseased seeds are introduced to other cassava producing areas.

Dry heat treatments (electric oven exposure at 60°C for 14 days) delayed the appearance of fungal infections but did not control these organisms. These treatments reduced bacterial infections although not significantly (Table 4). Treatments with Arasan (Thyran 75) gave better control of both fungal and bacterial infections/infestations, but germination was similar to the controls. However, when the heat and the fungicide treatments were combined infections/infestations were controlled and germination increased. The effect of heat in breaking seed dormancy appeared significant, as previously reported (Cassava Annual Report, 1979). The maximum effect was obtained when seeds were heat-treated and then dusted with the fungicide (Table 4).

In vitro tests with different fungicides commonly used for seed treatment showed that in addition to Arasan the following were also efficient at controlling both fungal and bacterial seed infections/infestations: Orthocide (Captan = N-(Trichloromethylthi) 4-cyclohexenel, 2-dicarboximide), Vitavax 300 (carboxin = 5, 6-Dihydro-2 methyl-1, 4-oxathiin- 3-carboxanilide) Orthocide (captan). The following fungicides were able to control fungal but not bacterial infections/infestations: Benlate (benomyl = Methyl 1-(butyl-carbamoyl)- 2- benzimidazolecarbamate) and Brassicol (PCNB = Pentachlornitrobenzene)

Treatments with all fungicides were applied by shaking the seeds inside a paper bag with the fungicide (approximately 5 g/100 seeds) to provide an even covering.

A microwave oven was tested in an attempt to reduce the time needed to induce germination by the dry heat treatment (14 days). Groups of 40 seeds (with 14-15% moisture content) placed in 300ml of water were exposed 30 - 240 seconds to microwave treatments. Fungal and bacterial infections/infestations were controlled by 120 seconds of microwave exposure; germination (as percentage of seeds germinating on sterile

sandy seedling beds) was comparable to that obtained after heat treatments for 14 days with electric ovens (Table 5).

Consequently, to control fungal/bacterial contaminations on/in cassava seeds, their subsequent dissemination and to improve seed-germination, heat (120 seconds of microwave exposure or 14 days at 60°C in electric ovens) and fungicide (i.e. Arasan or Orthocide + Vitavax) treatments should be applied after collection.

Ecosystem Studies

Of the 31 clones planted initially in 1978 (see Cassava Annual Report, 1979) five clones are still surviving in Carimagua, 14 in Popayan, 23 in Media Luna, 28 in Caribia and 31 in CIAT after the first three growing cycles. All others were eliminated because the existing stresses (biotic and/or abiotic) in each of the ecosystems did not allow them to produce sufficient vegetative planting material for the following cycle. None of existing clones are able to adapt to all five ecosystems and, in general, clones which behave well in a given ecosystem show a gradual decline in their performance in other ecosystems. However, clones which behave well in a given ecosystem continue to show a stable performance up to the present time.

The presence of diseases and insects and their severity during the last four years are recorded in Table 1 for each ecosystem/year of evaluation. The aggressiveness observed for those diseases which in 1978-79-80 initially caused severe damage (i.e. anthracnose in Caribia and Carimagua; cassava bacterial blight in Carimagua; concentric ring-leaf spot and anthracnose in Popayan) in each ecosystem was moderated this year. These results indicate that biotic disease problems reach a certain biological balance with the existing clones. This could be the result of the elimination of susceptible genotypes during the previous cycles with a consequent decrease in the inoculum potential of the causal agents. Those diseases detected after the first cycle and which could have been introduced to the ecosystem (i.e. frog skin; root rot caused by *Diplodia manihotis*) are presently showing an increase in severity, reaching epidemic proportions this year.

The superelongation disease in Carimagua's ecosystem trials was only of moderate severity this year (Table 1), whereas in other trials at this station it was epidemic. The great genetic variability of the host, due to evaluation of new clones carried out by the program, could cause the yearly fluctuations of disease severity found at this station; under such conditions a host-pathogen equilibrium will be difficult to attain. Because the genetic host-pathogen relationship forms a part of the whole disease complex, it is possible that the resistance showed by some clones can suddenly be overcome by the evolution of the pathogen (this has been already observed: the resistance shown by M Col 22 in 1976 and P Per 245 in 1981 appears to be broken). Thus, the general decrease in the severity of the disease observed after few cycles of evaluation under the host-variable conditions present in Carimagua does not reflect a stable resistance. It may require several cycles of evaluations and careful qualitative selection of the resistance shown by parental material, including different mechanisms of resistance.

The severity and presence of diseases which are disseminated by infected planting materials (frog skin) or insect vectors (smallpox) were related to the sanitary condition of the planting material used or the insect-vector population present in each cycle.

Four cycles of pest population data for the five ecosystems studied indicate that although many pests are common to several or all of the ecosystems, their population can vary between ecosystems and from one year to another. The most significant pests are mites, thrips, whiteflies and lacebugs. These are observed in all ecosystems but they do not constitute a pest in all (Table 1). The cassava hornworm is found in all ecosystems although sporadically and usually in low populations. Thrips are consistently found at all sites and can reach moderate to severe damage levels at all sites except Popayan. Lacebugs are found in all ecosystems but constitute a problem only at the Carimagua and CIAT sites. Whiteflies are also found in all ecosystems with moderate to high populations at Caribia and Media Luna. Stemborers (*Chilomina clarkei*), gallmidges and leaf cutter ants only reach moderate populations at Carimagua. Mite populations reach moderate to high levels consistently at all sites.

The Popayan ecosystem receives the least insect pressure with only scales and the Oligonychus mite attaining consistently high populations. The Carimagua and CIAT sites receive the heaviest insect pressure, which may, in part, be due to its continual concentration of cassava. The Caribia and Media Luna sites show moderate insect population levels.

Average yields (fresh root and starch) this year were lower than in the previous year. The most stable yields after the three cycles have been obtained with some clones in Carimagua and CIAT (Table 6). Cyanide content is a character that has shown great stability in each location; root post-harvest deterioration has been very high this year and during the preceding two cycles in susceptible clones at CIAT and Popayan, but moderate to absent in Caribia, Media Luna and Carimagua. The correlations of harvest index between CIAT-Media Luna, CIAT-Caribia and Media Luna-Caribia during the three cycles are very high (Table 7). Comparing this year's results to those of previous years, great variations during the different growing cycles in each location have been observed among several clones, but some have shown stability. This year, the highest correlation in yield (fresh root, starch and stakes), deterioration, HCN content and harvest index were found between CIAT-Media Luna and Media Luna-Caribia. However, correlations among different locations in relation to diseases and pests were low to negative, indicating the location specificity of the biotic stresses on cassava (Table 1 and 7). These data show that, for fresh root and starch yields during the first cycles, a high correlation exists between CIAT-Media Luna and Media Luna-Caribia (Table 7).

Table 1. Cassava pests and diseases identified and evaluated in five different ecosystems in Colombia during 1979 (I cycle), 1980 (II cycle), 1981 (III cycle) and 1982.

Biotic Negative Production Factors	Location																			
	Caribia				Media Luna				Carimagua				CIAT				Popayan			
	1979	1980	1981	1982	1979	1980	1981	1982	1979	1980	1981	1982	1979	1980	1981	1982	1979	1980	1981	1982
Diseases																				
Bacterial blight	++ [a]	++	++	++	+	++	+	++	+++	+++	++	++	-	-	-	-	-	-	-	-
Superelongation	+	+	-	-	+	+++	+	+	+++	+++	+++	++	-	-	-	-	-	-	-	-
Concentric ring-leaf spot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		+++	++	++	+
Anthracnose	++	+++	+++	++	+	++	+	+	+++	+++	+++	++	+++	+	+	+	+++	++	++	+
Brown leaf spot	++	++	++	++	+	++	+	+	++	-	+	-	+	++	++	++	-	-	-	-
Brown leaf blight	++	++	++	++	+	++	+	+	++	-	+	-	+	++	++	++	-	-	-	-
White leaf spot	++	+++	+++	+++	++	++	++	+	-	-	+	-	-	-	-	-	-	+	+	+
Bacterial stem rot	+	+	+	+	+	+	+	+	+	+	+	-	++	++	+	-	-	-	-	-
Cassava ash	-	+	+	-	-	++	+	-	-	-	-	-	+	+++	++	++	++	++	++	++
Cassava common mosaic	+	++	++	+	+	++	+++	++	-	-	-	-	++	++	+++	+	+++	+++	++	+
Frog skin disease	-	+	+++	+++		+	-	-	-	-	-	-	-	++	+	++	-	-	-	-
Smallpox	-	+	++	++	-	++	+	+++	-	-	-	-	-	+	++	++	-	-	-	-
Root rots	-	+	++	++	-	+	+	+++	-	+	+	+	-	++	+	++	-	-	-	+
Choanephora leaf blight	-	-	+++	+++	-	-	++	++	-	-	+++	+	-	-	-	-	-	-	-	-
Diplodia	-	-	-	+	-	-	-	+++	-	-	-	+	-	-	-	+	-	-	-	-
Insects																				
Hornworm	+	+	+	-	+	+	+	+	+++	+	+	+	+	+	+	+	+	+	+	+
Whiteflies	++	+	+	++	++	+	++	+++	+	+	+	+	+	+	+	+	+	+	+	+
Thrips	++	++	+	++	+	+	+	++	++	++	+	+	+++	+++	+++	+++	+	+	+	-
Lacebugs	+	++	+	+	+	+	+	+	++	+++	++	++	++	++	+	+	+	+	-	-
Shoot flies	+	+	++	+	+	-	-	-	+	+	+	+	++	+	+	+	-	-	-	-
Fruit flies	+	+	+	+	-	-	-	+	+	-	+	+	++	++	++	++	-	-	-	-
Leaf beatles	-	-	-	-	-	-	-	-	-	-	-	-	++	++	++	++	-	-	-	-
Gallmidges	+	+	+	+	+	+	+	+	++	++	++	++	+	-	-	-	-	-	-	-
Termites	+	+	-	-	++	++	+	++	+	+	+	+	-	-	-	-	-	-	-	-
Stemborers	-	-	-	-	-	-	-	-	++	++	++	++	-	-	-	-	-	-	-	-
Leaf cutter ants	-	-	+	+	-	-	+	+	++	-	++	++	-	-	-	-	-	-	-	-
Scales	-	-	-	-	+	-	-	+	+	+	+	+	-	-	-	-	+++	+++	++	++
Mealy bugs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	++	-	-	-	-
Mites																				
Mononychellus sp.	+	+	+	+	++	++	+	+++	+	+	+	+	++	+++	++	++	+	+	+	+
Tetranychus sp.	+	+	-	-	+	+	-	++	+	+	-	+	+	++	++	++	-	-	-	-
Oligonychus sp	+	++	++	++	+	+	++	+++	++	-	+	++	+	+++	+++	+++	++	+++	+++	+++

a. +++ = Severe damage; ++ = Moderate damage; + = Light Damage; - = not observed.

Table 2. Yield (t/ha), percentage of yield reduction and number of cuttings per plant in the native clone Secundina in relation to cutting source and type of selection.

Treatment	Cutting source	Yield (t/ha)		Yield reduction (%)	Number of cuttings per plant/quality	
		Fresh root weight	Starch		Good	Poor
1	Secundina from meristem culture	24.0 a*	7.9 a	0	6.2 a	2.8 ab
2	Secundina from farms without symptoms of mosaic; selected cuttings	19.6 b	6.2 b	18.3	3.6 bc	4.9 ab
3	Secundina from farms regardless of mosaic symptoms; selected cuttings	18.2 b	5.8 b	24.2	3.8 b	4.4 ab
4	Secundina from farms with mosaic; selected cuttings	14.7 c	4.5 c	38.7	3.2 bcd	3.5 b
5	Secundina from farms regardless of mosaic symptoms and without selection of cuttings	7.3 d	2.4 d	69.5	3.4 bcd	5.5 a

*. Values with same letter(s) are not significantly different for Duncan's multiple range test (P = 0.05).

Table 3. Yield and number of stakes per plant in the native clone Secundina and the hybrid CM 342-170 hybrid CM 342-170 in relation to cutting source and type of selection.

Treatment	Cutting source	Yield (t/ha)		Number of cuttings per plant quality	
		Fresh root weight	Starch	Good	Poor
1	Secundina from meristem culture	26.0 a*	7.6 a	6.7 a	3.6 a
5	Secundina from farms regardless of mosaic symptoms and without selection of cuttings	8.2 b	2.6 b	3.3 b	5.4 b
6	CM 342-170 from CIAT; selected cuttings	26.1 a	7.0 a	6.3 a	9.6 b
7	CM 342-170 from farms; selected cuttings	17.8 c	4.3 c	6.0 a	9.1 b

* Values with the same letter(s) are not significantly different for Duncan's multiple range test (P = 0.05).

Table 4. Effect of dry heat and Arasan treatments on botanical seed infections/infestations and germination.

Treatment	Percentage[a] of infected/infested seed by Fungi	Bacteria	Germination[b] (%)
Dry heat[c]	95	40	70 b*
Arasan[d]	30	10	30 c
Arasan + Dry heat	0	0	65 b
Dry heat + Arasan	0	0	85 a
No treatment	85	55	40 c

a. Average of 100 seeds/treatment. Visually selected and randomized seeds of clone CM 340-30 were used for each treatment.

b. Germination on Agar (18%) in Petri dishes.

c. Dry heat: electric oven exposure at 60°C for 14 days.

d. Arasan = Thyram 75 = Tetramethylthiuran disulphide; dust treatment.

* Numbers followed by the same letter are not significantly different at 0.05 level of the Duncan Multiple Range Test.

Table 5. Effect of microwave exposure on botanical seed infections/infestations and germination as compared with dry heat (60°C for 14 days) treatment with electric ovens.

Time of exposure (second)	Percentage of infected/infested[a] seed by Fungi	Bacteria	Germination[b] (%)
0	80	80	65 b*
30	12	90	60 b
60	8	56	65 b
90	6	28	68 b
120	0	0	95 a
150	0	0	55 b
180	0	0	0 c
240	0	0	0 c
14 days-dry heat[c]	0	0	90 a

a. Average of 40 seeds/treatment. Visually selected and randomized seeds of clone CM 340-30 were used for each treatment.

b. Germination on sterile sandy soils.

c. Dry heat in oven at 60°C. For germination test all seeds were treated with Arasan (Thyram 75) after the microwave or dry heat treatments.

* Numbers followed by the same letter(s) are not significantly different at a 0.5 level of the Duncan Multiple Range Test.

Table 6. Maximum, minimum, and average values for yield, starch, stake production (number of cuttings/plant), deterioration, harvest index and HCN content obtained from all 31 cultivars in CIAT, Media Luna, Carimagua, Caribia and Popayan ecosystems (first, second and third cycles).

Ecosystem	Cycle	Yield (t/ha)			Starch (t/ha)			Stake prod/ plant			Harvest index[a]			Cyanide Content[b]			Deterioration[c] (%)		
		MX[d]	MN	X	MX	MN	X	MX	MN	X	MX	MN	X	MX	MN	X	MX	MN	X
CIAT	I[e]	74.1	0.0	24.4	24.7	0.00	7.7	18.0	0.6	10.0	0.65	0.00	0.41	5.0	1.0	2.6	90.0	1.6	36.5
	II	55.4	1.6	20.8	17.1	0.34	6.9	34.8	7.6	17.5	0.71	0.05	0.46	5.0	2.0	3.2	49.5	1.3	14.2
	III	36.4	1.0	19.8	11.4	0.00	6.0	23.3	7.9	14.9	0.74	0.11	0.51	5.0	2.0	3.3	67.4	1.2	16.3
Media Luna	I	19.0	0.4	9.5	3.7	0.06	1.9	11.0	1.0	5.0	0.65	0.13	0.44	5.0	1.0	2.9	7.6	0.0	1.4
	II	70.1	0.0	27.0	15.4	0.00	7.1	16.5	0.0	7.1	0.80	0.00	0.56	5.0	2.3	3.7	16.0	0.3	4.0
	III	37.8	0.0	17.0	9.8	0.00	4.1	22.4	0.0	10.1	0.79	0.27	0.59	4.7	2.3	3.2	10.8	0.0	2.5
Carimagua	I	10.7	0.5	2.5	2.8	0.01	0.7	5.0	0.0	1.0	0.66	0.02	0.39	5.0	2.0	3.3	26.9	0.0	1.4
	II	11.6	0.0	1.9	2.9	0.00	0.6	10.5	0.0	0.7	0.61	0.00	0.15	4.3	2.7	3.3	0.1	0.0	0.0
	III	11.6	0.0	1.4	2.8	0.00	0.3	6.6	0.0	0.9	0.59	0.28	0.47	5.0	2.3	3.4	3.6	0.0	1.2
Caribia	I	55.9	2.4	23.2	16.3	0.33	6.4	16.0	2.0	8.2	0.61	0.12	0.40	5.0	1.0	3.0	28.1	0.0	3.6
	II	86.0	5.6	30.6	24.0	1.30	8.0	20.6	1.6	8.7	0.90	0.27	0.66	5.0	2.6	3.9	21.4	0.5	5.1
	III	46.6	0.6	22.5	12.0	0.10	5.7	18.6	1.2	11.7	0.74	0.07	0.55	5.0	2.0	3.3	10.7	0.0	1.8
Popayan	I	21.3	0.2	4.9	6.9	0.04	1.6	8.0	0.0	2.3	0.66	0.10	0.36	5.0	1.0	2.7	82.6	2.3	27.1
	II	26.4	0.0	5.9	8.8	0.00	2.0	16.9	0.0	5.3	0.82	0.00	0.47	5.0	1.3	3.0	71.8	7.0	42.0

a. Harvest index (root fresh weight/root fresh weight + foliage weight x 100)
b. Picrate paper method: 5 = high and 0 - low HCN content
c. 100% total deterioration: 0% = zero deterioration three days after harvest
d. MX = Maximum; MN = Minimum; X = Average
e. I = (1979-80); II = (1980-81); III = (1981-82)

Table 7. Relationship between ecosystems as regards yield, starch content, number of stakes, deterioration, HCN content, harvest index and general evaluation are shown by the correlation coefficient (R) from the 32 cultivars grown in each ecosystem (first, second and third cycles)

Ecosystems	Cycle	Yield (t/ha)	Starch content (%)	Number of stakes	Deterioration (%)	HCN content	Harvest index
CIAT-Popayan	I[a]	-0.116[b]	0.019	0.026	0.129	0.354	-0.052
	II	0.035	-0.013	0.178	-0.264	0.565***	0.189
Carimagua-Popayan	I	-0.152	-0.304	-0.038	-0.215	0.488*	-0.077
	II	-0.041	0.078	0.105	0.067	0.233	0.201
Media Luna-Popayan	I	-0.092	0.163	-0.084	0.130	0.451*	0.301
	II	-0.091	-0.196	0.015	0.187	0.409	0.234
Caribia-Popayan	I	-0.581**	-0.062	-0.325	-0.022	0.318	-0.342
	II	-0.435**	-0.421***	0.519**	0.519**	0.327	0.228
CIAT-Carimagua	I	0.273	0.415*	-0.101	0.359	0.567**	0.603***
	II	-0.190	-0.241	-0.160	-0.049	0.408*	0.219
	III	-0.135	-0.873**	0.087	-0.296	0.741*	-0.123
CIAT-Media Luna	I	0.540**	0.294	-0.299	0.209	0.224	0.801***
	II	0.563***	0.552***	0.403*	0.475**	0.539***	0.806***
	III	0.613***	0.610***	0.474**	0.584**	0.427*	0.773***
CIAT-Caribia	I	0.760***	0.300	0.430*	0.115	0.374*	0.649***
	II	0.265	0.266	-0.040	0.116	0.356*	0.801***
	III	0.398*	0.490**	0.077	0.583**	0.644***	0.614***

(Continued)

Table 7. (Continued)

Ecosystems	Cycle	Yield (t/ha)	Starch content (%)	Number of stakes	Deterioration (%)	HCN content	Harvest index
Carimagua-Media Luna	I	0.664***	0.591**	0.446**	0.552**	0.389*	0.536**
	II	0.366*	0.309	0.447*	-0.017	0.305	0.255
	III	0.283	0.151	0.430*	0.559	0.837**	-0.349
Carimagua-Caribia	I	0.483**	0.472*	-0.218	0.461*	0.214	0.522**
	II	0.309	0.224	0.333	-0.239	0.248	0.171
	III	0.466**	0.377	0.404*	-0.300	0.866**	0.252
Media Luna-Caribia	I	0.661**	0.535**	0.235	0.416*	0.567**	0.622***
	II	0.573***	0.593***	0.301	0.346	0.512**	0.739***
	III	0.630***	0.621***	0.460**	0.568**	0.646***	0.695***

a. = I = Cycle I (1979-1980); II = Cycle II (1980-1981); III = Cycle III (1981-1982)

b. = Results of yields, starch content and number of stakes are for the 31 clones initially planted; the other parameters are only for clones actually surviving at each ecosystem.

* = Significant at 5% level; ** = Significant at 1% level; *** = Significant at 0.1% level of the Duncan Multiple Range Test.

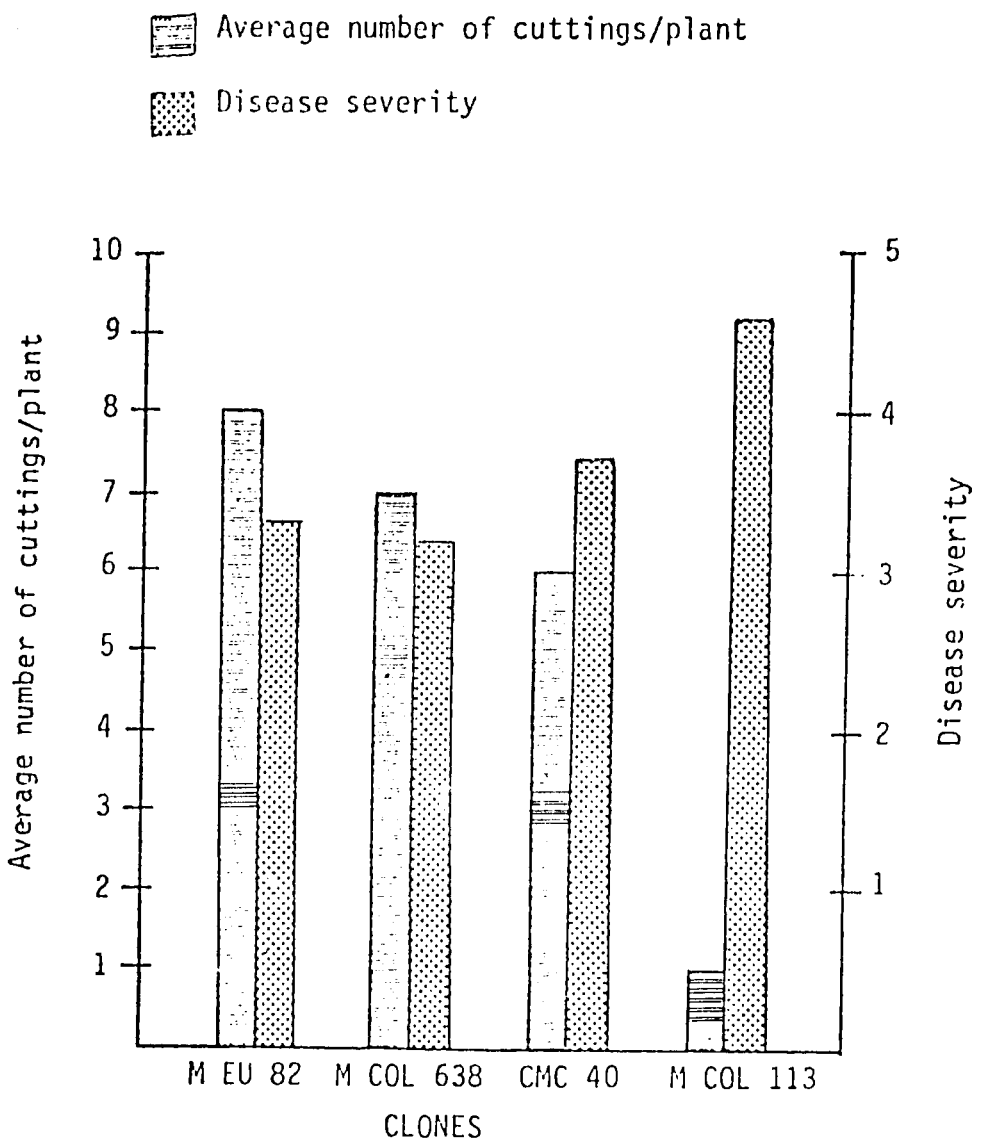


Figure 1. Effect of Elsinoe brasiliensis on cutting production at Carimagua on four clones with different levels of resistance (M EU 82, M Col 638, = resistant; CMC 40 = intermediate resistant, M Col 113 = susceptible; 1 = resistant 5= susceptible). Data show average results from monoclonal and multiclonal plots (14 replicates/planting system).

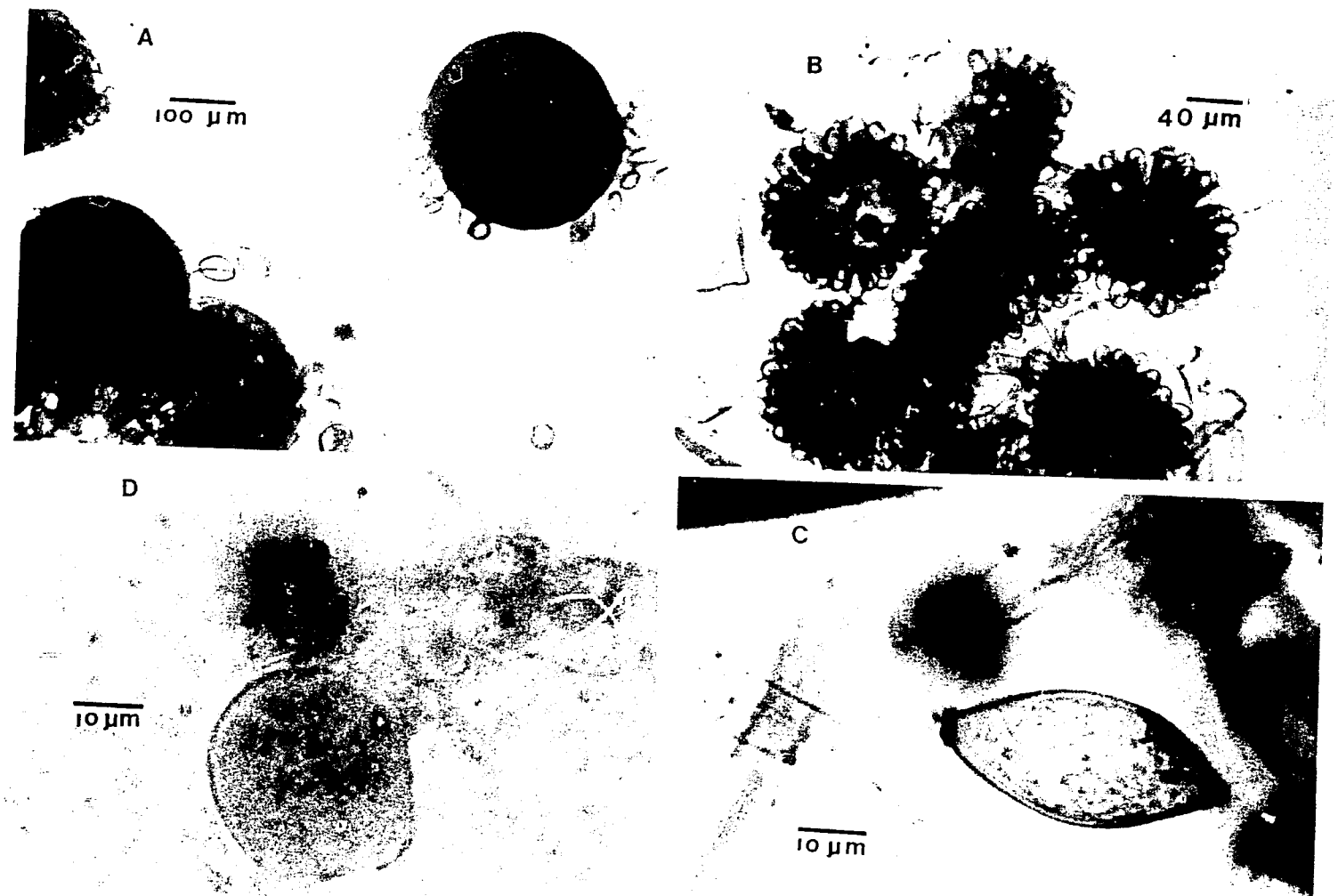


Figure 2. Choanephora cucurbitarum isolated from cassava (M.esculenta) leaves. A = nodding columellate sporangium, B = compound conidiaphore bearing one celled, brown striate ellipsoid conidia without appendages; C = faintly striated sporangiospores which usually bear bristle-like appendages; and D = globose chlanydospore.

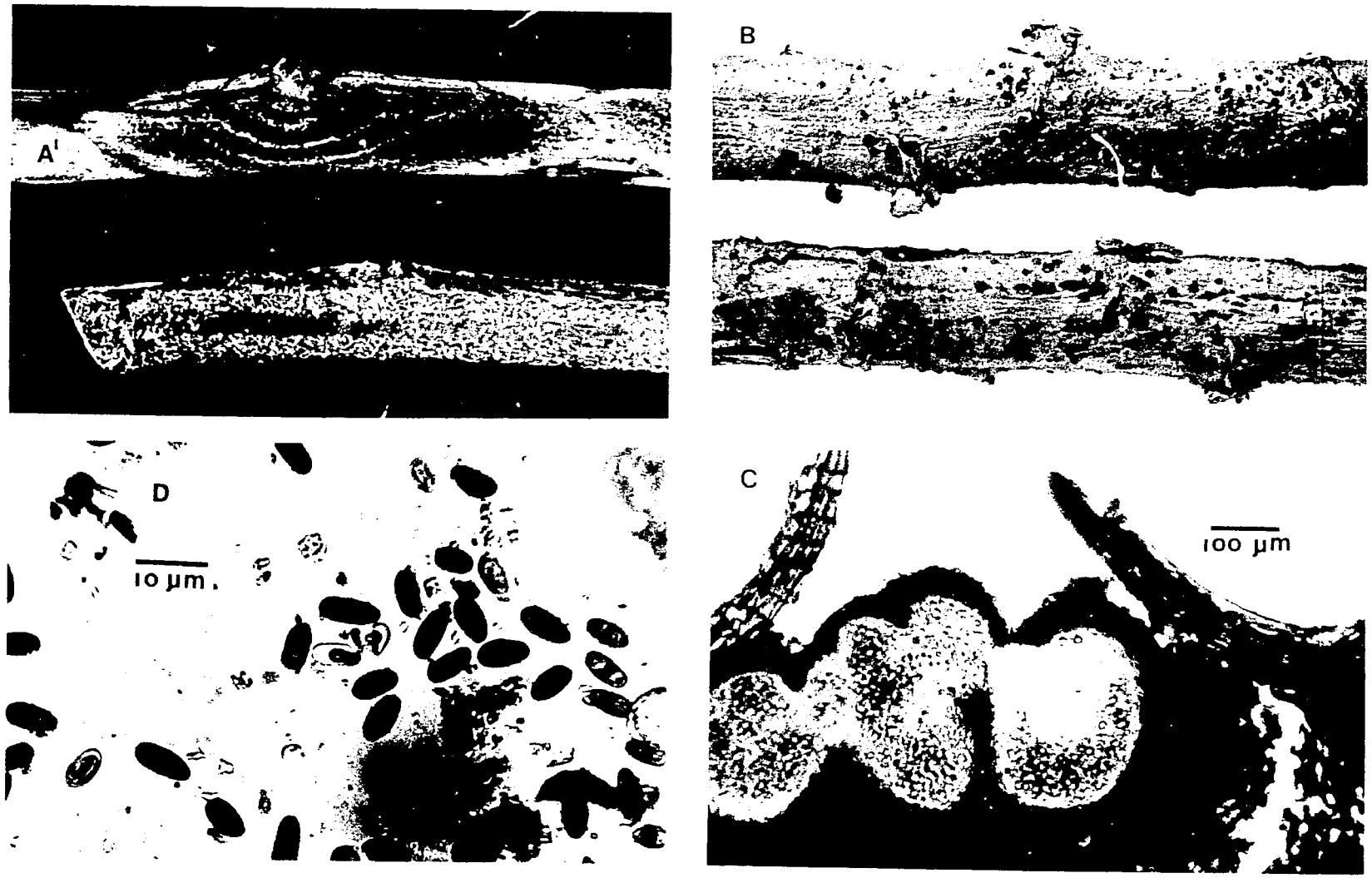


Figure 3. Diplodia manihotis. A = diplodia stem rot on a cassava twig (below) as compared with anthracnose (Colletotrichum sp.) stem rot (above); B = pigniostroma borne on epidermal tissue; C = pignidia in a pigniostromum; and D = brown-dark two celled pigniospores.

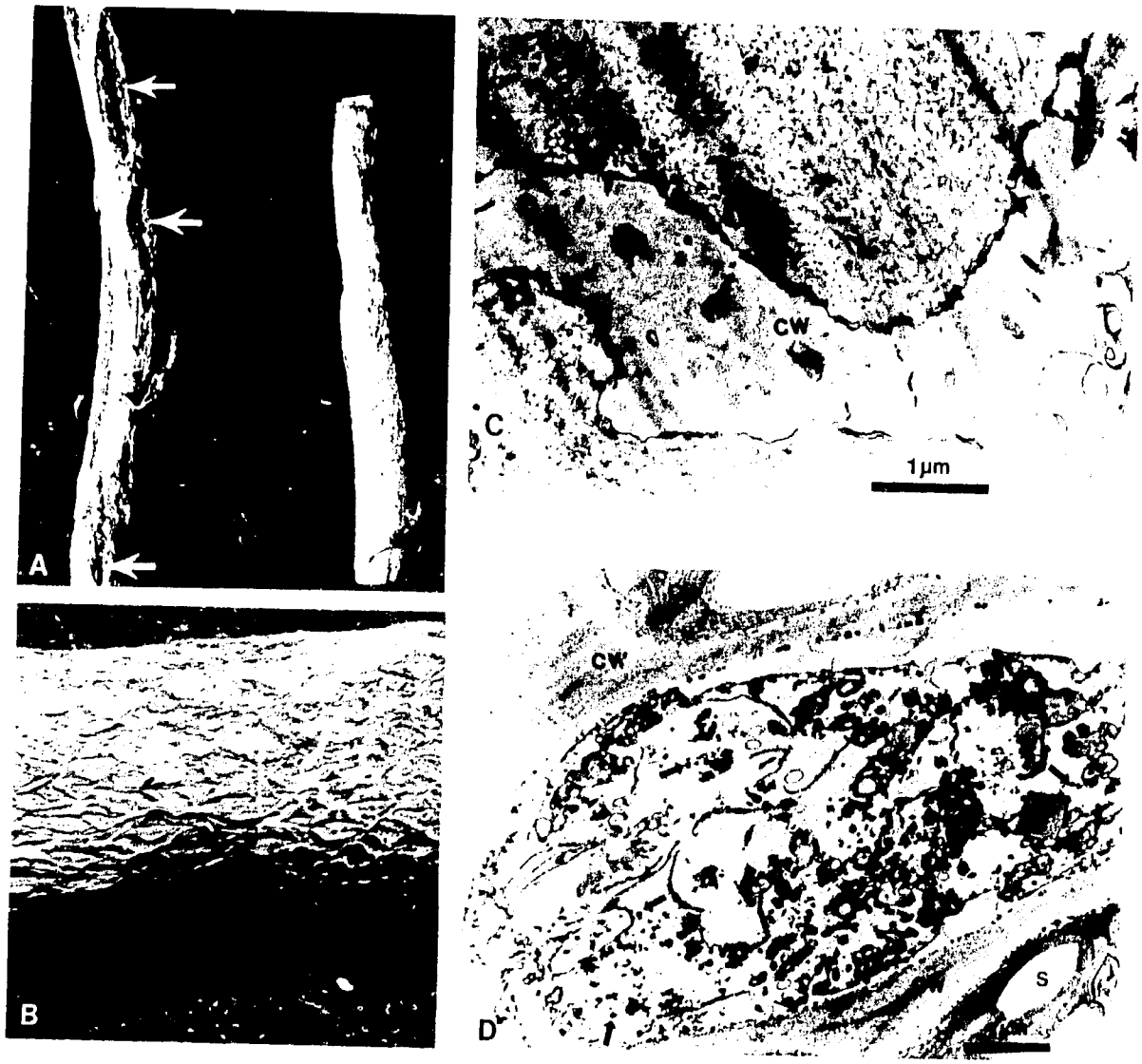


Figure 4. Frog skin disease in cassava. (A) characteristic lesions (arrows) on 60 day old rootlets (left). Healthy control (right); (B) symptoms on mature roots; (C) ultrathin sections of a healthy root showing P-proteins (P) in the phloem. Cell wall (CW); and (D) ultrathin section of a diseased root showing total degradation of the phloem cell. Arrows show spherical virus-like particles. Cell wall (CW), chloroplast (CH), starch grains (S).

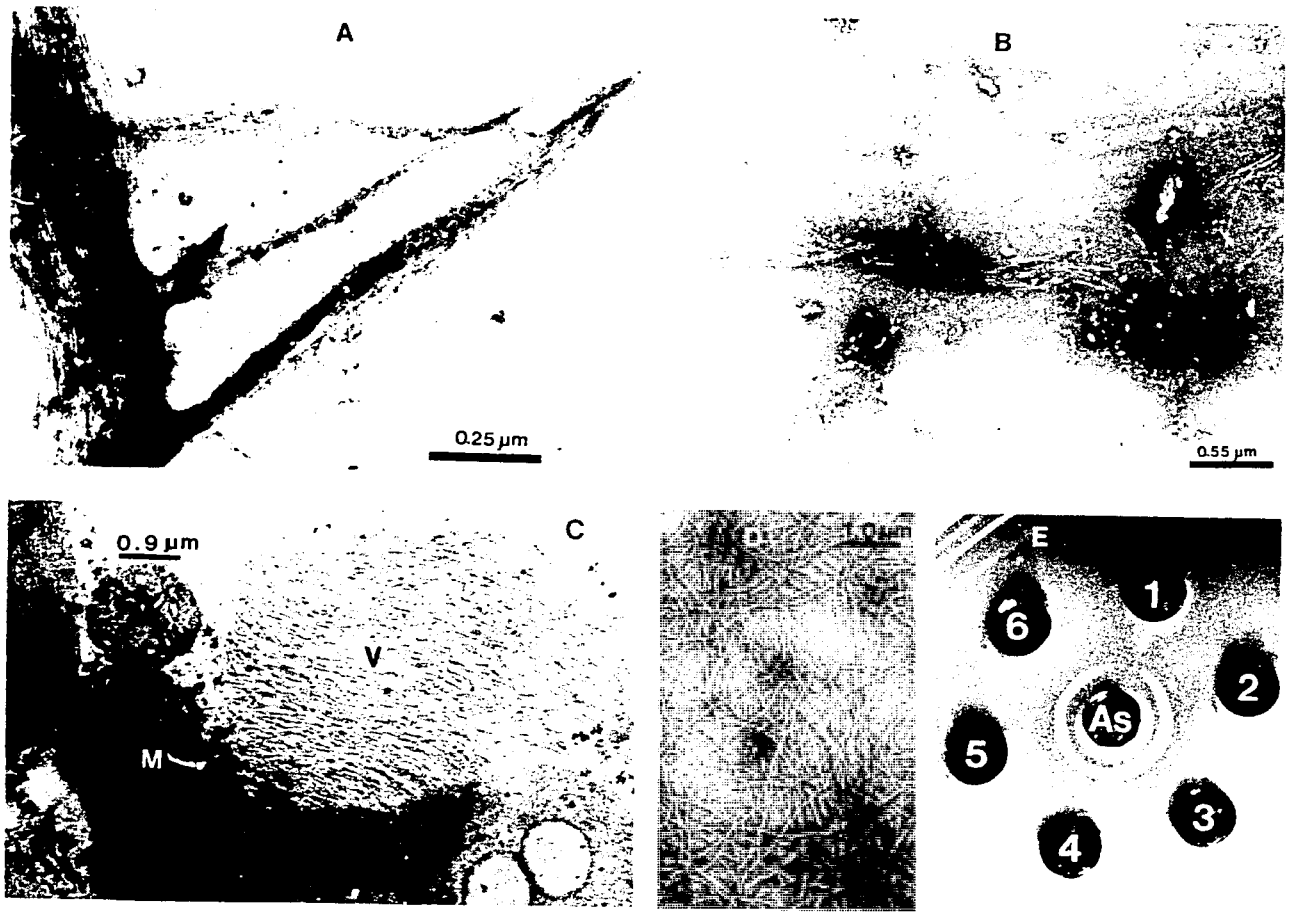


Figure 5. Caribbean mosaic virus. (A) Dip preparations from cassava infected with Caribbean mosaic showing filamentous virus- like particles; (B) dip preparations from chenopodium quinoa showing particles after mechanical transmission; (C) ultrathin sections of C. quinoa showing viral inclusions (V), and mitochondria (M); (D) purified flexous particles; and (E) antiserum (As) prepared against the flexous particles used in serology. Wells 2, 3, 4 and 5 are different isolates of the same virus from cassava. Well 6 is purified homologous antigen. Well 1 is the healthy control.

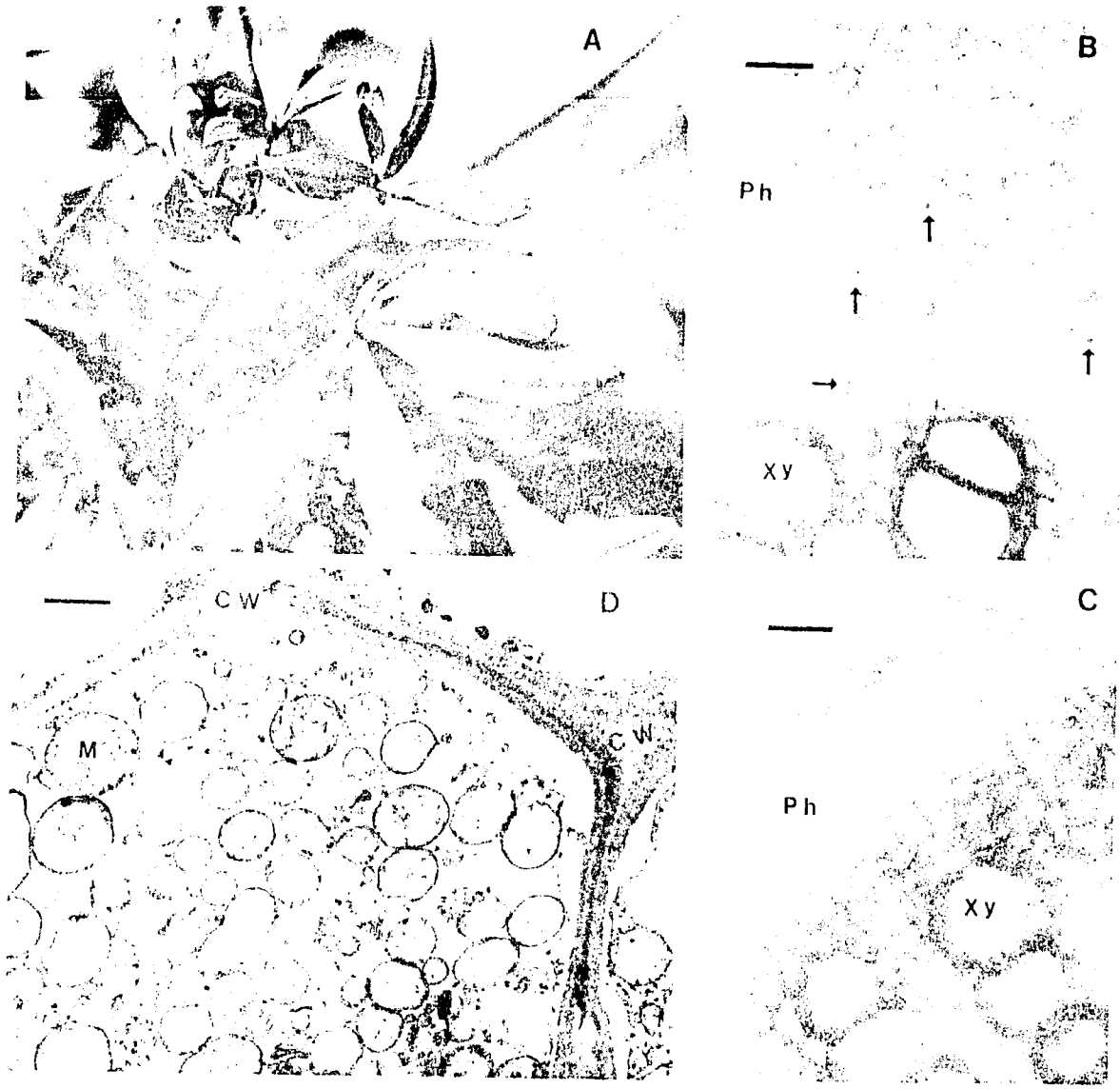


Figure 6. Antholysis in cassava. (A) an infected plant showing phyllody; (B) hand cut sections of the diseased petiole stained with Dienes' stain showing granular material (arrows) in the phloem elements (Ph), Xylem (Xy), Bar represents 40 µm; (C) hand cut section of healthy cassava petiole stained with Dienes' stain, phloem (Ph), Xylem (Xy); (D) ultrathin section of the diseased petiole showing mycoplasma- like organisms completely filling the phloem cells. Mitochandrion (M) cell wall (CW), Bar represents 0.42µm.

Germplasm Development

The Germplasm Development section continued to emphasize germplasm collection and introduction, evaluation of the germplasm bank in diverse sites in Colombia, and improvement of the germplasm base for breeding. New gene sources are brought into the active breeding populations to increase potential for long term gains for disease and insect resistance, root quality, yield and others.

Germplasm Collection and Introduction

The IBPGR has made cassava a priority crop for further collection and conservation. At a meeting of the IBPGR, international center and national program scientists, priority collection areas were defined based on genetic diversity, amount of collection already done and the potential for genetic erosion. Under this new initiative, collections were carried out in 1982 in Mexico and Peru, and are planned for the near future in Brazil, Paraguay, Cuba, and Colombia.

The CIAT Genetic Resources Unit continues to introduce national program collections by meristem culture. During 1982, 352 new accessions from Brazil were introduced. Thus, the previous low representation of the very valuable Brazilian germplasm in CIAT's collection is now being rectified. A total of 535 clones from Brazil are now maintained at CIAT, and further introductions have been arranged.

Germplasm accessions are maintained at CIAT as a field collection, and are simultaneously being transferred to long term storage *in vitro*. The rapid expansion of CIAT's collection (now over 3,000 clones) makes it imperative that more secure and lower cost conservation methods be used, as compared to field maintenance.

Germplasm Evaluation

The purpose of a thorough evaluation of the germplasm collection are to: (1) identify clones which may have promise directly as a recommended variety; (2) identify gene sources for traits requiring improvement in the CIAT or national program breeding populations; or (3) provide information to national programs on performance of their clones under specified conditions, especially to identify vulnerability to pests and diseases.

Germplasm accessions are evaluated in edaphoclimatic zones I (lowland tropics, long dry season), II (lowland tropics, acid soils, savanna vegetations), IV (middle altitude tropics) and as resources permit, V (highland tropics). These evaluations in highly diverse sites provide a good basis for judging the attributes and deficiencies of any clone. General edaphoclimatic adaptation, resistance to diseases and pests, yield potential and root quality are the principal evaluation criteria.

All germplasm accessions are first evaluated in a single row trial, and those which appear promising in each edaphoclimatic zone continue

through the same standard evaluation and selection procedures as for new hybrids.

Media Luna and Valledupar (Edaphoclimatic Zone I)

Germplasm evaluation in the north coast region is divided between two sites. Media Luna has low fertility soils and a long dry season, but disease and insect problems are usually not severe. A preliminary evaluation in single row trials is first done at Media Luna, and the best clones continue in more advanced trials in both Media Luna and Valledupar. Soils in the Valledupar region are relatively more fertile, but mite attacks are consistently severe during the long dry season. Selection emphasis is on high dry matter content, high yield potential and mite resistance. Evaluation across the two sites should permit identification of clones broadly adapted within the edaphoclimatic zone I.

Some 500 new accessions were evaluated during 1981/82 in Media Luna, and 15 selected for further testing (Table 1).

Over several years of evaluation, some outstanding germplasm accessions have been identified, as well as others less outstanding, but which should serve as parents to contribute specific traits (Tables 2 and 3).

M Ven 25. This clone has been consistently excellent for Media Luna conditions, with a high dry matter content, good yield, and nearly ideal plant type. It is very high in HCN, and thus only potentially useful for processing. It is moderately resistant to mites but susceptible to thrips. Unfortunately, flower production is very low, and therefore it has so far contributed little to improvement of the gene pool for the edaphoclimatic zone I.

M Ven 23 and M Ven 45A. These clones appear identical and are similar in performance to M Ven 25. Under drought stress they maintain a high leaf area, which probably contributes to their ability to maintain a very high dry matter content.

M Col 2215. Among the best germplasm accessions on the North Coast, few combine high yield potential with good eating quality. M Col 2215 has an intermediate plant type under both high and low fertility conditions, and appears to be efficient at converting increased biomass into increased root yield under favorable conditions.

M Bra 12. This clone was first identified for its resistance to a range of mite and insect pests. It also has high yield potential, with intermediate dry matter and HCN content. M Bra 12 has already been used in many cross combinations and produces excellent progeny both for yield and pest resistance. High susceptibility to CBB and superelongation are major deficiencies.

M CR 2. M CR 2 has an outstanding ability to maintain high dry matter content, along with good yield potential especially under low

fertility conditions. (Under high fertility, it tends to be overly vigorous.)

Carimagua (Edaphoclimatic Zone II).

Carimagua selections emphasize CBB, superelongation and mite resistance, along with tolerance to acid soils and a moderately long dry season. Because of the very low frequency of accessions which combine reasonable tolerance to a combination of stresses in this environment, it has been difficult to expand the germplasm base of breeding populations for the edaphoclimatic zone II. Nevertheless, several new clones (different from the M Ven 77 group) have shown good resistance and reasonable yield over several cycles (Table 4).

M Per 242 and M Per 245. These accessions, which may be the same clone, have been consistently outstanding in yield in Carimagua. They are highly resistant to CBB and moderately resistant to superelongation. Because of poor flower production they have been difficult to incorporate into the breeding population.

M Bra 5. In contrast to M Per 242 and M Per 245, this clone flowers profusely, and has already contributed extensively to new hybridizations for Carimagua conditions. Good overall performance of the progeny show it to have good general combining ability (GCA). M Bra 5 is a rather compact plant type in Carimagua and combines high CBB resistance with moderate superelongation resistance, yield and dry matter.

M Col 1894. M Col 1894 continues to maintain moderately high yield levels in Carimagua with stable resistance to CBB and superelongation. HCN levels are very low (comparable to Llanera) and dry matter content is intermediate. This clone is susceptible to thrips and mites, and is difficult to use in crosses because of its flowering rate.

M Col 1964. This is one of the few germplasm accessions which combine resistance to CBB, superelongation, mites and thrips. It is consistently a moderately good yielder in Carimagua. As yet it has not been possible to produce crosses with M Col 1964 due to absence of flowering in CIAT.

Popayan (Edaphoclimatic Zone V).

Accessions from Colombian middle and high altitude regions, and the entire Ecuadorian collection are being evaluated for adaptation in the low temperature station at Popayan. Preliminary observations (preharvest) show at least 15-20 potentially adapted clones, based on plant vigor and *Phoma* resistance. The germplasm base for adaptation to the highlands is still very narrow and further sources of adaptation and yield potential are needed.

Evaluation of Asian clones.

Many national programs are not able to evaluate their germplasm because the critical factors do not exist in the country, or are present only sporadically and at low levels. This is especially true in Asia,

where several major cassava pests have not been introduced or are limited in their distribution. It is highly useful for a national program to have some information on the vulnerability of their crop in the event of accidental pest introduction.

The most widely planted Thai and Malaysian cassava clones were introduced to CIAT last year, multiplied, and are now being evaluated in four sites (Table 5). All are susceptible to CBB and superelongation. Rayong 1 (M Thai 1) and Black Twig (M Mal 2) have intermediate resistance to mites and thrips.

Improved Breeding Populations

Experience to date shows that only a small number of germplasm accessions combine the requisite traits for a given edaphoclimatic zone, especially for moderate and high stress situations. Those that do meet basic criteria, such as those described above, can be used directly in crosses to produce superior progeny for immediate selection.

On the other hand, many germplasm accessions have individual desirable traits, but are deficient in other aspects. These clones, when used in hybridization, have little chance of directly producing progeny superior to the present generation of hybrids. As a strategy for broadening the germplasm base for genetic improvement, the germplasm development section undertakes the development of improved hybrids from these latter types of accessions to act as a bridge between germplasm accessions and the most advanced hybrids of the varietal improvement section.

The first generation of these bridge hybrids is now at the preliminary yield trial stage at Media Luna, Valledupar, Carimagua, and Popayan. The generally good performance of these populations gives evidence to the efficacy of the methodology.

Media Luna and Valledupar

For Media Luna and Valledupar, hybrids are being selected to combine high yield, dry matter content and mite resistance. Hybrids follow the same selection scheme as germplasm accessions, i.e., preliminary selection in single row trials only at Media Luna, followed by preliminary and replicated trials at both sites. Selection criteria are similar at the two sites, except for the additional stress of mites at Valledupar. Yields in both sites were high, comparable to the best previous selections for this zone (Tables 6 and 7). This completely new germplasm base, if combined with presently available hybrids, has the potential to produce even further yield increases for this important cassava-growing zone.

Although mite resistant parents have not been used extensively in crosses, the contribution of several intermediately resistant parents, along with two generations of selection under mite pressure in Valledupar, can already be observed (Figure 1). Many of the highest yield potential germplasm accessions for this zone are susceptible to mites, so the combination of high resistance and high yield potential

will take time. One advanced hybrid showing special promise is CM 681-2, which had the highest yield at Valledupar and is mite resistant (Table 3).

Carimagua

The expanded germplasm base built up in Carimagua has yield, resistance and quality traits which are already acceptable (Table 8). For both CBB and superelongation resistance, the hybrids in the observational and preliminary yield trials are already superior to the selected germplasm bank selections in the replicated yield trial (Figures 2 and 3).

Crosses were made between mite resistant CBB and superelongation resistant clones to combine these important resistances for Carimagua. Most of the progeny were intermediate for all resistances, and could not survive the multiple stresses over the growing cycle. The combination of resistances to wet season and dry season problems seems to be difficult. The resistance genes appear to reside in rather distinct gene pools at the present time. The choice of a balance between selection for resistance to wet season and dry season problems will require careful study.

Popayan

The breeding program for Popayan is relatively new, and crosses directed specifically for this zone are only at preliminary selection stages. Vigor and disease resistance of those selections demonstrate that adaptation to the low temperature zones will not be difficult to achieve when adapted parents are used. In just one selection cycle for resistance to phoma leaf spot, nearly all hybrids have moderate to high resistance levels (Figure 4). Though this zone receives minor attention in breeding, improvements over local varieties should be possible. Low temperature adaptation should be a non-site specific phenomenon, and therefore selection in Popayan for other highland areas such as in Africa.

Table 1. Results of germplasm evaluation in Media Luna, (edaphoclimatic zone I) 1981-82.

	Yield (kg/plant)	Harvest index	Dry matter (%)
Mean of trial (539 clones)	2.1	0.47	32.7
Mean of selected clones (15)	4.2	0.63	31.2
Checks			
M Col 22	2.7	0.64	32.3
M Col 1468	3.7	0.60	25.5
M Col 2063 (Secundina)[a]	1.9	0.50	38.4
M Bra 12	3.3	0.60	32.4
M Ven 77	2.6	0.53	30.8
CM 342-170	3.5	0.71	29.1

a. Regional variety.

Table 2. Results of replicated yield trial in Media Luna (edaphoclimatic zone I) 1981-82.

Clone	Yield (t/ha)	Harvest index	Dry matter (%)	HCN[a]
M Ven 25	33.7	0.65	34.4	8.5
M CR 2	18.8	0.53	38.5	9.0
M Ven 23	18.8	0.56	37.6	8.5
M Ven 45A	18.5	0.54	36.7	8.5
CM 342-55	17.9	0.52	21.3	8.0
M Col 72	17.1	0.68	37.5	5.5
M Col 2216	15.7	0.52	36.2	6.0
M Mex 24	15.2	0.51	34.8	9.0
M Col 2215	15.0	0.65	39.1	4.5
CM 681-2	14.9	0.53	33.0	6.5
Checks				
M Col 22	18.3	0.67	31.3	6.5
M Col 1468	27.7	0.61	22.3	6.5
M Col 1684	15.9	0.76	28.8	9.0
M Col 2063 (Secundina)[b]	4.7	0.45	35.4	6.5
M Bra 12	22.9	0.57	31.6	7.0
M Ven 77	22.7	0.54	28.8	6.0
CM 342-170	21.8	0.72	26.9	7.5
Mean of trial (26 clones)	15.7	0.55	33.7	7.1

a. 1-9 scale based on the picrate test: 1 = very low; 9 = very high.

b. Regional variety.

Table 3. Results of replicated yield trial in Valledupar (edaphoclimatic zone I) 1981-82.

Clone	Yield (t/ha)	Harvest index	Dry matter (%)	HCN[a]	Mites[b]
M Col 681-2	31.4	0.46	34.4	6.0	2.8
M Col 2215	29.4	0.67	31.8	8.0	3.0
M Ven 23	27.9	0.47	34.0	8.0	3.0
M Ven 45A	25.4	0.43	32.8	8.0	2.0
M Bra 3	22.7	0.49	25.8	7.0	4.5
M Bra 15	21.4	0.44	28.2	7.0	2.5
M Col 1805	20.7	0.49	36.0	4.0	4.0
M Col 76A	20.4	0.63	34.2	5.0	3.8
M Col 1719	19.2	0.53	38.7	6.0	3.0
M Col 948D	18.3	0.57	40.2	5.0	2.3
Checks					
M Col 22	32.2	0.60	30.2	7.0	4.0
M Col 1468	24.3	0.50	27.5	7.0	4.0
M Col 1684	26.1	0.45	31.2	7.0	4.5
M Col 2207 (Enanita)[c]	21.1	0.51	37.2	5.0	4.5
M Bra 12	37.0	0.58	33.6	6.0	4.8
M Ven 77	15.3	0.47	28.6	8.0	3.5
CM 342-170	17.4	0.42	31.1	7.0	5.0
Mean of trial (40 clones)	17.7	0.47	33.5	6.4	3.7

a. 1-9 scale based on the pircate test: 1 = very low; 9 = very high.
b. 1-5 scale: 1 = very low damage; 5 = very high damage.
c. Local variety.

Table 4. Results of replicated yield trial in Carimagua (edaphoclimatic zone II), 1981-82.

Clone	Yield (t/ha)	Harvest index	Dry matter (%)	Response to HCN[a]	CBB[a]	Super-elongation[a]
M Per 242	30.0	0.56	34.2	5.5	1.8	3.5
M Per 245	22.9	0.60	30.6	5.0	2.5	3.5
M Col 1894	18.2	0.53	31.9	3.0	2.3	2.0
M Col 1772	17.4	0.49	31.6	4.0	2.3	2.0
M Bra 5	16.4	0.57	32.6	5.0	2.2	3.0
M Col 638	15.3	0.49	26.3	5.0	2.0	2.0
M Per 241	15.0	0.45	32.0	4.5	2.5	4.0
M Col 1900	15.0	0.51	33.7	5.0	2.8	2.0
M Col 1942	13.9	0.51	34.6	8.0	1.8	3.5
M Col 1964	13.5	0.59	30.3	6.5	2.3	2.0
Checks						
M Col 22	7.3	0.52	31.2	5.5	3.3	5.0
M Col 1438 (Llanera)[b]	13.3	0.58	35.8	3.5	2.3	3.0
M Col 1468	10.1	0.41	29.8	5.5	2.8	4.0
M Col 1684	9.2	0.57	28.1	8.5	3.0	4.0
M Bra 12	6.2	0.36	29.1	5.0	3.0	5.0
M Ven 77	11.7	0.53	29.6	5.0	3.0	2.0
CM 523-7	8.9	0.42	35.6	6.5	3.0	4.0
Mean of trial (33 clones)	11.7	0.49	31.2	5.5	2.6	3.1

a. 1-5 scale: 1 = very low damage; 5 = very high damage.

b. Local variety.

Table 5. Evaluation of Asian clones for disease and insect resistance.

Clone	Common name/origin	Evaluation[a] *Mononychellus* sp. mites	Thrips	CBB	Super-elongation
M Tai 1	Rayong 1 (Thailand)	3	3	4	4
M Tai 1	M-4 (Malaysia)	4	4	4	4
M Mal 2	Black Twig (Malaysia)	3	3	4	4
M Mal 3	(C-5 (Malaysia)	4	5	4	5

a. 1-5 scale: 1 = very low damage; 5 = very high damage.
Evaluation for mites in Valledupar, Cesar; for thrips in CIAT, Palmira; and for CBB and superelongation in Carimagua.

Table 6. Results of a preliminary yield trial, Media Luna, 1981-82.

	Yield (t/ha)	Harvest index	Dry matter (%)	HCN[a]
Selected clones (15)	31.7	0.59	30.1	5.0
Checks				
M Col 22	34.2	0.62	29.1	4.0
M Col 1468	20.1	0.49	22.7	5.0
M Col 2063 (Secundina)[b]	6.5	0.40	33.1	4.0
M Bra 12	21.6	0.51	29.0	5.0
M Ven 77	33.5	0.53	26.8	5.0
CM 342-170	34.5	0.70	28.3	6.0

a. 1-9 scale based on the picrate test: 1 = very low; 9 = very high.

b. Local variety.

Table 7. Results of a preliminary yield trial in Valledupar, 1981-82.

	Yield (t/ha)	Harvest index	Dry matter (%)	HCN[a]	Mites[b]
Selected clones (15)	38.9	0.54	32.2	6.4	2.9
Checks					
M Col 22	25.9	0.48	31.6	5.5	4.5
M Col 1468	45.9	0.53	24.7	5.5	5.0
M Col 1684	19.6	0.58	29.9	8.0	5.0
M Bra 12	29.7	0.56	31.6	7.5	5.0
M Ven 77	22.6	0.41	28.8	6.0	4.5

a. 1-9 scale based on the picrate test: 1 = very low; 9 = very high.

b. 1-5 scale: 1 = very low damage; 5 = very high damage.

Table 8. Results of a preliminary yield trial in Carimagua, 1981-82.

	Yield (t/ha)	Harvest index	Dry matter (%)	HCN[a]	CBB[b]	Super-elong-ation[b]
Selected clones (8)	13.1	0.48	31.5	5.1	2.8	2.9
Checks						
M Col 22	9.2	0.50	31.5	4.0	3.0	5.0
M Col 1438 (Llanera)[c]	13.2	0.47	32.6	4.0	2.0	3.0
M Col 1684	14.2	0.62	28.3	9.0	3.0	4.0
M Braz 12	8.6	0.35	29.2	5.0	3.0	5.0
M Ven 77	13.2	0.57	29.7	5.0	2.5	2.0
CM 523-7	10.4	0.49	34.0	4.0	3.5	4.0

a. 1-9 scale based on the picrate test: 1 = very low; 9 = very high.

b. 1-5 scale: 1 = very low damage; 5 = very high damage.

c. Local variety.

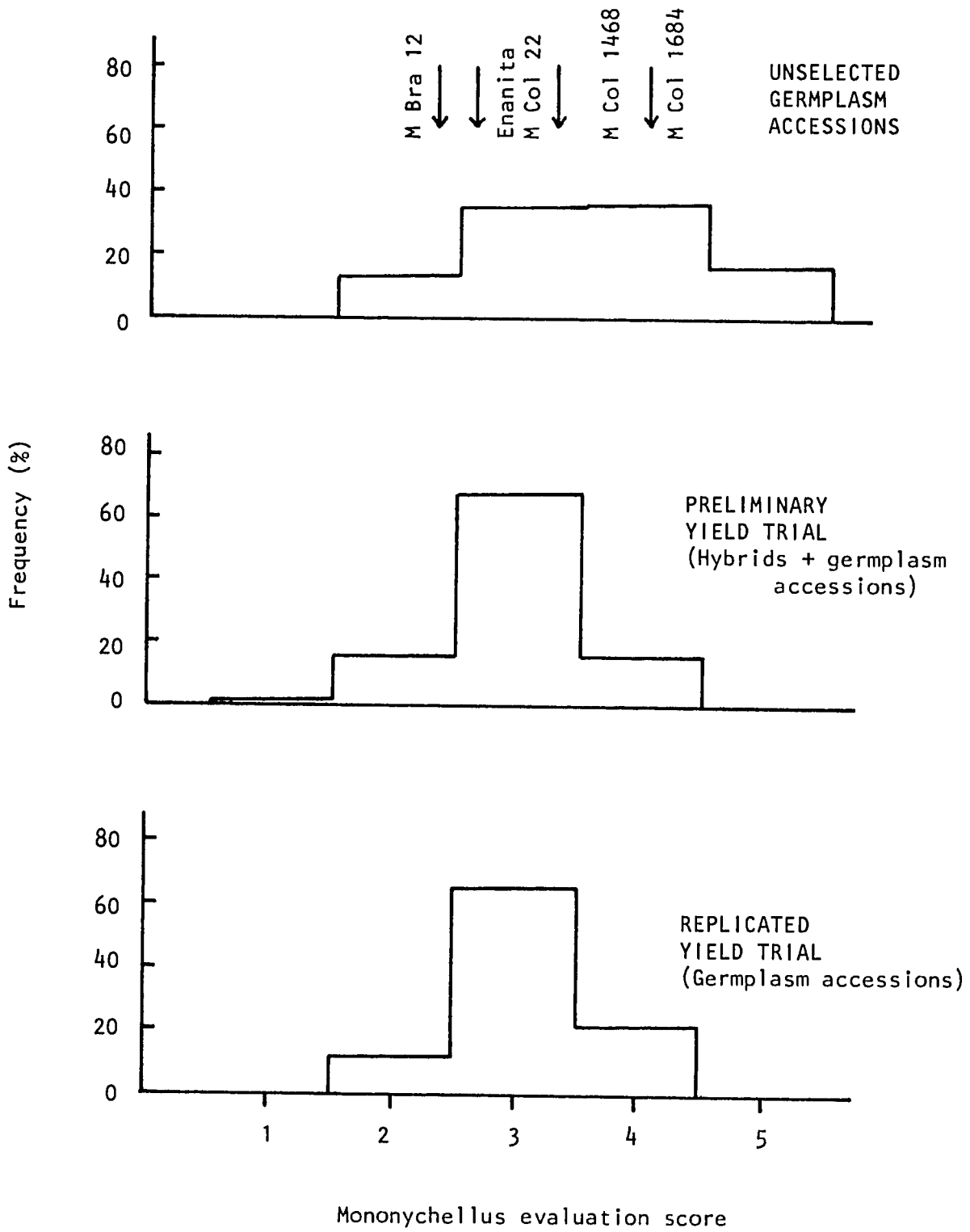


Figure 1. Frequency of mite resistance (scale of 1-5 where 1 = very low damage; 5 = very high damage) in various populations on the Colombian North Coast.

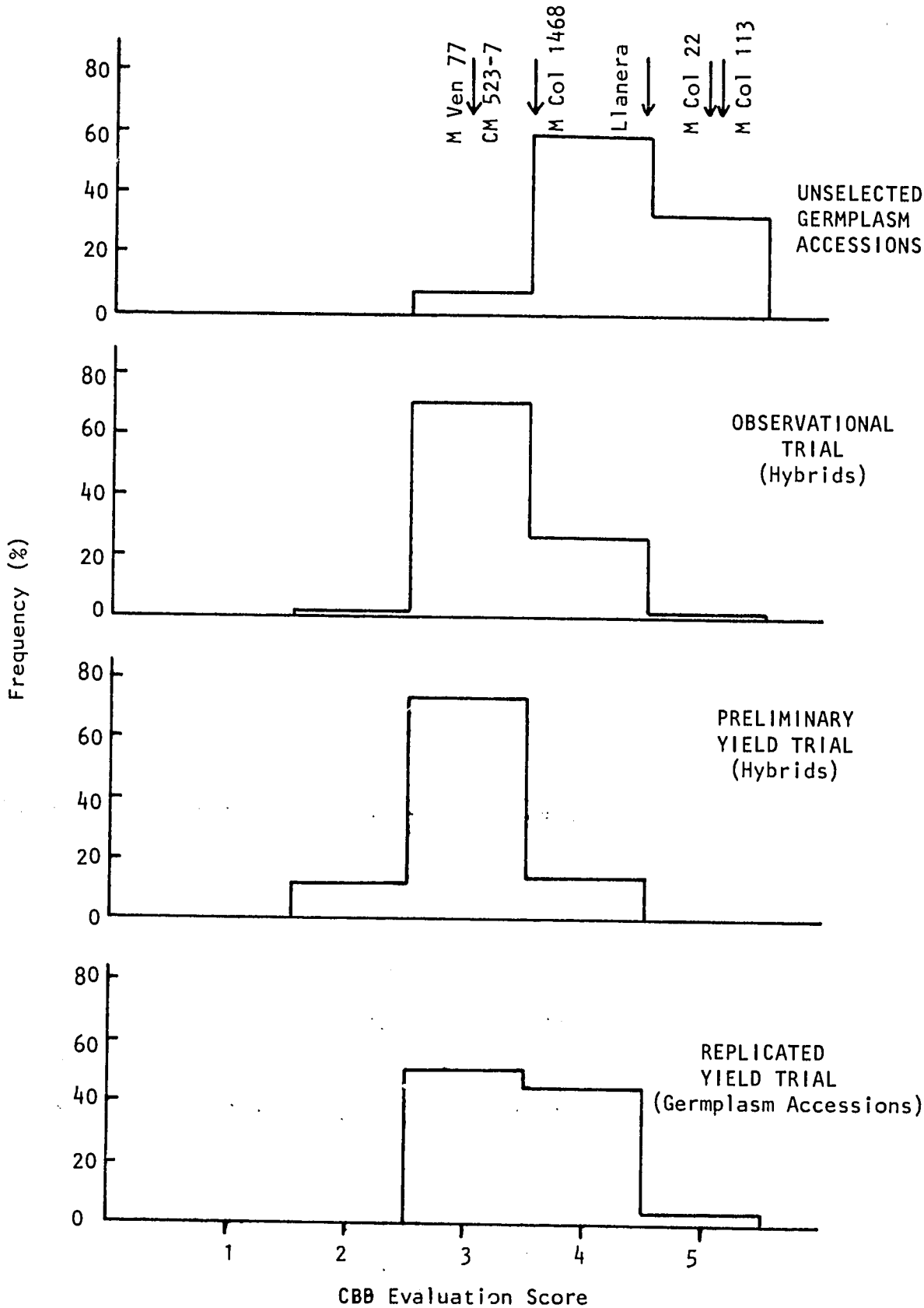


Figure 2. Frequency of CBB resistance in various populations at Carimagua.

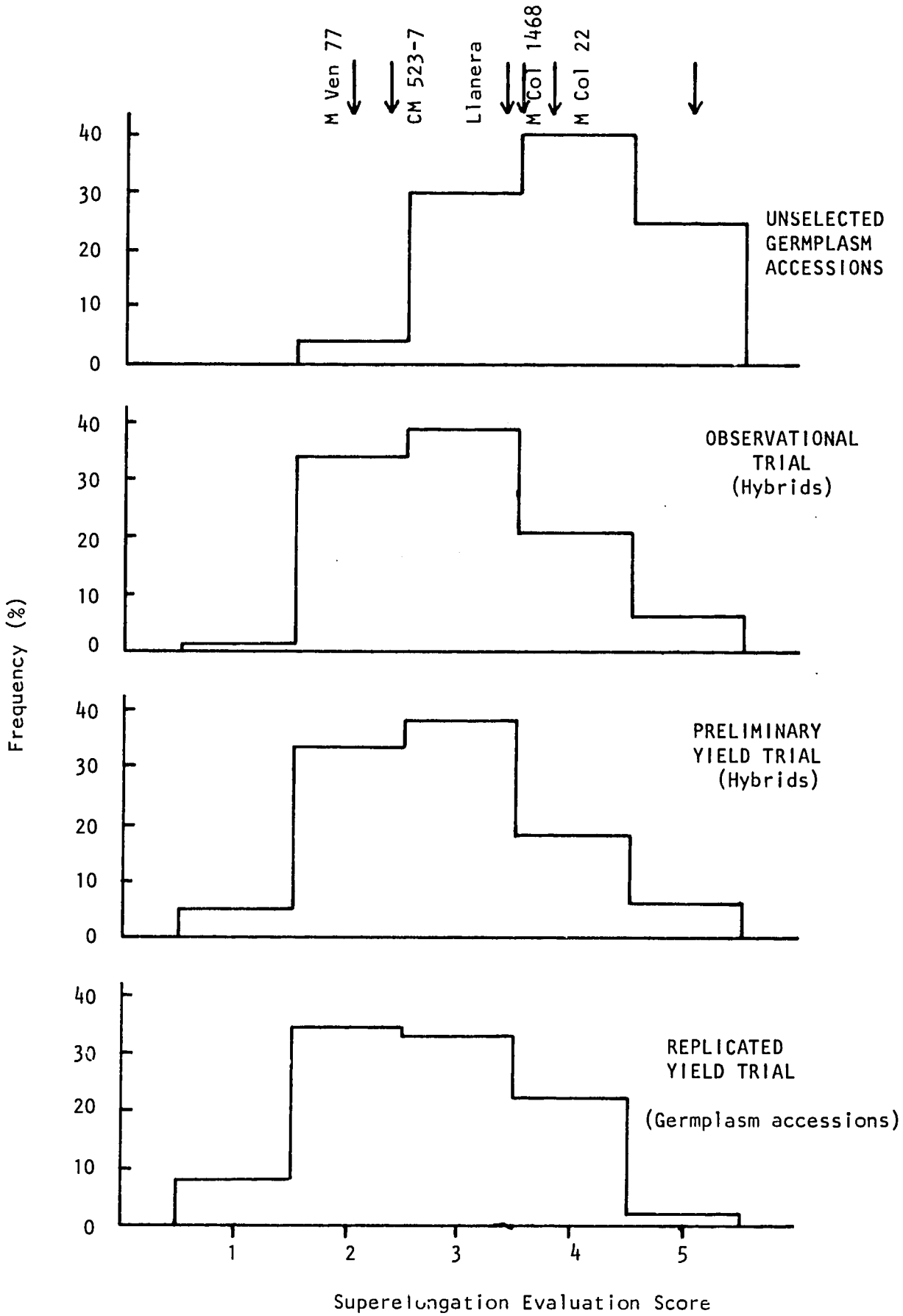


Figure 3. Frequency of superelogation resistance in various populations at Carimagua.

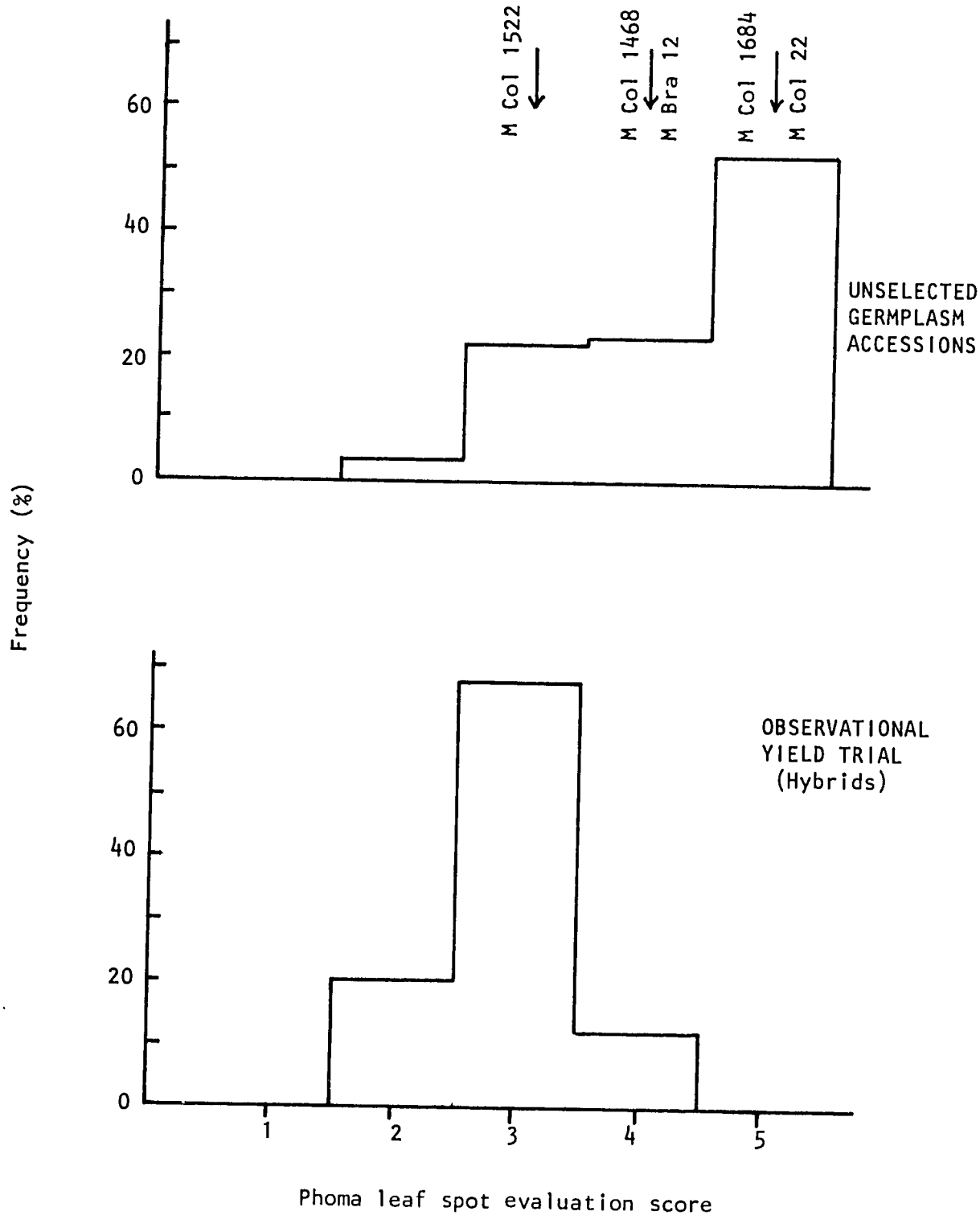


Figure 4. Frequency of phoma leaf spot resistance in different populations at Popayan.

Varietal Improvement

Evaluation and selection of genetic materials continued actively at ICA-Caribia and ICA-CIAT-Carimagua stations while hybridization and initial selections were concentrated at the CIAT-Palmira headquarters. Major evolutions in basic breeding strategy in recent years are:

(1) Greater importance was given to selection at Caribia as a more representative environment of a vast cassava area of hot lowland tropics and selection at Carimagua as an environment with the highest number of factors adverse to yield. As a consequence, the relative importance of selection at CIAT declined.

(2) More importance was given to selection for general adaptation measured by yield and yield stability as opposed to single trait selection. This is partly due to the improvement already attained through selection for single traits such as harvest index, CBB and superelongation resistance.

(3) There has been a shift from selection of finished cultivars toward selection of cross parents for producing hybrid populations to be used as sources of selection by national programs.

Selection at Caribia

No fertilizer and pesticide application or irrigation have been done in the trials at Caribia. In any case, the soil condition within the Caribia station is highly variable so that yields of selected clones and local cultivars have been extremely variable. Nevertheless, a long term yield improvement is clear.

The harvest in March (1981/82A) came from a poor soil section which had an unfavorable rainfall pattern, thus representing a less productive growth cycle within the total environment of the area (Table 1). Both selected hybrid clones and germplasm accessions gave reasonably high yields. Germplasm accessions selected in Media Luna by the germplasm section showed good combination of yield and high root dry matter content. These accessions had been incorporated into the hybridization scheme for crosses with advanced hybrid clones. Thousands of F_1 seeds have been obtained.

On the contrary, the harvest in September (1981/82B) came from a good soil spot with a favorable rainfall pattern, thus representing a highly productive growth cycle (Table 2). Many hybrid clones resulted in very high yield and some of them were combined with high root dry matter content.

M Col 22, one of the earliest germplasm selections, has shown a combination of high yield and good yield stability over the years at Caribia. M Col 1684, one of the best germplasm accessions has shown very high yield capacity at Caribia although its yield has been highly variable. In both yield trials (1981/82A) and (1981/82B), the great

majority of high yielders were crosses which included M Col 22 or M Col 1684 (Tables 1 and 2).

The yields of local cultivars (Manteca, Montero, Venezolana, Secundina) at Caribia have been low. While the comparatively low yields of local cultivars in the trials may be a true representation of their yielding capacity, these low yields could also be a result of: (a) infection of unknown diseases accumulated over the years; and/or (b) preferential theft of local cultivars.

At the Caribia station where the soil condition is highly heterogeneous, the yield trial has only two replications/planting, and theft has become more indiscriminate (hybrid clones have also been preferred in recent years), thus, individual yield figures for a single experiment are not reliable.

Carimagua Selection

Soils at the Carimagua station are extremely poor (low pH, low available phosphorus, high exchangeable Al, etc.), thus, all the trials in this station receive an application of 500 kg/ha of dolomitic lime, 75 kg/ha of N, 150 kg/ha each of P_2O_5 and K_2O, and 10 kg/ha of Zn. Yet the total biomass production by cassava plants is much lower at Carimagua than at Caribia and CIAT-Palmira. Intensity of major diseases (CBB, superelongation, anthracnose) during the wet season and pests (mealybug, lacebug, mites) during the dry season is extremely high. No artificial control of diseases and pests was practiced after the 1977 plantings. Thus, our experiments at Carimagua offer evaluation under very intensive growth constraints as well as immediate selection for the edaphoclimatic zone II.

Yields have been low and variable, yet the average yield of selected hybrid clones (average of all entries in the yield trial), which used to be significantly lower than that of local cultivars, has risen much higher over recent years.

Both selected hybrid clones and germplasm accessions gave reasonably high yields in the harvest in March (1981/82A) (Table 3). The September planting trial (1981/82B) was heavily attacked by mealybugs, thus, the yield has been modest (Table 4). In both trials, some hybrid clones combined good yield with high dry matter content.

Under these high stress conditions, stable yield (good temporal yield stability) is difficult to obtain, yet some hybrid clones (CM 430-37, CM 507-37, CM 523-7) have shown considerable yield stability. These clones have been actively used in hybridization programs not only for the edaphoclimatic zone II but also for the edaphoclimatic zone I.

During the first experiments at Carimagua, CBB and superelongation were the overwhelmingly important yield constraints and the same holds true if planting is done with CBB and superelongation susceptible clones. While significant progress has been made toward improved CBB and superelongation resistance the major yield constraints to cassava at Carimagua shifted to insect attacks during the dry season. In the Llanos

Orientales of Colombia (where the Carimagua station is located) continuous large scale planting has no precedent. Local cultivars have been grown on a very modest scale on isolated farms. The continuous cassava cultivation for more than 10 years has created a new ecosystem and a genotypic shift toward higher CBB and superelongation resistance. This visible change in the spectrum of disease and pest population does not occur at Caribia possibly because the northern coast of Colombia (where Caribia is located) is a traditional cassava growing area.

The great majority of high yielders were hybrid selections from local cultivars (Llanera, M Col 638, M Col 647) (Tables 3 and 4). This is noteworthy particularly since the advanced Carimagua population (Tables 3 and 4) and the advanced Caribia population (Tables 1 and 2) came from the same population source. This suggests that the decentralized selections have been highly effective. While widely adapted clones exist such as M Col 1468 (CMC 40), M Col 1684 and CM 507-37, decentralized final adjustment may be needed in varietal release scheme.

Since the major objective is to provide a superior population source from which national programs can effectively select their final cultivars, decentralized selection has two possible drawbacks: (a) excessive narrowing of germplasm base; and (b) overadjustment to a specific local condition. To overcome the former, newly identified germplasm accessions such as M Ven 25, M Ven 131, and M CR 2 for edaphoclimatic zone I and M Per 245, M Bra 5, M Ven 77, M Col 1916, and M Pan 101 for edaphoclimatic zone II have been incorporated into the hybridization scheme. Frequent use of widely adapted clones in hybridization would lessen the danger of the latter.

Selection at CIAT

CIAT-Palmira represents a relatively insignificant portion of cassava growing area (edaphoclimatic zone IV). High yielding clones for this area such as CM 91-3, CM 489-1, and CM 849-1, have been actively used in hybridization. Thus, the importance of the experiments at CIAT-Palmira has shifted toward maintenance of genetic materials and hybridization.

Soil conditions at the CIAT-Palmira station are highly variable and no fertilizer, pesticide application or irrigation was done, so that the yield has been variable. Yet, the last three harvests (1980/81B, 1981/82A, 1981/82B) resulted in lower yields. This might have been partly a consequence of the unfavorable rainfall pattern, however, the main cause appears to be attack by insects (thrips, mealybugs, and mites). In the first experiments at CIAT-Palmira, the insect problem was minor or non-existent. However, 10 years of intensive, continuous cassava cultivation favored a build up of the insect populations. Traditionally cassava was not grown on large scale in the Cali-Palmira area. A new ecosystem was created and insects responded to it.

Hybridizations

A brief summary of the hybridizations from 1973 to 1982 is presented in Table 5. Parental selection in the early years was based on all germplasm evaluations at CIAT-Palmira and subsequent evaluations of selected 300 accessions at Caribia and Carimagua. This is followed by hybrid clones selected in all of these locations. The germplasm section started evaluating all germplasm accessions at Media Luna (edaphoclimatic Zone I) and Carimagua in 1978 and new genes from these evaluations began to be incorporated in 1980.

No cultivar was given special importance at the start of hybridization although over time some clones such as M Col 1684 gained special status in their use as parents. Starting hybridizations with parents selected from all germplasm accessions evaluated in three radically different environments makes the hybrid population resistant to a genetic narrowing.

The build up of the insect population at CIAT-Palmira included the fruitfly which feeds on cassava fruits. By 1979, up to 90% of the fruits were destroyed by the flies, so that the pollination block was sprayed with insecticide starting on January 1980, thus recovering the previous level of hybrid seed production (Table 5). One welcome side effect of spraying was the elimination of thrips and mite damage, thus resulting in profuse flowering of such clones as M Ven 77 or M Pan 101 which did not usually flower at CIAT-Palmira because of susceptibility to thrips.

From 10,000 to 30,000 F_1 seeds have been used annually in the selection program. Up to 40,000 seeds have been distributed to national programs. Major recipients of these seeds have been Brazil, Mexico, and Thailand. Recently, China, Malaysia, and the Philippines joined this rank.

Role of Widely Adapted Clones in Hybridization

A physiological study has demonstrated that genotypes adapted to areas with an average temperature below 20°C were completely different from those adapted to warmer areas. Hence, for the edaphoclimatic zone V, an independent hybridization scheme may be required. Recently another physiological study demonstrated significant effect of photoperiod on yield formation. Thus, the edaphoclimatic zone VI may require another specific hybridization scheme. Distinction among the edaphoclimatic zones I, II, III, and IV seems to be less clear-cut than that between these and edaphoclimatic zones V and VI. Target areas of many national programs fall between these major edaphoclimatic zones. Thus, equal importance has been given to hybridizations among parents selected within the same zones and to these across different edaphoclimatic zones.

Through the regional trial network, several widely adapted clones have been identified (Table 6). Wide adaptability (spatial stability) across major edaphoclimatic zones may not be necessary for national programs but it is extremely favorable to use widely adapted cross parents because the resulting hybrid population should offer selection opportunity at a wide variety of locations. Those widely adapted clones

have been actively crossed with more specifically selected clones from each zone.

Up until now there is no selection field in the edaphoclimatic zone III (rain forest). However, the result of regional trials demonstrated that these widely adapted clones were also adapted to the edaphoclimatic zone III. Hybrid populations based on these clones may also serve for zone III.

Significance of Selection Under High Stress

Significance of the edaphoclimatic zone II in terms of actual acreage may be small although the future potential may be great. Even with the edaphoclimatic zone II, the stress at the Carimagua station must be extraordinarily high. The combination of low soil fertility, the intensive dry season, and endless spectrum of diseases and insects makes Carimagua and ideal site for selection for yield adverse factors.

Genotypes selected under higher numbers of adverse factors also tend to perform well under less stress. CM 507-37 and CM 523-7 were selected in Carimagua and evaluation there played an important role in selecting M Col 1684 and CM 91-3.

Most of the target areas of national programs are less severe in factors adverse to yield both in number and intensity. The most difficult part of selection for long term yield stability is the fact that breeders have to be prepared for presently unobserved factors which may come into play when the breeders change the ecosystem by introducing new cultivars and changing cultural practices so that input from selection under highest stress may be beneficial over the long term even though it may not be visible over the short term.

Table 1. Results of a yield trial at Caribia, 1981/82A.

Hybrid clones	Root fresh yield (t/ha)	Root dry matter content (%)	Root dry yield (t/ha)
CM 847-11[a]	32	34	10.8
CM 1195-2[a]	28	35	9.8
CM 586-1	28	35	9.6
CM 342-170[a]	32	30	9.5
CM 998-10[a]	32	30	9.5
CM 713-3[a]	31	29	8.9
CM 726-6[a]	23	36	8.4
CM 1016-4[a]	24	35	8.4
CM 1054-3[a]	24	35	8.4
CM 681-2[a]	23	36	8.2
CM 982-22[a]	28	29	8.2
CM 728-18[a]	23	35	8.1
CM 1178-2[a]	23	35	8.1
CM 922-2[a]	17	37	6.3
CM 913-3	19	29	6.0
Germplasm accession			
M Col 22	30	34	10.1
M Ven 25	26	37	9.5
M Col 1684	26	34	9.0
M Ven 23	23	37	8.3
M Ven 131	22	38	8.2
M CR 2	22	37	8.0
M Col 1468 (CMC 40)	29	26	7.5
Local cultivar			
Manteca	6	33	2.1
Secundina	4	34	1.4

a. Hybrid clone from M Col 22 or M Col 1684.

Table 2. Results of yield trial at Caribia, 1981/82B.

Hybrid clones	Fresh root yield (t/ha)	Root dry matter content (%)	Root dry yield (t/ha)
CM 1288-17[a]	65	33	21.5
CM 976-15[a]	58	35	20.3
CM 982-20[a]	64	31	19.6
CM 981-8[a]	51	36	18.4
CM 1016-3[a]	58	31	18.0
CM 1322-2	62	29	17.8
CM 1016-34[a]	54	32	17.6
CM 1015-16[a]	52	33	17.1
CM 1350-7[a]	52	33	16.9
CM 1015-34[a]	49	34	16.7
CM 1252-6[a]	49	34	16.5
CM 1297-9[a]	48	33	16.0
CM 1016-35[a]	53	30	16.0
CM 696-1[a]	56	28	15.6
CM 1015-42[a]	50	31	15.6
CM 1305-3[a]	53	30	15.5
CM 1016-4[a]	50	31	15.3
CM 962-4[a]	49	30	14.9
CM 1014-12[a]	47	32	14.8
CM 1286-7	56	26	14.5
Germplasm accessiones			
M Col 1684	64	32	20.3
M Col 1468 (CMC 40)	43	29	12.5
M Col 22	34	31	10.6
Local cultivar			
Secundina	18	33	5.8
Manteca	14	30	4.2

a. Hybrid clones from M Col 22 or M Col 1684.

Table 3. Results of a yield trial at Carimagua, 1981/82A.

Hybrid clones	Root fresh yield (t/ha)	Root dry matter content (%)	Root dry yield (t/ha)
CM 1585-13[a]	28	33	9.1
CM 1559-5[a]	22	37	8.1
CM 1559-12[a]	25	31	7.8
CM 1223-1	24	32	7.5
CM 842-174[a]	24	31	7.3
CM 1564-3	19	37	7.1
CM 1559-11[a]	23	30	7.0
CM 841-179[a]	26	27	6.9
CM 1054-2	22	32	6.9
CM 1608-3[a]	21	32	6.8
CM 507-37[a]	21	33	6.7
CM 1585-5[a]	24	28	6.5
CM 723-3[a]	18	35	6.4
SM 297-35[a]	23	28	6.2
CM 1649-1[a]	22	28	6.2
CM 842-174[a]	19	32	6.2
CM 1613-1[a]	22	28	6.1
CM 840-31[a]	19	31	6.1
CM 840-160[a]	20	30	6.0
CM 523-7	17	36	6.0
Germplasm accessiones			
M Col 1916	25	31	7.6
M Per 245	24	31	7.6
M Bra 35	23	29	6.6
M Ven 77	18	31	5.8
M Col 1468 (CMC 40)	17	23	4.1
M Col 1684	12	28	3.4
Local cultivar			
Llanera	11	35	4.0
M Col 638	8	30	2.3

a. Hybrid clone from local cultivars (Llanera, M Col 638, M Col 647).

Table 4. Results of yield trial at Carimagua, 1981/82B.

Hybrid clones	Fresh root yield (t/ha)	Root dry matter content (%)	Root dry yield (t/ha)
CM 523-7	20	36	7.1
CM 854-21[a]	21	34	7.0
CM 978-28[a]	23	28	6.4
CM 1307-3	21	31	6.4
CM 946-2[a]	19	34	6.4
CM 621-214[a]	21	30	6.3
CM 430-37[a]	19	31	6.0
CM 621-251[a]	19	31	6.0
CM 507-37[a]	18	34	6.0
CM 1335-4[a]	16	37	5.7
CM 1663-1[a]	17	33	5.6
SM 267-10[a]	16	36	5.6
CM 996-6[a]	21	26	5.5
CM 723-3[a]	16	34	5.4
CM 1733-7[a]	16	33	5.4
SM 367-16[a]	16	32	5.2
CM 840-31[a]	15	35	5.1
CM 841-168[a]	17	29	5.0
SM 301-3	16	32	4.9
CM 1662-4[a]	15	32	4.9
Germplasm accessiones			
M Col 1684	14	30	4.3
M Col 1468 (CMC 40)	13	30	3.8
M Ven 77	7	30	2.1
Local cultivar			
M Col 638	13	29	3.8
Llanera	10	31	3.3

a. Hybrid clone from local cultivars (Llanera, M Col 638, M Col 647).

Table 5. Hybridizations and frequently used parents from 1973 to 1982.

Year	Cross number		No. F_1 seeds obtained	Frequently used parents
1973	CM 1	CM 337	5337	Llanera, M Col 22, M Mex 55, M Mex 59.
1974	CM 301	CM 450	22,348	M Col 22, M Col 113, M Col 647, M Col 1468, M Mex 55, M Mex 59, M Ven 270.
1975	CM 451	CM 624	25,439	Llanera, M Col 113, M Col 638, M Col 655A, M Col 882, M Col 1515, M Col 1684.
1976	CM 625	CM 856	12,497	M Col 638, M Col 1684, M Ven 185, M Ven 218, M Ven 270, M Pan 70, CM 180, SM 76.
1977	CM 857	CM 1416	33,891	M Col 22, M Col 638, M Col 1292, M Col 1468, M Col 1684, M Mex 17, M Ven 218, M Ven 270, CM 309, CM 321, CM 323, CM 324, CM 334, CM 446, CM 462.
1978	CM 1417	CM 1771	14,683	M Col 1684, M Mex 1, M Pan 70, M Ven 143, CM 307, CM 309, CM 314, CM 321, CM 323, SM 92.
1979	CM 1662	CM 2095	14,317	Llanera, M Col 647, M Col 638, M Col 1684, M Ven 270, CM 91, CM 305, CM 309, CM 326, CM 430, CM 507, CM 516, CM 517, CM 630, CM 727.
1980	CM 2096	CM 3250	90,055	M Col 638, M Col 1468, M Col 1684, M Col 1515, M Col 1912, M Ven 52, M Ven 62, M Ven 77, M Bra 5, M Bra 12, M Bra 35, M Pan 12B, M Pan 101, CM 91, CM 180, CM 311, CM 430, CM 507, CM 516, CM 517, CM 523, CM 630, CM 723, CM 727, CM 840, CM 845, CM 951, CM 1023, CM 1278, CM 1288, CM 1305, CM 1362, CM 1382, CM 1399.
1981	CM 3251	CM 3956	63,371	M Col 22, M Col 1684, M Bra 12, M Ven 77, CM 91, CM 342, CM 507, CM 523, CM 621, CM 586, CM 681, CM 723, CM 727, CM 849, CM 978, CM 982, CM 1015, CM 1023, CM 1399.
1982	CM 3956	CM 4300	62851	M Col 22, M Col 1468, M Col 1684, M Bra 12, M Ven 77, M Ven 131, M CR 2, Secundina, CM 342, CM 489, CM 507, CM 523, CM 586, CM 681, CM 727, CM 728, CM 845, CM 849, CM 922, CM 942, CM 950, CM 976, CM 981, CM 982, CM 1015, CM 1016.

Table 6. Adaptation of frequently used cross parents to major edaphoclimatic zones.

Parental clone	Adaptation to zone[a]					
	I	II	III	IV	V	VI
M Col 1468 (CMC 40)	+	+	+	+	--	++
M Col 1684	++	+	++	+	--	+
CM 91-3	0	+	+	++	--	
CM 507-37	+	++	++	+	--	
CM 523-7	+	++	+	+	--	
CM 982-20	++	0		+	--	

a. -- = very low; - = low; 0 = indeterminate; + = high; ++ = very high.

Cultural Practices

Multiple Cropping

Crop competition studies were continued this year with two experiments, one growing intercrops of vastly contrasting cassava an maize genotypes at CIAT-Palmira, and the other using different spatial arrangements in a cassava-cowpea association at CIAT-Quilichao.

Cassava-maize intercrops

The local cassava variety M Col 113, a medium vigorous, medium height, early branching, leafy type, and a CIAT hybrid, CM 849-1, a very vigorous, tall cultivar were intercropped with two maize varieties, a low statured, early yellow flint type named "Population 31" and a tall, late, white dent type, "La Posta". Soil was prepared in ridges at 0.8 m. Cassava was planted as a solo crop in a 0.8 x 1.2 m arrangement and intercropped with maize in a 1.6 x 0.6 m spacing (10,416 plants/ha). Maize was planted at 0.8 x 0.3 m in monoculture and 1.6 x 0.15 m in association (41,666 plants/ha). A fertilization of 150, 44, 83, 10 and 1 kg/ha of N, P, K. Zn and B respectively was applied half at planting and half 45 days later. Plant height and width were recorded biweekly. The early, short maize reached physiological maturity 65 days after planting whereas the tall, late variety matured 121 days after planting. Maize grain yield and components were recorded at harvest.

The cassava was harvested 12 months after planting and yield and quality parameters recorded. Land equivalent ratios and competitive ratios were calculated for all crop combinations.

Growth of different genotypes

After planting, the maize plant height increased faster and stayed on top of cassava during the whole period the two crops grew together. This was particularly so when the tall maize La Posta was intercropped either with M Col 113 or CM 849-1 (Figure 1A and B). However, since maize has a canopy which is vertically arranged in different strata, there was considerable interaction between the crops, especially when the short, early Population 31 grew with cassava (Figure 1C and D). When Population 31 was intercropped with CM 849-1, most of the maize canopy was actually below that of cassava although the maize tops reached a level slightly above it.

Cassava and maize yields

Curiously, when M Col 113 was associated with maize Population 31 fresh root yield was a 10 t/ha greater than the monoculture yield. When planted in association with La Posta, the fresh root yield was identical to the monoculture yield. On the other hand, CM 849-1, which yielded 18.5 t/ha more than M Col 113 as a solo crop, suffered a moderate yield reduction when intercropped with maize Population 31 and a significant reduction when intercropped with La Posta (Table 1). For M Col 113 there was a tendency to show a lower starch percentage when intercropped with maize whereas for CM 849-1, this tendency was not observed.

Monoculture maize yields reflected the different yield potentials of the two varieties used, the tall and late La Posta outyielding the short, early Population 31 by more than 1,700 kg/ha. Grain yields of both maize varieties were reduced when cassava was intercropped, reduction being smaller with the slow-growing M Col 113 than with the vigorous, fast growing hybrid CM 849-1. There was a surprising consistency in yield reduction percentage; intercropping M Col 113 led to a 16% reduction in both maize varieties whereas CM 849-1 brought about yield reductions of 21-22% (Table 2).

Intercropping also reduced the 100 seed weight slightly and had an influence on the degree of barreness of the maize. While in Population 31 grown in single culture five out of 100 plants had two ears, intercropping with M Col 113 reduced the ear number per plant so that five out of 100 plants had two ears, intercropping with M Col 113 reduced the ear number per plant so that out of 100 plants, three had no ears and out of 100 plants intercropped with CM 849-1, 11 were without ears. A similar reduction in ears per plant was observed in La Posta where 12-13 out of 100 plants were without ears in the intercropped plots.

Competition among crops and land use efficiency

The cassava hybrid CM 849-1 had a fast, vigorous and aggressive growth. It therefore appeared more competitive with the maize than M Col 113. This impression was supported by the fact that CM 849-1 reduced maize yields by 21-22% whereas M Col 113 reduced them only by 16%. Also, CM 849-1 had a higher competitive ratio than M Col 113 in combination with any of the two maize varieties. However, the data presented here suggest that it is not exclusively a vigorous, aggressive growth habit which confers competitiveness to a cassava cultivar. Competitiveness can also well be the result of a high degree of tolerance to competition from companion crops without suffering a reduction in productivity. This was the case with M Col 113 which did not show a root yield reduction when intercropped with the fast growing, tall maize (La Posta) an even demonstrated a yield increase when exposed to mild competition by the short, early maize (Population 31).

It is well known from earlier work in cassava that M Col 113 when grown in a pure stand may form an excessively large leaf area, to the detriment of root production. Leaf area measurements could not be taken in this experiments but it may be assumed that intercropping with maize reduces[1] source size from excessive to a near optimum level for root production when the associated maize variety was Population 31 whereas intercropping with La Posta may have reduced the source size below optimum, leading coincidentally to a root production similar to that with excessive leaf area in monoculture.

The relatively high competitive ratio obtained for M Col 113 when intercropped with Population 31 (Table 3), clearly reflects the high

---

[1] Possibly due both to fewer leaves and a shorter leaf life due to shading.

tolerance to intercropping of this type of cassava whereas cassava hybrid CM 849-1 showed competitiveness due to vigorous growth and a high yielding ability in either of the two combinations with maize. Both M Col 113 and CM 849-1 showed rather similar land use efficiencies as indicated by the land equivalent ratios (LER's) given in Table 3.

It appears from the above that both types of cassava, the early branching, leafy growth type of M Col 113 as well as the tall, very vigorous type of CM 849-1, are suitable for intercropping with tall, vertical canopy crops such as maize although the suitability of M Col 113 derives more from its tolerance to intercropping rather than from competitiveness conferred by vigorous growth, as in the case of CM 849-1. On the other hand, the two types would be inappropriate for intercropping with short statured, close to the ground, horizontal canopy crops such as non-climbing grain legumes which would suffer considerable reductions in their productivity.

Spatial arrangements in a cassava-cowpea intercrop

Cassava M Ven 77 and Cowpea TVu 1977-OD were planted at CIAT-Quilichao in monoculture and association using three different arrangements for cassava, 1 x 1 m (10,000 plants/ha), 1.4 x 0.7 m (10,204 plants/ha) and 1.8 x 0.55 m (10,101 plants/ha). In the 1 x 1 m arrangement, cowpea was interplanted in two rows, with 0.4 m distance on each side to the next cassava row and 0.2 m between the two cowpea rows. With cassava spaced at 1.4 x 0.7 m, two cowpea rows were planted at 0.5 m from the cassava and 0.4 m between the cowpea rows and in the 1.8 x 0.55 m cassava spacing, three cowpea rows were grown at 0.6 m from cassava and with 0.3 m on each side between the central row and the two lateral rows. Distances between cowpea plants were adjusted to give a density of approximately 110,000 plants/ha in each of the systems. The spatial arrangements were preserved in the respective monocultures. The trial was planted without ridges. A basal dressing of 0.7 t/ha of dolomitic lime was incorporated prior to planting and a fertilization of 100, 66, 83, 10 and 1 kg/ha of N, P, K, Zn and B respectively was applied at planting. Cowpea was harvested 86 days after planting and grain yield and yield components were determined. Cassava was harvested 12 months after planting and yield and quality parameters were recorded.

Cowpea and cassava yields

Intercropping reduced cowpea yields to 75% of the level of the corresponding monoculture plots when cassava was planted in the 1 x 1 m arrangement, but only by 13.5% and 14.8% in the 1.4 x 0.7 and 1.8 x 0.55 m arrangements, respectively. An additional cowpea monoculture, planted outside the regular design, with cowpea spacing at 0.3 x 0.3 m produced the greatest grain yield (Table 4). Yield reductions due to intercropping were mainly the result of reduced pod numbers/plants, with little changes in the other yield components. Arrangements, either in monoculture or intercropped, did not produce any significant changes in yield or yield components.

Cassava root yields showed opposite trends in response to arrangements comparing monoculture and intercropped plots. In

monoculture and intercropped plots. In monoculture, fresh root production averaged over 50 t/ha (Table 5). The small downward trend in yield when moving from square to rectangular planting was not significant although the variability in this part of the trial was very low and consequently precision very high (C.V.% = 6.4). An inverse yield trend was observed with intercropped cassava, the 1 x 1 planting yielding the lowest and the 1.8 x 0.55 m arrangement the highest, differences this time being large but non-significant probably due to the high degree of variability in intercropping yields (C.V.% = 32.6). As with cowpea, yield reduction due to intercropping was greatest in the square planting reaching 37% in this arrangement as opposed to 31% and 19% in the 1.4 x 0.7 m and 1.8 x 0.55 m arrangements, respectively.

Competition and land use efficiency

The competitive ratio (CR) does not quantify competition in absolute terms. Rather, it shows how competitive one crop was relative to the other (by definition, the CR value of one crop is the reciprocal of the other). Thus, in the present trial, cowpea was relatively more competitive than cassava in all arrangements. However, while the most favorable conditions for cowpea were the 1 x 1 m and 1.4 x 0.7 m arrangements, an almost perfect competitive balance of both crops was achieved in the 1.8 x 0.55 m arrangement, CR values of both cassava and cowpea being almost equal. This better balance of competition between the two crops with cassava spaced in a rectangular pattern was also clearly reflected by an increase in land use efficiency, expressed as the land equivalent ratio (LER) which improved over the one obtained with square planting by almost 0.3 (Table 6).

Considerable effort has been spent in the past (Cassava Annual Report, 1977 and 1978) to demonstrate the flexibility of cassava grown in monoculture with regard to changes in spatial arrangement. Also, trials were conducted to identify the optimum row arrangements of grain legumes when intercropped with cassava (Cassava Annual Report, 1979). In the present trial, the spatial arrangement of cassava grown both in monoculture and intercropped was changed. Cassava monoculture yield data suggest that in fact this practice does not affect root yield significantly within the limits of the arrangements examined. Furthermore, in the intercropping situation, it showed that growing cassava in a square arrangement generates the highest degree of interspecific competition (greatest yield reduction percentage in both crops) whereas this interspecific competition can be minimized when a rectangular spacing of cassava is adopted.

Weed Control

While research in the past had been conducted principally on cultural and chemical pre-emergence systems of weed control in cassava, this year's research focused on the post-emergence aspect. In traditional cassava cultivation, the farmer uses post-emergence systems of weed control such as hand-weeding and tractor cultivation. However, with the development of new, low cost hand-carried equipment for chemical post-emergence weed control, an evaluation and comparison appeared appropriate of the traditional with new systems under different

degrees of weed pressure. Trials were conducted to clarify basic questions of weed competition in post-emergence weed control systems and evaluations of different control systems were carried out in three different edaphoclimatic zones, covering a range of crop and weed growth situations.

Weed control between rows vs. between plants

A problem with post-emergence control of weeds in cassava is that many systems, such as tractor cultivation and some of the chemical machine-applied systems, control weeds only between rows whereas the weeds between plants within rows are left in place. The importance of weed control between rows and between plants for yield formation in cassava was therefore evaluated. At Caribia, on the Colombian North Coast, cassava variety M Col 22 was planted on ridges in a 1 x 1 m spacing. Four treatments of weed control (manually by machete) were established: (1) complete weeding, i.e. between rows and between plants; (2) weeding only between plants leaving weeds between the rows uncontrolled; (3) weeding only between rows leaving weeds between plants within rows uncontrolled; and (4) no weeding at all. Weedings were carried out at weekly intervals to keep the weeded areas permanently clean. A fertilization of 50, 83 and 10 kg/ha of N, K and Zn respectively was applied at planting. At ten months, the cassava was harvested and growth parameters as well as fresh root yield and components were determined.

Plant height at harvest showed numerical but nonsignificant differences whereas a statistically significant response of total top weight and number of stakes per plant was observed for the different weeding treatments (Table 7). Fresh root yield was most clearly affected in different places by weed competition and each treatment belonged to a statistically different group. The yield reduction due to weed competition resulted from fewer thickened roots which were least reduced when weeds were controlled between plants within rows and most reduced with no control at all, the control between rows taking an intermediate position. On the other hand, root size (length and perimeter) was similar to the complete control treatment when weeds were controlled either between plants or between rows; only in the non-weeded treatment was there a significant reduction of root size in addition to the reduced root number (Table 8).

Results from this trial show that leaving weeds uncontrolled either between rows or between plants within rows can reduce root yield significantly, however, weeds growing between plants within rows appear to have a more detrimental effect on root production than weeds left between the rows. This probably occurred in the ridge planting system adopted in this trial because: (a) weeds growing on the ridge together with the cassava closed in on the crop more aggressively than weeds growing between ridges; and (b) cassava had to compete at equal height with weeds growing together with it on the ridge whereas weeds growing in the furrows started to grow from a lower level than the cassava.

Thus, the portion of weeds controlled by many post-emergent systems, i.e. the weeds growing in the furrows appear to be less

detrimental to root yield formation than the very competitive weeds between cassava plants on the ridges which are mostly not controlled by these systems. The identification of post-emergent control systems which also cover the area between plants would, therefore, be essential if the yield potential of cassava were to be fully exploited.

Evaluation of post-emergent weed control systems

Trials were conducted at three different sites, CIAT-Palmira, the ICA-Carimagua research station in the Eastern Plains of Colombia and at ICA-Caribia on the Colombian North Coast. Weed pressures under the specific trial conditions ranged from low to intermediate and high in these three locations, respectively. At Palmira, land was prepared in ridges at a 1.6 m distance and a cassava hybrid, CM 849-1, was planted in a 1.6 x 0.6 m arrangement (10,416 plants/ha). At Carimagua, the cassava hybrid CM 523-7 was planted on ridges in a 1.2 x 0.8 m spacing (10,416 plants/ha) and at Caribia, the variety M Col 22 was planted as in Carimagua. Fertilization was 50, 22, 42, 5 and 1 kg/ha of N, P, K, Zn and B, respectively, at CIAT-Palmira, 50, 44, 83 and 10 kg/ha of N, P, K and Zn, respectively, at Carimagua and 100, 83, 10 and 1 kg/ha of N, K, Zn and B, respectively, at Caribia. At Carimagua, 0.5 t/ha of dolomitic lime was incorporated pre-planting whereas no soil amendments were applied at the other two locations. Five different systems of postemergent weed control were evaluated: (1) tractor cultivation was done approximately at 15 and 45 days after planting; (2) complete hand weeding was done by hoe until the cassava closed the canopy; (3) a herbicide wipe-on device consisting of a PVC-pipe with an inserted wick at one end was used for the application of a 2:1, water-glyphosate mixture; (4) a spinning-disk ultra low volume (ULV) applicator was used. This battery-driven, hand carried device covers a width of 1.2 m in one pass. In the trials reported here a mixture of 3 l/ha of goal (Oxifluorfen) with 1 l/ha of gramoxone (Paraquat) was used in 30 l/ha of liquid; (5) the same herbicide mixture was applied with a conventional knapsack sprayer with TK 2.5 shielded nozzle, using 400 l/ha of liquid and; (6) an uncontrolled check was left for comparison. Due to differences in weed incidence at the three locations, treatments were carried out at different frequencies. While the tractor cultivations were done uniformly at Palmira and Carimagua, two hand weedings were done in Palmira and Carimagua and three in Caribia. The wipe-on herbicide application was done once at Palmira, twice at Carimagua and three times at Caribia. Weed control with both the ULV-applicator and the knapsack sprayer was done once at Palmira and twice at Carimagua and Caribia.

The cassava was harvested at 12 months in Palmira and Carimagua whereas harvest age was 10 months at Caribia.

Cassava yields

At Palmira, exceptionally high yields were obtained, the trial average being 51.6 t/ha. The best treatment goal + gramoxone applied with the ULV equipment yielded 58.3 t/ha. Even without weed control, a fresh root yield of 47.3 t/ha was obtained, possibly as a result of both a low weed incidence and the cultivation of a very competitive, high

yielding hybrid line (Table 9). At Carimagua, yields were generally much lower than at Palmira, but this was only partly due to the higher weed pressure at this location which in addition to weeds has a very infertile soil and a high incidence of insects, mites and diseases. Under these conditions, two hand weedings controlled weeds most efficiently (ranking 1) but the ULV - applicator which had ranked in first place at Palmira, followed in second place with little actual root yield difference. At Caribia (the location with the highest weed pressure-see weedy check data) hand weeding gave the greatest yield, followed by glyphosate application with the chemical hoe, leaving the ULV - applicator in third place.

Comparing results from the three locations, it is evident that at Palmira, yields were high due to exceptional agronomic conditions, no matter what control system was adopted. This included the tractor cultivated plots were no weed control between plants within rows was achieved. There was little differentiation among the various post-emergent control systems, yield figures forming only two statistically different groups.

At Carimagua, on the other hand, the weed control by tractor cultivation which did not include weeds on the ridges between plants showed a clearly inferior yield level to hand weeding and to the chemical treatments where either complete or at least some degree of control between plants within rows was reached. Statistical analysis of root yields indicates a greater differentiation among treatments at this location, and performance of the various systems showing three distinct levels.

At Caribia, hand weeding was the most efficient in terms of root production, followed by the chemical system which used the systemic compound glyphosate. The two chemical systems which used contact herbicides apparently were no longer able to effectively reduce the extremely abundant weed growth at this location, even when a perfect coverage of weeds with micro-droplets was reached. The high weed pressure of the Caribia site is reflected first of all by the very low root yield obtained under non-weeded conditions and also by the strong differential reaction of root yields to the effectiveness of the various treatments, four statistically distinct levels of performance being observed at this location.

Cost of equipment, product and labor requirements

The cost of equipment used in the different post-emergent weed control systems, the dosis and cost of herbicides, and man/days required in each of the systems at each of the three sites are shown in Table 10. While tractor cultivation is of course a capital-intensive option, there are a number of alternatives using low cost equipment. The chemical hoe is outstanding for its low price, its ease of handling and the economical use of herbicide it allows. In addition, when used in a low weed pressure situation, it can reduce labor costs to 30% of that of hand weeding, whereas with an intermediate and high weed incidence this reduction is smaller but still can reach 50 and 70% of hand weeding in these two situations, respectively. Both the ULV-applicator and the

knapsack sprayer are somewhat more costly than the chemical hoe, and the cost of the chemicals used with this equipment can also be greater but the labor-saving effect in these two systems is significant, the ULV applicator requiring even less labor than the traditional sprayer due to a lower volume of liquid being moved.

While the above considerations per se are important determinants of the practicality of the various control systems under different agronomic conditions, it is essential to confront the cost side of each system with its effectiveness in terms of cassava production. This is done in an economic analysis of the five post-emergent weed control systems presented in the economics section.

Erosion Control in Hillside Cassava

In many mountainous areas of the tropics, cassava is grown on slopes with moderate to strong inclines. Although farmers under these conditions often minimize soil preparation, erosion is a serious problem since cassava has slow initial growth and leaves the soil surface exposed for many weeks. The recommendation that farmers not grow cassava on hillsides is often unsuccessful when no reasonable alternatives can be offered for these sloped, poor soils areas. Cultivation systems to reduce soil erosion therefore need to be devised and tested to preserve the soil and maintain the productivity of such hillside areas.

Evaluation of erosion control methods

A trial was established in June 1979 on a hillside with about a 30% slope, at Santa Rosa close to Popayan, in the Cauca Department of Colombia. The site has an elevation of 1700 msl, a precipitation of over 1500 mm, an annual mean temperature of 18°C and a very acid soil with low P and base status but a high organic matter content. Cassava variety Regional Amarilla was planted in four cultivation systems: (1) traditional land preparation (whole area prepared) and cassava spaced at approximately 1 x 1 m, no fertilizer; (2) preparation[a] of 1.2 m wide 0.6 m and an application of a soil stabilizer[b] in the prepared area at planting, no fertilizer; (3) land preparation and cassava spacing as in strips leaving 0.6 m unprepared between them, cassava spacing at 1.8 x (2) but with cowpea intercropped, one row at 0.45 m on each side of the cassava, no fertilizer; and (4) land preparation, cassava spacing and cowpea intercropping as in (3) but fertilized with 1 t/ha of basic slag (15; P_2O_5) plus 50, 22, 42, 5 and 1 kg/ha of N, P, K, Zn and B, respectively, at planting. Large plots of 558 m^2 (18 m wide x 31 m down the slope) were established to obtain representative soil erosion figures. This, however, precluded the use of a replicated design. The four plots were located side by side with alleys of 2m width and wooden plank separation on each side so as to prevent interference of different erosion processes. At the low end of each plot, retention of eroded soil was achieved across the width of the whole plot by covering a 5 m

---

[a] A small two wheel, hand-operated tractor was used.
[b] Hoechst Curasol at a rate of 15 kg/ha.

wide area with plastic which on one side was raised over a 0.3 m tall level. Eroded soil was collected and weighed at monthly intervals throughout the trial period of 15 months.

In the intercropped plots cowpeas were harvested 120 days after planting and the cassava harvested 15 months after planting.

Soil loss due to erosion as well as cowpea and cassava yields of the first cycle of this experiment are shown in Table 11. The amount of eroded soil was comparatively small in all treatments, possibly due to the unusually low amount of rainfall during the trial period which totaled only 1090 mm. Nevertheless, erosion was clearly greater in the traditional cultivation system than in any of the other systems. Strip cultivation as compared to whole area preparation of the soil appeared to be decisive for reducing erosion whereas neither the soil stabilizer nor intercropped cowpea contributed much additional erosion control. Cowpeas in particular showed a very slow canopy development and consequently were not very efficient in protecting the soil. Strip cultivation left 0.6 m wide strips of land unprepared which facilitated the spontaneous reestablishment of the native pasture melinis minutiflora, forming live barriers which very effectively prevent soil from being carried away with run-off water. This establishment of live barriers was fast and vigorous in the two intercropped treatments but was somewhat inhibited in the treatment where the soil stabilizer had been applied. This probably contributed to slightly lower erosion figures for the two intercropped plots as compared to the plot treated with soil stabilizer. However, cassava yields were greater in the latter treatment and there was little difference between the strip-prepared, intercropped and fertilized system. On the other hand, the strip prepared, intercropped and unfertilized system as well as the traditional cultivation systems produced lower yields, representative of the average cassava yield levels of the region.

Erosion in a traditional vs. improved cultivation systems

No immediate effects of soil erosion on crop production was expected during the first cycle of this experiment. A follow-up trial was therefore established on Sept. 25, 1981, repeating the same treatments in the same plots, with the exception of the soil stabilizer treatment which was discontinued. Also, cowpea intercropping was eliminated. This trial was concluded in March 1982, thus, completing an 18 month cycle. Total rainfall during this period reached normal levels totaling 2560 mm. Consequently, differences in erosion according to cultivation system were more pronounced. Figure 2 shows the rainfall pattern and soil loss in the traditional cultivation system during the first 13 months of this follow-up trial. Numbers in brackets accompanying the rainfall data indicate the number of rains that produced the corresponding amount of rainfall and erosion shown in the graph. Likewise, Figure 4 shows this information of the strip cultivated and fertilized treatment. Erosion was mainly a consequence of rainfall, soil loss increasing with the amount of precipitation and decreasing when rains subsided. However, due to the growth and canopy formation of cassava, there was a general tendency toward decreasing soil loss over time.

The efficiency of the strip cultivation and live barriers in reducing erosion can be seen in Figure 4, and in Table 12 where figures for total soil loss and loss of individual soil components are shown. Total soil loss in the strip-cultivated system was reduced to 22% of that observed in the traditional cultivation systems. Organic matter suffered the greatest loss due to the high organic matter content of the soil at that location. Mineral elements were lost in minor quantities, possibly due to the generally very unfertile soil conditions. However, in all cases, losses of elements were smaller in the strip-cultivated than in the traditionally cultivated plot. Cassava yields after 18 months of growth were 5.3 t/ha in the traditional system against 12.2 t/ha in the strip cultivated fertilized systems showing a cumulative negative effect on yield in the strongly eroded plot and a clear positive effect on yield in the improved system.

These data, for three years of erosion research in cassava, indicate that cultivation methods can be found for cassava planted on hillside without inducing an immediate, drastic erosion process. Furthermore, the repeated cultivation of the same strips in the second cycle (improved system) together with the self-establishment of grass barriers lead to the initiation of a terrace-formation process which over time would have reduced soil loss in this system to minimal levels (Figure 4). It appears therefore feasible to grow cassava under hillside conditions, however, the technology required is likely to be labor-intensive.

Table 1. Cassava fresh root yield and quality parameters of the variety M Col 113 and hybrid CM 849-1 in monoculture and intercropped with the maize varieties "population 31" and "La Posta" at CIAT-Palmira 1981-82.

Variety and system	Fresh root yield (t/ha)	Fresh root yield (%)	No. of commercial (roots/plant)	Starch (%)
M Col 113 monoculture	31.8[a]	100	6.7	32.5
M Col 113 with population 31	41.3	130	7.4	31.8
M Col 113 with La Posta	31.2	98	5.9	30.5
CM 849-1 monoculture	50.3	100	8.3	36.7
CM 849-1 with population 31	43.9	87	8.8	36.1
CM 849-1 with La Posta	33.3	66	7.3	37.4
C. V. (%)	20.7		26.1	7.0
LSD (5%)	12.6		3.2	3.9

a. According to the design, two average monoculture cassava yields could be calculated. Figures show the higher average to give an idea of the maximum possible yield reduction due to intercropping with maize.

Table 2. Grain yield and yield components of Population 31 and La Posta synthetic varieties in monoculture and intercropped with cassava the variety M Col 113 and hybrid CM 849-1 at CIAT-Palmira 1981-82.

Variety and systems	No. of plants/ha x 10^3 Nominal	Actual	Ears/plant (no.)	100-seed weight (g)	Grain yield[b] (kg/ha)	Percentage
Population 31 monoculture	41.7	39.2	1.05	26.3	3014[a]	100
Population 31 with M Col 113	41.7	40.6	0.97	24.6	2521	84
Population 31 with CM 849-1	41.7	40.6	0.89	25.1	2366	79
La Posta monoculture	41.7	41.0	1.00	31.1	4739	106
La Posta with M Col 113	41.7	44.3	0.87	30.7	3999	84
La Posta with (M 849-1)	41.7	43.8	0.88	30.0	3693	78
C.V. (%)	-	3.4	10.35	9.2	15.8	
LSD (5%)	-	2.3	0.16	4.2	861	

a. According to the design, two average monoculture maize yields could be calculated. Figures show the higher average to give an idea of the maximum possible yield reduction due to intercropping with cassava.

b. At 14% H_2O

Table 3. Land equivalent ratios (LER)[a] and competitive ratios (CR)[b] for cassava-maize associations with four different gentoype combinations at CIAT-Palmira 1981-82.

Cassava-maize combination	LER	CR	
		Cassava	Maize
M Col 113 - Population 31	1.35	1.54	0.64
M Col 113 - La Posta	1.46	0.73	1.36
CM 849-1 Population 31	1.37	1.75	0.57
CM 849-1 La Posta	1.44	0.85	1.18

a. Land equivalent ratios were calculated based on the maximum monoculture yield of the higher yielding cultivar.

b. The competitive ratios were calculated according to Willey and Rao (1980) by dividing the LER of one crop (yield in association over yield in monoculture) by the LER of the other crop. A correction factor to account for the portions of space assigned to each crop was not applied, since space allocation followed a 1:1 ratio.

Table 4. Cowpea grain yield (14% H_2O) and yield components of the variety TVu 1977-OD grown in monoculture and intercropped with cassava M Ven 77 in three spatial arrangements at CIAT-Quilichao, 1981.

Planting system and arrangement	Grain yield (kg/ha)	Pods/ plant	Grains/ pod	100-seed weight (g)
Monoculture				
0.4 - 0.2 - 0.4 m, 2 rows	1811 a*	16.9 ab	14.5 a	9.7 a
0.5 - 0.4 - 0.5 m, 2 rows	1580 ab	19.8 a	15.2 a	10.0 a
0.6 - 0.3 - 0.3 - 0.6 m, 3 rows	1512 b	15.0 b	15.0 a	9.9 a
0.3 - x 0.3 m additional[a]	2409	18.4	15.6	9.8
C.V. (%)	9.6	12.2	5.5	4.9
Intercropped				
0.4 - 0.2 - 0.4 m, 2 rows (1 x 1)[b]	1447 a	12.2 a	14.7 a	10.0 a
0.5 - 0.4 - 0.5 m, 2 rows (1.4 x 0.7 m)	1392 a	13.7 a	15.4 a	9.7 a
0.6 - 0.3 - 0.3 - 0.6 m, 3 rows (1.8 x 0.55 m)	1317 a	12.3 a	15.3 a	9.6 a
C.V. (%)	10.9	13.0	3.8	7.4

a. Plots were grown outside the experimental design, therefore data were not included into statistical analyses.

b. The corresponding cassava arrangement is given for comparison.

* Means in the same column followed by the same letter are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

Table 5. Cassava fresh root yield, harvest index and starch content in roots of M Ven 77 grown in monoculture and intercropped with cowpea TVu 1977-OD in three spatial arrangements at CIAT-Quilichao 1981.

Planting system and arrangement	Total fresh roots (t/ha)	Harvest index (%)	Starch (%)
Monoculture			
1 x 1 m	53.2 a*	65 a	28.8 a
1.4 x 0.7 m	51.1 a	64 a	29.1 a
1.8 x 0.55 m	48.4 a	64 a	28.8 a
C.V.%	6.4	2.3	4.8
Intercropped			
1 x 1 m	33.6 a	70 a	28.7 a
1.4 x 0.7 m	35.2 a	70 a	28.7 a
1.8 x 0.55 m	39.1 a	67 b	28.4 a
C.V. (%)	32.6	1.7	2.8

a. Means in the same planting system and column followed by the same letter are not significantly different at P = 0.05, according to Duncan's Multiply Range Test.

Table 6. Competition and land use efficiency as demonstrated by competitive ratios (CR) land equivalent ratios(LER) in a cassava-cowpea intercropping trial with different spatial arrangements of crops at CIAT-Quilichao 1981.

Planting pattern	CR[a]		
(arrangement)	Cassava	Cowpea	LER[b]
1 x 1 m	0.79	1.27	1.43
1.3 x 0.7 m	0.78	1.27	1.57
1.8 x 0.55 m	0.93	1.08	1.68

a. The competitive ratios were calculated according to Willey and Rao (1980) by dividing the LER of one crop (yield in association over yield in monoculture) by the LER of the other crop. A correction factor to account for the different portions of space assigned to each crop was not applied to preserve the next expression of yield relationships.

b. Calculation based on corresponding monoculture yields for comparison among arrangements within the intercropping system.

Table 7. Effect of weed control between rows and between plants within rows and no weeding on cassava growth parameters and stake production at Caribia, 1981.

Treatment	Plant height at harvest (cm)	Total top weight (t/ha)	Number of stakes/plant
Complete control	234 a*	23.5 a	7.8 a
Control between plants only	207 a	16.4 b	4.3 b
Control between rows only	209 a	11.3 b	3.5 b
No weeding	201 a	3.7 c	0.1 c

* Means in the same column followed by the same letter are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

Table 8. Effect of weed control between rows and between plants within rows, compared to complete and no weeding on cassava yield parameters in Caribia, 1981.

Treatment	Root length (cm)	Root perimeter (cm)	Number of thickened roots/plant	Total root yield (t/ha)
Complete control	22.0 a*	22.3 a	8.9 a	23.4 a
Control between plants only	22.7 a	22.2 a	7.6 b	18.4 b
Control between rows only	22.5 a	20.5 a	5.6 c	12.5 c
No weeding	17.3 b	17.2 b	1.9 d	2.5 d

* Means in the same column followed by the same letter are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

Table 9. Cassava fresh root yields obtained at three locations, CIAT-Palmira, ICA-Carimagua and ICA-Caribia with five post-emergent weed control treatments and in the weedy check plots, 1981-82.

	Cassava fresh root yields					
	Palmira		Carimagua		Caribia	
Weed control systems	Ranking	(t/ha)	Ranking	(t/ha)	Ranking	(t/ha)
Tractor cultivation	3	51.9 ab*	5	14.9 b	-	-[a]
Hand weedings	2	52.9 ab	1	20.6 a	1	28.0 a
Wipe-on device	4	51.1 ab	4	17.6 ab	2	23.9 ab
ULV applicator	1	58.3 a	2	19.4 ab	3	18.9 bc
Knapsack sprayer, shielded nozzle	5	47.9 b	3	18.0 ab	4	15.4 c
No weed control	6	47.3 b	6	9.5 c	5	1.4 d

a. The tractor cultivation treatment could not be carried out.

* Means in the same column followed by the same letter (s) are not significantly different at P = 0.05, according to Duncan's Multiple Range Test.

Table 10. Capital [a] and labor requirements of different post-emergent weed control systems at three sites in Colombia, 1981.

Weed control systems	Equipment		Chemicals			Labor[b]					
						Palmira		Carimagua		Caribia	
	Name or type	Cost/ unit ($US)	Common name	Dosage	Cost/ liter (US$)	Man-days	Cost (US$)	Man-days	Cost (US$)	Man days	Cost (US$)
Tractor cultivation	Tractor 35 HP with cultivator	12,000	-	-	-	0.75	90[c]	0.75	90	-	-
Hand weeding	Hoe or machete[c]	15	-	-	-	27	121	32	143	42	188
Chemical hoe	"Wick-it" herbicide applicador	25	Glyphosate	1.5 l/ha	18	8	36	16	72	30	134
ULV-applicator	"Herbi"	170	Oxyfluorfen & Paraquat	3 l/ha 1 l/ha	21 6	1	5	2	10	2	10
Knapsack sprayer, shield nozzle	Sprayer "Triunfo" with nozzle and shield	100	Oxyfluorfen & Paraquat	3 l/ha 1 l/ha	21 6	2	10	2	10	4	20

a. All cost figures represent quotations in Colombian pesos converted to US dollars at a rate of 67:1.

b. Man day and cost figures represent total per ha, adding up value from individual applications.

c. With the above equipment, three machine-hours are necessary to cultivate one hectare. The cost of US$15.00/hr includes machine operation and operators' salary.

Table 11. Soil loss due to erosion, and cowpea and cassava production in four cultivation systems on a hillside in Santa Rosa, Cauca Department, Colombia. Data from the first growing cycle, 1979-1980.

Cultivation system	Soil loss[a] (t/ha)	Cassava fresh root yield (t/ha)	Cowpea grain yield (kg/ha)
Traditional preparation (whole area)	8.6	7.3	-
Strip preparation, soil stabilizer	2.3	10.4	-
Strip preparation, cowpeas intercropped, unfertilized	1.6	6.4	290
Strip preparation, cowpeas intercropped, fertilizer	1.6	10.0	562

a. Dry soil

Table 12. Loss of soil and soil components due to erosion in a traditional vs. improved cassava cultivation system on a hillside in Santa Rosa, Cauca Department, Colombia. Data from the second growth cycle 1980-82.

Cultivation system	Total soil loss[a] (t/ha)	Losses in kg/ha				
		O.M.[b]	Ca	K	Mg	P
Traditional preparation (whole area), unfertilized	33.4	9800	14	3	2	0.2
Strip preparation, grass barriers, fertilized	7.4	1800	7	1	0.5	0.1

a. Dry soil
b. Organic matter

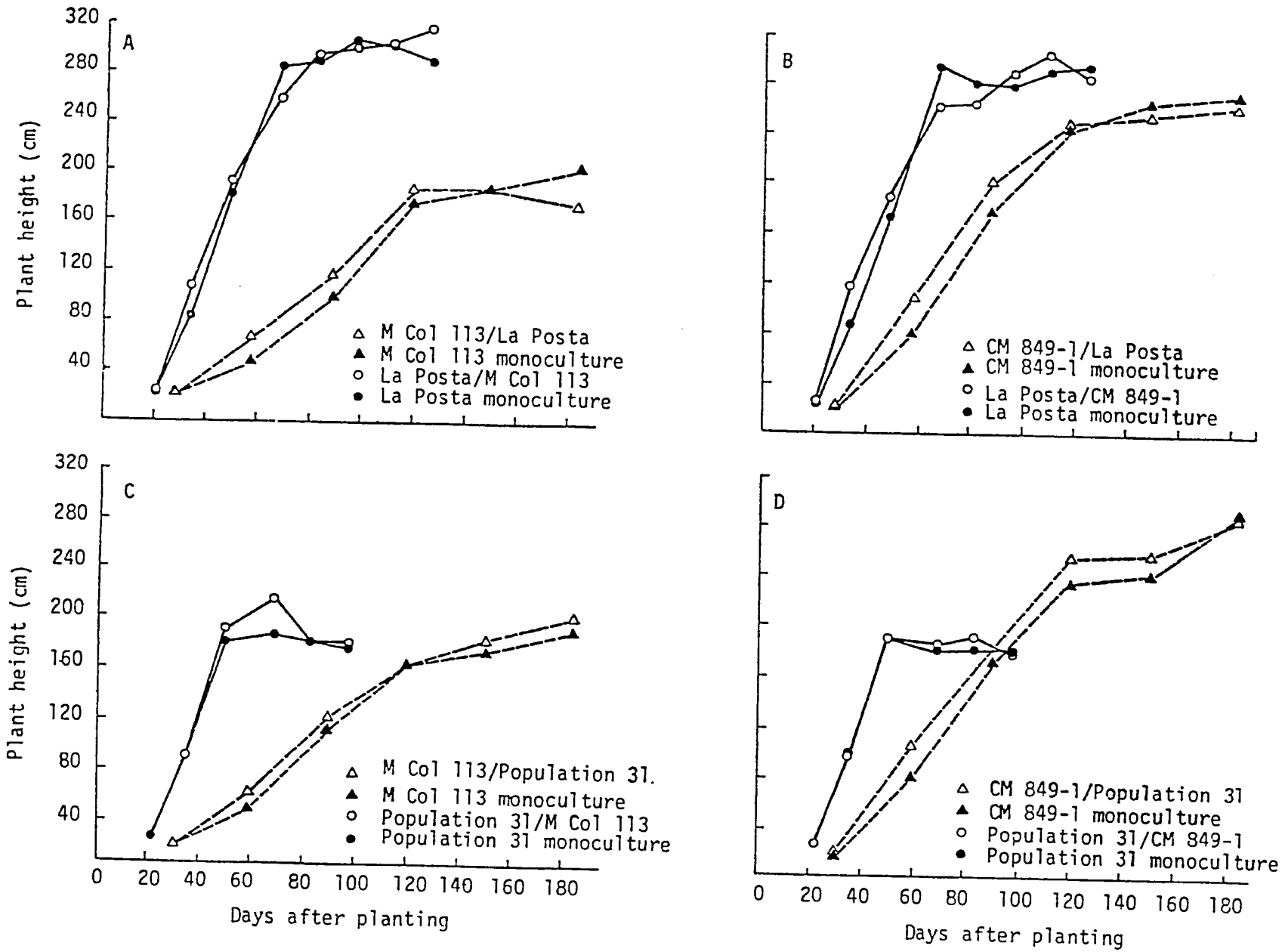


Figure 1. Plant height of two cassava (M Col 113 and CM 849-1) and two maize (La Posta and Population 31) cultivars grown in monoculture and intercropped. CIAT-Palmira 1981-82.

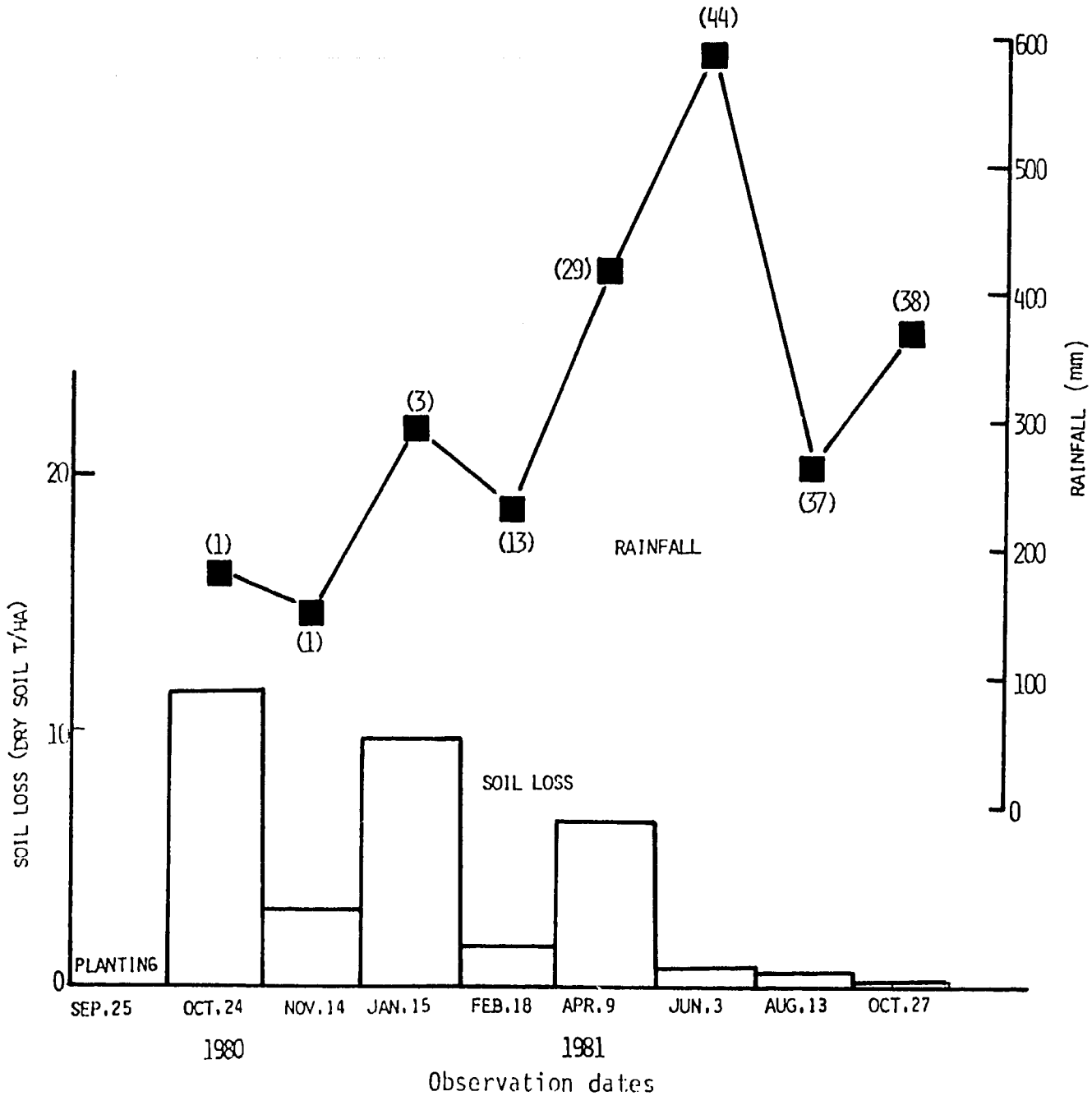


Figure 2. Rainfall pattern and soil loss due to erosion in a hillside cassava crop traditionally cultivated (whole area prepared). Numbers in brackets show the number of rains that produced the amount of precipitation and erosion indicated in the graph. Santa Rosa, Popayan, 1980-82.

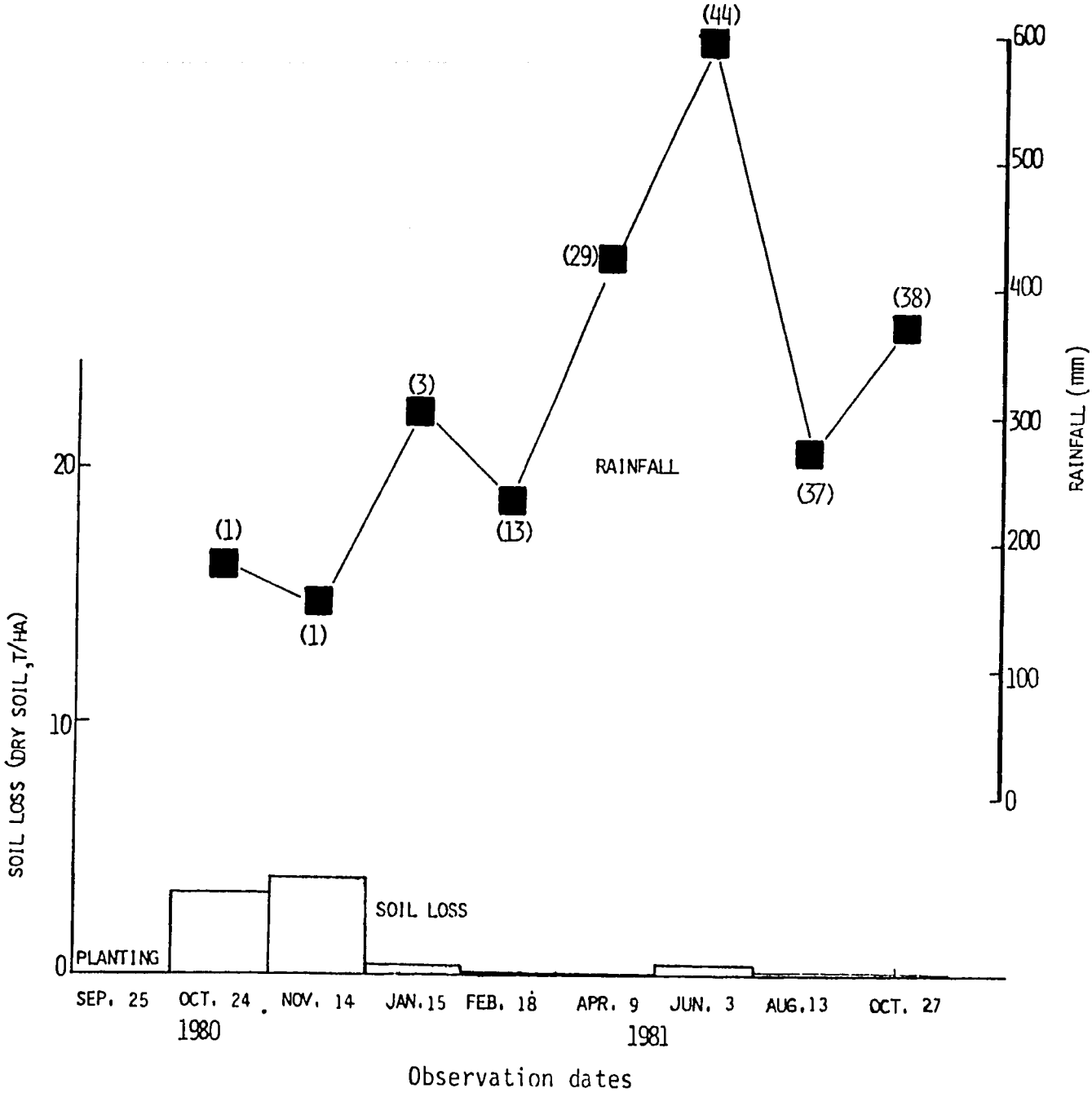


Figure 3. Rainfall pattern and soil loss due to erosion in a hillside cassava crop planted on strip-prepared land with grass barriers between strips. Numbers in brackets show the number of rains that produced the amount of precipitation and erosion indicated in the graph. Santa Rosa, Cauca Department, 1980-82.

Regional Trials

Results of the Eighth Cycle

The eighth testing cycle for promising CIAT selections under improved low input technology (Cassava Annual Report, 1974) was completed in 1982 at nine locations in Colombia. Table 1 shows the main edaphic and climatic conditions of the nine trial sites.

Lime and fertilizer were used only at Carimagua and Quilichao. At these two locations 145 kg/ha of calcium and 60 kg/ha of magnesium were applied two months before planting through disk incorporation. At Carimagua, nitrogen, phosphorus, and potassium were applied at the rate of 100, 87, and 167 kg/ha, respectively, using a complete 10-20-20 fertilizer as a source. Zinc was also applied as zinc sulphate at the rate of 10 kg/ha at planting time. Nitrogen, phosphorus, and potassium were band-applied, half at planting and half 60 days later in both locations.

Rates used at Quilichao were 50, 43.5, 83.5, and 1 kg/ha of nitrogen, phosphorus, potassium, and boron respectively.

The overall average yield of the trials, including all the varietal entries in all locations, was 8.2 t/ha at 12 months in root dry matter, which is nearly three times the Colombian average yield of 3 to 3.5 t/ha in root dry matter (Table 2). Average yield of best local cultivars was 5.9 t/ha, which is about twice the national average. This reconfirms the fact that by adopting simple but improved agronomic practices, which are always used in the regional trials, yield can be increased 100% with existing cultivars.

The overall average yield of four selections (M Col 1684; CM 516-7; CM 507-37; CM 489-1; CM 922-2) that were evaluated in seven out of the total of eight locations was 8.8 t/ha (Table 2). This indicates that more than a 200% yield improvement over the national average may be expected by adopting simple technology together with an average CIAT selection.

Cultivar M Col 1684 has been a high yielder and widely adapted since the 1977/78 regional trials; the next three are 1975 crosses and selections with proven high yielding capacity.

New selected hybrid lines (original crosses made in 1977) like CM 992-2 although tested only this year had an average yield of 9.8 t/ha which indicates that in the newer selections there is more potential as can be seen in the other 800 and 900 lines (Tables 2).

Again the average yield of CIAT selections was higher than the yield of best local cultivar in all the trial sites (Table 2).

The average yield of the best performing CIAT selection in each location was 10.9 t/ha (Table 2). This is about four times the national average and suggests that by further selecting among CIAT lines in each location, 400% of national average yield can be obtained without

depending on irrigation, fertilizer application and chemical control of diseases and insects under a broad range of environmental variations.

Overall Eight-year Results

Average yields of CIAT genotypes and their relative values in comparison to the yield of local cultivars at each location in eight years are presented in Tables 3 and 4, respectively.

The CIAT selections have consistently yielded well and their relative advantage over local cultivars has been highly significant at Media Luna and Nataima. A similar tendency can be observed for Chigorodo, Carimagua, CIAT-Palmira, and Rionegro. The yield level was high and selected genotypes maintained their superiority over the local cultivar at CIAT-Palmira, Chigorodo, and Caicedonia. These data indicate that CIAT genotypes are a useful source of variability for selection in at least three edapho-climatic zones.

CIAT genotypes were of little value at Popayan, Pereira, CIAT-Quilichao, and Florencia which indicates that more effort has to be put towards increasing cassava breeding for these areas.

The cultivar M Col 1684 has been considered as a benchmark variety since it was first evaluated in regional trials. It has demonstrated a wide range of adaptation as well as good stability.

During the eight years of regional trials (below 1300 msl) in which local cultivars were included, the average yield of local cultivars in all the trial locations basically remained constant while that of the CIAT genotypes increased slightly and that of the best CIAT genotypes increased significantly. This reflects the effectiveness of selection over time.

Table 1. Main edaphic and climatic characteristics of locations planted to regional trials.

Location	Altitude (msl)	Mean temp. (°C)	Days to harvest	Rainfall (mm)[a]	DM (%)	Bray II	P_2O_5 me/100 g	pH
Media Luna	10	28	323	1130	0.6	14.9	0.12	6.5
Rionegro	350	27	323	1924	1.8	5.0	0.12	4.5
Chigorodo	28	28	335	3745	6.1	19.7	0.28	6.3
San Martin	340	25	320	1811	4.1	11.6	0.45	4.5
CIAT-Palmira	1000	24	321	1066	4.2	78.0	0.73	6.9
Carimagua	200	26	266	1499	0.3	3.2	0.20	4.4
Quilichao	1070	24	321	1583	5.7	3.7	0.11	3.6
Florencia	480	25	257	2732	5.0	12.9	0.41	4.6

a. Refers to actual rainfall during growing cycle.

Table 2. Yield of promising ICA-CIAT varieties and hybrids at eight locations in Colombia during 1981-82 regional trials.

Varieties and hybrids	Dry matter yield (t/ha)								Average yield (t/ha)
	Media Luna	Chirigodo	Carimagua	Rionegro	San Martin	Florencia	CIAT-Palmira	Quilichao	
Best local[a]	6.6	7.8	2.4	5.2	5.1	4.2	4.2	10.9	5.9
CM 681-2	9.0	13.9		7.0	4.6				8.6
CM 849-1	8.8	13.6					13.6	14.2	12.5
CM 342-55	8.6	10.7		4.9	6.8		8.5		7.9
CM 728-2	8.4			5.8					7.1
M Col 1684	8.3	14.6	2.8	7.2	7.9	8.3	9.4		8.3
CM 834-1	8.2	13.9					11.1		11.0
CM 922-2	8.0	12.7		6.6	7.8	5.9	13.0	14.7	9.8
CM 728-3	7.9	13.3		4.3		6.2			7.9
CM 342-170	7.6	11.3		5.0			10.5	10.0	8.8
CM 516-7	7.5	13.1	4.7	7.1		4.8	9.9	13.1	8.6
CM 507-37	7.4	11.1	7.1	8.8	8.5	7.2	10.1		8.6
CM 962-4	7.2	13.3		5.7			13.0	12.7	10.3
CM 507-34	6.3		5.3	7.2	8.5	6.0			6.6
CM 517-2	6.1								6.1
CM 462-6	5.8		2.8	4.3	6.0		9.7		5.7
CM 848-3	5.8	10.6		3.7		4.7	10.7		7.1
CM 451-1	5.8			4.5					5.1
CM 489-1	5.1	13.6	3.4	4.7	6.1		13.7	15.8	8.9
Secundina	5.0								5.0
CM 946-2		15.0	6.6		5.1				8.9
CM 976-14		14.6		6.2			9.7		10.1
CM 982-20		14.2		9.4	9.1	6.4	12.8	14.7	11.1
CMC 76 (M Col 1505)		14.0							14.0
CM 975-5		14.0		5.1			12.1	12.1	10.8
ICA HMC-1		13.8							13.8
CM 523-7		12.9	4.9				8.9	12.9	9.9
CMC 40 (M Col 1468)		12.6							12.6

(Continued).....

Table 2. (Continued)

Varieties and hybrids	Dry matter yield (t/ha)								Average yield (t/ha)
	Media Luna	Chirigodo	Carimagua	Rionegro	San Martin	Florencia	CIAT-Palmira	Quilichao	
CM 894-2		11.9		6.3			10.1		9.4
ICA HMC-53		6.2							6.3
CM 91-3			7.2				11.2	12.0	10.1
CM 723-3			7.0		6.1	4.3			5.8
CM 996-6			6.7		5.0			10.5	7.4
CM 840-31			5.9						5.9
CM 951-6			5.9		5.1	3.2			4.7
CM 841-168			4.3						4.3
CM 430-37			4.2		5.5		9.5		6.4
CM 391-2			3.3				9.6		6.4
CM 430-9			2.9						2.9
ICA HMC-7				6.8					6.8
ICA HMC-2					8.1	5.7			6.9
CM 323-375					7.2				7.2
CM 321-188					6.8				6.8
M Mex 59					5.0				5.0
Tempranera				3.2					3.2
CM 955-2						7.3	13.9	15.2	12.1
CM 950-3							12.2	12.8	12.5
CM 311-69							11.6		11.6
CM 305-38								12.7	12.7
CM 535-13								10.8	10.8
Average including local varieties	7.1	12.6	4.8	6.0	6.4	5.6	10.7	12.8	8.2
Best promising hybrid or variety	9.0	15.0	7.2	9.4	9.1	8.3	13.9	15.8	10.9

a. Best local varieties: for Media Luna, cultivar Venezolana; for Chirigodo, Casposa; for Carimagua, Llanera; for Rionegro, Venezolana; for San Martin, Llanera; for Florencia, Caquetana; for CIAT-Palmira, M Col-113; for Quilichao, M Col 113.

Table 3. Average yield of CIAT selections in eight years for regional trials (dry matter, t/ha per year).

Location	Planting year								Average
	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	
Media Luna	6.1	4.0	2.8	4.6	6.4	4.9	7.5	7.1	5.4
Chigorodo	-	-	-	-	-	14.9	7.9	12.6	11.8
Carimagua	-	6.3	5.9	7.3	2.5	2.1	5.8	4.8	5.0
Rionegro	6.8	5.5	9.9	6.2	7.6	5.6	8.6	6.0	7.0
San Martin	-	-	-	-	-	6.6	6.2	6.4	6.4
Nataima	11.0	5.6	7.8	7.5	7.1	-	9.6	-	8.1
Florencia	-	-	4.3	-	-	7.7	6.8	5.6	6.1
CIAT-Palmira	13.2	9.2	10.7	9.0	10.0	12.4	10.2	10.7	10.6
CIAT-Quilichao	-	-	-	13.3	6.9	6.9	-	12.8	9.9
Caicedonia	13.3	7.3	14.6	9.3	16.7	13.3	15.3	-	12.8
Pereira	5.2	12.2	-	12.1	9.6	-	-	-	9.8
Popayan	0.6	-	1.7	5.2	2.8	-	-	-	2.6

Table 4. Yield performance of CIAT selections relative to local cultivars in eight years of regional trials[a]

Location	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	Average
Media Luna	119	303	153	250	238	152	136	108	182
Chigorodo	-	-	-	-	-	159	153	164	158
Carimagua	-	91	106	225	65	153	271	206	160
Rionegro	167	155	196	162	133	128	140	116	150
San Martin	-	-	-	-	-	128	139	129	132
Nataima	154	-	296	111	224	-	103	-	177
Florencia	-	-	77	-	-	96	107	110	98
CIAT-Palmira	123	119	138	106	180	138	197	261	158
CIAT-Quilichao	-	-	-	86	119	92	-	118	104
Caicedonia	98	129	98	207	102	138	115	-	127
Pereira	93	74	-	84	67	-	-	-	80
Popayan	28	-	11	35	92	-	-	-	42

a. Average yield of all CIAT selections relative to that of local cultivar(s) in percentage at each location in each year.

Cassava Utilization

The activities undertaken by the utilization section during 1982 have been grouped in the following areas: (a) animal feeding trials; (b) pilot project on the Atlantic Coast of Colombia; (c) cassava drying; (d) cassava deterioration and storage.

Pilot Project on the Atlantic Coast of Colombia

The DRI/CIDA (Programa de Desarrollo Rural Integrado/Canadian International Development Agency Programme) has initiated a cooperative project with the CIAT Cassava Program to study the technical and economic feasibility of processing cassava for animal feed, including: (a) the development of new cassava production technology; (b) the development of appropriate cassava processing technology for small to medium scale plants; (c) the implementation of suitable credit systems; (d) market studies; and (e) the transfer of technology to field technicians, extension officers and farmers.

To carry out the development work on processing and obtain the information on marketing dry cassava, the activities of the DRI/CIDA-CIAT project have been centered on the construction and operation of a pilot plant for natural drying of cassava at Betulia in the Department of Sucre. In the experimental phase (1981) the plant processed 19 tons of fresh cassava to obtain seven tons of dried chips and data was collected on drying performance both on concrete floors and on inclined trays. The semi-commercial phase (1982) used the same infrastructure as the previous phase, but the operational period was extended to four months and a total of 38.3 tons of dried chips were obtained from 110.9 tons of fresh roots; data on labor input and operational costs were collected, as well as experience in the organization of the farmer's group. With the experience and information accumulated in these two phases, economic feasibility studies are being prepared to back up the third phase in which the pilot plant will be expanded and further plants will be set up in other areas of the region; this third phase will be implemented in 1983.

The economic feasibility study undertaken by the Economic and Utilization Sections of the Cassava Program underlines the fact that the profitability of the natural drying process depends to a large extent on the price paid for the raw material and the price obtained for the dry product. Figure 1 graphically shows the profitability of the process, in terms of the percentage of internal rate of return, at different levels of fresh and dry cassava and for two plant sizes, 500 and 1000 m^2 of concrete floor. With interest on capital loans at 21%, those combinations with percentage returns equal to or greater than 21% will be profitable.

As a consequence of the positive results obtained in the experimental and semi-commercial phases and with the first feasibility study, the project induced various farmers' groups on the Atlantic Coast to replicate the process in other locations in the third phase to be executed in 1983. In Betulia, the farmers opted to extend the pilot plant from 300 to 1000 m^2 which will enable refinements to be made in

processing techniques on a larger operational scale. The drying floor will be constructed of soil-cement instead of concrete to reduce the capital investment.

The experience obtained has shown that the process of natural cassava drying is an agroindustrial activity that is technically, economically, and socially viable offering the following advantages: (a) it promotes technology which is rapidly assimilated by the farmers; (b) it stimulates the formation and consolidation of farmers' groups or associations, orienting them toward the integration of cassava production, processing and marketing activities; and (c) it encourages the active, continuous and integrated participation of the institutions involved in rural development projects through the technical assistance provided to the farmers.

It is evident that the development of a cassava based agroindustry at the regional level requires further research aimed especially at increasing the production and productivity of the crop so as to reduce the costs of the raw material, and improving drying efficiency to increase plant capacity per unit investment. These two factors should insure the profitability of the process along with adequate promotion and consolidation of farmers' groups.

Cassava Drying

Work on the development of cassava drying systems restarted at CIAT in 1981. Previous work (CIAT, 1972, 1976) concentrated on improved natural drying of cassava chips in vertical and inclined trays, methods which proved to be more efficient than traditional drying on concrete floors. In 1981 and 1982, work continued in the following two areas: (1) the testing and introduction of modifications to the processing of cassava chips in the pilot natural drying plant at Betulia, Sucre, to improve drying efficiency and plant operation; and (2) the development and evaluation of a through circulation drier.

Development at the pilot plant, Betulia.

During the experimental phase of the DRI/CIDA-CIAT project in 1981, a comparison was made of drying on the concrete floor and in mesh trays, using loading densities of 8, 10 and 12 kg of cassava chips per square meter. The results of these trials indicated that the higher the loading density, the longer the drying time and that at all loading densities the cassava chips dry faster in trays than on concrete.

Despite the advantages of trays in terms of efficiency, this method of drying was not evaluated at the semi-commercial phase of the project as it requires closer operational control than concrete drying and its introduction at that stage of the project was, therefore, not considered appropriate. The maintenance cost of the trays and their useful life are two other factors that weigh against this drying method as compared with concrete floors. (As the Thai experience has shown, once concrete drying has become established, attempts to introduce trays are unlikely to be successful). However, when a high quality product is required, such as

dried cassava for incorporation into bakery products, tray drying would be important.

The overall results achieved in the semi-commercial phase of the DRI/CIDA-CIAT project showed that, with loading densities on the concrete floor of between 10 and 12 kg/m^2, for the 27 batches processed, an average drying time of 54.6 hours was required to reach a moisture content of 10-14%. The mean climatic conditions during the processing period were: temperature 27.5^{o}C and relative humidity 68%. During this phase slight modifications were made to the Thai type chipper to eliminate the end pieces of the root that escape between the machine frame and cutting disc. The modifications included placing a metal ring around the cutting disc and reducing the diameter of the cutting apertures from 1" to 3/4".

To reduce the cost of the concrete floor, the 700 m^2 extension to the drying plant at Betulia will be constructed in a soil-cement mixture. Laboratory studies on soil samples from Montanitas Farm, which were undertaken by the infrastructure section of the Instituto Colombiano Agropecuario, ICA, at Tibaitata, indicate that an 8:1 mixture of soil-cement should give adequate results.

The increased output capacity of the Betulia plant in 1983, (to produce 270 tons of dry chips) will require further modifications to the operation of the plant, together with the introduction of simple labor saving equipment to facilitate the feeding of the chipper and the recollection of the dry cassava.

Development of a through circulation drier.

In a joint project with the Universidad del Valle, CIAT has developed a through circulation drier of cassava chips.

Through circulation drying is a batch process commonly employed on farms for drying a wide range of agricultural crops, usually grains. It has seldom been applied to cassava drying, but in terms of technological sophistication the method may be considered as an advance on natural drying on concrete or in trays. Instead of relying on natural circulation, air is forced through a static bed of chips supported on a perforated floor. The air used may be at ambient temperature and relative humidity, heated by any of the conventional means or combined with a solar collector.

The objective of this project is to develop and evaluate, technically and economically, forced air through circulation systems using ambient, solar heated and fuel heated air. The immediate goal is to introduce a drying system that will extend plant operation. For example, in Betulia on the Atlantic coast, natural drying is restricted to approximately four months of the year.

The experimental system constructed at CIAT is an adapted version of the system developed at the Centro Nacional de Treinamento em Armazenagem, CENTRINAR, Brazil and consists of a 10 m^2 solar collector, a centrifugal fan capable of delivering 38 m^3/min against a head of 1/2"

water gauge and a 2 m^2 drying bin (Figure 2). The centrifugal fan draws air through the solar collector and passes it through a 305 mm diameter duct into the plenum chamber of the drying bin.

To date three sets of trials were done to determine, respectively, the optimum drier loading, air flow rate and time to start drying. The results indicate that, under the ambient conditions prevailing at CIAT, it is possible to dry cassava chips in 48 continuous hours at a loading density of 125 kg/m^2 of drying floor, with an airflow rate of 18 m^3/min per m^2 of drying floor.

The solar collector which is still under evaluation, gives average overall increases in air temperature of between 1 and 3°C, with corresponding decreases in relative humidity of between 5 and 10%.

Comparative trials in which drying was started at 8, 11, 14, and 17 hours showed that there was a clear advantage to starting drying in the afternoon rather than in the morning (Table 1) since this makes best use of the night hours, when the relative humidity of the air is high, to remove moisture from the fresh cassava chips and then, on the second day of drying, the warmest hours of the day terminate the process. The drying system is continuing to be evaluated using ambient air (in 1983 a coal-fired air heater will be tested).

Animal Feeding Trials

Poultry and swine feeding trials have been performed to evaluate least-cost diets containing cassava meal as a substitute for feed cereal grains, notably sorghum. The price of cassava meal used was the equivalent of 80% of the current price of sorghum.

Experimental results obtained in several feeding trials with broilers produced the following conclusions:

- Whole roots of high cyanide varieties, such as M Col 1684 or CMC 84, can be safely used in broiler feeds if properly processed. Sun-drying of whole-root chips has proved to be an efficient method of cassava processing to reduce cyanide contents to inoccuous levels for animal feeding.

- The satisfactory results obtained with broilers fed diets containing 20 and 30% of a cassava meal experimentally produced to contain high levels of cyanide (300 ppm) suggest that the limit of hydrocyanic acid (100 ppm) set by the European Economic Community for dried cassava products needs to be reevaluated.

- The inclusion of cassava meal at a level of 20% in a least-cost diet for broilers has produced the best biological and most economic results, similar or slightly better than those obtained with a commercial, balanced feed used in practical broiler production.

- The combination of three protein sources (soybean meal, fish meal, and cottonseed meal) in balanced diets containing 20% cassava meal has produced better broiler performance than that obtained with the use of

two (soybean meal and fish meal) or one (soybean meal) protein sources. Palatability aspects of the protein sources appear to be important consideration in obtaining the optimum nutritional value of cassava meal.

Feeding trials with growing pigs as well as with lactating sows and their litters have also shown that cassava meal produced from whole roots of high-cyanide varieties can be used at levels of 30-40% of the diets leading to satisfactory results similar to those obtained with sorghum-based diets.

Balanced feed production for broilers and pigs in Colombia during 1981 amounted to approximately 308,000 and 140,000 tons respectively; the inclusion of 20% cassava meal in the balanced feeds for these species would require a total of almost 90,000 tons of dried chips. To satisfy this demand a significant increase in production and productivity of cassava in areas such as the Atlantic coast and the establishment of many small- to medium - scale processing and drying plants would be required.

Cassava Deterioration and Storage

The Tropical Products Institute (TPI)-CIAT project on cassava deterioration and storage was extended for a two year period from 1981 to include studies not only of the physiological deterioration process itself but also the testing of simple storage systems and related root quality aspects. The main objectives are: (a) to continue studies on the variations in susceptibility of roots to physiological deterioration; (b) to further evaluate the effect of pruning on physiological deterioration and root quality; (c) to test medium-term (2-6 weeks), low-cost storage systems under ambient conditions which maintain root quality at an acceptable level for human consumption.

Variations in susceptibility to physiological deterioration

Previous work at both TPI and CIAT, (Cassava Annual Report, 1980) showed that the post-harvest accumulation of scopoletin, a coumarin, was implicated in the development of the blue-black tissue discoloration characteristic of physiological deterioration. A rapid spectrophotometric assay for scopoletin has been developed and used to study the relationship between the root parenchyma scopoletin content two days after harvest and the degree of physiological deterioration which develops three days after harvest (Cassava Annual Report, 1979). Results showed that a positive correlation ($r = 0.832$, $n = 20$, P .001) exists between these two parameters, with roots resistant to physiological deterioration accumulating less scopoletin than susceptible roots. The close association between scopoletin content and mechanical damage to the root is demonstrated in Table 2, where injured roots accumulated high amounts of scopoletin close to the damaged proximal end of the root, gradually decreasing toward the distal end almost to the levels found in uninjured, whole roots.

The fact that mechanical damage increases the scopoletin content noticeably within 24 hours of harvest is a further indication of the importance of careful harvesting and transportation in avoiding post-harvest losses.

An experiment was conducted with the cultivars M Col 22, M Col 113, M Col 1684, and the hybrid CMC 342-170 in which plants were harvested from four months to 12 months of age at two monthly intervals (Table 3). There was great variation in the susceptibility to physiological deterioration during this period, although no consistent varietal trends were apparent.

In general, the dry matter content of roots increased with age, apart from M Col 113 which maintained very low levels throughout. The cultivar with the highest dry matter content (M Col 22) had the highest deterioration values, while the low dry matter content of M Col 113 was associated with a consistently low deterioration.

The root cooking times increased with plant age, due probably to the increasing starch, fiber and lignin/cellulose content of the roots. This was related to root hardness as measured by a simple fixed force penetrometer, although roots with a high moisture content (hence high penetration and low starch contents) were often difficult to cook due to a hard "glassy" texture which developed.

Pre-harvest environmental factors

Defoliation due to various causes and preharvest pruning have been shown to increase root resistance to physiological deterioration (Cassava Annual Reports 1980, 1981). These may be more important in determining susceptibility than genetic factors considering one cultivar can show a wide range of deterioration susceptibilities depending on the environmental conditions. In one experiment at CIAT, M Col 22 maintained a marked resistance to physiological deterioration for five months after pruning. Although the initial loss in root starch content caused by pruning was gradually replaced during this period, the quality of the roots for human consumption remained poor with cooking times in excess of 40 minutes.

Storage systems

While resistance to physiological deterioration can be obtained through pre-harvest pruning or post-harvest curing (high relative humidity and temperature conditions which promote wound healing) medium-term storage can only be achieved through the control of the subsequent secondary or microbial deterioration which normally commences five to seven days after harvest. Any storage system must have low cost and labor requirements if adoption by farmers, intermediaries and/or wholesalers is to be achieved. Previous work (Cassava Annual Reports 1973, 1974) demonstrated that earthen field clamps and boxes packed with moist sawdust were successful, but a more practical solution permitting easy transport of roots, was sought. Hence, the plastic bag system (Cassava Annual Report, 1977) was further studied.

Initially, experiments were carried out in the laboratory in which roots were treated with potassium sorbate (a low-cost anti-microbial agent with minimal residue problems) followed by storage in plastic bags to provide the curing conditions. Whereas other workers have suggested that roots can be stored for over four weeks without pre-treatment, under

CIAT conditions substantial fungus and bacterial growth was invariably observed after only 7-10 days storage. No microbial growth was observed in roots treated with potassium sorbate, even after two weeks of storage. Physiological deterioration was totally prevented by curing. Subsequent large scale experiments using perforated bags to reduce the amount of free-water formed inside the closed bag system permitted root storage for up to four weeks without the necessity of the sorbate treatment (Table 4).

Perforations in plastic bags permit a balance between the high humidity needed to obtain good curing conditions and the problem of excess free water encouraging microbial activity. Further trials of different plastic thickness, perforation density and bag size are presently underway.

Table 1. Through circulation drying[a] of cassava chips to: determine the optimum time of starting drying.

Trial	Time drying started (hr)	Drying time (hr)
1	0800	54
2	1100	49
3	1400	47
4	1700	46

a. Drier loading: 125 kg/m^2; initial cassava chip moisture content; 213% dry basis (68% wet basis); mean airflow rate: 16.5 $m^3/min\ m^2$; average conditions of drying air: 26°C and 69% relative humidity.

Table 2. Effect of mechanical damage on scopoletin content in parenchyma tissue of M Col 1684 roots.

Days after harvest	Injured roots[a]			Whole roots		
	Proximal	Central	Distal	Proximal	Central	Distal
	(ug g^{-1} DM)			(ug g^{-1} DM)		
0	51.7[b]	50.8	46.8	41.5	50.1	44.7
1	105.0	65.9	65.8	64.8	53.4	43.2
2	234.0	114.4	88.4	56.6	48.4	50.9
3	285.6	117.6	107.5	66.6	102.3	92.6

a. Injury consisted of transverse cut at proximal end of root.

b. Apparent high initial scopoletin contents caused by background interference from other, non-accumulating phenolic compounds.

Table 3. Deterioration, dry matter content, cooking time and penetration results for four cassava cultivars harvested at four ages.

Age (months)	M Col 22	M Col 1684	CM 342-170	M Col 113
		Deterioration (%)		
4	42.2	6.4	30.3	1.1
6	17.0	24.8	27.1	4.4
8	37.1	12.0	26.5	1.5
10	18.6	5.4	12.8	5.9
		Dry matter content (%)		
4[a]	-	-	-	-
6	31.2	29.6	31.8	29.5
8	35.2	28.3	35.5	28.0
10	35.3	30.8	33.0	26.0
		Cooking time (min)		
4[a]	-	-	-	-
6	10.6	10.6	12.6	11.2
8	19.9	20.0	15.0	27.7
10	23.4	36.4	20.0	41.2
		Penetration (mm)		
4[a]	-	-	-	-
6	3.17	2.59	2.69	3.36
8	2.06	2.20	2.21	2.75
10	1.79	2.01	2.21	2.83

a. Not tested due to small root size.

Table 4. Storage of cassava using perforated and unperforated plastic bags with a 20 kg root capacity under two different environments.

Storage time	Treatment	Ambient (18-30°C)	Controlled (20-23°C)
2 weeks	Perforated bags	0.3[a]	0.6[a]
	Unperforated bags	0.7	0.6
	Open air storage	2.7	4.5
4 weeks	Perforated bags	0.6	1.2
	Unperforated bags	1.4	2.1

a. Roots evaluated for total deterioration on 0-5 scale, where 0 = absent; 1 = ends of roots and damaged regions only affected; 2 = deterioration progressing from ends inward to less than 25% of root; 3 = deterioration from 25-50%; 4 = deterioration from 50-75%; 5 = deterioration from 75-100%. Forty roots evaluated per treatment.

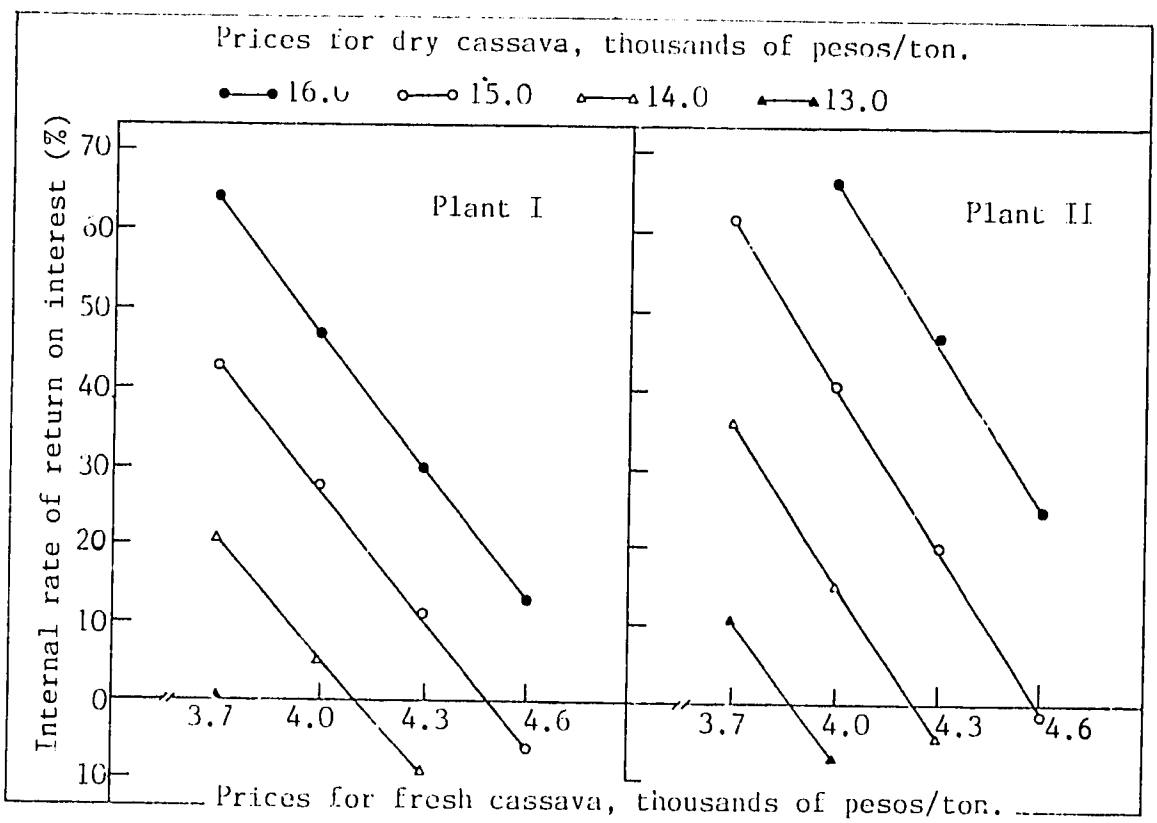
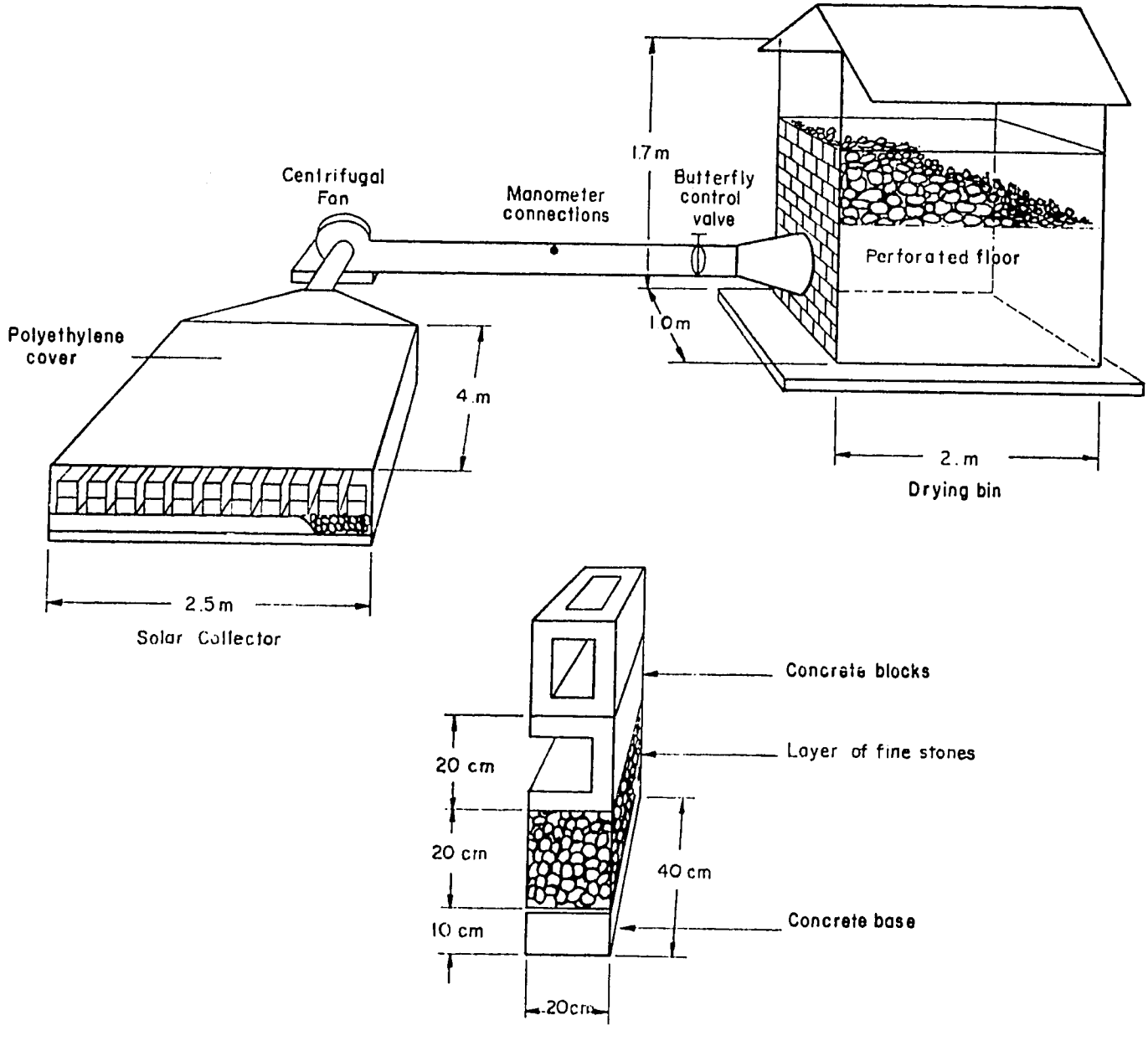


Figure 1. Internal rate of return on interest rates at different cassava prices for fresh and dry cassava.



Detail of internal solar collector construction

Figure 2. A trough circulation cassava drying system with solar collector.

Economics

The economics section focused on three areas of research in the past year: (a) Regional studies of cassava production and utilization in Latin America and Asia were undertaken. These will provide a base for more in-depth country studies to be undertaken in the future; (b) research activities were stepped up in the integrated, cassava production and market expansion project on the North Coast of Colombia. The project is attempting to develop cassava as a basic carbohydrate source in the feed concentrate market in Colombia; (c) the on-farm trials were continued focusing on incorporating farmer stratification in the trial design. Only the on-farm trial work will be reported here.

On-Farm Trials

The CIAT Cassava Program focuses on achieving a significant increment in farm level yields through the development of a relatively low-input production technology. The major component of this technology will be improved, high-yielding varieties. This orientation raises two principal issues at the farm level. First, what is the size of this yield increment? Second, what are the changes in traditional management practices required to maintain the stability of this higher plateau over time?

A principal determinant of cassava yields and their stability over time is soil fertility management. This is particularly so since cassava is generally grown on relatively low fertility soils. Yet, most studies of traditional cassava production systems have found little or no fertilizer use, and in general, yields tend to be maintained at a relatively low-level equilibrium through a fallowing system. Given that the higher yield of new hybrids will imply a higher rate of nutrient off-take, the achievement of a higher yet stable yield level with these new hybrids would imply a change in traditional practices of soil fertility management and, in particular, imply the use of chemical fertilizers. The issue is whether the response is sufficient to guarantee profitable use and whether fertilizer can profitably replace the fallow system.

The on-farm trials in 1982 thus sought to evaluate the interaction between variety, fertilization, and fallow system in the four principal sites (the trials in Socorro, Santander have not yet been harvested and will not be reported). The trial design makes use of previous results where soil factors were identified as a significant yield determinant and of previous fertilizer trials on similar soils. Thus, although the basic objective of the trial was the same, the treatments varied between regions, being defined by the particular soil and fallow systems in each region.

The other major component of the trial design was the attempt at a prior stratification of cassava plots based on fallow state. This was done first, to reduce the number of farmers in the trials through stratification based on prior information and second, to evaluate whether cropping history of the plot was a necessary component together

with a chemical soil analysis in the prior determination of a fertilizer recommendation. This year's trial design focused on understanding in more detail known sources of inter-farm variation in yields that were identified in past on-farm trials in the region.

Mondomo

Previous on-farm trials in the Mondomo region identified length of fallow as a principal determinant of yield and as a factor influencing fertilizer response. Together with the CIAT-IFDC Phosphorous Project a trial was designed to assess the interaction between fertilizer strategy and fallow system. (Previous fertilizer trials in the region has identified phosphorous as the major limiting nutrient.) The trial evaluated two phosphorous sources (TSP and rock phosphate) at four levels (0,25, 50 and 100 kg/ha of P) with and without a base application of 50 kg/ha of N and 50 kg/ha of K. Of the four blocks per farm, two received a base application of 500 kg/ha of dolomitic lime while two blocks received none.

The farmers' plots were selected to conform to four distinct cropping histories of fallow states:

(a) Degrading fallow: a long crop history with the last cycle consisting of three years in fallow followed by one or two years of cassava.

(b) Minimum level of fallowing: a long crop history with the last cycle consisting of 3-5 years in fallow followed by no cassava plantings.

(c) Intermediate level of fallowing: 8-10 years in fallow followed by no cassava plantings.

(d) Maximum level of fallowing: land that had never been planted to cassava.

Three farmers were selected for each fallow state[a].

The soils as described by a chemical soil analysis were uniformly acid, of low fertility, and having a high aluminum content. Averages across the four fallow states show no consistent differences in nutrient status of the soils (Table 1). Based on these soil tests, cassava would be expected to be very responsive to both phosphorous and potassium fertilization.

The contribution of the different factors to explaining yield variance were analyzed with a multi-set ANOVA procedure, where the variation between farms was partitioned for fallow state. Fallow state

a. Two farmers in each fallow state were selected in Mondomo and one each in nearby Pescador by the Phosphorous Project. The data from Pescador has not yet been pooled with the Mondomo results, so that the results reported here reflect only eight farmers.

was found to be a significant factor explaining root yields. However, while the long-term fallow (fallow state "D" as above) gave significantly higher yields, the other three fallow states did not stratify yields according to prior hypothesis (Table 2). There appears to be another soil factor confounding the effect of fallow which could be loosely termed soil type.

Though differences in soil type are not completely distinguishable by soil analysis, farmers recognize a "good" and "poor" soil essentially on the basis of past experience. The two plots in fallow state "C" (as above) were apparently left to fallow for such a long period because of "poor" soils. Although the only difference in the soil analyses was the distinctly lower level of potassium. The plots in fallow state were kept in production because of the "good" soil. Again, the issue is raised of needing more observations across fallow states to average out other exogenous effects or needing more information on which to stratify to sample.

Nevertheless, there were other differences between fallow states, if not overall yield. Fallow state was the only one to show a significant response to lime and yet was very unresponsive to fertilizer application. On the other hand, fallow states were very responsive to phosphorous application but only to the base application of nitrogen and potassium (Table 3). Whereas, in the long-term fallow there was a significant response to phosphorous both with and without the base nutrients. Finally, in none of the fallow states was there a response to nitrogen and potassium without application of phosphorous.

While phosphorous was shown to be a critical constraint on yields in the zone, fertilization failed to completely compensate for the effect of long term fallow. The question thus arises whether the fallow state D will eventually degrade to the yield potential of the other fallow states, even with fertilization. This will be analyzed over the course of the three year trial. Moreover, in examining this issue total plant yield will be considered, as opposed to just root yield.

The local variety used is known in the area for its yielding ability under low fertility conditions. The variety does this by apparently adjusting the distribution of photosynthate between roots and tops as a reaction to soil stress. Using harvest index as a simple measure of this distribution, the range of the harvest indices across farms was from 0.44 on a fallow state farm where the root yield was the highest to 0.72 on a fallow state C farm, where the variety responded very efficiently to fertilizer application. Thus, on the fallow state D plots total plant weight would be a better indication of yield potential, given that a more efficient variety could be substituted on these plots. In the fallow state D, even without fertilizer, total plant yield was over 30 tons and went as high as 46 tons. Only in the very high fertility plots of fallow state B did total plant yield ever reach 30 tons (Table 4). Therefore, while fallowing is a very costly means of maintaining soil fertility, a soil management strategy based on fertilizer alone does not appear to be an adequate substitute for fallow. Moreover, the issue arises as to whether a variety with an

efficient plant type could sustain a stable yield in the zone, even with a moderate to high fertilizer input.

Figure 1 demonstrates the profitability of fertilizer application though this varies distinctly by fallow state. In fact, profitability of cassava production almost stratifies according to fallow state. Fallow state D was the most profitable across all treatments while fallow state A was the least profitable. Apart from fallow state D the phosphorous had to be applied with base nutrients to guarantee profitability and apart from fallow state D, 50 kg of P as TSP with base nutrients was the most profitable treatment. This treatment added an additional 40% to normal variable production costs. This is not a significant amount given the resource position of these farmers. Moreover, as fallow shortened any skimping on fertilizer the application would have achieved no economic benefit.

The rock phosphate was always economically inferior to the triple superphosphate. Interestingly, the best response to rock phosphate came under the long-term fallow. The superiority of TSP was expected but what is at issue is whether the rock phosphate is a more economical means of increasing available phosphorous in the soil, and hopefully the longer term yield potential of the shorter term fallow.

Finally, quality parameters were determined for some of the treatments for each farm. Although these could not be tested statistically, there was nevertheless a marked tendency for the long-term fallow to produce a higher quality root. For each quality parameter apart from the deterioration rating, the long term fallow plots had the highest rating (Table 5). In the long-term fallow plots the roots from Algodona were of quite acceptable eating quality; in the other plots they were not.

Media Luna

Past fertility trials in the area had identified nitrogen as the principal limiting nutrient on these sandy soils. Moreover, previous farm trials had identified soil color as an indicator of yield potential and finally, the hybrid (CM 342-170) was identified as having a high yield potential in the area. These components were combined in the assessment of a three year fallow system which was practiced in the zone. The following fallow states were defined: (a) three or more years in continuous planting to cassava; (b) one to two years planted to cassava after fallowing; (c) at least three years in a guinea grass fallow.

The results in Media Luna were similar to those in Mondomo in that there was a significant effect due to both fallow state and soil color but the rotation states did not stratify exactly according to prior hypothesis, at least for the local variety Secundina (Table 6).

The yields of the hybrid variety did in fact stratify according prior hypothesis, but the effect of rotation was potentially confounded by a generalized appearance of root rot in the hybrid (i.e. the problem occurred in all plots) that had not appeared in previous trials. The

above normal rainfall in the area produced relatively high yields but was apparently a contributing cause of the root rot.
While the hybrid still maintained a significant fresh weight yield difference over the local variety, Secundina was superior in terms of dry weight yield.

While fallow state A gave a significantly lower yield than the other two, especially for the white soils, there were no significant differences between fallow state B and C when Secundina was used as the indicator variety. Unlike Mondomo there was no response to fertilizer in the long-term rotation, though there was a modest, although uneconomical response in fallow state B. On the other hand, there was a significant and profitable response to fertilizer in fallow state A on both soil types and the most profitable response in both cases came with the 50 kg/ha application of N with base nutrients. Moreover, it was only in fallow state A that there was a response to the base nutrients. Thus, on the basis of the first year's results in Media Luna, and unlike Mondomo, it appeared that fertilization was a potentially profitable substitute for fallow.

Llanos

In the piedmonte area of the llanos annual crops are cultivated essentially in rotation with pasture, i.e. annual crops in a two-to-three year sequence are used as a means of pasture establishment and pasture upgrading. Farm size is large (average of 300 ha) and although annual crops are important, beef-pasture systems are the major activity. Under such conditions land for fallow rotation is not a major constraint and the issue is not whether fertilizer is a profitable substitute for fallow but whether fertilizer will profitably raise yields, even on a long-term fallow.

Since there had been little previous research in the area, a composite fertilizer (10-20-20) was applied at various levels on two fallow states. These two fallow states were either an opening up of pasture land for cultivation or the end of a three year cropping sequence before the planting of an improved pasture. For the cropping sequence both plots had previously been planted to cassava, preceded by an annual crop, either upland rice or maize.

The results in Table 7 suggest a very high yield potential when pasture land is brought into production. Moreover, although there is a modest response to the lowest level of fertilizer application - with a tendency for yields to decline at higher levels, this application level was not profitable. The averaged data for the other fallow state suggests that yields decline substantially in the cropping sequence. While average yields in both farms were significantly below those farms in the long-term pasture rotation, one of these farms had markedly lower yields than the other due to poor management of weeds. Thus, the average yield for the cropping sequence plots was biased downward due to other factors and thus may overestimate the yield decline in the cropping sequence plots. Maintaining a relatively high and standardized level for the non-treatment variables is important in this type of

trial, where only a relatively small number of farms is selected in each of the sampling strata.

Another major result from these trials was the very high yield performance of the hybrid CM 507-37. Even in the cropping sequence rotation average yields of 20 t/ha were achieved with the lowest level of fertilizer application. For the land just brought into production 30 t/ha were achieved without fertilizer application. Moreover, dry matter content was good or better than the local variety. Within this type of farming system the maintenance of quite high yields with this variety appear very feasible, with little requirements in terms of purchased inputs. However, if a new market were to open up in this area and if these farms were eventually to move to continuous production systems, the yield stability and cost issues would have to be re-examined.

Summary

The existing evidence suggests that traditional cassava farmers in Latin America do not use fertilizer and instead employ a fallow system. On the basis of this year's farm trial results the dual issues of whether fertilizer can replace the fallow system and whether there is a profitable response to fertilizer at the farm level remain inconclusively answered, in that the answer seemed to depend on the type of fallowing system and underlying soil conditions.

Fallowing contributes more to yield potential than can be determined by the chemical soil analyses. All the soils in the trials were of a low fertility status and the nutrient levels would imply a significant response to fertilizer. Nevertheless, chemical soil analyses did not distinguish between the fallow states as defined. Yet, in all cases there was a significant yield effect due to fallowing, though yields did not in all cases stratify perfectly according to prior hypothesis. Moreover, in two cases there was no economic response to fertilizer on the long-term fallow.

Given that cassava farmers rarely cultivate more than two to three hectares of cassava, fallowing appears to be a reasonable alternative to fertilizer use where farm size is sufficiently large in relation to fallowing period. Where farm size is limited in relation to fallowing period and where market conditions allow larger extensions of area cultivated in cassava, fertilizer is a critical element in determining cassava yields. Moreover, the rate of application is not excessively large, all three sites giving an application rate of 50 kg of N, 50 kg of P, and 50 kg of K as the most profitable rate on plots that were at the end of the fallowing-cropping cycle.

Nevertheless, fertilizer did not appear to substitute perfectly for a long term fallow and alternative hypotheses must be put forward as to why this is the case. The first is that fallowing is associated with changes in the mycorrhiza population, either in terms of the total population or in the change in species from the dominance of effective strains to less effective strains. The second hypothesis is that chemical soil analyses do not give an accurate indication of nutrients available to the plant at low nutrient levels. Especially in the case

of phosphorous, this may be associated with the changing equilibrium between available and unavailable phosphorous in the soil. The third is that a micro-nutrient or another biotic factor have been overlooked in the trials, although there were no visible expressions of these two factors.

Profitability of Alternative Weed Control Methods

In traditional cassava production systems weed control is the principal cost component, often accounting for half of total production costs. Moreover, even in small-farm systems labor many be a critical constraint at peak periods in the cropping cycle, usually at planting and the first weeding. Thus, identifying lower cost weed control techniques is a potential avenue to reducing per unit production costs and under certain farm and labor market conditions herbicides may be a necessary component in the expansion of area in cassava.

Various weed control systems were evaluated in three sites by the cultural practices section and the results were analyzed within a simple partial budgeting framework using the data collected from the trials (see Tables 9 and 10 in the Cultural Practices Section).

At the price levels used in the budgeting, weeding costs were remarkably similar across alternatives within any particular site and weeding costs were a very small percentage of gross revenues. The result of this was that the most profitable system was the one having the highest yield level, even though a relatively conservative output price (for Colombian conditions) was used. Hand weeding, the traditional method used by farmers, gave a consistently high yield across sites and in sites with relatively moderate to high weed incidence hand weeding was the most profitable system.

In general, hand weeding became more profitable as weed pressure increased. This then leads to the issue of what wage rates (either market wage rates or shadow wage rates within the farm) would have to be for a purely herbicide system to be competitive. Using the ULV applicator system as the most effective pure herbicide method, one finds that at current output prices in Palmira, herbicide is competitive at current wages rates ($4.50/day); in Carimagua the wage rate would have to be $7.50/day to be competitive and in Caribia the wage rate would have to rise to $19.80/day to make herbicides profitable. Nevertheless, this result is primarily based on the yield differences that result as the effectiveness of herbicides declines with increased weed pressure.

Finally, this analysis raises a methodological point. Profitability analysis of experimental results based on current output prices are usually dominated by yield differences and not cost differences. Output prices in Colombia are currently quite high when compared to world market grain prices but not so high when compared to the average yield level of 6-8 t/ha. With the yield levels obtained in the experiments market prices would be expected to fall substantially, which would give more potential weight to cost differences in the profitability analysis. However, determining what these price levels would be requires an understanding of demand and market conditions, a research area also of importance in the work of the economics section but which is not reported here.

Table 1. Chemical soil analyses of the different fallow states in Mondomo, Media Luna, and the Llanos.

Region/ fallow state	pH	Organic matter (%)	Bray II Phosphorous (ppm)	Potassium (meq/100 g)	Aluminium (meq/100g)
Mondomo					
Degrading Fallo	4.6	4.6	0.9	0.09	2.40
3-5 years	5.4	7.6	0.7	0.09	0.55
8-10 years	4.7	3.5	0.7	0.03	3.73
Long term Fallow	4.6	6.1	1.2	0.07	2.87
Media Luna					
Red soils					
3 or more years cassava	5.6	0.6	3.9	1.00	-
1 or 2 years cassava	5.8	0.6	3.8	0.11	-
3 or more years fallow	6.1	0.8	5.8	0.07	-
White soils					
3 or more years cassava	4.9	0.8	5.1	0.07	-
1 or 2 years cassava	5.9	0.8	1.8	0.07	-
3 or more years fallow	6.2	0.9	9.3	0.05	-
Llanos					
3 years cropping cycle	4.3	0.4	1.9	0.11	2.85
Pasture	4.2	1.9	1.1	0.11	3.08

Table 2. Root yield, total plant yield, and harvest index by fallow state in Mondomo.

Fallow State	Root yield (t/ha)	Total plant yield (t/ha)	Harvest index
A. Degrading fallow	8.9	15.5	0.56
B. 3-5 years	8.8	15.5	0.55
C. 8-10 years	8.3	11.5	0.72
D. Long term fallow	17.4	34.0	0.52

Table 3. Root yield response to the different fertilizer treatments by fallow state at Mondomo.

Base nutrients	Degrading		3-5 years		8-10 years		Long term	
	Without (t/ha)	With[a] (t/ha)	Without (t/ha)	With (t/ha)	Without (t/ha)	With (t/ha)	Without (t/ha)	With (t/ha)
Treatment:								
Farmer check	6.24	-	1.66	-	6.67	-	10.47	-
TSP (kg of P/ha)								
0	7.49	8.38	4.45	3.80	3.80	4.07	15.14	14.29
25	7.89	8.92	9.88	16.71	6.89	12.91	19.33	20.22
50	7.22	12.40	9.77	19.21	7.59	15.08	15.77	21.11
100	8.33	13.21	8.25	17.91	8.63	14.27	19.66	24.31
Rock phosphate (kg/ of P/ha)								
20	7.49	8.38	4.45	3.80	3.80	4.07	15.14	14.29
25	6.95	9.28	7.27	10.64	6.40	8.90	15.83	17.56
50	6.84	9.36	7.71	8.14	7.22	7.60	16.53	16.82
100	6.78	10.42	5.10	9.11	7.11	8.22	19.68	20.40

a. 50 kg of N and kg of K as elemental nutrients.

Table 4. Total plant yield of the different fertilizer treatments by fallow state in Mondomo.

Fallow state base nutrients	Without (t/ha)	With[a] (t/ha)	Without (t/ha)	With (t/ha)	Without (t/ha)	With (t/ha)	Without (t/ha)	With (t/ha)
Treatment:								
Farmer check	10.08	-	3.36	-	9.26	-	21.55	-
TSP (kg of P/ha)								
0	13.90	15.66	7.01	6.95	6.84	6.19	30.98	30.63
25	12.91	17.49	17.04	29.62	9.40	17.52	36.01	39.10
50	11.86	21.62	17.51	33.10	9.99	20.46	32.05	40.21
100	13.69	23.75	14.76	31.04	11.32	19.64	37.13	46.16
Rock phosphate (kg of p/ha)								
0	13.90	15.66	7.01	6.95	6.84	6.19	30.98	30.64
25	11.75	16.40	13.57	17.91	9.07	12.53	31.02	35.14
50	11.57	16.94	12.81	15.63	9.93	10.64	32.84	33.61
100	11.11	17.62	9.33	15.84	9.61	12.07	36.50	38.92

a. 50 kg of N and 50 kg of K as elemental nutrient

Table 5. Quality characteristics of the non-fertilized plots by fallow state in Mondomo.

Fallow state	Dry matter content (%)	Total HCN (ppm)	Cooking time (min)	Eating quality index[a]	Deterioration rating[b] (%)
Degrading	33.3	252	56	3	22
3-5 years	30.7	387	50	0	41
8-10 years	36.8	299	65	4	31
Long term	35.3	212	49	8	40

[a] Rating was the sum of the evaluation of two factors: texture - bland (4) and hard (0) and flavor - good (4), fair (2), acceptable (1), and not acceptable (0).

[b] Rating of 10 separate evaluations three days after harvest, where scale runs from 0 (free of deterioration) to 100% (complete deterioration).

Table 6. Root yields of different fertilizer treatments by fallow state and soil color in Media Luna.

Variety/ fallow state	Soil color	Fertilizer level 0-0-0 (t/ha)	0-50-50 (t/ha)	50-50-50 (t/ha)	100-50-50 (t/ha)	200-50-50 (t/ha)
Secundina						
3 or more years cassava	Red	12.8	13.7	15.8	16.0	14.0
	White	8.8	10.2	12.4	12.4	14.0
1 or 2 years cassava	Red	16.7	15.4	18.9	17.6	13.0
	White	16.3	15.9	18.4	17.2	19.4
3 or more years fallow	Red	16.4	14.1	14.7	14.2	12.7
	White	14.1	13.9	14.8	12.4	15.2
CM- 342-170						
3 or more years cassava	Red	13.7	14.4	19.0	17.0	18.8
	White	12.7	11.1	11.8	14.7	17.0
1-2 years cassava	Red	17.9	17.2	18.3	19.8	18.0
	White	15.5	12.6	18.3	19.4	18.5
3 or more years fallow	Red	20.4	21.8	22.0	24.4	20.8
	White	17.0	18.4	21.8	18.5	21.3

Table 7. Root yields of different fertilizer treatment by fallow state in the Llanos.

Variety fallow state	0-0-0 (t/ha)	Fertilizer treatment 50-100-100 (t/ha)	100-200-220 (t/ha)	150-300-300 (t/ha)	200-400-400 (t/ha)
Guajiba					
3 year cropping cycle	6.2	7.3	8.4	9.6	10.0
Pasture	16.2	17.3	19.0	14.2	15.8
CM 507-37					
3 year cropping cycle	12.0	20.2	17.7	18.0	16.9
Pasture	29.5	32.8	32.7	31.1	29.5

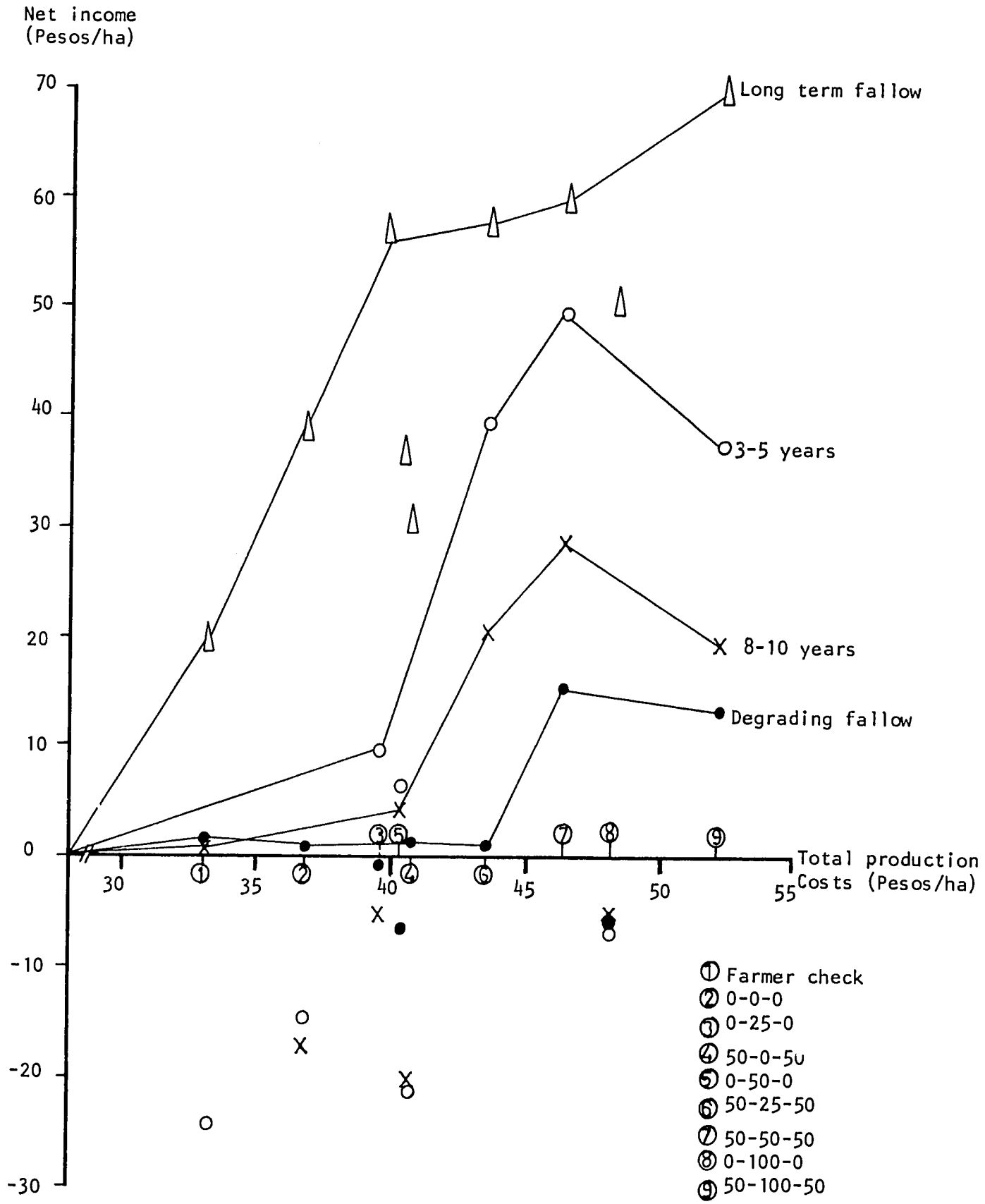


Figure 1. Profitability of fertilizer treatments on different fallow states with TSP as phosphorous source in Mondomo.

Scientific Training

While giving due attention to the degree of development of the national research programs and to their capability to carry out their projects, the CIAT Cassava Program has contributed with its training activities and conferences to the steady increase in the number and technical level of researchers of those countries in which (1) this species is relevant; (2) adequate ecological means are available to expand or intensify production; and (3) an interest is shown through government support and allocation of the necessary resources for program development. Through 1982, 410 professionals (Figure 1) of 36 countries have been trained, 73.4% of the participants from Latin America, 20.1% from Asia and Africa and 6.5% from other countries.

Outstanding Features of 1982.

Interested countries were offered a training program consisting of an intensive multidisciplinary course, followed by formally organized courses in specific fields. This sequence gave to participants a broad multidisciplinary team exposure to research and production aspects and an opportunity to pursue knowledge and experience in a specialized field, as well. Experiences gained and research results obtained by the program since its inception were compiled and published in a reference manual, which has been distributed to all visiting researchers and is available for distribution. Similar compilations are being prepared for publication in specific disciplines like integrated cassava pest control.

National institutions continued to receive support and collaboration for the organization of in-country training.

Joint efforts were made this year in training as well as in conferences in some specific areas to work with other international centers, CIP and IITA, both of which have species and research areas on tropical roots and tubers related to CIAT's Cassava Program.

Four workshops held during 1982 were focused on germplasm exchange evaluation of advanced germplasm in the countries, a critical process evidencing the need for collaborative interdependence with the national programs to reach increases in production and productivity.

Training Activities at CIAT Headquarters During 1982.

During 1982, 39 professionals from 13 different countries were trained (Figure 2). The training program on cassava research financed partly by the United Nations Development Program (UNDP) and partly by the German Foundation for International Development (DSE), consisted of a six-week intensive multidisciplinary phase, followed by a specialized phase by discipline, which lasted eleven weeks. Three out of the sixteen intensive-phase participants continued their training in breeding, four in agronomy and soils, two in integrated pest control and two in meristem culture (Table 1). The high participation percentage in the specialization phase reflects the capacity of the program to transfer generated technology and the interest of national programs for increasing

Previous Page Blank

the specialization of its experts. A complete list of the participants is given at the end of this section.

For the first time and as part of the specialization phase a course on "Integrated Cassava Pest Control" was held with emphasis on biological control and varietal resistance, for eight entomologists from three Latin American countries and lasted four weeks.

Similarly, an intensive course on "Meristem Culture Techniques for Cassava and Potato" was held in cooperation with CIP. The course was attended by eight professionals during four weeks, following the multidisciplinary phase. A very intensive program of laboratory practices was included in this course to develop the participants' skills in the management of meristem techniques and rapid propagation when receiving or sending breeding materials. This will provide national programs with tools to obtain clean and disease-free material in sufficient quantities which would further research and production efforts in their countries.

The number of participants trained in cassava in 1982 and the number of months per person are slightly less than in 1981; nevertheless, greater emphasis has placed on meeting the needs in training by disciplines, (Table 2). Worth mentioning is the emphasis given to special fields related to genetic materials so that national institutions may advance in the dissemination of new high-yielding clones with good adaptation characteristics for the different edaphoclimatic zones in the countries interested in cassava production. (The slight reduction in number of participants trained at CIAT in 1982 as compared to 1981, is more than offset by the 70 trained in in-country courses).

Training Related to Academic Degrees

This training aims to strengthen the research leadership in national programs and at the same time to increase their research capability. Within the framework of this program this year, a visiting associated researcher from Brazil started research for his doctoral thesis on plant physiology for a Ph.D. degree at Arizona State University. Two other students from the United States also worked on their Ph.D. thesis, one on entomology with Cornell University and the other one on intercropping with Purdue University. Two students, one from Honduras and one from Colombia, are presently working on their MS. theses research in Agronomy with Mississippi State University and in Breeding with the Universidad de Lavras, Minas Gerais, Brazil, respectively. A list of these professionals in given in Table 3.

Collaboration of CIAT's Cassava Program With National Institutions Through Training During 1982.

This year, the cassava program trained 39 professionals from 13 countries around the world, thirty five came from research and extension institutions of Latin America and the Caribbean, one from Asia and three from developed countries. Table 4 shows the number of these professionals and institutions from which they came. The emphasis is

marked in Colombia and Brazil, countries in which cassava is highly relevant and extensively grown.

Support To Courses In Other Countries.

Once the cassava program has generated high-yield germplasm as well as cultural and plant-health protection practices, the transfer of these technologies to farmers is increasingly relevant.

The direct training of extensionists at CIAT's headquarters is not in the Cassava Program's plans. However, its inter-institutional transfer strategy provides assistance to national research and extension programs, so that they can conduct in-country training courses for extensionists. This way, they should be able to disseminate improved cassava technologies to farmers. That is why the program continues to emphasize collaboration with national institutions in programming and developing training courses for extensionists in the interested countries (Table 5).

Haiti.

A course for twenty-four Haitian professionals was held from July 26 to 31, 1982 in co-operation with the Department de L'Agriculture des Resources Naturelles et du Development Rural (DARNDR), and the Organisme de Developpement du Nord (ODN). The teaching of this course relied largely upon three Haitian professionals previously trained at CIAT and three members of the CIAT scientific staff. A booklet on cassava production was compiled in French as a result of this course and distributed to the participants and collaborative agencies. It is now available at the Faculte de Agronomie et Medicine Veterinaire de Pourt au Prince.

Brazil.

Twenty-four professionals from the states of Parana, Santa Catarina and Rio Grande do Sul attended the "Primer Curso Intensivo para a Capacitacao Tecnica na Cultura da Mandioca na Regiao Sul Brasileira", which was held between March 22 and April 3, 1982. It was organized by EMBRATER, EMBRAPA, ACARESC, EMPASC. Five members of the CIAT Cassava Program staff cooperated as instructors. Most of the participants were professionals from state organizations for technical assistance in the three states. The 90 hour course included classroom instruction, field practice and study tours across the main production areas close to the municipality of Camboriu, Santa Catarina.

Five entomologists were trained in techniques to establish an integrated control program for the Phenacoccus hereni, a great problem encountered throughout the northeast of Brazil, this group training was carried out in the municipality of Feranova, state of Pernambuco and was financed by IICA. Two entomologists from CIAT's cassava program taught the group during four weeks, between April 10 and May 10.

Dominican Republic.

The second intensive course on cassava production was organized by the ministry of agriculture. It was supported by a member of the CIAT Cassava Program. It was attended by 16 members of the agriculture extension service of the Dominican Republic. This activity was launched in 1980 with the cooperation of CIAT. The Ministry of Agriculture of the Dominican Republic plans to continue a series of yearly courses on their own, until an appropriate number of trained persons is reached.

Colombia.

Seventeen experts belonging to the DRI system (ICA, INCORA, CECORA, Caja Agraria) of Colombia participated in a short training course on cassava production, held in Sincelejo between March 16 and 18 of 1982. This course is similar to those held in previous years, as part of the DRI/ACDI/CIAT agreement, in which the cassava program cooperates to increase production and seeks new forms of cassava utilization on the Atlantic coast.

The cassava program pays special attention to in-country training courses, since some developing countries can carry out this kind of training and the multiplier effort. The Cassava Program hopes that in the future national institutions for example in the Dominican Republic, will assume increasingly major responsibilities for in-country training, based on scientific staff trained at CIAT.

A complete account of the participants in the cassava program training by countries and institutions during 1982 can be seen on Table 6.

Postdoctorals.

Two scientists with a Ph.D. degree, one came from Sri Lanka working in plant pathology on the characterization of viral diseases in cassava, and one from England researching environmental effects on cassava deterioration after harvest in cooperation with Wye College, University of London and the Tropical Products Institute, London (Table 7).

Table 1. Training program for cassava research and courses on specific subjects during 1982.

Multidisciplinary phase	Specialization phase	No. participants
Intensive multidisciplinary course 16 participants 5 Multidisciplinary phase only	Specialization by disciplines	11
	Breeding	(3)
	Agronomy-soils	(4)
	Integrated pest control	(4)[a]
	Meristem culture	(4)[a]
	Integrated pest control course	6
	Meristem Culture Course[b]	6
Total of Participants		23

a. Participated in the courses on integrated pest control and on meristem culture.

b. Jointly with CIP.

Table 2. Number and man-months of professionals trained in CIAT's Cassava Program during

Commodity/discipline of specialization	Visiting associate researchers		Visiting researchers			Multidisciplinary intensive course participants	
	Thesis PhD	Non thesis	Thesis MS	Specialization	Specialization with multidisciplinary intensive course	Course only	Sub-Totals
Cassava Program	No.months	No.months	No.months	No.months	No.months	No.months	No.months
Physiology	1 (7)						1 (7)
Agronomy	1 (12)		1 (12)	1 (0.5)	2 (10)		5 (34.5)
Entomology	1 (7)			6 (6)	2 (4)		9 (17)
Plant breeding			1 (12)	1 (3)	3 (15)		5 (30)
Economy				1 (6)			1 (6)
Soils					2 (10)		2 (10)
Genetic resources[b]				8 (12)	2 (4)		10 (16)
Production research[a]						5 (5)	5 (5)
Utilization		1 (4)					1 (4)
TOTAL 1982	3 (26)	1 (4)	2 (24)	17 (27.5)	11 (43)	5 (5)	39 (129.5)
TOTAL 1981	5 (35)	1 (3)	3 (30)	19 (36)	8 (29)	10 (14)	46 (147)

a. Multidisciplinary, research intensive short course
b. Meristem propagation technology

Table 3. Professionals trained in the CIAT Cassava Program in relation to academic degrees during 1982.

Name	Country	Institution	Discipline of research	State [a]
Visiting associate researchers, Ph.D. thesis				
Marcio Porto de Carvalho	Brazil	EMBRAPA	Physiology	P
Jan Margaret Salick	USA	Cornell University	Entomology	C
Stephen Mason	USA	Purdue University	Agronomy	P
Visiting researchers, M.S. thesis				
Jose Moises Luna	Colombia	ICA	Agronomy	P
Jose Walterio Caceres	Honduras	Min. Natural Res.	Agronomy	P

a. P = in progress
C = completed

Table 4. National institutions with which the cassava program collaborated in training during 1982.

Country	Institution	No. participants
Latin America and two Caribbean countries		
Colombia	ICA	6
	Universidad Nacional	2
	Universidad de Caldas	1
	Universidad del Valle	1
	Fedecafe	1
	Secretariat of Agriculture of Valle	1
Brazil	EMBRAPA	1
	EMBRATER	1
	UEPAE	1
	IPA	2
	Pesagro-Rio	1
	EMAPA	!
	ASTER	1
	EPAMIG	1
Ecuador	UDRI	1
	INIAP	2
Bolivia	IBTA	1
Mexico	INIA	2
Nicaragua	MIDINRA	2
Peru	Univ. Nacional Pedro Luis Gallo	1
Costa Rica	Universidad de Costa Rica	1
Dominican Rep.	Secretariat of Agriculture	1
	CESDA	2
Honduras	Department of Natural Resources	1
Asia		
Thailand	State Department of Agriculture	1
Developed Countries		
Holland	Department of Foreign Affairs	1
United States of America	Cornell University	1
	Purdue University	1

Table 5. Countries with which the Cassava Program collaborated through in-country training in 1982.

Country	National program(s)	Subject	No. of participants
Haiti	DARNDR/ODN	Cassava production course	24
Brazil	EMBRATER	Cassava production course	24
	IICA/EMBRAPA	Integrated control training Phenacoccus	5
Colombia	DRI/ACDI-CIAT	Cassava production course	17

Table 6. Visiting researchers in the cassava program by disciplines of training in 1982.

Name	Country	Institution	Short course Particip.	Discipline	Supervisor	Months	ST
Visiting research associate, PhD. thesis							
Porto, Marcio	Brazil	EMBRAPA		plant physiology	Cock, J.	7	C
Mason, Stephen	USA	Univ. of Purdue		Agronomy	Leihner, D.	12	C
Salick, Margaret	USA	Cornell Univ.		entomology	Belloti, A.	7	C
Visiting research associate							
Manrique, Luis	Colombia	Univ. Nal. de Colombia		utilizacion	Gomez, G.	4	C
Visiting researchers, MS thesis							
Caceres, Jose	Hounduras	Ministerio de Rec. Naturales		plant physiology	Leihner, D.	12	P
Luna, Jose	Colombia	ICA		plant breeding	Toro, J.C.	12	P
Visiting researchers							
Janssen, Gerardus	Holland	Ministerio de Rel. Exteriores	N	economics	Lynam, J.	3	P
Sanchez, David	Mexico	INIA	Y	soils	Howeler, R.	5	C
Huete, Fernando	Costa Rica	Univ. de Costa Rica	N	germplasm-genetic resources	Roca, W.	1	C
Garcia, Eligio	Colombia	ICA	N	agronomy	Leihner, D.	0.5	C
Delgado, Guillermo	Peru	Univ. Nal. Pedro Ruiz Gallo	N	germplasm-genetic resources	Roca, W.	5	C
Legorreta, Felipe	Mexico	INIA	Y	agronomy	Toro, J.	5	C
Ulloa, Miguel	Bolivia	IBTA	Y	agronomy	Toro, J.	5	C
Sosa, Miguel	Dominican Rep.	Secretaria de Estado de Agric.	Y	plant breeding	Hershey, C.	5	C
de Freitas, Helena	Brazil	PESAGRO-Rio	Y	soils	Howeler, C.	5	C
Durans, Jose	Brazil	EMAPA	Y	plant breeding	Hershey, C.	5	C
Martinez, Edmundo	Nicaragua	MIDINRA	Y	germplasm-genetic resources	Roca, W.	2	C
Soares, Genival	Brazil	EMATER	Y	entomology	Bellotti, A.	2	C
Noyola, Maria	Dominica Rep.	Secretaria de Estado de Agric.	Y	germplasm-genetic resources	Roca, W.	2	C
Cenpudee, Uthai	Thailand	Department of Agriculture	N	plant breeding	Kawano, K.	3	C
Dias, Almir	Brazil	EMPASC	Y	plant breeding	Hershey, C.	3	C
Negrette, Gilberto	Colombia	ICA	Y	entomology	Bellotti, A.	2	C
Short Course Participants							
Faria, Marilda	Brazil	EPAMIG		germplasm-genetic resources	Roca, W.	1	C
Alves, Jose	Brazil	IPA		germplasm-genetic resources	Roca, W.	1	C
Forero, Maria Clemencia	Colombia	ICA		germplasm-genetic resources	Roca, W.	1	C
Reyes, Luz Marina	Colombia	ICA		germplasm-genetic resources	Roca, W.	1	C
Cedeno, Jorge	Ecuador	INIAP		germplasm-genetic resources	Roca, W.	1	C
Estrella, Diego	Ecuador	INIAP		germplasm-genetic resources	Roca, W.	1	C
Warumby, Jandira	Brazil	IPA		entomology	Bellotti, A.	1	C
Vargas, Hector	Colombia	Univ. del Valle		entomology	Bellotti, A.	1	C
de la Cruz, Jaime	Colombia	Univ. Nal. de Colombia		entomology	Bellotti, A.	1	C
Castano, Oscar	Colombia	Univ. de Caldas		entomology	Bellotti, A.	1	C
Londono, Francisco	Colombia	Not hired by institution		entomology	Bellotti, A.	1	C
Diaz, Fernando	Dominican Rep.	CESDA		entomology	Bellotti, A.	1	C
Andrade, Maria do Socorro	Brazil	EMBRAPA		production	Dominguez, C.	1	C
de Santana, Manuel	Brazil	ASTER/Roraima		production	Dominguez, C.	1	C
Astudillo, Alvaro	Colombia	ICA		production	Dominguez, C.	1	C
Acevedo, Maria Clemencia	Colombia	Secret. de Agric. y Fom. del Valle		production	Dominguez, C.	1	C
Carmona, Victor	Ecuador	UDRI		production	Dominguez, C.	1	C

Y = yes; N = no; P = process; C = completed.

Table 7. Postdoctoral scientists in the Cassava Program during 1982.

Name	Institution/country	Discipline	Project
Christopher Wheatley	Wye College Univ./England	Pathology	Post-harvest deterioration
Upali Jayasinghe	Univ. Wageningen/Sri Lanka	Virology	Virus characterization

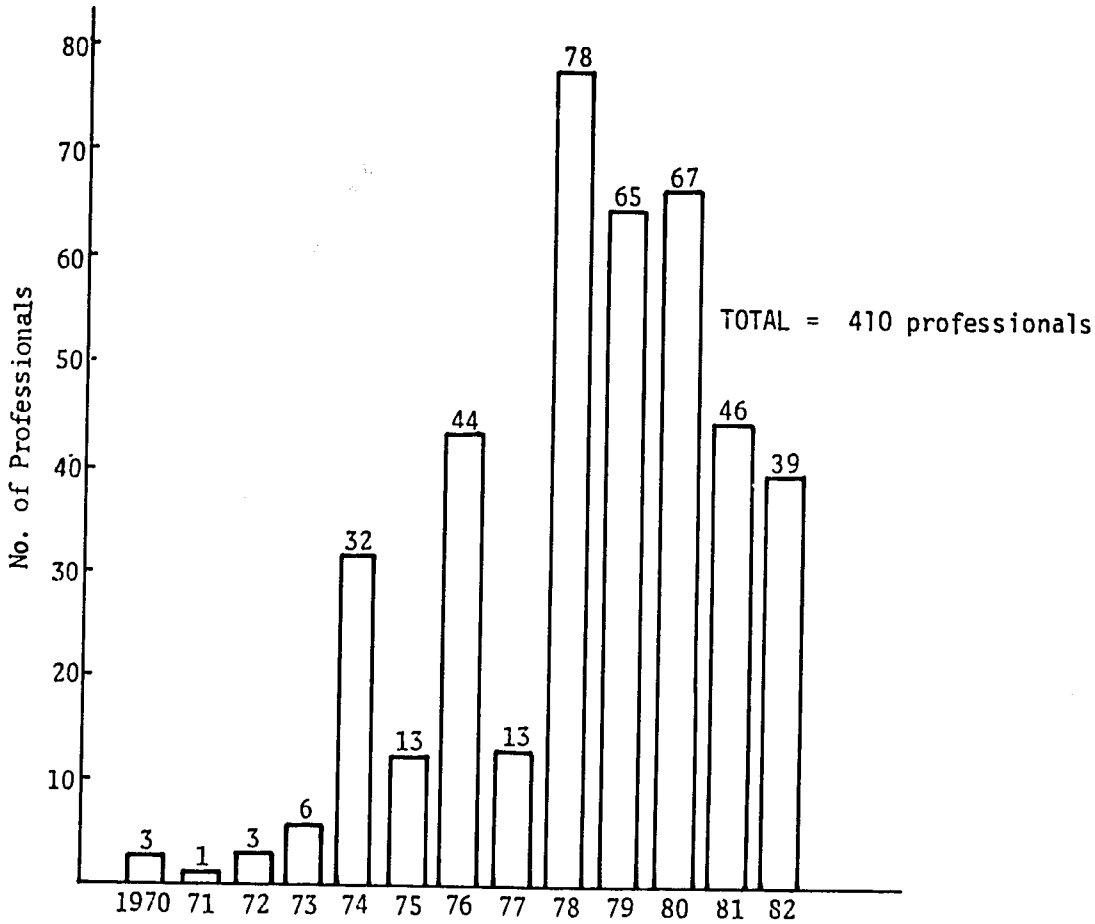


Figure 1. Number of professionals who have completed training at CIAT in the Cassava Program from 1970 to 1982.

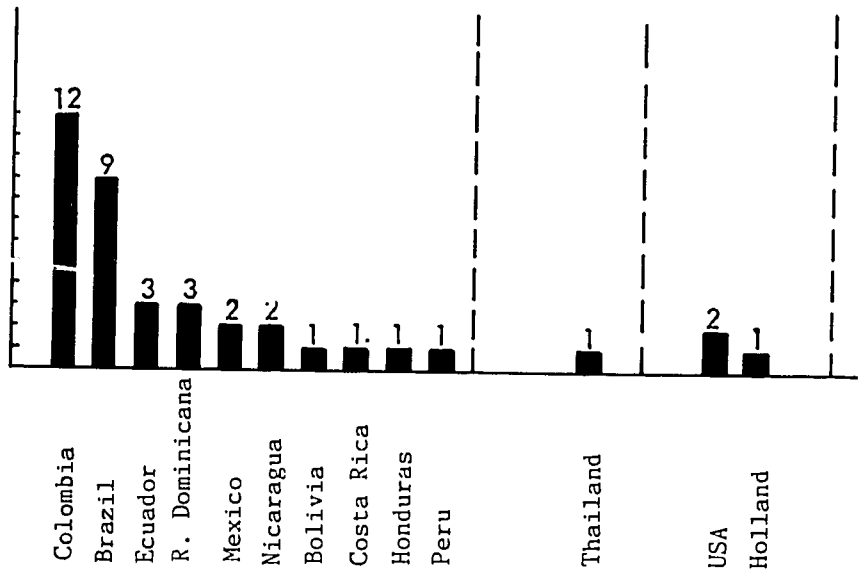


Figure 2. Number of professionals trained at CIAT in the Cassava Program during 1982, by countries.

International Cooperation

Training at CIAT

Thirty five professionals from nine countries attended three cassava training courses at CIAT during 1982. These courses were sponsored by the United Nations Development Project (UNDP).

Intensive cassava production course

This course was attended by 16 professionals, among them 6 were from Brazil; 3 from Colombia; 2 from Mexico; 2 from the Dominican Republic; 1 from Bolivia; 1 from Ecuador and 1 from Nicaragua. This was a six week course in which very comprehensive and practical aspects of production were given to persons with research and/or extension background.

Intensive cassava tissue culture course

This course covered both potato and cassava. The formal instruction during four weeks was given by the staff of the CIAT Cassava Program with the collaboration of two members of the Potato Program from the Centro Internacional de la Papa (CIP). The total participation of eight trainees was as follows: 2 from Brazil; 2 from Colombia; 2 from Ecuador; 1 from Nicaragua and 1 from the Dominican Republic. Besides the fundamentals of tissue culture, the course included intensive laboratory work to enable the student to master the skills of this important activity in the movement of material from one place to another. Also, the principal rapid multiplication methods were studied to fill the gap for certified seed production.

Intensive biological control course in cassava

This course was carried out with the participation of two guest instructors, Dr. Louis Falcon from the University of California at Berkely, USA and Marcos Kogan from the University of Illinois, USA and eight experienced researchers and teachers mainly from Colombia (5).

Although the course was normally given to eight participants, the real attendance was as high as 150 persons. Most of the researchers from the experimental station of the Instituto Colombiano Agropecuario (ICA) and CIAT agronomists participated informally. These specialized training courses are receiving more attention from both CIAT and donor institutions to reinforce current cassava national programs.

PhD and master research thesis

This year, one Brazilian student from the University of Arizona at Tucson, started research for a PhD on cassava physiology. In the field of agronomy, one student from Purdue University at West Lafayette, Indiana, USA and one student from Honduras from Mississippi State University at Starkville, USA, are pursuing advanced research on cassava multiple cropping systems for a PhD and MS, respectively.

In-Country Training

As indicated in previous reports, this type of training is not only receiving more consideration but is also proving to be a very efficient way to extend the benefits of the new technology since more extensionists are involved in these courses.

Haiti

This course was organized by the following institutions: the Departement de L'Agriculture, des Resources Naturelles et du Developpement Rural (DARNDR); the Projet de Developpement de L'Agriculture Integral (PDAI) with the collaboration of the Faculte de Agronomie et Medicine Veterinaire (FAMV); the Organisme de Developpement du Nord (ODN); the United States Agency for International Development (USAID); Texas A & M University (TAMU) and the Centro Internacional de Agricultura Tropical (CIAT).

Twenty-four Haitian professionals participated as students and 12 others as instructors with the collaboration of three CIAT Cassava Program members and one from the USAID-TAMU group. The course (which ran for one week) was offered in French at the Cap Haitien location giving 18 hours of technical instruction and 18.5 of field practice and roundtable discussion.

As a result of the course a book of cassava production was published to be distributed among participants, collaborating institutions and farmers in general.

Brazil

With the participation of 24 agronomists from Parana, Santa Catarina and Rio Grande do Sul a course organized by the Empresa Brasileira de Asistencia Tecnica e Extensao Rural (EMBRATER) with the cooperation of CIAT was offered in the municipality of Camboriu, Santa Catarina, from March 22 to April 3. Most instructors were Brazilians with the collaboration of four members of the CIAT Cassava Program. The majority of participants were extension agronomists engaged in Cassava technical assistance throughout the three southern states of this country.

Dominican Republic

This was the third intensive cassava production training course given in this country so far. This year, the course was organized and conducted by professionals from the Dominican Republic without any external assistance. This fact demonstrates the effectiveness of training people to train others when the national institutions are really interested. The course was offered to eight extension agronomists and 12 technicians.

The course is in such high demand that it is expected to be conducted every year until a satisfactory level of trained personnel is reached.

Workshops

Three cassava workshops sponsored by UNDP and one sponsored by the International Development Research Centre (IDRC) were held this year.

The three workshops sponsored by UNDP were mainly related to the exchange of cassava and potato germplasm. One of these was held at CIAT in January, one at Manila, Philippines in April and one at Ibadan, Nigeria in June. The organizers of these workshops were CIAT, CIP and the International Institute of Tropical Agriculture (IITA), respectively. The proceedings of the workshops held at CIAT have already been published in Spanish.

Under the auspices of IDRC a workshop on the evaluation of promising cassava varieties in Latin America and the Caribbean was held at CIAT in May. The proceedings in Spanish are also available.

Activities in Latin America

Eight Latin American countries were visited by program scientists in relation with the development of several aspects of the national programs. Countries visited were Brazil, Paraguay, Mexico, Cuba, Venezuela, Panama, Haiti and the Dominican Republic.

Cuba

This country has shown tremendous progress during the last four years. At present, of the total area planted to cassava (37,218 ha), 65% is planted with selected or improved varieties. This represents a 15,000 hectare increase over the last four years. Four varieties have been released during this period, Senorita, Pinera, CMC-40 and CEMSA 5-28. It is expected that by the end of 1985 the whole area will be planted with certified seed.

The variety CMC-40 (M Col-1468, Mantiqueira or IAC-24-2) originally from Brazil and introduced to Cuba from CIAT, has been multiplied through rapid propagation techniques. There are about 250-300 hectares planted to this variety throughout the country at present. By 1985, it is expected that this variety will represent at least 5% of the total area planted with improved varieties.

The hybrid CEMSA 5-28 is being multiplied with a goal of 15% of the area planted to superior varieties by 1985.

Activities in Asia

Philippines, Thailand, India, Indonesia, Malaysia and China were visited by several members of the cassava team to strengthen cooperation and to emphasize future developments in that important part of the world.

China

This is the first time that scientists of the CIAT Cassava Program visited China. Cassava for human food is of little importance on a global scale but for some communes it is a basic staple. The official estimates of cassava production are about 3.0 million tons from some 350,000 ha- figures which probably do not include the private plots. Yields are commonly in the 6-8 t/ha range although weed control is excellent.

According to the CIAT Cassava Program's observations, agronomic practices can increase yield. Cassava for animal concentrates offers great potential for the expansion of the crop in this vast country.

China will send some professionals for training in cassava as soon as possible.

Philippines

The CIAT varieties CMC-40, CM 308-197 and M Col-1684 are being multiplied as promising for Philippine conditions. After further evaluations some will be released.

Thailand

The varieties CM 407-37 and CM 305-13 have been released as Huey Pong 4 and 5 respectively. These two varieties were widely evaluated across the country before being multiplied for release. Although these varieties do not have a big yield difference over the local variety (Rayong-1), they will diminish the risk represented by the planting of a single genotype in such a large country as Thailand (1.2 million ha).

Tissue Culture

During 1982 work focused on the use of meristem tip culture techniques to: (a) recover healthy clones from systemically infected varieties; (b) build up a gene bank *in vitro*; and (c) exchange germplasm with national programs. In addition, research continued to improve and refine current methodologies, and to open new areas of application.

Recovery of Healthy Clones

As shown previously, heat therapy enhanced the effectiveness of meristem culture in cleaning cassava materials of frog skin disease (Cassava Annual Report, 1981). The differential effect of the high temperature on virus multiplication and movement, and on the promotion of shoot growth probably account for such results. Hence, the size of the meristem explant used for culture should play a crucial role in the cleaning rate.

Research was carried out on the interaction of temperature, rate of growth and size of the meristem explant, in the recovery of clean plants from frog skin and mosaic-infected clones. In addition, chemotheraphy was tested as a means to clean frog skin disease.

Thermotherapy

Effect of thermotherapy on shoot tips in vitro. Large shoot tip explants (1.0 to 1.2 mm in size) were isolated from greenhouse-grown (25° to 28°C) stakes of two varieties infected with frog skin disease, and cultured under three temperature regimes: 25°C D/N[a], 30°C D/N and 40°/35°C D/N. Throughout a three-week period, and at each temperature treatment, the culture's shoot elongation was monitored and plants were grown, potted and transplanted to the field for evaluation.

Irrespective of temperature, the highest peaks of *in vitro* shoot elongation occurred between the 10th to the 16th days of treatment, peaking at 0.3 - 0.5, 0.4 - 0.7, and 0.5 - 2.0 mm/day for the 25°C, 30°C and 40°/35°C regimes, respectively. Field evaluation at 4 - 5 months showed all plants infected throughout the 25°C treatment. However, at 30°C, the highest rates of frog skin symptom-free plants coincided with the highest peaks of *in vitro* shoot elongation. At the 40°/35°C regime, cleaning rates gradually increased from 40% on the 12th day to 100% on 21st day, with no relation to elongation rates.

It appears that high elongation rates of the cultures may enhance cleaning only at intermediate temperatures and that the increase in cleaning rate due to the higher culture temperature overrides any elongation effect *per se*.

Effect of kind of explant used for rooting. Under the conditions described above and prior to potting and field transplanting, every differentiated shoot was taken either as a whole or only the stem tip was cut and transplanted into another medium for rooting. The use of stem tips, instead of entire shoots, resulted in a 20% to 30% increase

---

[a] D/N: day/night temperatures, respectively.

in cleaning rates at both the 30°C and the 40°/35°C regimes.

Effect of thermotherapy on sprouting stakes. Meristem explants of three sizes were isolated from buds of frog skin-infected stakes which were sprouted under two temperature conditions.

The cleaning rate was inversely related to the size of the meristem explant. All plants remained infected when large explants were obtained for culture from stakes sprouted at the lower temperature. However, at the higher temperature, the rates of cleaning achieved greatly increased even when the explants used were medium and large in size (Table 1).

The results indicate that thermotherapy of the stakes is required during sprouting and of small meristem explants to achieve high cleaning rates. Thermotherapy of 3 - 4 weeks must enhance such rates further.

Cleaning plants of double viral infections. Stakes obtained from frog skin diseased plants of the M Col 33 were sprouted in the greenhouse, at a mean temperature of 26°C, and under heat therapy, at 40°/35°C D/N.

Mild leaf mosaic symptoms appeared in the plants differentiated on large shoot tip explants from the greenhouse-sprouted stakes, the proportion being higher when the explants were cultured at 30°C than at 40°/35°C (Table 2). Interestingly, the mosaic symptoms were not visible in the original plants in the greenhouse nor in the field, but they showed up through grafting done in collaboration with the cassava pathologists (See "Viral and Mycoplasmal Diseases - Frog skin disease (FSD)" in the Pathology Section of this report). However, when the same material was subjected to heat therapy during sprouting, and both small and large meristem explants were used, all plants were free of both frog skin and mosaic, even if the explants were cultured at 30°C (Table 2).

Chemotherapy

Many chemotherapeutical substances particularly virazole or ribavirin seem to interfere directly with the synthesis of a wide range of RNA and DNA viruses. Water solutions of virazole (0 through 40 ppm) were applied to both rooted stem cuttings in a sterile substrate and to large shoot tip explants *in vitro*, obtained from the M Col 33 plants with frog skin disease.

After four weeks of treatment, virazole concentrations above 20 ppm were fitotoxic to the stem cuttings and similar levels retarded the growth of the shoot-tip cultures. All plants grown from the stem cuttings remained with the disease symptoms. However, the shoot tip cultures treated with 20-40 ppm virazole yielded plants completely free of symptoms only if the stem tip of each culture were cut prior to potting and used for rooting in a virazole-free medium, following 40-80 days of treatment.

Due to the promise of virazole as a chemotherapeutic agent for frog skin disease, more studies are underway to enhance the cleaning process through meristem culture.

Regeneration of varietal decline

Gradual decline or degeneration of local cultivars may result from the accumulation of latent disease or from physiological breakdown over time. Preliminary results, of thesis research with the M Col 1438 (Llanera) and M Col 1468 (CMC 40) are presented here.

Hot water therapy to stakes. Fresh stakes, obtained from plants apparently free of diseases, were immersed in water baths at 40°C and 50°C for 5-30 minutes, and then planted in the field for evaluation.

The best treatment, i.e. 40°C for 5 - 20 minutes, increased root yield 20% and the production of planting material 25-30% of the CMC 40; but only a 2% increase in root yield and 10% in "seed" production was obtained with Llanera.

Hot air therapy of stakes during sprouting followed by meristem culture. Meristem tips were isolated for culture from stakes of the two varieties sprouted either in the greenhouse or under heat therapy, at 40°/35°C D/N for four weeks. The resultant plants were planted in the field along with non-treated stakes for evaluations.

At the third month in the field, differences in leaf lobe size of the variety Llanera were quite obvious between all the plants grown from stakes and the entire plant population, i.e. a total of 100, obtained by meristem culture, both with and without prior thermotherapy (Figure 1). Leaf length to width ratios were on the average 75% higher in the meristem plants than in the stake plants. Furthermore, the narrow lobed leaves were also 10% to 15% thicker than the control (stake plants) due solely to a 50% increase in the width of the spongy mesophyll. However, the total area of the meristem plant leaves was about 60% smaller than the stake plant leaves. In contrast to Llanera, the leaf length to width ratios of the CMC 40 remained almost unchanged in both meristem and stake plants.

Because the changes observed in leaf size remained throughout plant growth and failed to revert to the "normal" broader lobe in reciprocal grafts, its possible causality will be studied with the evaluations of root yield, "seed" production, etc. in the following reproductive generations.

Routine varietal cleaning process

Work continued to assist the Cassava Program in generating clean stocks from diseased varieties (Table 3). Local varieties from 10 cassava growing regions of Colombia were selected for cleaning. Healthy clones of those varieties will be delivered to the Cassava Program for inclusion as controls in regional trials.

In collaboration with the cassava pathologists, disease detection tests will be applied to these materials prior to processing by the thermotherapy-meristem culture procedure, to accelerate the process.

Germplasm conservation

Two approaches have been followed for the studies on the conservation of cassava clones *in vitro*: (a) through modification of the

physical or chemical environment of the cultures, to produce "minimal growth"; and (b) through storage at ultra-low temperature or "cryogenesis".

Minimal growth conditions for storage

As shown earlier, temperature and illumination interact with the composition of the culture medium in reducing the culture's rate of growth so as to extend the transfer period (Cassava Annual Report, 1980). However, the extent to which those treatments affect the viability of the cultures was not clearly defined. To test various physical and chemical factors, as they influence the rate of growth and the viability of cassava cloned stores *in vitro*, several experiments have been set up. Single node cuttings, from meristem-derived plantlets, were used as explants for the storage experiments.

Growth rate determinations were based on shoot elongation, taking into account that very low rates are often detrimental and very high ones tend to shorten the transfer period. As a measure of viability, the number of shoots formed per culture and the number of axillary buds per shoot represent the capability for plant regeneration through the culture of node cuttings. Results obtained from the initial 5-6 months of treatment are shown in the Tables 4, 5, 6, and 7, and in Figure 2, for which, these experiments are detailed below.

Effect of storage temperature. With the roots initiated on the node cuttings, the cultures were stored under three temperature regimes with three levels of illumination (Table 4).

The rate of growth of the cultures was directly related to storage temperature, without effects due to the illumination level. Viability tended to increase, with slightly more shoots per culture, at the medium temperature regime; and at 28°C, the formation of axillary buds doubled and further increased with illumination. Withdrawal of GA and NAA from the medium resulted in 100% increase of axillary buds per shoot, but only at 28°C. Except at the medium illumination level, root growth was always greater than shoot growth.

Storage at medium temperature, with the medium level of illumination, provided conditions for slow enough growth accompanied by good viability.

Effect of osmotic stress. To provide high osmotic pressure the culture media for storage was supplemented with three levels of sucrose in combination with several concentrations of mannitol. While mannitol is not metabolized by the cultures and thus acts as a powerful osmoticum, sucrose though metabolized can exert osmotic action only at a high concentration. Media osmotic concentration can affect the growth of cultures through a reduction of water and nutrient uptake by the tissues. The rooted cultures were maintained at two temperatures (Figure 2).

At both temperatures, all mannitol concentrations were highly detrimental to culture survival when sucrose was not present in the medium. At the lower temperature, viability increased with 0.25% and 0.12% mannitol levels, only if sucrose were present at 3% and 6%,

respectively. With increasing storage temperature, the surviving levels of mannitol were also higher. The extreme stress condition given by low temperature, high sucrose and high mannitol was completely damaging to culture survival (Figure 2). Single shoot cultures predominate at the lower temperature at all mannitol concentrations, increasing to 1.3 - 1.7 shoots per culture at the higher temperature, with the medium sucrose level. Similar relationships were maintained in the formation of axillary buds.

Thus, to provide reduced growth and high viability simultaneously, low concentrations of mannitol and sucrose should be used under low temperature storage. At a higher temperature, increasing levels of both osmotica are required.

Effects of medium and vessel volume. The volume of the medium and the availability of growth space for the cultures should influence the rate of growth and the viability of cultures during storage through various mechanisms, especially by dilution of toxic exudates (e.g. phenolic compunds) from the tissues and sufficient oxigenation for growth. Node cuttings were first rooted, then subjected to two storage temperatures in two types of vessels so as to provide different medium and growth space volumes (Table 5).

At either temperature, the culture's growth rate in the larger vessels was twice as high as in the test tubes; however, their viability, in terms of the number of shoots formed per culture, also doubled (Table 5). The improvement in micropropagation potential due to an increase in growth space could make it possible to maintain high viability, with protracted transfer periods, at storage temperatures lower than 23°C, if large vessels are utilized. Furthermore, both root and shoot appearance were healthier in the larger than in the smaller vessels.

Effect of activated charcoal. Earlier observations pointed out the detrimental effect on culture survival of phenolic exudates by the culture roots to the medium after the 3rd to 4th month of storage at 20° - 24°C (Cassava Annual Report, 1980). Although dependent mainly on the variety, deterioration due to phenolic oxidation could be reduced by absorbance of such compounds with activated charcoal.

Preliminary results showed, as expected, that charcoal in the medium greatly reduced root browning and deterioration, and leaf fall to about half at the low temperature (Table 6).

Surprisingly, however, charcoal reduced the rate of growth of the cultures, along with increased viability in terms of shoots formed per culture at both low and high temperature. In this respect, the two varieties tested showed a similar tendency (although one exhibited quite high rates of growth) (Table 6). It should be possible either to increase the concentration of charcoal or lower the storage temperature to reduce growth rates even further.

Effect of growth inhibitors. Growth reduction during storage should be accomplished through the addition to the medium of plant growth regulators that retard or inhibit growth.

A trial on the use of abscisic acid resulted in a highly detrimental effect of the cultures even at the lowest concentration (i.e. 2.5 mg/l) tested. It is suggested that cassava may be very sensitive to abscisic acid. Hence, even lower concentrations should be tried in the presence of sugar which may enhance viability.

Effect of low mineral nutrition. Reduction of the growth rate of the cultures could also be accomplished by lowering the level of certain mineral elements of the culture medium. Nitrogen was first studied because of its definite effect on vegetative growth. Rooted node cuttings were stored at two temperature regimes in media containing reduced amounts of total nitrogen (Table 7). At either temperature, the culture's growth rate was directly related to the concentration of nitrogen in the medium, becoming detrimental at the lowest concentrations. At 23°C, 40 mM of total nitrogen resulted in a growth rate which provided high viability; and at 28°C, the optimal nitrogen concentration was 10 to 20 mM (Table 7).

Further study is needed on the interaction of nitrogen with other major elements of the culture medium to devise a minimal medium.

The judicious utilization of the various physiochemical factors studied should aid in devising the conditions for "minimal growth" storage of cassava with high viability and genetic stability.

Cryogenics

The growth rate of the cultures can not only be retarded as shown above, but completely suppressed if the tissues are appropriately stored at an ultra-low temperature. At the temperature of liquid nitrogen (i.e. - 196°C) all the cell metabolic activities enter in a state of suspended animation and thus storage becomes potentially indefinite and the possibilities of genetic change practically eliminated.

Until about a year ago, cryopreservation work on cassava meristems was unsuccessful. Recently however, results from studies at Saskatoon, Canada are quite encouraging. The "droplet-freezing" method, as developed at Saskatoon, has increased survival up to 80%, but only a maximum of 20% of the frozen meristems gave rise to plants after retrieval from liquid nitrogen (Figure 3). While work continues to improve the current results, CIAT will continue to collaborate in the provision of materials and in testing clones recovered from cryopreservation.

Perspective

Given the recent advances in both the minimal growth and cryogenics of cassava, a dual clonal germplasm conservation system can be envisaged for the near future: (a) the base gene bank for long-term storage using liquid nitrogen; and (b) the active gene bank for short-term storage using minimal growth conditions.

Both storage methods are complementary. While retrieval from the long-term bank would be highly sporadic, turnover in the active collection would be much higher since it will provide materials for rapid micro-propagation and use for international exchange and regional trials.

Routine Germplasm Storage

Although the conservation methodologies of "minimal growth" still require some refinement, routine work was initiated in 1981 to gradually transfer the field cassava collection into *in vitro* culture form for storage. Rooted node cutting segments, obtained from meristem-grown plantlets, have been utilized as explants for storage.

From a total of 1,346 varieties, more than 50% entered storage in 1982 and the remaining have been stored for up to 36 months and only a few for 54 months.

The frequency of sub-culture increase with storage time, from about 0.5 in 12 months to 2.5 subcultures in 36 months (Table 8).

International Exchange of Clonal Material

Work continued this year to utilize *in vitro* methods for the exchange of selected materials (advanced hybrid lines and varieties) with the national programs of several countries.

The *in vitro* system, even though it provides adequate safeguards to minimize the risk of disease dissemination, is only effective if handled by well trained personnel in the receiving institutions. Training in the basic methodologies to recover and propagate plants from the imported cultures has been carried out for the personnel of most collaborating countries. This strategy has required the establishment of minimum facilities and results of the work carried out in several national programs have been quite successful (Figure 4).

Distribution from CIAT

In 1982, a total of 80 cassava varieties were distributed *in vitro* to nine countries (Table 9). Node cuttings, obtained from meristem cultures, prepared in turn from stakes sprouted under heat therapy, were rooted and grown under high illumination prior to packing in polyestyrene containers. In many instances, the node cuttings were obtained from the collection stored *in vitro*. It is expected that all future shipments will be prepared from the *in vitro* gene bank. Each shipment, generally sent via airfreight, was accompanied by a descriptive list of the materials, and a phytosanitary certificate. A "phytosanitary statement" has been prepared for inclusion in the package; it describes all treatments and indexing procedures carried out on the materials to increase the probability of their being free of diseases and pests.

Introductions to CIAT

Arrangements made in 1980-81 with CENARGEN (Centro Nacional de Recursos Geneticos, Brazil) and ICA (Colombia) have permitted the transfer to Colombia of 270 cassava varieties as meristem cultures from the collection held at the CNPMF (Centro Nacional de Pesquisa da Mandioca e Forticultura, Cruz das Almas - Brazil)

This year, with the collaboration of the IBPGR (International Board for Plant Genetic Resources), nearly 350 cassava cultivars were brought to CIAT from Brazil as meristem cultures. Most of these materials were held as collections in EMGOPA (Empresa Goiania de Pesquisa Agropuecuaria, Goias), EUPAE (Manaus), Rio Grande do Sul and CPATU (Para), and some from

Paraiba and Mato Grosso. A few stakes per variety were grown at CENARGEN where the meristem cultures for transfer was undertaken.

Table 1. Interaction of the sprouting temperature of stakes with the size of meristem explants used for culture in the cleaning rate of frog skin-infected clones (M Col 33).

Treatment[a]			Plants with symptoms[c]				
Sprouting temp. (0°C)	Meristem[b] size (mm)	Symptom-free plants (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
26	0.4	79	14	7	0	0	0
	0.8	16	17	18	33	16	0
	1.2	0	0	0	36	64	0
40/35	0.4	96	4	0	0	0	0
	0.8	65	35	0	0	0	0
	1.2	85	15	0	0	0	0

[a] Duration of treatment: two weeks

[b] Small (0.4 mm) explant comprised of 1-2 primordia. Medium (0.8 mm) explant comprised of four primordia. Large (1.2 mm) explant comprised 6-8 primordia.

[c] Symptom degree: 1 = mild; 5 = very severe. Data averaged over 5-6 plants per treatment.

Table 2. Effect of temperature treatments, during stake sprouting and/or during *in vitro* culture of meristem explants on the recovery of clean stocks from plants infected with both frog skin and mosaic diseases (M Col 33).

Treatments[a]			Symptom-free plants (%)[b]	
Sprouting temp. (°C)	Meristem size (mm)	*In vitro* temp. (°C)	Frog skin disease	Mosaic disease[c]
26	-	-	0	0
	1.2	30	0	5
		40/35	82	20
40/35	0.5	30	100	100
		40/35	100	100
	1.2	30	100	100
		40/35	100	100

[a] Duration of treatment: three weeks

[b] Frog skin disease evaluated in 4-5 month old plants; 5-6 plants per treatment.

[c] Mosaic disease evaluated by grafting with clean stakes of Secundina.

Table 3. Sources, diseases and amounts of materials cleaned by meristem culture in 1982[a].

Source	Diseases	No. of varieties[b]
M Col varieties	Frog skin, CBB	124
M Bra varieties	Preventive cleaning	123
M Per varieties	Frog skin, CBB	8
M Ecu, M Mex, etc. varieties	Frog skin	8
Others		10
	TOTAL	273

[a] 3-5 stakes per variety were exposed to heat therapy (40°/35°C, day/night) during sprouting prior to meristem culture.

[b] Delivered to the Cassava Program.

Table 4. Effect of temperature on the growth rate and the viability of cassava culture stored *in vitro* at three illumination levels.[a]

Treatment		Elongation of shoots (cm/month)	Viability[b]	
Illumination (lux)	Temp. (°C)		Shoots per culture (no.)	Axillary buds per shoot (no.)
500	18	0.2	1.0	6.7
	23	0.5	2.0	6.5
	28	1.6	1.3	13.0
1000	18	0.5	1.1	7.3
	23	0.6	1.4	7.0
	28	1.6	1.1	15.5
2000	18	0.4	1.2	6.5
	23	0.5	1.6	7.7
	28	1.5	1.2	17.0

[a] Data averaged over six cultures per treatment

[b] Represents the culture's potential capability for micropropagation. Culture medium: MS + 0.2 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA with 3% sucrose and 0.8% agar, dispenses in 25 x 150 mm test tubes.

Table 5. Effect of medium and vessel volume on the rate of growth and the viability of cassava cultures stored *in vitro* at two temperatures.[a]

Treatment		Elongation of shoots (cm/month)	Viability[c]	
Temperature (°C)	Volume of vessel[b]		Shoots per culture (no.)	Axillary buds per shoots (no.)
23	small	1.1	1.4	12.7
	large	2.0	2.8	11.2
28	small	1.0	3.6	9.7
	large	2.5	6.1	9.3

[a] Data averaged over six cultures per treatment.

[b] Small vessel: 25 x 150mm test tubes with 10 ml of media.
Large vessel: 55 x 140mm bottles with 70 ml of media.

[c] Represents the culture's potential for micro-propagation.
Medium: MS + 0.02 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA, 0.8% agar.

Table 6. Effect of adding activated charcoal to the culture medium on the growth rate and viability of cassava stored *in vitro* at two temperatures.

Treatment		Elongation	Leaf	Viability	
Temp. (°C)	A.C.[a] (%)	of shoots (cm/month)	fall (%)	Shoots per culture (no.)	Axillary buds per shoot (no.)
M Col 22					
23	0.0	0.8	80	2.0	7.5
	2.5	0.4	40	6.0	5.3
28	0.0	1.5	50	2.0	6.0
	2.5	1.0	40	3.0	8.7
M Col 1467					
23	0.0	2.1	70	1.0	15.0
	2.5	1.7	60	2.0	16.5
28	0.0	5.1	60	3.0	8.0
	2.5	2.4	50	4.0	4.0

[a] Activated charcoal added to the medium: MS + 0.02 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA with 3% sucrose and 0.8% agar. Vessels: 25 x 150 mm test tubes.

Table 7. Effect of medium nitrogen content on the rate of growth and the viability of cassava cultures stored *in vitro* at two temperatures[a].

Treatment			Viability[c]	
Temp. (°C)	Total N[b] (mM)	Elongation of shoots (cm/month)	Shoots per culture (no.)	Axillary buds per shoot (no.)
23	0	0.1	1.0	3.3
	10	0.1	1.0	5.0
	20	0.2	1.7	4.3
	40	0.4	2.0	6.7
	60	0.4	1.0	12.3
28	0	0.2	1.0	5.3
	10	0.4	1.0	10.3
	20	0.4	1.3	8.2
	40	0.6	2.0	8.3
	60	0.8	2.3	11.9

[a] Data averaged over 5-6 cultures per treatment.

[b] NO_3 + HN_4 nitrogen in the culture medium: MS + 0.02 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA with 3% sucrose and 0.8% agar, dispensed in 25 x 150 mm test tubes.

[c] Represents the culture's potential for micro-propagation.

Table 8. Source, amounts, storage-time intervals and frequency of sub-culture of cassava materials conserved *in vitro* under minimal growth conditions[a].

Source of materials	Amount of varieties (no.)	Storage-time interval (months)	Amount of varieties (no.)	Sub-culture (X-no.)
M Bra	599	0-6	704	0
M Col	531			
M Per	61	6-12	315	0.6
CIAT hybrids	50			
M Ven	30	12-24	255	1.2
M Mex	18			
M Cub	14	24-36	64	2.5
M Ecu	12			
Others	31	36-54	8	3.4
TOTAL	1,346[b]	TOTAL	1,346	

[a] Medium: MS + 0.02 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA, with 3% sucrose and 8% agar, dispensed in 25 x 150 mm test tubes. Conditions: temperature = 23°-24°C, illumination = 2000 lux, photoperiod = 12 hrs.

[b] Until November, 1982.

Table 9. Cassava material distributed in 1982 *in vitro* cultures from CIAT to other countries.

Country	Institution	Amount varieties (no.)
Mexico	INIA-Zacatepec	10
Nicaragua	IICA-MIDINRA	7
Malaysia	MARDI	9
Phillippines	Univ. Los Banos	6
Barbados	Min. Agric.	3
China	South China Inst. Bot.	6
Israel	Agric. Res. Org.	2
South Africa	Center Cassava Res.	12
	C.E.D.	12
U.S.A.	Univ. Florida	10
	Dekalb Agri. Research	3
	TOTAL	80

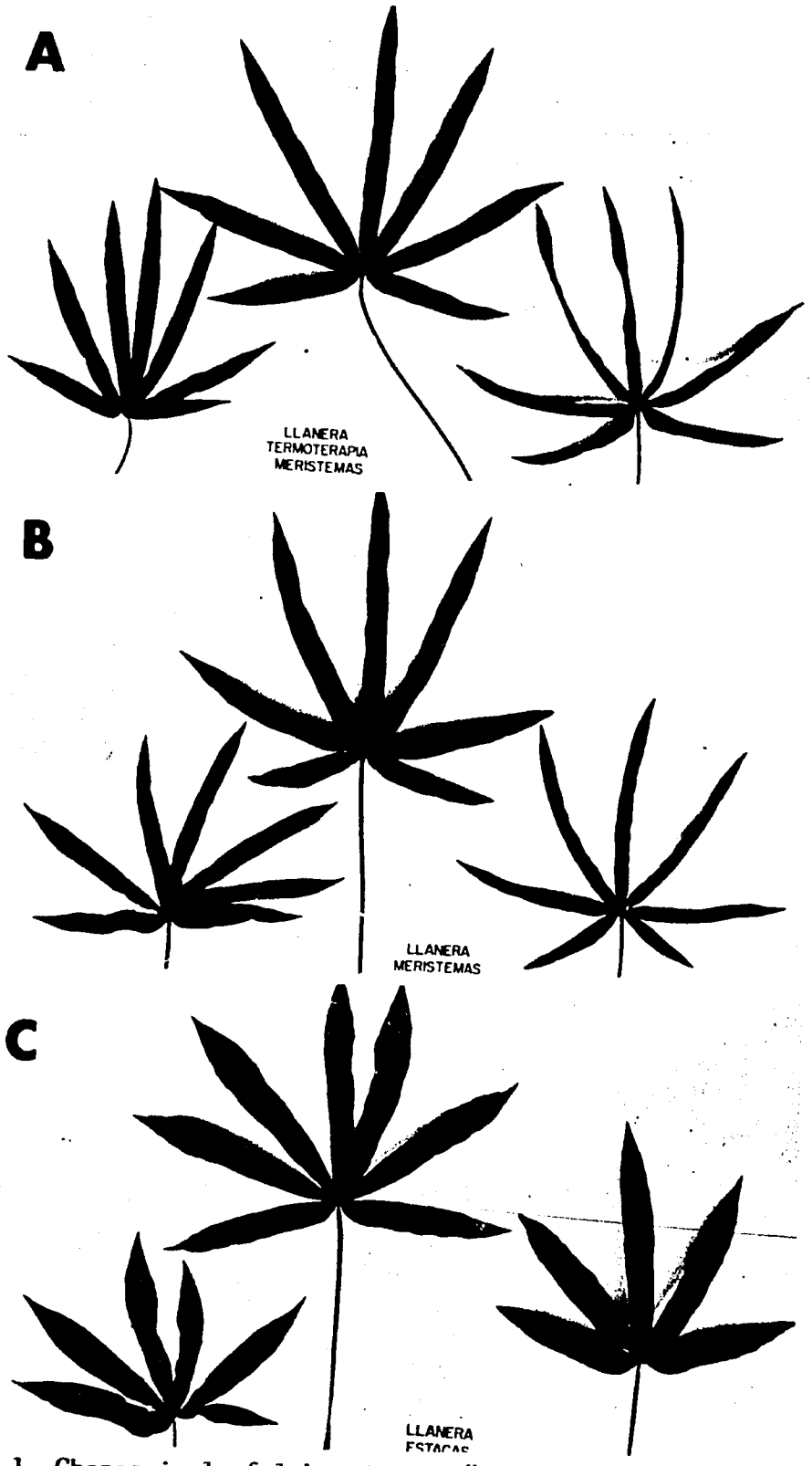


Figure 1. Change in leaf lobe size of "Llanera" regenerated from meristem culture. Left to right: lower, middle and upper leaves from four month old field -grown plants: (A) from meristem culture after heat therapy of stakes during sprouting; (B) from meristem culture without thermotherapy; (C) from stakes without heat therapy or meristem culture. Magnification of A, B, and C = X 0.2.

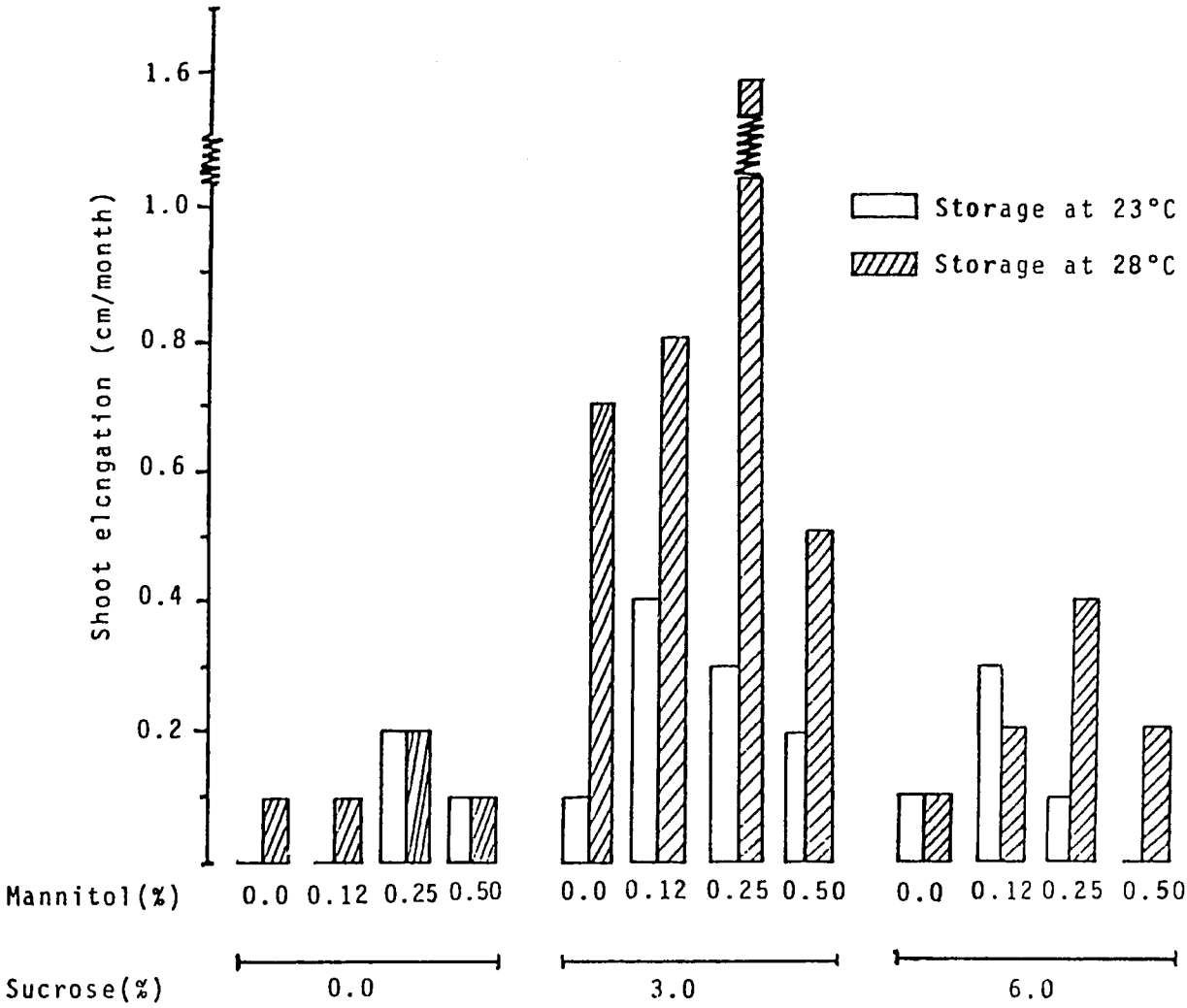


Figure 2. Effect of osmotic stress, provided by mannitol and sucrose in the culture medium, on the rate of growth of cassava stored in vitro at two temperatures.
-- Data averaged over six cultures per treatment.
-- Medium: MS + 0.02 mg/l BA + 0.1 mg/l GA + 0.01 mg/l NAA, with 0.8% agar, dispensed in 25 x 150 mm test tubes.

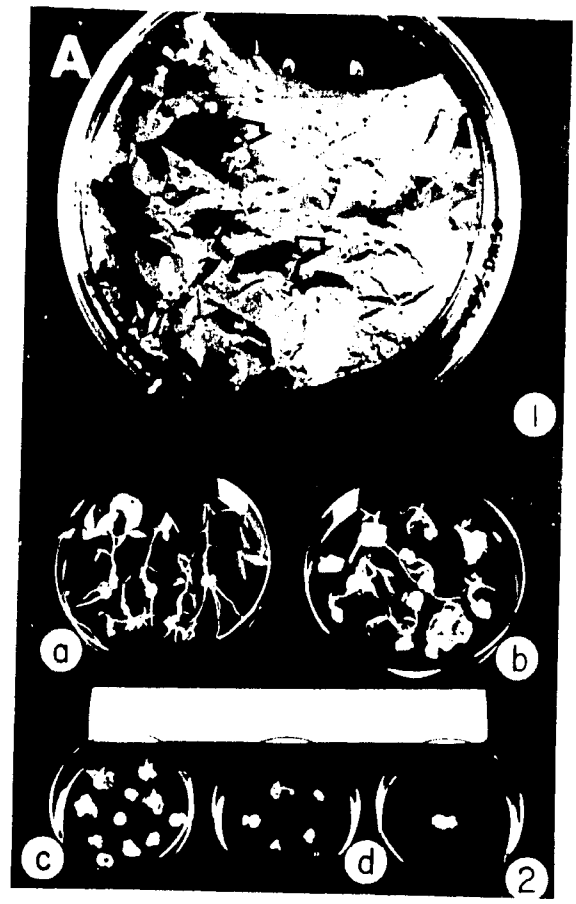


Figure 3. Cryopreservation of cassava meristems.
A: (1) meristem tips arranged for freezing on aluminum foil; (2) variability in the responses of meristems after retrieval from storage in liquid nitrogen: a and b show plant regeneration; c and d show leaf differentiation and callus formation, respectively.
(B): Potted cassava plants regenerated from meristems retrieved from storage in liquid nitrogen (-196ºC). (Photographs A and B supplied by Dr. K. K. Kartha, P. R. L., Saskatoon, Canada).

Personnel
(as of December 1982)

Senior staff
James H. Cock, Ph.D., Physiologist, Coordinator

Anthony C. Bellotti, Ph.D., Entomologist, Entomology
Guillermo G. Gómez, Ph.D., Nutritionist/Biochemist, Utilization
Clair Hershey, Ph.D., Plant Breeder, Plant Breeding
Reinhardt Howeler, Ph.D., Soil Scientist, Plant Nutrition and Soils
Kazuo Kawano, Ph.D., Plant Breeder, Plant Breeding (stationed in Rayong, Thailand)
Dietrich Leihner, Dr.agr., Agronomist, Cultural Practices
J. Carlos Lozano, Ph.D., Pathologist, Plant Pathology
John K. Lynam, Ph.D., Agricultural Economist, Economics
Julio César Toro, Ph.D., Agronomist, Agronomy

Visiting scientists
Rupert Best, Ph.D., Utilization
* Mabrouk El-Sharkawy, Ph.D., Physiology
* Shinichu Sawada, Ph.D., Plant Physiology

Visiting specialists
Ewald Sieverding, Dr.agr., Soil and Plant Nutrition
Christopher Wheatley, Ph.D., Utilization

Postdoctoral fellows
Upali Jayasinghe, Ph.D., Virology

Visiting research associates
* Jan Margaret Salick, M.S., Entomology

Research associates
* Alvaro Amaya, M.S., Germplasm
Rafael Orlando Díaz, M.S., Economics
Rafael Alberto Laberry, M.S., Plant Pathology
Benjamín Pineda, M.S., Plant Pathology
* Jorge Santos, M.S., Utilization
Octavio Vargas, M.S., Entomology

Research assistants
Bernardo Arias, Ing. Agr., Entomology
Darío Ballesteros, Ing. Agr., Soils (stationed in Carimagua)
Eitel Adolfo Burckhardt, Lic. Biol., Soils
Luis Fernando Cadavid, Ing. Agr., Soils
Fernando Calle, Ing. Agr., Germplasm
* Ernesto Celis, Ing. Agr., Agronomy
Carolina Correa, Lic. Econ., Economics
Julián Hernández, Ing. Agr., Soils (stationed in Carimagua)
Diego Izquierdo, Lic. Econ., Economics
Gustavo Jaramillo, Ing. Agr., Agronomy
* Lucy Kadoch, Lic. Biol., Physiology
Javier López, Ing. Agr., Cultural Practices
* Pedro Millán, Ing. Agr., Germplasm
Germán E. Parra, Ing. Agr., Physiology
Edgar Salazar, Ing. Agr., Cultural Practices
Mauricio Valdivieso, Zoot., Utilization
Ana Cecilia Velasco, Lab. Clin., Plant Pathology

* Left during 1982

Annual Report for 1983

Cassava Program

Centro Internacional de Agricultura Tropical

Previous Page Blank

Agroecological Studies

In recent years the cassava team has made effective use of their tentative classification (Cassava Annual Report 1982) of cassava growing regions into six edaphoclimatic zones. The need has long been felt, however, for a more rigorous quantitative approach to the classification and an investigation of the homogeneity of the zones in question. Clearly, any classification must reflect the response of cassava to the environment, and should not include more classes than can be easily managed in a decentralized breeding scheme. Nevertheless, the variability within classes must be recognized and so we envisage a hierarchic classification of environments. The results presented here are the first step toward this goal, and should not be taken even as a preliminary version of such a classification, but more as an investigation of the variability of environmental variation.

1. Production-area Definition: Cassava in Latin America

As a precursor to any work aimed at constructing a hierarchy of environments for cassava production, delineation of the actual production areas is indispensible. The aereal extent of cassava cultivation in Latin America has not been mapped until now, therefore the Agro-Ecological Studies Unit has produced initial small-scale ground maps in an attempt to define more precisely cassava-producing areas.

These maps have been compiled from a variety of data sources, ranging from agricultural censes of the 1970's and 80's to satellite imagery.

Each dot on the maps represents 1,000 hectares of cassava. It is true that local accuracy at such a small-scale is sacrificed, but data reliability doesn't as yet permit a more precise location of cassava. However, for the Agro-Ecological Studies Unit's purposes, the main objective in constructing these maps has been the spatial definition of production areas, and neither precise location of any one dot, nor the absolute quantities of the dot are of critical importance.

From these maps, it would appear reasonable to delineate the following major production areas, in terms of concentration and/or extent of cassava cultivation:

1. The northwest, or Caribbean Coast of Colombia.
2. The eastern-center of Colombia, notably Santander.
3. The southern Andean valleys of Colombia.
4. The northern coast/highlands of Venezuela.
5. The Belem and Sao Luis areas, northeast Brazil.
6. The Upland belt in northeast Brazil, west of the Coastal plain stretching from Recife to Salvador.
7. The Sao Mateus area, Espiritu Santo, and its westward extension, Brazil.
8. The Coastal area between Florianapolis and Laguna, Santa Catarina, Brazil.
9. The Porto Alegre area and westward extension, Rio Grande do Sul, Brazil.

Previous Page Blank

10. The Rio Uruguay Valley, southeast Brazil, and Missiones, Argentina.
11. The southern half of Paraguay.
12. Haiti and the Dominican Republic.
13. Cuba.

2. Progress in Defining Cropping Micro-Regions for Cassava

Delimitation of the spatial extent of cassava production has been succeeded by commencement of work on cropping micro-region definition.

Careful choice of the scale of the production area ground maps has facilitated full use of the FAO 1:5,000,000 soil maps (FAO soil map of the world, Volumes III and IV); since both sets of maps have the same scale and projection, the cassava maps were simply overlaid on the soil maps and the amount of cassava counted for each soil association, for the whole of Latin America.

Using the Papadakis Climatic Classification system, as used in the FAO map, climatic types have been assigned to each soil-cassava unit, the end result being the construction of a data-base suitable for the initiation of micro-region definition.

3. Results of a Preliminary Analysis of Cassava Micro-regions, based on Major Soil units (FAO) and Climatic Types

From the initial data-base, it has been possible to make a preliminary descriptive analysis of cassava production environments.

The tolerance of cassava to a wide range of physical environments is reflected by the fact that, as far as can be determined, it is found in 15 of the FAO major soil types within Latin America, and in 16 significantly different climatic environments.

The proportions of cassava as a percentage of total Latin American production found on each soil and climate type are given in Table 1 (keys to Table 1 are presented in Tables 2 and 3). This presents 114 different climate-soil environments (which in many cases will be spatially overlapping). Of these, five of them have one third of total Latin American cassava, and three-quarters of the total can be found in 27 of these environments. In terms of geographic areas, these environments do not represent specific regions, but rather separate facets of larger climatic or soil homogenes.

It would appear that, in terms of broad-scale physical environments, the following soil and climate types are of greatest importance for cassava production:

Soils: Acrisols (moderately leached and weathered, dystrophic "Savanna" soils) carrying almost 25% of Latin America's cassava.

Ferralsols (strongly leached and infertile oxic soils of the lowland tropics), with 20% of the cassava.

Luvisols (The entrophic clay soils of savanna and lowland tropics) with almost 20% of the cassava.

Climates: Humid Equatorial, carrying almost 25% of Latin America's cassava; Marine Savanna Tropical, with 15% of the cassava; Humid Subtropical, Humid Tierra Templada, Dry Tierra Templada, Continental Savanna Tropical and Continental Semitropical, with between 7 and 12% each of the cassava. Together these seven climatic units account for 90% of the cassava production by area.

Once we begin to assign physical qualities of significance to cassava, to such environments, the apparent simplicity of the above data disappears. When we consider that the 15 major soil units break down into 49 sub-units, and the 16 major climatic types into 68 sub-types, all with varying amounts of cultivated cassava, the complexities involved in defining the micro-regions for cassava become obvious. The solution to the problem lies in the use of statistical analysis to ascertain the relationships between the various sub-units, both within and between major soil and climate units. Our aim is to undertake a clustering of these production environments and logically simplify the apparent complexity, to erect a meaningful hierarchy of cassava environment types. (For a definition of the six edaphoclimatic zones, see Development Section, Table 3.)

4. Work Currently in Progress

Current work in agro-ecological studies on cassava is proceeding toward this fuller and more precise definition of the production environments, based on an expanded climatic data base suitable for statistical analysis, and on an agricultural suitability data-base for the FAO soil units, in accordance with soil properties of significance to cassava. Once these data requirements are fulfilled, the statistical analysis can proceed.

Classification of CIAT Installations, Regional Trials and On-Farm Test Sites, According to Climate and Soil Type

On the basis of our simplified breakdown of major climate and soil types on which cassava is grown in Latin America, we can classify the CIAT test-sites for the purpose of comparison and discussion.

The following is a list of test-sites for cassava in Colombia, with their respective climate and soil classes.

Site	Climatic type	Soil type
Florencia	1.1	Cambisols
Quilichao	1.2	Acrisols
Palmira	1.3	Fluvisols
Caribia, Fonseca	1.4	Luvisols
Carimagua	1.4	Ferralsols
Carmen de Bolivar	1.4	Vertisols
Media Luna	1.4	Fluvisols
Nataima	1.4	Kastanozems
Caicedonia, Popayan	1.7	Andosols
Rio Negro	1.7	Acrisols

(Corresponding soil-climate classes are shown boxed in Table 1).

Table 1. Percentage of Latin American cassava hectarage by the FAO soil unit and Papadakis climatic type (see Tables 2 & 3 for keys)

Climatic Soil type	Major soil group															Total
	A	B	F	H	J	K	L	N	P	Q	R	T	V	W	X	
1.1	8.5	0.3	7.5	0.2	4.3	0.1	0.4	0.6	0.2	1.8	0.1	0.1	0.3		*	24.4
1.2	0.7	0.1	0.2	*			0.1	0.1			*		*			1.3
1.3	1.6	2.2	2.1	0.4	0.2	*	5.4	2.2	*	*	0.1	*	1.1			15.4
1.4	2.6	0.3	1.1		1.4		4.3	0.3	*	1.3	0.1	0.1	0.8		*	12.4
1.5	0.1		0.4		0.2		1.2		*	0.6			0.3		0.3	3.1
1.7	1.5	0.7	3.0		*	0.5	1.2	0.8		0.1		1.1	0.5		*	9.5
1.8	0.2	0.3	2.4	0.3			5.0	0.3		0.1	0.3		0.7			9.5
1.9			*				0.2			*						0.3
2.2	*	0.3	0.6								*					1.0
2.3		1.2		*		0.1			*			*				1.3
2.4		0.1										*				0.1
3.4					0.3											0.3
4.1	3.7	0.1	0.4	3.0				0.2			0.9		0.1	1.8		10.2
4.3	3.8	*	0.4		1.2	*	0.2	0.2		*	*		0.4	0.7		7.3
4.4	0.7		0.7					2.0		0.2						3.6
5.3				*												
Total	23.6	5.5	19.0	4.0	7.6	0.8	18.0	6.8	0.3	4.3	1.7	1.5	4.2	2.5	0.4	

* = 0.1%

Table 2. Key to FAO Major Soil Units, with U.S. Soil Taxonomy equivalent orders/suborders.

A	Acrisols	(Ultisols)
B	Cambisols	(Inseptisols)
F	Ferralsols	(Oxisols)
H	Phaeozems	(Mollisols)
J	Fluvisols	(Fluvents)
K	Kastanozems	(Ustolls)
L	Luvisols	(Alfisols)
N	Nitosols	(Alfisols and Ultisols, younger and less leached)
P	Podzols	(Podzols)
Q	Arenosols	(Psamments)
R	Regosols	(Orthents and Psamments)
T	Andosols	(Andepts)
V	Vertisols	(Vertisols)
W	Planosols	(Mainly Alfisols with poor drainage)
X	Xerosols	(Mollic Aridisols)

Table 3. Key to climate types.

1.1	Humid Equatorial
1.2	Humid Tropical
1.3	"Marine" Savanna Tropical
1.4	Continental Savanna Tropical
1.5	Semiarid Tropical
1.7	Humid Tierra Templada
1.8	Dry Tierra Templada
1.9	Cool Winter Tropical
2.2	Low Tierra Fría
2.3	Medium Tierra Fria
2.4	High Tierra Fria
3.4	Marine Subtropical Desert
4.1	Humid Subtropical
4.3	Continental Semitropical
4.4	Marine Semitropical
5.3	Subtropical Pampean

Physiology

I. Water Relation.

A. Response to Air Humidity.

For the last few years the cassava physiology program has been conducting several studies in the laboratory as well as in the field to determine the response of cassava to water stress. Some of the results were reported previously and showed that cassava plants were extremely sensitive to air humidity (See "Stomatal Response in Cassava to Air Humidity", Physiology Section, Cassava Program Annual Report, 1982.) In controlled experiments in the laboratory, stomata were found to close in dry air where both rates of CO_2 uptake and H_2O loss decreased with increasing leaf-air vapor pressure differences (VPD). This type of response was observed in well-watered and water-stressed plants.

Here, we present some field data that confirm the laboratory observations. The cultivar M Col 1684, which was found to be sensitive to air humidity, was grown in the 1982/83 season at Santander de Quilichao in the newly constructed drainage lysimeter. The experiment consisted of two planting dates (June 14 and Sept. 14) and the lysimeter was covered with a black plastic sheet to exclude rainfall from Dec. 14, 1982 to March 15, 1983. One half of the lysimeter received no water during that period while the other half was regularly irrigated (underneath the plastic) to keep the soil reasonably wet (Ψ_{soil} above - 0.5 M Pa). In addition to growth and yield data, leaf photosynthetic rates as well as leaf resistance to water vapor were measured in the field several times a day and repeated for several days during the water stress period.

The rates of single leaf CO_2 uptake (photosynthesis), H_2O (transpiration) and the water use efficiency (WUE = CO_2 uptake/H_2O loss) are presented as a function of VPD in Figures 1, 2, 3. It is clear from the present data that M col 1684 strongly responded to changes in air humidity in the field. The CO_2 uptake rates decreased with increases in VPD in both stressed and non-stressed plants indicating closure of stomata at a higher VPD. Such response was again reflected in the transpiration rates, where it increased with VPD up to a certain level (between 2.5 - 3.0 K Pa) and then decreased with further increase in VPD. The stomata were, however, not only influenced by VPD, but also by Ψ_{soil} as transpiration was always less at lower values of Ψ_{soil}. The single leaf water use efficiency (WUE) showed curvilinear reduction over ranges of VPD. Both stressed and non-stressed plants responded similarly.

The general conclusion drawn from these data is that cassava cultivars like M Col 1684 respond strongly to changes in the atmospheric humidity irrespective of soil water conditions. In other words, cultivars with this type of response, with unlimited soil water may grow less in an environment with low atmospheric humidity than in one with relatively high humidity.

The accumulated dry matter production at six months of the M Col 1684, planted at two different times of the year in 1982, and under conditions of both unlimited and limited soil water, is shown in Table 1. The daily ambient air vapor saturation deficit (VSD) was different during the first three months of crop growth between the two planting dates. With the June 14 planting date, the plants experienced a relatively higher vapor saturation deficit during their first three months of growth than the ones planted in September 14 of the same year (2.0 and 1.4 K Pa during the periods June-Sept. and Sept.-Dec., respectively). Although the plots planted on June 14 were adequately supplied with water (no apparent water stress), they yielded less than the plots planted on Sept. 14 of the same year which were subjected to a long period of soil water stress (three months without watering). With respect to the June planting, the differences in total dry weight and root dry yield were 19% and 11% respectively (Table 1, 2). Furthermore, when the dry matter production was compared for the June 14 - planted plots versus the Sept. 14 - planted plots but without soil water stress, the differences in yield were obviously greater. The Sept. 14 - planted plots without soil water stress outyielded the June 14 - planted plot (16.9 t ha^{-1} total yield and 11 t ha^{-1} dry root yield as compared to 9.1 t ha^{-1} and 4.7 t ha^{-1}). This large difference of about 85% in total yield and about 130% in root yield in the absence of soil water stress in both plots must had been due, at least partially, to differences in atmospheric humidity during the first three months of crop growth. It appears that stress due to atmospheric conditions (high evaporative demand) overrides the soil water condition in this case. Whether soil water is limited or not, the stomatal response to changes in atmospheric humidity is a major limiting factor. Table 3 shows the rate of photosynthesis of field-grown M Col 1684 as a function of both soil water potential (ψ_{soil}) and leaf-air vapor pressure deficit (VPD). At VPD lower than 2 K Pa, the leaf photosynthetic rate decreased little with decreasing soil water potential and remained fairly unchanged down to ψ_{soil} of - 1.0 M Pa. On the other hand, with VPD higher than 2.5 K Pa, photosynthesis dramatically decreased with decreasing soil water potential. At wet soil ψ_{soil} 0.05 M Pa) photosynthesis decreased by 35% of the maximum rate, while at dry soil (ψ_{soil} = - 1.0 M Pa) it decreased by 80% (Table 3).

From these data presented in this report and others in previous reports, it is clear that varietal responses to changes in atmospheric humidity is a critical factor in cassava production under different water regimes. Currently, the laboratory is screening several cassava cultivars from different habitats for their responses to air humidity.

B. Varietal Response to a Long Period of Water Stress:

During the summer of 1983 (September), a field observation at Santander de Quilichao revealed a marked difference in the amount of leaf area retained, and consequently, in the percentage of intercepted light between the field-grown crops of M Col 1684 and the hybrid CM 507-37. The hybrid maintained a greater leaf area than the cultivar M Col 1684 despite a long period of summer water stress. The two cultivars were planted for commercial production on April 15, 1983, and received no water other than natural rainfall. This year was exceptionally dry during the summer periods as indicated by the rainfall pattern (Figure

4). From the beginning of June, when the plants were only 45 days old, to the first week of October (a period of about 130 days) the total amount of rainfall was 181 mm. This amount of rainfall fell far below the potential evaporation.

Compared with M Col 1684, the hybrid CM 507-37 maintained a higher leaf area index (1.1 and 0.4), a higher percentage of intercepted light (70% and 43%), higher leaf water potential (-0.6 and -1.0 M Pa), narrower stomatal aperture (2 μm and 3 μm) and lower leaf conductance (2.2 mms^{-1} and 2.8 mms^{-1}) (Table 4).

Differences in growth and dry matter production were also apparent between the two cultivars (Table 5). On a total dry matter basis, the hybrid CM 507-37 outyielded M Col 1684 by 19% (8.0 t ha^{-1} and 6.7 t ha^{-1}). Dry root yield was almost the same in both cultivars (3.6 t ha^{-1} and 3.7 t ha^{-1} for CM 507-37 and M Col 1684, respectively). On the other hand, dry weight of stems and leaves were much greater for CM 507-37. It appears that the extra dry matter in CM 507-37 was used to produce more leaves and stems.

The patterns of soil water depletion at the time of harvest and after 130 days of severe water stress differed between the two cultivars (Table 6). The upper one meter of the soil profile was more or less similarly depleted by both cultivars. On the other hand, CM 507-37 had drawn more water from soil layers deeper than one meter (about 3% per volume of soil more than M Col 1684). These patterns of soil water depletion coincided with different patterns of root distribution and root density as shown by the data in Table 7. The hybrid CM 507-37 had finer and more concentrated root density in the upper layer of soil and its root system penetrated into deeper soil layers (perhaps below the two meter depth) than M Col 1684. The more intensive and extensive root system of CM 507-37 was advantageous in terms of its ability to withdraw water from larger and deeper volumes of soil. This might partially explain the higher leaf area index retained by plants under severe and prolonged water stress. Differences in rooting characteristics at an early germinating stage were sought and it was found that CM 507-37 rooted better within the first three weeks of germination (see photograph, Figure 5). Currently, these two cultivars are planted in the field drainage lysimeter at Santander de Quilichao to study their comparative responses to an artificially imposed water stress period during the early part of their growth cycle.

C. Estimation of Crop Water Use

The amount of water actually used to successfully produce a crop depends largely on a complex of plant, soil and climatic factors. One way to estimate crop water use or the crop water requirement is to relate the amount of water lost through plant transpiration to dry matter production or the so-called "crop transpiration ratio". Presented here are some data of field-grown cassava cultivars from different years and under various soil water conditions (Table 8). Crops were grown either for experimental or production purposes. Total dry biomass production, estimated water consumption, the transpiration ratio and the average daily water use are shown in Table 8.

The estimated crop transpiration ratio (units of water/unit biomass) ranged from 330 to 470 across cultivars and soil water conditions. The daily average water use at Santander de Quilichao ranged from 1.5 mm per day under severe and prolonged soil water stress up to 3 mm per day with unlimited soil water. The regression lines and the equations for the daily biomass production as a function of daily water use, the total biomass production as a function of accumulated water use and the total biomass as a function of the transpiration/pan evaporation ratio are given in Figures 6, 7 and 8, respectively. All these relationships showed highly significant correlations (values of r^2 were 0.8 and 0.9). Although the data are limited, the strong positive correlation coefficients indicate the dependency of the rate of yield production on the amount of water transpired. Furthermore, the transpiration/pan evaporation ratio seems to be a reliable index for predicting rates of cassava crop production.

A very crude approximation of cassava crop water use was tried on the basis of a measured average leaf transpiration rate over a range of leaf conductances to water vapor and leaf area index. Table 9 shows the estimated crop water use as a function of time after planting for six cultivars (CM 91-3, M Col 22, M Col 638, M Col 1684, M Mex 59, M Ven 218) grown at high soil fertility at Santander de Quilichao (1982/83). Evaporation from bare soil was accounted for. The total values for soil evaporation and crop transpiration were 78 mm and 807 mm, respectively. The total dry matter production (average of the six cultivars) was 22.5 t ha^{-1}. The crop transpiration ratio with and without soil evaporation were 393 and 359, respectively. The average daily water use was 2.5 mm. These values are within the range given in Table 8, and again suggest a low transpiration ratio and that cassava may produce at an average rate of 25 kg dry matter per hectare - mm of water used. Also, the peak period of cassava water use appears to be between the fourth and eighth month of the growing cycle coinciding with the highest values of leaf area index.

To compare the water use efficiency of cassava with other field crops, values of crop transpiration ratio from published reports are given in Table 10. The relatively low transpiration ratio of cassava lies within the range of most of the highly productive C_4 tropical grasses such as corn, sorghum and millet. The C_4 data are, however, taken from plants growing at their maximum efficiency and not throughout their growth cycle as in the case of the cassava estimates. It should, however, be noted that the high water use efficiency of cassava is also associated with a lower maximum productivity level under good conditions of water availability.

II. Carbon Dioxide Compensation Point of Cassava.

The relatively high apparent photosynthetic rates recently reported by this section for several cassava cultivars (40 $\pm$ 5 mg CO_2 $dm^{-2}h^{-1}$), and the low rates of respiratory CO_2 release in intense light and CO_2 - free air (4 $\pm$ 2 mg CO_2 $dm^{-2}h^{-1}$) all pointed to the relatively high photosynthetic efficiency of the cassava leaves. These rates of apparent photosynthesis with thin and hypostomatus leaves tend to be at the higher end of the CO_2 uptake range of most known C_3 plants. One of the

characteristics commonly used to differentiate between plants with different photosynthetic pathways is the so-called CO_2 compensation point (the CO_2 concentration in the air surrounding the leaves at which apparent photosynthesis is zero). We recently measured the apparent photosynthetic rates of leaves of M Col 1684 was recently measured at different concentrations of CO_2 in external air and under intense light and optimum leaf temperature. Furthermore, the transpiration rates of the same leaves were measured simultaneously. The leaf resistances to water vapor were determined from these measurements and then were converted in terms of leaf resistance to CO_2 diffusion. The resistance values to CO_2 diffusion along with the corresponding apparent photosynthetic rates at each level of CO_2 concentration in the air were used to estimate the internal CO_2 concentration inside the stomatal cavity. Figure 9 illustrates the apparent photosynthetic rate as functions of the external CO_2 concentration as well as the estimated internal CO_2 in the leaf. Both relationships were linear over the CO_2 range studied with high correlation coefficients (r^2 values were 0.9 and 0.8). The intercepts of both regression lines with the X axis (the CO_2 concentration) were almost identical. The CO_2 concentration values at zero apparent photosynthesis calculated from the corresponding regression equations were 22 ppm and 26 ppm for the external CO_2 and the internal CO_2 curves, respectively. This very close agreement between the two values is really striking and their average value may be considered as a very good estimate of the CO_2 compensation point of M Col 1684. Compared to other crop species, the CO_2 compensation point of cassava is much lower than the values commonly found with C_3 crops (40 - 100 ppm CO_2 at high light and 25°C), and higher than the CO_2 compensation point of C_4 crops (5 - 10 ppm CO_2). The so-called intermediate (C_3 - C_4) plants of some monocots (as the panicoide group) and some dicots possess CO_2 compensation points less than 30 ppm and greater than 15 ppm CO_2. However, it is unknown at present if cassava behaves and possesses some other characteristics (such as biochemical ones) similar to C_3 - C_4 intermediate plants.

III. Photoperiodic Responses of Cassava.

In previous reports it was shown that cassava yields are reduced by long days (See "Photoperiod Response", Physiology Section, Cassava Program Annual Report, 1982.) Cultivars such as M Col 22 were less responsive to long days than cultivars such as M Col 1684. The responsive cultivars showed a marked reduction in the amount of assimilates directed to root production with no appreciable change in total dry matter yield. Thus, the main effect of long days was related to a reduced harvest index. Based on these observations, it was deemed important to determine at what stage in the crop growth cycle the effects of long days were expressed so that screening techniques might be developed for insensitive varieties. The field photoperiod studies at CIAT, Palmira, continued using the more sensitive cultivar M Col 1684. Plots were planted at different three month intervals on Sept. 17, 1981, Dec. 17, 1981, and March 17, 1982, to obtain differential plant ages while imposing the long day treatments. On March 17, 1982, and up to June 17, 1982 (a three month period) half of the plots were exposed to a 16 hr day with the aid of an artificial light system. The second half of the plots were left under normal daylength of about 12 hrs. Therefore,

the light treatments were imposed at ages of 0-3 months, 3-6 months, and 6-9 months. Data on growth and dry matter production were taken at 3, 6 and 9 months. Some of the data are presented in Figures 10 to 15. The extended day length treatment tended to increase plant height over the normal day plants when light was imposed from 0-3 and 3-6 months of age (Figure 10). In both treatments, the effects of long days persisted after the termination of the light period and was apparent at the final harvest at nine months. The light treatment at 6-9 months apparently did not affect plant height, the reduced plant height under light was initially observed before the start of the long day treatment.

Total dry matter yield showed no significant differences due to light treatments at 3-6 and 6-9 months (Fig. 11). On the other hand, the light treatment at the earliest stage from 0-3 months significantly increased the total dry matter yield at nine months. This difference in total dry matter production between a 16 hr day and normal day length was associated with differences in leaf area indices between the 6 and 9 month period (1.3 - 1.6 and 0.8 - 0.9 for plants of 16 hr day and normal day length, respectively) (Figure 12). At the end of the light period at three months age, both plants of the 16 hr day and normal day length retained similar leaf area indices (2.4 and 2.3). Irrespective of day length treatments, the planting date of Sept. 17, 1981, showed a superior total dry matter yield at nine months of age over the other two planting dates (Dec. 17, 1981 and March 17, 1982). This difference in total dry matter production was associated with differences in retained leaf area indices during the final six month period of the crop growth cycle. During the period, plants from the September planting retained more leaf area than those of the December planting which in turn retained more than the March planting. The fresh and dry root yields were affected by the extended day length at 0-3 and 3-6 months of age but not at 6-9 months of age (Figures 13, 14). The 16 hr day length at 0-3 month of age significantly reduced fresh and dry root yield at the 3 and 6 month harvests, but later yields at the nine month harvest increased up to the level of the normal day length plants. This recovery in root yield was associated with higher leaf area index resulting in greater total dry matter only partially offset by a lower harvest index (Figure 15).

As with the total dry matter, the 16 hr day length treatment at 6-9 months did not affect the fresh and dry root yield. It appears that at the age of six months or older, cassava plants do not respond to changes in day length whereas at younger ages long days tend to decrease the harvest indices and hence root yields (Figure 15). Due to greater leaf area indices after long days yields may later recover.

The results of this trial indicate that selection for insensitive lines could be achieved under long days either from 0-3, 3-6 months and harvesting them at six months of age.

IV. Response of Cassava to Fertility.

Six cassava clones of widely different plant types were grown at medium and high fertility. The yield potential of these varieties was estimated from independent trials at CIAT and Quilichao under high fertility conditions. The high yield potential clones CM 91-3 and M Col

1684 had intermediate peak LAI (3.6 - 4.7) under high fertility conditions whereas the lower yield potential clones had either lower (3.1) or intermediate to high LAI's (4.5 - 7.0). The lower yield potential clone M Col 22 had a high harvest index and hence its yield was low due to reduced total dry matter production resulting from insufficient LAI. The other lower yield potential clones had sufficient LAI for high total dry matter production, however, the low harvest index resulted in reduced yields. The two higher yield potential clones M Col 1684 and CM 91-3 maintained a good balance between leaf growth and root growth.

Reduced fertility tends to decrease top growth, hence LAI, and consequently increases harvest index. Hence, it might be expected that the more leafy low yield potential types would yield more at lower fertility levels. This did not occur, CM 91-3 and M Col 1684 were the highest yielding clones at the intermediate fertility level as well as at high fertility. Looked at in another way the highest yield potential clones were the most responsive to (Figure 16) and also were the highest yielders at medium fertility.

This suggests, in conclusion, that plant types that yield well at high fertility will also yield relatively well at low fertility. It also appears true, that varieties that yield well at lower fertility will be highly responsive to fertilizer.

Table 1. Effects of Soil Water Stress and Vapor Saturation Deficit of ambient air (VSD) on cassava productivity. C.V. M Col 1684grown in drainage field-lysimeter at Santander de Quilichao.

Date of Planting	Average daily VSD during the first 3 months of growth	Soil water condition	Dry matter production and its partitioning among plant parts at 6 months of age				
			Roots	Stems	Leaves	Stakes	Total Yield
					Kg ha^{-1}		
June 14, 1982	2.0 K Pa From June 14 to Sept. 14, 1982	No Soil Water Stress from planting up to day 180	4675	2238	1544	663	9120
					%		
			51	25	17	7	100
					Kg ha^{-1}		
Sept. 14, 1982	1.4 K Pa From Sept. 14 to Dec. 14, 1982	Soil water stress from day 90 to day 180	5175	4113	763	813	10864
					%		
			48	38	7	7	100
					Kg ha^{-1}		
Sept. 14, 1982	1.4 K Pa From Sept. 14 to Dec. 14, 1982	No soil water stress from planting up to day 180	10975	3650	1363	913	16901
					%		
			65	22	8	5	100

Table 2. % Change in total dry matter and root yield due to changes in soil water, and air humidity. C.V. M Col 1684.

Date of Planting	Average daily VSD during the first 3 months of growth	Soil Water Condition	Roots yield	Total yield
			%	
June 14, 1982	2.0 K Pa From June 14 to Sept. 14	No soil water stress from planting up to day 180	100	100
Sept. 14, 1982	1.4 K Pa From Sept. 14 to Dec. 14	Soil water stress from day 90 to day 180	111	119
Sept. 14, 1982	1.4 K Pa From Sept. 14 to Dec. 14	No soil water stress from planting up to day 180	235	185

Table 3. Effects of air humidity and soil water on apparent leaf photosynthesis % reduction in humidity (mg CO_2 dm^{-2} hr^{-1}) of CV M Col 1684 grown in a field-lysimeter 1982/83.

Leaf-air vapor pressure deficit (VPD) K Pa	Soil Water Potential within 80 cm depth Ψ_{soil} M Pa		
	<- 0.05	- 0.2	- 1.0
< 2.0	35(0)	29(17)	29(17)
>2.5	23(39)	18(49)	7(80)

Table 4. Leaf parameters of field grown plants measured the first week of October, 1983.

Cultivar	Leaf resistance S Cm^{-1}	Leaf conductance Cm S^{-1}	Stoma aperture μm	Leaf Water potential M Pa Ψ_L	LAI	Intercepted light (%)
M COL 1684	4.6	.283	3	- 1.0	0.4	43
CM 507-37	8.0	.225	2	- 0.6	1.1	70

Table 5. Production of 6 month old field grown crops. Planting date: April 15, 1983 at Santander de Quilichao.

	M COL 1684						C M 507-37						
	Root	Stake	Stem	Leaves	Fallen leaves	Total Weight	Root	Stake	Stem	Leaves	Fallen leaves	Total Weight	(%) Increase in total dry matter
Fresh Weight Kg ha^{-1}	10190	1509	5611	518	-	17828	9336	1567	7261	1750	-	19914	-
Dry Weight Kg ha^{-1}	3680	549	1513	206	775	6723	3639	623	2106	641	973	7988	19

Table 6. Soil Water content at harvest time (first week of October 1983). Planting date: April 15, 1983 at Santander de Quilichao.

	M COL 1684			CM 507-37		
	H_2O %			H_2O %		
Soil depth	Wet Weight	Dry weight	Volume	Wet Weight	Dry weight	Volume
0 - 20 cm	16.4	19.7	25.6	15.8	20.7	26.9
20 - 40 cm	23.0	30.2	39.2	22.3	28.7	37.3
40 - 60 cm	27.9	38.9	50.5	27.2	37.6	48.8
60 - 80 cm	29.6	42.1	54.7	29.8	42.7	55.5
80 - 100 cm	31.1	45.2	58.7	31.0	45.1	58.6
00 - 120 cm	32.0	47.3	61.5	31.7	46.6	60.5
120 - 140 cm	33.4	50.2	65.2	32.5	48.3	62.7
140 - 180 cm	34.6	53.0	69.0	33.0	48.7	63.3
Mean ($\bar{X}$)	28.5	40.8	53.0	28.0	39.8	51.7

Table 7. Patterns of root distribution and root density of six month old field grown plants of M Col 1684 and CM 507-37. Planting date: April 15, 1983 at Santander de Quilichao. Volume of soil sample = 390 cm^3.

	M COL 1684			CM 507-37		
Soil depth	Dry weight mg cm^{-3}	Length cm cm^{-3}	Diameter mm	Dry weight mg cm^{-3}	Length cm cm^{-3}	Diameter mm
0 - 20 cm	.070	.451	.970	.086	.712	.520
20 - 40 cm	.019	.190	.923	.020	.194	.576
40 - 60 cm	.006	.128	.688	.009	.128	.727
60 - 80 cm	.007	.069	.670	.004	.067	.553
80 - 100 cm	.007	.051	.715	.005	.067	.481
100 - 120 cm	.005	.051	.634	.004	.057	.488
120 - 140 cm				.001	.025	.504
160 - 180 cm				.004	.053	.554
180 - 200 cm				.004	.059	.536

Table 8. Estimated crop water use of field grown cassava.

Cultivar	Growth period (days)	Growth season	Water stress conditions	Estimated water consumption (mm ha^{-1})	Total dry biomass Kg ha^{-1}	Transpiration ratio unit water / unit biomass	Average daily water use mm day^{-1}(a)
M MEX 59 (d)	306	1979/1980	Rainfall was excluded (f) from day 109 to day 182	839 (c)	17969	467	2.7
M MEX 59 (d)	306	1979/1980	No water stress	901 (b)	20684	436	2.9
M COL 1684 (e)	190	1982/1983	Rainfall was excluded (f) from day 90 to day 190	432 (c)	10875	397	2.3
M COL 1684 (e)	190	1982/1983	No water stress	559 (b)	16900	331	2.9
M COL 1684 (e)	283	1982/1983	Rainfall was excluded (f) from day 183 to day 283	668 (c)	16525	404	2.4
M COL 1684 (e)	283	1982/1983	No water stress	832 (b)	21987	378	2.9
M COL 1684 (d)	178	1983	Natural water stress, total rainfall from day 45 to day 178 was 181 mm	271 (c)	6723	403	1.5
CM 507-37 (d)	178	1983	Natural water stress, total rainfall from day 45 to day 178 was 181 mm	297 (c)	7988	372	1.7

(a) Estimated average daily water use of cassava (six cultivars) on the basis of single leaf transpiration rate determined in laboratory under intense light, wet soil (pots), and at two equal periods of leaf-air vapor pressure difference (VPD). 2.6

Continued.

Table 8....

b Maximum possible evapotranspiration (MPET) calculated as : (0.7 x evaporation rate from water pan).

c Amount of soil water depletion adjusted to maximum possible evapotranspiration (MPET) during periods of abundant rainfall or irrigation.

d Field grown crops at the Santander de Quilichao Field Station (3° 0 6' N; 76°31' W, 990 masl) - CIAT, Colombia.

e Field lysimeter grown crops (drainage field lysimeter 30 m x 15 m x 2.3 m; was constructed in 1981/1982 at the Santander de Quilichao Field Station, CIAT; the bottom of the lysimeter was covered with 3 mm layer of black asphalt and with drainage tubes 3 m wide installed below 10 cm layer of sand and gravels; the tubes drain excess water to a nearby 2 m x 2 m x 1 m reservoir; the lysimeter was protected by a 1 m high brick wall and divided into two equal parts of 15 m x 15 m x 2.3 each).

f Rainfall exclusion was achieved by installing black plastic sheeting over the soil surface.

Table 9. Estimated crop evapotranspiration of field grown cassava (average of six cultivars) as a function of time after planting at Santander de Quilichao (1982 - 1983).

Period after planting Month	Leaf Area Index (LAI)	Evaporation from soil (mm)	Crop Transpiration (mm)	Crop evapo-transpiration (mm)	Daily water use (mm)
0 - 0.5	0	13**	0	13	0.86
0.5 - 1	0.1	13	2*	15	1.00
1 - 2	0.3	26	11	37	1.23
2 - 3	0.9	13	32	45	1.50
3 - 4	1.9	0	68	68	2.26
4 - 5	3.0	0	106	106	3.53
5 - 6	4.1	0	145	145	4.83
6 - 7	4.0	0	142	142	4.73
7 - 8	2.7	0	95	95	3.16
8 - 9	1.9	0	68	68	2.26
9 - 10	1.7	0	59	59	1.96
10 - 11	1.3	0	47	47	1.56
11 - 12	0.9	13	32	45	1.50
Total 12 month	1.9	78	807	885	2.45

Average total dry matter production of the 6 cultivars at high soil fertility and 12 month growing period. C.V. CM 91-3, M Col 22, M Col 638, M Col 1684, M Mex 59, M Ven 218.	22.5 T ha^{-1}
Crop transpiration ratio : $\left(\frac{8850 \text{ tons } H_2O}{22.5 \text{ tons dry matter}}\right)$	393

* Crop transpiration = (1 g H_2O dm^{-2} leaf area h^{-1}) (LAI) (12 h).

** Evaporation from soil was taken as the X axis intercept of the curve of total yield as a function of Transpiration / Pan evaporation ratio (Fig. 8) = 0.86 mm day^{-1} when the soil is not completely covered by the crop.

TABLE 10. Transpiration ratio (Units water used/Unit dry matter) for cassava as compared with some other crop species.

Crop Species	Photosynthetic pathway	Condition of growth	Transpiration ratio	Source
Cassava	C_3	Field grown crop	(370 / 400)	
Corn	C_4	Field grown rainfed	372	Carlson *et al* (1959)
Corn		Field grown irrigated	433	" " " "
Corn		Container	351	Briggs and Shantz (1914)
Millet	C_4	Container	338	" " " "
Sorghum	C_4	Lysimeter rainfed	333	Hanks *et al* (1968)
Sorghum		Lysimeter	321	" " " "
Sorghum		Field grown irrigated	344	" " " "
Sorghum		Field grown rainfed	335	" " " "
Wheat	C_3	Container	488	Briggs and Shantz (1914)
Wheat		Field grown rainfed and fertilized	500	El-Sharkawy *et al* (1977)
Oats	C_3	Container	562	Briggs and Shantz (1914)
Barley	C_3	Container	529	" " " "
Sugarbeets	C_3	Container	394	" " " "
Potatoes	C_3	Container	624	" " " "
Alfalfa	C_3	Container	832 - 1068	" " " "
Pineapple	CAM	Lysimeter grown	50	Ekern (1965).

Table 11. Characteristics of six cassava cultivars grown at high and medium soil fertility levels and yield potential estimated in different trials at high fertility level.

Clone	Fertility	Yield potential dry t /ha	Yield dry t/ha	Harvest index	Peak LAI	Average LAI
M Col 22	High	11.5	10.1	0.71	3.1	1.3
	Medium		7.5	0.78	1.7	0.7
CM 91-3	High	14.1	15.9	0.61	4.7	2.0
	Medium		11.2	0.66	2.9	1.3
M Col 1684	High	13.4	16.5	0.73	3.6	1.6
	Medium		9.3	0.71	2.9	0.9
M Mex 59	High	9.4	9.1	0.50	5.6	2.6
	Medium		8.2	0.70	3.2	1.2
M Ven 218	High	9.2	8.5	0.47	4.5	1.8
	Medium		9.1	0.61	3.0	1.1
M Col 638	High	8.1	9.2	0.55	7.0	2.4
	Medium		6.4	0.64	2.7	1.1

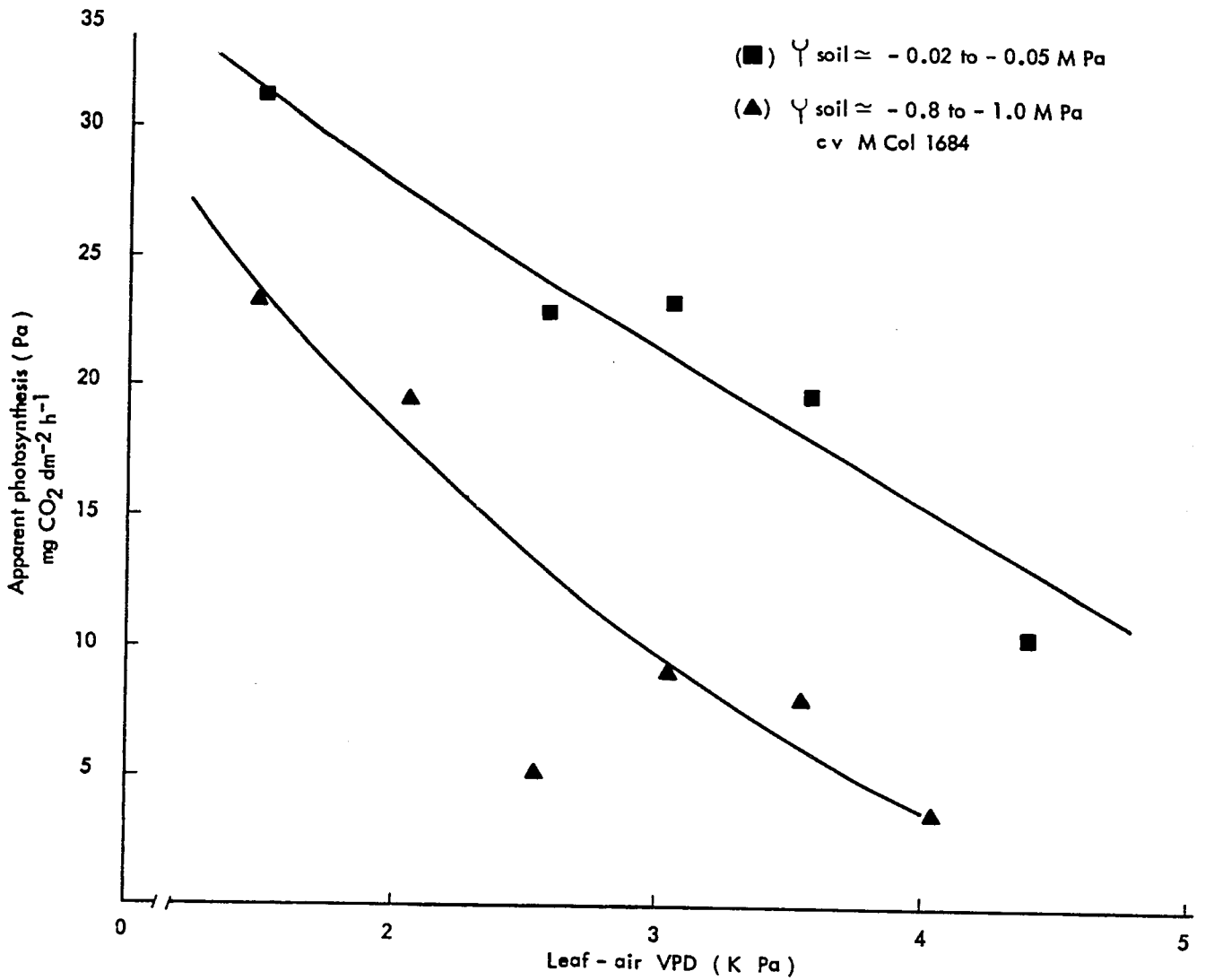


Figure 1. Response of leaf apparent photosynthesis to soil water and air humidity.

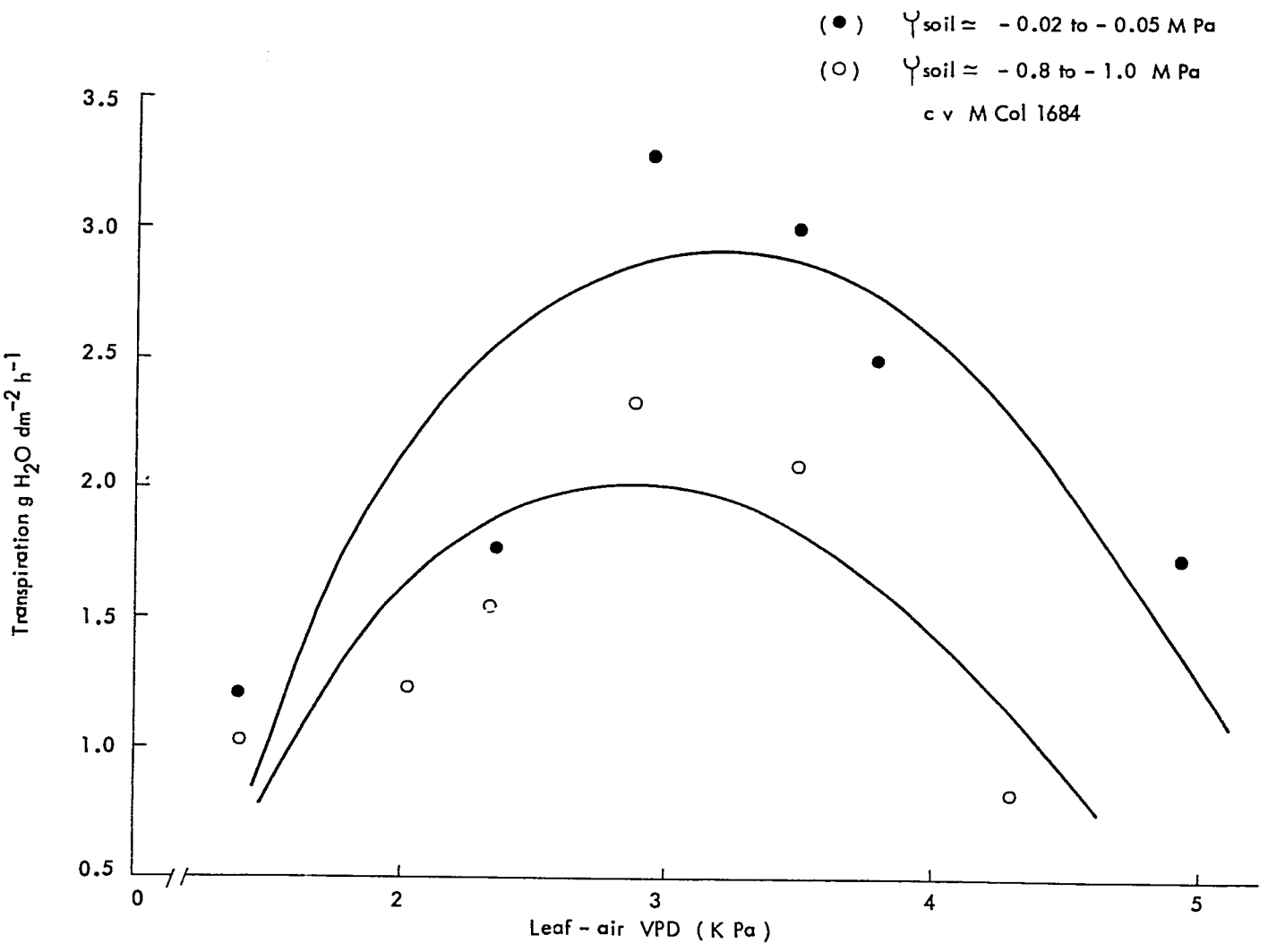


Figure 2. Response of leaf transpiration to soil water and air humidity.

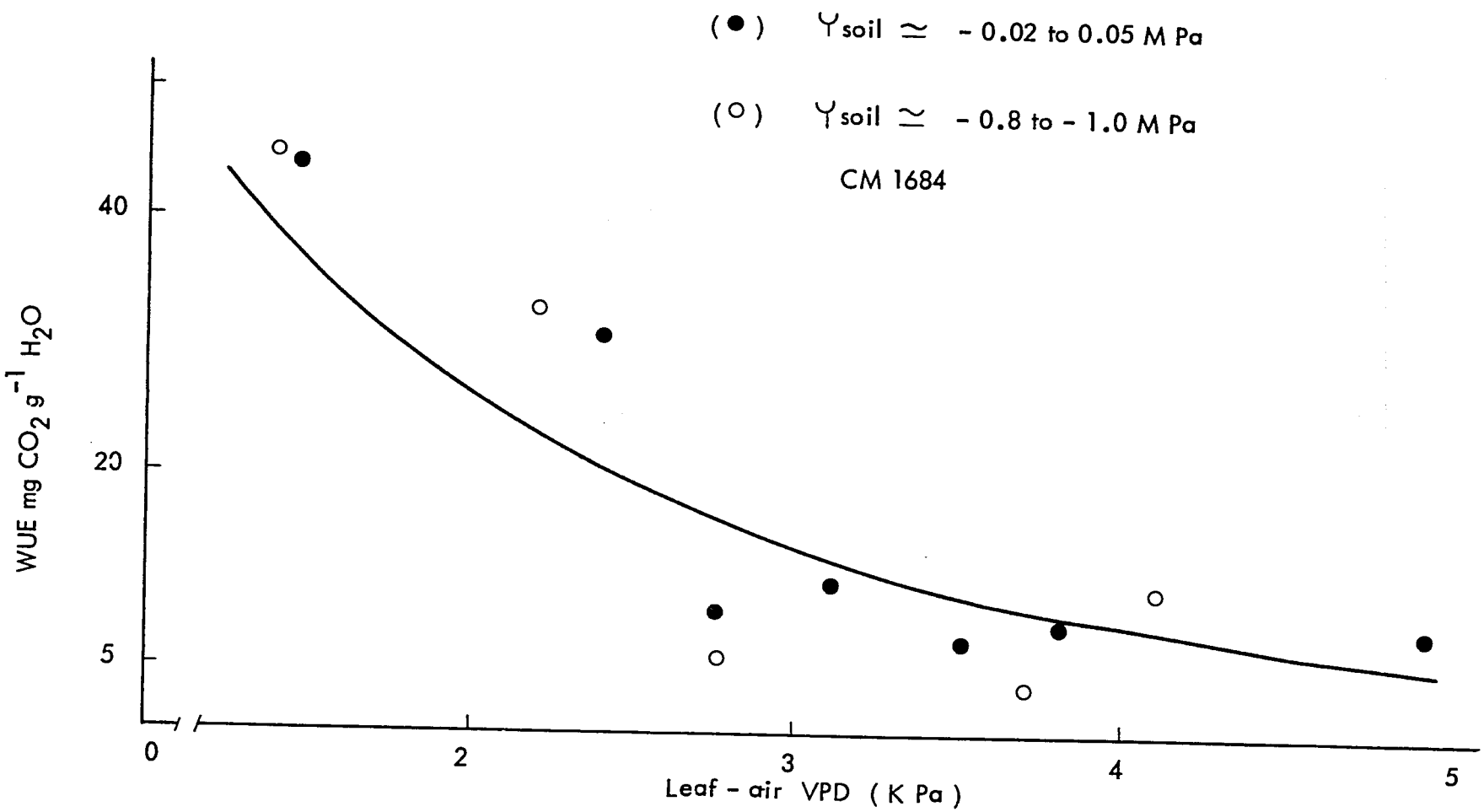


Figure 3. Leaf water use efficiency as affected by soil water and air humidity.

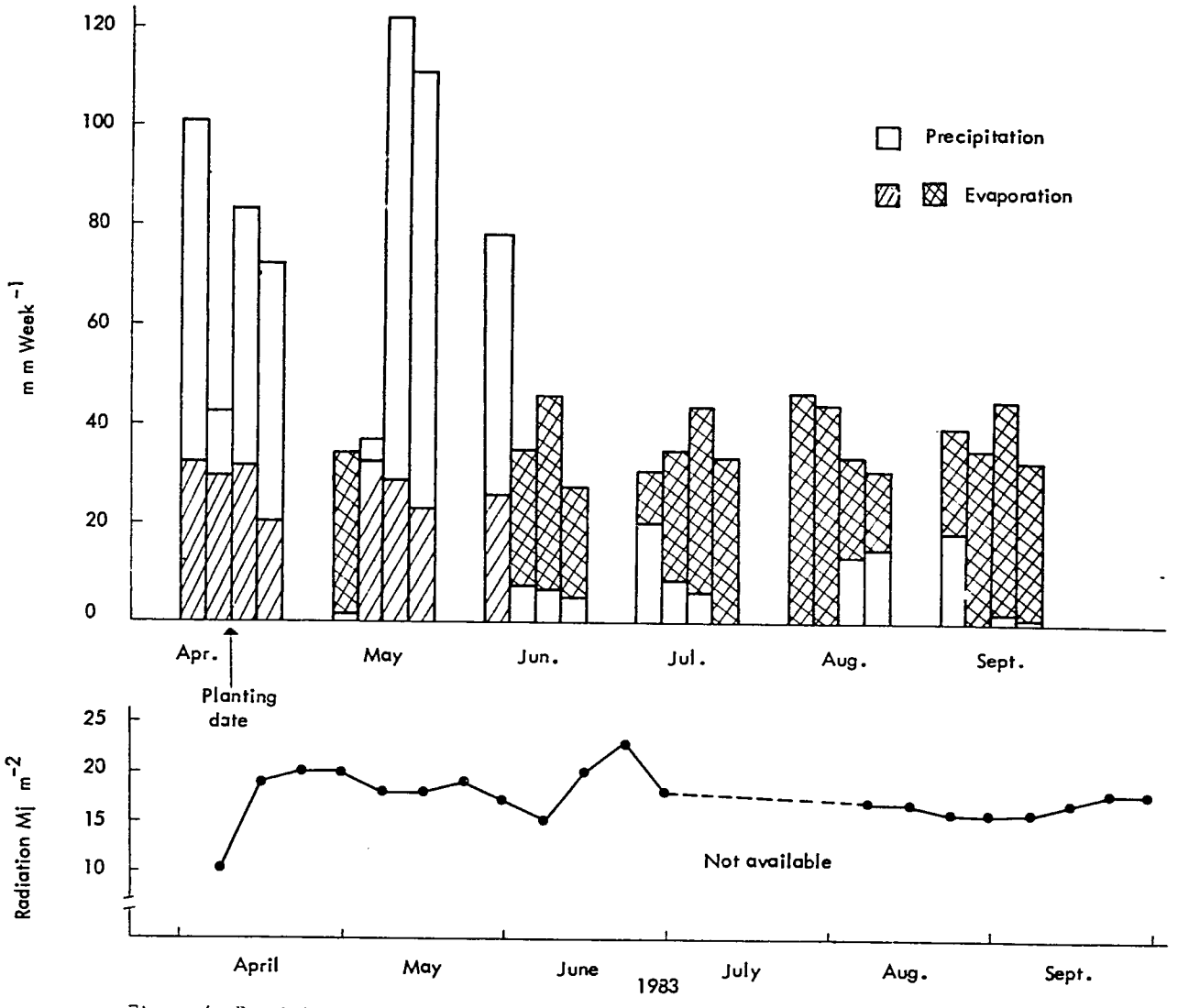


Figure 4. Precipitation, evaporation and irradiance during the period between April 1 and Oct.1, 1983 at Santander de Ouilichao.

Figure 5. Rooting characteristics during three weeks of germinating stakes of CM 507-37 and M Col 1684 cassava cultivars.

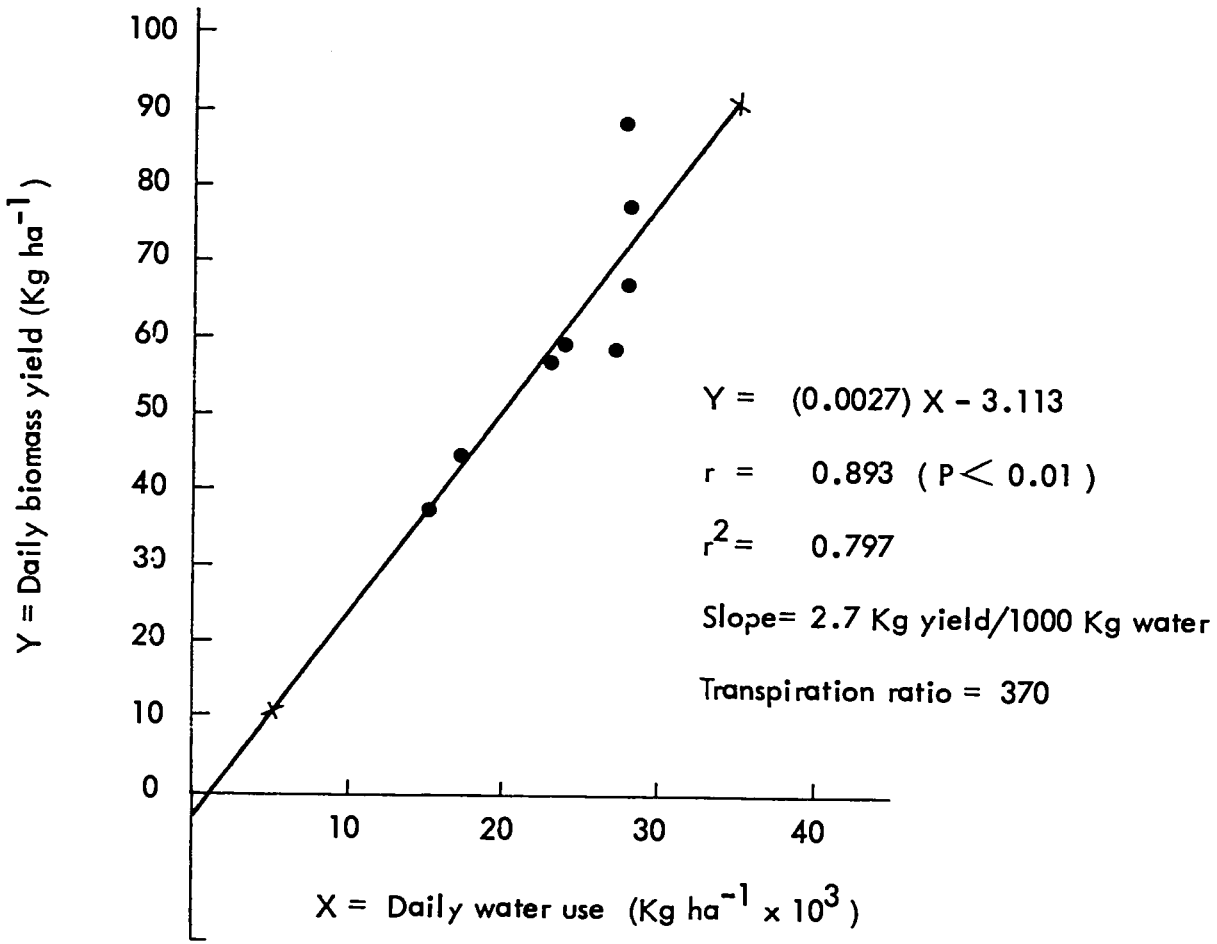


Figure 6. Cassava daily biomass production as a function of daily water use.

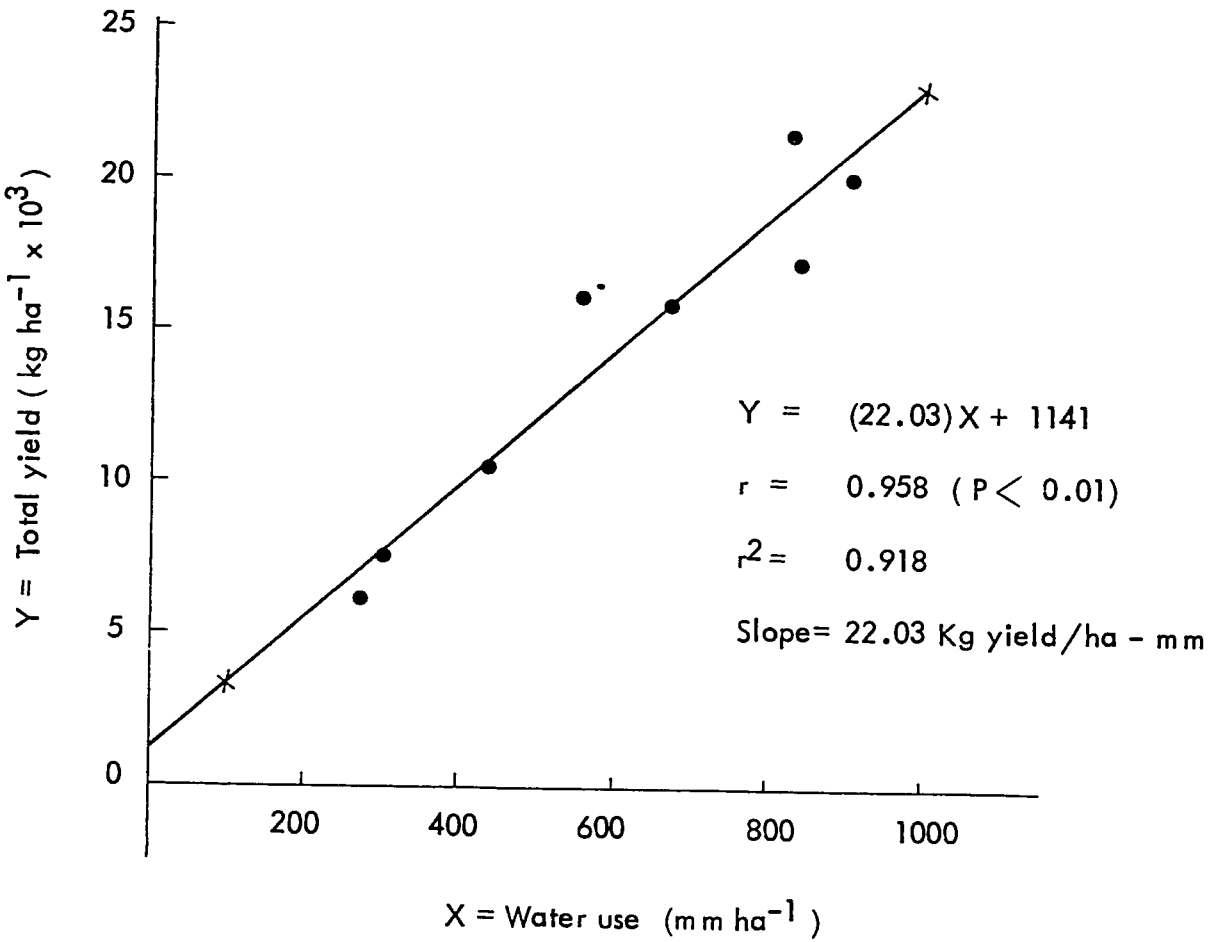


Figure 7. Cassava total biomass production as a function of total water use.

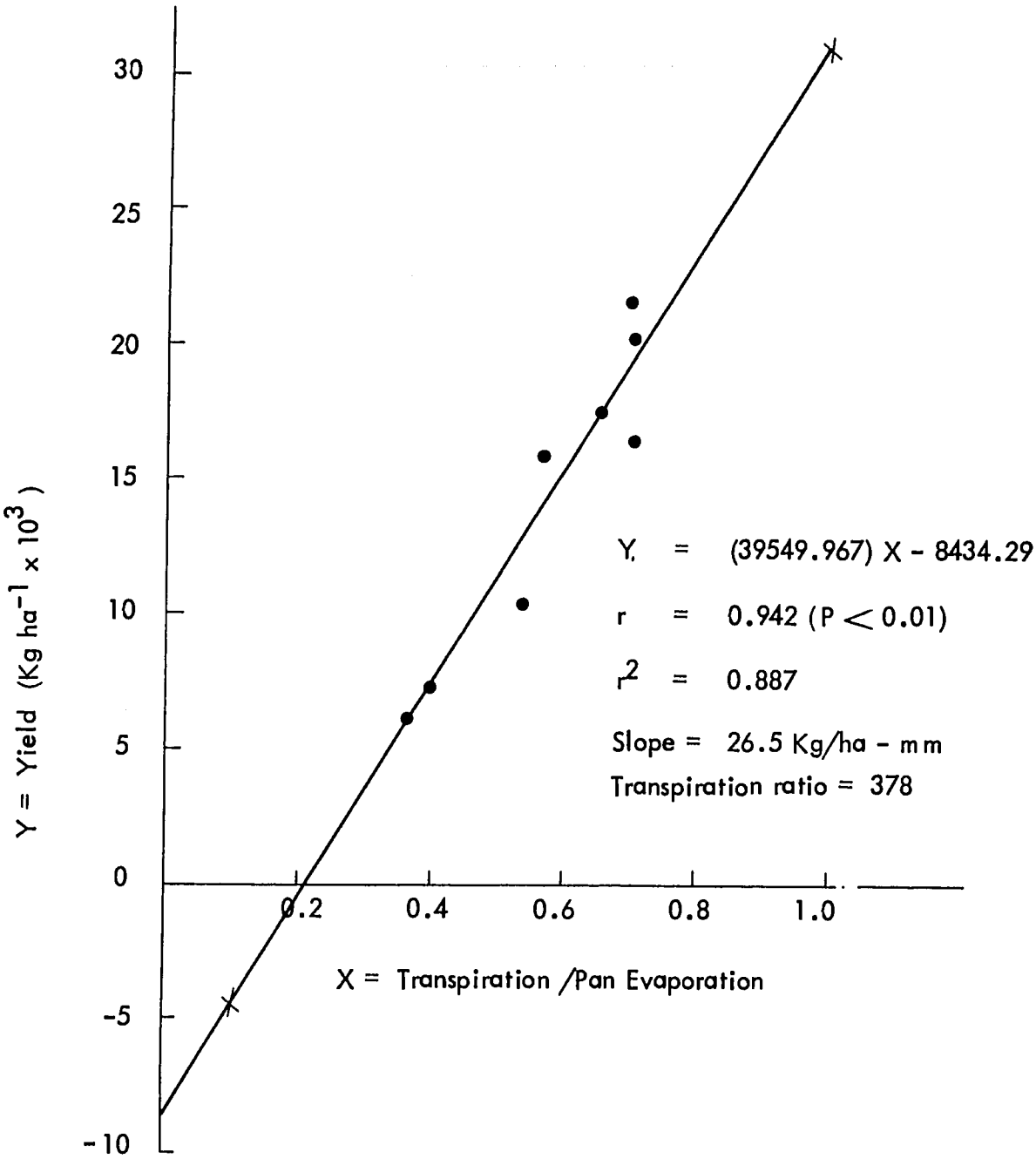


Figure 8. Cassava total biomass production as a function of crop transpiration/pan evaporation.
When Y= 0, X= 0.21 = 0.21x4.2 (mm day^{-1}) = 0.9 mm day^{-1} or daily water requirement for the survival of the crop " maintenance transpiration" or water compensation point at which the net gain in yield is zero,= 0.9 mm day^{-1}.

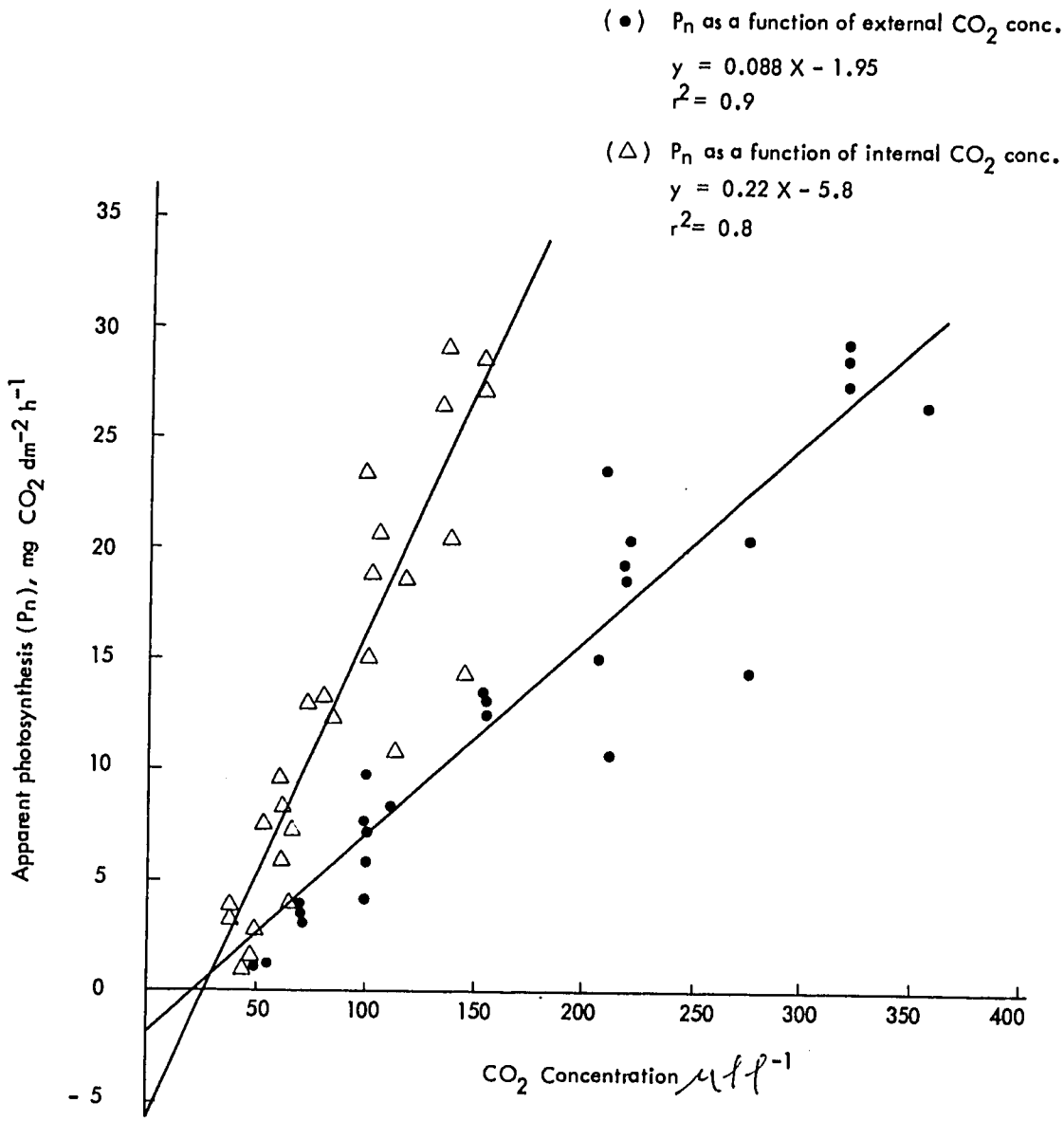


Figure 9. Apparent leaf photosynthesis (Pn) as a function of CO_2 concentration outside the leaf CO_2 ex and of CO_2 concentration inside the leaf CO_2 in, at photosynthetic photon flux density (PPFD) = 1500 $\mu Em^{-2}s^{-1}$, and leaf temperature 30± 2°C of CV M Col 1684.

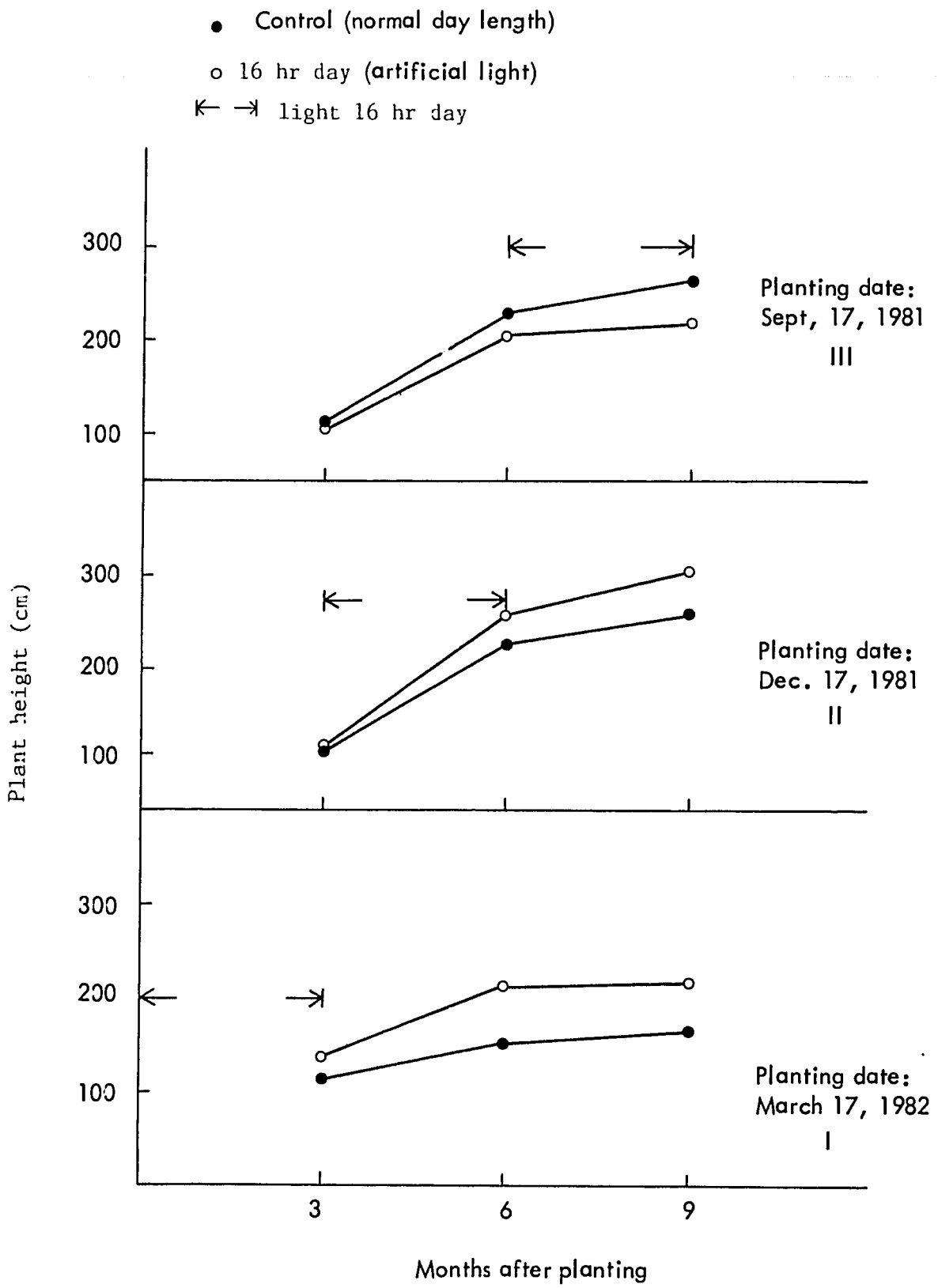


Figure 10. Effect of day length at different stages of growth on height of cassava plants.

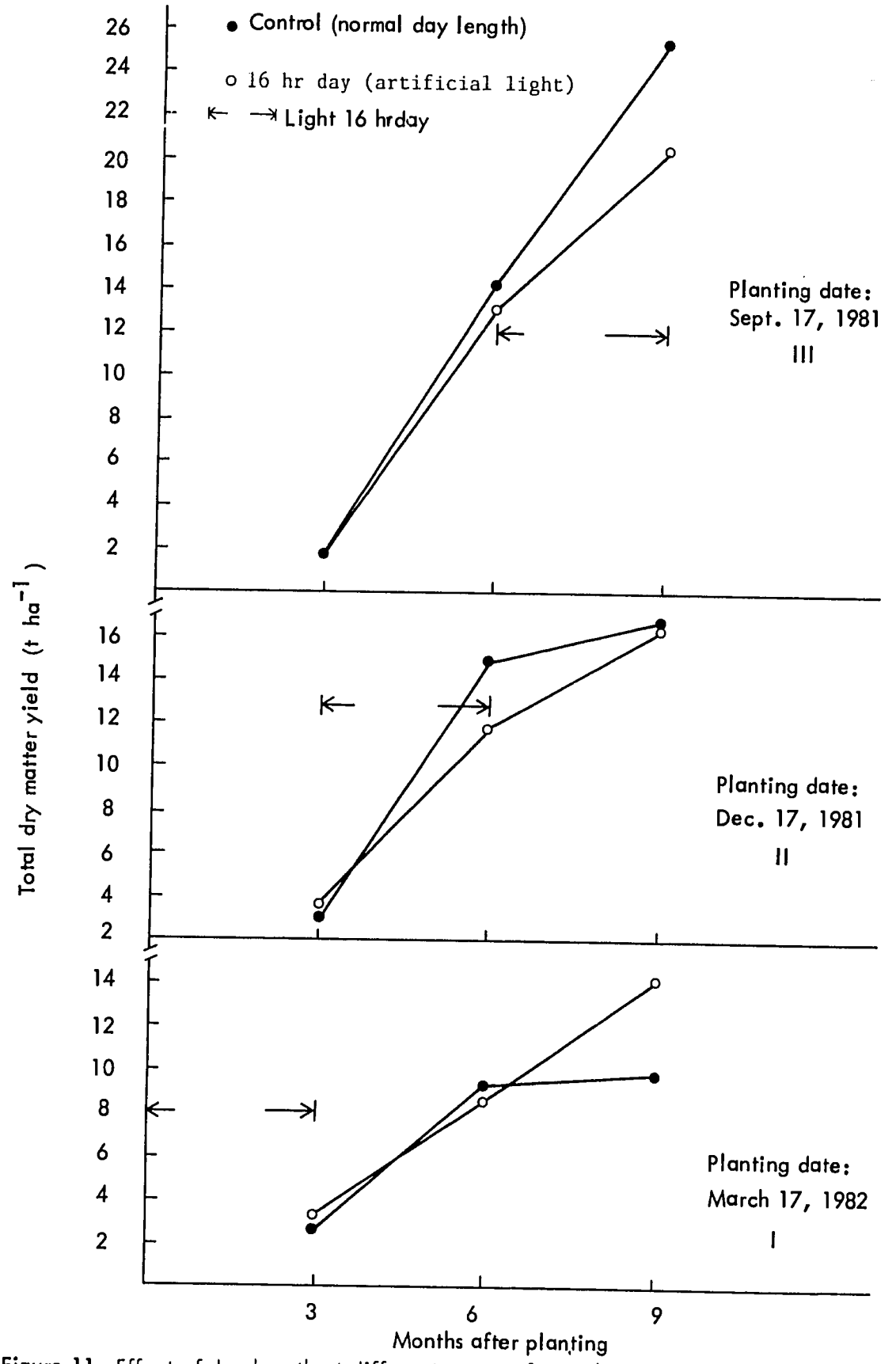


Figure 11. Effect of day length at different stages of growth on total dry matter productior of cassava plants.

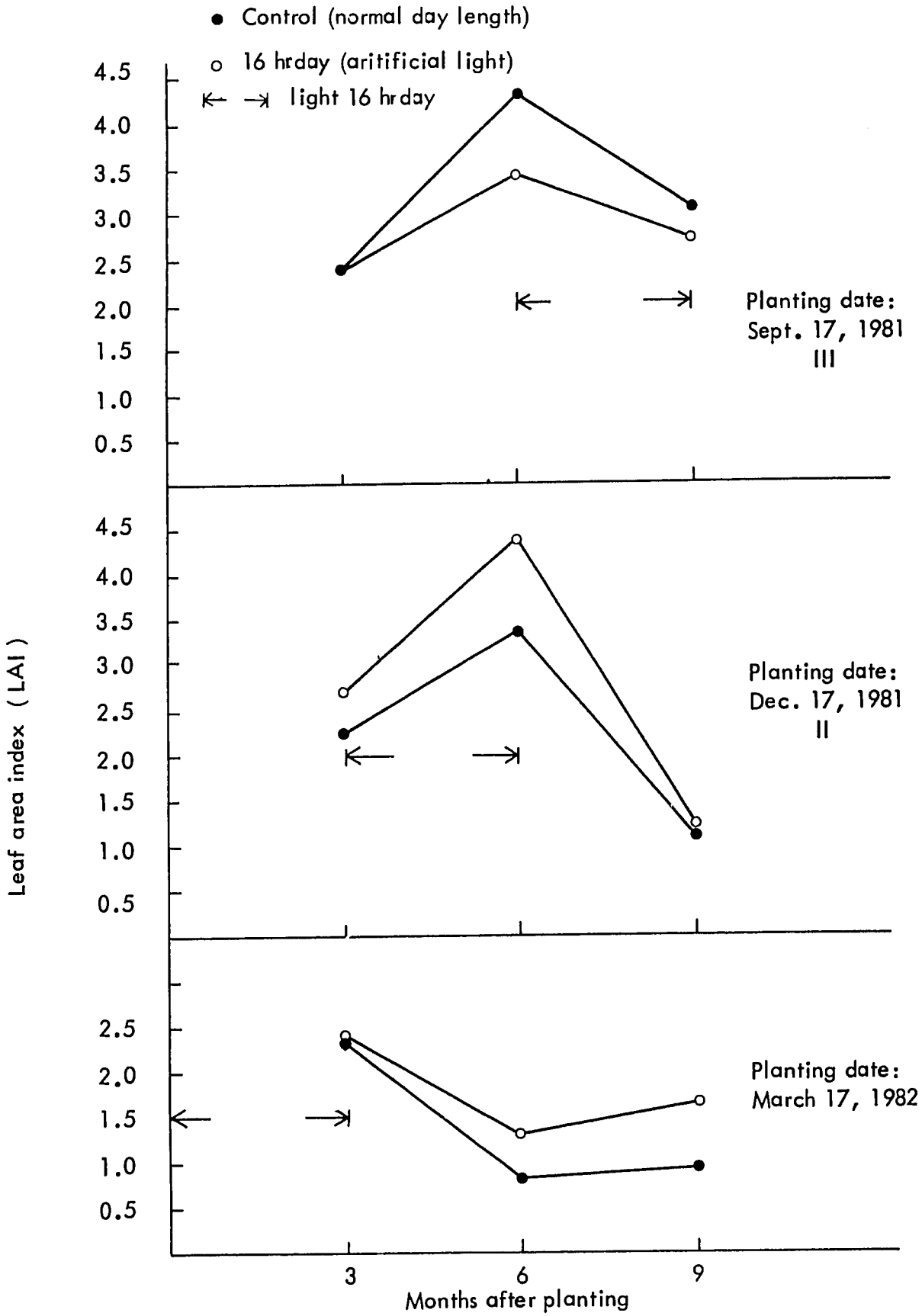


Figure 12. Effect of day length at different stages of growth on leaf area index of cassava plants.

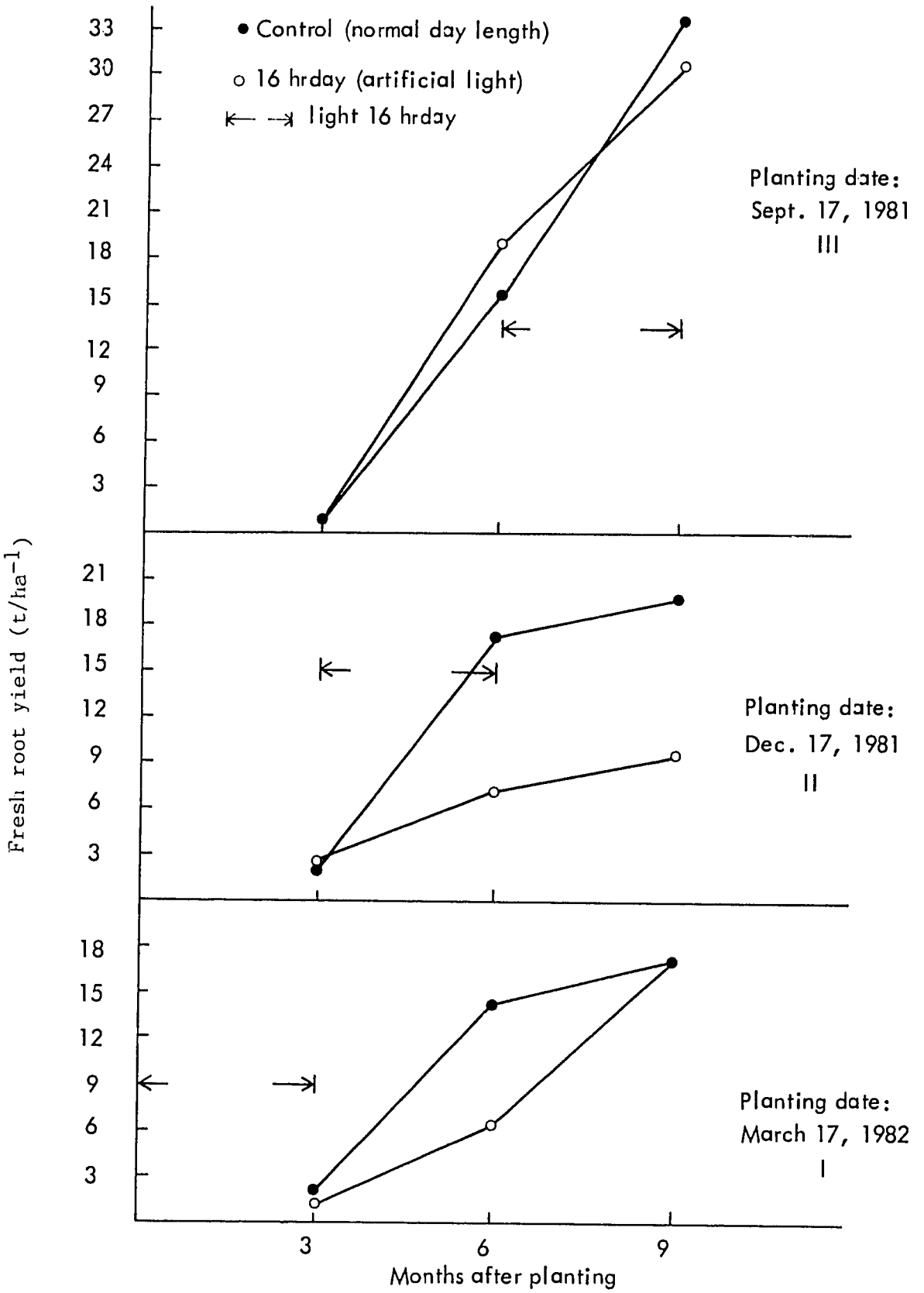


Figure 13. Effect of day length at different stages of growth on fresh root yield of cassava plants.

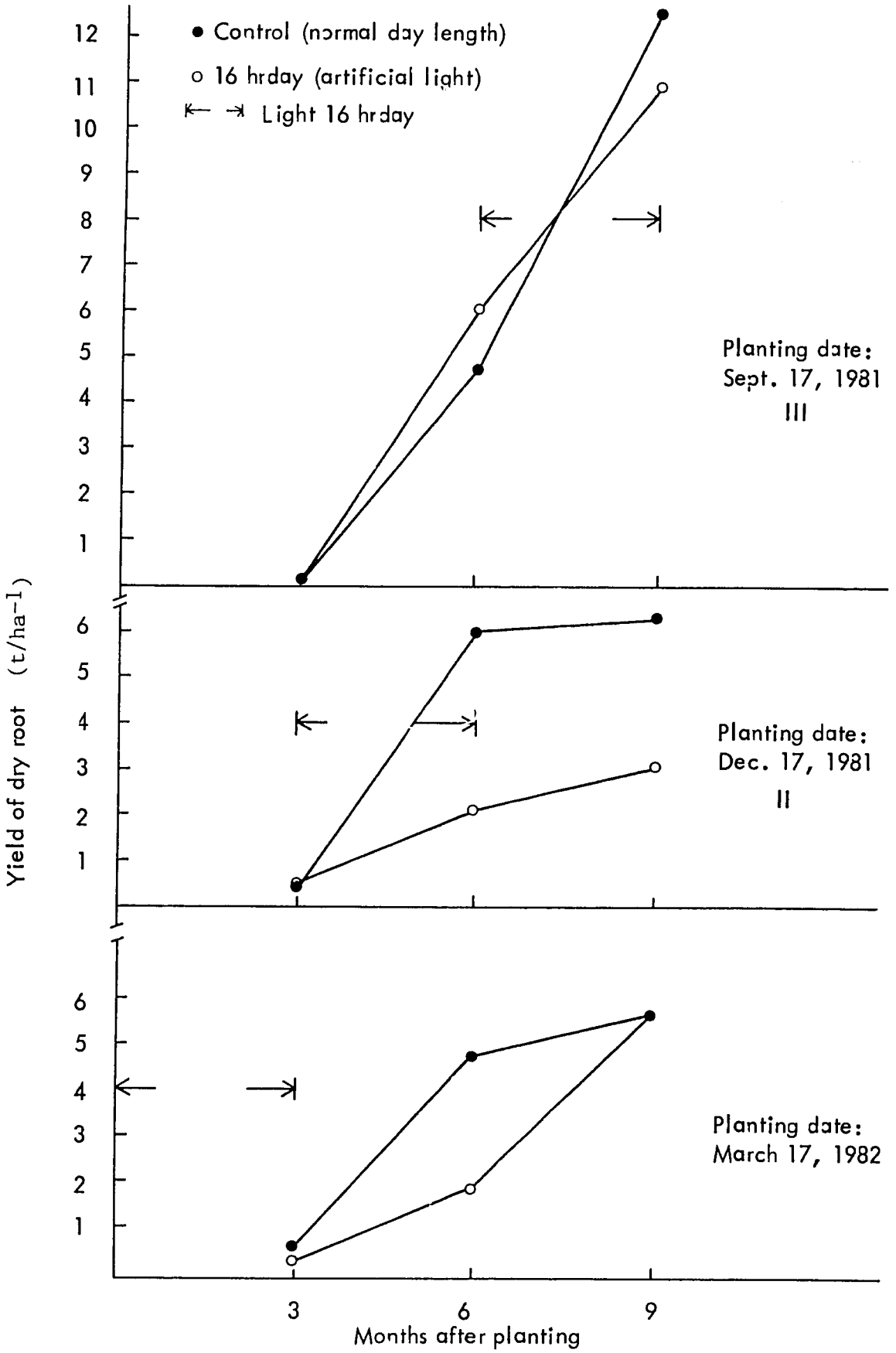


Figure 14. Effect of day length at different stages of growth on dry root yield of cassava plants.

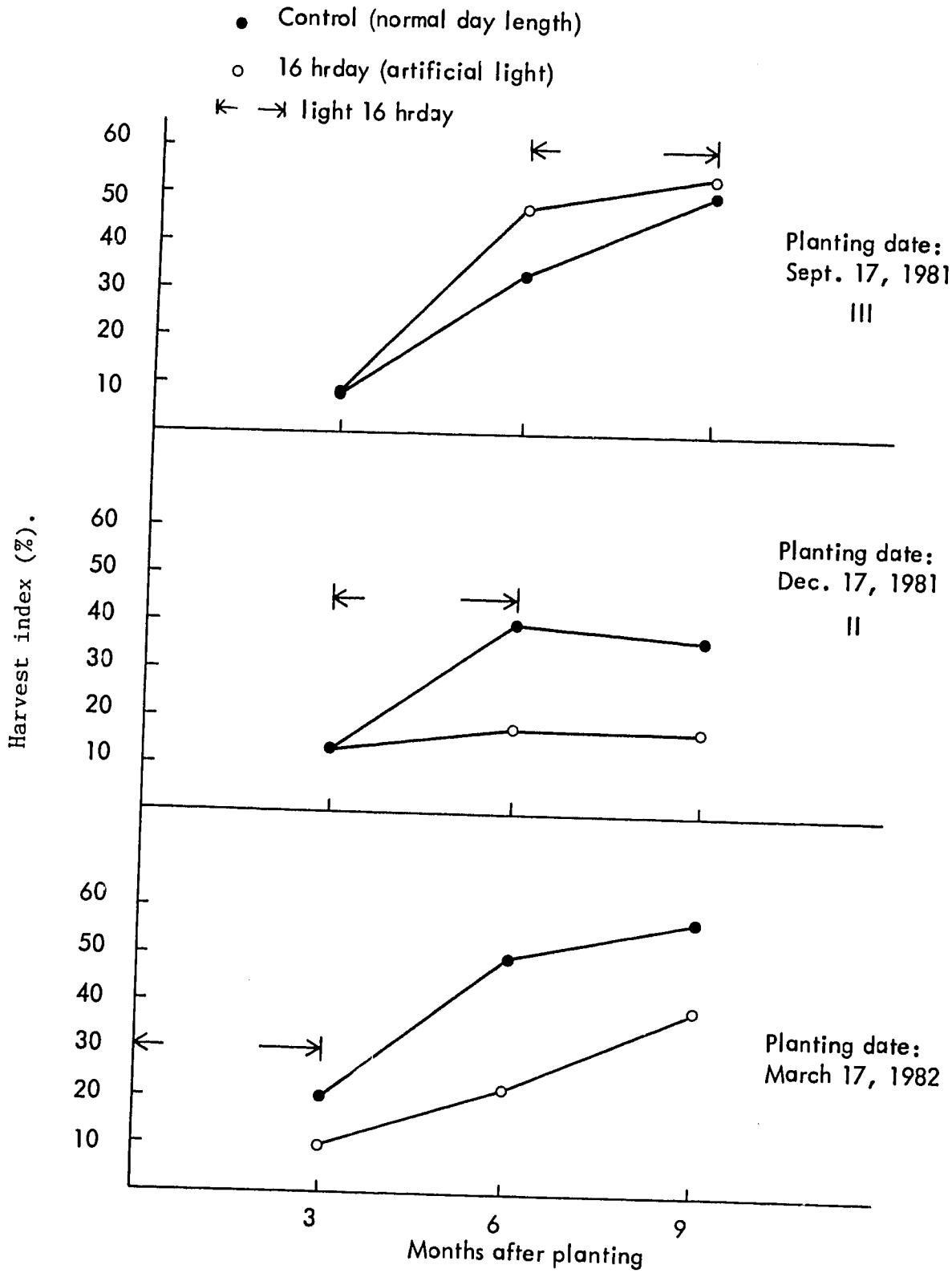


Figure 15. Effect of day length at different stages of growth on harvest index of cassava plants.

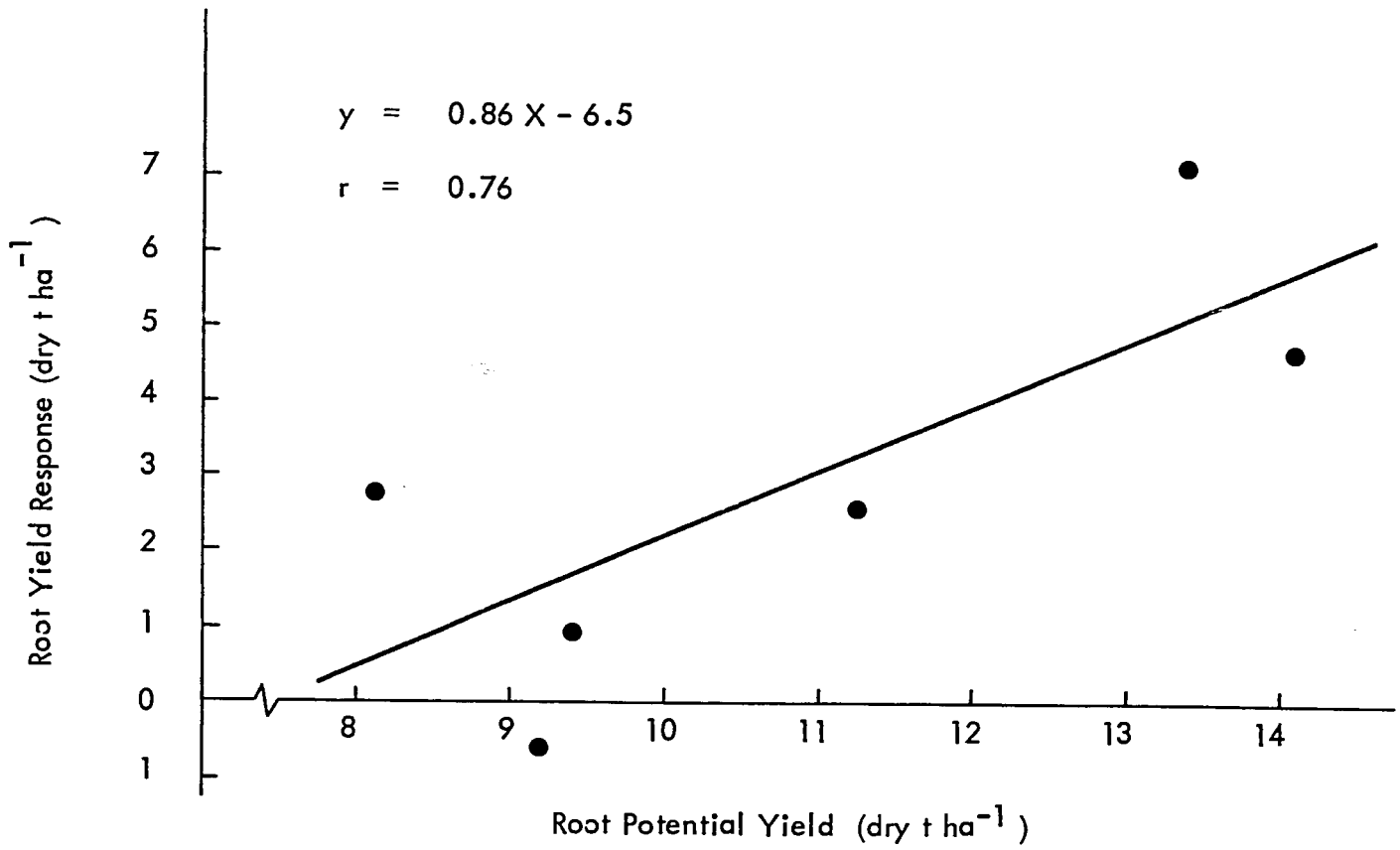


Figure 16. Cassava root yield response to soil fertility as a function of root potential yield.

Soils and Plant Nutrition

During 1983, the Soils and Plant Nutrition Section continued to evaluate germplasm for tolerance to adverse soil conditions; to study the absorption and distribution of nutrients in the plant; to determine the residual effect of NPK fertilizers over several years; to determine the response of cassava and three other crops to lime and NPK fertilizers and find cheap and effective methods of application of P, Ca and Mg; to study practical ways to control erosion in cassava grown on steep slopes; and to determine the effect of mycorrhizal inoculation on cassava yields. Most of the research were on-going trials and much of the methodology has been explained in previous Annual Reports.

Screening of Germplasm for Tolerance to Acid and Low P soils

In Santander de Quilichao (edaphoclimatic zone 4) another 688 accessions from the germplasm bank were screened for low P tolerance in plots which had received 0 and 75 kg P/ha as diammonium phosphate (DAP), banded at planting. (See "Germplasm Screening for Adaptation to High Acidity and Low P" in the Soils Section of the 1982 Cassava Annual Report). In the OP plots the same amount of N in the DAP was applied as urea, while both plots received an additional 32 kg N and 100 kg K/ha as urea and KCl, respectively.

Although about 25% of the cultivars were eliminated because of poor germination in one or both P plots, of the remaining 505 cultivars some showed extremely good yields even without P application, as indicated in Table 1. The average yields of the 505 cultivars were 13.9 and 21.9 t/ha, without and with the application of P, respectively.

In addition, the most promising 77 cultivars of last year's screening were re-evaluated in bigger plots with the same two levels of P and two replications. Average yields were 16.0 and 27.7 t/ha without and with the application of P, respectively. The cultivars with the highest P-adaptation indices were M Col 628, M Col 1514, M Bra 36, M Bra 41, M Ven 321 and CM 430-37.

A similar screening of 21 cultivars for low-P tolerance was conducted in a farmer's field in Mondomo at 1500 msl. where mean temperatures are only about 19° C. At that elevation the average yields were 8.0 and 24.7 t/ha without and with application of P, respectively. Some local cultivars like Americana and Sata Dovio had very high adaptation indices, similar to those of the best introduced cultivars like CMC 40 and M Col 113. Some cultivars of high yield potential in Quilichao, such as M Col 1684 and CM 91-3, lacked vigor and produced very low yields at this higher elevation in Mondomo, representative of edapho climatic zone 5.

In Carimagua (edaphoclimatic zone 2) 30 cultivars and 30 hybrids were screened for tolerance to high acidity and low-P by planting each in three plots with the following treatments:

(1) 4 t/ha lime, OP

Previous Page Blank

(2) 0 lime, 50 kg P/ha

(3) 4 t/ha lime, 50 kg P/ha

Yields at OP and 0 lime were compared with those obtained in the optimum treatment 3 to calculate the adaptation indices for low-P and high acidity, respectively. Average yields were 7.8, 17.4 and 15.6 t/ha for treatments 1, 2 and 3, respectively. While application of P more than doubled the yields, that of lime had no beneficial effect, even though the percentage Al saturation decreased from 74 to 26%, and the exchangeable Ca content increased from 0.37 to 1.72 me/100 g. The slight decrease in yield at the high lime level may be due to induced Zn deficiency even though 20 kg Zn/ha had been applied at planting. In general the hybrids produced much higher yields than the cultivars. Those with highest adaptation indices were CM 841-9, CM 978-28 and CM 621-251.

Table 2 shows those cultivars and hybrids that have shown high adaptation indices in various screenings in Quilichao and/or Carimagua. Those with acidity tolerance had been screened in Carimagua and are thus also well adapted to the disease and pest complexes of edaphoclimatic zone 2. Many of these cultivars are now used as parental material in the breeding program.

Absorption and distribution of nutrients

To determine the effect of fertilizers on dry matter (DM) production and nutrient absorption and distribution, cassava was planted in Quilichao in large plots which in 1978 had been used for a similar trial (see Cassava Annual Report, 1980). Both in 1978 and in 1982, all plots were limed with 500 kg dolomitic lime/ha. The fertilized plots received 1000 kg of 10-30-10 and 1 kg B/ha, which were both broadcast and incorporated. The cultivar M Col 22 was planted on ridges in fertilized and unfertilized plots. Plant and soil samples were taken at monthly intervals.

Figure 1 shows the cumulative total DM production in the plant during the 12 month growth cycle. DM production was slow during the first two months, increased rapidly during the third month and leveled of again after the eighth month. DM production slowed down during the end of the dry season but increased rapidly again about a month after the beginning of the rainy season. Fertilizer application increased DM production about 40%. The fertilizer response became pronounced after the second month.

Figure 2 shows the DM distribution between tops, roots, and fallen leaves. Roots became the dominant sink by the third month in this early maturing cultivar. Leaf fall commenced after the third month, increased steadily until the sixth month, stopped again during the beginning of the rainy season and continued slowly from the eighth month until harvest at 12 months. Total DM accumulation in fallen leaves was higher than that of leaves on the plant after the fifth month.

Figure 3 shows the N, P and K concentration in upper, middle, and lower as well as fallen leaf blades of fertilized plants. The concentration of all three nutrients decreased during the first 3-4 months and then more or less stabilized. The concentration decreased from the upper to the lower leaves and was lowest in the fallen leaves. Thus, considerable amounts of nutrients were translocated from older to younger leaves before leaf fall, nevertheless large amounts of absorbed nutrients returned to the soil in fallen leaves during the growth cycle. Of the total of 150 kg N/ha absorbed by the plant about 50 kg returned to the soil as fallen leaves, 40 kg remained in tops and 60 kg (40%) was removed in the roots. On the other hand, of the total of 75 kg K absorbed by the plant, only 10 kg returned as fallen leaves, 15 kg remained in the tops and 50 kg (67%) was present in the roots. Thus, a very large proportion of absorbed K is removed in the root harvest, and is not returned to the soil.

Figure 4 shows the change in nutrient content in the soil during the growth cycle in both fertilized and unfertilized plots. Inorganic N, available P (Bray II) and exchangeable K levels decreased during the growth cycle; initially, they were markedly higher in fertilized than unfertilized soil but these differences disappeared over time. The effect of N was already lost after five months, while the effect of P application remained through much of the growth cycle. The low levels of inorganic N, available P and exchangeable K at the seventh month correspond with increases in N, P, and K concentrations in leaves and increased DM production at the start of the rainy season. Thus, results from both soil and leaf analyses were affected by changes in plant growth as a result of changing climatic conditions.

During the growth cycle soil pH remained nearly constant at 4.0-4.1, exchangeable Al increased slightly from 3.5 to 4.0, while exchangeable Ca and Mg decreased from 1.6 to 0.7, and from 0.7 to 0.3 me/100 g, respectively. Thus, the nutrient extraction by the cassava plant is clearly indicated by the decrease in soil N, K, Ca and Mg during the growth cycle; the marked decrease in available P mainly in the fertilized plots is an indication of immovilization (fixation) by the soil of applied soluble P. Unless these nutrients are returned to the soil in the form of plant residues, and organic or inorganic manures, one crop of cassava can seriously affect the fertility of the soil.

Response of Cassava to Lime and NPK Relative to That of Other Crops

While cassava grows relatively well in very acid and infertile soils, the crop does respond to lime and fertilizer application. (See "Response to NPK Fertilization in Different Soils" in the Soils Section of the Cassava Annual Report, 1982.) To compare this response to that of other crops, which potentially could be intercropped with cassava, five cultivars of cassava and one each of upland rice, cowpea and peanut were grown in eight adjacent systematic design trials in Carimagua. Treatments consisted of 10 levels of dolomitic lime (combined with Zn) and 10 levels of 10-20-20 fertilizer in all possible combinations. Levels of lime and Zn increased systematically in increments of 200 and one kg/ha, respectively, in one direction, while levels of 10-20-20

increased in increments of 200 kg/ha from 0 to 2 t/ha in the perpendicular direction. Each plot was only 0.64 m^2 and treatments were replicated four times. The yield of each treatment was considered the average yield of that treatment and its eight surrounding neighbors, using the method of running averages.

Figure 5 shows the average relative response of the five cassava cultivars and those of peanut, cowpea and rice. While cassava was relatively more productive than any of the other crops without application of any lime or fertilizer, it did respond to rather high levels of application of both lime and 10-20-20. Thus, while peanut and cowpea reached their maximum yield at 1 t/ha of lime and 1.0 - 1.2 t/ha of 10-20-20, both rice and cassava required at least two t/ha of each to reach maximum yields. In an intercrop situation, cassava would be most competitive at either very low or very high levels of fertility, while at intermediate levels of lime or fertilizers cowpea and peanut would have a relative advantage over cassava.

Figure 6 shows the individual response of four cassava cultivars most adapted to the ecosystem. All produced nearly the same yield without application of lime or fertilizers, but they differed mainly in responsiveness to their application. Thus CM 523-7 produced relatively better at low to intermediate levels of lime and NPK, while M Ven 77 required high levels of both. Both HMC 2 and CM 430-37 were less responsive but also lower yielding, this being of no advantage to the farmer. An "ideal" cultivar should be both tolerant to low levels of fertility, but also responsive to more favourable nutritional conditions. For that reason the "adaptation indices", used in the screening work (See footnote b. of Table 1), use yield at both low and high levels of lime of P as a criterion for selection.

Residual Effect of NPK-fertilizers

It is of practical significance to know whether fertilizer applied in one year still has a beneficial effect in the following years, and therefore, whether fertilizer recommendations could decrease with time. To determine this experimentally, both in Carimagua and Quilichao three-year trials were initiated in 1980. During the first year, the whole trial received uniformly 1 t/ha of 10-30-10 or 10-20-20 in Quilichao and Carimagua, respectively. In the second year, four treatments of 0, 500, 750 and 1000 kg of NPK fertilizer/ha, were established, all band-applied at planting. In the third year, over each main plant with residual effect of the second year treatment subplots were superimposed with the same four levels of fertilization, band-applied at the third planting. Thus, in the third year there were 16 treatments: four residual effects, each with four recent applications of NPK fertilizers.

In Quilichao, the yield of M Col 1684 was 32.2 t/ha in the first year, it increased due to fertilization from 40 to 58 t/ha in the second year, and from 15 to 33 t/ha in the third year (Figure 7A); the year-to year variation was mainly due to very favourable weather conditions in the second and very unfavourable conditions in the third year. The gradual build-up of soil pathogens over time is another possible cause

of lower yields in the third year. The nearly linear response to the 10-30-10 application in the second year indicates that M Col 1684 is not only very high yielding but also very responsive to good soil fertility under favourable weather conditions. In the third year highest yields were obtained at the highest level of 10-30-10 application, and with the highest level of residual effect of 10-30-10 applied in the second year. However, the residual effect of the fertilizers was not significant, probably due to the increased nutrient extraction at increased levels of fertilization in the second year. For example, the 58 t/ha root yield of M Col 684 in the second year removed about 80 kg N, 18 kg P and 150 kg K while 100 kg N, 131 kg P and 83 kg K/ha had been applied at the highest level of fertilization. Thus, the residual effect is mainly due to a build up of soil P, while there was actually a net depletion of soil K. To maintain soil fertility, it would be recommended to decrease the P and increase the K application in subsequent years using, for example, a 10-20-20 or 15-15-15 compound fertilizer.

Using actual fertilizer costs and a modest price of Col $3.50/kg fresh cassava, the net economic return was calculated for the combined second and third year data for each level of fertilization. The highest net return was obtained with the application of 1 t/ha of 10-30-10 at each cassava planting. With this cultivar higher levels of application would probably have been even more economical.

Almost identical data were obtained with CMC 40 in Carimagua, although in that case yields were higher for the third than for the second year (Figure 7 B). Again, highest yields were obtained with the yearly application of 1 t/ha of 10-20-20 and the response to the recent application of fertilizer was much greater than the residual effect of fertilizers applied in previous plantings. Due to lower yields and higher levels of K-application in Carimagua than in Quilichao there was a net build-up of both P and K in Carimagua. Exchangeable K increased from 0.06 to 0.12 me/100 g, while available P increased from 1.5 to 14.4 ppm after two years of high fertilizer application.

Response to Ca and Mg application

In Carimagua-Alegria two trials were conducted to determine the best levels and sources of application of Ca and Mg for cassava. Calcium was applied at rates of 0, 100, 200 and 400 kg Ca/ha as gypsum either broadcast and incorporated or band-applied near the stake, or as broadcast calcitic or dolomitic lime. Magnesium was applied as magnesium sulphate or as potassium-magnesium sulphate (sulpomag) both band-applied, or as MgO or dolomitic lime, both broadcast at rates of 0, 20, 40 and 60 kg Mg/ha. The soil had a pH of 5.1 but contained only 0.18 me Ca and 0.05 me Mg/100 g and had about 80% Al saturation.

Figure 8 shows that the response to Ca application in CM 523-7 was highly significant with the broadcast application of gypsum, up to a level of 200 kg Ca/ha. The same product band-applied had no beneficial effect. With the application of calcitic or dolomitic lime, yields increased but not very markedly, as this cultivar is quite tolerant of soil acidity (see Figure 6). The response to gypsum was not a response to S since this element was applied to all plots in the form of

elemental S or magnesium sulphate. Since gypsum does not increase pH or decrease exchangeable Al, cassava's marked response to application of this product is an indication that the crop requires Ca mainly as a nutrient, and benefits from the greater solubility of gypsum compared to that of lime. Unfortunately, most commercial sources of gypsum contain only 10-15% Ca, compared with 25-30 in most limes, making transport costs considerably higher.

Figure 9 shows the relation between yield and the Ca content of youngest fully expanded leaves at three months of age. Although a clear plateau was never reached it appears that the critical level of Ca is above 0.60%. This is intermediate between the level of 0.46% obtained in a nutrient solution (See "Critical Levels of Ca and Mg in Plant Tissue" in the Soil Section of the Cassava Annual Report, 1982) and the level of 0.8% estimated for M Col 638 in Carimagua in 1980. These levels vary considerably among cultivars, M Ven 77 having consistently higher Ca concentrations in the leaves than CM 523-7.

Figure 10 shows the response to different levels and sources of Mg in CM 430-37. On the average there was a significant response to application of 40-60 kg Mg/ha, but the responses differed among sources. There was only a minor and variable response to dolomitic lime; sulpomag produced a major response to the level of 40 kg Mg/ha, while application of MgO and $MgSO_4.7H_2O$ resulted in highest yields at 60 kg Mg/ha. While MgO and dolomitic lime are the cheapest sources of Mg and give the highest net returns, the Magnesium sulphate and sulpomag are useful when S (or S and K) are also required.

Alternative Methods of P Application

In most Oxisols and Ultisols P is the main limiting nutrient for cassava; compared with N and K it is also the most expensive nutrient. Since much of the P applied to the soil is fixed and unavailable to plants, alternative methods of application have been sought to bypass the soil and reduce losses. In both Quilichao and Carimagua, a trial was established to compare the response to foliar application and stake treatments of P with the traditional method of banding triple superphosphate (TSP) or broadcasting basic slag. An additional treatment is which TSP was applied five times in small doses was also included. These and the foliar applications were applied monthly during the first five months.

Table 3 shows that in both Quilichao and Carimagua there was a good response to P, but only to the traditional method of soil application. None of the foliar applications or stake treatments increased the P concentration in the plant or root yield. In both locations basic slag was slightly superior to TSP, while fractionation of TSP had no advantage over a basal application. Thus, some of these alternative methods, which appeared promising in greenhouse trials, did not prove to be effective under field conditions.

Effect of Mycorrhiza

Research reported in previous years showed that inoculation with mycorrhizal (VAM) fungi may be another alternative to high levels of P fertilization of cassava (See "Effect of P Sources and Levels on Mycorrhizal Efficiency" in the Soil Section of the Cassava Annual Report, 1982.) Greenhouse and field trials were continued to look for better strains, and more effective methods of inoculum production and application.

1. Strain selection in the greenhouse

Mycorrhizal strains selected by the Mycorrhiza Project as being highly effective in sterilized soil were evaluated in non-sterilized soil to determine their efficiency in competition with native micro-organisms.

Figure 11 shows that the response of cassava, M Ven 77, to inoculation with eight strains in three different soils. For comparison a non-inoculated treatment in sterilized soil was included. With the latter treatment plants did not grow at all in any of the soils. In the unsterilized Quilichao soil inoculation, all but one strain increased DM production over that produced with the local VAM, but this increase was statistically significant only for C-1-1 and C-10. Responses were relatively low because of the high efficiency of the native strains. In the Carimagua-Reserva soil, however, the native population was quite inefficient, resulting in low yields for the noninoculated check in unsterilized soil. In this case, the response to inoculation of all but one strain was highly significant, but with the best response again to C-1-1 and C-10. In Carimagua-Alegria the native strains were intermediately effective and only inoculation with C-1-1, C-10 and C-15-2 was significantly better than the non-inoculated treatment.

A similar trial was conducted in soils from CIAT-Palmira, Mondomo and San Emigdio (in the mountains near Palmira). Although the CIAT-Palmira soil is high in P and has a high VAM population, this population is probably not very effective because there was a significant response to inoculation with C-10 and C-20-2. The Mondomo soil came from a relatively fertile non-eroded area with a high native VAM population, resulting in non-significant responses to inoculation except with C-1-1. The San Emigdio soil was from an eroded site with low native VAM population. All strains increased DM production but due to the high variability none of these increases were statistically significant. From these and other similar trials it was concluded that in general the most efficient strains are C-1-1 and C-20-2, both *Glomus manihotis* collected in Quilichao and Carimagua, respectively, as well as C-10 (*Entrophospora colombiana*) and C-15-2 (*Acaulospora mellea*) both from Carimagua. All these are new species, only recently collected and described in the literature. It is clear that a significant response to inoculation can only be expected in those soils with a low or inefficient native VAM population, such as those of the very acid and infertile savanna soils or on eroded mountain soils.

2. Efficiency of the root inoculum

Under greenhouse conditions small quantities of root inoculum is often as effective as the use of larger amounts of soil-root mixtures. This is especially true for Glomus manihotis (C-1-1) which produces spores inside the root. To determine how much root inoculum is required and how different treatments affect the inoculum, rooted tip cuttings of M Ven 77 were grown in sterilized and unsterilized Quilichao soil inoculated with various amounts and kinds of inoculum consisting of roots of maize and kudzu infected with C-1-1. Figure 12 shows that inoculation markedly increased plant growth, especially in the sterilized soil. There were no differences between the use of 1, 2, or 4 gm cut-up fresh roots, but DM production was considerably increased by mixing the inoculum with sterilized sand to improve its distribution below the plantlet. Sun or oven-drying the inoculum reduced its effectiveness only in sterilized soil, while storage over one month at room temperature or in the cold room actually seemed to improve the effectiveness of the inoculum, at least in the unsterilized soil. Thus, the use of small amounts of root inoculum for inoculation with C-1-1 is highly effective; its effectiveness can be improved by mixing with sterile sand, and storage for at least one month does not seem to affect its viability.

3. Strain selection under field conditions

In Carimagua and in Mondomo several mycorrhizal strains were evaluated in field-grown cassava. In Carimagua, two trials were conducted simultaneously in adjacent plots. In one trial TSP was band-applied at 50 and 100 kg P/ha after planting; in the other trial 50 kg P/ha was broadcast either as Huila Rock phosphate (HRP) or basic slag, and incorporated in main plots. In eight subplots plants were either non-inoculated with one of seven strains by placement of 250 gm of a soil-root inoculum below the stake at time of planting. Figure 13 shows that inoculation with all strains increased yields although not always significantly. Yields increased more by inoculation than by the application of an additional 50 kg P/ha as TSP. Significant yield increases were obtained with C-1-1, C-4-2, C-10 and C-19-1. When 50 kg/ha of P were applied as HRP there was a significant response to C-1-1, C-4-2 and C-10, but with application of basic slag the response to inoculation was not significant.

In Mondomo, a similar trial was conducted with treatments of 0 and 50 kg P/ha applied as banded TSP in the main plots, and strains in the subplots. In this case, two replications were located on a black non-eroded soil and two on a reddish eroded soil. The effect of erosion was more important than that of either P application or inoculation. Without P application average yields were 7.7 t/ha in the eroded soil and 22.6 t/ha in the non-eroded soil; with 50 kg P/ha they were 18.3 and 30.0 t/ha, respectively. Figure 14 shows that in the eroded soil, inoculation could more than double yield without P, but had no positive effect when 50 kg P/ha had been applied. In the non-eroded soil with a high native VAM population, inoculation was effective in the case of only a few strains. The strain C-10 tended to be more effective than C-1-1; the strain C-4-2 (Glomus caledonicum from Mondomito), which was

quite effective in Carimagua, was also effective in Mondomo but only in the absence of applied P. While some strains may have a large range of adaptability to different soil and climatic conditions, others are more specific, and strains may have to be selected for specific conditions.

Erosion Control Practices

A previous trial (see "Soil Management for Erosion Control" in the Soils Section of the Cassava Annual Report, 1982) had shown that soil loss by erosion can be greatly reduced by using proper erosion control practices in cassava grown on steep slopes. Another similar trial was established in Agua Blanca on a volcanic ash soil with about a 40% slope. Seven treatments of different methods of soil preparation, fertilization, mulching and intercropping with pasture species were established in large plots. Eroded soil was collected in plastic-covered channels below each plot and this soil was weighed, dried, and analyzed monthly. Figure 15 shows the accumulated soil-loss during the growth cycle in five treatments. Unlike last year's trials, soil losses were minimal during the initial stages of growth but increased markedly during the heavy rains of November and December, and during the second rainy season of April-May, when plants were already partially defoliated. Soil losses were particularly severe in the unfertilized plots where plant growth was poor and weeds were able to compete with cassava. In several days of heavy rain shortly after a hand weeding, this treatment lost as much as 20 t/ha of dry soil. Intercropping double rows of cassava with imperial grass (*Axonopus escoparius*) was not very effective in controlling erosion due to poor initial growth of the grass. Only after the grass was fertilized at six months did it grow satisfactorily and controlled erosion. Fertilization of cassava produced vigorous plants which protected the soil from the impact of rainfall and did not allow much weed growth, reducing the need for weeding. Soil losses were further reduced by application of maize mulch on the soil surface, by intercropping with *Brachiaria humidicola* and by zero tillage. Competition from *B. humidicola* was reduced by periodic cutting of runners and herbicide application, and yields of cassava were only slightly reduced by this practice (Table 4). Still, a less competing grass like Imperial, which is also more valuable to the farmer as fodder, produced higher cassava yields but was less effective in controlling erosion. Highest yields were obtained by zero tillage, *i.e.* direct planting of cassava stakes in cleared but unprepared soil. This also resulted in the least amount of erosion. Some soil preparation may be necessary on more compacted or already eroded soil, where heavy subsoil is exposed. Thus, to obtain high cassava yields with adequate control of erosion, soil preparation should be reduced to a minimum, cassava should be adequately fertilized, and some contour strips of grasses should be established that reduce run-off without competing with the cassava crop. With the use of these erosion control practices cassava may actually cause less erosion than other crops because of its long growth cycle, good soil cover once established, and its minimal requirement for land preparation.

Table 1. Cassava cultivars highly adapted to low-P soils as determined in a screening of 688 cultivars in Quilichao.

	Cassava yield[a] (t/ha)		Low P adapt index[b]
	OP	75P	
M Col 85	33.0	52.0	5.60
M Col 102	57.0	34.0	6.36
M Col 109	44.3	38.0	5.53
M Col 118	36.0	57.3	6.77
M Col 157	30.7	60.0	6.05
M Col 253	36.0	43.7	5.16
M Col 346	39.7	54.7	7.13
M Col 1858	33.7	73.0	8.08
M Col 2142	32.7	61.7	6.62
M Ven 118	34.7	59.3	6.76
M Ven 164	30.7	49.3	4.97
M Ecu 68	36.7	58.0	6.99
CM 1305-3	38.7	56.3	7.15

a. Yield based on four plants in single row plots.

b. Low-P adaptation index = $\frac{\text{yield OP x yield 75P}}{\text{X X yield OP x X yield 75P}}$

Table 2. Germplasm with high tolerance to soil acidity and low levels of P.

	Acidity	P
M Bra 5	++	++
M Bra 20	+	+
M Bra 22	++	+
M Bra 29	+	+
M Bra 33	+	+
M Bra 36	+	++
M Col 1495	++	+
M Col 1513	+	+
M Col 1643		+
M Col 1684	+	+
M Col 1772	+	+
M Col 1777	+	+
M Col 1895	+	
M Col 1914	++	++
M Col 1916	+	++
M Pan 90	++	+
M Pan 97	++	++
M Pan 101	++	++
M Per 188	+	+
M Per 237	++	++
M Per 239	+	+
M Per 241	+	++
N Per 242	++	++
M Ven 77	++	+
M Ven 295		+
M Ven 310		+
M Ven 321	++	++
CM 517-1	++	++
CM 523-1	++	++
CM 996-6	++	+
CM 621-214	+	

Table 4. Cassava yield and soil loss due to erosion with various soil conservation practices in Agua Blanca (Cauca).

Treatment	Soil loss[a] (t/ha)	Cassava yield[b] (t/ha)
1. Soil preparation with oxen; without fertilizer; cassava planted 80x80cm.	35.9	6.9
2. Soil preparation with oxen; with fertilizer; cassava planted 80x80cm.	22.9	13.6
3. Soil preparation with oxen; with fertilizer; cassava planted 80x80cm; maiz mulch.	15.1	15.9
4. Soil preparation with hoe in one metter strips with cassava planted in double rows at 60x60cm; one meter without preparation between double rows.	14.1	15.6
5. Soil preparation with oxen; double row cassava alternated with one meter of imperial grass.	18.9	15.8
6. Soil preparation with oxen; double row cassava alternated with one meter of Brachiaria humidicola.	9.8	13.3
7. Without soil preparation; with fertilizers; cassava planted 80x80 cm.	9.8	17.6

[a] Loss of dry soil during 14 months between planting and harvest of cassava.

[b] Average yield of three cultivars: C M C 92, Batata, Regional Amarillo.

Table 3. Response to alternative methods of P application to cassava grown in Quilichao and Carimagua.

Treatments	Cassava yield (t/ha) Quilichao[a]	Carimagua[b]
Check without P	26.1	5.7
50 kg P/ha as TSP, banded at planting	35.6	12.1
50 kg P/ha as TSP, fractionated in 5 applic.	36.3	9.3
50 kg P/ha as basic slag, broadcast at planting	38.7	13.3
5 foliar applications with 2% KH_2PO_4	21.5	6.9
5 foliar applications with 5% KH_2PO_4	25.7	7.9
5 foliar applications with 2% TSP	24.1	3.9
5 foliar applications with 5% TSP	25.3	6.1
Stake treatment with 5% KH_2PO_4	25.0	6.0
Stake treatment with 10% KH_2PO_4	26.0	2.4
Stake treatment with 5% TSP	23.5	4.1
Stake treatment with 10% TSP	26.5	6.7

[a] Average of M Col 1684 and CMC 40

[b] M Ven 77.

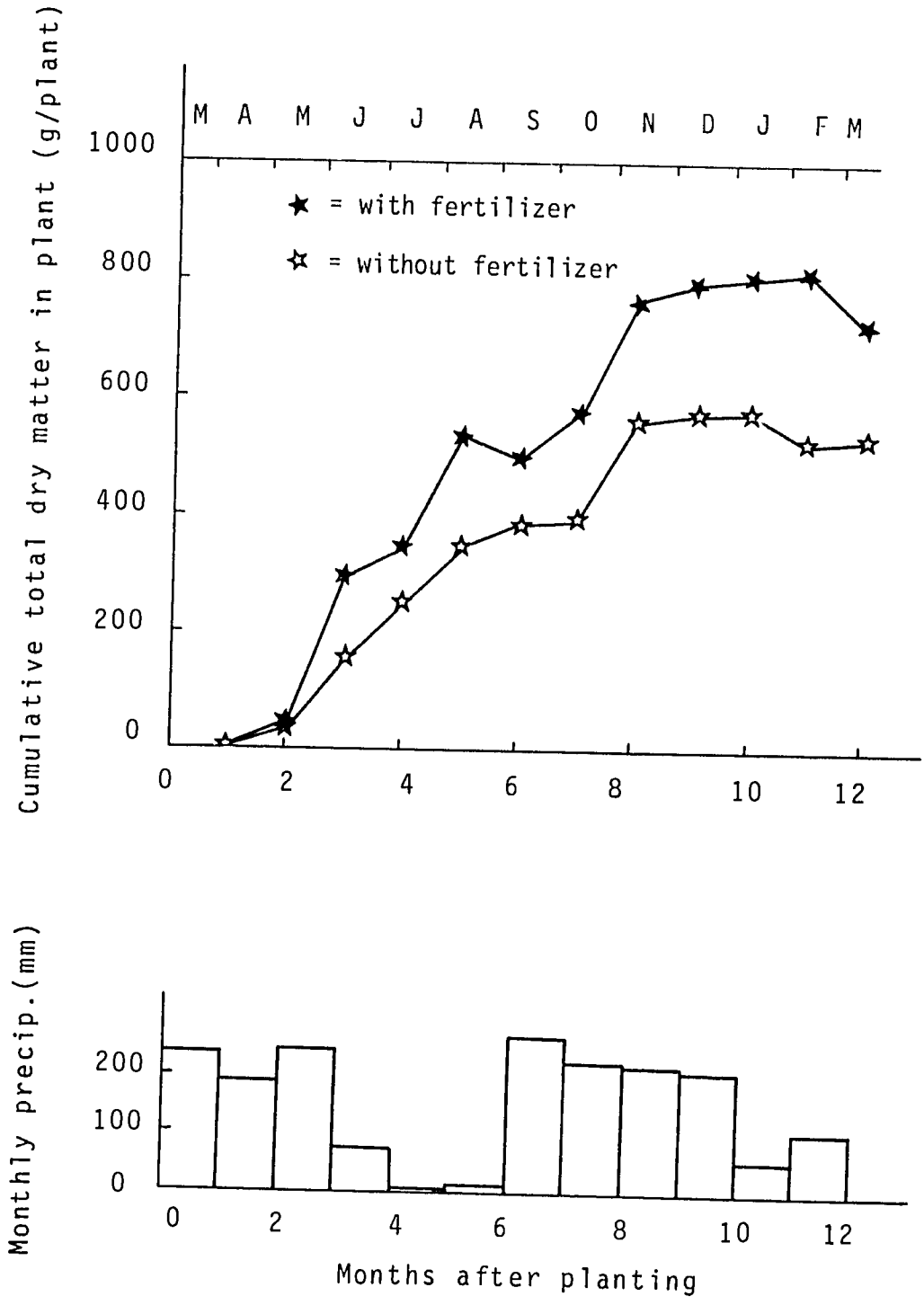


Figure 1. Cumulative total dry matter in fertilized and unfertilized cassava, M Col 22, during a 12 month growth cycle in Quilichao. Below: monthly precipitation during the growth cycle.

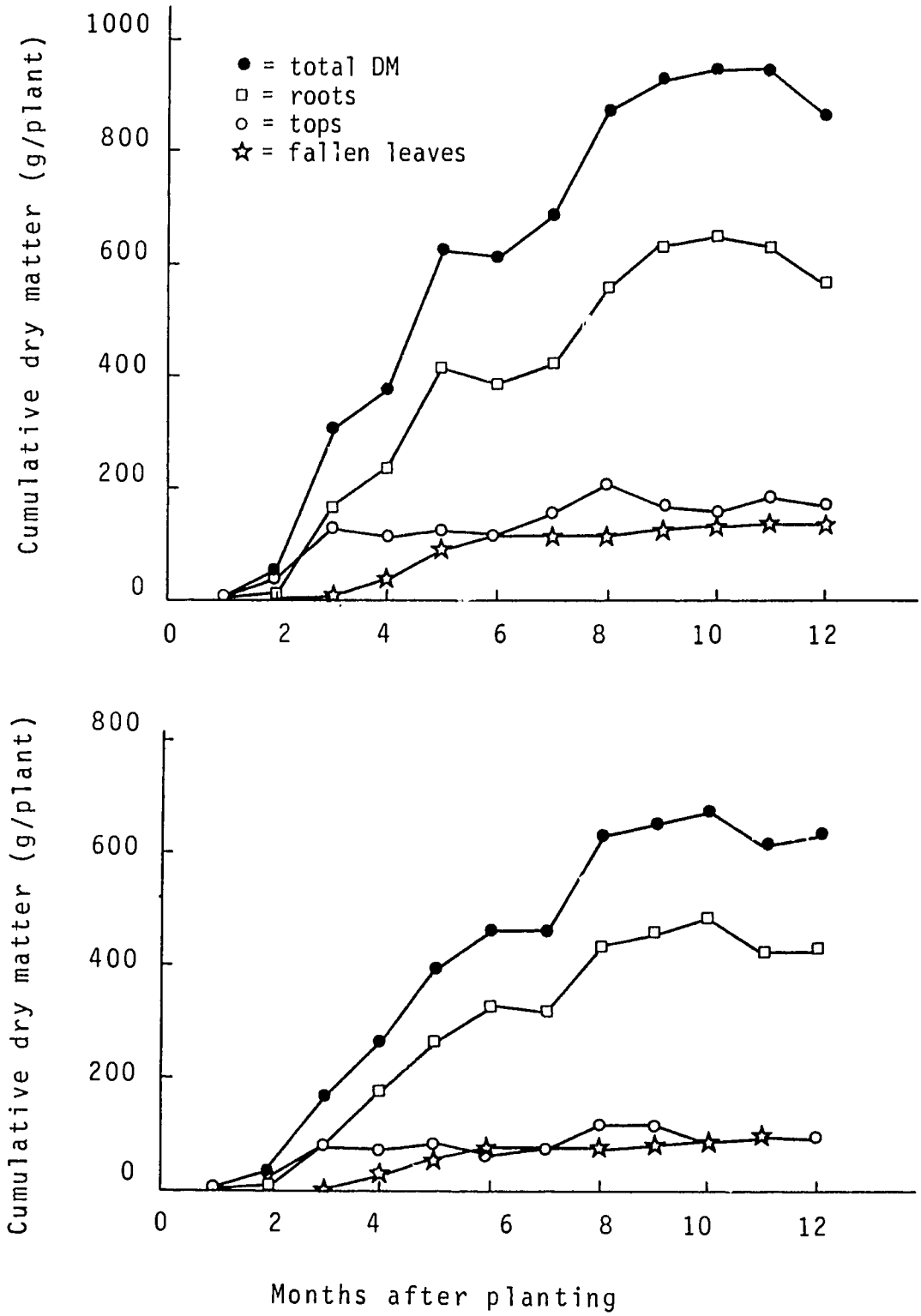


Figure 2. Cumulative total dry matter produced, and its distribution between tops, roots and fallen leaves of fertilized (top graph) and non fertilized (bottom) cassava, M Col 22, during a 12 month growth cycle in Quilichao.

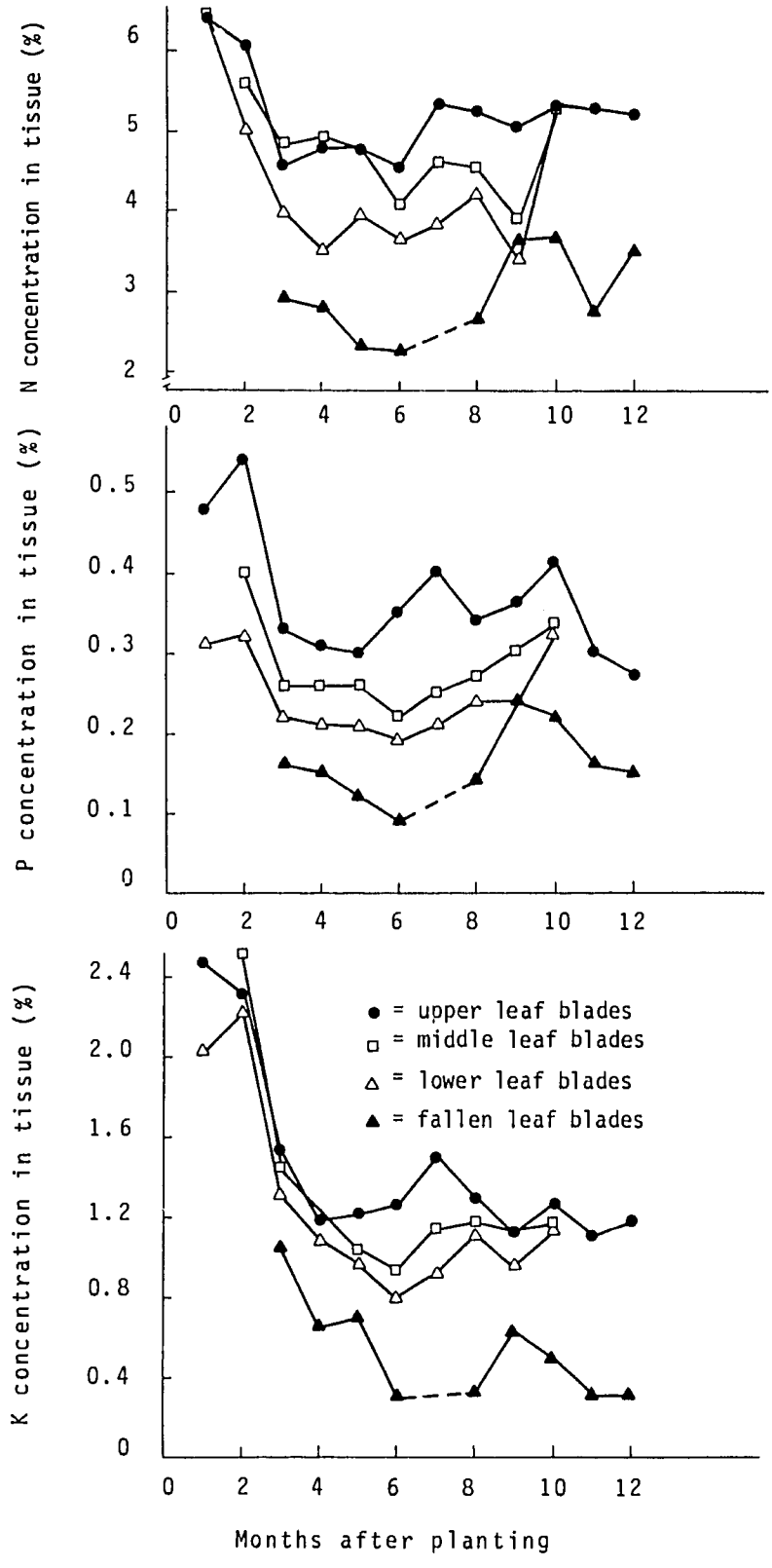


Figure 3. Concentration of N, P and K in leaf blades from the upper, middle and lower part of the plant as well as from fallen leaves of fertilized cassava, M Col 22, during a 12 month growth cycle in Quilichao.

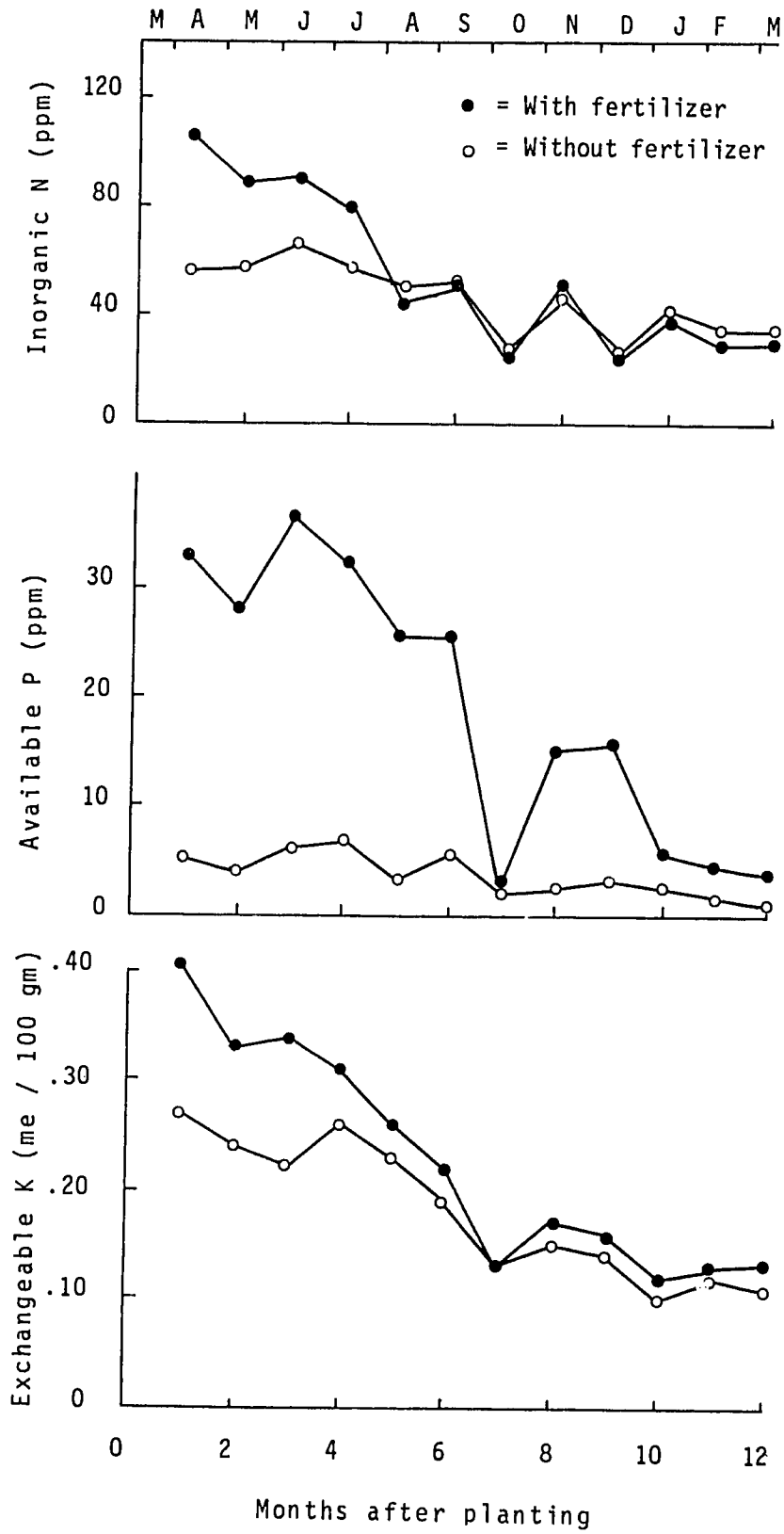


Figure 4. Change in inorganic N, available P (Bray II), and exchangeable K in fertilized and non-fertilized plots of cassava, M Col 22, during a 12 month growth cycle in Quilichao.

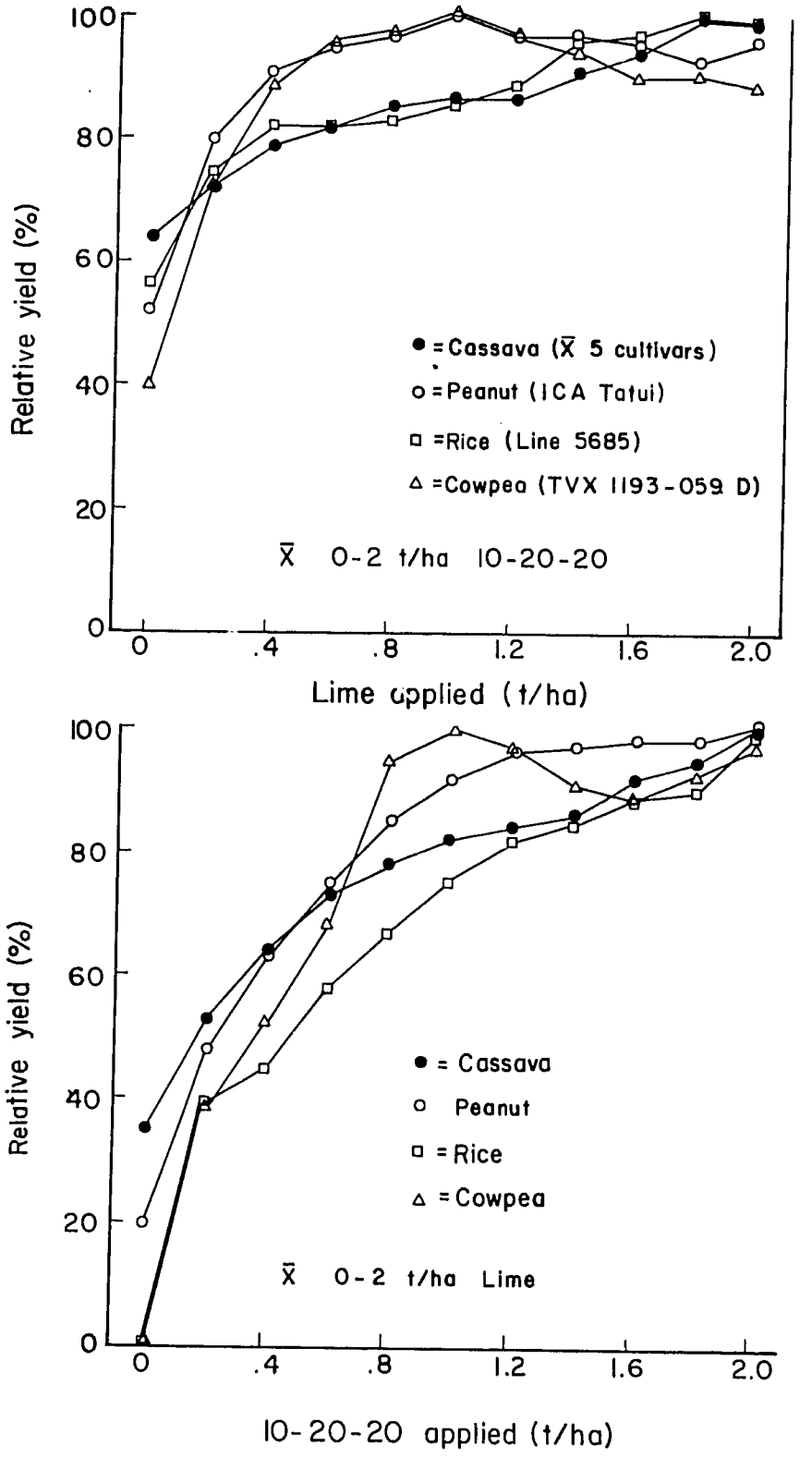


Figure 5. Average relative response of cassava, peanut, upland rice and cowpea to application of lime (A) and 10-20-20 fertilizers (B) in systematic design trials in Carimagua.

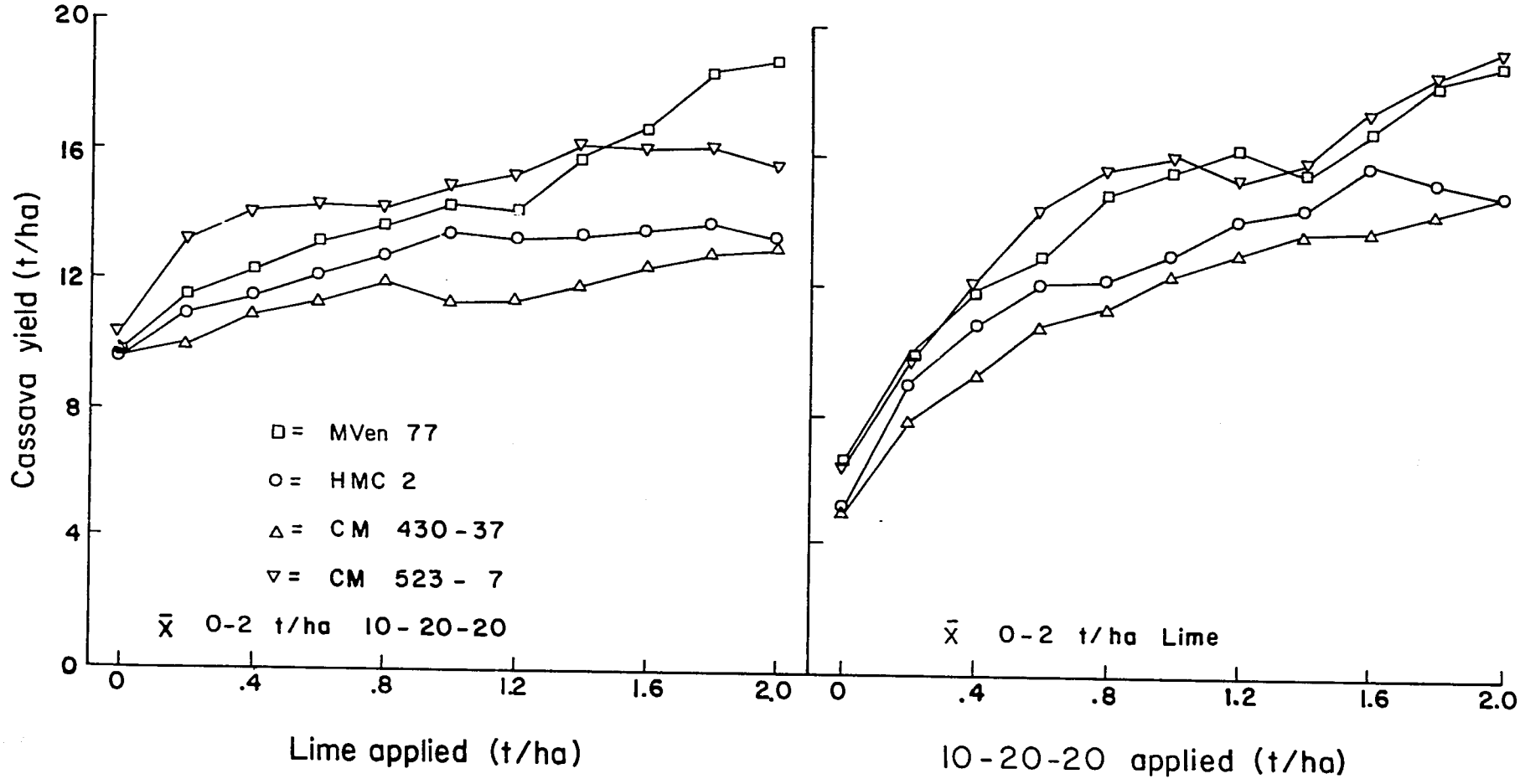


Figure 6. Response of four cassava cultivars to the application of lime (A) and 10-20-20 fertilizers (B) in four systematic design trials in Carimagua.

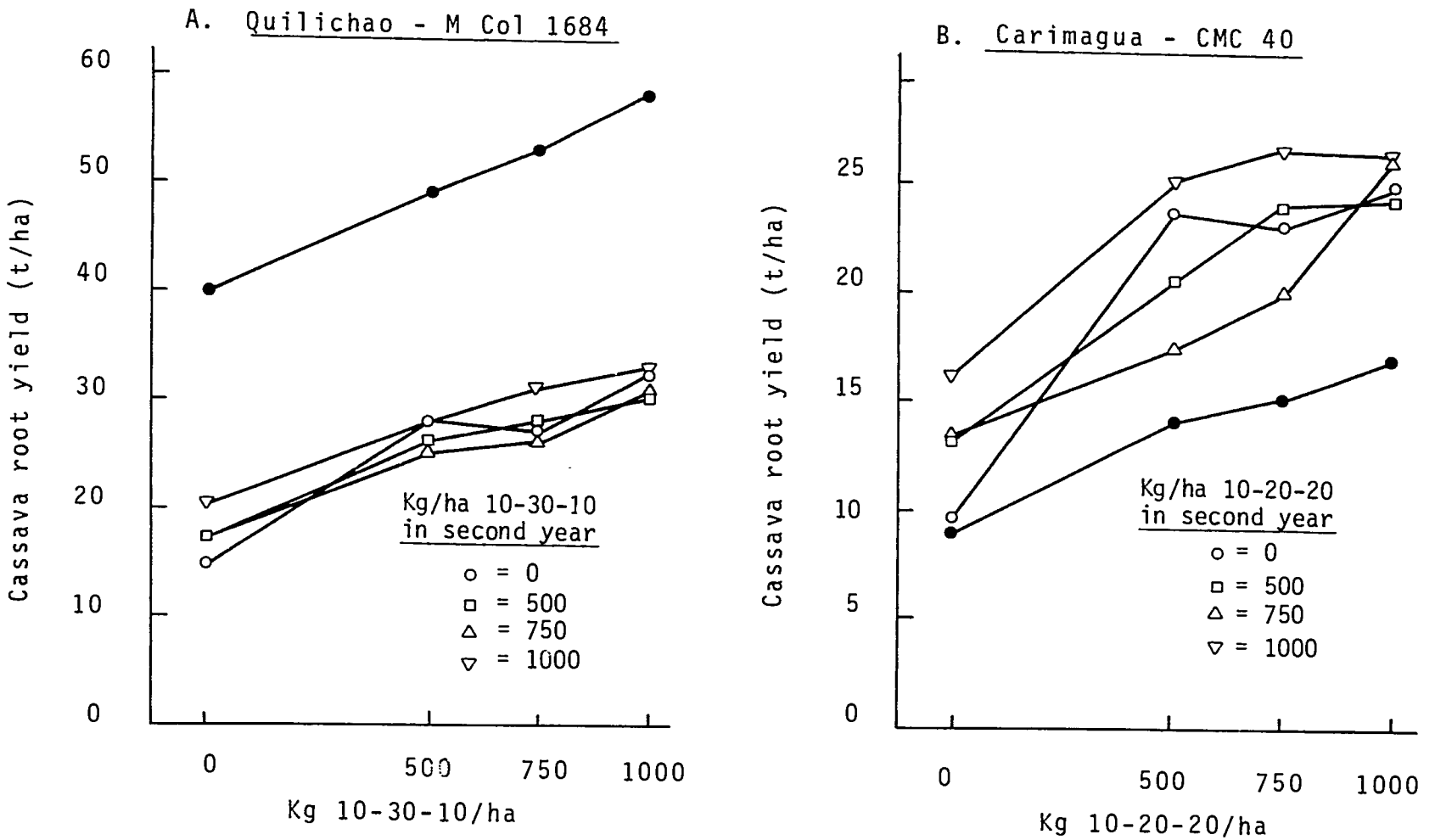


Figure 7. Closed symbols indicate the second year response of cassava in Quilihao (A) and in Carimagua (B) to the application of four levels of NPK fertilizers with the residual effect of 1 t/ha of fertilizer applied in the first year. Open symbols indicate the third year response to the application of four levels of NPK fertilizers with the residual effect of four NPK- levels applied in the second and 1 t/ha application in the first year.

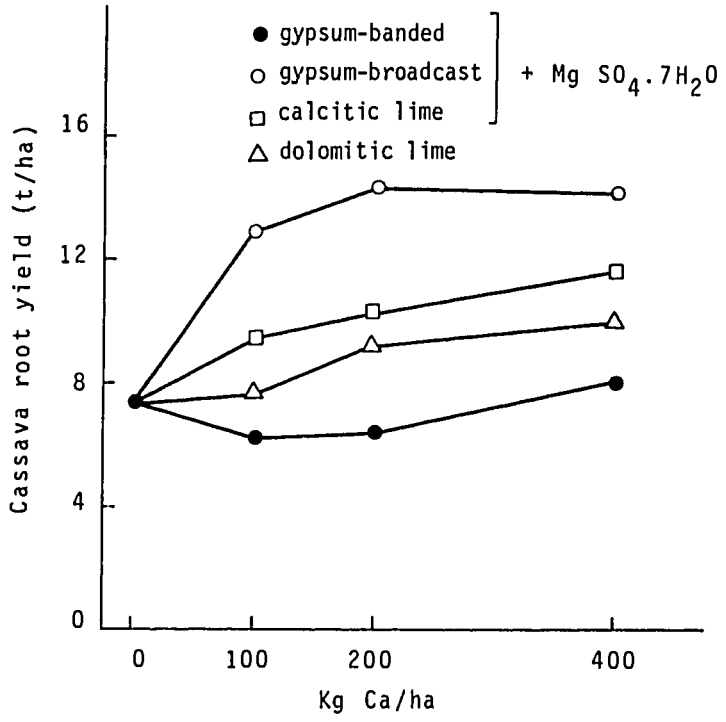


Figure 8. Response of cassava, CM 523-7 to various levels of Ca applied as four different sources in Carimagua- Alegria.

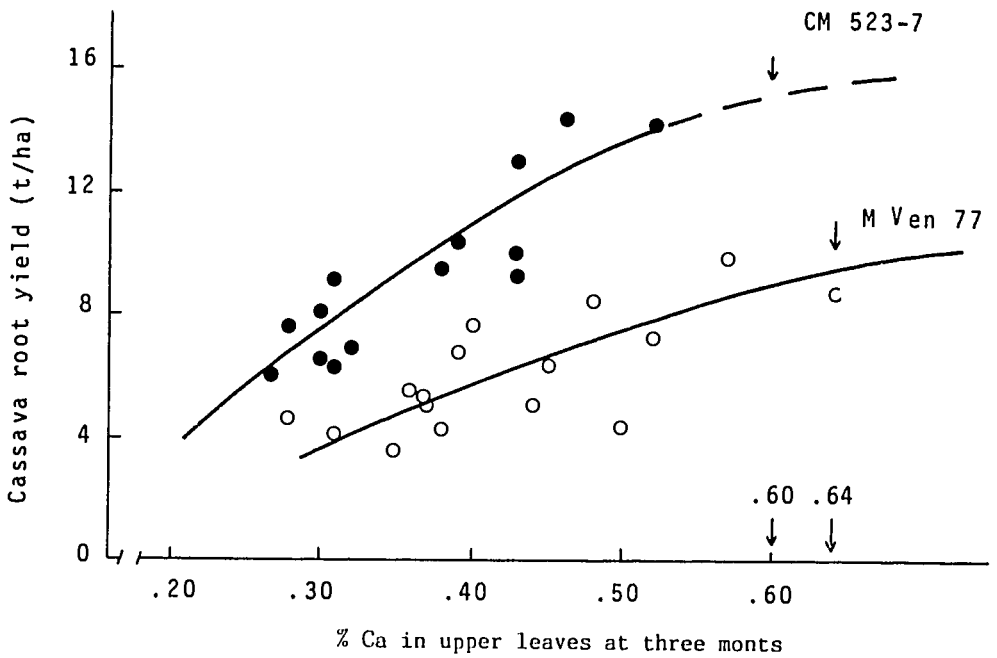


Figure 9. Relation between the root yield of two cassava cultivars and the Ca concentration of YFEL blades at three months after planting in Carimagua- Alegria. Arrows indicate the estimated critical levels.

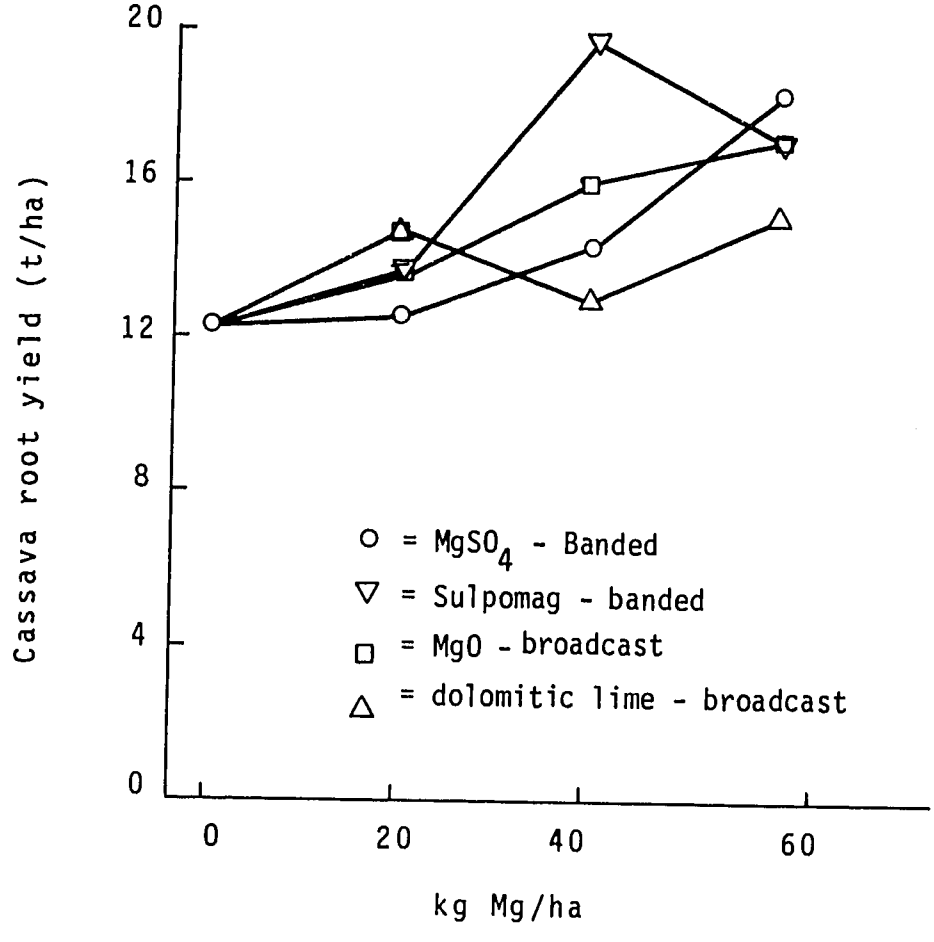


Figure 10. Response of cassava, cv CM 430-37, to various levels of Mg applied as four different sources in Carimagua-Alegría.

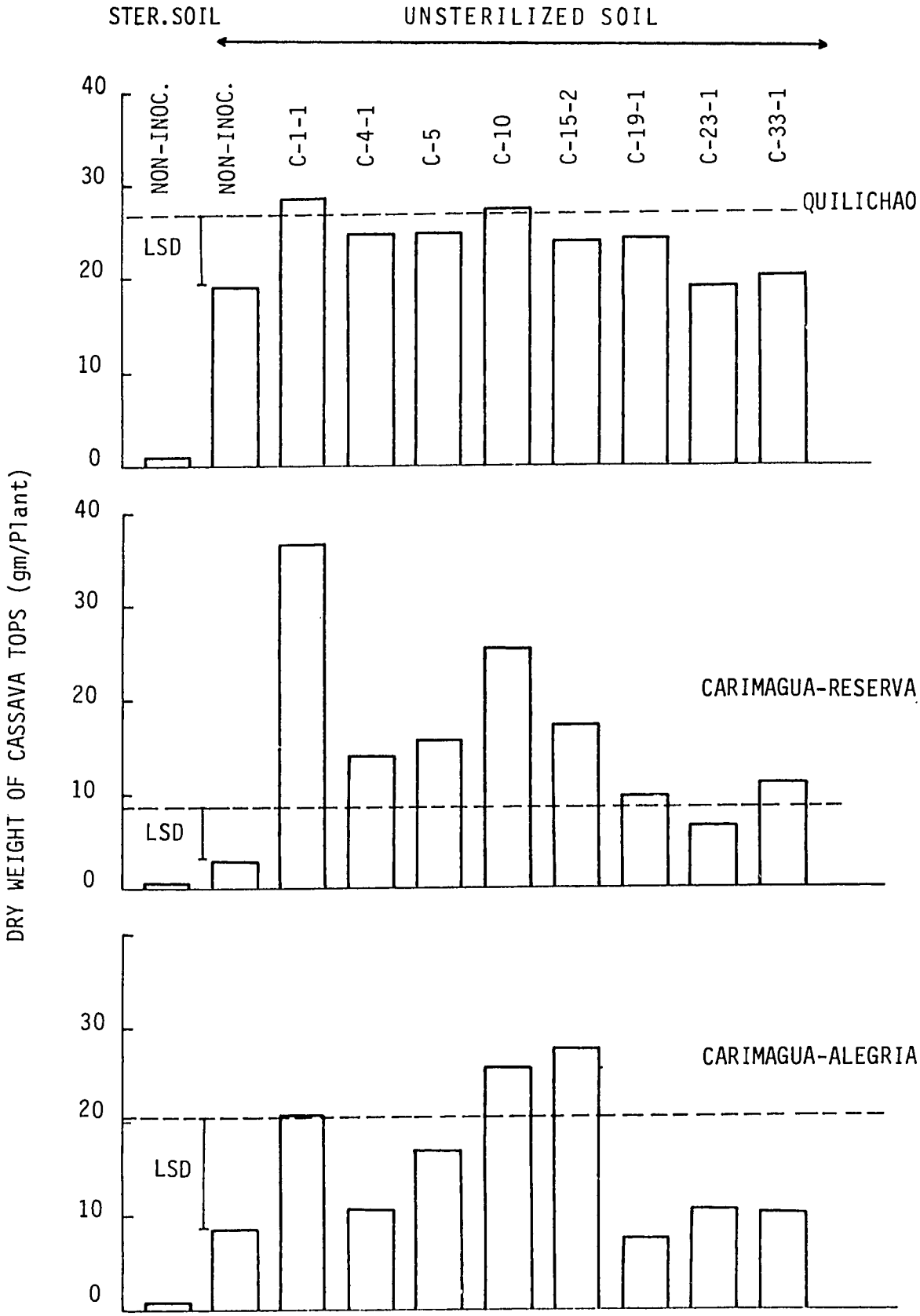


Figure 11. Effect of inoculation with various mycorrhizal strains on DM production of three month old cassava, M Ven 77, grown in three unsterilized soils, compared with the non-inoculated checks in sterilized and unsterilized soils in the greenhouse.

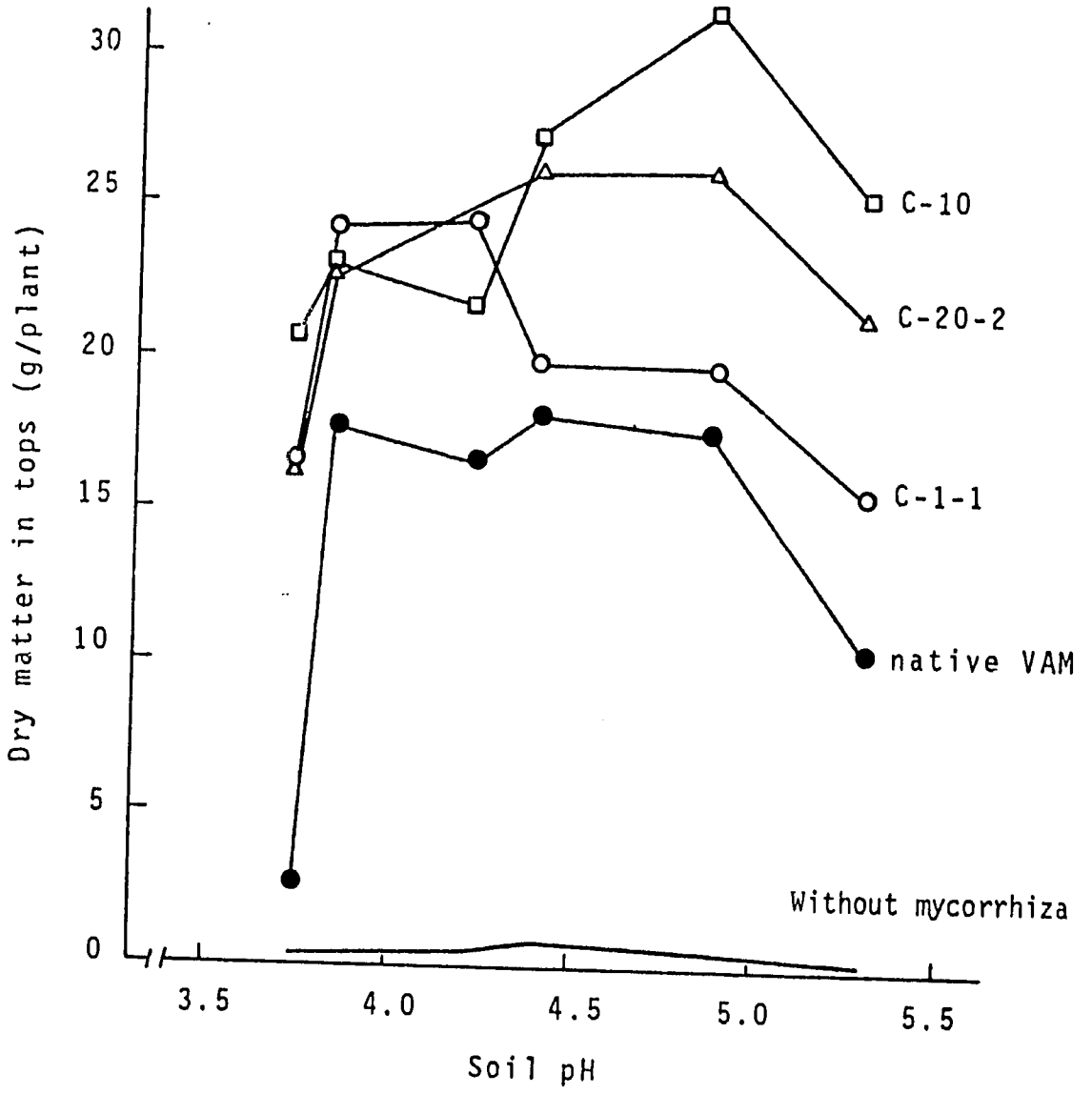


Figure 12. Effect of soil pH on DM production of 2-1/2 month old cassava, M Ven 77, grown without inoculation in unsterilized soil (with native VAM), and without inoculation or inoculated with three mycorrhizal strains in sterilized Quilichao soil in the greenhouse.

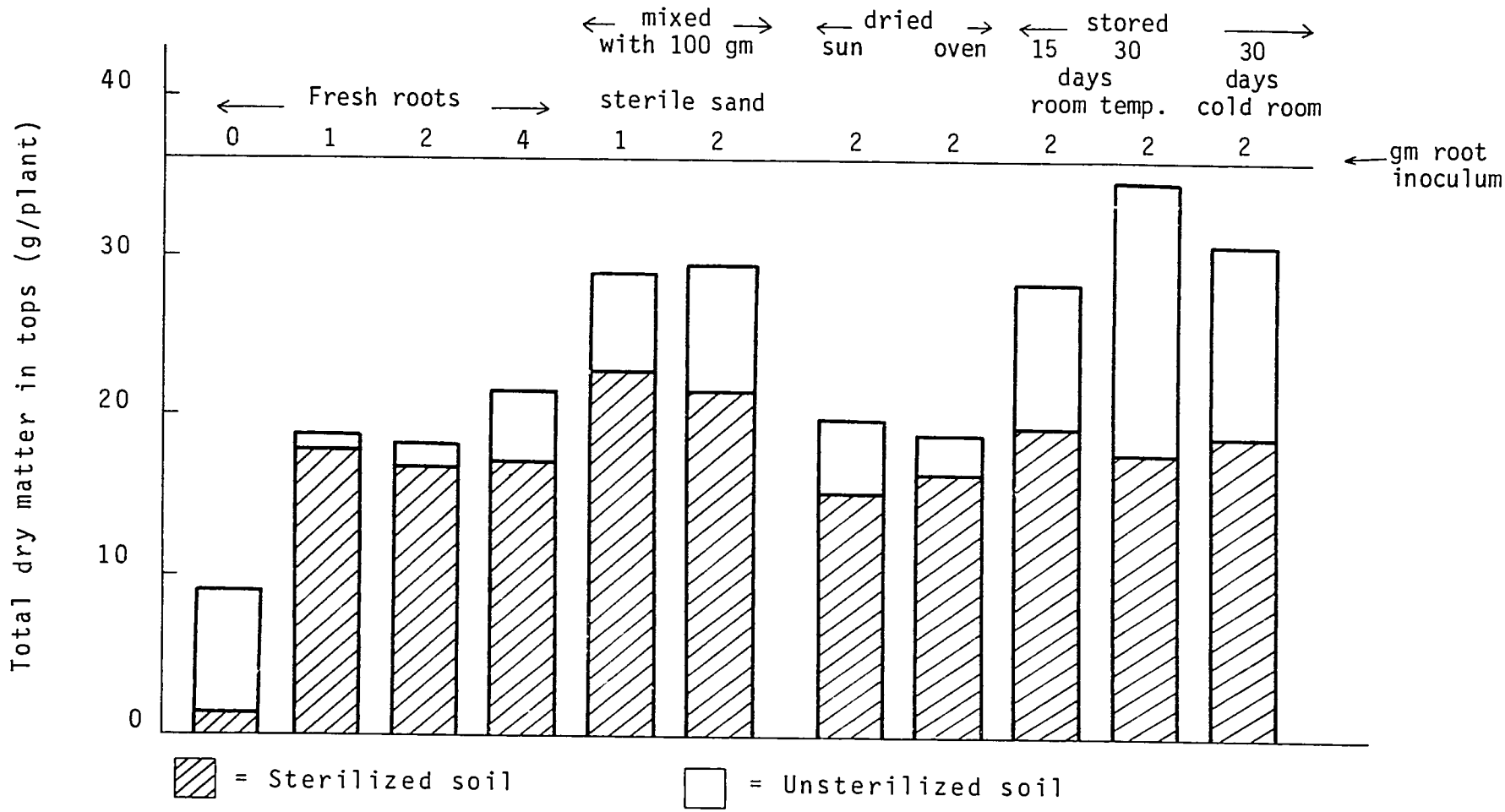


Figure 13. Effect of various amounts and treatments of maize-Kudzu root inoculum infected with C-1-1, on the efficiency of inoculation in increasing DM production of three month old cassava. M Ven 77, grown in sterilized or unsterilized Quilichao soil in the greenhouse.

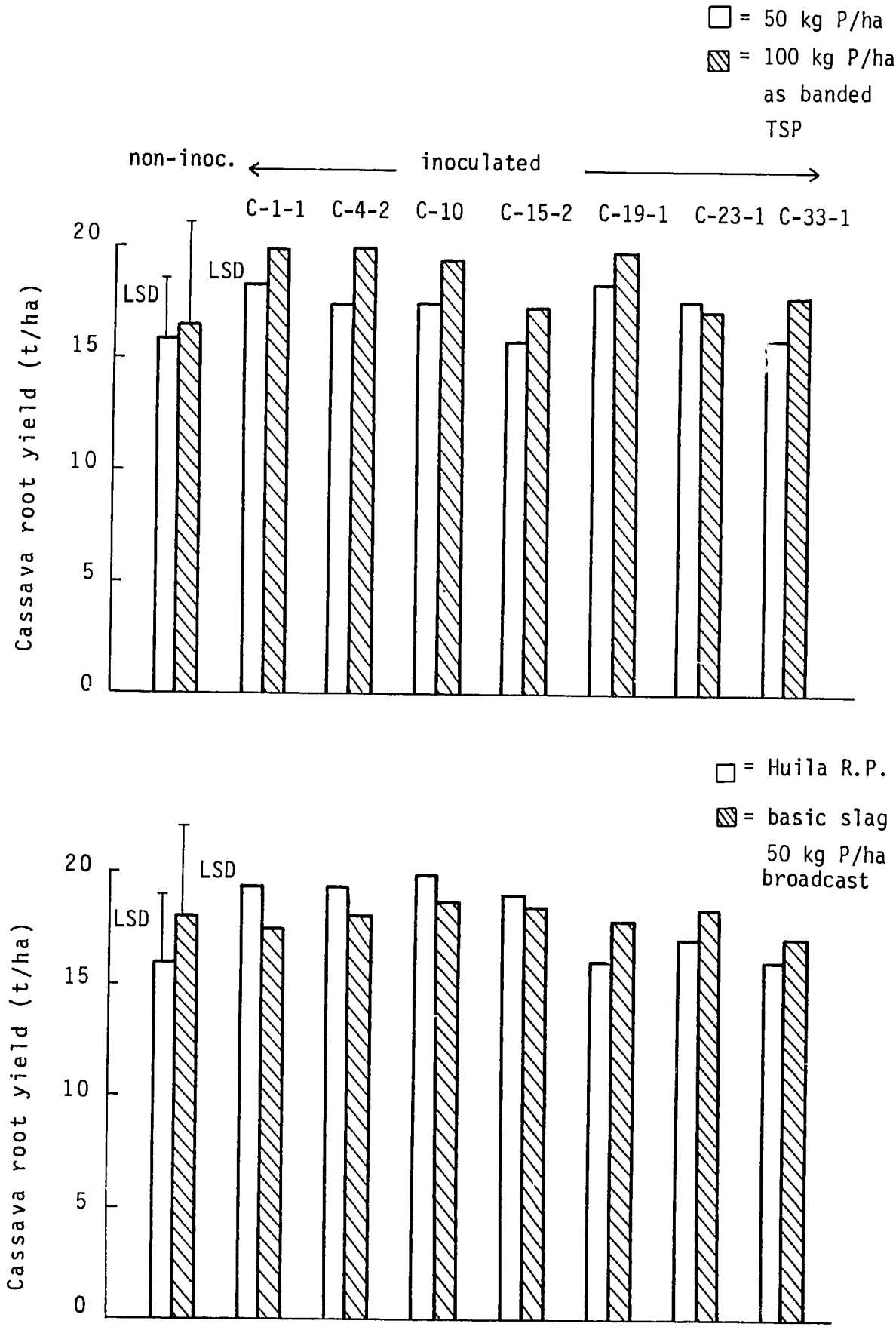


Figure 14. Effect of inoculation with seven mycorrhizal strains and four levels or sources of P on root yield of cassava, M Ven 77, in Carimagua-Alegria.

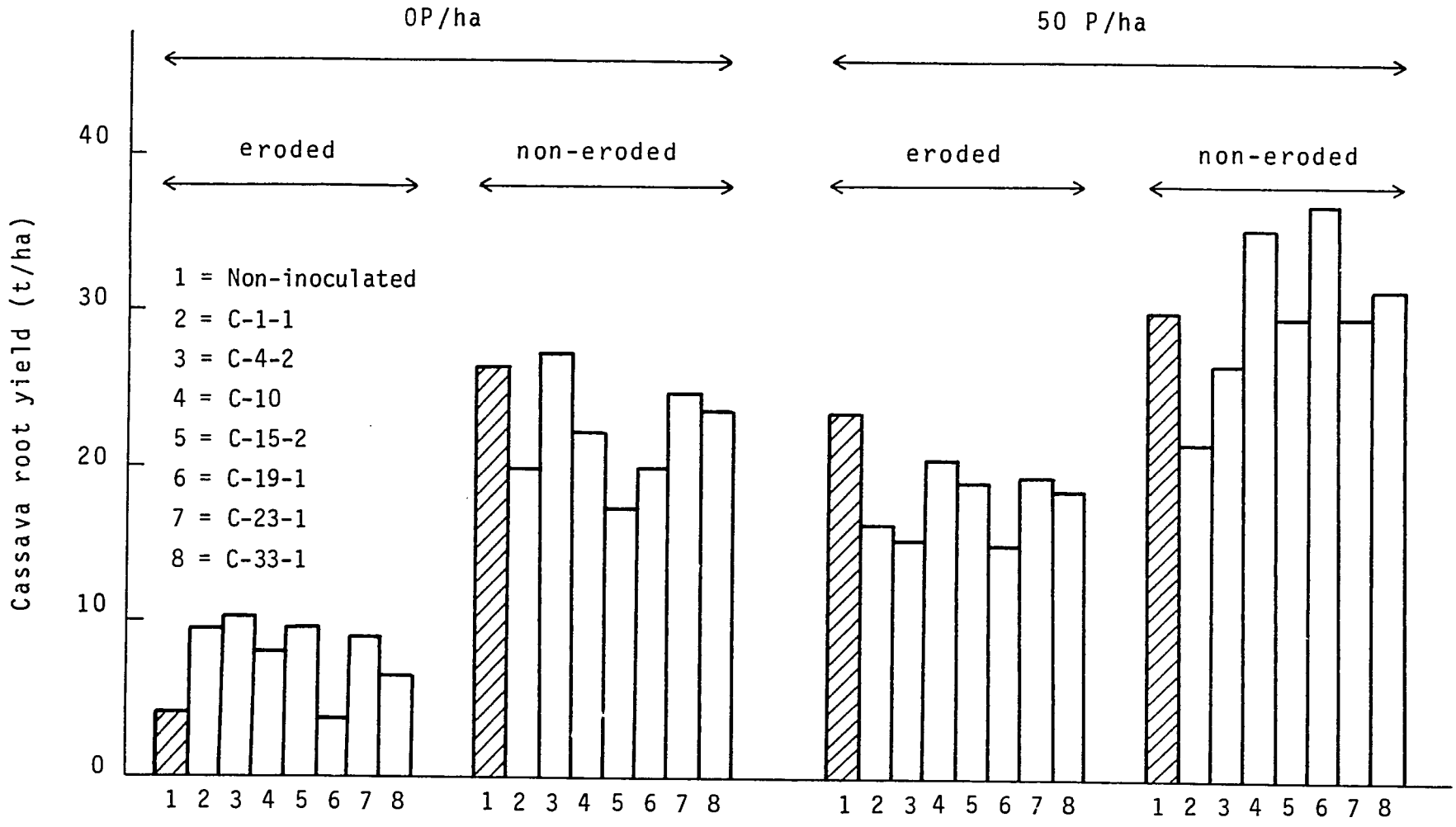


Figure 15. Effect of inoculation with seven mycorrhizal strains and two levels of P on root yield of cassava, CMC 92, in eroded and non-eroded soil in Mondomito, Cauca.

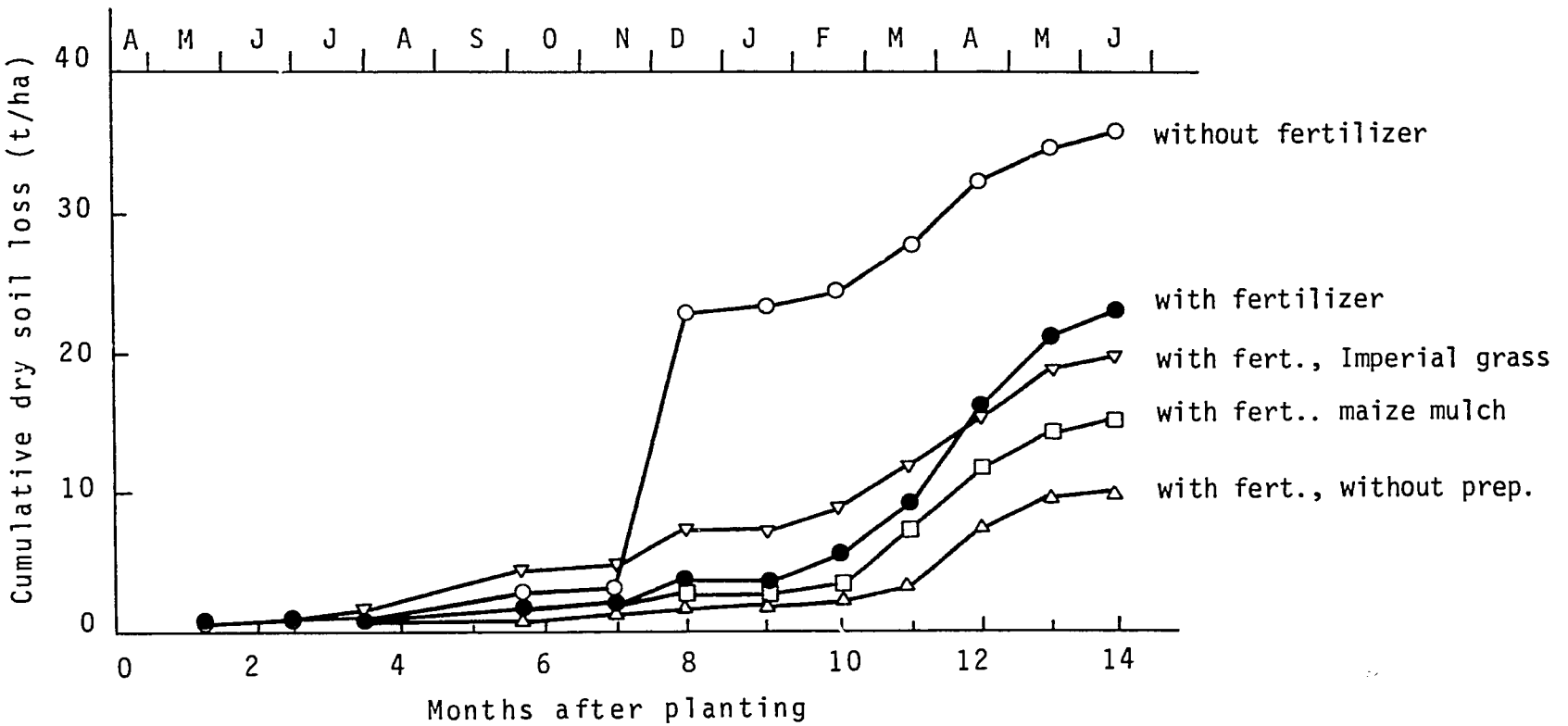


Figure 16. Effect of various soil and crop management treatments on the cumulative soil loss due to erosion in cassava grown on a 35% slope in Agua Blanca, Cauca.

Mycorrhiza Project

During 1983 emphasis was placed on evaluation of VA mycorrhizal isolates under greenhouse and field conditions (see flow chart, Figure 1 of the Cassava Annual Report, 1982). Research was also carried out to determine the long-term effects of agricultural practices on the indigenous mycorrhizal population in the field.

Mycorrhizal Strain Evaluation.

Test I - Effectivity

From CIAT's mycorrhizal strain collection (approximately 300), 70 strains were evaluated for effectivity in the greenhouse Test I (for Test I conditions see "Strain Evaluation" in the Mycorrhiza Section of the Cassava Annual Report, 1982). Parameters for the evaluation in sterilized soil were:

(1) Plant top growth and P uptake, which gives indications about the mycorrhizal strain efficiency for plant production.

(2) Total length of fine roots, which may indicate the beneficial effect of the mycorrhizal strain on the plant's water uptake (i.e. increased potential of the plant for water uptake via the fine roots).

(3) The percentage of infection of the root length by the mycorrhizal fungi which indicates the competitive ability of the strain against indigenous mycorrhizal fungi in the field.

The mycorrhizal strains were classified for each evaluation parameter as follows: where 0 = not effective, i.e. the parameters of evaluation are not significantly different from non mycorrhizal (NM) plants; X = low effectivity, i.e. the values are significantly higher than with NM plants but smaller than the average value of the trial; XX = moderate effectivity, i.e. values are not significantly different from the trial average, and XXX = high effectivity, i.e. values are significantly higher than the trial average. In this way it is possible to list these strains with high potential for increasing cassava production (Table 1), for increasing growth of fine roots (Table 2), for competition with the native mycorrhizal population (Table 3) or those that are not expected to be effective at all (Table 4). From the four tables it is clear that there is a good correlation between growth and P uptake, but a general correlation between root infection and beneficial effect of the mycorrhiza does not exist. This leads to some practical conclusions:

(1) With Test I we can screen the fungal strains for their ability to compete with the native mycorrhizal population and for their effectivity to increase plant growth. Only those strains which at the least are termed moderately effective for all parameters, should be tested in the greenhouse Test II, and in the climatic adaptation trials (soil temperature).

(2) If the correlation between root infection and plant growth does not generally exist there is not much sense in determining root infection by indigenous fungi in the field when the mycorrhizal species which are involved in the infection are unknown.

Test II - Competitive ability

The ability of mycorrhizal strains to compete with native mycorrhizal fungi is evaluated in Test II (for test conditions see "Strain Evaluation" in the Micorrhiza Section of the Cassava Annual Report, 1982). Tables 5 and 6 show that there are several mycorrhizal strains which might be more beneficial for plant growth than the native mycorrhizal fungi. In the test, the native mycorrhizal population from CIAT-Quilichao is used which has a high quantity of more than 2000 infective mycorrhizal propagules/100 g dry soil and which contains two effective mycorrhizal species, i.e. Entrophospora colombiana, Glomus manihotis, and several low to moderate effective species, i.e. Acaulospora longula, A. appendicula, unidentified Acaulospora sp. (type C-4-8) and Gigaspora sp. (type C-37-6). It is clear, however, from the tables that only G. manihotis (C-1-1, C-20-2) competes in root infection with the native mycorrhizal population. Thus, in practical terms only this species can be recommended for field inoculation at sites with high natural competition.

Competitive Ability of G. manihotis and E. colombiana Against Given Quantity and Quality of Single Mycorrhizal Species.

These greenhouse trials are part of a series first reported in the Cassava Annual Report, 1981 where the ability of G. manihotis is tested to improve performance at different population levels in the soil. By mixing known numbers of spores of a mycorrhizal species of known effectivity with sterilized soil, we are able to simulate some natural mycorrhizal population conditions. Additionally, the plants are then inoculated under the plant roots with an effective strain. This is done to predict under what natural mycorrhizal population conditions a field inoculation would be successful. Figure 1 shows that inoculation with G. manihotis may be worthwhile if the field contains a low number of E. colombiana. Additional inoculation with E. colombiana in a field containing the same species, can decrease yields. This may be due to the very high presence of E. colombiana, draining carbohydrates from the host plant for its own development. Under conditions, where G. occultum, a mycorrhizal species of generally low to moderate effectivity is established (Figure 2), both introduced mycorrhizal species were able to compete with very high quantities of G. occultum. The antagonistic effect of G. manihotis to very high spore numbers of G. occultum. should be noted.

Two other trials (Figures 3 and 4) were conducted under similar conditions, with the difference that the established mycorrhizal species was also inoculated additionally and that the additional inoculation in all cases was carried out with infected soil material containing 1000 spores. (In the aforementioned trials, Figures 1 and 2, the additional inoculum contained 2000 spores). Figure 3 shows that plant growth can

colombiana, P uptake at higher P levels was similar to those plants inoculated with G. manihotis alone.

Comparison of Inocula Containing Single or Several Mycorrhizal Species.

The objective was to test inocula which either contained single species (1000 spores/pot), two species (500 spores of each) or three (330 spores of each) on plant growth and on competitive ability of the inocula against the native mycorrhizal population. Results in Table 7 show that G. manihotis was the most effective inoculum when applied as a single strain. Mixtures of different strains were effective only when they contained G. manihotis. It was observed that the proportion of root infection by G. manihotis decreased when G. occultum or E. colombiana were inoculated. This indicates, that when inoculated a single more ineffective species can displace G. manihotis from root infection. This may be due to the inoculation method, i.e. the first sprouting roots are infected by the inoculated strain, thus the naturally occurring effective mycorrhizal species have a lesser chance of infecting the root.

Field Inoculation Trials

Results are now available from field inoculation trials on farmers' fields in the Mondomo region, department of Cauca. In all trials, CMC 92 (adapted to the region) was used. The objectives were: (a) to compare the effectivity of three isolated mycorrhizal strains at three different sites, when either triple- superphosphate (TSP) (50 kg P/ha in a side band) or Huila rock phosphate (HR) (50kg P/ha broadcasted and incorporated) were applied; (b) to compare different methods of applying the mycorrhizal inoculum to the planting stakes of cassava (50 kg P/ha applied as Huila rock phosphate); (c) to compare inoculation with mycorrhizal strains from different climates (50 kg P/ha as Huila rock phosphate); and (d) to test the hypothesis that field inoculation is worthwhile when the native mycorrhizal population is low.

A. Comparison of mycorrhizal strains and P sources

At each trial, site the treatments were randomly distributed and had four replications. Each replicate consisted of 35 plants, (planting distance 80x80 cm) from which the 15 plants in the center were taken for measurement of fresh yields. Table 8 shows the fresh root yields of cassava harvested one year after planting. Between sites great differences were found in yields. Cassava, infected with the natural mycorrhizal fungi (non- inoculated) generally yielded more when TSP was applied than if fertilized with rock phosphate. On the average, all inoculated treatments produced more than without inoculation, the strain C-1-1 being most effective when TSP was applied, and C-33-1, when HR was used. In nearly all cases, TSP application (non-inoculated) could be substituted by rock phosphate plus inoculation with any mycorrhizal strain. Taking into account only the most effective strains at each site, the root yields increased by an average of 3.5 t/ha (27%) when TSP was applied and by 5.0 t/ha (50%) when HR was used as P fertilizer. From these results, it can be concluded that: (a) field inoculation increased yields considerably; (b) soluble P fertilizers could be

be stimulated by higher quantities of A. appendicula. An additional inoculation at high field spore numbers of A. appendicula (80 spores/ 100g dry soil) would only be likely to be efficient with G. manihotis. A clear synergistic effect of E. colombiana with increasing quantities of Gigaspora pellucida a mycorrhizal species without effectivity for cassava plant growth, was found (Figure 4). In general, the most efficient mycorrhizal species competing with different quantities and qualities of other mycorrhizal species, is G. manihotis.

Adaptation of Mycorrhizal Strains to Different Soil Temperatures.

Methods were worked out for evaluation of mycorrhizal strains for adaptation to low soil temperature (20°C) or medium/high temperature (30°C). For the test, one liter of sterilized soil was placed in white painted beakers which were put in water baths with constant water temperatures of 20° and 30°C. M Col 113 was used as the test plant as it is known to be relatively insensitive to different temperatures in plant production. Plants were inoculated with pure mycorrhizal strains. Figure 5 shows that most strains are effective at 30°C soil temperature While only a few are effective at 20°C. It is also clear that the effectivity of a mycorrhizal species (i.e. E. colombiana in this case) may depend on its origen; E. colombiana from Popayan was effective at 20°C but the same species from Carimagua was not. G. manihotis from the north coast of Colombia (high mean annual temperature) was effective at both temperatures. In Figure 6 results are shown for Acaulospora spp., isolated from the Popayan area. They show that Acaulospora spp. vary greatly in effectivity, but at 20°C only two species increased plant growth more than noninoculated plants. The results show that at least for the introduction of strains to colder regions (i.e. elevation more than 1400 msl) an evaluation on adaptation to lower temperatures is required. The same could be useful, when the field is to be inoculated and mulching is planned. By mulching, soil temperature is decreased considerably (See "Mulching" in the Mycorrhiza Section of the Cassava Annual Report, 1982).

Evaluation of Adaptation of Mycorrhizal Species to Different P Application Levels.

In the Cassava Annual Report, 1982 (See "Evaluation of Cultural Practices - Fertilization" in the Mycorrhiza Section) it was concluded that some mycorrhizal species may be adapted to high levels of P application. This hypothesis was tested in a greenhouse trial with G. manihotis, E. colombiana, and G. occultum as well as the mixture of all three species at increasing levels of P. The mycorrhizal strains were mixed with sterilized soil (1000 spores/100 g soil or 330 of each in the mixture). P was incorporated as triple superphosphate (0, 50, 100 and 200kg P/ha). N and . were applied in solution (100 kg/ha of each element). Figure 7 shows the results for plant top growth and P uptake. This trial confirmed that G. manihotis was able to take up the most P at highest P application levels, E. colombiana favored plant growth most at 50 kg of applied P/ha. G. occultum had the lowest effectivity at all P levels. When plants were inoculated with the mixture, plant growth response at 50 kg P/ha was similar to that of plants inoculated with E.

from three trial sites are compared with the root yield increase due to inoculation. It is likely that there is a direct negative correlation between the quantity of native mycorrhizal fungi and the yield increase by inoculation (at least with the C-1-1/C-10 mixture used). However, it s also likely that in addition to native mycorrhizal population quantity, other factors are involved in the success of the inoculation such as the utilization of the field before inoculation. Also, it appears that the quantity of the native mycorrhizal population correlated with the percentage organic matter of the field. This was confirmed by results from other soils (Figure 10).

Effect of Agricultural Practices on the Native Mycorrhizal Fungi Population

At two different sites the effect of the cassava cropping systems on the mycorrhizal spore population was observed. At Media Luna (on the north coast of Colombia) soil samples to determine the population were taken after the third cropping cycle. Cropping systems were: (a) three years continued cassava cropping; (b) three years continued intercropping; (c) crop rotation 1st. year cassava, 2nd. year grain legumes (twice), 3rd. year cassava; and (d) crop rotation 1st. year pasture fallow, 2nd. year grain legumes (twice) and in the 3rd. year cassava. Each cropping system was grown with and without fertilization. Fertilized plots received a total annual application of 50 kg N, 44 kg P, 50 kg K, 10 kg Zn and 1 kg B/ha. The mycorrhizal spore numbers per 100 g dry soil for each treatment is shown in Table 11. It is clear that one mycorrhizal species was dominant in the whole field (i.e. the spore type "J" *Glomus* sp. "FAS". The mycorrhizal spore composition was especially changed by the continuous cropping of cassava, when fertilizers were applied. There, the spore types "G" (non-identified sp.) and "H" (*Acaulospora* sp.) were more numerous than in the other cropping systems. In all other treatments, including different soil depths, no clear tendencies were observed. It seems that each cropping system and fertilizer application can individually change the mycorrhizal species composition.

At Caicedonia, continued cassava cropping was compared with crop rotation systems (Table 12). The systems were both fertilized and unfertilized. It seems that in the crop rotation system the mycorrhizal spore population was more numerous than in the cassava continuous cropping system. In both systems the mycorrhizal spore number was depressed by fertilizer application. However, not all mycorrhizal species were equally affected by cropping system and fertilization.

substituted by rather insoluble rock phosphate when the latter was combined with field inoculation; (c) the mycorrhizal strain C-1-1 (G. manihotis) may be suitable with both P sources; however, the strain C-33-1 may be more suitable when rock phosphates are applied. This must be investigated more carefully as C-33-1 (G. occultum) is known to be only moderately effective in greenhouse trials.

B. Comparison of inoculation methods

In two trials the inoculum was placed in different ways around the planting stake. The methods are given in Table 9. Root yields at one year after planting showed clearly that the most effective placement method may be the application of half of the inoculum at planting time under the cassava planting stake and applying the other half in a side-band to the stakes after 4-5 months growth (i.e. during the dry season, see also "Spread of Mycorrhizal Infection in the Field" in Mycorrhiza Section of the Cassava Annual Report, 1982). However in both trials there were some anomalies. At Tres Quebradas the native mycorrhizal population was very high (more than 1700 infective mycorrhizal propagules per g dry soil), This may explain why the success of field inoculation was low, and even negative, when the inoculum was placed under the stakes. At Agua Blanca there was a severe attack by Phoma sp., from eight months after planting until harvest. Reduced photosynthetic potential may have resulted in the low yield increase by field inoculation; a higher yield increase by inoculation was expected because the natural mycorrhizal population was low at time of planting.

C. Comparison of mycorrhizal strains from different climates

At two sites, fields were inoculated with either the mixture of C-1-1/C-10, (C-1-1 from CIAT-Quilichao, a site with 23°C mean temperature and C-10 from Carimagua, mean annual temperature 28°C) as well as with E. colombiana (C-3-5 from Popayan) and with A. longula (C-3-6 from Popayan with a mean annual temperature of 19°C). The inoculum was infected soil 400 g of which was applied under each stake at planting. The trial sites have similar climatic conditions as Popayan. The results (Figure 8) showed clearly, that a cool climate adapted strain (C-3-5), can be more effective than the strains C-1-1/C-10, both evaluated to be effective in the greenhouse; C-10, however, was not adapted to cool climates. Figure 9 shows the result at another site, where the strain mixture was compared with C-3-6, a strain of moderate effectivity, but not well adapted to cool climates. Even so, C-3-6 increased root yield production significantly, but not as much as the strain mixture C-1-1/C-10. The fact that the strain mixture was more effective in the last trial than in the aforementioned one can be explained by the smaller total native mycorrhizal population (see below).

D. Effect of native mycorrhizal population on inoculation efficiency.

At planting soil samples were taken at the three trial sites for determination of infective mycorrhizal propagules with "the most probable number" method. In Table 10 the data of soil characteristics

Table 1. Mycorrhizal strains with high potential for increasing cassava production.

Strain No.	Species code	Effectivity in sterilized soil for			
		Dry matter	P uptake	Root length	Root infection
C-1-1	MAN	xxx	xxx	-	xxx
C-1-4	COL	xxx	xxx	-	xxx
C-3-5	COL	xxx	xxx	-	xx
C-4-1	FOV	xxx	xxx	-	xxx
C-6-2	LON	xxx	xxx	-	xx
C-7	007	xxx	xxx	-	0
C-10	COL	xxx	xxx	-	x
C-11-2	COL	xxx	xxx	xxx	0
C-12-1	LON	xxx	xxx	xxx	0
C-12-2	OCC	xxx	xxx	xx	x
C-13-1/2	APP	xxx	xxx	xx	x
C-16-1	LON	xxx	xxx	xxx	xx
C-17-1	MAN	xxx	xx	xx	xxx
C-18-2	OCC	xxx	xxx	xx	x
C-18-5	LON	xxx	xxx	xx	xxx
C-20-2	MAN	xxx	xxx	xx	xxx
C-20-3	COL	xxx	xxx	xx	x
C-22-4	A.sp.	xxx	xxx	xx	xx
C-23-3	TRA	xxx	xxx	xx	xxx
C-23-8	A.sp.	xxx	xxx	xx	xx
C-25-1	Gl.sp.	xxx	xxx	xx	xx
C-25-3	OCC	xxx	xxx	xxx	xxx
C-26-1	MAN	xxx	xxx	xxx	xxx
C-27-1	COL	xxx	xxx	xxx	xx
C-27-3/4	APP	xxx	xxx	xxx	xx
C-31-1	COL	xxx	xxx	xxx	xx
C-32-1	MAN	xxx	xxx	-	-
C-33-4	MAN	xxx	xxx	xx	xxx
C-73-1	MAN	xxx	xxx	xxx	xxx
C-75-2	COL	xxx	xxx	xxx	xx
C-78	054	xxx	xxx	xx	xx
C-80	CLA	xxx	xxx	xx	xxx
C-82	MAN	xxx	xxx	xxx	xx

-: Lost data
0: Not effective

x: Low effectivity
xx: Medium effectivity
xxx: High effectivity

Table 2. Mycorrhizal strains with high potential for increasing growth of fine roots.

Strain no.	Species code	Effectivity in sterilized soil for			
		Dry matter	P uptake	Root length	Root infection
C-11-2	COL	xxx	xxx	xxx	0
C-12-I	LON	xxx	xxx	xxx	0
C-15-1/2	MEL	xx	xx	xxx	xx
C-16-1	LON	xxx	xxx	xxx	xx
C-25-3	OCC	xxx	xxx	xxx	xxx
C-26-1	MAN	xxx	xxx	xxx	xx
C-27-1	COL	xxx	xxx	xxx	xx
C-27-3/4	APP	xxx	xxx	xxx	xx
C-28-5	LON	x	x	xxx	xx
C-31-1	COL	xxx	xxx	xxx	xx
C-74-1	MOR	xx	xx	xxx	xx

0: Not effective
x: Low effectivity
xx: Moderate effectivity
xxx: High effectivity

Table 3. Mycorrhizal strains with high potential for infecting cassava roots.

Strain no.	Species code	Effectivity in sterilized soil for			
		Dry matter	P uptake	Root length	Root infection
C-1-1	MAN	xxx	xxx	-	xxx
C-1-4	COL	xxx	xxx	-	xxx
C-3-3	GEO	xx	xx	-	xxx
C-4-1	FOV	xxx	xxx	-	xxx
C-4-9	CLA	xx	xx	-	xxx
C-5	FAS	x	x	-	xxx
C-8	FAS	x	x	-	xxx
C-17-1	MAN	xxx	xx	xx	xxx
C-18-1	FAS	xx	xx	xx	xxx
C-18-5	LON	xxx	xxx	xx	xxx
C-20-2	MAN	xxx	xxx	xx	xxx
C-22-3	TRA	xxx	xxx	xx	xxx
C-23-1	LON	xx	xx	x	xxx
C-24-4	OCC	xx	xx	xx	xxx
C-25-3	OCC	xxx	xxx	xxx	xxx
C-26-1	MAN	xxx	xxx	xxx	xxx
C-26-2	OCC	x	xx	x	xxx
C-77-1	MOR	0	0	x	xxx

-: Lost data
0: Not effective
x: Low effectivity
xx: Moderate effectivity
xxx: High effectivity

Table 4. Mycorrhizal strains found to be ineffective.

Strain no.	Species code	Effectivity in sterilized soil for			
		Dry matter	P uptake	Root length	Root infection
C-2-5	OCC	x	xx	-	xx
C-3-7	PEL	0	0	-	xx
C-3-8	FAS	0	0	-	xx
C-4-6	Gl.sp.	0	0	-	xx
C-11-1	LON	x	x	x	x
C-14	MOR	0	x	0	xx
C-17-2	LON	0	0	0	xx
C-27-10	OCC	x	xx	x	xx
C-28-7	-	0	0	0	xx
C-29-1	FAS	x	x	-	-
C-29-2	OCC	0	0	x	x
C-29-3	LON	x	x	-	-
C-31-2	MOR	0	0	-	-
C-33-2	A.sp.	0	x	-	-
C-34-1	OCC	x	x	xx	x
C-75-1	NIG	0	0	x	xx
C-76-1	SCR	0	0	xx	xx
C-83-1	PEL	x	x	-	-

-: Lost data
0: Not effective
x: Low effectivity
xx: Medium effectivity
xxx: High effectivity

Table 5. Effect of mycorrhizal strains on cassava growth in soil with high mycorrhizal competition (unsterilized soil from Quilichao) in Test II.

Strain no.	Species code	Shoot dry weight g/plant	P content mg P/g dry weight	Root length m/plant	Root length infected (%)
Native		5.66 d*	1.65 c	19.4 a	41.0 bc
C-1-1	MAN	14.05 a	1.70 bc	11.4 a	62.3 a
C-3-5	COL	8.82 bcd	1.78 bc	14.4 a	35.2 bc
C-6-2	LON	7.55 bcd	1.63 c	17.3 a	33.9 bc
C-7	007	11.49 ab	1.85 bc	15.6 a	25.0 cd
C-10	COL	9.95 bc	1.90 bc	13.6 a	42.3 bc
C-12-1	LON	8.19 bcd	2.45 a	13.3 a	48.5 ab
C-12-2	OCC	6.57 cd	2.00 b	10.6 a	37.9 bc
Mean		9.04	1.87	14.45	40.76

* Figures followed by the same letter (s) were not statistically different at the 0.05 level of the Duncan Test.

Table 6. Effect of mycorrhizal strains on cassava growth in soil with high mycorrhizal competition (unsterilized soil from Quilichao), Test II.

Strain no.	Species code	Shoot dry weight g/plant	P content mg P/g dry weight	Root length m/plant	Root length infected (%)
Native		3.77 [c]	1.88 [abcd]	10.7 [a]	34.2 [b]
C-1-1	MAN	6.49 [ab]	1.97 [abc]	9.3 [a]	81.3 [a]
C-15-1/2	MEL	8.76 [a]	1.85 [bcd]	10.5 [a]	16.8 [c]
C-16-1	LON	5.90 [bc]	2.23 [a]	14.0 [a]	34.4 [b]
C-18-2	OCC	5.81 [bc]	1.73 [cd]	14.1 [a]	38.3 [b]
C-18-5	LON	6.33 [b]	1.55 [d]	13.8 [a]	41.8 [b]
C-20-2	MAN	7.39 [ab]	2.15 [ab]	15.4 [a]	81.4 [a]
Mean		6.35	1.91	12.5	46.8

Table 7. Influence of mixed inocula on cassava growth and root infection in unsterilized soil from Quilichao.

Treatment [a]	Shoot dry weight g/plant	Root length m/plant	Root length infected with HAV [b] (%)	Root length infected with vesicles [c] (%)
Native My.	2.78	19.7	33.5	10.2
MAN	3.60	16.0	47.5	26.3
OCC	2.79	13.6	32.9	4.2
COL	3.38	14.0	34.6	6.6
MAN+OCC	3.47	10.6	60.6	24.8
MAN+COL	3.57	10.8	59.0	28.5
OCC+COL	3.18	13.1	41.6	12.1
MAN+OCC+COL	3.45	12.8	65.0	30.4

[a] MAN: *Glomus manihotis*, OCC: *Glomus occultum*, COL: *Entrophospora colombiana*

[b] Infected with either hyphae, arbuscles or vesicles

[c] Of all mycorrhizal species in this trial, only *Glomus manihotis* forms vesicles in the roots.

Table 8. Effect of field inoculation and P sources [50 kg P/ha as triple superphosphate (TPS) or Huila rock phosphate (HR)] on fresh root yields (t/ha) of CMC 92, at three sites in Cauca Department of Colombia.

Inoculation [a]	Pescador		Mondomito		Agua Blanca		Average	
	TSP	RH	TSP	RH	TSP	RH	TSP	RH
Not inoculated	18.5	11.3	7.0	6.2	13.1	12.7	12.9	10.1
C-1-1	22.9	17.3	7.2	8.0	18.1	15.5	16.1	13.6
C-10	19.7	18.7	7.8	9.5	16.0	11.8	14.5	13.3
C-33-1	21.1	20.4	8.2	9.2	14.0	14.6	14.4	14.7

[a] Inoculated with 500 g soil substrate infected with *Glomus manihotis* (C-1-1), *Entrophospora colombiana* (C-10) or *Glomus occultum* (C-33-1).

Table 9. Effect of methods of inoculum placement (inoculum mixture of *Glomus manihotis*, C-1-1, with *Entrophospora colombiana* (C-10) on root yields (t/ha) of CMC 92 at two locations in Mondomo, Cauca. Inoculum consisted of infected soil substrate (400 g inoculum/plant).

Method of inoculum placement	Trial sites	
	Tres Quebradas	Agua Blanca [a]
A. Not inoculated	17.7	15.6
B. Inoculum placed under stakes, all at planting	15.7	17.6
C. Half of inoculum under stakes at planting, half in side bands, 5 MAP [b]	19.1	18.3
D. Inoculum placed in side bands, all at planting	c	16.8
E. Inoculum placed in side bands, half at planting, half 5 MAP	17.5	-
F. Inoculum placed in side bands, all 5 MAP	-	14.1

[a] At Agua Blanca eight replications were used as trial was designed for long term observation effect of inoculation. At 8 MAP a severe attack by disease (*Phoma* sp.) occurred in some replications.

[b] MAP: Months after planting.

[c] Treatments were not conducted.

Table 10. Correlation between soil chemical and biological characteristics and the yield increase due to field inoculation.

Trial no.	Utilization of field before planting	Soil OM %	Native infective mycorrhizal propagules per 100 g	P ppm Bray II	Not inoc.	Inoc.[a]	Yield increase to inoc.
1.	3 years cassava	18.9	1717	1.4	17.7	15.7	- 2.0
2.	1 year cassava	8.5	823	2.9	24.7	27.8	+ 3.1
3.	Pasture	3.2	103	1.2	21.2	27.1	+ 5.9

[a] Inoculation with 400 g under stakes at time of planting; inoculum consisted of infected soil substrate, mixture of *Glomus manihotis* (C-1-1) and *Entrophospora colombiana* (C-10).

Table 11. Effect of cassava cropping systems (with and without fertilization) on the composition of mycorrhizal species population (No. of spores/100 g dry soil) at two soil depths at Media Luna (means of four replications).

Cropping system	Fertil-ization	Soil depth cm	Mycorrhizal species [a]														Total
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	
			No. of spores/No. g dry soil														
Three years continued cassava cropping	NO	0-20	1	2	7	3	0	1	1	1	1	42	0	9	2	0	70
		20-40	0	0	1	3	0	2	0	13	0	43	0	5	7	1	74
	YES	0-20	3	0	20	2	0	2	0	17	1	71	0	3	1	0	120
		20-40	1	0	40	4	2	4	1	17	4	48	0	2	0	0	130
Three years cassava inter-cropped with legumes	NO	0-20	0	0	2	1	2	2	0	2	0	36	1	3	0	1	50
		20-40	0	0	0	0	0	2	2	10	3	33	0	2	0	0	52
	YES	0-20	0	1	0	0	0	11	0	0	10	36	0	4	0	0	62
		20-40	0	0	2	0	0	1	0	2	3	52	0	0	0	1	63
Crop rotation: cassava- twice legumes- cassava	NO	0-20	1	2	9	12	4	9	4	4	1	47	0	1	0	0	94
		20-40	2	0	4	3	0	2	0	0	3	48	0	0	0	0	62
	YES	0-20	0	1	6	0	0	4	1	2	5	67	0	3	0	0	89
		20-40	0	1	0	0	0	2	0	2	1	33	0	0	0	0	39
Crop rotation: fallow-twice legumes-cassava	NO	0-20	0	0	6	2	0	5	0	0	3	49	0	5	0	0	70
		20-40	0	0	3	2	1	10	0	0	4	33	0	1	0	0	53
	YES	0-20	0	0	1	3	0	0	0	0	3	44	0	1	1	0	53
		20-40	0	2	1	3	0	9	0	6	3	83	0	0	1	0	108
Means			1	1	6	2	1	4	1	5	2	60	0	2	1	0	86

a Mycorrhizal species: A, *Glomus* sp.; B, *Acaulospora* sp.; C, *Glomus* sp. "MAN"; D, *Acaulospora* sp.; E, *Glomus* sp.; F, *Glomus* sp.; G, nonidentified genera; H, *Acaulospora* sp.; I, *Glomus* sp.; J, *Glomus* sp. "FAS"; K, *Gigaspora* sp.; L, *Sclerocystes* sp.; M, *Gigaspora* sp.; N, *Gigaspora* sp.

Table 12. Effect of continued cassava cropping and of crop rotation [a] on mycorrhizal spore population (spores/100 g dry soil) at Caicedonia,

Mycorrhizal species	Continuous cassava fertilization		Crop rotation fertilization		Mean
	-	+	-	+	
A. *Glomus* sp. "OCC"	10	26	47	22	26
B. *Glomus* sp.	30	15	42	23	28
C. *Acaulospora* sp. "MOR"	23	38	12	17	23
D. *Glomus* sp. "FAS"	128	94	201	155	145
E. *Gigaspora* sp. "GIG"	18	4	18	16	14
F. *Glomus* sp.	15	26	10	6	14
G. *Glomus* sp.	0	0	1	0	1
H. Unidentified genera	16	28	61	27	33
I. Unidentified genera	0	0	1	1	1
Total	240	231	393	267	265

a. Eight years continued cassava cropping, three years fertilized and unfertilized. Crop rotation: five years cassava - *Crotalaria* - maize - cassava - maize - beans - sorghum.

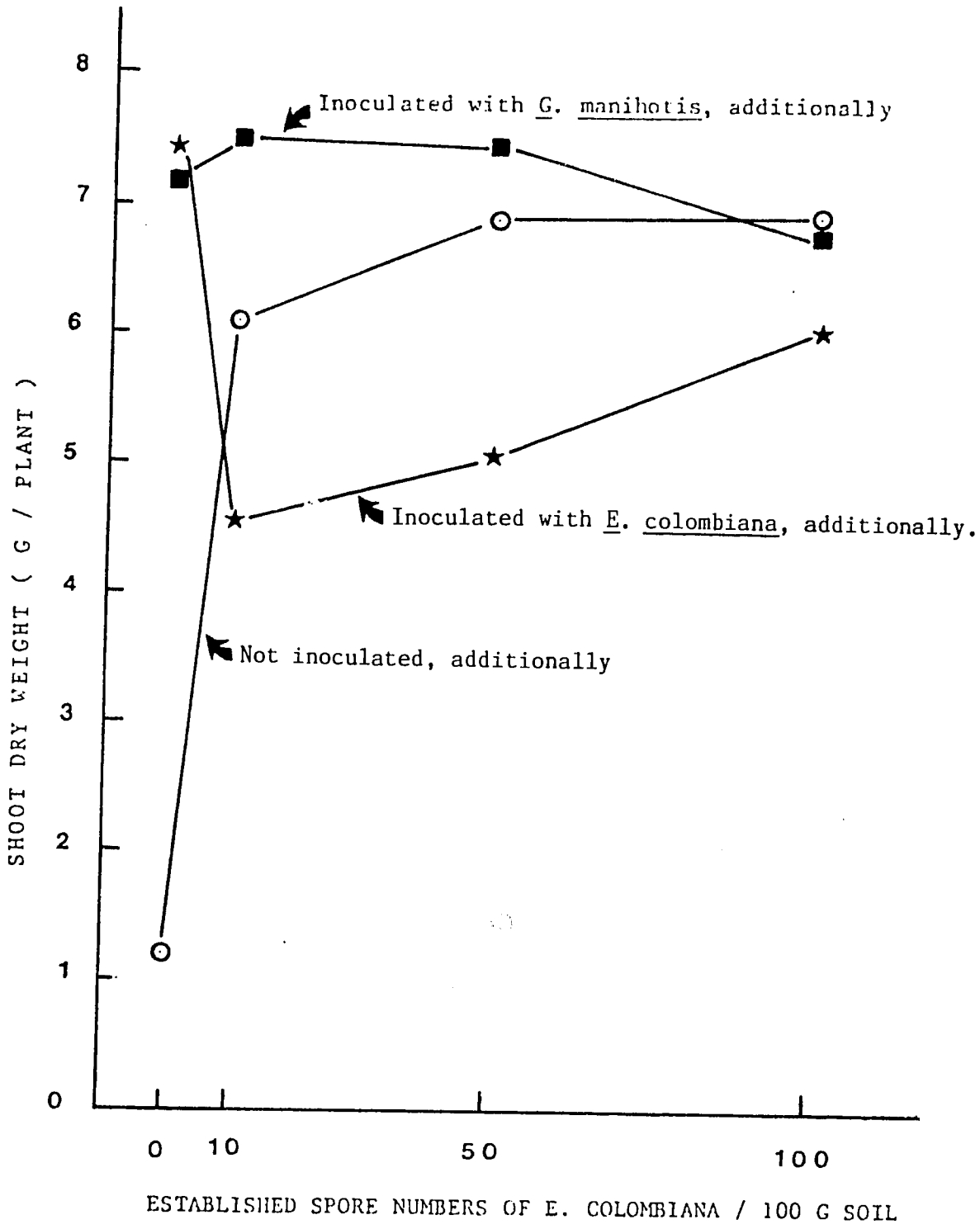


Figure 1. The effect of inoculation with Glomus manihotis (C-1-1) and Entrophosphora colombiana on growth of cassava in competition with a given quantity of E. colombiana (C-10) added to sterilized Quilichao soil.

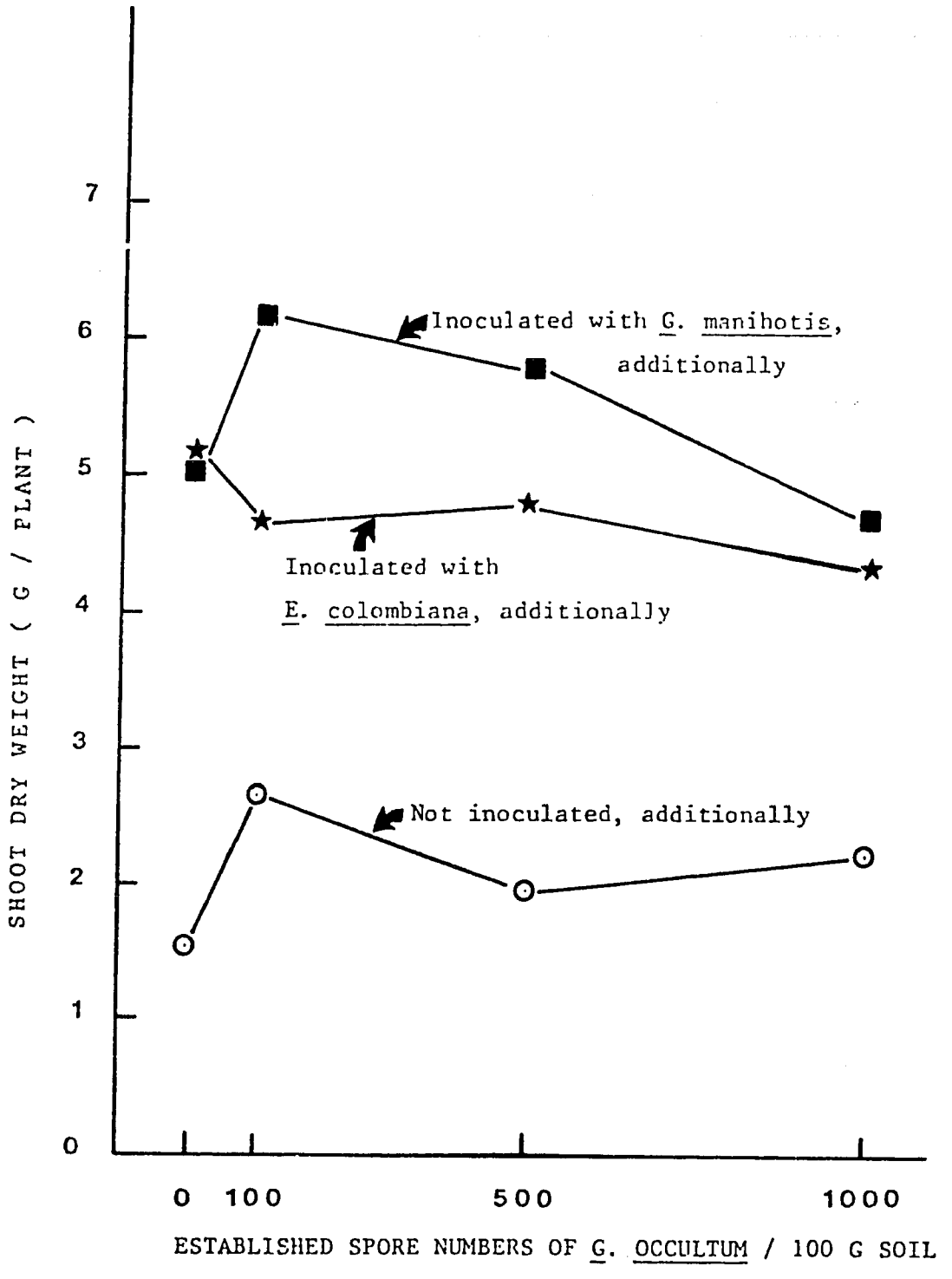


Figure 2. As Figure 1 in competition with a given quantity of Glomus occultum.

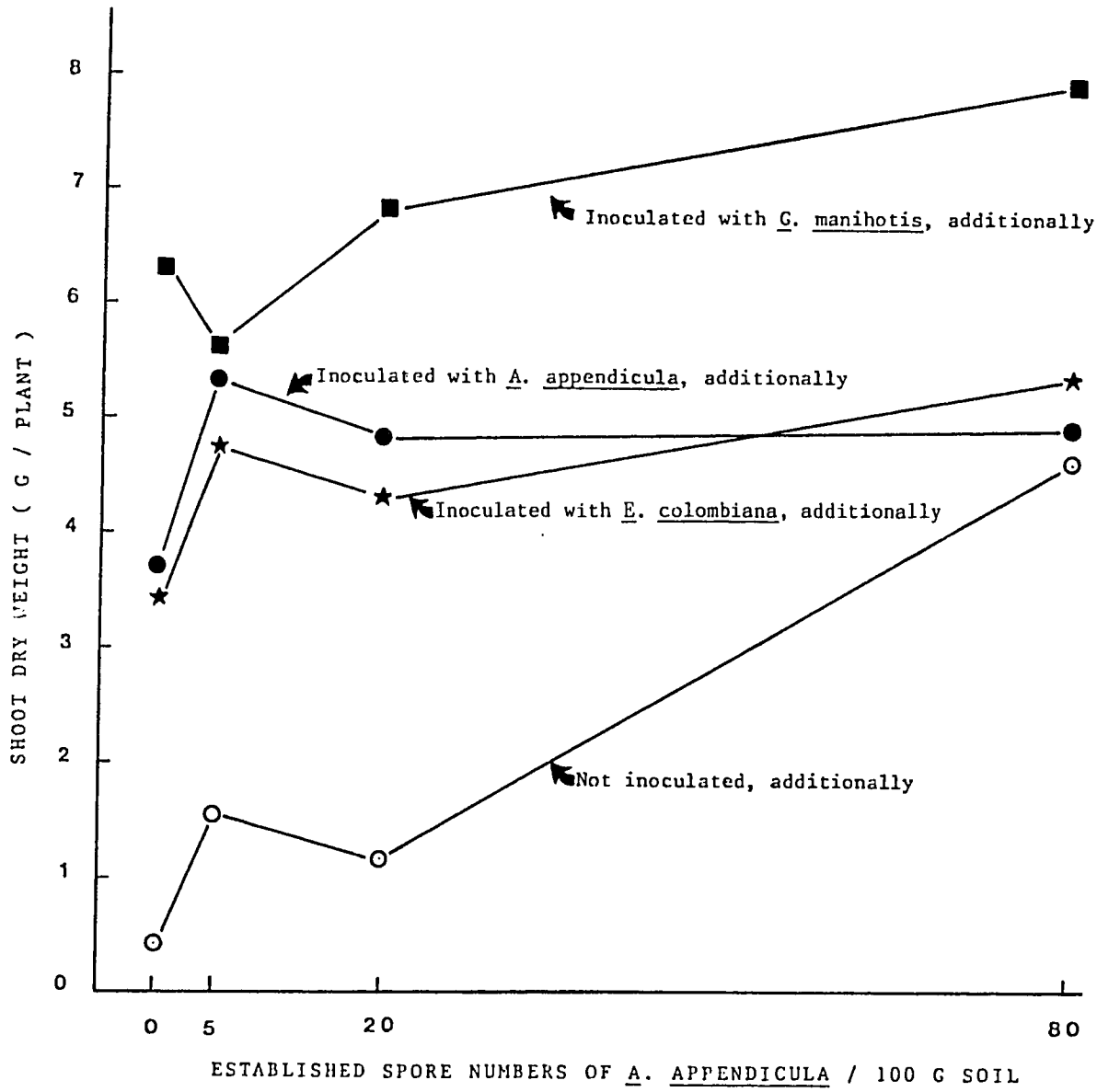


Figure 3. As Figure 1 in competition with a given quantity of Acaulospora appendicula.

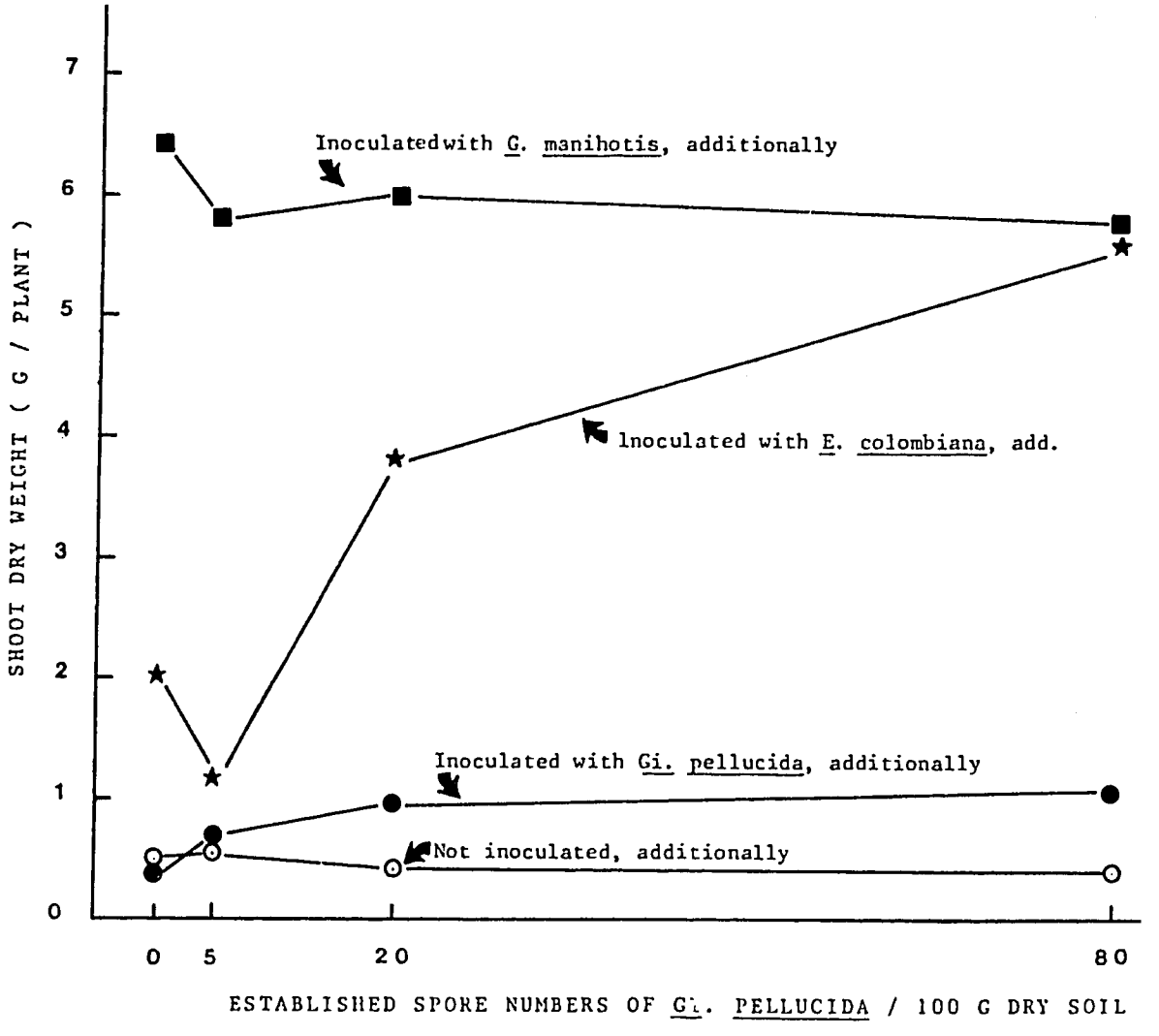


Figure 4. As Figure 1 in competition with a given quantity of Gigaspora pellucida.

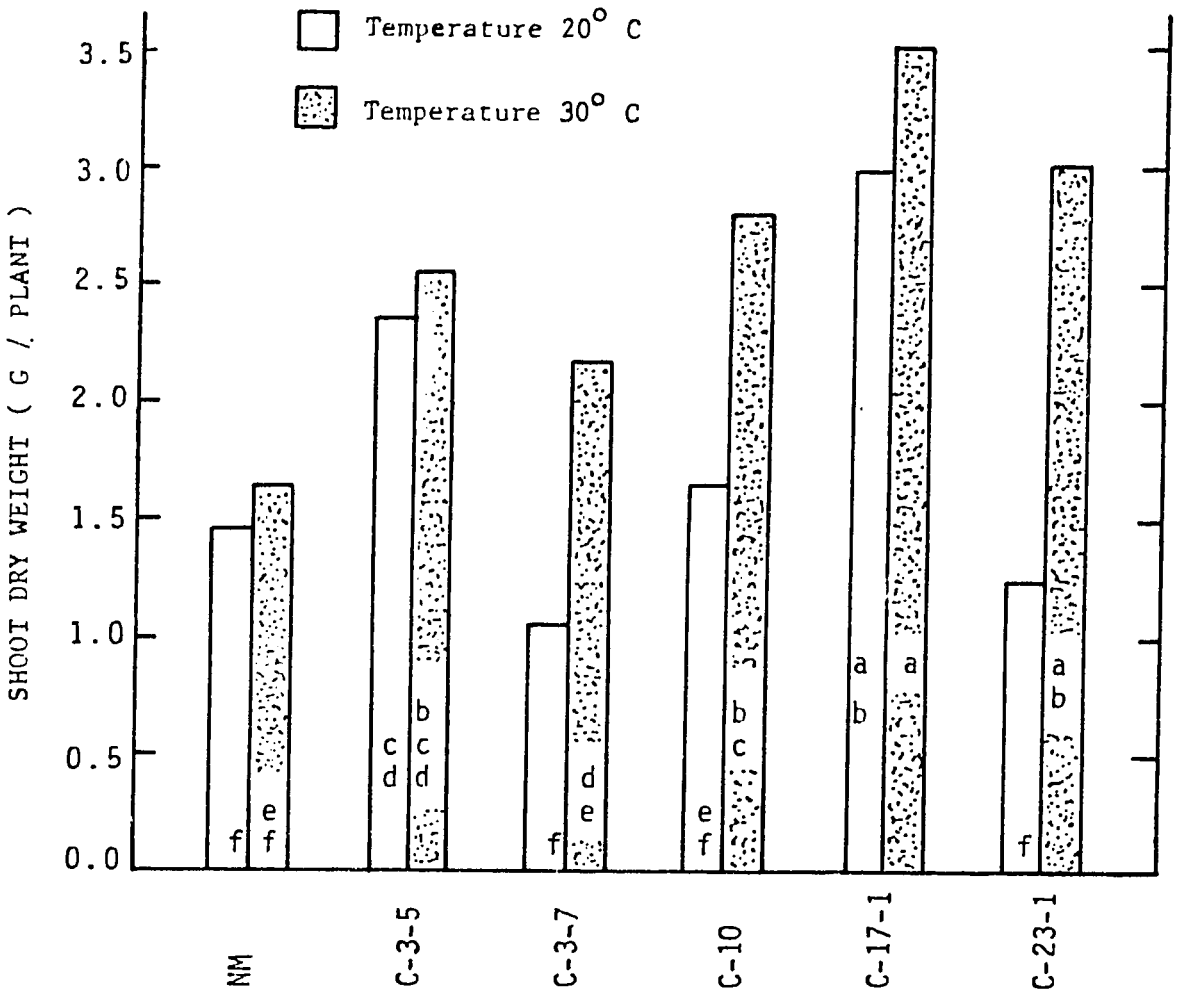


Figure 5. Effect of different soil temperatures on growth of cassava M Col 113 without mycorrhiza (NM) or inoculated with different mycorrhizal strains (C-3-5, E. colombiana from Popayan; C-3-7, Gi. pellucida from Popayan; C-10, E. colombiana from Carimagua; C-17-1, G. manihotis from the North Coast of Colombia; C-23-1, A. longula from Antioquia).

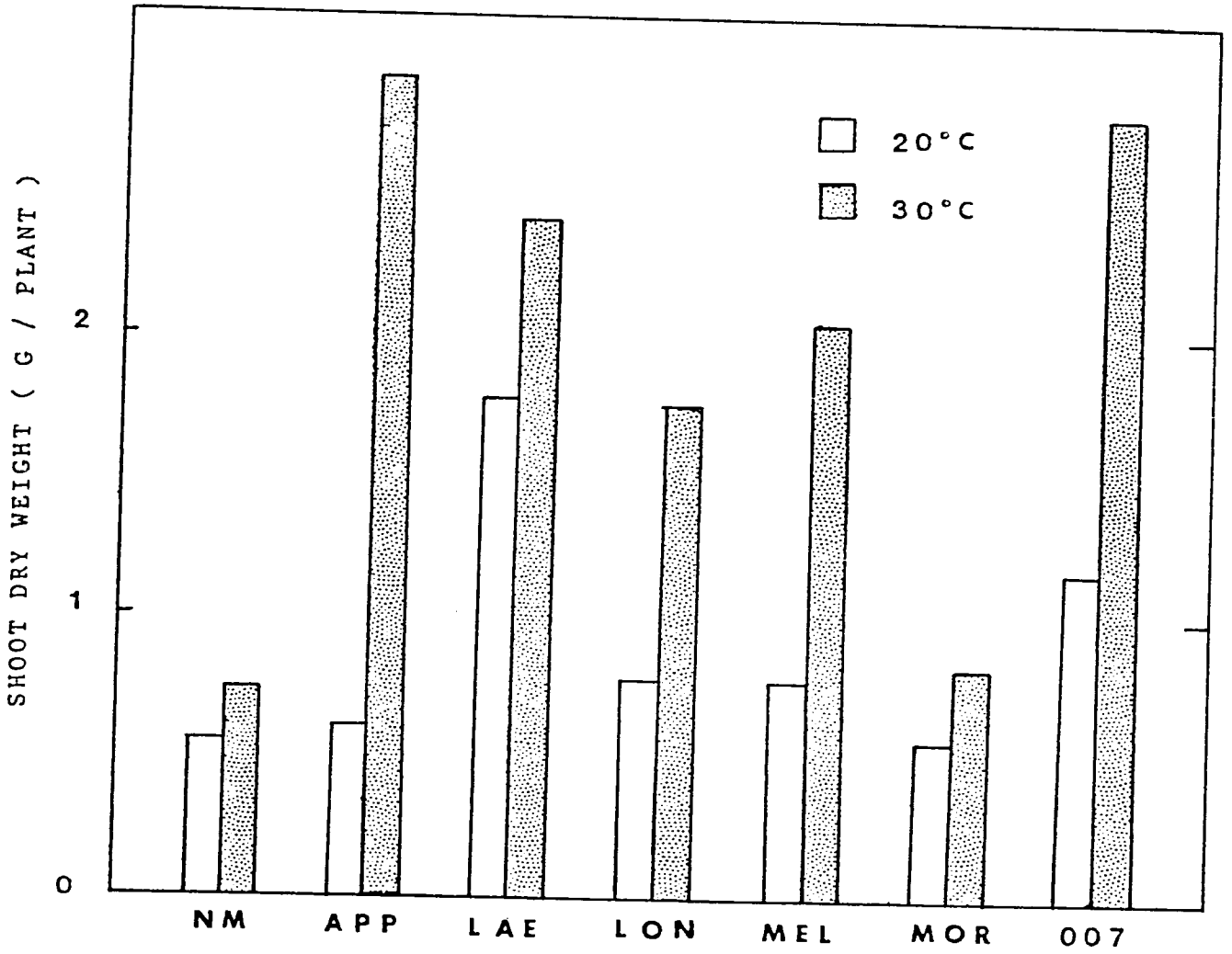


Figure 6. Effect of soil temperature and inoculation with different Aucaulospora species from Popayan on shoot dry weight of M Col 113 (NM: Nonmycorrhizal, APP: A. appendicula, LAE: A. laevis, LON: A.longula, MEL: A.mellea, MOR: A.morrowae, 007: Acaulospora sp. Strain C-7).

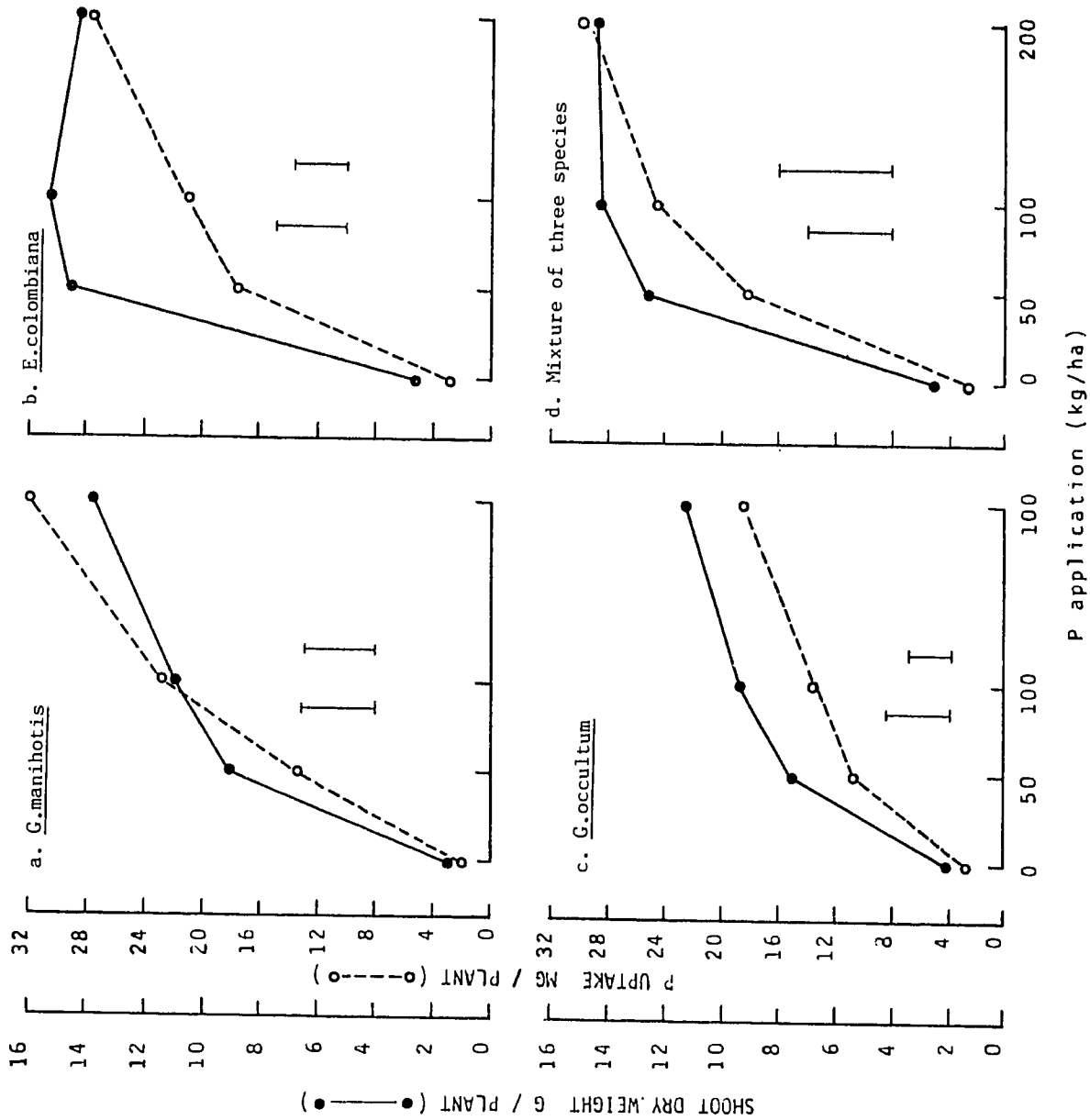


Figure 7. Effect of increasing P application on shoot production and P uptake in shoots of M Ven 77 inoculated with different mycorrhizal species (Bars indicate LSD 5%; left bar for dry weight, right bar for P uptake).

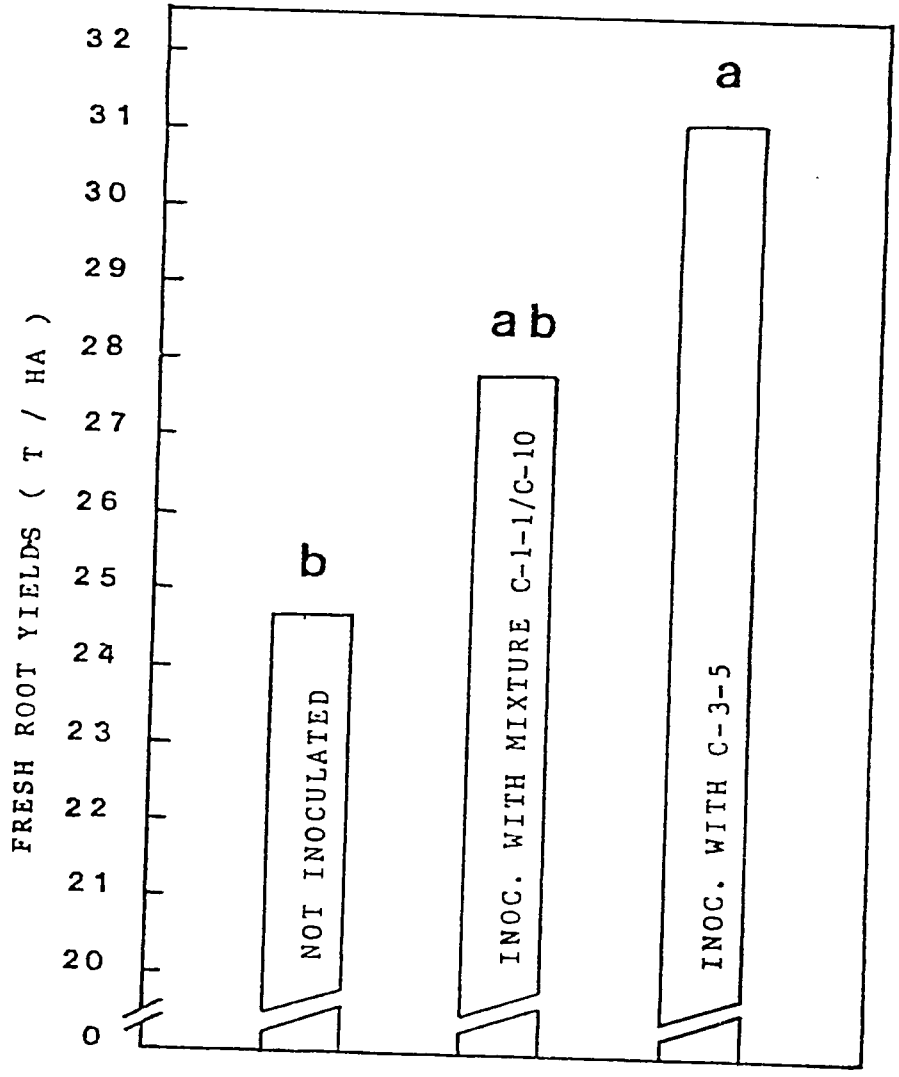


Figure 8 : Effect of field inoculation with Glomus manihotis (C-1-1)/ Entrophospora colombiana (C-10) and E. colombiana (C-3-5) on cassava yields in Agua Blanca, Cauca.

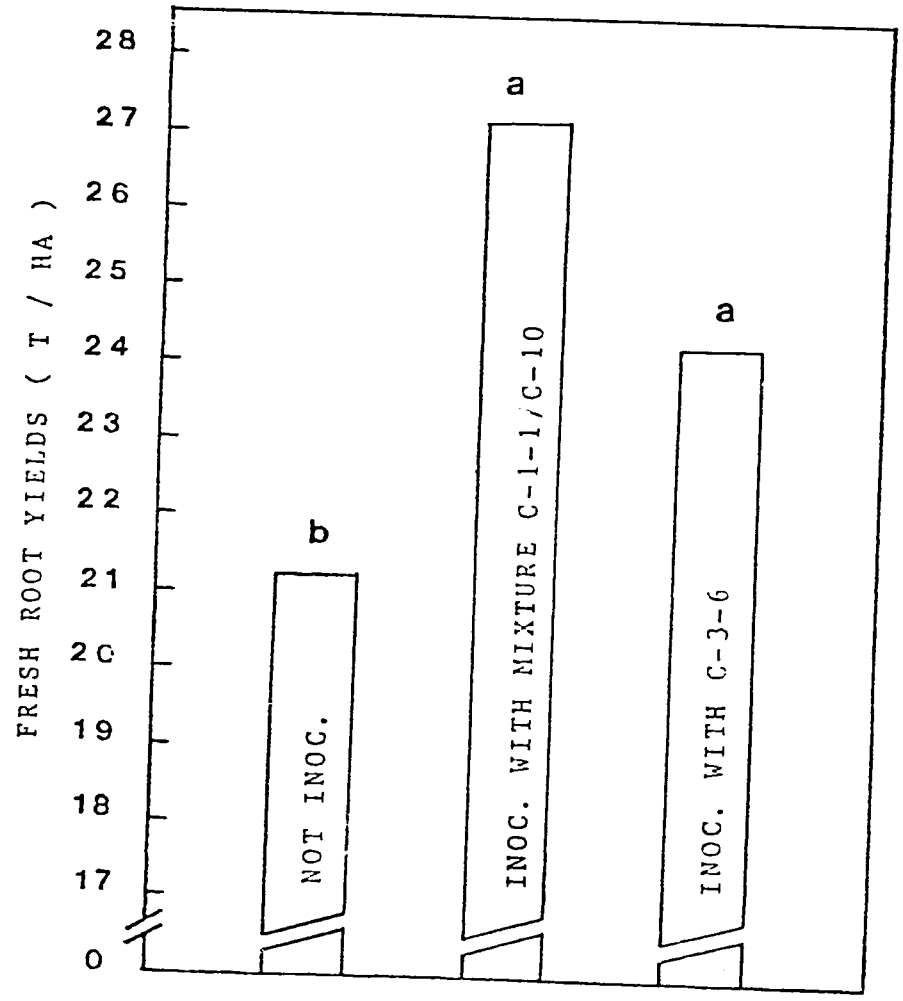


Figure 9 : Effect of field inoculation with Glomus manihotis (C-1-1)/ Entrophospora colombiana (C-10) and Acaulospora longula (C-3-6) on cassava yields in Agua Blanca, Cauca

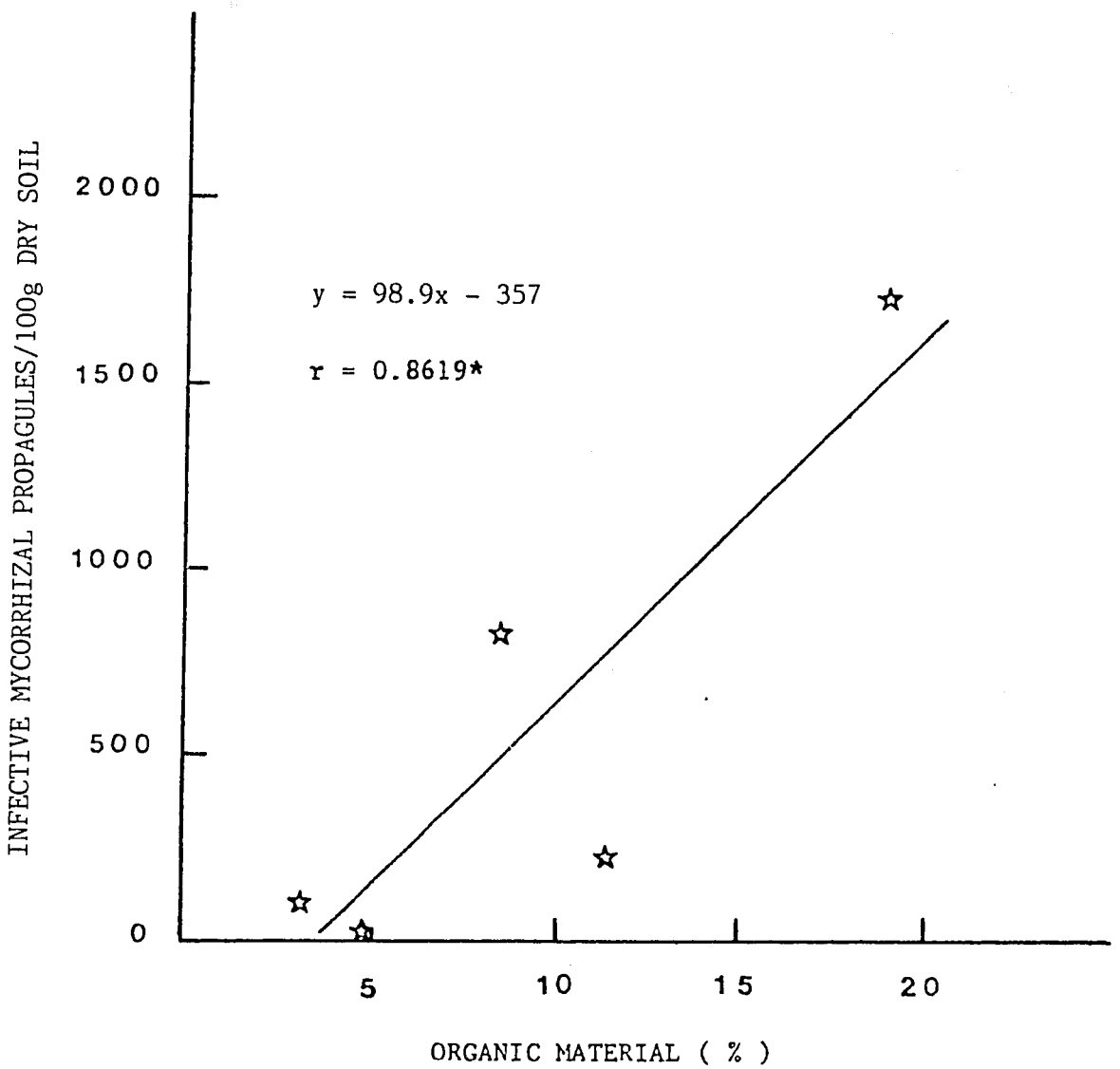


Figure 10. Correlation between infective mycorrhizal propagules and soil organic matter.

Entomology

During 1983, the Cassava Entomology Program concentrated its research on mites, mealybugs, whiteflies and Cyrtomenus bergi, a subterranean sucking insect that atacks the roots. Varietal resistance studies for mites and whiteflies advanced into the progeny evaluation stage. More than 2000 varieties from the cassava germplasm bank were evaluated for mealybug resistance. Biological control studies were intensified for cassava mites and mealybugs. The baculovirus for the cassava hornworm (Erinnyis ello) was produced in concentrated powder form from diseased hornworms. Bioecological studies were done for C. bergi, mealybugs and the hornworm.

The insect and mite complex at CIAT was monitored for the third consecutive year. An analysis was done to determine the presence of pesticide residues in cassava roots.

Mites

More than 46 species of mites have been identified attacking cassava throughout the cassava-growing regions of the world. Research emphasis during the past year was on evaluating host plant resistance and biological control of the major species. Recent taxonomic work by Doreste (Venezuela, 1982) has divided the most important species in the Americas and Africa, Mononychellus tanajoa into two species. These are M. tanajoa and M. progresivus. Both species are found feeding on cassava in the Americas and Africa.

Varietal resistance studies centered on the evaluation of several hybrids which were developed by crossing the mite resistant varieties M Col 414, M Bra 12, M Col 282, M Col 113, M Mex 1 and M Ven 185 with the mite susceptible but agronomically desirable varieties M Col 22 and M Col 1684 (Cassava Annual Report, 1979). Progeny from these crosses were first evaluated at CIAT and final selection was made in Fonseca, Guajira. The present evaluation was done at CIAT. Two rows of 10 plants each were evaluated for mite damage, mite population (Mononychellus sp. and Tetranychus sp.) and yield. Half of the plants treated with an acaracide and half were untreated. Yield depression caused by mite feeding was thereby measured.

Results show that mite resistance and good yielding ability can be combined in a cultivar (Table 1). The yield of nine untreated hybrids, was actually 21% higher than the treated plants with an average of 5.9 kg/plant vs. 4.9 kg/plant respectively. The combined yielding ability of all the parents was 3.0 kg/plant for the untreated and 3.1 kg/plant for the treated. This was about a 43.5% reduction on the part of the parents compared with the hybrids.

Mite populations of the hybrids measured were slightly lower than those of the parents, 5.19 mites per 2.54 cm^2 vs. 5.32 (Table 1). Mite populations were highest on the two most susceptible parents, M Col 22 and M Col 1684 and two of the hybrids CG 22.2 and CG 1-56. Consequently the damage ratings were also slightly lower on the untreated hybrids than those on the untreated parents (1.8 vs. 2.1, respectively).

Previous Page Blank

Biological control

Biological control studies with mites had previously centered around the effectiveness of insect predators. Emphasis, during the past year, was shifted toward the Phytosiid predators of mites. Exploration to identify the major or most important Phytosiids was initiated. A systematic evaluation of the cassava fields in the Department of Valle, Colombia was started during 1983 (Figure 1). Four groups have been identified at present, with the Neoseiulus and Typhlodromalus groups being predominant representing 40.6 and 57.1% respectively of the specimens collected (Table 2). Biological and morphological characteristics of the species collected will be described in future studies.

Exploration in other areas of Colombia for Phytosiidae and insect predators of mites was also initiated during 1983. Several species have been recorded (Figure 2 and Table 3). One of the most important species found is Neoseiulus idaeus. This species was found in Valledupar, Cesar, associated with Mononychellus progresivus and M. caribbeanae on cassava. Preliminary observations indicate that this species is a voracious consumer of mites. This species has been sent to IITA for release in Africa.

Methodology for laboratory rearing of Phytosiidae mites has been developed using a modification of the McMurtry and Scriven (1965) method. The rearing unit consists of a large petri dish, a ½ cm plastic sponge, which is permanently saturated with water, and a sheet of stiff cardboard coated with black paint. The paint waterproofs the cardboard and prevents the Phytosiidae mites from coming in contact with the water. The border of the cardboard is covered with strips of cotton saturated with water, which acts as a barrier and prevents escape of Phytosiid and phytophagous mites. Fine threads of cotton are laid across the blackened paper to keep the mites grouped. This also favors oviposition of the Phytosiid mites. Colonies of phytophagous mites (Tetranychus or Mononychellus) are maintained on cassava plants in the screenhouse. When needed, these tetranychids are brushed onto humid filter paper. They can be fed directly or can be maintained in the refrigerator at 6°C until needed.

Whiteflies

Previous studies have shown that high infestation of whiteflies (Aleurotrachelus sociales) causes considerable yield losses in cassava (Cassava Annual Reports 1978, 1979, 1980, 1981, 1982). More recent studies in the Cassava Pathology Section have shown that whiteflies may transmit several virus diseases. Studies during 1983 centered on evaluation of materials developed for resistance to whiteflies (Cassava Annual Report 1982). Previously, through extensive screening of cassava germplasm at the ICA station in Nataima, Tolima, several resistant varieties were selected. Crosses were made between Resistant x Resistant (M Ecu 72 x M Bra 12) and Resistant x Susceptible (M Bra 12 x M Col 511). M Bra 12 is a variety which normally has high whitefly populations but does not display severe damage symptoms; M Ecu 72 normally does not have very high whitefly populations nor does it display very severe damage

symptoms. Previous studies from these crosses have shown high levels of whitefly populations for progeny of the R x S cross but only a moderate level of damage symptoms. The R x R progeny show a moderate whitefly population but a very low level of damage symptoms.

During 1982 selections were made from 82 of the F_1 progeny of the abovementioned crosses and 68 promising hybrids were multiplied. During 1983 a trial was planted in Quilcase, Cauca, to evaluate both whitefly resistance and yield ability of the hybrids. Two repetitions of ten plants each were planted and monthly whitefly population evaluations were made. The plants were harvested at nine months. At harvest all plants showing frog skin disease, a virus disease transmitted by whiteflies, were discarded. These hybrids were compared to the two regional varieties, Quilcase and M Col 113.

Results show that resistance to whiteflies and good yielding ability can be combined (Table 4). Those hybrids resulting from M Bra 12 x M Ecu 72 crosses (CG 489) gave better results than those from the M Col 511 x M Bra 12 crosses (CG 360). Twenty-seven of the hybrids had yields of 10 t/ha or better without frog skin disease symptoms and 19 hybrids had yields of 12 t/ha or better (Table 4). The hybrids CG 489-57, CG 489-1 and CG 489-14 yielded more than 26 t/ha. These yields are 4-6 times greater than the two regional varieties, Quilcase and M Col 113 which yielded only 7.5 and 4.6 t/ha, respectively. The 27 selected hybrids showed no symptoms of frog skin disease while the regional varieties had high levels of this disease. The combined average yield of the 27 selected hybrids was 62% greater than that of the regional varieties.

Whitefly populations, in general, were much lower on the resistant hybrids than on the regional varieties. Whitefly population levels averaged 1.4 on a 0-5 scale for resistant hybrids and 3.5 for the regional varieties. Pupal populations were also considerably higher on the susceptible regional varieties. These results also indicate that the incidence and severity of whitefly-transmitted diseases, such as frog skin disease may be greatly reduced through the use of resistant varieties. Resistant varieties can greatly reduce the level of whitefly populations and this may result in an effective control of whitefly transmitted diseases.

Screening for whitefly resistance

Over a period of several years (see previous Cassava Annual Reports) the cassava entomology section has developed a pool of varieties that are termed "insect resistant". This pool consists of varieties selected from the CIAT cassava germplasm bank that have shown resistance to one or more insects (mites, thrips, lacebugs, mealybugs or whiteflies). More than 200 varieties have been identified as containing resistance to one or more of these insects; 53 of these were planted at Quilcase and evaluated for resistance to whiteflies as well as yield ability. Two replications of 10 plants each were grown and periodic evaluations of whitefly populations were made; plants were harvested at 15 months.

Thirteen of the 53 varieties evaluated were selected as promising for resistance to whiteflies (Table 5). Whitefly populations were

considerably higher in this trial than in that previously described; whitefly adult and pupal populations averaged 3.7 and 2.4, respectively, on a 0-5 scale. However, damage symptoms were 0 for all 13 varieties. These results indicate that a tolerance mechanism may be involved in the resistance. It is interesting to note that none of the 13 selected varieties showed symptoms of frog skin disease.

Yields of the 13 varieties were high; M Col 749 yielded 89 t/ha and the average yield was 40.5 t/ha. Varieties that showed symptoms of frog skin disease or were very low yielding were discarded.

Resistance studies will continue with these varieties. It should be noted that a number of these varieties have displayed resistance to several pests. M Bra 12, for example, has been selected for resistance to mites, thrips and lacebugs as well as whiteflies.

The Cassava Hornworm

Yield losses

Studies on yield losses, bioecology and biological control of the cassava hornworm (*Erinnys ello*) continued in 1983. Yield losses due to hornworm attack are difficult to predict since reductions are associated with several factors; these include the cassava variety being grown (vigorous *vs*. nonvigorous), the age of the plant (evidance indicates that yield reductions are greatest if the attack occurs during the first five months of crop growth), environmental conditions (attacks during the rainy season allow for greater or more rapid plant recuperation), the severity of attack (the greater the hornworm populations, the more foliage consumed) and the number of hornworm attacks. A hornworm attack tends to be quite brief, usually lasting only about 15 days. The most destructive period is actually only about 3-5 days, when larvae are in the fifth instar. Given the long cassava crop cycle and the comparatively short cycle of the hornworm, several hornworm attacks may occur during one crop cycle and often they occur consecutively. Frequently, a single hornworm attack results in little or no yield reduction (an 18% yield reduction was measured in a farmer's field after a single hornworm attack; see Cassava Annual Reports, 1977 and 1981). The effect of two consecutive hornworm attacks on cassava root yields was studied at CIAT-Quilichao. Hornworm damage was simulated by removing 100% of the foliage for two consecutive months throughout the first five months of the crop cycle. Foliage was removed during the 1st and 2nd month in treatment 1, during the 2nd and 3rd month in treatment 2, during the 3rd and 4th month in treatment 3, and during the 4th and 5th month in treatment 4. No foliage was removed from the control plot. Three varieties were used - CM 305-41, a medium-leafed hybrid, M Mex 59, a wide-leafed variety and HMC 2 a narrow-leafed variety.

Yields were reduced considerably for the three varieties for all treatments except when damage occurred during the first two months of M Mex 59 (Table 6). Yield reductions were greatest when damage occurred during the 2nd and 3rd months or during the 3rd and 4th month, indicating that the critical period in cassava crop growth in relation to hornworm attack is from the 2nd to 4th month in the crop growth cycle. Total root

yield was most severely affected when damage occurred during the 2nd and 3rd month period (Table 7), while commercial root production (for the fresh market) was most severely affected when damage occurred during the 3-4 month period (Table 8).

The variety HMC 2 was the most sensitive to hornworm damage with an average reduction in yield of nearly 62% while M Mex 59 was the least affected with an average reduction of only 21.4%; yield of the hybrid CM 305-41 was reduced by 49% (Table 8).

Acceptable or selected planting material was also reduced considerably due to hornworm damage for all three varieties (Table 6). Average reductions were 74% for CM 305-41, 75.5 for M Mex 59, and 70.4 for HMC 2. The production of planting material was most severely affected when damage occurred during the first three months of the plant growth cycle. This data supports similar results obtained during attacks of fruitflies and shoot flies (Cassava Annual Reports 1980, 1981).

Bioecology studies

Adult hornworm populations were monitored daily using light traps (black light type BLB) throughout 1983 (see Cassava Annual Report, 1982 for previous studies) at CIAT and CIAT-Quilichao, Valle. In general, hornworm populations were low throughout the year but were slightly higher at CIAT. Total capture at CIAT was 446 adults vs. 355 at CIAT-Quilichao. Populations had two peaks at Quilichao, the March/April and the July/August periods; at CIAT the peak capture was during the January/February period and then remained relatively low the rest of the year (Figures 3 and 4). There were no serious hornworm larval outbreaks at either site during the year.

At the same time that adult populations were being monitored, hornworm oviposition and egg parasitism were also being evaluated. In general, peaks in oviposition coincided with high adult populations with the exception of the second peak adult population at Quilichao. These data reinforce the recommendation that hornworm outbreaks can be monitored using light trapping of adults.

Parasitation of hornworm eggs averaged 65.8% throughout the year at CIAT and 84.2% at Quilichao. This high level of parasitism at Quilichao probably prevented hornworm outbreaks, especially during the month of April when 1470 eggs were recorded on a 100 plant sample (Figure 5). However, 1300 eggs or 88% were parasitized resulting in only 1.7 larvae per plant instead of 14.7 larvae per plant had there been no parasitism. Due to the high levels of parasitism, plus other natural enemies, hornworm larval populations remained low throughout the year with the maximum being 13 per 100 plants during August at CIAT (Figure 6).

Biological control

A granulosis virus has been observed infecting natural populations of the hornworm (Cassava Annual Report, 1980). This virus has been named the cassava hornworm baculovirus. Studies were carried out during 1983 to produce and to apply this virus in a cassava hornworm pest management

program. Field studies were done at CIAT-Quilichao; virus applications were made in fields containing hornworm larvae with a viral solution. Virus-infected hornworm larvae were liquified in a blender and mixed with water for a 30% concentration. Five and ten cc of this solution were mixed with one liter of water and applied to the cassava fields. Hornworm larvae were allowed to feed in the virus infected fields for 24 hours. Fifty larvae were then collected from each plot where the virus was applied, as well as from fields where no virus was applied (control plots). All larvae were brought into the laboratory, kept separated and fed with non-virus infected leaves. Mortality results were measured every 24 hours.

Larval mortality was first observed between 24 and 48 hours after application of the virus in the field. At the 10 cc dosis, larval mortality was 82% after 48 hours and 100% at 72 hours (Figure 7). At the 5 cc dosis, larval mortality was 45% at 48 hours, 88% at 72 hours and 100% at 96 hours. Mortality of the control larvae was 8% at 72 hours and 32% at 96 hours. Some contamination of the control larvae may have occurred during observations.

Production of hornworm baculovirus

A laboratory procedure was established to produce a stable powdered form of the virus. This procedure begins with the liquification of virus-infected hornworm larvae collected in the field. There is a 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 into a powdered form (Figure 8). The virus is stable in this condition for 15 to 20 years.

Preliminary field experiments indicate that cassava fields can be infected with the virus. Farmers' fields were sprayed with a solution of the virus which resulted in complete control of the hornworm. Post application attacks by the hornworm have resulted in continual larval mortality showing baculovirus symptoms.

Mealybugs

Cassava mealybugs constitute one of the world major agricultural pests, causing severe damage to the crop on two continents: the Americas and Africa. There are two major species, *Phenacoccus manihoti* and *P. herreni*. Both species are present in the Americas but, at the present time, only *P.* herreni causes significant crop losses. *P. manihoti*, which is native to the Americas is causing severe crop losses in Africa. During 1983 research on *P. herreni* emphasized three areas; bioecological studies, host plant resistance and biological control.

Previous research had determined the duration of the life cycle, fecundity and longevity of *P. herreni*. Research was initiated this year to study the distribution and dissemination of the mealybug within the plant and within cassava fields. Four plots each of 255 cassava plants in a 16 x 16 design were isolated at CIAT by planting a 10 m border of corn around the plots (Figure 9). The distance between plants was six

meters and the variety M Col 113 was used. When the plants were three months old, eight central plants in each plot (see diagram) were infested with mealybugs. Plants were initially infested by placing three mealybug egg masses in the terminal shoot of the plant. One month later a second infestation was made by placing about 200 mealybugs in their early instars in each terminal shoot. Population dissemination data was recorded by carefully inspecting each plant at periodic intervals beginning one month after the second infestation.

Results indicate that the dispersion of the mealybugs from the infested plants was random (Figure 9). Dispersion was not very rapid since an average of only 60 plants or 23% of the plants in each plot contained mealybugs seven weeks after infestation (Table 9). However, there was steady increase in number of infested plants (Figure 10). Simultaneously, with the study of dispersion, observations were made on the distribution of the mealybug within the plant. Previous field observations had indicated that mealybug populations were usually concentrated toward the terminal part of the plant. To record distribution of the mealybugs, the plant was divided into four zones. These were: the terminal shoot, the upper 1/3 of the plant, the middle 1/3 and the lower 1/3. Observations were made on how often mealybugs appeared in each zone of the plant.

The distribution of mealybugs on the initial eight plants in each plot differed dramatically from that of plants that were naturally infested (Figure 11). When plants were artificially infested mealybugs eventually became evenly dispersed throughout the four zones of the plant (Figure 11). However, in those plants where there was a natural mealybug infestation there was a significant tendency for mealybugs to locate in the lower zones of the plant. Very few mealybugs were found in the terminal shoot or in the upper 1/3 portion of the stem. This distribution needs to be further studied as it has important implications for future studies. These results indicate that control recommendations, especially the application of pesticides, should be aimed toward the lower portion of the plant. Additionally, with respect to studies on parasitism, sampling of the lower portion of the plant will be necessary to get an accurate description of the effectiveness of natural enemies.

Resistance Studies

The evaluation of the cassava germplasm bank for resistance to the cassava mealybug, *P. herreni*, was continued in the field and greenhouse at CIAT during 1983. Greenhouse screening (average temperature 24°C and 70% RH) is done by inoculating two pot grown plants of each variety with two mealybug ovisacs. Plants are 4-5 weeks old when inoculated at the growing point and evaluations are made two to four weeks later. Mealybug populations as well as damage symptoms are recorded.

Four hundred varieties were evaluated during 1983, giving a total of 800 varieties evaluated under greenhouse conditions. Of the 400 varieties evaluated during 1983, only 8 or 2% were selected as promising for resistance. These selected varieties displayed light damage symptoms (1-2 or a 0-5 damage scale) although several had a high population level (Table 10). More than 50% of the varieties evaluated presented a very

high mealybug population (5.0 on a 0-5 scale, see Table 10 for description of population and damage scales). Those clones selected as promising for resistance under greenhouse conditions will be re-evaluated under field conditions during the dry period when there is rapid build-up of mealybug populations.

More than 2000 varieties in the CIAT cassava germplasm bank were evaluated in the field during a natural infestation of the mealybug. Approximately 24% showed no damage symptoms and about 40.8% had a damage rating of 2.5 or less (Figure 12). More than 59% had a damage rating of three or above and were described as susceptible. Those varieties with a rating of 2.5 or lower will be reevaluated in the field and greenhouse. Undoubtably, most of the 540 varieties with a 0 rating are escapes and not truly resistant to the mealybug. However, this evaluation greatly reduces the number of varieties to be evaluated.

Biological control

Biological control offers a promising means of reducing mealybug populations. Natural populations of mealybugs at CIAT-Palmira, and CIAT-Carimagua were systematically monitored for the presence of natural enemies. The terminal shoots from infested plants were placed in small jars and the anthropod complex associated with the mealybug populations was allowed to emerge and was measured. Samples at CIAT and Carimagua were taken at random from mealybug-infested fields at periodic sample dates. About 100 samples were taken on each date and brought to the laboratory for study.

Results show that the complex of natural enemies associated with mealybug populations at CIAT differs from that at Carimagua. The complex at CIAT consisted of three parasite species and six predators (Figure 13). The predominant natural enemy at CIAT was the parasite *Acerophagus coccois* which accounted for more than 40% of the species found. Two other parasites *Anagyrus* sp. and *Aenasius massil* were found in very low numbers. Several predators were also collected; *Kalodiplosis coccidarum* was the most frequently observed predator. Numerous other anthropod species were found in association with mealybug populations but their role was not determined.

The complex of natural enemies collected at Carimagua differed from that at CIAT in that predators were predominant over parasites (Figure 14). Three major groups of predators were found. The dipteran *Ocyptamus* sp. was the predominant predator accounting for about 42% of the total anthropods collected. Other predators were in the *Coccinellidae* and *Chrysopa* groups. Only two parasites were collected *Apoanagyrus diversicornis* and *Anagyrus* sp., but these were observed in very low numbers and combined accounted for only about 4% of the anthropods collected.

Laboratory colonies of the two parasites, *Acerophagus coccois*, found at CIAT, and *Apoanagyrus diversicornis* found at Carimagua have been established at CIAT. Techniques for the mass rearing of the two species are being studied. *A. diversicornis* has been released into CIAT cassava fields.

A study was also done at Carimagua to measure the rate of increase of the mealybug infestations. During the months of December 1982 and January-February 1983, a large cassava field was divided into equal sized plots and these plots were sistematically evaluated for mealybug infestation by counting the percentage of terminal shoots infested with mealybugs. At the same time predator and parasite populations were recorded. The number of terminal shoots infested with mealybugs rose dramatically in a one month period of time (Figure 15). The populations of Ocyptamus sp. also rose over this period but populations were not high enough to control mealybug populations. Populations of the parasite A. diversicornis remained low.

The Chinch bug, Cyrtomenus bergi

Nymphs and adults of this subterranean sucking insect feed on cassava roots by means of a thin, strong stylet. Insect feeding combined with soil pathogens induce the appearance of brown to black spots on the white fleshy root, rendering it commercially unacceptable. Previous studies have described root damage, the life cycle of the insect, and its preference in the laboratory for sweet (low HCN content) varieties.

More recent studies have measured field incidence of C. bergi, its preference for feeding on bitter or sweet cassava roots and chemical control. In CIAT-Quilichao, an experiment was designed to measure populations of C. bergi in cassava fields. Since feeding by C. bergi is underground, populations were determined by escavating around cassava roots on a monthly basis and nymphs and adults were recorded. Another experiment was designed to determine at what stage in the crop growth cycle C. bergi attacks are initiated and to monitor the damage done to roots throughout the crop cycle. To do this, 20 plants were uprooted each month and roots examined beginning at the second month of plant growth.

Results show that C. bergi populations are present in the soil throughout the crop cycle (Figure 16). Two varieties were compared, both with low HCN content, CMC 40 and M Mex 59. Nymphs and adults were found around the roots of both varieties beginning at the second month of crop growth. Populations were about three times higher around the roots of CMC 40 and M Mex 59. Nymphs and adults were found around the roots of both varieties beginning at the second month of crop growth. Populations were about three times higher around the roots of CMC 40 as compared to M Mex 59. In general, populations increased with the age of the plant for CMC 40 but remained more constant with M Mex 59.

By measuring root damage it was determined that root attack began by the second month of plant growth (Figure 17). At this point 25% and 35% of the roots of M Mex 59 and CMC 40 show damage from the feeding of C. bergi. By eight months, 85% of the roots of CMC 40 and 65% of M Mex 59 were damaged by C. bergi attack. There was a definite upward trend in damage with increased plant age. These results indicate that C. bergi is a severe pest of cassava roots causing a considerable loss in their commercial value. Results also indicate that any control measures undertaken must begin very early in the crop growth cycle, most probably at planting.

Feeding preference

Since laboratory studies have indicated that there is a strong preference for C. bergi to feed on sweet or low HCN varieties vs. bitter or high HCN varieties, it was decided to test this observation under field conditions at CIAT-Quilichao. The varieties compared were CMC 40 (low HCN) and M Col 1684 (high HCN). Ten blocks of nine plants each were randomly planted for each variety and at the end of the 10 month growth cycle 30 roots were evaluated for each variety.

Results show that there exists a definite preference for low HCN varieties (Table 11). Only 0.3% of the roots of M Col 1684 (high HCN) were damaged while 27.3% of those of CMC 40 (low HCN) were damaged. The possibility of using this non-preference in a pest management program will need to be studied.

Control

Research to determine adequate control of C. bergi was initiated during 1983. Two approaches were followed -chemical control and cultural control practices. The latter involved the use of crop rotation and intercropping with a non-preference host, the results of which will be available during 1984. The results of preliminary chemical control studies are available. An experiment was designed to evaluate three insecticides and two methods of application. The pesticides Sistemin (48%) and Furadan PF were foliar-applied and Furadan 3% and Aldrex 2% were applied to the soil. All pesticides were applied at monthly intervals but Sistemin was also applied every two months as a separate treatment. The control plots received no insecticide application. Two varieties were compared, CMC 40 (low HCN) and M Col 1684 (high HCN). Plants were harvested at 10 months.

Results show that all pesticide applications reduced the incidence of C. bergi attack on CMC 40 resulting in fewer damaged roots (Table 12). Sistemin was the most effective product and there was no significant difference with application at one or two month intervals. An average of about 9% of the roots of the Sistemin-applied plots were damaged. Furadan applied in the soil was more effective in reducing C. bergi damage than the foliar application (18.5 vs. 31.7%, respectively). Aldrex was also effective in reducing damage (23.5% of roots damaged) but not as effective as Sistemin. Damage levels in the control plots with CMC 40 were very high, with 85% of the roots attacked.

In comparing the two varieties CMC 40 was severely attacked while M Col 1684, a bitter variety suffered only minor damage. These results again show the strong preference of C. bergi for feeding on low HCN varieties.

Results with chemical applications indicate that pesticides can be used to reduce C. bergi damage. However, further studies are needed to determine the optimal number and time of application and the effect of constant chemical applications on the accumulation of pesticide residues in cassava roots.

Pesticide Residues

Increased cassava production in several areas of the Americas and Africa combined with problems with insect and mite pests has led to an increased use of pesticides in certain areas. Although the use of pesticides in cassava production is low when compared to certain other crops, severe pest outbreaks which have occurred in recent years (especially in Africa and the Americas) have obligated farmers to use pesticides to control them. Results of experiments designed to control cassava root pests such as C. bergi indicate that foliar or soil-applied pesticides are transported by the plant to the root.

An experiment was designed to evaluate the accumulation of pesticide residuals in cassava roots. Four pesticides were applied bimonthly; these were dimethoate, an organophosphate, carbofuradan and aldicarp from the carbamate group and endosulfan, a chlorinated hydrocarbon. Dimethoate and endosulfan were applied in solution to the foliage while carbofuradan and aldicarp were applied in granular form to the soil at the base of the cassava plant. The commercial dosis was used for all products (Table 13). At harvest one root was taken from each of five control plants for each treatment. Roots were sent to the Department of Pharmacology and Toxicology of the Universidad de Caldas, Manizales, Colombia, for analysis. Only the presence or absence of pesticides could be determined and not which of the pesticides was present nor in what quantities.

Results showed the presence of pesticide residues in the peel of the cassava root but not in the pulp or paranchyma of the root. Further studies will be done to corroborate these findings. However, the results indicate that the use of pesticides in cassava is not a hazard to human consumption as long as the root peel is removed prior to cooking or processing. (The normal procedure in the fresh consumption of cassava is to remove the root peel.) However, in processing cassava the peel may be left intact. In addition the processing of cassava for animal feeds often leaves the peel intact. This is not a recommended practice if pesticides are applied to the crop until studies can be done to evaluate the effect of residual accumulations of pesticides on animal production.

Cassava Pest Complexes

Previous studies by the cassava entomology, pathology, and breeding programs have demonstrated that ecosystems where cassava is grown have insect and mite pest complexes that are unique to each ecosystem. Although many similar pests may be observed across several ecosystems, their populations may differ and often do. The climatic conditions of each ecosystem along with several other factors (varieties grown, planting patterns, natural enemies, cultural practices being used) will determine pest populations. Previous research has also shown that high populations of most pests are needed before the crop suffers significant yield losses. Since cassava is a long season crop it may be subject to the attack of several pests throughout its growing season or, frequently, more than one attack by the same pest. In addition, pests such as mites, will often attack the crop over a continual period of several months.

Three years ago trials were started to measure the pest complex attacking cassava at the CIAT ecosystem (edaphoclimatic zone 4). In the original trial (Cassava Annual Report, 1981), two varieties were used CMC 40 and M Col 113, both are vigorous varieties and produce well at CIAT. M Col 113 is native to the CIAT ecosystem and the traditional variety of many farmers in the area, while CMC 40 is an introduced variety and not a traditional variety for the CIAT ecosystem. In 1982, a third variety was added to the trial, M Col 22 which is native to the Colombian coastal area (edaphoclimatic zone 1), it is less vigorous than the other two varieties with an LAI of about 2.5 to 3.0.

The major pests that attacked the varieties throughout their growing cycles were mites (Mononychellus and Tetranychus species), thrips and mealybugs (Phenacoccus herreni). This did not differ greatly from the previous two years data. Pest populations, however, were generally higher than in previous years. Mite populations were high on all three varieties (Figures 18, 19, 20); the Mononychellus mite was the predominant species. Mealybug populations were higher than in previous years, increasing impressively during the dry season. Tetranychus mite populations, in general remained low. Thrips populations were not as high as in previous years even on the susceptible variety CMC 40.

The damage level to the plant caused by these pest populations was also measured. Since varieties will react differently to insect attack, damage levels are also indicative of possible reduction in root yields. Damage levels were highest on CMC 40, an introduced variety, and lowest on M Col 113 and M Col 22 (Figures 21, 22, 23). CMC 40 was especially susceptible to mealybug and thrips attack while M Col 22 suffered mostly from mite and mealybug attack. Damage levels due to mealybugs rose to the 3rd level (on a 0-5 scale) on CMC 40 and mite levels rose to about 1.5 on M Col 22. Damage levels on M Col 113, in general were low; mite damage levels rose to about 1.2 and there was some thrips and mealybug damage.

Previous year's data showed that this pest complex did not have an effect on the yield of cassava roots. However, this year's data shows that the pest complex reduced yields for M Col 22 and CMC 40 (Table 14). Plots were treated with pesticides and compared to the non-pesticide-treated plots at harvest. Yields of CMC 40 and M Col 22 were reduced by 40 and 35%, respectively. Yields with M Col 113 were actually 30% higher in the non-pesticide-treated plot. This was primarily due to the high incidence of root-rotting in the treated plots. The CMC 40 treated plots also suffered considerably from root rotting. The treated plots for CMC 40 and M Col 113 both presented considerably higher incidence of root-rotting than the non-treated ones. The reason for this difference is not understood at this time. Interestingly, roots from those plots receiving pesticide treatment had a higher starch content than those from the non-treated plots. The plants were harvested at 10-11 months and yields were not very high but similar to those of the previous year's trials. There was also a reduction in planting material produced for the varieties CMC 40 and M Col 22; treated plots produced 37.6 and 14.3% more cuttings than the non-treated plots.

(This is the third year of this trial and it should be noted that planting material utilized is carried over from one crop cycle to the next.)

Cassava White Scale

Scales, especially the white scale, Aonodimytilus albus can reduce the germination of planting material and severe attacks can reduce root yield (Cassava Annual Report, 1975, 1977). The pesticide treatment of cassava cuttings to prevent scale outbreaks has became a standard practice in some areas. Scale attack in a cassava plantation are disseminated from one crop cycle to another through the planting of infested cuttings. As the crop develops the scale attack progresses upward from the infested cutting to the stem and branches of the developing plant. A severe attack, which usually occurs in areas of prolonged dry seasons, will cause defoliation and the drying of branch and stem tissue. Cuttings from heavily infested plants are useless for continued crop propagation and should be discarded and destroyed. However, the presence of scales on cuttings when populations are low is often difficult to detect without very close inspection. Since farmers cannot carefully inspect every cutting for the presence of scales, a pesticide dip is recommended in areas where scales are prevalent.

A study was designed to measure the effect of cutting position on the development of scale populations during the ensuing crop cycle. Three cutting positions were tested: horizontal (the cutting completely underground), inclined (a portion of the cutting aboveground, and vertical (about 1/3 of the cutting aboveground). The variety, CMC 40 used in the experiment came from a scale infested field and the cuttings selected for planting had a few scales around the buds (population level 1). The treated cuttings were submerged for five minutes in an insecticidal solution consisting of triona (10 cc/lt/water) plus dimethoate (2 cc/lt/water).

Results show that the horizontal cutting position is the least favorable for population growth of the white scale (Figure 24). The infestation levels of the inclined and vertical positions were considerably higher. There were no scales on plants that originated from treated cuttings in the horizontal position and very low population on plants from the non-treated cuttings. Scales were found on plants originating from treated cuttings in both the inclined and vertical position. These results indicate that scales are more apt to be a problem in areas where inclined or vertical cutting positions are used and least likely where a horizontal cutting position is employed.

Table 1. The effect of mite attack (*Mononychellus* sp.) on selected cassava parents and progeny.

		Damage Grade		Mononychellus Mites/disc 2.54 cm^2		Yield kg/plant	
		Treated	Nontreated	Treated	Nontreated	Treated	Nontreated
CG 5-55	Col 22 x Col 414	0.82	2.06	0.53	4.93	1.88	2.18
CG 5-78	Col 22 x Col 414	0.71	1.31	1.10	3.98	6.79	5.30
CG 5-79	Col 22 x Col 414	0.91	1.73	0.87	4.78	7.31	8.40
CG 5-99	Col 22 x Col 414	0.62	1.58	0.48	4.37	2.36	3.95
CG 1-56	Bra 12 x Col 22	0.60	2.08	0.65	7.11	5.54	5.47
CG 4-81	Col 22 x Col 282	1.02	1.47	0.63	5.05	4.48	7.52
CG 7-56	Col 113 x Col 22	0.88	1.50	0.77	3.31	9.77	10.94
CG 22-2	Mex 1 x Col 1684	0.88	2.52	0.72	8.92	2.38	3.30
CM 681-2	Ven 185 x Col 22	1.22	2.16	0.69	4.27	3.55	6.50
Col 22		0.90	2.55	0.62	7.66	2.52	2.15
Col 113		0.75	2.03	0.86	4.90	2.35	2.47
Col 282		1.01	2.12	0.70	3.12	2.44	2.05
Col 414		1.08	1.85	0.86	5.32	1.08	0.66
Col 1684		0.80	2.06	0.33	7.32	5.30	2.00
Bra 12		0.96	1.94	0.94	5.62	4.09	5.96
Mex 1		0.86	1.92	0.57	3.03	5.41	6.00
Ven 185		1.05	2.14	1.11	5.63	1.68	3.07

Table 2. Occurance of several species of phytosiidae feeding on cassava phytophagous mites in the department of Valle, Colombia.

Locality	No. mounted specimens	% Neoseiulus group	% Typhlodromalus group	% Amblyseius group	% Iphiseiodes group
CIAT	212	83.49	16.50	-	-
Cali	85	9.41	80.0	9.4	1.17
Palmira	352	40.34	59.37	0.28	-
Pto. Tejada	97	25.7	70.10	4.21	-
Ginebra	42	54.76	42.8	2.3	-
Buga	26	73.07	26.9	-	-
El Cerrito	108	61.1	37.96	0.92	-
Guacari	14	78.57	21.42	-	-
Yotoco	78	1.28	91.02	7.69	-
Vijes	12	58.33	41.66	-	-
Darien	23	-	95.65	4.34	-
Miranda	13	38.46	61.53	-	-
Mondomo	27	18.51	81.48	-	-
Florida	43	6.97	90.69	2.32	-
Candelaria	33	-	96.9	3.03	-
Pradera	19	100	-	-	-
TOTAL	1184	40.62	57.12	2.16	0.07

Table 3. Mite species of the family phytoseiidae registered in Colombia.

Locality	Species	%	Year
CIAT-Palmira Valle	Neoseiulus anonymus	100	1977
	Neoseiulus anonymus	88.9	1978
	Typhlodromina sp.	11.1	1978
	Neoseiulus anonymus	40	1979
	Typhlodromalus limonicus	60	1979
	Neoseiulus anonymus	42.86	1980
	Typhlodromalus limonicus	42.86	1980
	Iphiseiodes zuluagai	14.28	1980
	Neoseiulus anonymus	100	1982
	Neoseiulus anonymus	75.34	1983
	Typhlodromalus limonicus	24.66	1983
CIAT-Santander de Quilichao - Cauca	Typhlodromalus limonicus	100	1983
Golondrinas - Cali	Neoseiulus anonymus	100	1980
Mondomo - Cauca	Typhlodromalus limonicus	100	1981
Sevilla - Magdalena	Typhlodromalus aripo	16.70	1982
	Typhlodromalus limonicus	83.30	1982
	Typhlodromalus limonicus	100	1983
Media Luna-Magdalena	Typhlodromalus limonicus	100	1982
	Neoseiulus anonymus	100	1983
Fonseca - La Guajira	Galendromus annectens	80	1980
	Neoseiulus anonymus	20	1980
	Galendromus annectens	36.36	1981
	Galendromus longipilis	63.63	1981
Valledupar - Cesar	Neoseiulus idaeus	100	1983

Table 4. Selected hybrids showing resistance to whiteflies (*Aleurotrachelus sociales*) and with no symptoms of frog skin disease at Quilcase (Cauca, Colombia).

Hybrid	Population level	Pupal level	Damage level	Yield t/ha [a]
CG 489-57	1	1	1	28.3
CG 489-1	2	1	0	26.7
CG 489-14	1	1	0	26.3
CG 360-15	2	1	0	22.6
CG 489-59	1	1	0	20.9
CG 489-52	1	1	0	20.2
CG 489-10	1	1	1	18.1
CG 489-62	1	1	0	17.2
CG 360-7	3	1	1	17.7
CG 489-30	1	1	0	17.2
CG 489-2	1	1	0	16.7
CG 360-8	3	1	0	16.6
CG 489-53	1	1	0	13.9
CG 489-15	1	1	0	13.8
CG 489-24	2	1	0	13.7
CG 489-38	1	1	0	13.7
CG 489-26	1	1	0	12.7
CG 489-31	1	1	0	12.7
CG 489-12	1	1	0	12.4
Quilcase	4	3	1	7.5
M Col 113	3	3	1	4.6

[a] Harvest at nine months

Table 5. Selected varieties displaying resistance to whitefly (*Aleurotrachelus sociales*) attack without frog skin disease symptoms at Quilcase (Cauca, Colombia).

Variety	Population level	Pupal level	Damage level	Yield t/ha [a]
M Col 749	3	1	0	89.2
M Col 1524	4	1	0	67.8
M Ven 214	5	5	0	61.2
M Mex 25	3	1	0	44.6
M CR 10	2	2	0	37.5
M Mex 71	4	2	0	33.2
M Col 1420	3	2	0	32.7
M Bra 12	3	3	0	29.4
M Col 1328	5	5	0	28.6
M Col 1684	2	1	-	27.9
M Col 1292	5	3	0	25.9
M Col 877 B	4	2	0	25.4
M Per 254	5	3	0	22.7

[a] Harvested at 15 months

Table 6. The effect of simulated hornworm (*Erinnyis ello*) damage (two consecutive attacks) at different plant ages on the yield of cassava at CIAT-Quilichao (Valle del Cauca, Colombia).

	Commercial roots		Planting material	
Months of damage	Yield t/ha	% reduction	No. cuttings	% reduction
1-2	24.5	30.2	4.0	95.8
2-3	12.9	63.2	26.0	72.5
3-4	14.6	58.4	36.0	62.0
4-5	19.8	43.5	33.3	64.8
Control	35.1	-	94.7	-
1-2	17.0 +	16.5	16.7	84.5
2-3	10.9	23.2	13.3	87.7
3-4	7.1	50.0	35.7	67.0
4-5	10.2	28.2	40.3	62.8
Control	14.2	-	108.3	-
1-2	18.4	47.4	0.0	100
2-3	10.1	71.1	10.7	92.8
3-4	8.5	75.1	60.7	56.7
4-5	16.2	53.7	95.0	32.2
Control	35.0	-	140.3	

Table 7. The effect of simulated hornworm (*Erinnyis ello*) damage (two consecutive attacks) at different plant ages on the total root yield of three cassava varieties at CIAT-Quilichao (Valle del Cauca, Colombia).

Months of attack	Total average of [a] 3 varieties (t/ha)	% yield reduction
1-2	24.1	27.2
2-3	16.2	51.1
3-4	22.0	33.5
4-5	28.3	14.5
Control	33.1	-

[a] CM 305-41 ..... medium leaf
M Mex 59 ..... wide leaf
HMC 2 ..... narrow leaf

Table 8. The effect of simulated hornworm (*Erinnyis ello*) damage (two consecutive attacks) at different plant ages on the commercial yield of three cassava varieties at CIAT-Quilichao (Valle del Cauca, Colombia).

Months of attack	Average commercial [a] yield of 3 varieties (t/ha)	% yield reduction
1-2	20.0	28.8
2-3	11.3	59.7
3-4	10.1	64.1
4-5	15.4	45.2
Control	28.1	-

[a] CM 305-41 ..... medium leaf
M Mex 59 ..... wide leaf
HCM 2 ..... narrow leaf

Table 9. Periodic dissemination rates of mealybug (*Phenacoccus herreni*) infestation in four cassava field plots at CIAT, Palmira.

Field plot	No. plants infested					No. plants per plot	% plants infested
	Sample date						
	Sept. 12	Sept. 19	Oct. 3	Oct. 17	Oct. 31		
1	9	23	50	64	67	256	26.2
2	27	32	52	59	61	256	23.8
3	11	21	45	45	49	256	19.1
4	16	31	51	60	66	256	25.8
Total	63	107	198	228	243	1024	23.7
% infestation	6.1	10.4	19.3	22.2	23.7		

Table 10. Selected cassava clones from 400 varieties evaluated for resistance to the cassava mealybug *Phenacoccus herreni* in the greenhouse (Temp x 24°C and 70% RH).

Variety	Population level [a]	Damage level [b]
M Col 726	3	2
M Col 745	4	2
M Col 775	5	2
M Col 785	2	2
M Col 833	5	1
M Col 967	5	2
M Col 982	5	2
M Col 1027	3	2

a

0 = No biological stage

1 = Presence of nymphs on growing shoot

2 = Presence of nymphs and adults on growing shoot

3 = Presence of ovisacs and biological stages on growing shoot

4 = Presence of ovisacs and biological stages on growing shoot and leaves

5 = Presence of nymphs, adults and ovisacs on all plant parts

b

0 = No damage

1 = Small undulations in the margins of apical leaves

2 = Slight curling of leaves on growing shoot

3 = Rossetting and yellowing of leaves in growing shoot

4 = Necrosis and death of apical leaves. Sooty mold often present

5 = Death of growing shoot, plant defoliation. Presence of sooty mold

Table 11. Feeding preference of the subterranean sucking insect *Cyrtomenus bergi* (Froeschner) in two cassava varieties, CMC 40 (low HCN content) and M Col 1684 (high HCN content) under field conditions (CIAT-Quilichao).

Varieties [a]	No. Damaged Roots [b]	% Damaged Roots
CMC 40	8.2	27.3
M Col 1684	0.1	0.3

[a] Ten blocks of nine plants each for each variety.

[b] Thirty roots evaluated in each block

Table 12. Chemical control of the subterranean sucking insect, *Cyrtomenus bergi* (Froeschner) attacking cassava at CIAT-Quilichao.

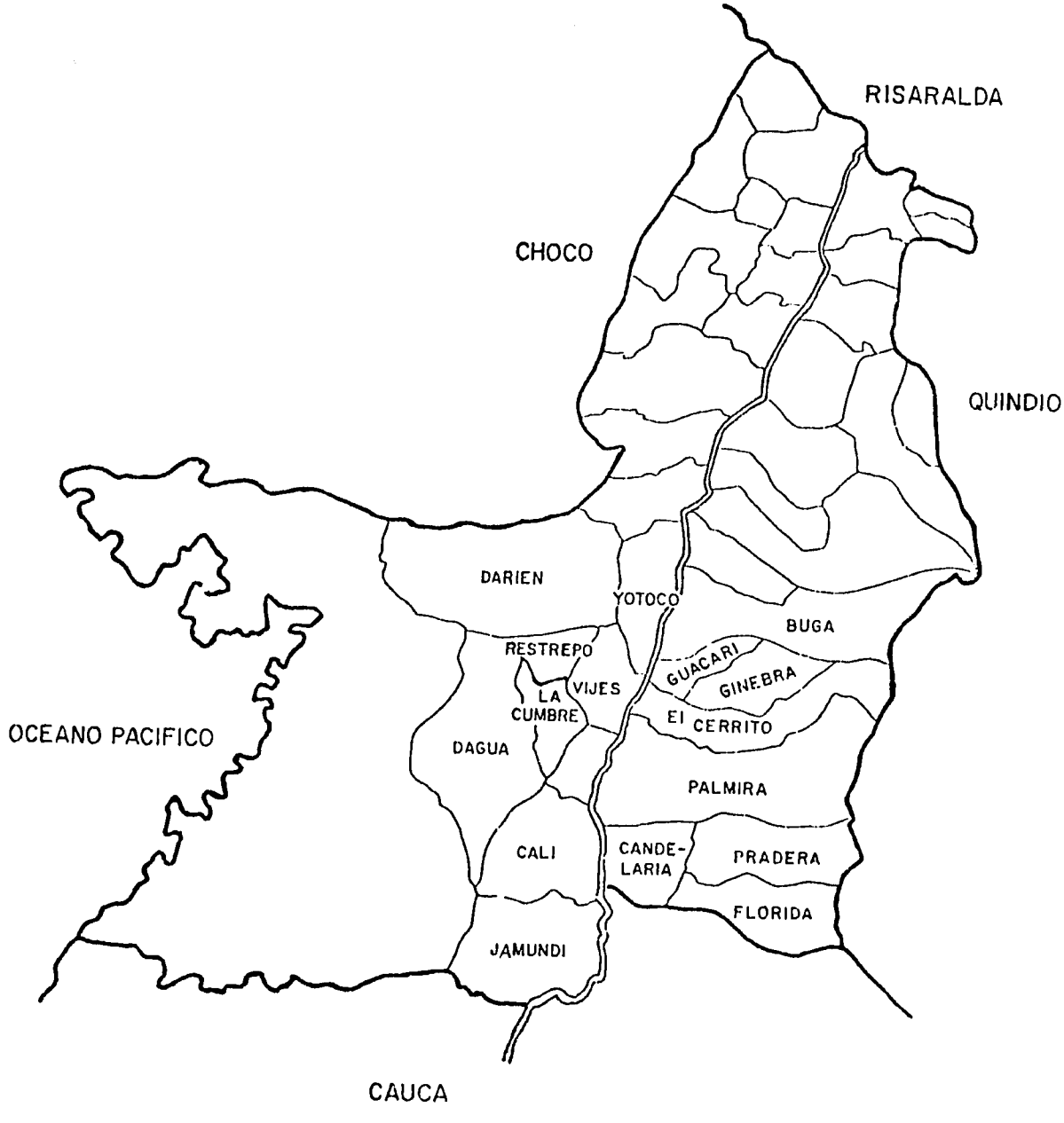
Treatment	No. damaged roots		% damaged roots	
	CMC 40	M Col 1684	CMC 40	M Col 6184
Sistemin 48% 2 cc/L. H_2O Every 2 months Foliage application	1.7	0	8.3	0
Sistemin 48% 2 cc/L. H_2O Every month Foliage application	2.0	0	10.0	0
Furadan 3% - 1 gr/plant Every month	3.7	0.7	18.5	3.5
Aldrex 2% - 2 cc/L. H_2O Every month Soil application	4.7	0	23.5	0
Furadan PF - 1 cc/L. H_2O Every month Foliage application	6.3	0	31.7	0
Control (no treatment)	17.0	0	85.0	0

Table 13. The accumulation of pesticide in cassava roots after monthly and biomonthly foliage and soil application.

Pesticides:	Dimethoate	40%: 2 cc/lt. water/foliage
	Carbofuradan	3%: 3 gr/plant/soil
	Aldicarp	10%: 1 gr/plant/soil
	Endosulfan	35%: 8 cc/lt water/foliage
Results:		Pesticide accumulation
	Root Part	
	Peel	+
	Pulp (Parenchyma)	-

Table 14. The effect of the cassava insect and mite complex on the root and cutting yields of three cassava varieties with and without insecticide treatment at CIAT-Palmira, Colombia.

Variety	Treatment	Production t/ha	Roots			Planting material	
			% Difference	% Root rot	% Starch	No. cuttings/ plant	% Difference
CMC-40	With insecticide	17.9	40.8	24.0	30.88	9.3	37.6
	Without insecticide	10.6		6.6	28.30	5.8	
M Col-113	With insecticide	7.7	+ 30.0	28.2	29.10	6.0	- 15.0
	Without insecticide	11.0		13.8	29.30	7.1	
M Col-22	With insecticide	16.0	35.0	2.0	32.76	7.0	14.3
	Without insecticide	10.4		2.0	25.82	6.0	



Political administrative divisions (municipalities) of the deparment of valle

Figure 1. Municipalities named in map have been sampled for phytoseiidae mites.

FIGURE 2. Geographic distribution of Phytosiid mites in Colombia (1983).

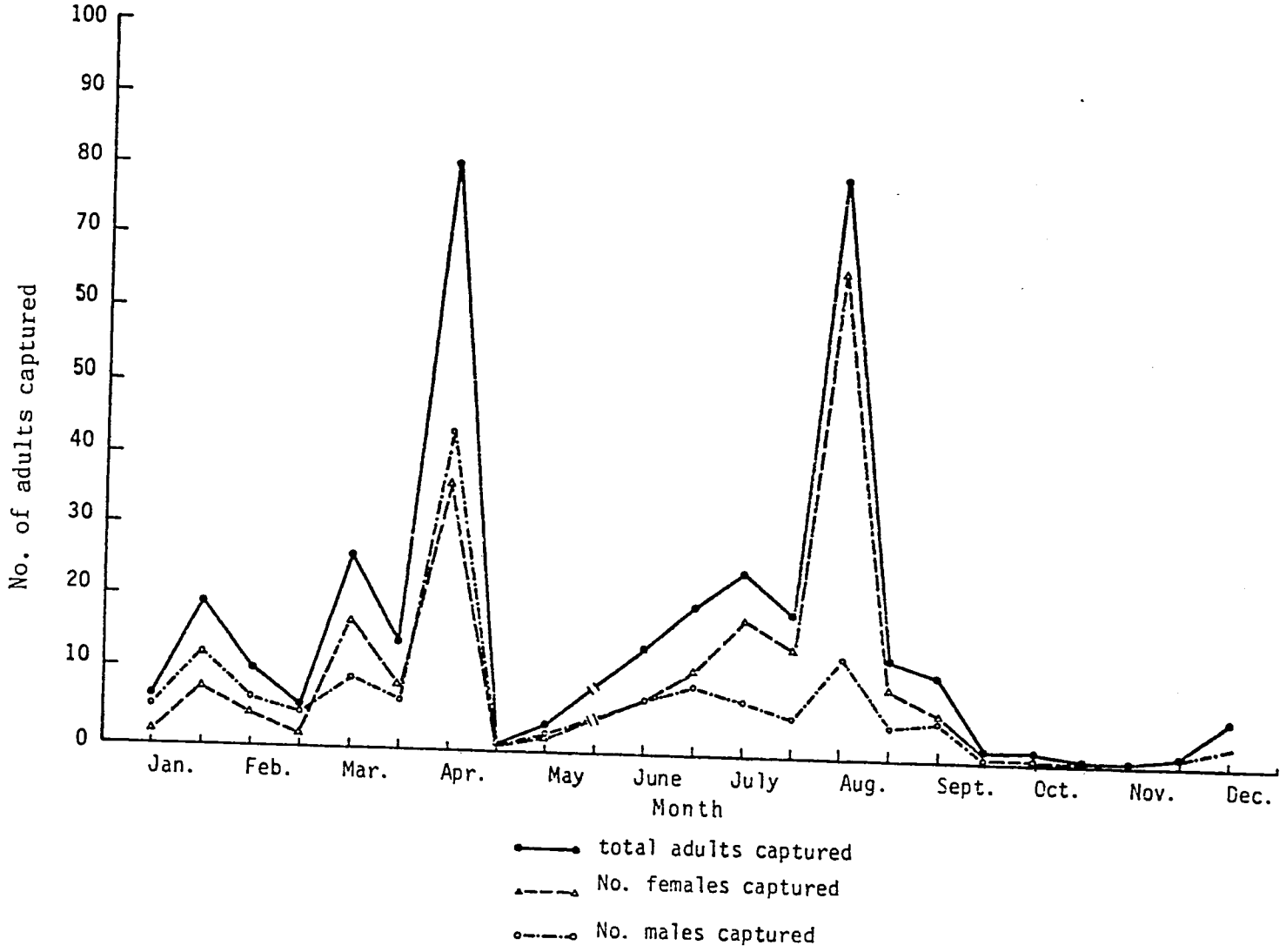


Figure 3. The capture of Erinnyis ello adults at CIAT- Quilichao during 1983 with a black light trap.

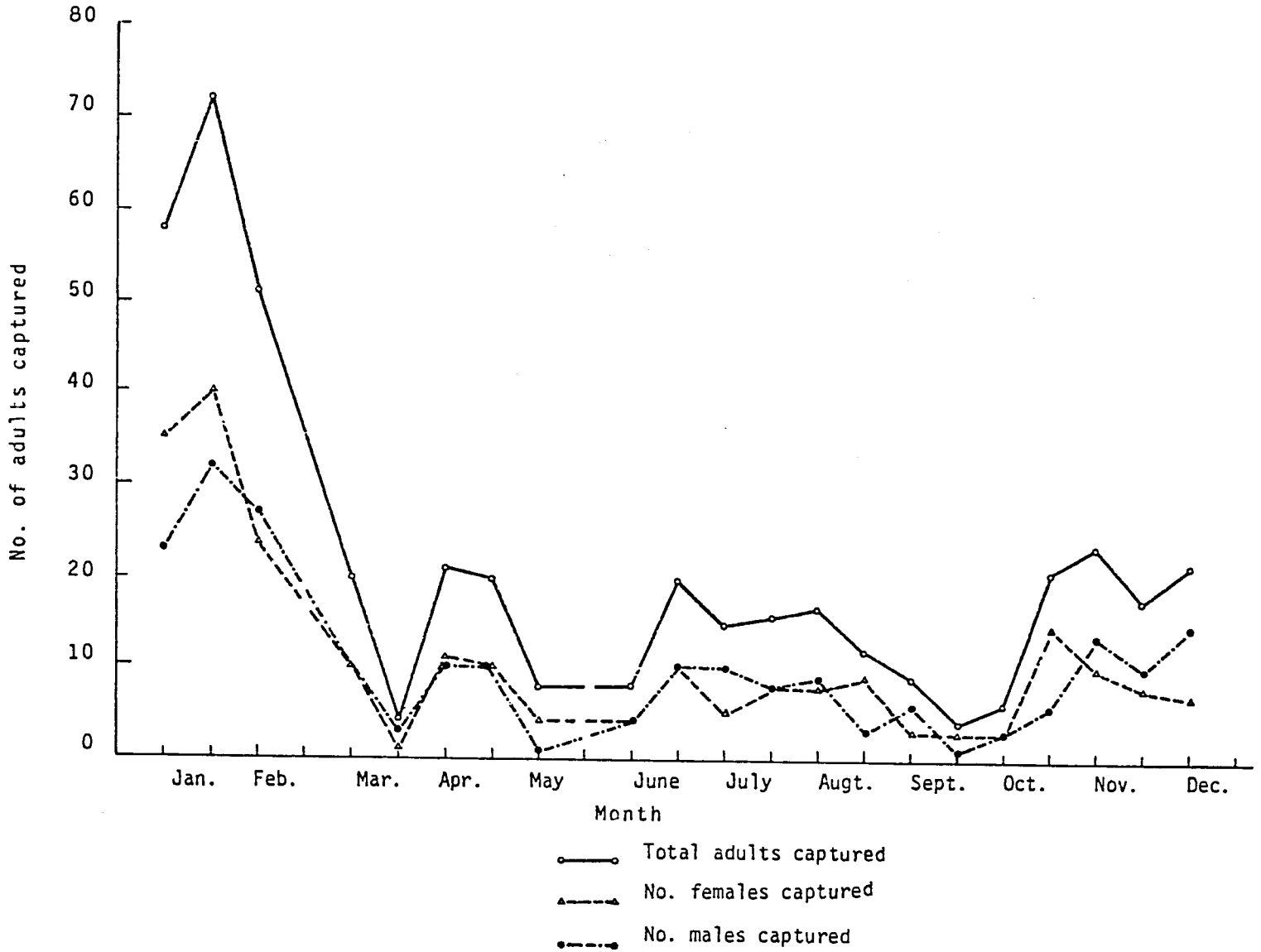


Figure 4. The capture of Erinnyis ello adults at CIAT- Palmira during 1983 with a black light trap.

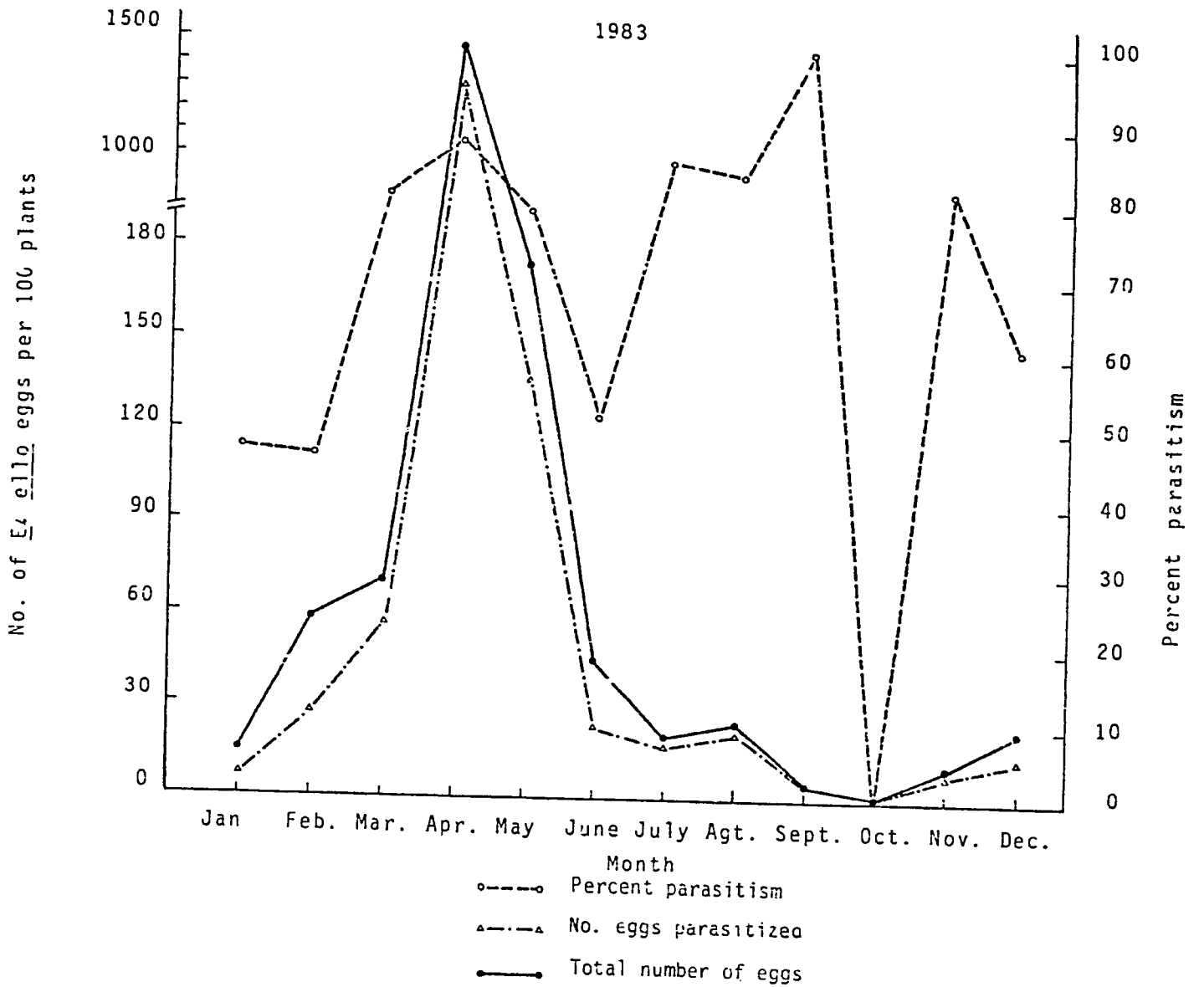


Figure 5. Parasitism of Erinnyis ello eggs by Trichogramma sp. at CIAT-Quilichao.

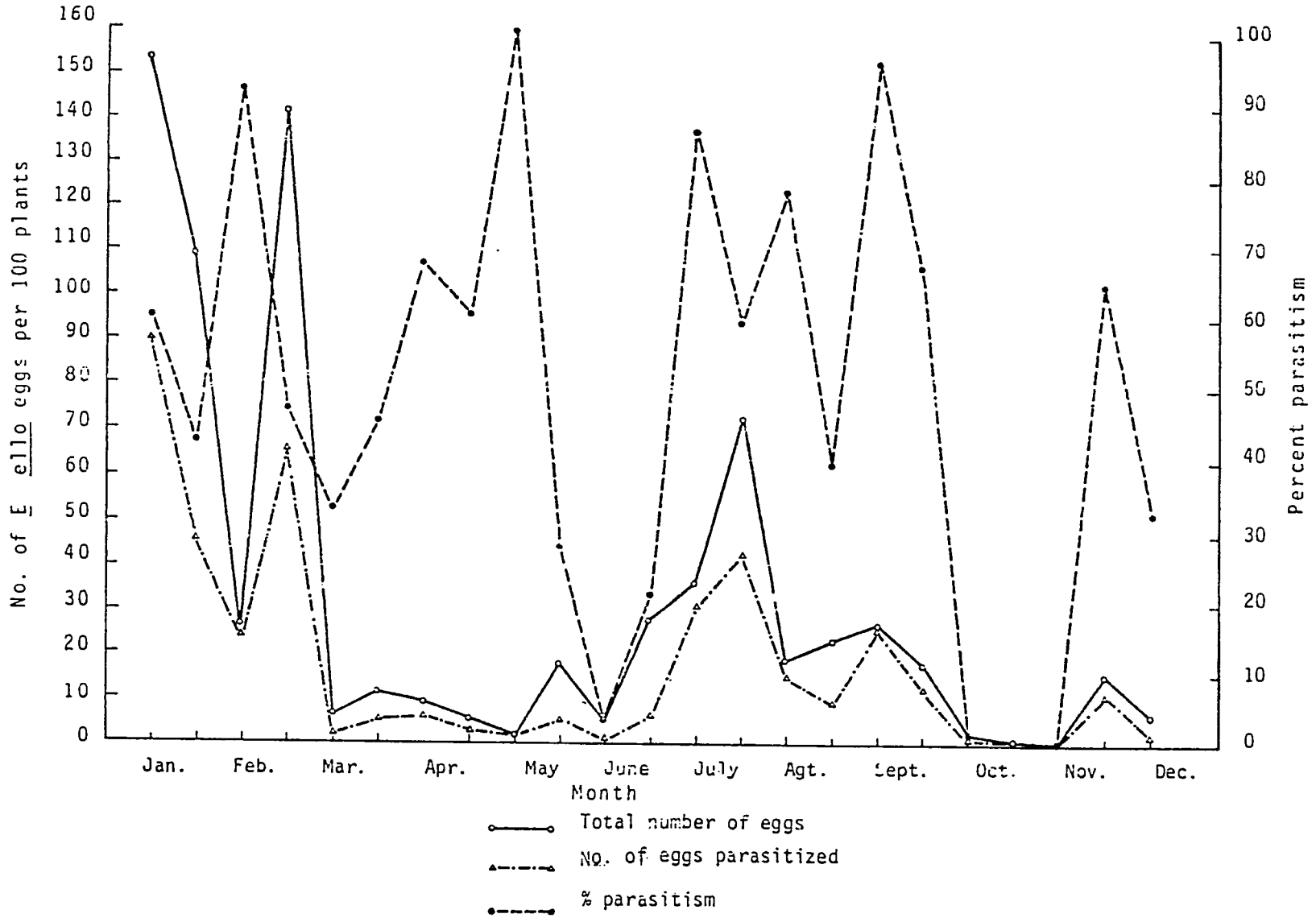


Figure 6. Parasitism of Erinnyis ello eggs by Trichogramma sp. at CIAT-Palmira.

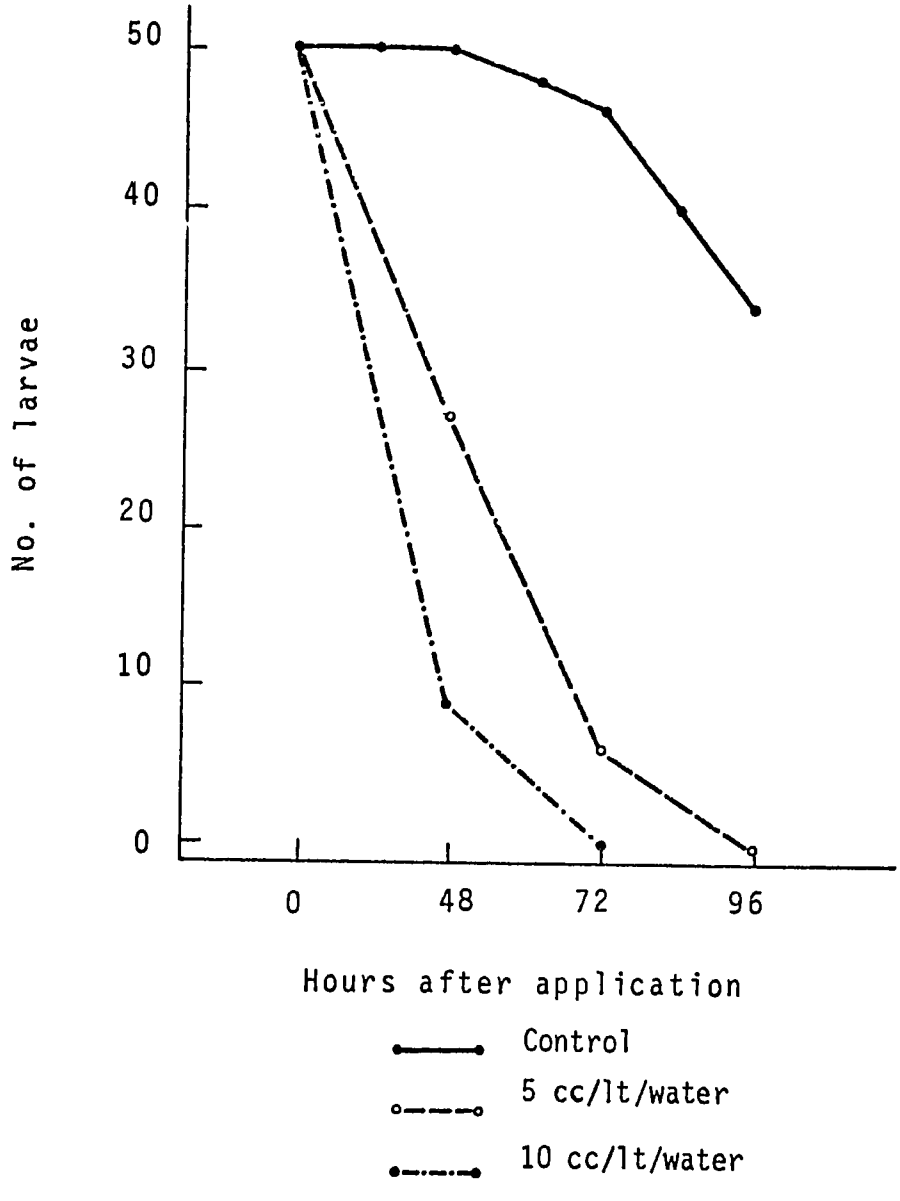


Figure 7. The effect of field applications of the cassava hornworm baculovirus on populations of Erinnyis ello .

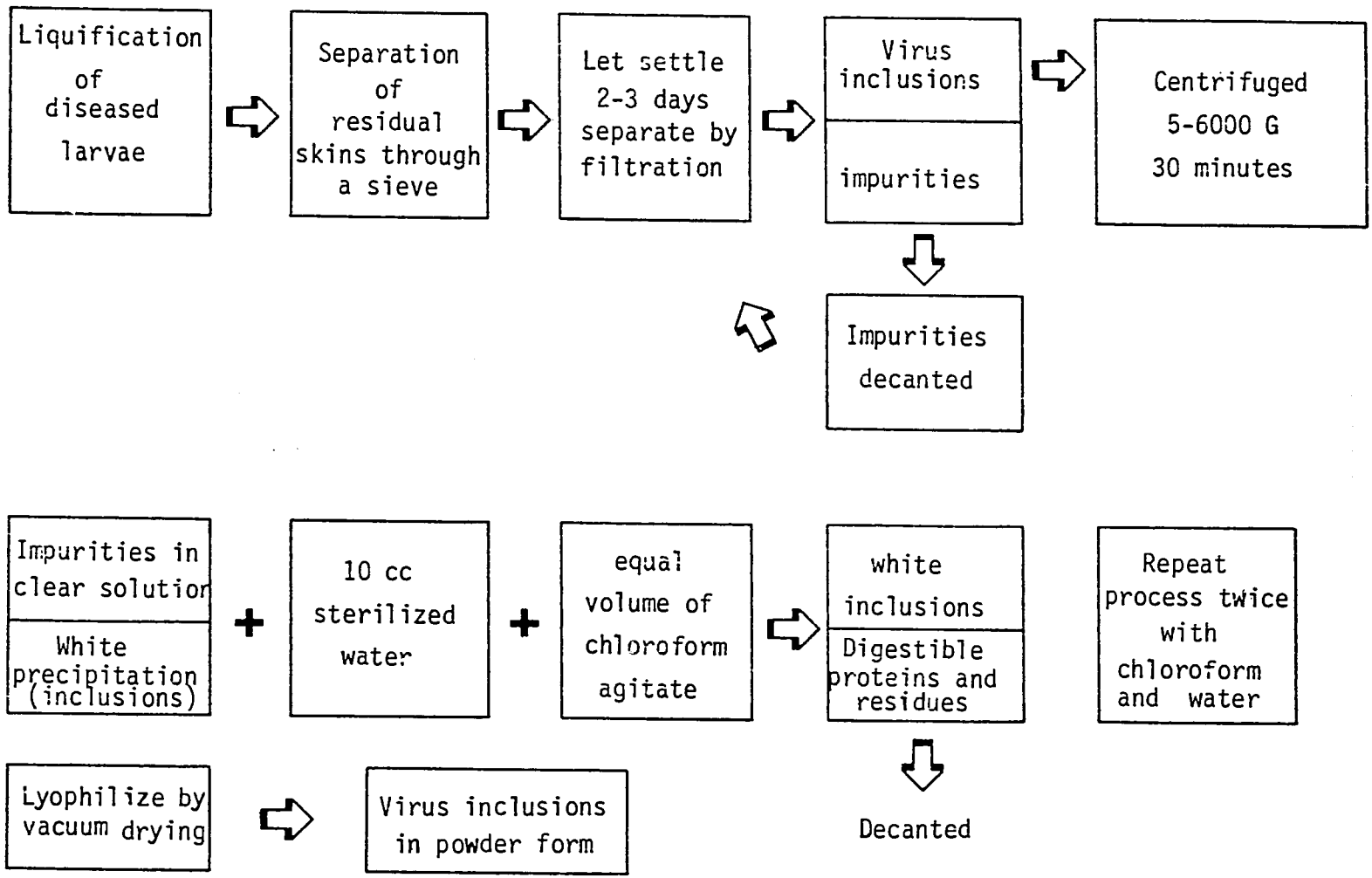


Figure 8. Procedure for production of cassava hornworn Erinnyis ello.

0 = Artificially infested plants

● = Plants with no mealybugs

1 to 5 = Weeks after artificial infestation when mealybug observed

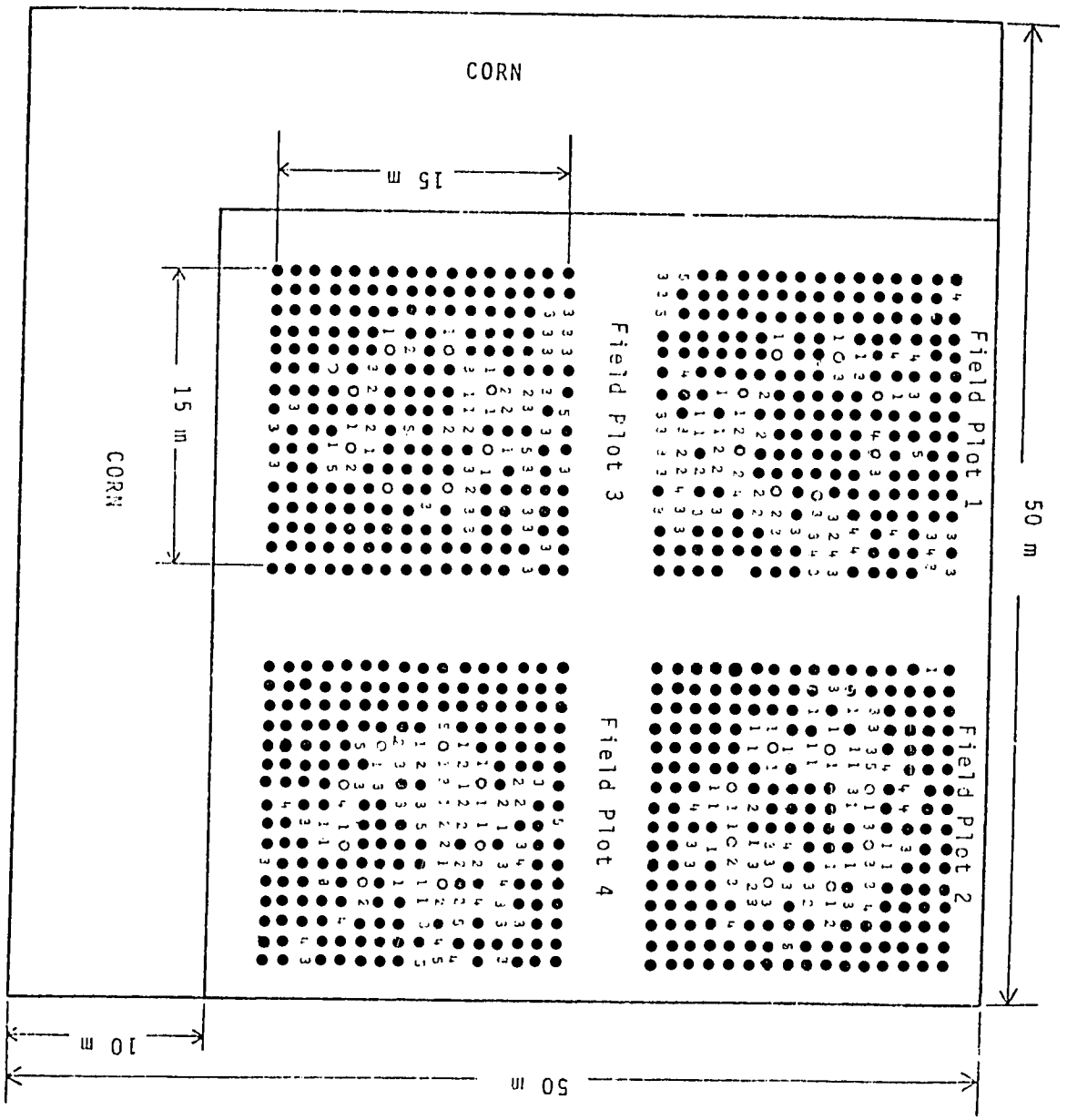


Figure 9. Spread of mealybug (Phenacoccus herreni) populations five weeks after artificial infestation of eight central plants in each plot.

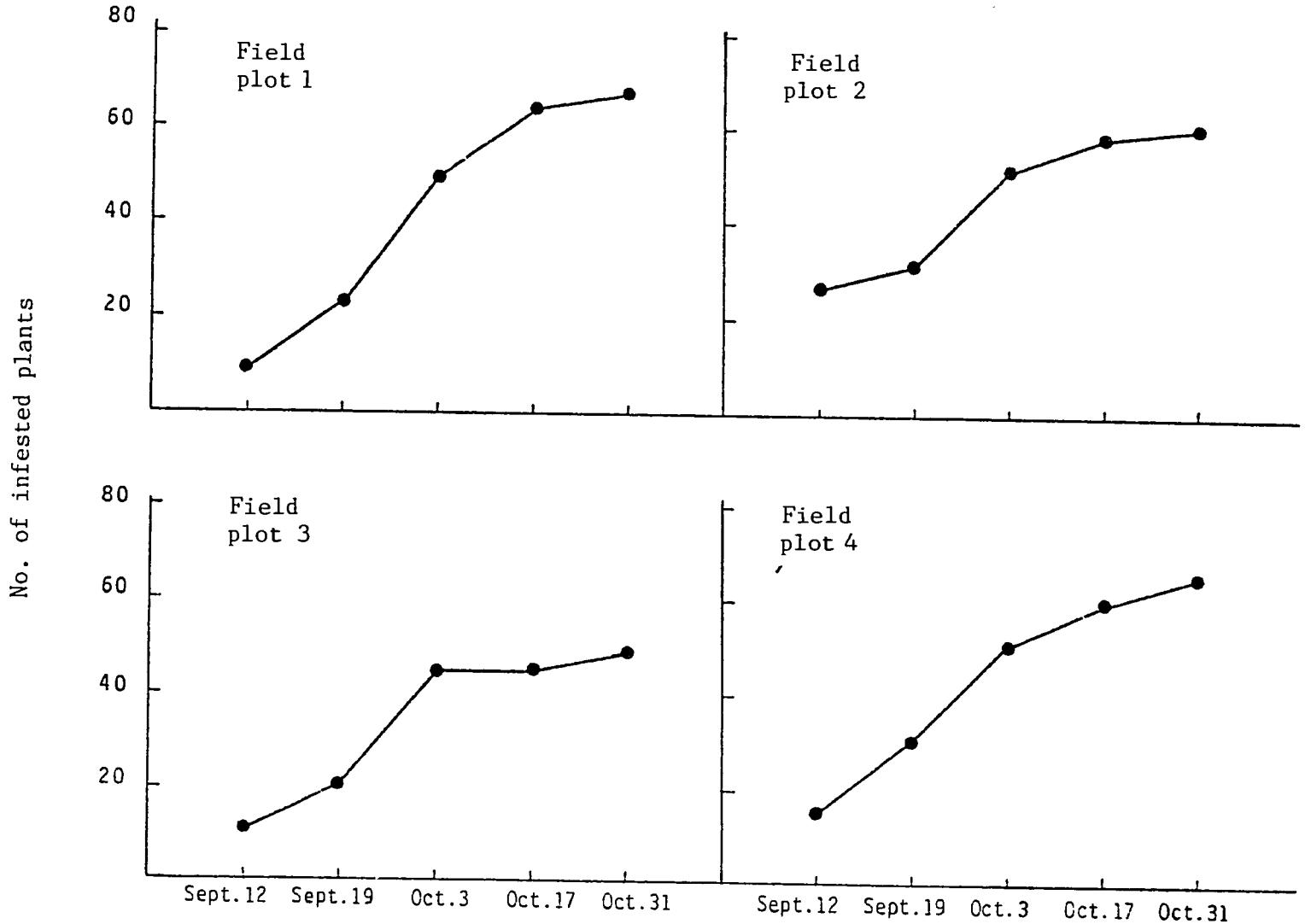


Figure 10. Dissemination of Phenacoccus herreni populations in cassava fields by measuring infested plants over a seven week period (Sept.-Oct. 1983).

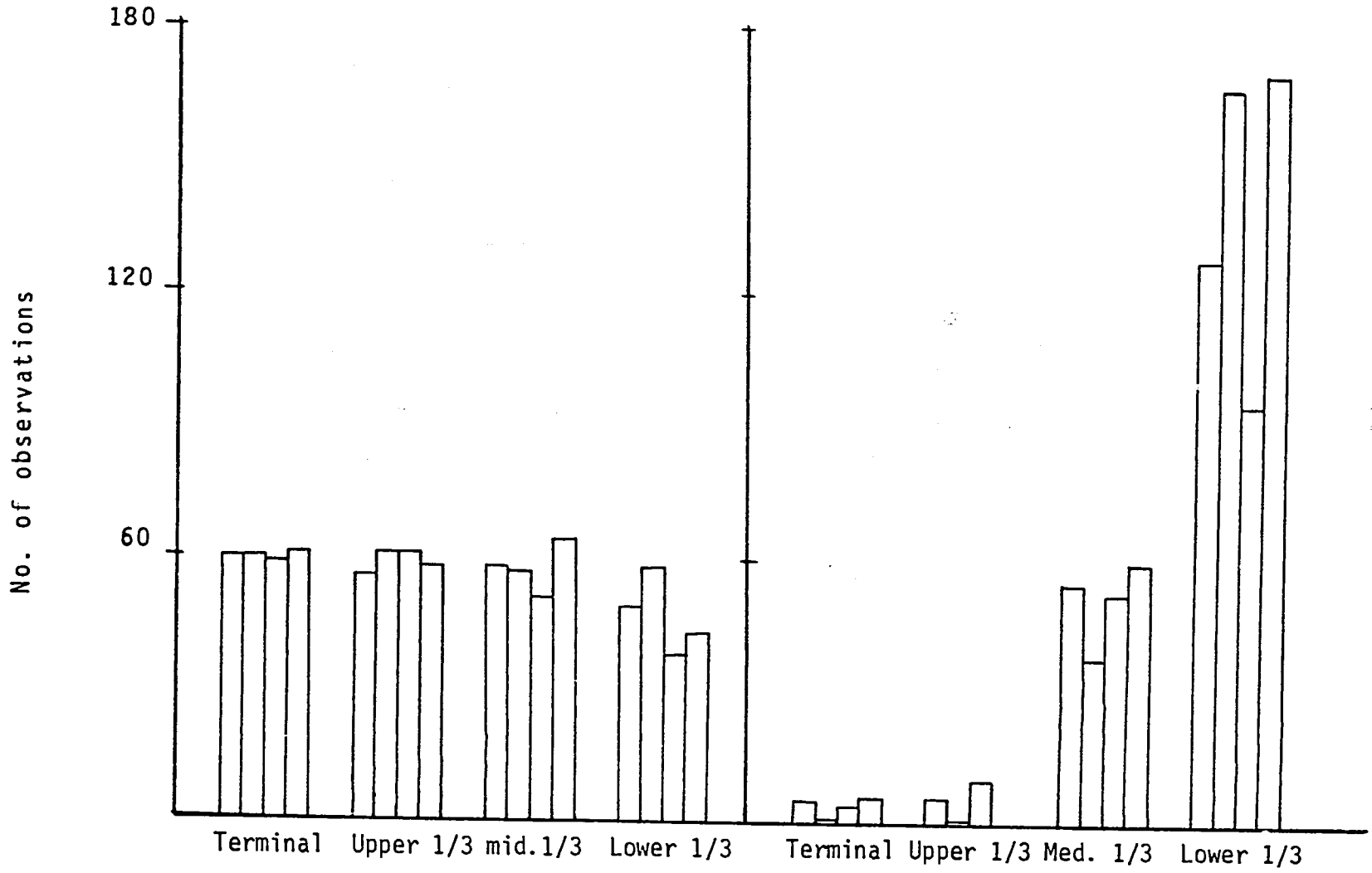


Figure 11. Distribution of Phenacoccus herreni populations within the cassava plant resulting from a natural infestation.

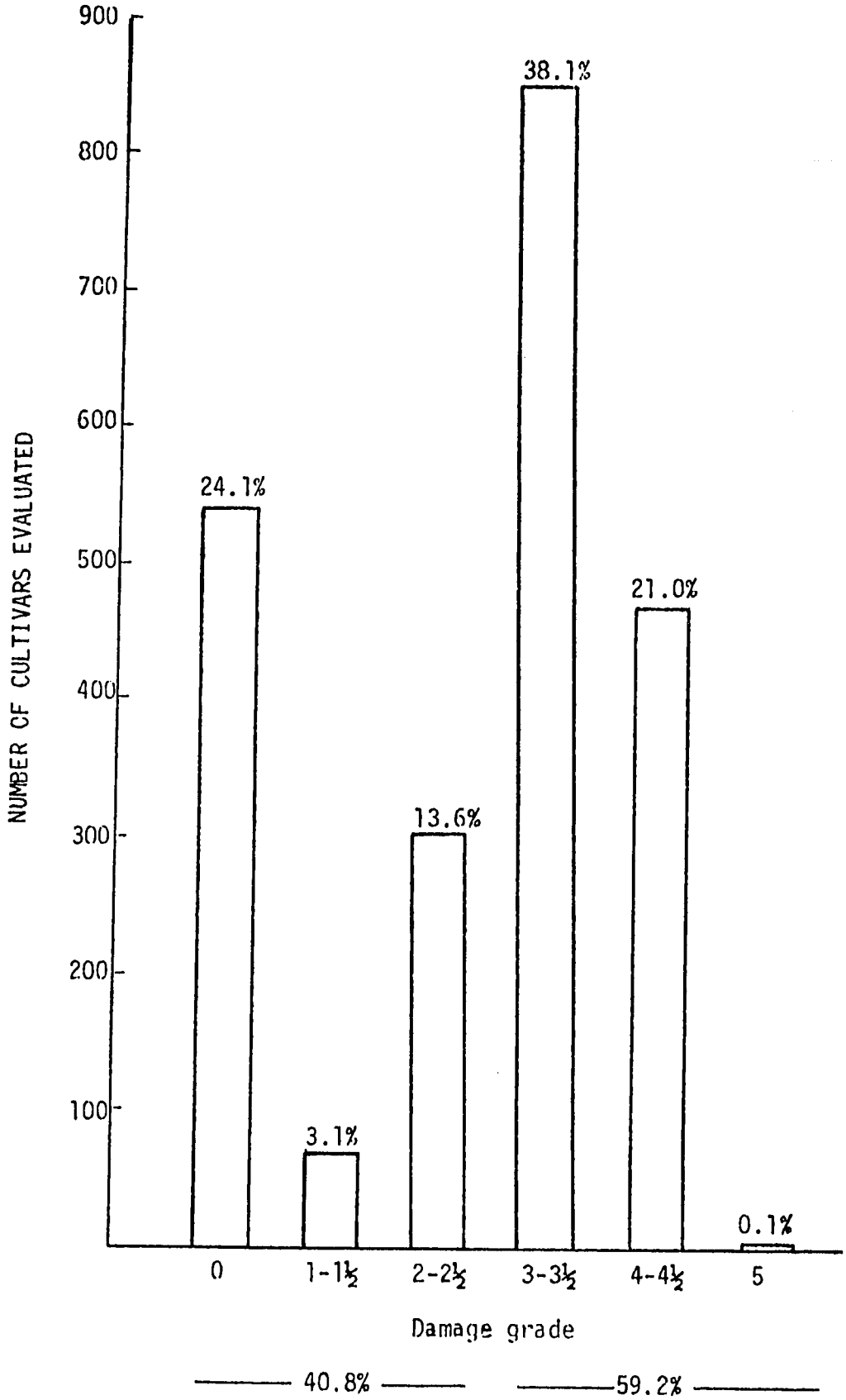


Figure 12. Evaluation of the CIAT Germplam Bank for resistance to the mealybug Phenacoccus herreri (1983).

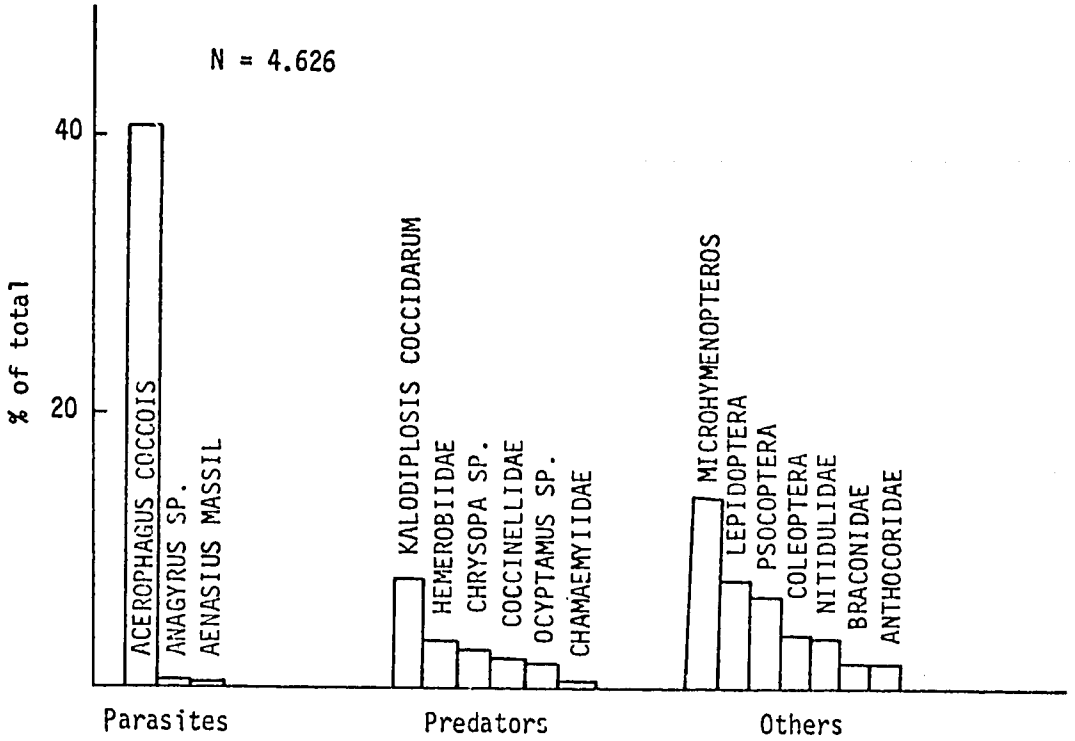


Figure 13. Insect species found in association with the mealybug Phenacoccus herreni on cassava at CIAT (September to November 1982).

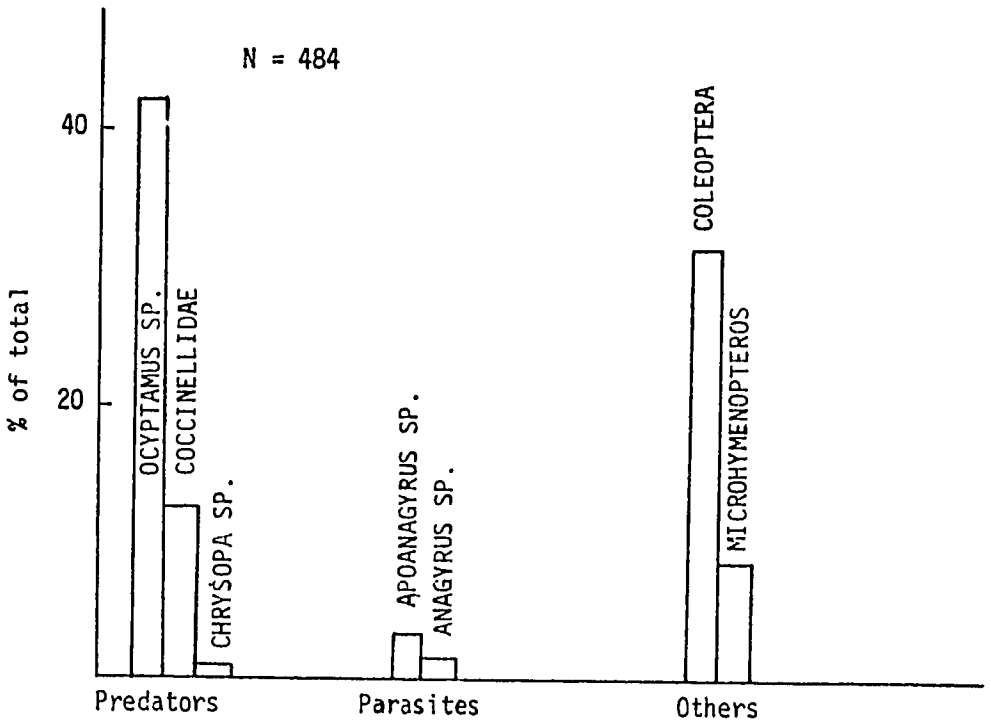


Figure 14. Insect species found in association with the mealybug Phenacoccus herreni on cassava at Carimagua (December 1982 to February 1983)

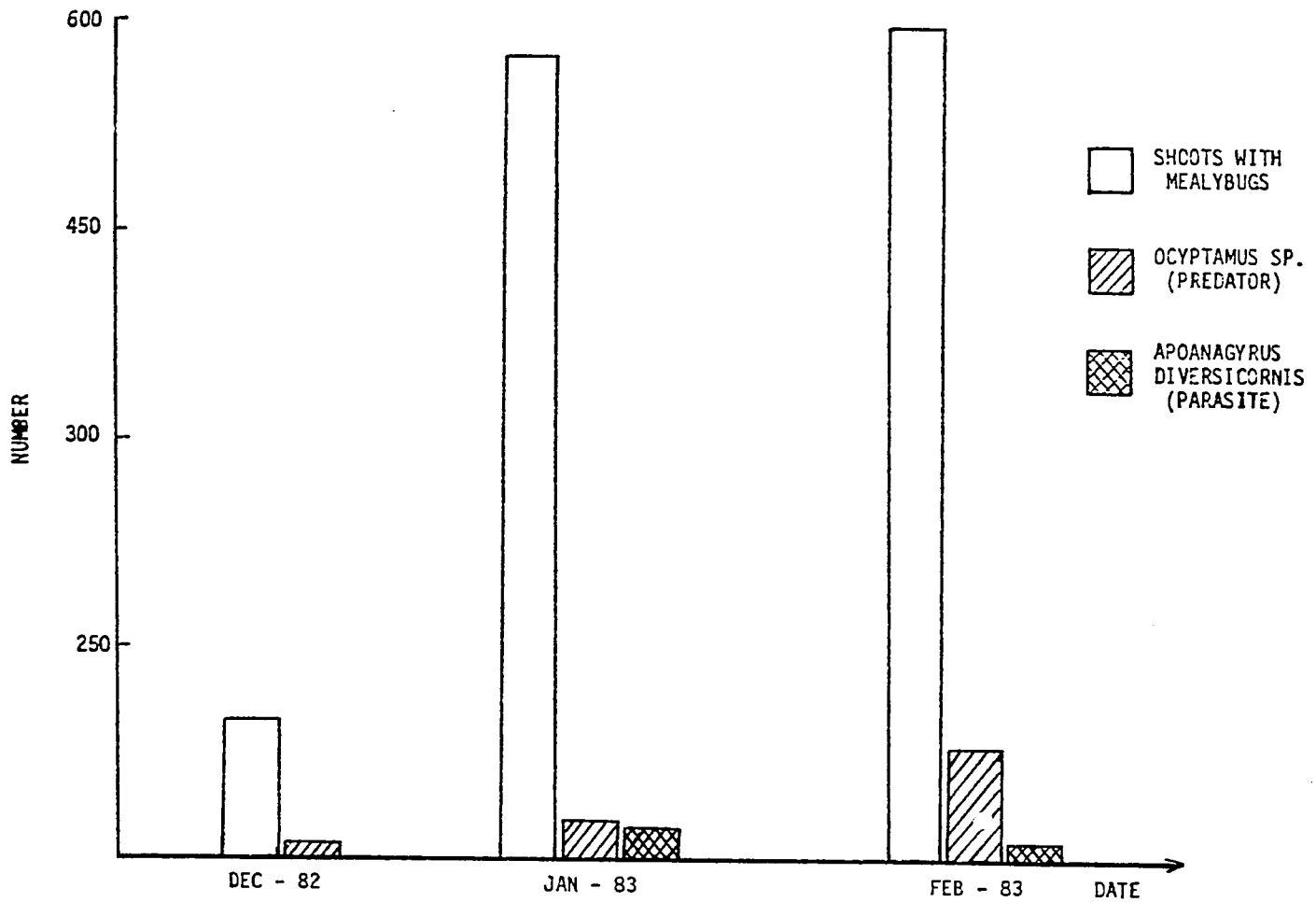


Figure 15. CARIMAGUA: Increase in the mealybug Phenacoccus herreni population. The number of infested terminals in samples of 55 plants chosen at random on each sampling date, and the number of Ocyptamus sp., and of Apoanagyrus diversicornis, in samples of 100 randomly chosen terminals.

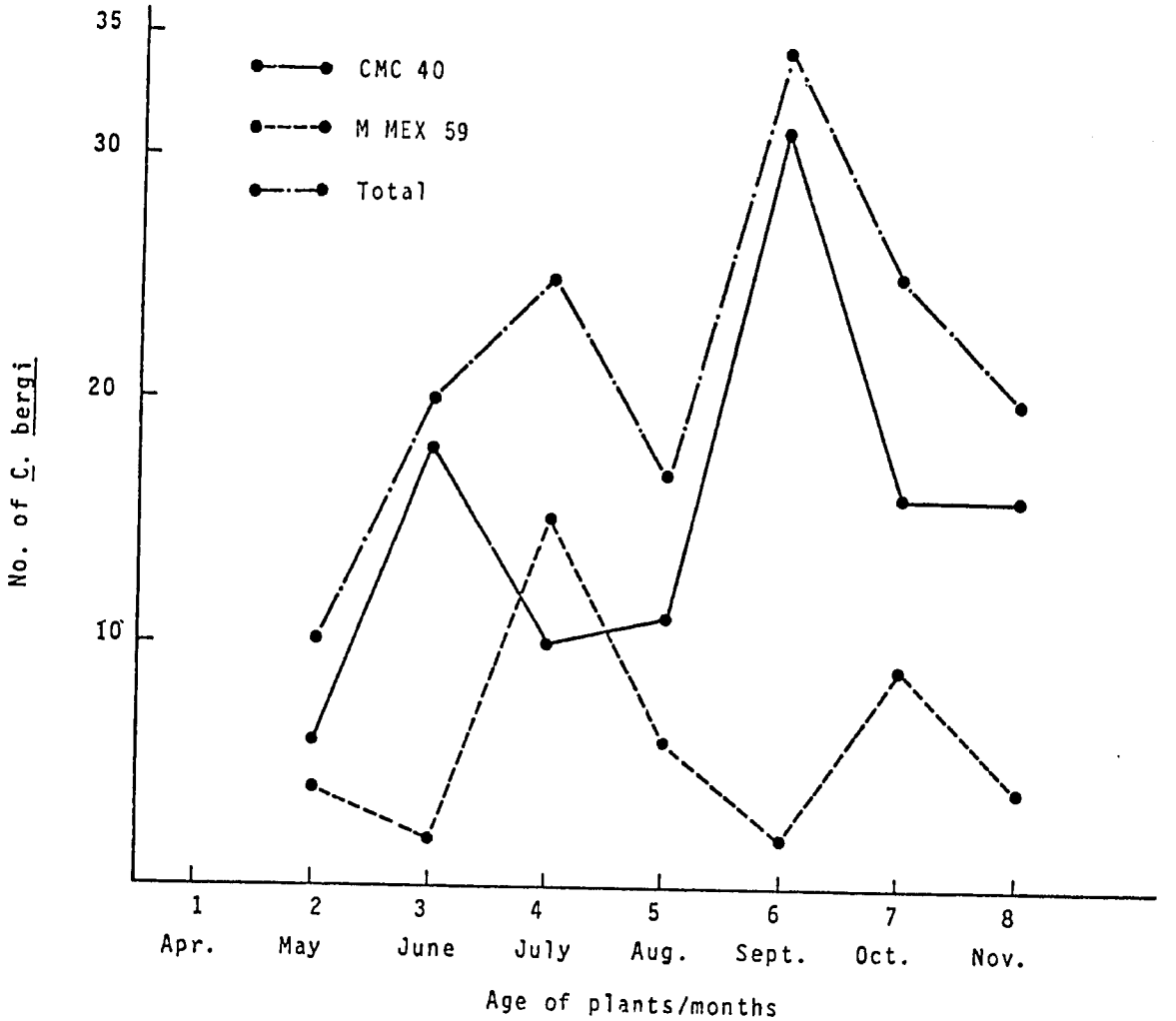


Figure 16. Populations of Cyrtomenus bergi associated with cassava roots over an eight month period at Santander de Quilichao, Valle, Colombia.

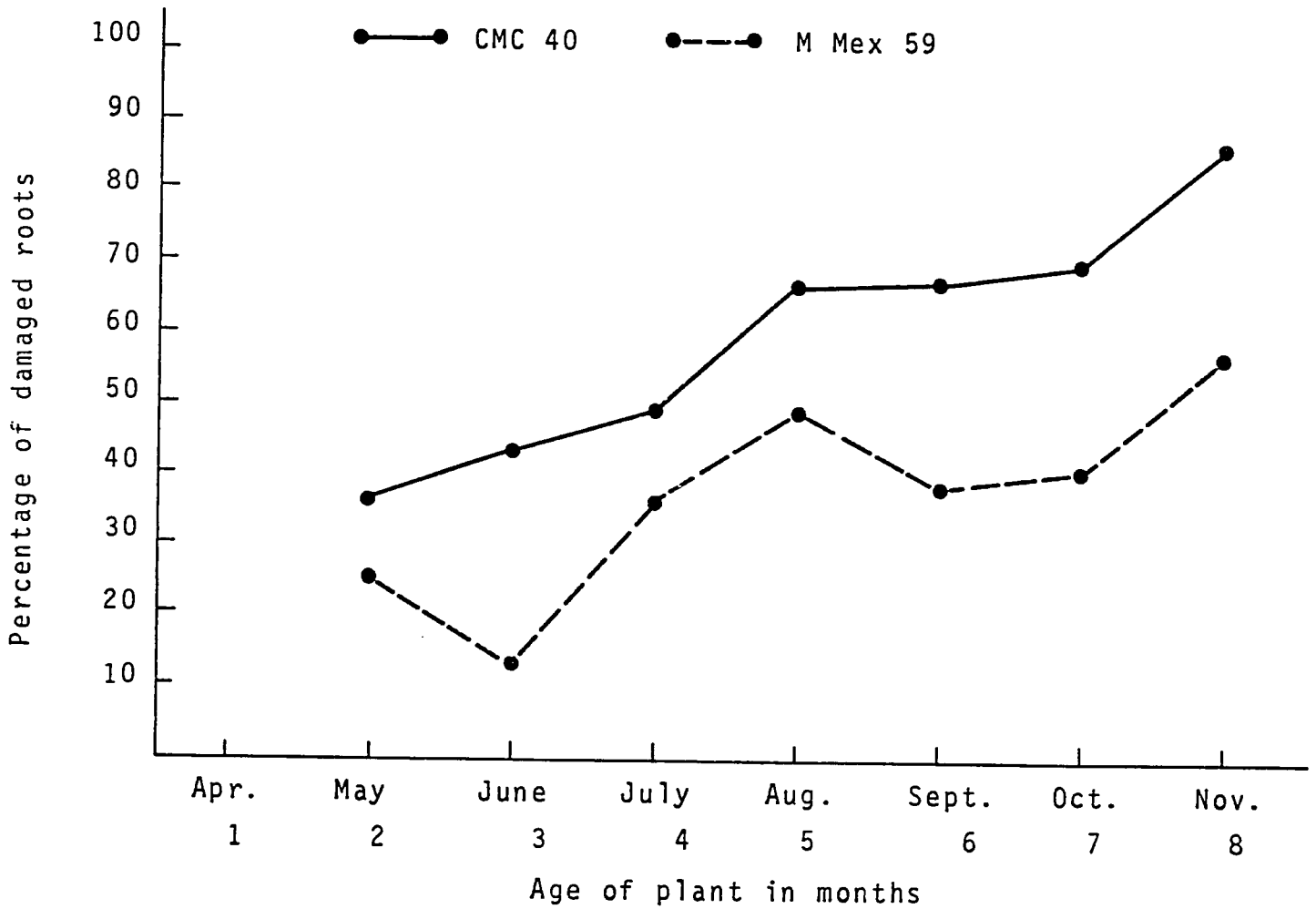


Figure 17. Percentage of cassava roots damaged by an attack of the subterranean sucking insect Cyrtomenus bergi (Froschener).

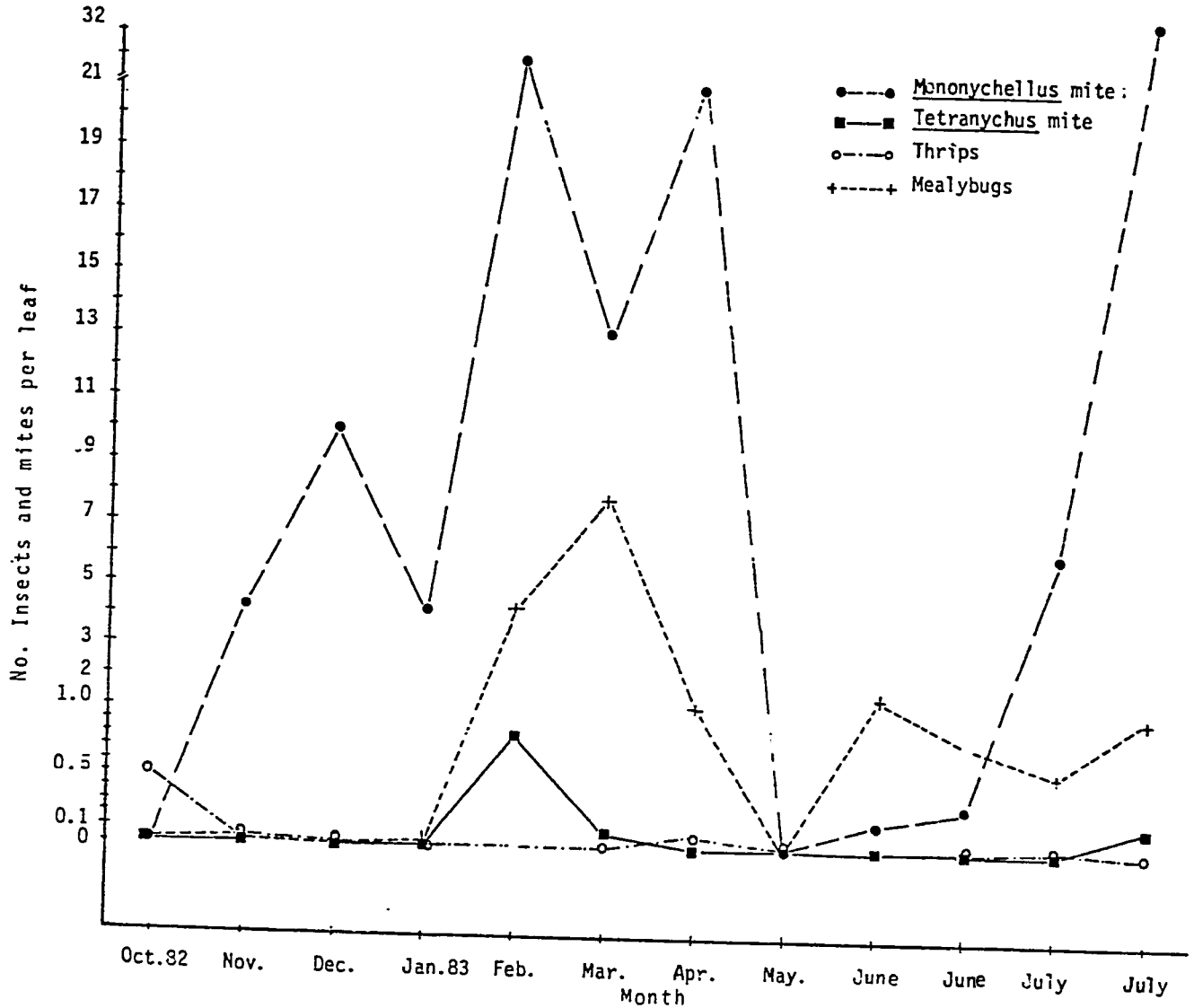


Figure 18. Population fluctuation of insects and mites on M Col 113, at CIAT 1982 to 1983.

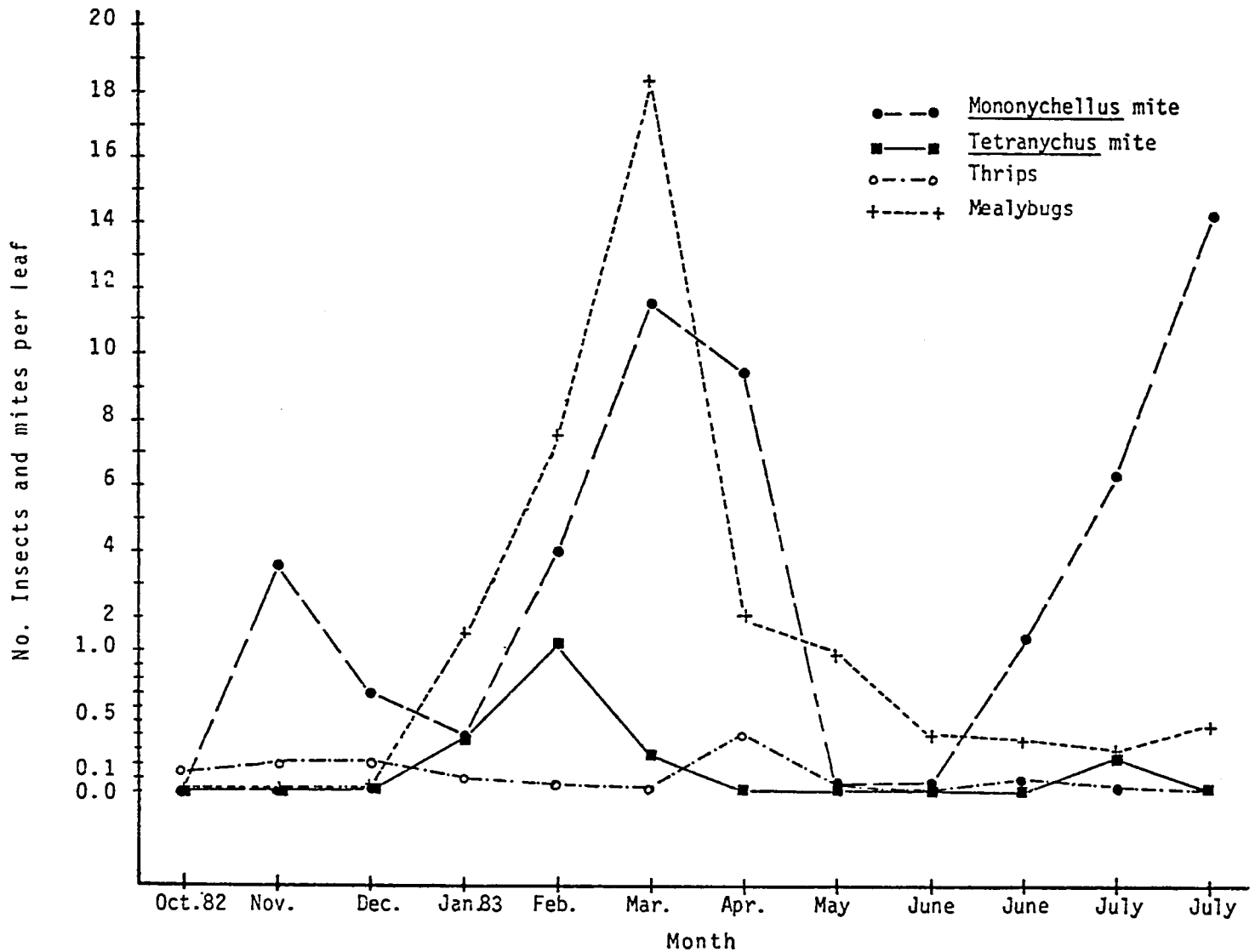


Figure 19. Population fluctuation of insects and mites on CMC 40 at CIAT, 1982 to 1983.

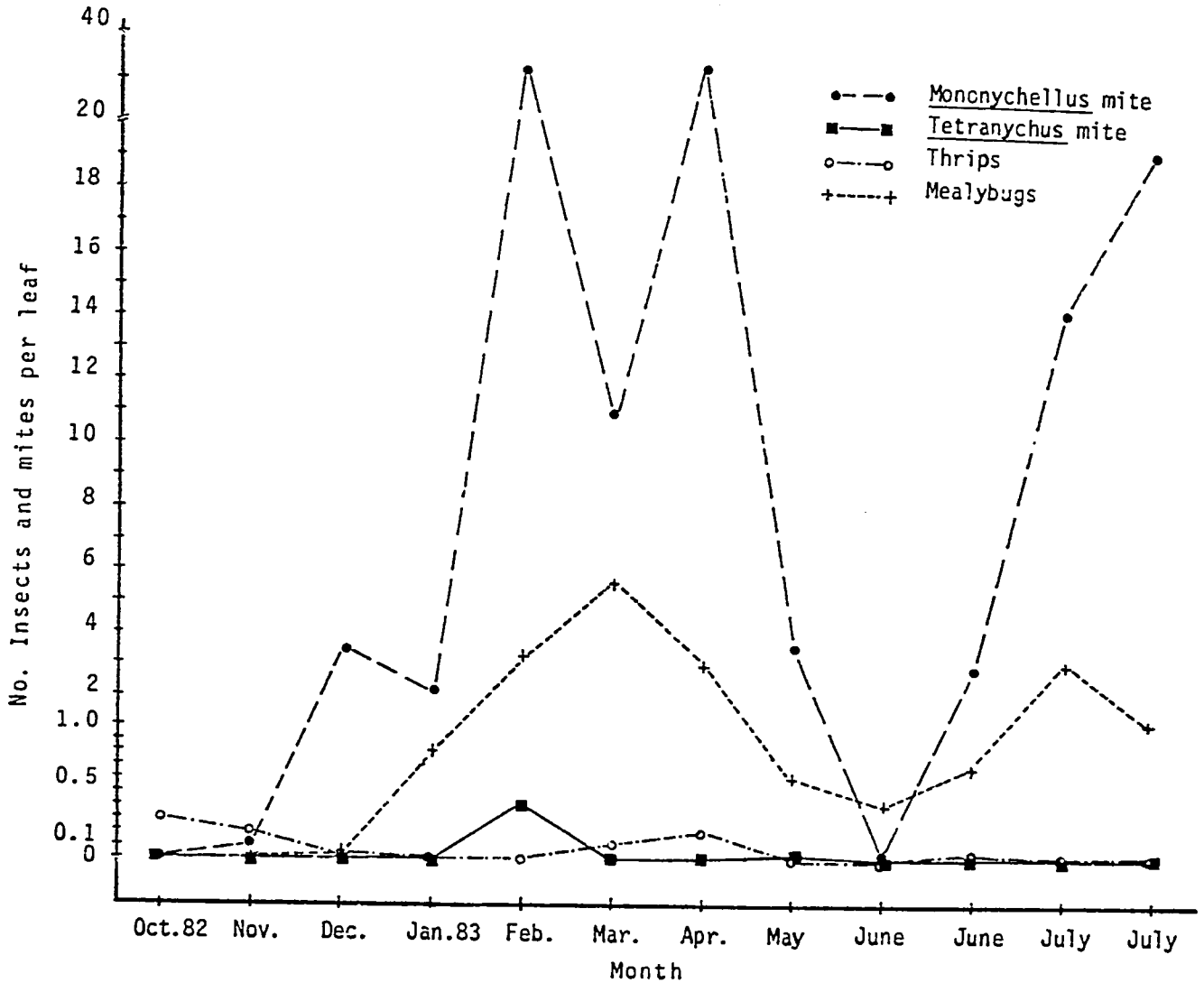


Figure 20. Population fluctuation of mites and insects on M Col 22 at CIAT, 1982 to 1983.

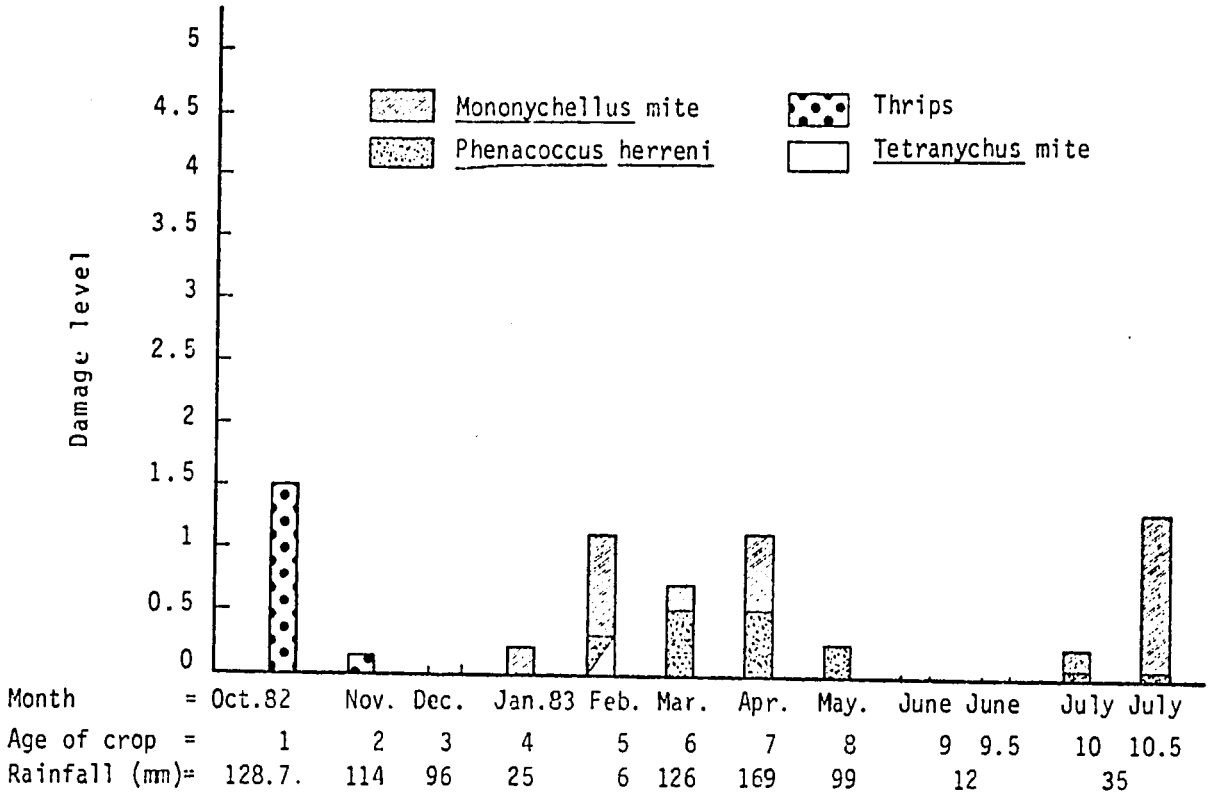


Figure 21. Plant damage levels caused by the feeding of the insect and mite complex attacking the cassava variety M Col 113 from October 1982 to July 1983 at CIAT.

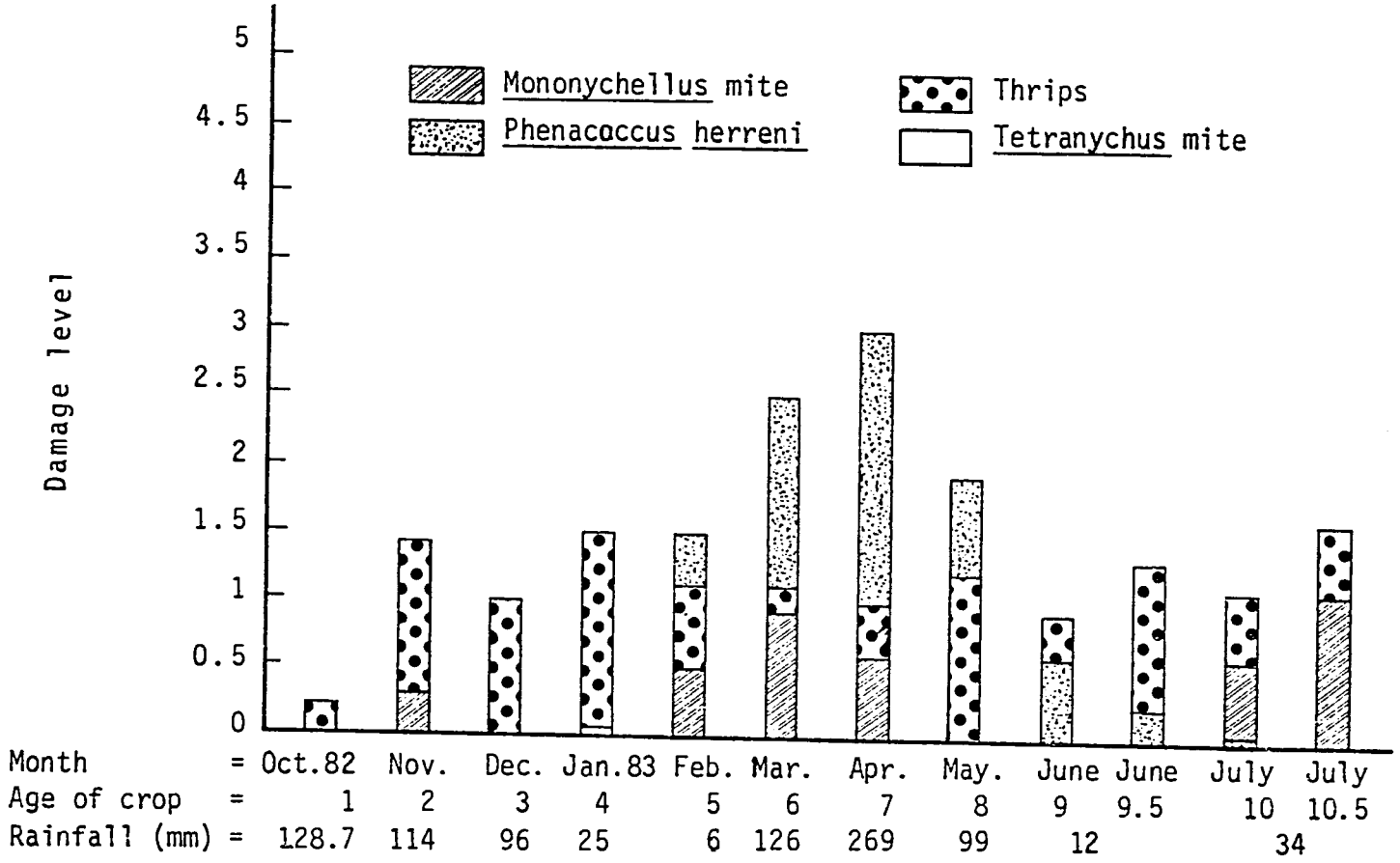


Figure 22. Plant damage levels caused by the feeding of the insect and mite complex attacking the cassava variety CMC 40 from October 1982 to July 1983 at CIAT- Palmira.

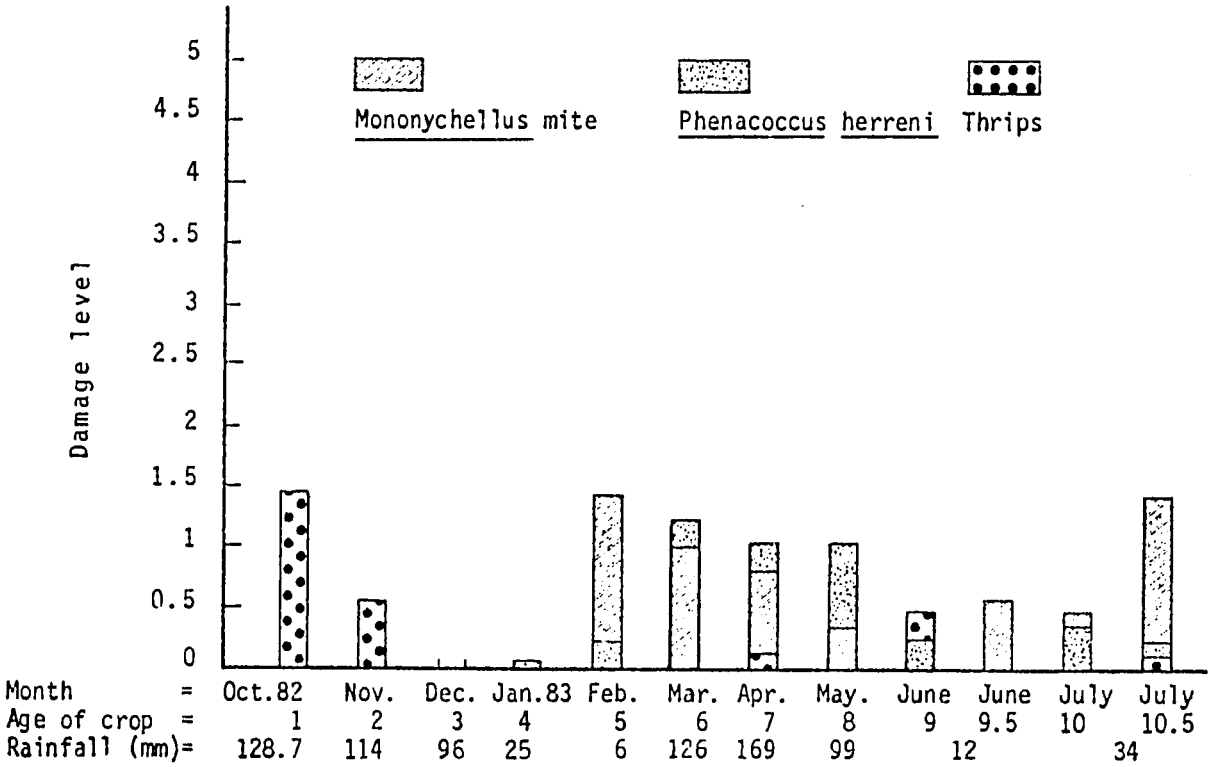


Figure 23. Plant damage levels caused by the feeding of the insect and mite complex attacking the cassava variety M Col 22, from October 1982 to July 1983, at CIAT- Palmira.

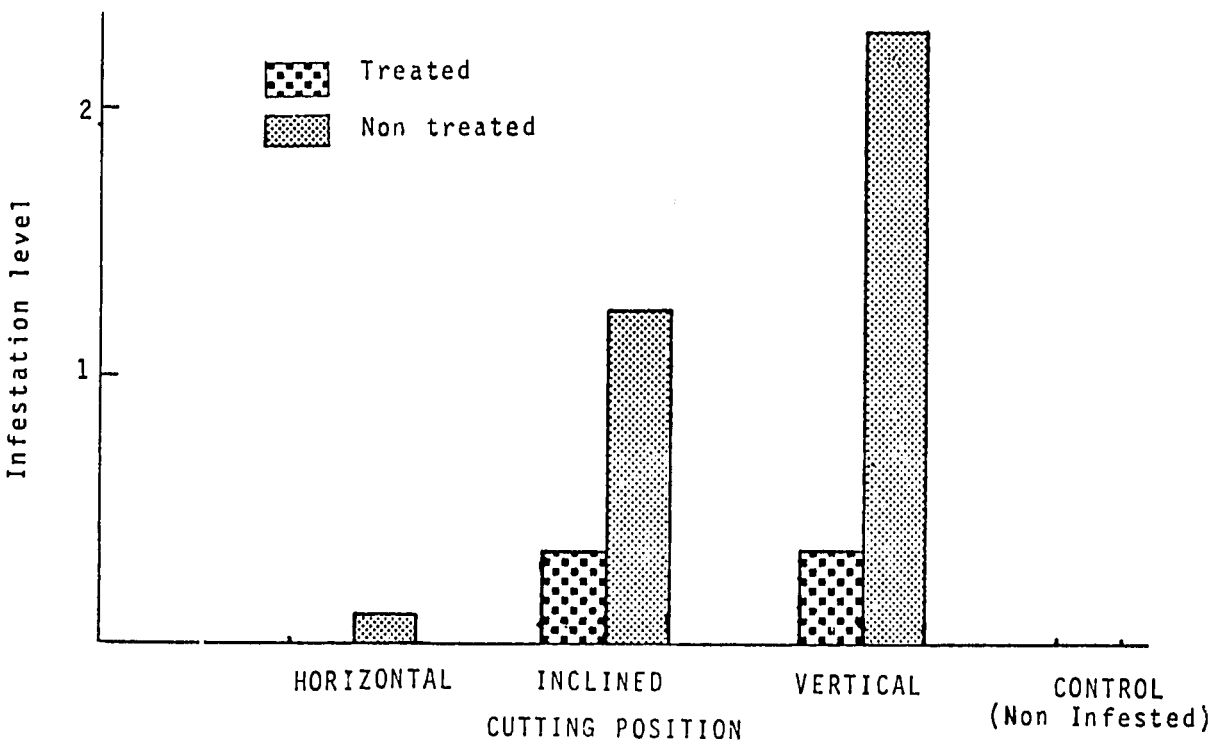


Figure 24. The effect of three different cutting positions at planting on population growth of the cassava white scale Aonidomitilus albus.

Pathology

Investigations in cassava pathology have focused on four groups of pathological problems dealing with the improved production of the crop: (a) of botanical seeds; (b) affecting vegetative propagative material; (c) that effect the crop during the growing cycle; and (d) related to preharvest root rots.

Pathological Problems of Cassava Botanical Seeds

The pathological problems of botanical seeds not only complicate the breeder's work but also represent a quarantine risk in areas where the infected/infested material is introduced. Before 1983 (Cassava Annual Reports 1979, 1981, 1982) the causal agents of cassava bacterial blight (CBB, *Xanthomonas campestris* pv. *manihotis*) and anthracnose (*Colletotrichum* spp.) were reported as seed-borne pathogens. This year's results have led to the conclusion that there are several seed-borne fungi in most of the cassava growing areas. A relatively high percentage of fruits as well as the seeds collected in five different locations were affected by pathological problems. Similarly, a very high percentage of these seeds floated in water, indicating low density values which were related to poor germination (r = 0.93*** correlation) (Table 1). It is likely, however, that the low rate of germination was due to a combination of factors, including pathogens, seed immaturity, and others. Twelve fungal species belonging to eight different genera were isolated from seeds collected at four locations (Table 2). When seed samples were collected at different periods from CIAT-Palmira, results indicated that some pathogens are found more commonly affecting the seeds during the wet season than others and that some fungal species affect a higher percentage of seeds than others (Table 3). Similarly, a very high correlation (r = 0.93**) was found between fruit fly damage and pathogen-affected seeds collected from insect-damaged fruits.

Artificial inoculations with species of *Fusarium*, *Colletotrichum*, and *Diplodia* induced root and stem rots. Seeds affected by species of these genera and *Penicillium* and *Aspergillus* showed inhibition of root formation and severe root rots on plantlets from seeds growing on a PDA medium. The control of these pathogens was highly effective when seeds selected by the water density system (seeds floating in water were discarded) were treated for 120 seconds of microwave exposure (156°F - 78°C) (Table 4) followed by an arasan dust. When seeds were dry heated (60°C) for 14 days followed by an arasan dust, *Fusarium* and *Colletotrichum* species were not eradicated (Table 4).

Pathological Problems Affecting Vegetative Propagative Material

During previous reports the need for the use of clean vegetative propagative material was demonstrated as a prerequisite for satisfactory yields. This lead to the inclusion of selection and pesticide treatments in all technological packages for cassava production. Results of this year's investigations confirm previous work and indicate better production stability if selection and treatment of planting material are included. When clean cuttings from meristem cultured plants were

Previous Page Blank

selected for satisfactory agronomic characters (size, maturity, 5-6 internodes and unwounded) the highest yield (both in terms of fresh root and starch production) was obtained; when no selection or fungicidal treatments were given to either clean or uncleaned cuttings the yield was the lowest (Figure 1). Results also indicate that the selection of the cuttings is a much more important practice than the fungicidal treatments for yield production (Figure 1).

After cleaning four traditional clones by the meristem culture technique, the height of the plants obtained was greater than that of plants from uncleaned cuttings even when they were not treated with pesticides (both fungicides and insecticide mixtures were applied every 15 days during the growth cycle) to control both diseases and insects (Figure 2). A similar trend was observed in relation to yield (Figure 3 and Table 5), indicating the existence of one or more detrimental production factors in the traditional clones, possibly acquired during the continuous culturing of traditional genotypes from the time they were created. This supports the concept of a continuous decrease in performance of cassava genotypes caused by both biotic and abiotic stresses; by cleaning traditional genotypes and growing them under good conditions their original performance (yield) can be recuperated and yield increases can be obtained.

The problem requiring study is the maintenance of such yields with planting material produced in the field over several generations. Results of three years of continuous planting of the regional clone Secundina and the recently created hybrid CMC 342-170 have indicated that yields of Secundina can be maintained at relatively stable levels if, before planting, cuttings are selected and treated with fungicides. The yield of the hybrid, decreased in the third year (Table 6). It is not clear whether this is due to degeneration of the planting material or to changes in disease or pest pressure or climatic conditions in the last year that highlight a genetic weakness in the hybrid to tolerate stress conditions.

Pathological Problems That Affect the Crop During the Growth Cycle

This year's work builds on the understanding of the numerous pathological problems that affect the crop; the investigation of this topic was initiated early in 1971 and since then a great deal of information has been accumulated on viral, bacterial and fungal causal agents, the diseases they induce, and their different etiological and epidemiological aspects. This year's research has particularly emphasized the viral problems of the crop and the epidemiology of several diseases endemic in four edaphoclimatic locations.

Viral problems

A. This year, a previously unreported virus-like disease was found affecting some traditional clones and progenies from crosses with symptomless parents. This disease is characterized by leaf distortion, vein yellowing and, at times, a mild mosaic (see Table 7). These symptoms disappeared when plants were treated for two weeks at 36-40°C; however, they returned two weeks after plants were incubated at

temperatures below 36°C (Table 8). Hand sections under the light microscope showed crystal inclusions such as those induced by potex-viruses. The disease was 100% transmitted by the use of infected cuttings taken from infected plants. However, its seed-born transmission has not been elucidated conclusively.

B. Latent viruses have been detected on symptomless clones after using Secundina, a highly mosaic-susceptible clone, as scion. Symptoms on Secundina appeared three weeks after grafting as a severe mosaic, leaf distortion, curling, stunting and necrosis. These symptoms are different from those reported for the Caribbean mosaic (Table 7); partial purification showed a polyhedral-shaped virus at very low concentrations. A massive grafting onto more than 150 symptomless clones indicated that more than 40% of these clones are affected; some of those affected appear to have originated in areas where Secundina (the susceptible indicator) was readily infected approximately 60 days after planting this clone on traditional farms. This may indicate and endemic condition of the disease in the areas where resistant, symptomless clones were developed by the farmers. The economic importance of this problem is under investigation in relation to both resistant-symptomless and susceptible clones.

C. The frog skin disease (see Cassava Annual Reports 1981, 1982) incidence was surveyed in the department of Cauca in southern Colombia. The disease was found to affect about 60% of the plantations in the area, inducing losses ranging from 20-80% (based on healthy plants present on each farm).

Randomized plots planted with plants originating from meristem culture (Cassava Annual Report, 1982) and from farms of two native clones, showed losses up to 72% at Quilcase (a disease endemic location) (Table 9). When several genotypes were planted at this location some clones were 100% affected only 6 - 9 months after planting, but others M Col 113 and Quilcase) showed a low percentage of infected plants after two consecutive growth cycles (21 months); the clone M Col 1468 has not been affected even after 24 months of planting (Figure 6). This might indicate the existence of resistance to the disease and/or to the insect vector, since this disease is disseminated by whiteflies.

Grafting Secundina onto diseased stocks of other clones produces severe mosaic and root symptoms on the indicator clone; inoculating Secundina with viruliferous whiteflies in cages results in similar mosaics being readily induced, but mild root symptoms were developed. Nicotiana benthamiana was infected by sap mechanical inoculation; the purified virus was serologically related to the common cassava mosaic, but its host range was different. Thus, it appears that the frog skin a disease is induced by a complex of viral agents.

Healthy planting material of two native clones has been given to the State Secretary of Agriculture in Colombia and to technified cassava growers; training for the selection of cuttings from diseased plantations was given to both extensionists and cassava growers as an attempt to reduce the disease incidence. Presently, there are around 250 ha planted

with healthy cuttings and growers claim an increase in yields (in tons of fresh roots) of around 10 t/ha from previous yields of 1/2 t.

D An elongated virus was purified from plants showing symptoms of the Caribbean mosaic. This virus was also related to the common mosaic, but rub inoculations on Secundina induced different symptoms to those of the original affected plants. This may also suggest that the Caribbean mosaic can be a reaction to a complex viral infection and/or that in the area several viral problems exist endemically.

Disease Complexes at Carimagua

Anthracnose, superelongation disease and cassava bacterial blight are the most important diseases at Carimagua (edaphoclimatic zone II) where they occur at epidemic levels on susceptible clones. Their incidence on each of three resistant, intermediate and susceptible clones (these clones were selected by field evaluation over several growing cycles) was recorded monthly during the rainy season (from April to October) on randomized plots planted every month. Monthly yield (in tons of fresh roots and number of cuttings/plant) 11 months after each planting were also recorded.

Results demonstrate the existence of multiple resistance on cassava and the advantages of this selection system to evaluate such type of resistance (Figure 5). Anthracnose induced the highest rate of severity on the selected resistant clones, but this range was the lowest recorded for all genotypes tested. The disease reaction of the tested clones correlated with yields: resistant clones yielded much more than those with intermediate resistance; susceptible clones were heavily affected by these diseases (Figure 5) and their yields were near zero in all monthly plantings (Figure 6).

This investigation stresses the need for field evaluations to identify genotypes with multiple resistance, which appears to be the most appropriate for the crop yield stability. Planting at the beginning of the rainy season facilities the identification of clones with this type of resistance which should then be reconfirmed during several cycles of evaluation.

Ecosystem Studies

The presence of diseases and insects and their severity during the last five years are recorded in Table 10 for each ecosystem/year of evaluation. Caribia readings were not included for 1983 due to inconvenience in maintaining the trials. Diplodia stem rot, Choanephora leaf blight, root rots, brown leaf spot and mites were the most severe pests (diseases and insects) this year at Media Luna (edaphoclimatic zone I), superelongation disease and mealybugs at Carimagua (edaphoclimatic zone II), mites at CIAT (edaphoclimatic zone III) and Popayan (edaphoclimatic V), and scale insects were also particularly severe at Popayan (Table 10). As reported last year (Cassava Annual Report, 1982), the five cycles of pest evaluation data for the four ecosystems studied, indicate that their incidence and/or population can vary between ecosystems and from one year to another. Yields were particularly low in

Caribia, but in general they were more stable than in previous years, indicating a general balance between the clones still surviving at each location (Table 11).

The correlations of harvest index between CIAT-Media Luna, CIAT-Caribia and Media Luna-Caribia are still very high (Table 12), but great variations during the different growing cycles in each location have been observed among several clones; however, some clones have shown stability. This year, the highest correlation in yield (fresh root and starch content) and harvest index were found between CIAT-Media Luna, CIAT-Caribia and Media Luna-Caribia. As in previous years different disease and pest complexes were found in each location, indicating the location specificity of the biotic stresses on cassava (Table 10).

Pathological Problems Related to Preharvest Root rots

Previous investigations to control root rots have dealt with drainage and planting on ridges, debris elimination and crop rotation (Cassava Annual Report, 1973-1980). This year's work was related to the control of these pathological problems by means of beneficial bacterial inoculations.

Pseudomonas fluorescens and *P. putida* are beneficial bacterial species reported as being highly effective in promoting yields on sugar beets and a few other crops. Their effect on cassava was investigated for the first time this year with very encouraging results. Some 136 isolates of *P. fluorescens* and *P. putida* from different Colombian locations and clones were collected by using the King medium B and ultraviolet light for identification of fluorescent bacterial growth on this medium. Only those isolates of fluorescent pseudomonas able to inhibit *Erwinia carotovora* pv. *carotovora* (a root pathogen of cassava) were used to inoculate cassava plantlets or cuttings to observe their effect on the inoculated plants (Table 13). Four groups of strains were distinguished according to the effect induced on the inoculated cassava plantlets under greenhouse controlled conditions (light and temperature): (a) those that produced a negative effect (loss of vigor and root development in relation to controls); (b) increase of vigor and nutritional appearance; (c) induced swollen root formation; and (d) induced root development and vigor. Strains belonging to group (d) which promoted the root formation were used to inoculate cuttings (deep inoculation) or soils before planting the cuttings on plastic pots. Considerable increase in root formation resulted 2-3 months after planting, but no increase in the above-ground plant parts was recorded (Table 14).

By inoculating six selected strains belonging to the same group (d) differences in root induction were found, indicating a possible type of strain specificity; again no increase in the above-ground part of the inoculated plants was observed (Table 15). After inoculating a root-inducing strain at different bacterial concentrations no differences in the induction of root formation were found in relation to bacterial concentration but the root promotion effect (on a root weight basis) was highly significant compared with the controls. No promotion of the above-ground plant parts was recorded (Table 16). When cuttings were

inoculated at planting and at 15 and 30 days after planting, root weight increased by more than 94%, but the above-ground effect was not recorded (Table 17). These results show that strains of these bacterial species are able to induce an increase in root development. This could possibly be due to the inhibitory effect on the population of microbes capable of hindering the development of the root system of cassava plants. These bacterial species were tested against six known bacterial pathogens of cassava and other crops (*Xanthomonas campestris* pv. *manihotis*, *X. campestris* pv. *cassavae*, *Pseudomonas solanacearum*, *Erwinia carotovora* pv. *carotovora*, *X. oryzae* and the rice bacterial brown blotch pathogen) *in vitro*. A clear inhibitory zone of growth was observed in all cases. Similarly, when storage roots were deep-inoculated with two *P. putida* strains one of the strains considerably reduced the microbial deterioration after 15 days of storage (Table 18). NPK analysis of fully formed leaves of inoculated plants with four different *P. putida* root-promoted strains did not show any increase in these elements. The above results suggest that there is a group of fluorescent pseudomonad strains that induce root development which appears to be associated with the inhibitory effect on the detrimental microorganism population of rhyzospherae; it appears that there is no nutritional effect or that it is very low. Results so far are very encouraging and suggest a very promising possible biological control for the root-rots commonly found in any cassava plantation.

Table 1. Sanitary condition of fruits and botanical seeds collected in five edapho-climatic zones at the end of the dry season from 10-11 month old plants.

Edaphoclimatic zone	% of Fruits		% of Seeds			
	Healthy	Affected [a]	Sinking [b]	Weight (g)	Floating	Weight (g)
CIAT (IV)[d]	27.0[c]	73.0	19.0	0.12	81.0	0.06
Media Luna (I)	27.0	73.0	43.0	0.12	57.0	0.07
Carimagua (II)	85.0	15.0	19.0	0.10	81.0	0.07
Caribia (IV)	21.0	79.0	34.0	0.12	66.0	0.08
Popayan (V)	0.5	99.5	0.0	-	100.0	0.04
Average	32.1	67.9	23.0	0.12	77.0	0.06

[a] The sanitary conditions were determined visually. Affected fruits refer to those with signs of disease infection or insect infestations. Most of the problems were due to fruit flies, mealybugs, thrips, Colletotrichum spp., Fusarium spp. and Cladosporium spp.

[b] Density selection of seeds in water.

[c] Data taken from 350 or more fruits or seeds/edaphoclimatic zone.

[d] Edapho-climatic zone according to CIAT identification (Annual Report, 1981).

Table 2. Fungal infections of botanical seeds collected in four edaphoclimatic zones.

Edaphoclimatic zone	Fungal species and % [a] of seeds affected by each fungal species							
	Penicillium spp.	Neurospora sp.	Fusarium spp.	Cladosporium sp.	Aspergillus spp.	Rhizopus sp.	Colletotrichum spp.	Diplodia manihotis
CIAT (IV)	9	4	7	7	5	3	1	1
Media Luna (I)	19	2	1	0	1	2	0	78
Carimagua (II)	40	19	18	3	9	1	1	1
Caribia (IV)	27	14	5	0	1	6	0	53

[a] Data taken from 50 seeds from each edaphoclimatic zone. Seeds were planted on PDA (Potato, Dextrose, Agar) medium. Fungal species were isolated six days after incubation at 28°C. *Xanthomonas campestris* pv. *manihotis* (causal agent of CBB) was isolated from seed collected in Carimagua, Media Luna and Caribia, where the CBB is endemic.

Table 3. Fungal species isolated from botanical seeds collected at CIAT during different dry and wet periods.

Date of collection	Fungal species isolated and % of affected seed/fungal species							
	Penicillium spp.	Neurospora sp.	Fusarium spp.	Rhizopus sp.	Aspergillus spp.	Cladosporium sp.	Diplodia manihotis	Colletotrichum spp.
January/82 (dry)	0 [a]	0	50	0	0	0	0	0
February/82 (dry)	3	0	11	5	0	33	0	1
September/82 (end of drought)	3	0	13	14	0	0	0	3
October/82 (wet)	5	18	0	15	4	0	0	0
November/82 (wet)	4	3	10	0	3	3	0	3
March/82 (end of drought)	0	0	7	0	7	0	4	0

[a] Data from more than 80 seeds per sample. Seeds were planted on a PDA (Potato-Dextrose-Agar) medium and incubated at 25°C. Data taken after six days of incubation.

Table 4. Fungal species isolated from botanical seeds of four clones after selection/treatment.

Treatments	Penicillium spp.				Neurospora spp				Fusarium spp.				Diplodia manihotis				Colletotrichum spp.				Aspergillus sp			
	a[1]	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
1[2]	0[3]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0
3	0	0	0	0	0	0	4	0	68	0	40	0	0	0	0	0	60	0	12	0	0	0	4	0
4	0	4	0	0	0	0	8	0	76	12	56	4	0	0	4	0	65	0	18	0	0	4	7	8

[1] Clone: a = CM 340-30; b = SG 715; c = SG 821; d = SG 828

[2] Treatments: 1 = 120 seconds of microwave exposure (78°C) followed by an arasan dust; 2 = dry heat (60°C) for 14 days followed by an arasan dust; 3 = selected seeds by the water-density system; 4 = unselected-untreated seeds. Seeds were collected at CIAT during the dry season.

[3] Data taken from 30 seeds per treatment/clone.

Table 5. Average yield (t/ha)[a] of fresh roots and starch in relation to source of planting material and pesticide applications to control both disease and insect damage during the growth cycles. Summarized data from four different clones planted at CIAT-Palmira.

Source of cuttings and/or pesticide treatments	Yield (t/ha)		Yield reduction (fresh roots) %
	Fresh roots	Starch	
1. From meristems and treated with pesticides	33.6 a	9.2 a	0
2. From farms and treated with pesticides	27.7 b	8.3 ab	16.6
3. From meristems, but not treated	24.6 b	6.8 b	26.8
4. From farms, but not treated	18.4 c	5.3 c	45.2

[a] Data taken from four replicates of four different clones. Each plot had 30 plants, but borders were eliminated.

Table 6. Stability of the native clone Secundina and the clone CM 342-170 during three continuous cycles at Media Luna. Secundina was cleaned by meristem culture. Each year for three years meristem-cultured planting material was introduced with planting material then being taken from these plants for the successive cycles. Thus, cycles I to III were harvested simultaneously.

Clone	Cycle no.	Fresh root	Starch	Number of cuttings
Secundina	I	25.1 a[a]	7.1 a	10 a
	II	23.0 a	6.8 a	10 a
	III	22.0 a	5.6 a	9 a
	CK[b]	8.9 b	2.1 b	3 b
	C.V.	17.9	20.4	34.9
CM 342-170	I	34.8 a	7.9 a	14 a
	II	36.2 a	8.4 a	10 ab
	III	15.1 b	3.1 b	6 b
	C.V.	23.7	23.5	22.7

[a] Data taken from five replicates with 36 plants each. Cuttings were selected and treated with fungicide/insecticide (bavistin-orthocide-malathion) before planting each cycle.

[b] CK refers to plots planted with planting material collected from traditional farms. The planting material was unselected and untreated, simulating the farmer's planting system.

Table 7. Viral and mycoplasmal diseases so far encountered by CIAT.

Virus code name	Symptoms on cassava	Hosts	Transmission	Particle shape	Antisera
UPALI	So far back transmission is negative; original symptoms are mild mosaic.	*Chenopodium amaranticolor*, *C. quinoa*, *C. album*, *R. communis* and *C. globosa*	Mechanical, unknown vectors	Flexous rods	Available at CIAT
BPL	Mosaic; severity relative to temperature.	*C. quinoa*, *C. amaranticolor*, *C. album*, *E. prunifolia*	Mechanical unknown vector	Flexous rods	Available at CIAT
NIEVES	Mild mosaic	*C. amaranticolor*, *C. quinoa*, N. *benthamiana*, *R. communis*	Mechanical unknown vector	Flexous rods	Available at CIAT
WF* **	Very severe mosaic and leaf distortion. Roots showing frog skin symptoms.	*Nicotiana benthamiana*, *Chenopodium amaranticolor*	Mechanical, white flies	**	--
Frog Skin*	On roots	--	White flies, grafting	Unknown	--
Latent	Usually no symptoms except on certain clones such as Secundina which shows severe mosaic, leaf distortion, curling, stunting and necrosis.	So far negative	Grafting, unknown vectors	Spherical particles	--
Shoe Stringing (E.T.)	Severe leaf narrowing, leaf distortion, vein yellowing; at times mild mosaic	*N. benthamiana*	Mechanical unknown vector	--	--
Antholysis	Virescence, phyllody	--	Grafting	MLO	--

* Certain results indicate that these two isolates are the same.

** The virus transmitted to *N. benthamiana* proved to contain more than one virus. A Carlavirus (virus-WF) separated from the mixture is serologically related to viruses, Upali, BPL, Nieves but differ in their host range.

Table 8. Effect of temperature on the expression of symptoms of two viral and one mycoplasmal disease of cassava under controlled environmental conditions.

Disease	Temperature range and severity of symptoms			
	20-25°C [a]	26-30°C	31-35°C	36-40°C
Caribbean mosaic (virus)	+++ [b]	+++	-	-
Shoe stringing (virus)	+++++	+++++	++++	-
Antholysis (mycoplasma)	++++	-	-	-

[a] Night/day temperature ranges; incubation in growth chambers at 80% relative humidity and 5000-6000 lux for 12 hr photoperiod.

[b] Symptom expression: - = absent; + = light; ++ = mild; +++ = moderate; ++++ = severe; +++++ = very severe.

Table 9. Yield (t/ha of fresh roots and starch) of two native clones planted in Quilcase (a frog skin endemic area) after cleaning by the meristem culture technique. Cleaned parent material was disease-tested (electrophoretic technique, CIAT, 1981) before production of large number of plants for planting material.

Clone	Cutting source	% of affected plants at harvest	Yield (t/ha)		Reduction of fresh root yield (%)
			Fresh roots	Starch	
Quilcase	From meristem culture first cycle	0.0 [a]	17.4	5.3	-
	From meristem culture second cycle	10.4	12.9	3.9	25.9
	From farm plantations	100.0	7.5	2.1	57.9
M Col 113	From meristem culture first cycle	6.2	16.5	4.3	-
	From meristem culture second cycle	28.5	7.2	1.9	56.4
	From farm plantations	100.0	4.6	1.2	72.1

[a] Data taken from four replicates with 30 plants each; with respect to data collection for yield, border plants were eliminated.

TABLE 10 CASSAVA PESTS AND DISEASES IDENTIFIED AND EVALUATED IN FIVE DIFFERENT ECOSYSTEMS IN COLOMBIA DURING 1979 (I CYCLE), 1980 (II CYCLE), 1981 (III CYCLE), 1982 (IV CYCLE), AND 1983 (V CYCLE).

	LOCATION																									
	CARIBIA Año 19..					MEDIA LUNA Año 19..					CARIMAGUA Año 19..					CIAT Año 19..					POPAYAN Año 19..				
BNPFs	79	80	81	82	83	79	80	81	82	83	79	80	81	82	83	79	80	81	82	83	79	80	81	82	83
DISEASES																									
BACTERIAL BLIGHT	++ [A]	++	++	++		+	++	+	++	++	+++	+++	++	++	++	-	-	-	-	-	-	-	-	-	-
SUPERELONGATION	+	+	-	-		+	+++	+	+	-	+++	+++	+++	++	+++	-	-	-	-	-	-	-	-	-	-
CONCENTRIC RING-LEAF SPOT	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	++	++	+	++
ANTHRACNOSE	++	+++	+++	++		+	++	+	+	++	+++	+++	+++	++	++	+++	+	+	+	+	+++	++	++	+	++
BROWN LEAF SPOT	++	+++	+++	++		+++	+++	++	++	+++	++	+	++	+	+	+	++	++	++	++	-	-	++	-	+
BROWN LEAF BLIGHT	++	++	++	++		+	++	+	+	+	++	-	+	-	-	+	++	++	++	++	-	-	-	-	-
WHITE LEAF SPOT	++	+++	+++	+++		++	++	++	+	+++	-	-	+	-	+	-	-	-	-	+	-	+	+	+	+
BACTERIAL STEM ROT	+	+	+	+		+	+	+	+	+	+	+	+	-	+	++	++	+	-	+	-	-	-	-	+
CASSAVA ASH	-	+	+	-		-	++	+	-	-	-	-	-	-	-	+	+++	++	++	++	++	++	++	++	+
CASSAVA COMMON MOSAIC	+	++	++	+		+	++	+++	++	+++	-	-	-	-	-	++	++	+++	+	++	+++	+++	++	+	+
FROG SKIN DISEASE	-	+	+++	+++			+	-	-	-	-	-	-	-	-	-	++	+++	+++	+++	-	-	-	-	-
SMALLPOX	-	+	++	++		-	++	+	+++	++	-	-	-	-	+	-	+	++	++	++	-	-	-	-	+
ROOT ROTS	-	+	++	+++		-	+	+	+++	+++	-	+	+	+	+	-	++	+	++	++	-	-	-	+	+
CHOANEPHORA LEAF BLIGHT	-	-	+++	+++		-	-	++	++	+++	-	-	+++	+	+	-	-	-	-	-	-	-	-	-	-
DIPLODIA	-	-	-	+		-	-	-	+++	+++	-	-	-	+	++	-	-	-	+	++	-	-	-	-	-
ANTHOLYSIS									++	-				-	-				+	++	-	-	-	-	-
INSECTS																									
HORNWORM	+	+	+	-		+	+	+	+	-	+++	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WHITEFLIES	++	+	+	++		++	+	++	+++	++	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
THRIPS	++	++	+	++		+	+	+	++	++	++	++	+	+	+	+++	+++	+++	+++	++	+	+	+	-	-
LACEBUGS	+	++	+	+		+	+	+	+	+	++	+++	++	++	++	++	++	+	+	+	+	+	-	-	-
SHOOT FLIES	+	+	++	+		+	-	-	-	-	+	+	+	+	+	++	+	+	+	+	-	-	-	-	++
FRUITFLIES	+	+	+	+		-	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-	-	+++
LEAF BEATLES	-	-	-	-		-	-	-	-		-	-	-	-		++	++	++	++	++	-	-	-	-	+
GALLMIDGES	+	+	+	+		+	+	+	+	+	++	+++	++	++	++	+	-	-	-	+	-	-	-	-	-
TERMITES	+	+	-	-		++	++	+	++	++	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
STEMBORERS	-	-	-	-		-	-	-	-	-	++	++	++	++	+++	-	-	-	-	-	-	-	-	-	-
LEAF CUTTER ANTS	-	-	+	+		-	-	+	+	+	++	-	++	++	++	-	-	-	-	-	-	-	-	-	-
SCALES	-	-	-	-		+	-	-	+	+	+	+	+	+	+	-	-	-	-	-	+++	+++	++	++	+++
MEALYBUGS	-	-	-	-		-	-	-	-	-	-	-		-	+++	-	-	+	++	++	-	-	-	-	-
MITES																									
Mononychellus sp.	+	+	+	+		++	++	+	+++	++	+	+	+	+	+	++	+++	++	++	+++	+	+	+	+	+
Tetranychus sp.	+	+	-	-		+	+	-	++	++	+	+	-	+	+	+	++	++	++	+++	-	-	-	-	-
Oligonychus sp.	+	++	++	++		+	+	++	+++	+++	++	-	+	++	++	++	+++	+++	+++	+++	++	+++	+++	+++	+++

[A] +++ = SEVERE DAMAGE; ++ = MODERATE DAMAGE; + = LIGHT DAMAGE; - = NOT OBSERVED.

TABLE 11. MAXIMUM(MX), MINIMUM(MN), AVERAGE($\bar{X}$) VALUES FOR YIELD(T/HA), STARCH(T/HA), STAKE PRODUCTION (NUMBER OF CUTTINGS/PLANT), DETERIORATION(%), HARVEST INDEX AND HCN CONTENT OBTAINED FROM ALL 31 CULTIVARS IN CIAT, MEDIA LUNA, CARIMAGUA, CARIBIA AND POPAYAN ECOSYSTEMS (FIRST, SECOND THIRD AND FOURTH CYCLES).

		YIELD (T/HA)			STARCH (T/HA)			STAKE PROD./ PLANT			HARVEST INDEX 1/			CYANIDE CONTENT 2/			DETERIORATION (%) 3/		
ECOSYSTEM	CYCLE	MX 4/	MN	$\bar{X}$	MX	MN	$\bar{X}$	MX	MN	$\bar{X}$	MX	MN	$\bar{X}$	MX	MN	$\bar{X}$	MX	MN	$\bar{X}$
CIAT	I 5/	74.1	0.0	24.4	24.7	0.00	7.7	18.0	0.6	10.0	0.65	0.00	0.41	5.0	1.0	2.6	90.0	1.6	26.5
	II	55.4	1.6	20.8	17.1	0.34	6.9	34.8	7.6	17.5	0.71	0.05	0.46	5.0	2.0	3.2	49.5	1.3	14.2
	III	36.4	1.0	19.8	11.4	0.00	6.0	23.3	7.9	14.9	0.74	0.11	0.51	5.0	2.0	3.3	67.4	1.2	16.3
	IV	42.7	0.4	20.2	12.8	0.86	6.6	29.8	5.9	15.2	0.69	0.02	0.45	-	-	-	22.9	0.0	5.4
MEDIA LUNA	I	19.0	0.4	9.5	3.7	0.06	1.9	11.0	1.0	5.0	0.65	0.13	0.44	5.0	1.0	2.9	7.6	0.0	1.4
	II	70.1	0.0	27.0	15.4	0.00	7.1	16.5	0.0	7.1	0.80	0.00	0.56	5.0	2.3	3.7	16.0	0.3	4.0
	III	37.8	0.0	17.0	9.8	0.00	4.1	22.4	0.0	10.1	0.79	0.27	0.59	4.7	2.3	3.2	10.8	0.0	2.5
	IV	33.1	0.0	15.4	8.6	0.00	3.5	22.5	0.0	10.7	0.71	0.11	0.55	-	-	-	3.5	0.0	0.8
CARIMAGUA	I	10.7	0.5	2.5	2.8	0.01	0.7	5.0	0.0	1.0	0.66	0.02	0.39	5.0	2.0	3.3	26.9	0.0	1.4
	II	11.6	0.0	1.9	2.9	0.00	0.6	10.5	0.0	0.7	0.61	0.00	0.15	4.3	2.7	3.3	0.1	0.0	0.0
	III	11.6	0.0	1.4	2.8	0.00	0.3	6.6	0.0	0.9	0.59	0.28	0.47	5.0	2.3	3.4	3.6	0.0	1.2
	IV	10.1	0.0	1.2	2.3	0.00	0.3	6.8	0.0	1.1	0.73	0.36	0.49	-	-	-	1.8	0.0	0.6
CARIBIA	I	55.9	2.4	23.2	16.3	0.33	6.4	16.0	2.0	8.2	0.61	0.12	0.40	5.0	1.0	3.0	28.1	0.0	3.6
	II	86.0	5.6	30.6	24.0	1.30	8.0	20.6	1.6	8.7	0.90	0.27	0.66	5.0	2.6	3.9	21.4	0.5	5.1
	III	46.6	0.6	22.5	12.0	0.10	5.7	18.6	1.2	11.7	0.74	0.07	0.55	5.0	2.0	3.3	10.7	0.0	1.8
	IV	32.4	0.3	17.8	8.5	0.07	4.4	26.3	0.0	16.1	0.79	0.03	0.59	-	-	-	18.8	0.1	5.9
POPAYAN	I	21.3	0.2	4.9	6.9	0.04	1.6	8.0	0.0	2.3	0.66	0.10	0.36	5.0	1.0	2.7	82.6	2.3	27.1
	II	26.4	0.0	5.9	8.8	0.00	2.0	16.9	0.0	5.3	0.82	0.00	0.47	5.0	1.3	3.0	71.8	7.0	42.0
	III	16.9	0.0	3.2	5.3	0.17	1.2	12.2	0.6	3.5	0.63	0.12	0.42	5.0	2.0	3.6	91.1	8.6	39.2

1/ HARVEST INDEX (ROOT FRESH WEIGHT/ROOT FRESH WEIGHT + FOLIAGE WEIGHT x 100)
2/ PICRATE PAPER METHOD: 5=HIGH AND 0=LOW HCN CONTENT
3/ 100% TOTAL DETERIORATION: 0%=ZERO DETERIORATION 3 DAYS AFTER HARVEST
4/ MX=MAXIMUM; MN=MINIMUM; $\bar{X}$=AVERAGE
5/ I=(1979-80); II=(1980-81); III (1981-82); IV=(1982-83)

TABLE 12 RELATIONSHIPS BETWEEN ECOSYSTEMS AS REGARDS YIELD, STARCH CONTENT (%), NUMBER OF STAKES, DETERIORATION (%), HCN CONTENT, HARVEST INDEX AND GENERAL EVALUATION ARE SHOWN BY THE CORRELATION COEFFIENT (R) FROM THE 31 CULTIVARS GROWN IN EACH ECOSYSTEM (FIRST, SECOND, THIRD AND FOURTH CYCLES).

ECOSYSTEMS	CYCLE	YIELD (TONS/HA)	STARCH CONTENT (%)	NUMBER OF STAKES	DETERIORATION (%)	HCN CONTENT	HARVEST INDEX
CIAT-POPAYAN	I 1/	-0.116 2/	0.019	0.026	0.129	0.354	-0.052
	II	0.035	-0.013	0.173	-0.264	0.565***	0.189
	III	-0.194	-0.305	0.036	0.484	0.368	0.283
CARIMAGUA-POPAYAN	I	-0.152	-0.304	-0.038	-0.215	0.488*	-0.077
	II	-0.041	0.078	0.105	0.067	0.233	0.201
	III	-0.154	-0.157	-0.003	0.586	0.616	-0.468
MEDIA LUNA-POPAYAN	I	-0.092	0.163	-0.084	0.130	0.451*	0.301
	II	-0.091	-0.196	0.015	0.187	0.409	0.234
	III	-0.311	-0.353*	-0.286	-0.249	0.552**	0.435*
CARIBIA-POPAYAN	I	-0.581**	-0.062	-0.325	-0.022	0.318	-0.342
	II	-0.435**	-0.421*	-0.549***	0.519**	0.327	0.228
	III	0.443*	-0.480**	-0.526**	-0.247	0.466*	0.048
CIAT-CARIMAGUA	I	0.273	0.415*	-0.101	0.359	0.567**	0.603***
	II	-0.190	-0.241	-0.160	-0.049	0.408*	0.219
	III	-0.135	-0.873**	0.087	-0.296	0.741*	-0.123
	IV	0.145	-0.018	-0.014	-0.522	-	-0.213
CIAT-MEDIA LUNA	I	0.540**	0.294	-0.299	0.209	0.224	0.801***
	II	0.563***	0.552***	0.403*	0.475**	0.539***	0.806***
	III	0.613***	0.610***	0.474**	0.584**	0.427*	0.773***
	IV	0.676***	0.626***	0.310	0.602**	-	0.841***
CIAT-CARIBIA	I	0.760***	0.300	0.430*	0.115	0.374*	0.649***
	II	0.265	0.266	-0.040	0.116	0.356*	0.801***
	III	0.398*	0.490**	0.077	0.583**	0.644***	0.614***
	IV	0.545***	0.493**	0.136	0.369	-	0.616***
CARIMAGUA-MEDIA LUNA	I	0.664***	0.591**	0.446**	0.552**	0.389*	0.536**
	II	0.366*	0.309	0.447*	-0.017	0.305	0.255
	III	0.283	0.151	0.430*	0.559	0.837**	-0.349
	IV	0.342*	0.263	0.535**	0.039	-	0.202
CARIMAGUA-CARIBIA	I	0.483**	0.472*	-0.218	0.461*	0.214	0.522**
	II	0.309	0.224	0.333	-0.239	0.248	0.171
	III	0.466**	0.377	0.404*	-0.300	0.865**	0.252
	IV	0.188	0.212	0.463**	0.835**	-	0.033
MEDIA LUNA-CARIBIA	I	0.661**	0.535**	0.235	0.416*	0.567**	0.622***
	II	0.573***	0.593***	0.301	0.346	0.512**	0.739***
	III	0.630***	0.621***	0.460**	0.568**	0.646***	0.699***
	IV	0.574***	0.617***	0.401*	0.315	-	0.616**

*=SIGNIFICANT AT 5% LEVEL; **=SIGNIFICANT AT 1% LEVEL; ***=SIGNIFICANT AT 0.1% LEVEL.
1/= CYCLE I (1979-1980); II=CYCLE II(1980-1981); III=CYCLE III(1981-1982);IV=CYCLE IV (1982-1983).
2/= RESULTS OF YIELDS, STARCH CONTENT AND NUMBER OF STAKES ARE FOR THE 31 CLONES INITIALLY PLANTED; THE OTHER PARAMETERS ARE ONLY FOR CLONES SURVIVING AT EACH ECOSYSTEM.

Table 13. Source, number of isolates collected and number of isolates of *Pseudomonas fluorescens* which inhibit *in vitro* *Erwinia carotovora* pv. *carotovora*.

Source	No. isolates collected	No. isolates inhibiting *Erwinia carotovora* pv. *carotovora*	No. of isolates selected
CIAT	33	16	44 [a]
Popayan	18	5	61 [a]
Quilcase	35	3	64[a] 71[a]
Carimagua	25	6	87
Caicedonia	13	8	56
Mondomo	12	3	

[a] Isolates with an inhibiting effect and induced greater root growth on plants of the clone CM 523-7 when inoculated for 15 minutes in bacterial suspensions of O.D. = 0.5.

Table 14. Weight of the roots and aerial part at 2-3 months after a single inoculation of plants of the clone CM 523-7 with the isolate No. 44 of *Pseudomonas putida*. Inoculation of the cuttings was done by immersion of the cutting material or by soil inoculation (10 ml of the inoculum/plant). (A bacterial suspension of 10^9 cells/ml, approximately, was used.) Cuttings of the same size, weight and thickness were used for all treatments.

Inoculation system	Evaluation period (months)			
	Root wt (g)[a]		Wt of aerial part[a]	
	At 2 months	At 3 months	At 2 months	At 3 months
Of stakes	5.84 b* (8.2)[c]	8.48 a (11.6)[c]	8.73 a	10.41 a
Soil[b]	8.49 a (57.3)	9.37 a (23.3)	9.20 a	9.24 ab
Control	5.40 b	7.60 a	9.28 a	7.38 b

[a] Data represent an average of 10 plants/inoculation system.

[b] The soil inoculation was done 15 days after planting the cuttings; a bacterial suspension was used of equal concentration as the cutting inoculum.

[c] Increase in the percentage with respect to the control.

* Figures followed by the same letter(s) do not differ significantly according to the Duncan Multiple Range Test.

Table 15. Reaction of the clone M Ven 218 to inoculation with six strains of flourescent pseudomonads three months after inoculation. The inoculation was done by first immersing the cutting in the inoculum (O.D. = 0.5) for 15 minutes at planting, then applying 20 ml of inoculum at 15 and 30 days after planting.

Isolation	Root	Avg. wt. of aerial part (g)
64	13.46 a[a*] (63.3)[b]	27.29 abc
44	10.91 bc (32.4)	26.46 bcd
71	10.00 dc (21.3)	28.09 ab
61	9.18 cdf (114)	25.10 bcd
56	9.48 cdf (15.1)	24.02 cde
87	12.42 ab (50.7)	22.80 def
0	8.24 efg	30.60 a

[a] Data correspond to an average of 10 plants/cutting inoculated.

[b] Percentage increase with respect to the control.

[*] Figures followed by the same letter(s) were not statistically different at 0.05 level of the Duncan Multiple Range Test.

Table 16. Weight of the root system and weight of the aerial part of the plants of clone CM 523-7 inoculated with the strain No. 44 *Pseudomonas putida* at different bacterial concentrations/ml.

Inoculum concentration[a]	Root wt. (g)	Wt. of aerial part (g)
O.D. = 0.1	6.28 a[b*] (46.4)[c]	12.20 a
O.D. = 0.2	6.05 a (41.1)	10.65 a
O.D. = 0.4	6.36 a (48.2)	11.90 a
O.D. = 0.5	6.38 a (48.8)	12.50 a
O.D. = 0.7	6.45 a (50.3)	11.62 a
O.D. = 0.0 (control)	4.29 b	9.84 a

[a] Cuttings were inoculated before planting by immersion in the inoculum 15 minutes. The concentration was measured according to optical density (O.D.) in spectronic 20.

[b] The data correspond to the average of 10 inoculated stakes.

[c] Percentage increase with respect to the control.

[*] Figures followed by the same letter(s) are not significantly different at the 0.05 level of the Duncan Multiple Range Test.

Table 17. Root weight, weight of the aerial part and total weight of the plants from clone CM 523-7 inoculated with the isolate No. 44. *Pseudomonas putida* (O.D. = 0.5) two months after inoculation. Inoculation was done by immersion of the stakes in the inoculum for 15 minutes before planting and pouring the inoculum over the soil around the stakes at different periods.

Treatments (inoculations)	Root wt. (g)	Wt. of aerial part (g)
At planting and at 15 and 30 days	9.27 a[a*] (94.7)[b]	12.27 a
At planting and at 15 days	7.06 ab (48.4)	12.64 a
At planting	6.14 b (28.9)	12.58 a
Control	4.76 c	10.74 ab

[a] The data correspond to averages of 10 plants/treatment.

[b] Percentage increase with respect to the control.

[*] Figures followed by the same letter(s) are not significantly different according to the Duncan Multiple Range Test.

Table 18. Deterioration of cassava roots of the clone CMC 40 at 14 months after 8 and 15 days storage in polyethylene bags. Before storage the roots were submerged in bacterial suspensions (O.D. = 0.5) of two strains of *Pseudomonas putida* for 15 minutes.

Strain no.	% deterioration		Superficial growth of fungi [a]	
	At 8 days	At 15 days	At 8 days	At 15 days
61	6.8[b]	49.0	20.8	65.0
64	6.9	21.3	14.4	28.1
Control	13.7	55.35	24.4	68.4

[a] Average evaluation according to the percentage of the surface visually covered by fungal mycelium.

[b] Percentages of the average evaluations on a scale of 0-5: 0 = no deterioration of the cortex; 5 = cortex deteriorated. The results represent the evaluation of 5 kg of roots/bag, and five bags/treatment were used.

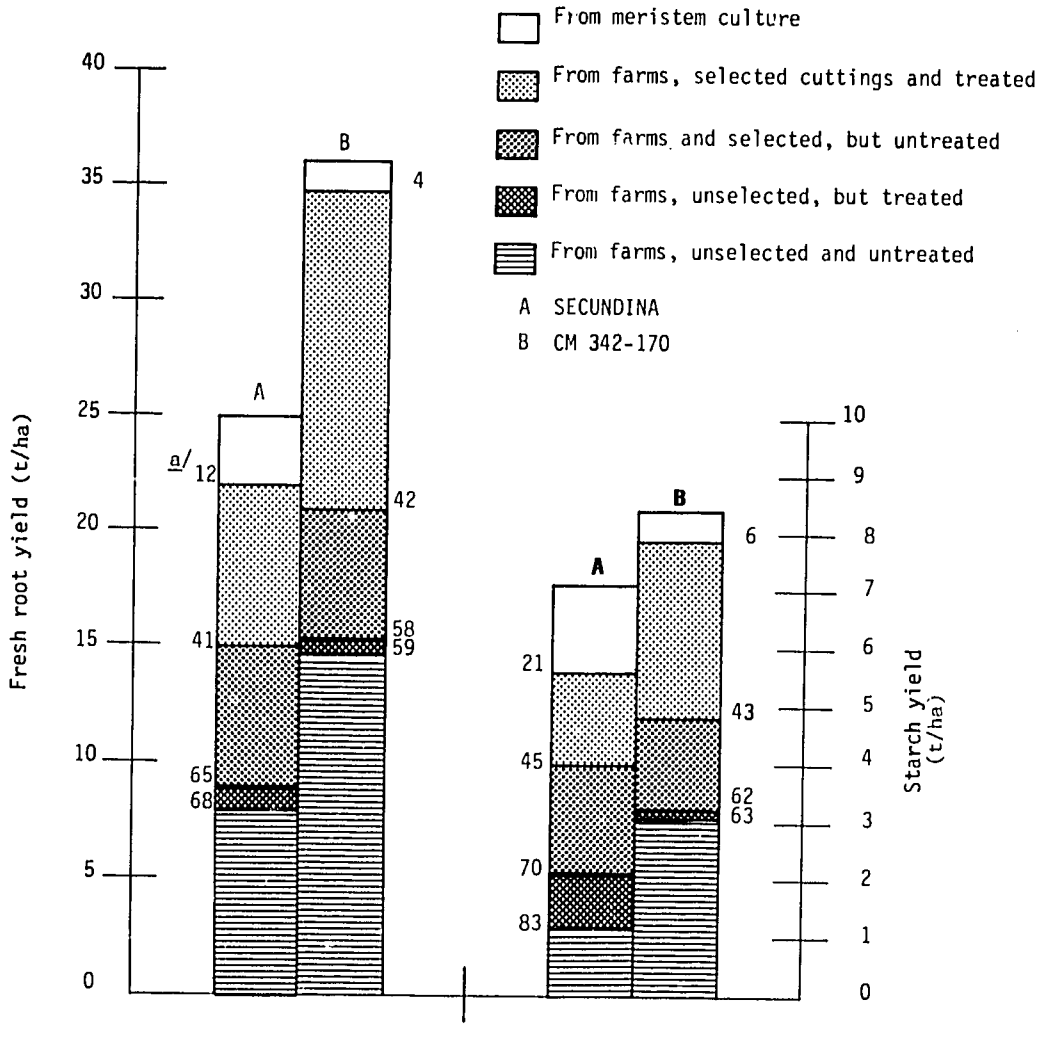


Figure 1. Effect of pesticide treatments on cleaned (cuttings from meristem cultured plants) and uncleaned (cuttings from farmer's fields) as the source of cuttings.
a/ Numbers refer to % of maximun yield for each clone.

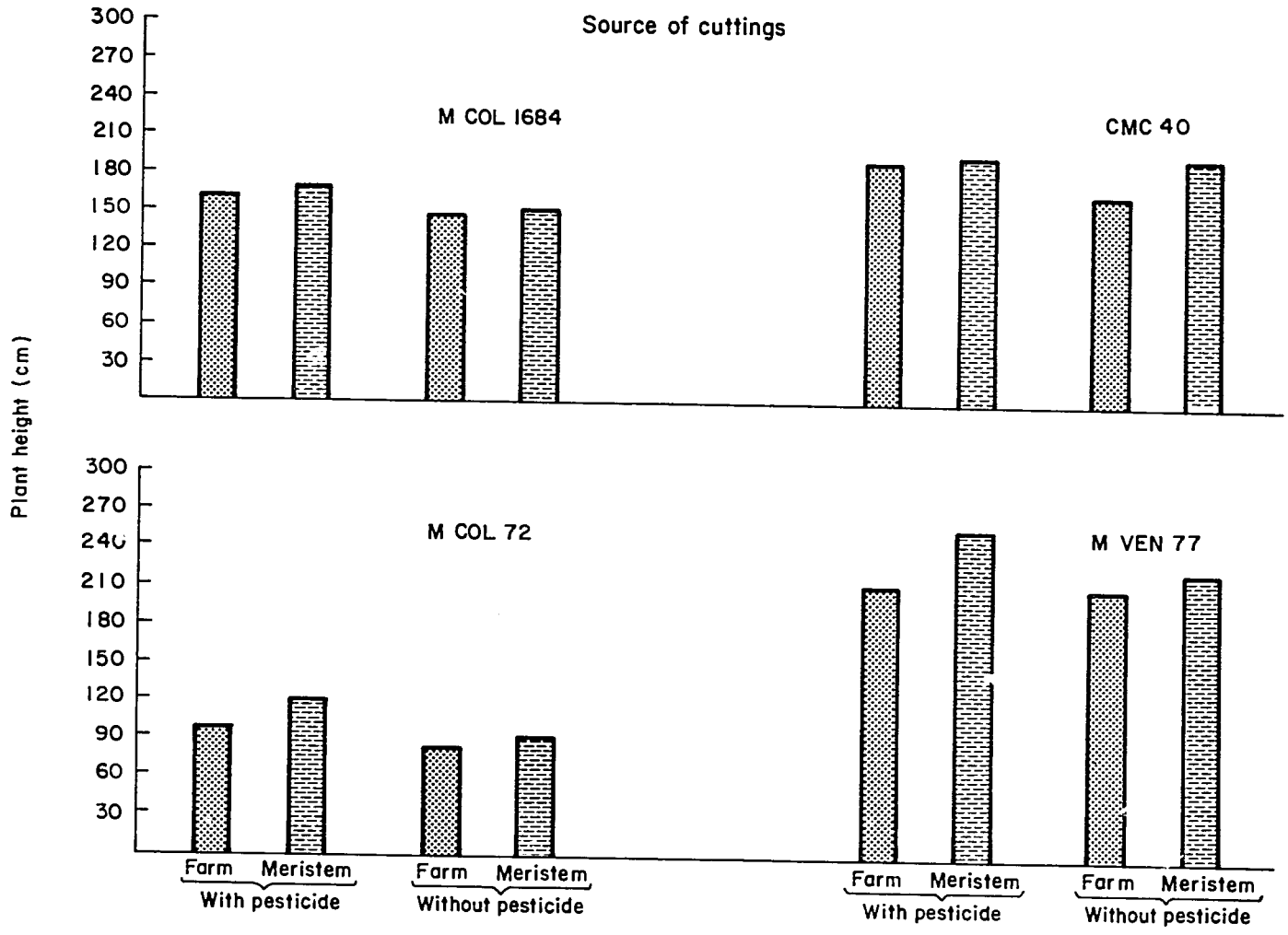


Figure 2. Plant height (cm) of four different clones from two sources grown at CIAT- Palmira in relation to pesticide applications to control both disease and insect damage during the growth cycle. Readings were taken six months after planting.

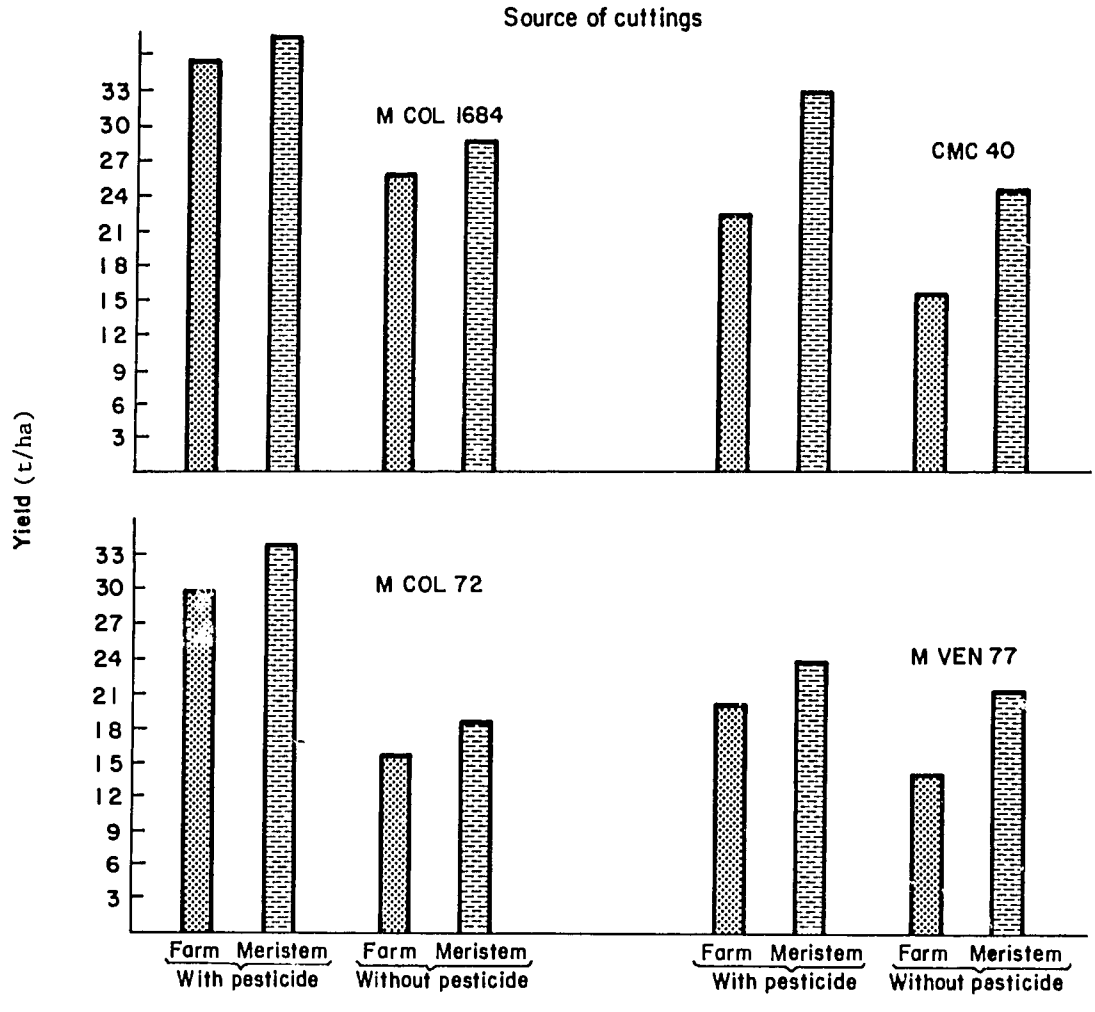


Figure 3. Yield (t/ha) of four different clones from two sources grown at CIAT- Palmira in relation to pesticide applications to control both disease and insect damage during the growth cycle. Readings were taken 11 months after planting.

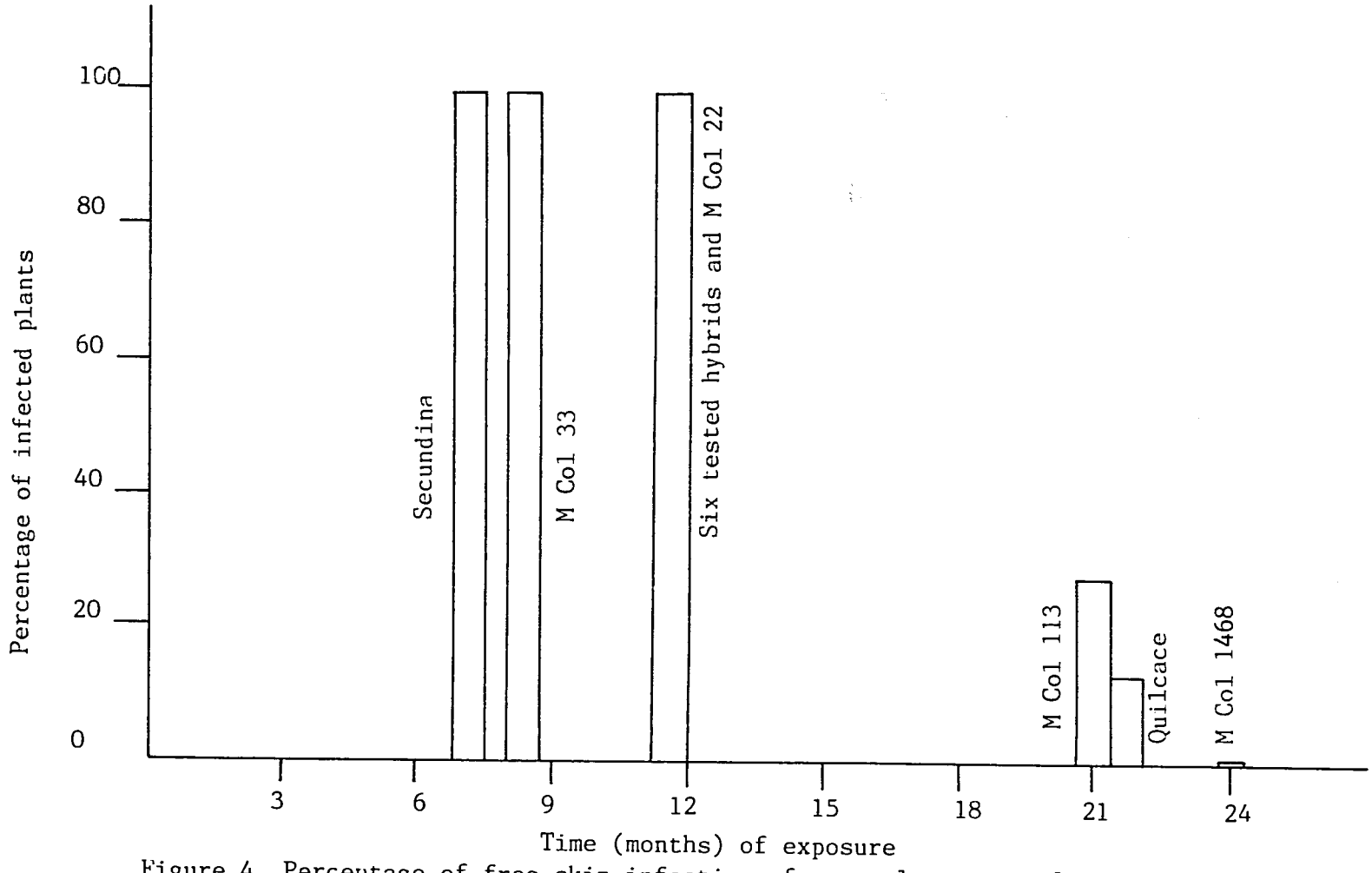


Figure 4. Percentage of frog skin infection of several cassava clones in Quilcace, a frog skin endemic area, after two years (two growing cycles) of disease exposure.

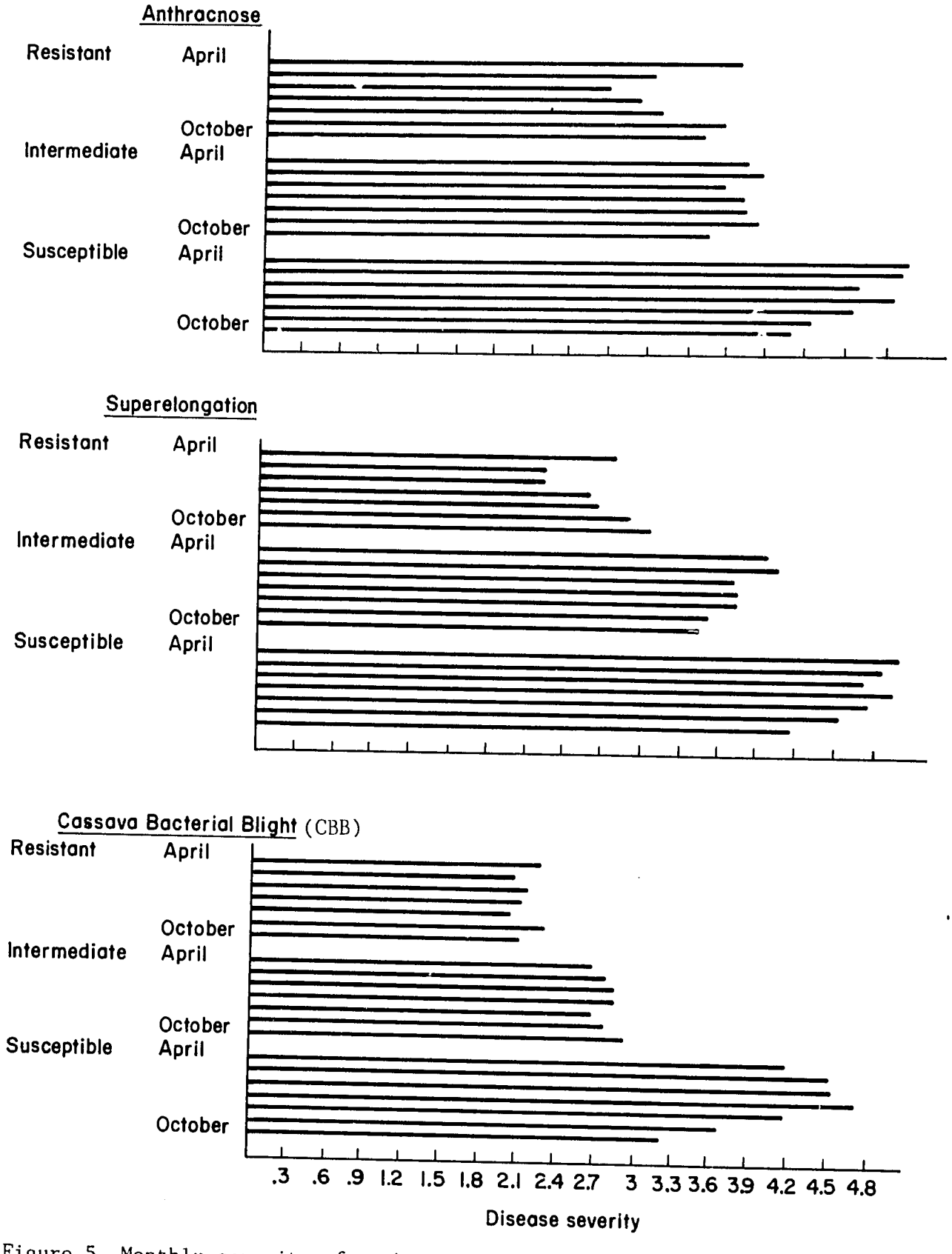


Figure 5. Monthly severity of anthracnose, superelongation and CBB on resistant, intermediate and susceptible clones in Carimagua (Edaphoclimatic zone II). The same clones were used for all three disease evaluations.

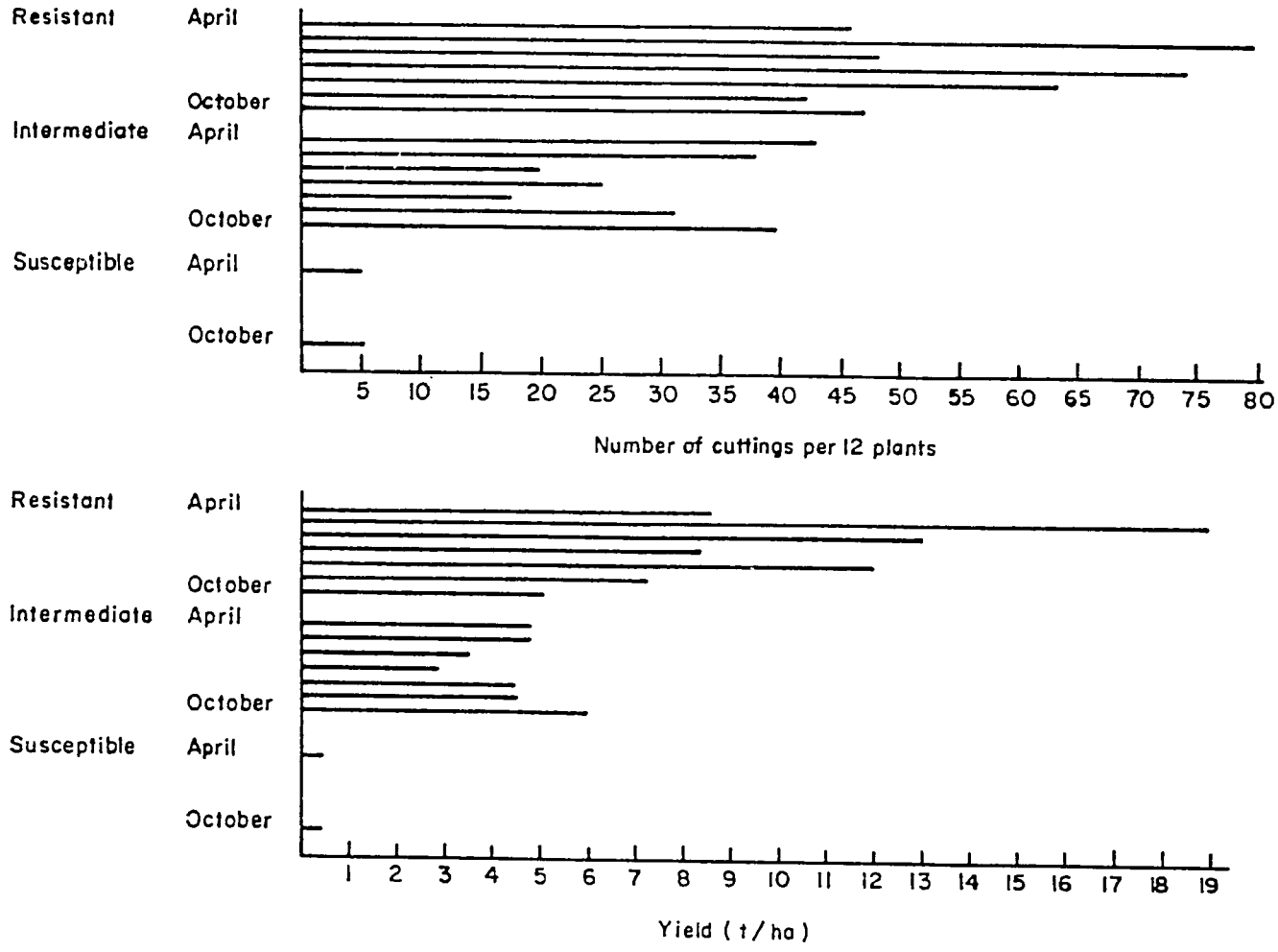


Figure 6. Number of cuttings and yield (t/ha) produced from 12 month old plants of resistant, intermediate and susceptible clones harvested monthly over a seven month period as affected by anthracnose , superelongation and CBB at Carimagua (Edaphaclimatic Zone II).

Germplasm and Breeding

Summary

During 1983 the two breeding sections (Germplasm Development and Varietal Improvement) were consolidated into a single unit, with one breeder moving to a regional coordination post for cassava breeding in Asia. Selection was further decentralized, with edapho-climatic zones serving as the basis for dividing breeding populations. Consequently, the numbers of genotypes evaluated increased in each zone by moving materials out of CIAT-Palmira headquarters at an earlier selection stage. First priority for selection shifted from edaphoclimatic (ECZ) zone 2 (Carimagua) to zone 1 (North Coast) which is more in line with the global importance of different cassava-growing areas. Breeding emphasis continues to be on adaptation to moderate and high stress conditions, where cassava has an advantage over many other crops.

Advances were made for all selection sites in yield, root quality, and pest and disease resistance. The germplasm base has improved for all zones in which selection has been done to the stage where large numbers of progeny can be produced for selection of superior clones in most parts of Asia and Latin America. Emphasis is given to defining appropriate parents for individual national programs, and on developing a systematic interchange of data on progeny performance. A list of elite clones (germplasm accessions and hybrids) has been compiled, along with a complete description of morphological, agronomic and quality traits. These are available as *in vitro* cultures to all interested persons.

Germplasm Collection, Conservation and Evaluation

The basis of a successful breeding program is a broad-based, well-maintained and thoroughly evaluated source of genetic variability. For CIAT's Cassava Program this variability is maintained as the world's largest cassava germplasm collection, presently consisting of some 3,400 accessions from all over Latin America, plus a few from Asia (Table 1). In 1983 an IBPGR-CIAT sponsored collection in Paraguay brought an additional 150 clones from subtropical regions. Previously, little germplasm was available for adaptation to low winter temperature and long photoperiod areas. Additionally, this collection (also maintained in Paraguay) gives impetus to Paraguay's increasing interest in improving cassava productivity. A second phase of the collection is planned for early 1984.

During the year, 524 clones were introduced from existing collections through *in vitro* transfer by the Genetic Resources Unit. Over a period of five years a total of 1,348 new accessions have been introduced via *in vitro* methods, to minimize risks of introducing new pests or pathogens.

The cassava collection is maintained at CIAT-Palmira headquarters as a field-grown collection, with annual renewal. As the collection becomes larger and more diverse, the risks increase of losing valuable germplasm due to poor adaptation, or pest and disease outbreaks. Thus, the Genetic

Previous Page Blank

Resources Unit has been moving the collection to *in vitro* storage under minimum growth conditions. At the end of 1983, the *in vitro* collection stood at 2,017 accessions.

Though highest priority is given to collection and conservation of cultivated cassava, in recent years a small seed collection of wild *Manihot* species has been established (Table 2). Until routine techniques are available for propagation of these species either vegetatively or sexually, this collection will be maintained primarily as a seed collection. These collections are small and not yet available for distribution outside CIAT.

An IBPGR working group on cassava genetic resources has tentatively defined basic descriptors for characterization of cassava. During 1983 CIAT's entire collection was classified according to a systematic description of some of the most stable morphological traits (Table 3). Analysis of the data is still in process, but this information will aid in varietal identification, and help determine genetic similarity among clones within the germplasm collection. Data will also be used as one of various criteria to identify and eliminate duplicates in the collection.

Evaluation of agronomic traits for new accessions was temporarily suspended during 1983 because of the additional effort required for consolidation of the hybrid production and evaluation activities. Nevertheless, accessions previously identified as promising continue to move through various stages of selection, and are being added to breeding populations.

Edaphoclimatic Zones for Cassava Production

Information accumulated over several years on the interaction of cassava with its physical and biological environment has been used to describe six distinct edaphoclimatic zones where cassava is produced (Table 4). Each zone with its unique combination of physical and biological constraints requires basically distinct genotypes. Thus, the entire cassava breeding strategy is based on improving varieties for each of the edaphoclimatic zones. For the Colombian-based breeding program, the principal elements of this strategy are: parental selection according to zone adaptation; formation of separate breeding populations for each zone; centralized production and planting of hybrid seed at CIAT-Palmira; and decentralization of all selection stages past the F_1, by evaluation in sites representative of each zone.

For international distribution of germplasm, edaphoclimatic, pest and disease conditions are matched to those most closely corresponding to Colombian selection sites to maximize the possibility of local adaptation.

Gene Pool Development

The creation of new variability for selection of improved varieties begins with the formation of parental populations. Parents (either germplasm accessions or hybrids) are selected primarily on the basis of overall adaptability, wide resistance to the pests and diseases of each

zone and root yield and quality. Of course, few clones combine all these traits in acceptable levels, and sets of parents are chosen which compensate each other's weak points, to achieve balanced improvement of the progeny. Single character improvement without regard to other traits, with later combination of characters into a single genotype, is considered and inefficient means of achieving acceptable varieties.

Two distinct mechanisms are used for genetic recombination: controlled pollination and open pollination in polycross blocks. Parents are separated according to zone, and most interpollination occurs among parents selected for the same zone. In controlled pollinations, crossing between groups for zones 1 and 2, and 2 and 6 is used primarily as a means to improve the levels of disease resistance in material for edaphoclimatic zones 1 and 6.

Open pollination is a less expensive means to produce large quantities of seed. The resulting half-sib progeny can be used to measure general combining ability of the parental clones, and for direct selection. Controlled pollination allows more control over the recombination of specific characters, and is most useful where a clone needs to be improved for specific traits, or a national program has very specific requirements in terms of varietal characteristics. For most situations, seed from open pollination is acceptable, if parents are selected well and selfing is minimized by planting design of the polycross blocks. In the polycross blocks, groups of parents for different zones are separated by male sterile borders to minimize contamination by pollen from other lots.

The parental gene pools are highly dynamic. New germplasm accessions showing promise in any edaphoclimatic zone are added to the respective pool to bring in new variability, thus avoiding a narrowing of the germplasm base. Selected hybrids are also brought back into the gene pools for the gradual accumulation of additive gene effects in a recurrent selection process.

Table 5 shows hybrid seed production from controlled and open pollination over the last five years. Mealybug and mite attacks resulting from abnormally low rainfall at CIAT-Palmira in 1983 adversely affected seed production this year. Future plans call for building ample seed reserves to avoid disruption of selection or international distribution activities due to variable seed production.

Selection Strategy for New Hybrids

Because major modifications were made in selection strategy during 1983, a detailed outline of the present strategy will be given here. The two principal changes were: (1) complete decentralization of selection based on edaphoclimatic zone on definition; and (2) shifting priorities for selection from zone 2 and 4 to zone 1.

Decentralization

During 1983, decentralization of selection was emphasized for zones 1, 2, 4 and 5. The addition of zones 3 (rainforest) and 6 (subtropics) is planned for 1984 (Figure 1).

All F_1 seeds (15-20,000 each semester) are planted at CIAT-Palmira, where adequate care can be given the delicate plantlets in the early growth stages. F_1 populations are grouped according to zone of adaptation of the parents. Because CIAT is not representative of any important cassava growing region, only slight selection pressure is applied in the F_1 to eliminate obviously inferior genotypes. Six months after transplanting, the F_1 plants are harvested. Two 20 cm stakes are cut from each plant. Within a family (set of progeny from an individual cross combination) stakes are numbered consecutively with a felt tip marker, with the two stakes from each plant having the same number. Stakes are then packed and labeled according to cross code. One of the duplicate sets of stakes remain in CIAT-Palmira for multiplication and evaluation while the other set goes to the principal selection site of the appropriate zone. The first clonal stage, the F_1C_1, is handled much like an F_1 population in that only a single plant per genotype exists within a given site, thus allowing for evaluation of large numbers of genotypes in each major zone. Selection in each zone continues from F_1C_1 (single plant), observational trial (single row of 5-7 plants), preliminary yield trial (plot of 20 plants; unreplicated), and advanced yield trial (plot of 25-30 plants; three replications) (Figure 2). All genotypes selected in any site are also advanced and maintained at CIAT-Palmira. This prevents reintroduction of material from disease and pest-infested areas into CIAT-Palmira and permits additional evaluations at the Palmira station.

Popayan (ECZ 5) is an exception to the above scheme, as duplicate material is not maintained at CIAT-Palmira until the advanced selection stages. Reintroduction of clones from Popayan to Palmira is easily achieved without danger of introducing new pests or pathogens, and additional evaluations at Palmira for this zone are of little use.

Across-ECZ evaluation.

Primary emphasis is given to selection for adaptability across the range of variability within a given zone. Nevertheless, because individual selection sites in Colombia cannot possibly represent the variability existing for any zone on a world-wide basis, broader evaluation is necessary. Across-site evaluation begins at the middle stages of selection. Among the lowland zones, any clone selected at the observational trial stage in any site is automatically evaluated across all zones. This is most important as a mechanism to eliminate any material which may be highly susceptible to a pest or disease which is present, but of lesser importance, in the principal adaptation zone. For example, CBB is not a serious problem in most of ECZ 1, though it is widespread across the zone and in some years may be quite severe. Evaluations in Media Luna often do not allow the breeder to distinguish levels of resistance. Thus, evaluations in Carimagua of ECZ

1-selected material identify resistance levels, and some of the most susceptible genotypes may be discarded.

Progress in Improvement of the Germplasm Base

Long-term advances in genetic improvement can only be achieved by continual upgrading of the active germplasm base i.e. that set of clones which genetically contributes to production of progeny for selection. Part of the responsibility of the germplasm development section over the past five years has been to identify and incorporate new parents into breeding populations, and then continue to improve those populations such that a high proportion of superior progeny could be obtained for selection by CIAT or directly by national programs.

This germplasm base improvement is difficult to quantify, but indications can be obtained from the number and quality of new clones incorporated into breeding populations.

ECZ 1.

For ECZ 1, the principal constraints were: (1) the combination of existing high yield potential in new hybrids with high dry matter content; and (2) adaptation to more stressful conditions, especially drought. M Col 22 and M Col 1684 had contributed heavily as parents of hybrids for this zone (Table 6). Thus, evaluations began in Media Luna in 1978 to identify new parents in the germplasm collection (see Cassava Annual Reports 1980, 1981). Potential new parents were identified and incorporated into the hybridization program. Several have been used extensively in recent years, such as M Bra 12, M Col 72, M Col 948C, M Col 1505, M Col 1818, M Col 1826, M Ven 23, M Ven 25 and M Ven 185. Others, more recently identified, will soon be contributing to the gene pool.

ECZ 2.

In Carimagua, where disease pressures are exceptionally high, most resistance to CBB and superelongation disease had been derived from a relatively narrow range of accessions, especially M Col 638, M Col 647 and M Col 1438 (Table 6). A wider base of resistance, as well as yield and quality factors, was sought through large-scale germplasm evaluations in Carimagua. Only a small group of materials was identified which could tolerate the combined stressed of this site (see Cassava Annual Reports 1979, 1980); however, these have now been used to broaden and strengthen the germplasm base for ECZ 2. The most important contributions have been M Bra 5, M Col 1772, M Col 1894, M Col 1900, M Col 1916, M Col 1942, M Pan 12A, M Pan 12B, M Per 242, M Per 245 and M Ven 77. All of these clones, however, are susceptible to mites and thrips, and a major challenge in future years will be to recombine resistance to the wet season diseases with resistance to the dry season mites and insects in ECZ 2.

ECZ 5.

In 1978, only the local clone "Popayan" (M Col 1522) had been identified as consistently high yielding in the low temperature highlands of Popayan. Two approaches were taken to improve this germplasm base. First, a collection expedition to Colombian highland areas was organized, and secondly, evaluations of existing germplasm were undertaken at Popayan. The collection expedition resulted in some 10 clones with good overall performance in Popayan, while partial evaluation (about 700 clones) of the germplasm collection showed no new well-adapted material. Thus, the germplasm base for this zone remains rather narrow. To broaden the base further, crosses of adapted by non-adapted clones have been made. A few cycles of recombination and selection will be required for these new genes to be incorporated into suitably adapted genotypes. Nevertheless, even in the first cycle hybrids have been selected with reasonable yield and adaptation, and good dry matter content (Table 7). Though yields are well below that of the local variety, they are far better than those of the non-adapted parents. Further crossing with highland-adapted clones should result in the incorporation of new genes into that gene pool.

ECZ 6.

While CIAT cannot evaluate cassava germplasm directly in ECZ 6 (subtropics), a gene pool has been formed from germplasm accessions selected by national programs as promising for the subtropics, particularly Cuba and Brazil. In addition to tolerance to long photoperiod and low winter temperatures, which these clones already posses, higher levels of CBB resistance are needed for some subtropical regions. Thus, CIAT has been improving the resistance of this pool by crossing with clones highly resistant to CBB from the pool for ECZ 2.

Progress in Varietal Improvement

Advanced yield trials were harvested in six sites and two seasons in 1983, encompassing four edapho-climatic zones.

ECZ 1.

From 1979 to 1982 trials were planted in three sites in ECZ 1: on the Caribia station of ICA (high productivity site); Media Luna (low productivity site); and Valledupar or Guajira (moderate productivity site with high mite populations). In 1983 evaluations in Caribia were discontinued to emphasize selection in higher stress sites. Final trials there were harvested in March of this year.

After quickly achieving high yield potential in new hybrids for ECZ 1, emphasis in the last several years has been on improving root quality, particularly dry matter content. Local clones of the north coast region are known for their very good root quality, though yield potential is low. In Caribia, high yields of hybrids have been maintained, while gradually improving root dry matter (Table 8; Figure 3).

While mean yields in Media Luna are approximately half those of Caribia (Table 9), germplasm accessions and hybrids with good yield and high dry matter have been identified. The yield obtained for the local variety Secundina (7.1 t/ha) is about average for the region, so yields of 15-20 t/ha for selected clones should be commercially feasible. The yield trial planted in the second semester in Media Luna was destroyed when cattle entered the lot, and was replanted for harvest in 1984.

Valledupar serves as a secondary selection site for ECZ 1, where material selected initially in Media Luna is evaluated for mite resistance and adaptation under intermediate productivity conditions. The goal of combining high yield potential, high dry matter content, and moderate to high mite resistance has been obtained for only a few clones, and considerable emphasis continues toward this objective (Table 10).

ECZ 2.

Carimagua in the eastern plains of Colombia is a high stress site in terms of physical and biological constraints. Soils are low pH and of low native fertility, particularly phosphorus. During the rainy season from April to November, CBB, superelongation disease and anthracnose consistently devastate susceptible clones. In the dry season, thrips, mites and recently, mealybug attacks can be severe.

Yield trials were harvested in first and second semesters of 1983 (Tables 11 and 12). A rather wide range of hybrids now have adequate disease resistance combined with a yield potential well above that of local cultivars. The advances in yield potential (where yield is an integrated measure of adaptation, physiological efficiency, pest and disease resistance) over nine years of trials in Carimagua can be seen in Figure 4. Sharp fluctuations in the last few years of mean yield compared to those of local checks reflect the instability of local checks as pest populations have built up, rather than the instability of new hybrids.

Over several years of trials in Carimagua, second semester plantings consistently outyielded those of first semester. While yields were severely reduced by CBB and superelongation when susceptible or only moderately resistant clones were planted at the beginning of the rainy season, these same clones could yield well by escaping the most severe disease pressure when planted at the end of the rainy season. As disease resistance improved over the years, more clones entered the dry season with abundant, healthy foliage. Climatic conditions during the dry season being favorable to mite and insect build up, the availability of healthy but susceptible host plants completed the necessary requisites for pest breakouts.

Thus, in 1982 the trend for higher second semester yields was reversed (Figure 5). Because early rainy season plantings will likely continue to be most important for this zone, priority is still given to maintaining good levels of disease resistance. Insect or mite attacks which occur after good plant growth and development may not affect yields very much. First semester plantings will probably suffer less from dry

season pests, just as second semester plantings suffer less from wet season diseases.

Figures 6 and 7 illustrate the high yield losses caused by increasing damage levels from CBB and superelongation disease, respectively, in first semester plantings which were negatively correlated to yield. However, a heavy mealybug attack during the dry season in the same trial was positively correlated with yield (Figure 8). A plausible explanation is that the mealybugs most heavily attacked those clones with more foliage, those being the ones with better disease resistance and higher yield potential. Nevertheless, the mealybug attack significantly reduced root dry matter content (Figure 9).

In the second semester planting, there was little mealybug attack due to escape (location of the trial). High mite populations occurred, but damage rating was not correlated with yield. Results indicate, however, that few clones combine good resistance to both diseases and pests. It appears that the appropriate balance in levels of resistance to the two classes of problems will depend largely on time of planting. Thus, we can envision stratification of breeding objectives for this zone based on time of planting, where early rainy season planting will require clones with high disease resistance and moderate mite and insect resistance; late rainy season planting will require moderate disease resistance and high mite and insect resistance. This type of stratification should be preferable to attempting high resistance levels to both classes of problems, as it would entail sacrificing progress in other important aspects of crop improvement.

ECZ 4.

CIAT-Palmira station has become primarily a site for centralized germplasm maintenance, hybridization, and maintenance and multiplication of selected hybrids. Because of previous progress made in breeding in this zone, and the relative low importance of ECZ 4 in world cassava production, continued selection for this zone has low priority. This shift in emphasis can be observed in the leveling off of yields at CIAT-Palmira over the last few years (Figure 10). In addition, continued build-up of pest problems and root rots in the station has caused declining yields of the check varieties as well. Further selection at CIAT-Palmira will be principally an opportunistic selection of hybrids developed for other zones, which also do well in ECZ 4.

ECZ 5.

The breeding of highland-adapted clones was begun four years ago with parental selection and development of a selection methodology. Because of an 18-month growing season for cassava under these conditions, progress in breeding is slower than for other zones. Crosses of adapted x adapted parents are still at the intermediate stages of selection, and results, though preliminary, indicate potential for improving the productivity and quality of cassava in this zone.

International Germplasm Exchange

Two forms of germplasm are available to national programs or other institutions: true seed, or clones in the form of aseptic *in vitro* cultures. Clones provide advanced, thoroughly evaluated material to programs with the ability to receive and multiply *in vitro* cultures. Seeds provide a wide range of genetic diversity, and therefore a higher chance for local adaptability, to programs with the ability to carry out all stages of selection from the F_1 onwards. Many programs opt to receive both forms of germplasm. Table 13 summarizes cassava germplasm distributed since 1973. Anticipated future needs for cassava seed are given in Table 14.

In 1983 a list of 42 elite clones was compiled and published for interested programs. Clones are described for adaptation to each of the six edaphoclimatic zones, yield, quality and resistance characteristics. They are available *in vitro* for rapid dispatching by the Genetic Resources Unit.

Table 1. Origin of accessions in CIAT's cassava germplasm collection.

Origin	No. of accessions
Argentina	20
Bolivia	3
Brazil	843
Colombia	1490
Costa Rica	16
Cuba	74
Dominican Republic	5
Ecuador	118
Malaysia	3
Mexico	64
Panama	21
Paraguay	153
Peru	261
Puerto Rico	15
Thailand	1
Venezuela	244
CIAT Hybrids	81
Total	3412

Table 2. Seeds of wild Manihot species held at CIAT.

Species	Country of origin
M. aesculifolia	Mexico, Panama
M. alutacea	Brazil
M. angustiloba	Mexico
M. anomala	Brazil, Paraguay
M. attenuata	Brazil
M. caerulescens	Brazil, Paraguay
M. cartaginensis	Colombia
M. caudata	Mexico
M. chlorosticta	Mexico
M. crassisepala	Mexico
M. davisiae	Mexico
M. falcata	Brazil
M. fruticulosa	Brazil
M. glazziovii	Brazil
M. gracilis	Brazil
M. grahami	Paraguay
M. longipetiolata	Brazil
M. michaelis	Mexico
M. oaxacana	Mexico
M. oligantha	Brazil
M. paviaefolia	Brazil
M. peltata	Brazil
M. pentaphylla	Brazil
M. pringlei	Mexico
M. purpureo-costata	Brazil
M. reptans	Brazil
M. rhomboidea	Mexico
M. rubricaulis	Mexico
M. salicifolia	Brazil
M. tripartita	Brazil, Paraguay
M. websterae	Mexico

Table 3. Descriptors evaluated for characterization of CIAT's cassava germplasm collection.

Leaves	Stems	Roots
- Color of apical leaves	- Branching angle	- External root color
- Color of fully expanded leaves	- Height of first branch	- Color of root cortex
- Leaf vein color	- Plant height	- Color of root parenchyma
- Petiole color	- Plant form	
- Number of leaf lobes	- External stem color	
- Leaf lobe length	- Color of stem epidermis	
- Leaf lobe width	- Color of stem cortex	
- Form of leaf lobes	- Intensity of pigmentation of stem cortex	
- Pubescence of apical leaves		

Table 4. Edaphoclimatic zones for cassava production and their main characteristics.

Edaphoclimatic zone no.	General description	Sites in Colombia for germplasm evaluation and technology testing	Major yield constraints
1	Lowland tropics with long dry season, low to moderate annual rainfall, high year-round temperature.	Caribia, Fonseca, Media Luna, Nataima, Rionegro	Drought, mites, thrips, mealybugs, termites, CBB, root rots, viruses
2	Acid soil savannas with moderate to long dry season, low relative humidity during dry season.	Carimagua	Low soil fertility, drought, CBB, superelongation, anthracnose, *Cercospora* leafspot, mites, mealybugs, lace bugs.
3	Lowland tropics with no pronounced dry season, high rainfall, constant high relative humidity.	Chigorodo, Florencia	Low soil fertility
4	Medium-altitude (800-1500 msl) tropics with moderate dry season and temperature.	Caicedonia, CIAT-Palmira, CIAT-Quilichao	Thrips, mites, mealybugs, CBB, mycoplasma, anthracnose, root rots, and viruses.
5	Cool, tropical highland (1600-2200 msl) area with mean temperatures of approx. 17-20°C.	Popayan	Low temperatures, *Phoma* leafspot, anthracnose, mites.
6	Subtropical areas, with cool winters and fluctuating daylengths.	None	Low winter temperature, CBB, superelongation, anthracnose.

Table 5. Production of hybrid cassava seed in CIAT during last five years.

Year	Germplasm development		Varietal improvement	Total
	Controlled pollination	Open pollination	Controlled pollination	
1979	4,033	12,481	14,314	30,828
1980	8,911	35,511	90,055	134,477
1981	17,839	87,196	63,371	168,406
1982	10,351	73,332	62,851	146,534
1983 [a]	4,527	51,265		55,792
Mean	10,283	52,130	57,648	120,061

[a] Production from first semester only; data excluded from mean.

Table 6. Frequency of occurence (%) of commonly used parents in geneology of cassava hybrids[a] in various yield trials.

Clone	Caribia: 1982-83A	Media Luna: 1982-83B	Carimagua: 1982-83A	Carimagua: 1982-83B
M Col 22	86	73	36	14
M Col 638	3	0	29	50
M Col 647	24	19	51	61
M Col 1438	3	19	60	46
M Col 1684	40	51	27	18
Any one of above:	95	97	91	93

[a] Hybrids derived from the same original source populations.

Table 7. Results of yield trial of hybrids in Popayan: June 15, 1982 - Nov. 2, 1983.

Clone	Parents	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)	Phoma leaf-spot (1-5)[a]
CM 1087-17	M Col 1522 x M Col 22	23	37.1	9	2.0
CM 1090-52	M Col 1522 x M Col 1684	22	30.1	7	2.0
CM 1089-1	M Col 1522 x M Col 1292	21	31.4	7	3.0
CM 1090-17	M Col 1522 x M Col 1684	20	32.6	7	4.0
CM 1088-9	M Col 1522 x M Col 655A	20	34.2	7	3.7
CM 1090-40	M Col 1522 x M Col 1684	20	31.5	6	2.7
CM 753-7	M Col 638 x M Col 1522	19	34.1	7	2.3
CM 1091-8	M Col 1522 x CM 314-20	19	26.6	5	2.7
CM 1089-20	M Col 1522 x M Col 1292	19	34.5	7	2.7
CM 1091-36	M Col 1522 x CM 314-20	18	34.9	6	2.0
Checks					
M Col 22		2	24.4	<1	<5.0
M Col 1468		6	30.9	2	3.3
M Col 1522		33	31.9	10	2.0
M Col 1684		3	30.3	1	5.0
M Bra 12		2	32.7	1	3.7
M Ven 77		4	28.5	1	3.7
Trial mean		16	31.6	5	3.1

[a] Scale of 1-5: 1 = no symptoms; 5 = severely affected.

Table 8. Results of yield trial of hybrids in Caribia; May 14, 1982 - March 15, 1983.

Clone	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)
CM 1022-12	46	30.3	14
CM 982-22	40	28.2	11
CM 1223-16	39	24.2	9
CM 1533-19	37	29.6	11
CM 1533-12	37	29.1	11
CM 1223-18	36	30.6	11
CM 1223-11	36	31.8	11
CM 713-3	35	31.1	11
CM 847-11	35	26.4	9
CM 1579-7	35	31.1	11
CM 922-2	34	32.1	11
CM 1579-14	33	35.9	12
CM 1014-2	32	26.1	8
CM 1223-13	32	32.2	10
CM 681-2	32	33.4	11
CM 998-10	32	32.6	10
CM 342-170	31	25.7	8
CM 1581-1	31	28.3	9
CM 728-18	30	28.6	9
CM 1645-3	30	30.9	9
Checks			
M Col 22	24	28.6	7
M Col 1468	15	25.3	4
M Col 1684	36	30.6	11
Montero	13	28.4	4
Venezolana	15	35.9	5
Trial mean (43 genotypes)	28	30.1	8

Table 9. Results of yield trial of hybrids and accessions in Media Luna; April 29, 1982 - March 21, 1983.

Clone	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)
CM 342-170	21	25.0	5
M Ven 25	21	30.0	6
CM 681-2	20	30.0	6
M Ven 185	20	32.1	6
CG 6-26	19	26.0	5
M Col 1826	19	31.7	6
M Mal 1	18	26.2	5
CG 1-61	18	29.6	5
M CR 2	17	35.3	6
M Ven 23	17	34.6	6
M Mal 2	17	30.7	5
M Col 1681	17	28.8	5
M Ven 157	17	29.8	5
CM 1016-30	17	29.8	5
M Mal 3	16	26.2	4
M Col 2215	16	36.2	6
M Tai 1	15	27.8	4
CG 1-37	15	31.3	5
M Mex 24	14	34.6	5
CM 1022-4	13	32.9	4
Checks			
M Col 22	18	28.1	5
M Col 1468	19	22.0	4
M Col 1684	19	27.6	5
M Bra 12	18	28.4	5
M Ven 77	11	25.7	3
Secundina	7	32.4	2
Trial mean (45 genotypes)	14	31.8	4

Table 10. Results of yield trial in Valledupar; May 3, 1982 - March 23, 1983.

Clone	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)	Mites[a] (1-5)
CM 342-170	30	30.3	9	3.0
CG 6-14	28	26.2	7	3.5
CG 6-7	25	30.1	8	3.0
CG 1-48	23	25.0	6	2.5
M Tai 1	22	31.0	7	3.0
CG 1-37	21	27.6	6	3.0
CG 6-18	21	31.1	7	4.0
CM 1016-30	21	33.2	7	3.5
CM 1022-4	20	33.9	7	3.5
CG 6-26	20	24.4	5	4.0
M Ven 45A	20	31.6	6	3.0
CM 681-2	18	33.5	6	3.0
CG 5-55	18	30.9	6	2.0
M Mal 2	18	28.2	5	3.0
CG 6-54	18	28.6	5	4.0
M Col 2216	18	32.1	6	3.5
M Col 1823	16	32.2	5	3.0
M Ven 185	16	33.0	5	3.0
CG 22-7	15	23.4	3	3.0
CG 1-3	14	31.1	4	3.5
Checks				
M Col 22	11	29.7	3	3.0
M Col 1468	12	24.2	3	4.0
M Col 1684	15	28.0	4	4.0
M Bra 12	16	28.6	5	2.5
M Ven 77	8	24.3	2	3.5
Enanita	12	35.8	4	3.0
Trial mean (47 genotypes)	15	30.9	5	3.7

[a] Scale of 1-5: 1 = no symptoms; 5 = severely affected.

Table 11. Results of yield trial of hybrids and accessions in Carimagua; March 29, 1982 - April 7, 1983.

Clone	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)	CBB[a] (1-5)	SED[b] (1-5)
CM 1223-1	30	29.9	9	3.5	4.0
CM 1983-2	29	27.6	8	2.8	4.0
CM 841-179	27	21.5	6	2.0	2.0
CM 2086-16	26	28.9	7	2.5	2.0
M Bra 35	25	26.2	7	2.5	2.0
CM 1579-14	23	28.6	7	3.0	3.5
CM 2086-7	23	25.4	6	2.5	2.0
CM 507-37	23	28.9	7	3.0	4.3
CM 2068-7	21	31.3	7	2.5	2.0
CM 1989-4	21	27.2	6	3.0	2.0
M Col 1916	21	26.6	6	3.0	2.0
CM 2088-1	20	25.9	5	3.0	3.0
CM 1668-101	20	30.6	6	3.3	4.0
CM 1054-2	19	30.7	6	3.0	2.5
CM 1585-13	19	28.7	5	2.7	3.0
CM 1855-3	19	26.3	5	3.0	2.5
CM 2063-16	19	28.2	5	3.5	2.5
CM 1869-1	18	27.8	5	2.5	2.5
CM 1855-4	18	28.0	5	3.0	3.5
CM 1918-3	18	29.0	5	2.5	2.5
Checks					
M Col 22	3	29.0	1	4.5	4.5
M Col 638	7	19.3	1	3.0	3.0
M Col 1438	6	29.1	2	3.0	4.0
M Col 1468	11	25.3	3	4.0	4.5
M Col 1684	9	26.5	2	3.0	3.0
M Ven 77	16	23.5	4	2.5	2.0
Trial mean	15	28.2	4	3.2	3.4

[a] Scale of 1-5: 1 = no symptoms; 5 = severely affected for CBB and SED

[b] SED = Superelongation disease

Table 12. Results of yield trial of hybrids and accessions in Carimagua; March 29, 1982 - April 7, 1983.

Clone	Fresh root yield (t/ha)	Root dry matter (%)	Root dry matter yield (t/ha)	Mites (1-5)	CBB (1-5)	Super-elongation disease (1-5)
CM 2174-7	21	33.6	7	4.0	3.0	2.0
CM 2306-7	21	29.8	6	3.0	3.0	2.0
CM 2398-1	18	30.1	6	4.0	4.0	3.0
CM 2174-4	17	34.7	6	4.0	3.0	2.0
CM 621-251	17	26.7	5	3.5	3.0	2.0
CM 523-7	17	37.1	6	4.8	3.0	3.0
CM 996-6	17	28.6	5	4.5	3.0	2.0
CM 1585-13	16	35.6	6	4.0	3.0	2.0
CM 430-37	16	33.9	5	3.0	3.0	3.0
CM 2144-1	16	32.4	5	2.0	3.0	2.0
CM 1662-1	16	35.1	5	3.5	3.0	3.0
CM 1335-4	15	35.4	5	3.0	3.0	2.0
CM 2173-6	15	26.2	4	4.5	4.0	2.0
CM 2458-7	15	28.2	4	4.0	3.0	4.0
CM 2369-1	15	26.5	4	4.0	3.0	2.0
CM 2298-3	15	31.5	5	2.0	4.0	3.0
CM 1307-3	15	29.4	4	3.8	3.0	4.0
CM 2452-5	15	32.5	5	4.5	4.0	3.0
CM 1663-1	15	33.1	5	3.5	4.0	4.0
CM 2087-101	14	29.8	4	2.0	3.0	2.0
Checks						
M Col 638	9	31.6	3	3.5	2.0	2.0
M Col 1438	7	32.6	2	3.0	3.0	4.0
M Col 1468	3	28.9	1	4.5	4.0	3.0
M Col 1684	4	29.2	1	5.0	4.0	3.0
M Ven 77	10	29.4	3	4.5	3.0	2.0
Trial mean (96 genotypes)	10	30.6	3	3.6	3.3	3.0

[a] Scale of 1-5: 1 = no symptoms; 5 = severely affected.

Table 13. International distribution of cassava clones and seeds from 1973-1983.

Region/country	Number of clones/seeds sent [a]		
	Stakes	In vitro	Seeds
South America			
Argentina	23	5	
Bolivia	14		
Brazil	26	54	16,921
Ecuador	39	8	10,010
French Guiana	1		
Peru			3,462
Surinam	12		
Venezuela	40		470
Central America, Mexico and Caribbean			
Bahamas	7		
Barbados	5	3	
Costa Rica	27	18	
Cuba	24	17	13,784
Dominica	2		
Dominican Republic	26		3,700
El Salvador	15		
Guatemala	6		
Haiti	31		2,500
Honduras	35	10	
Jamaica	16		
Mexico	51	34	5,350
Nicaragua		13	125
Panama		24	125
Santa Lucia	3		
Trinidad & Tobago	11	5	
Virgin Islands			1,600
Asia and Middle East			
Bangladesh			1,500
China		19	13,900
India		5	2,100
Indonesia	5	18	5,450
Israel		4	
Japan	14		1,300
Malaysia	6	19	8,550
Philippines	29	36	67,550
Sri Lanka		9	

[a] Total includes clones sent more than once to the same country.

Table 13. (continued)

Region/country	Number of clones/seeds sent [a]		
	Stakes	In vitro	Seeds
Taiwan	15		1,500
Thailand	10	23	37,350
Turkey	2		
Vietnam			1,900
Africa			
Egypt			200
Kenya	20		350
Nigeria			73,845
Seychelles	6		250
South Africa	12	29	1,000
Tanzania			1,020
South Pacific			
Australia	33	8	264
New Zealand			900
Samoa			350
Tahiti	6		
Tonga			350
North America			
Canada	35	12	100
United States	23	63	17,525
Europe			
England	27	3	5,280
France	7	5	3,100
Holland	5		
Italy		5	

[a] Total includes clones sent more than once to the same country.

Table 14. Expected cassava seed requirements over the next three years.

Region/country	Year 1984	1985	1986
Latin America			
Colombia (CIAT)	40,000	40,000	40,000
Brazil	8,000	8,000	8,000
Cuba	3,000	3,000	4,000
Mexico	2,000	3,000	3,000
Dominican Republic	2,000	2,000	2,000
Others	4,000	4,000	4,000
Sub-total:	59,000	60,000	61,000
Asia			
Thailand		9,000	9,000
Indonesia	8,000	8,000	8,000
Philippines	4,000	4,000	4,000
China	4,000	4,000	4,000
Malaysia	3,000	3,000	3,000
India		2,000	2,000
Vietnam		2,000	2,000
Others	3,000	4,000	4,000
Sub-total:	22,000	36,000	36,000
Africa			
Nigeria (IITA)	4,000	4,000	4,000
Others	2,000	2,000	2,000
Sub-total:	6,000	6,000	6,000
Total	87,000	102,000	103,000

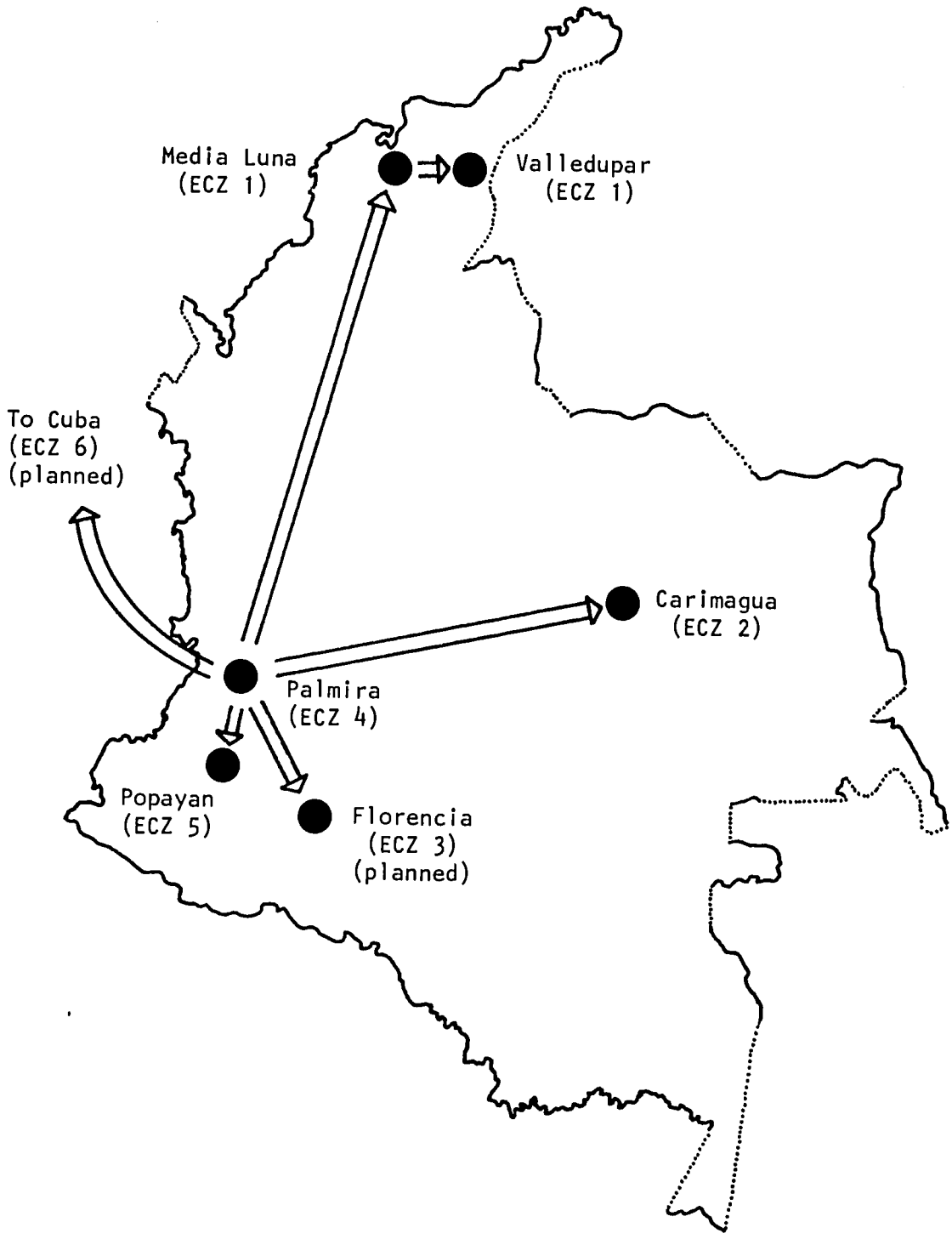
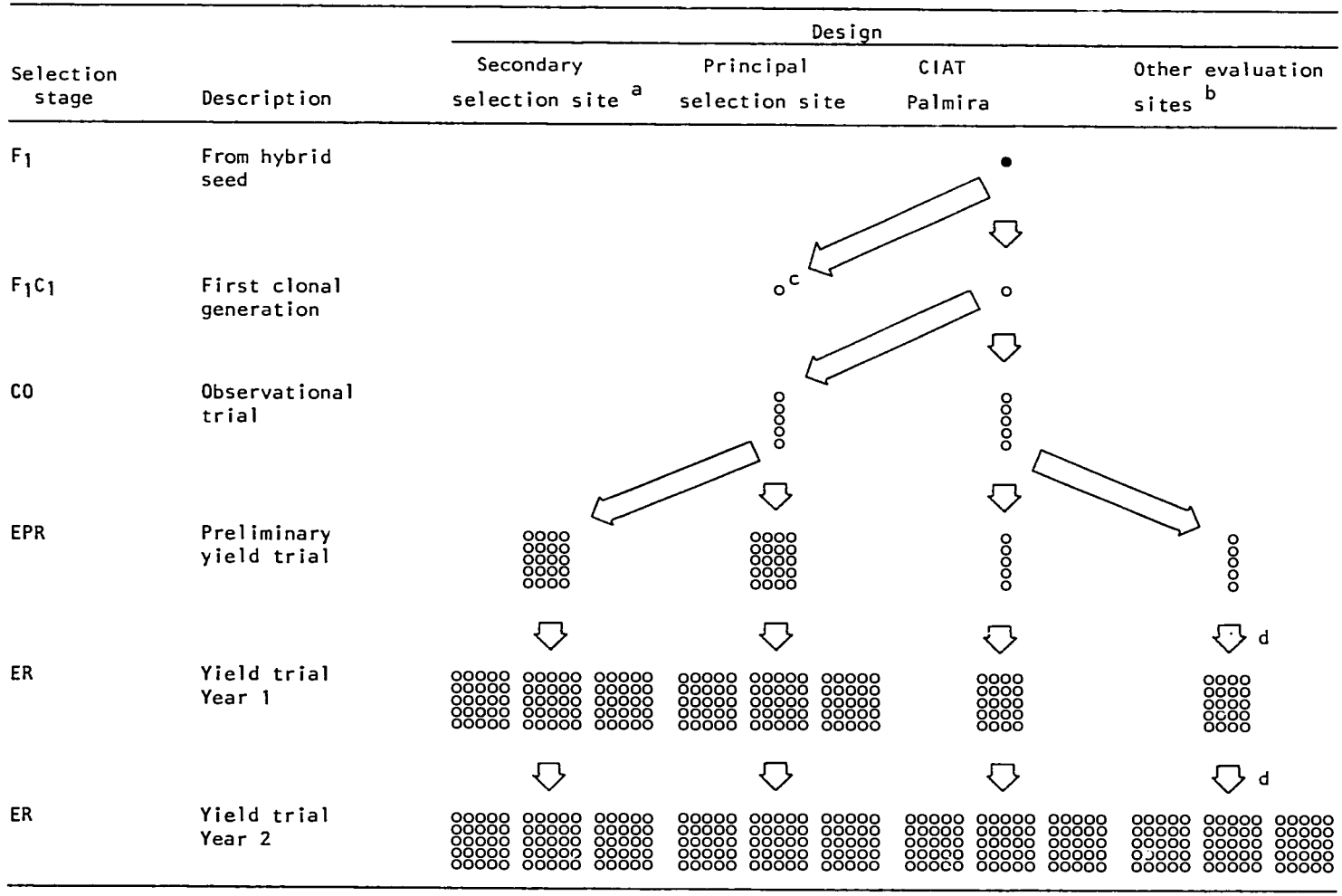


Figure 1. Movement of germplasm from CIAT-Palmira to principal selection sites within edaphoclimatic zones.

Figure 2. Stages of selection in CIAT cassava breeding program.



a Same edaphoclimatic zone ECZ as principal selection site
b Different ECZ than principal selection site
c Selection in principal selection site, but stakes are from CIAT-Palmira
d Evaluation continued only if performance satisfactory

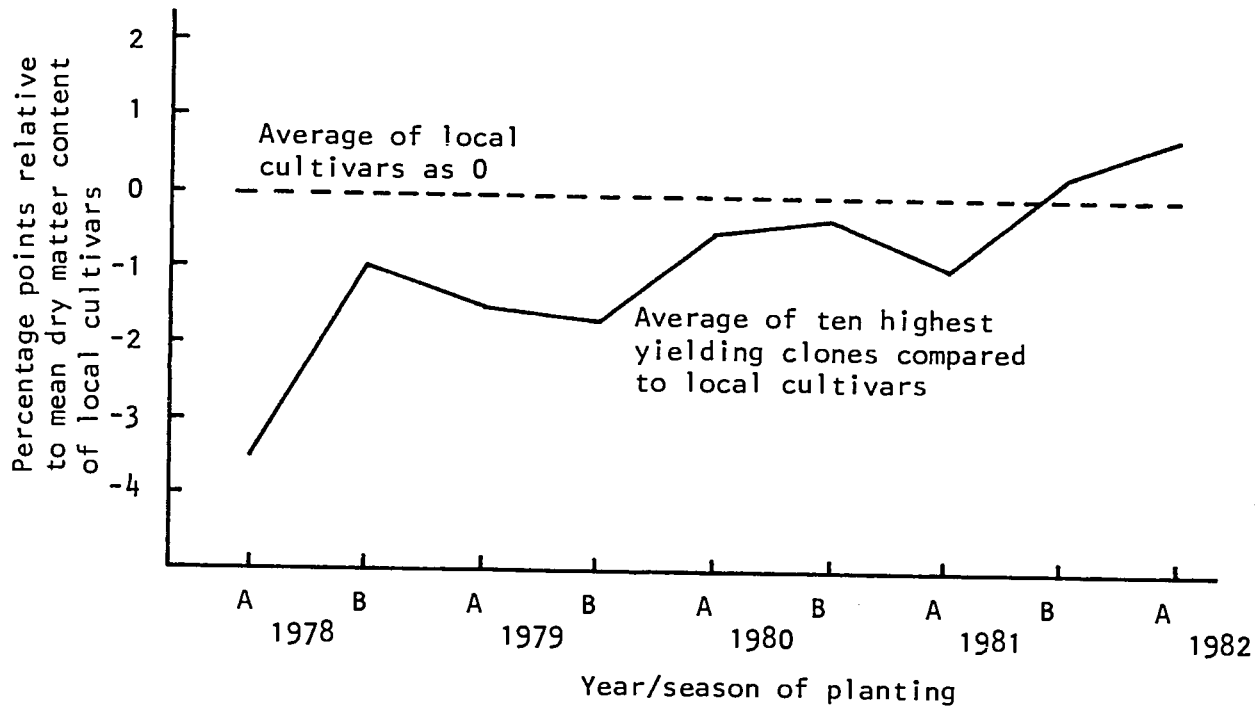


Figure 3. Change in average dry matter content of the ten highest yielding cultivars in cassava yield trial, expressed as percentage points above or below mean of local cultivars, from 1978 to 1982 at Caribia (local cultivars: Manteca, M Col 22).

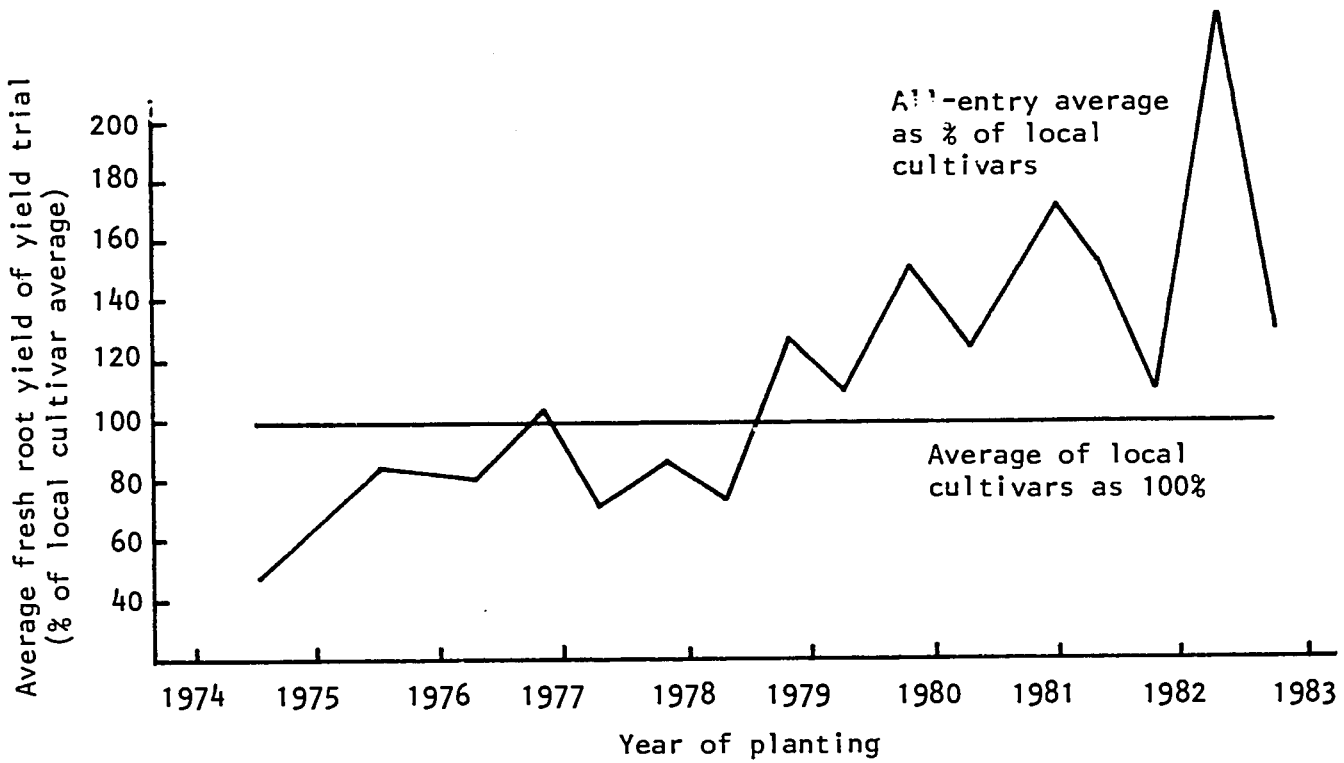


Figure 4. Change in average yield of cassava yield trial, expressed as percentage of local cultivars, from 1974 to 1982 at Carimagua (local cultivars: M Col 1438, M Col 638).

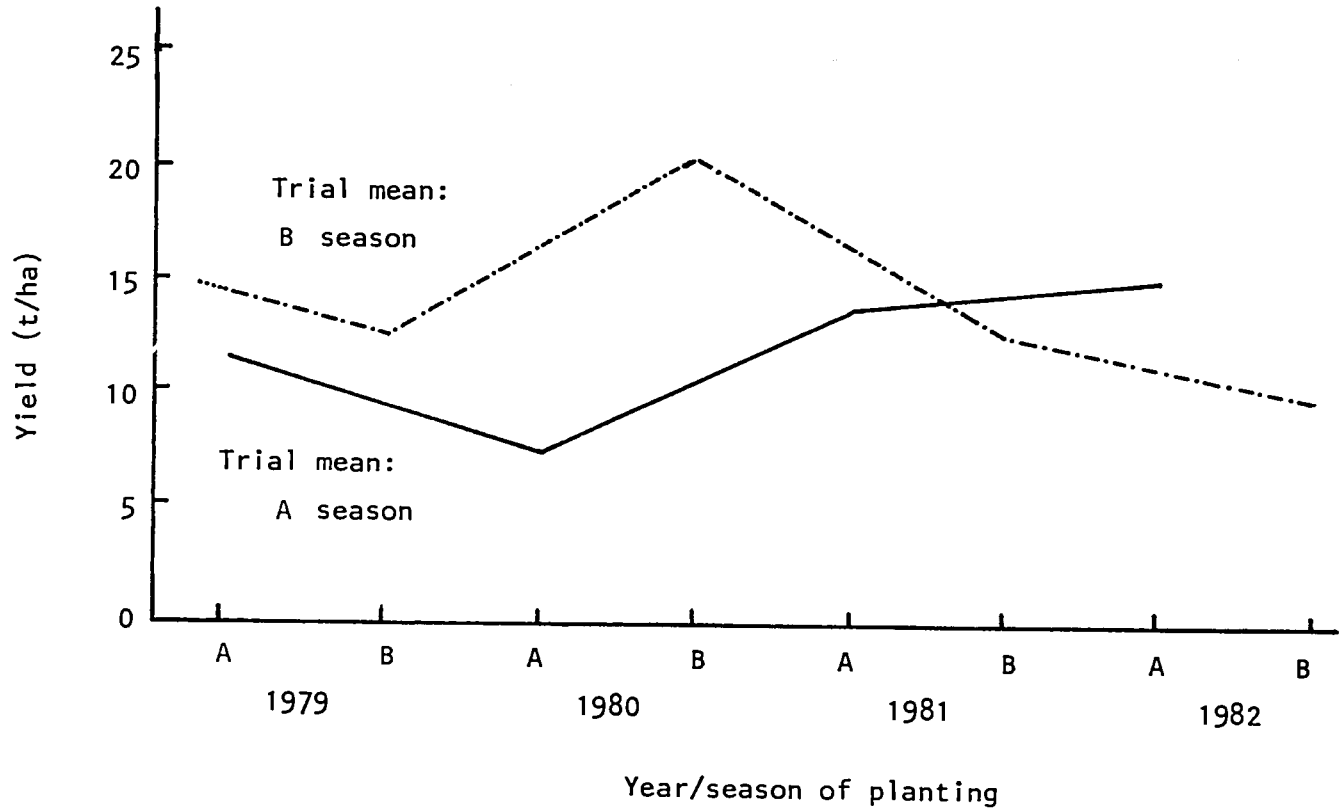


Figure 5. Mean yield of replicated yield trials in Carimagua over four years; comparison of A season (April-May) and B season (Sept.-Oct.) plantings.

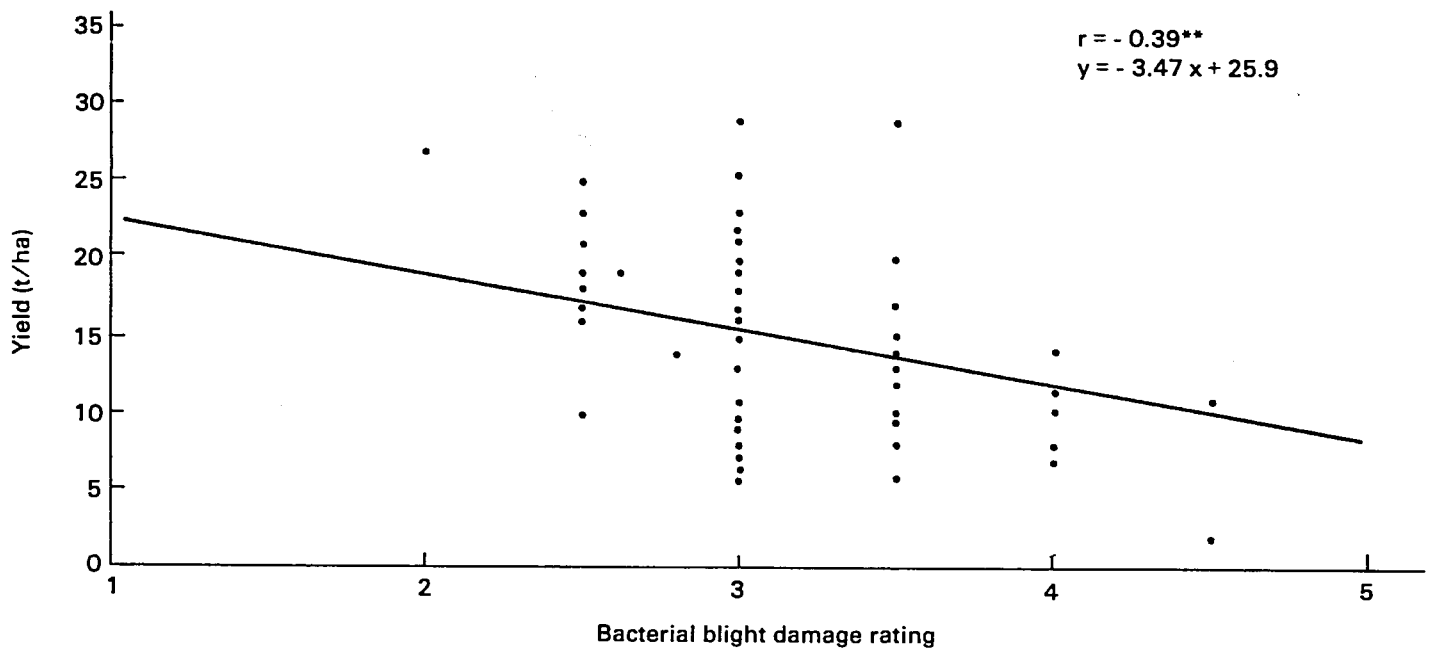


Figure 6. Effect of CBB damage on cassava yield in Carimagua; 1982-83A replicated yield trial.

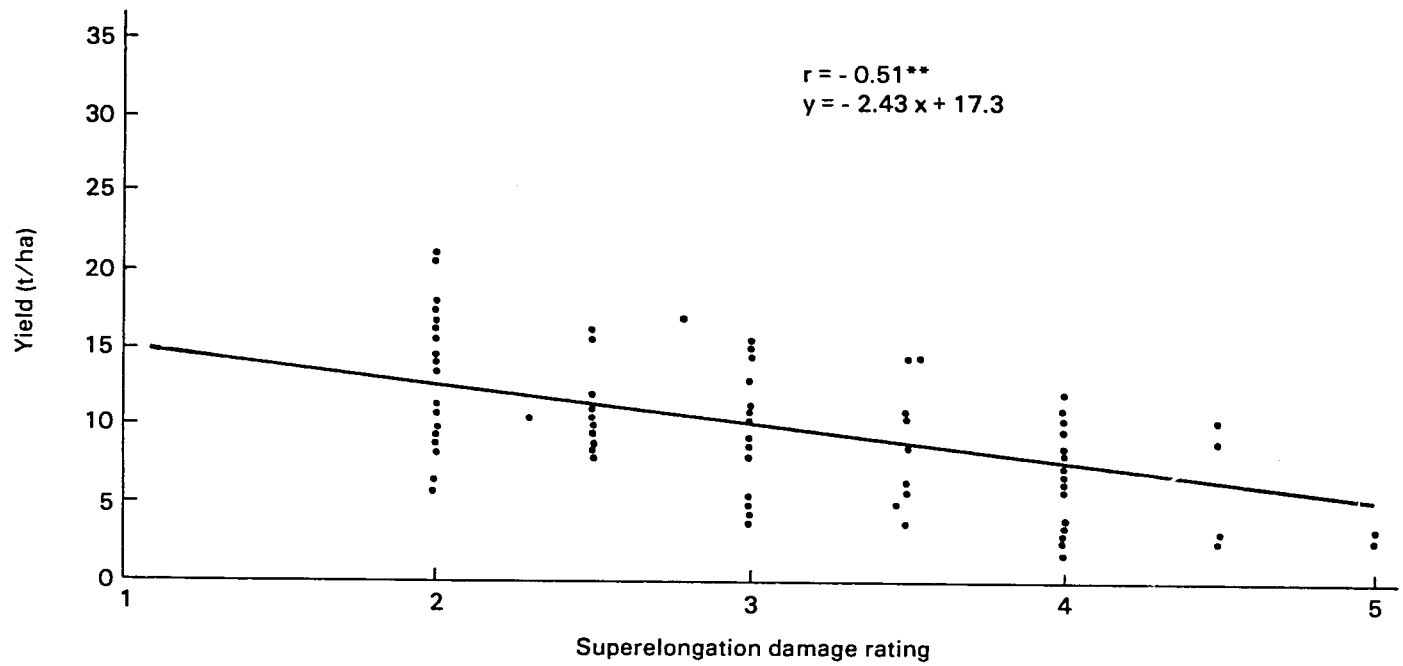


Figure 7. Effect of superelongation damage on cassava yield in Carimagua; 1982-83A replicated yield trial.

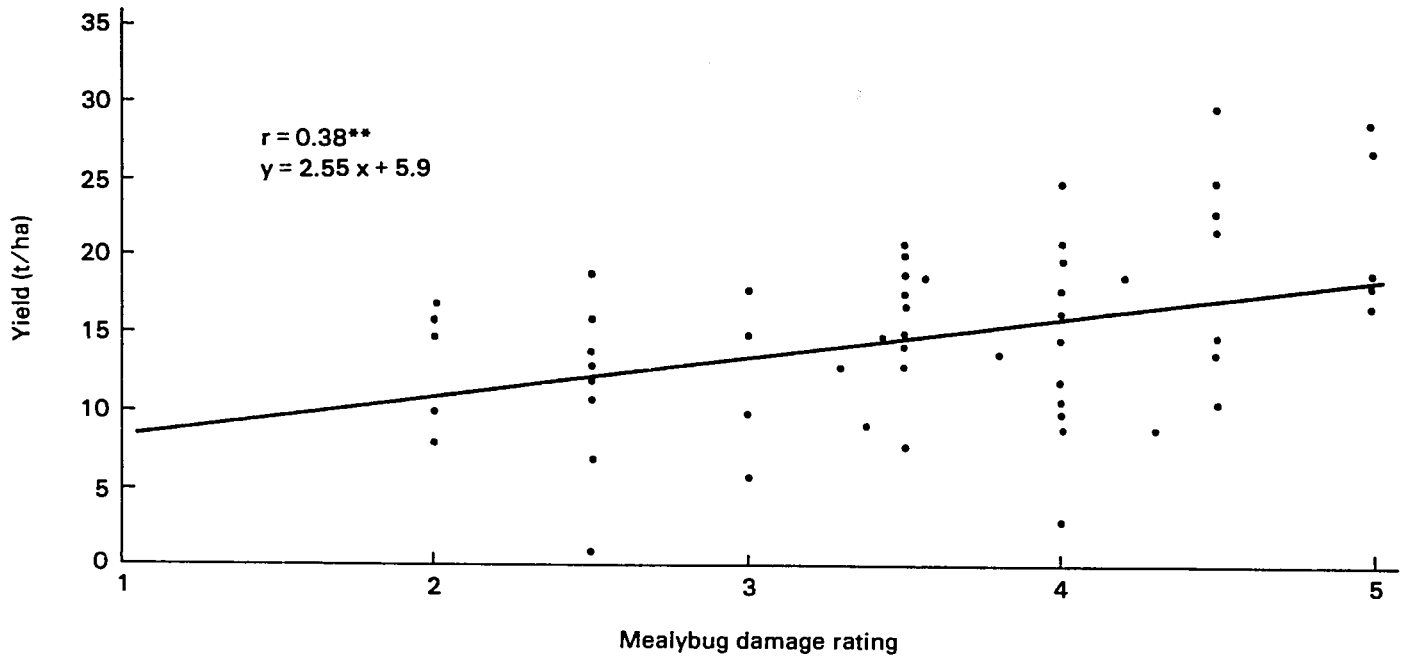


Figure 8. Effect of mealybug damage on cassava yield in Carimagua; 1982-83A replicated yield trial.

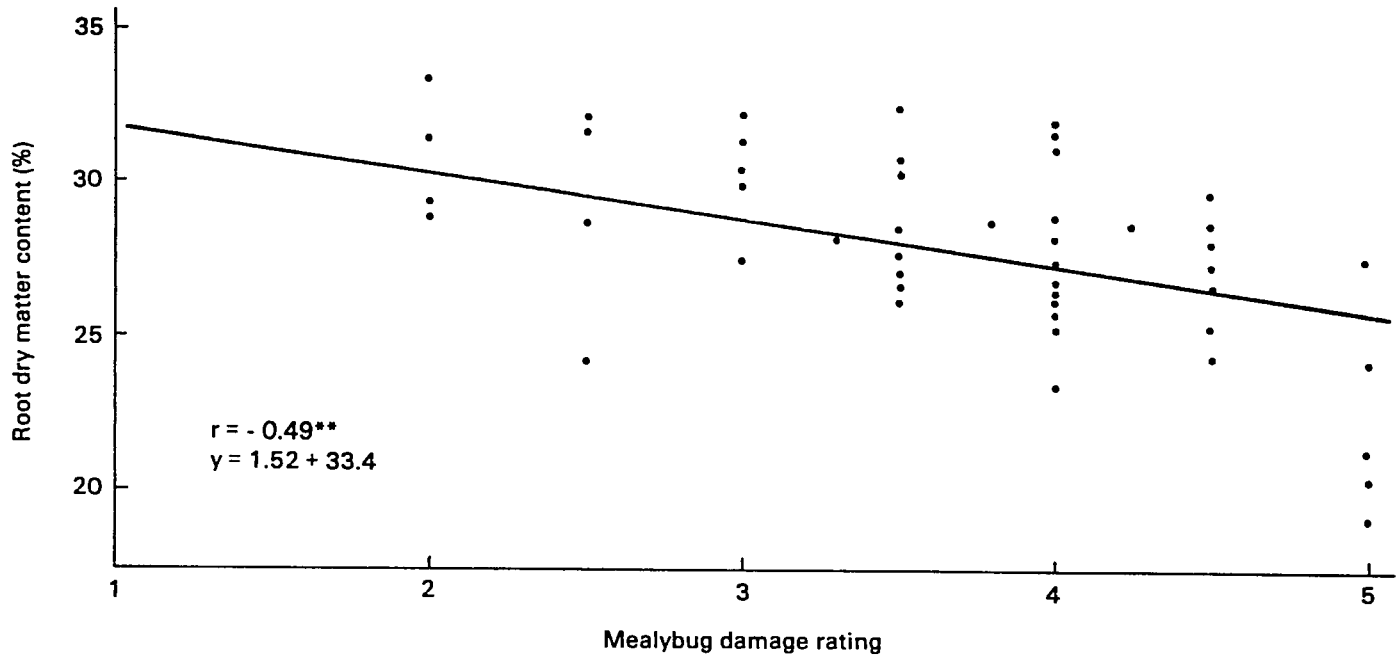


Figure 9. Effect of mealybug damage on cassava root dry matter content in Carimagua; 1982-83A replicated yield trial.

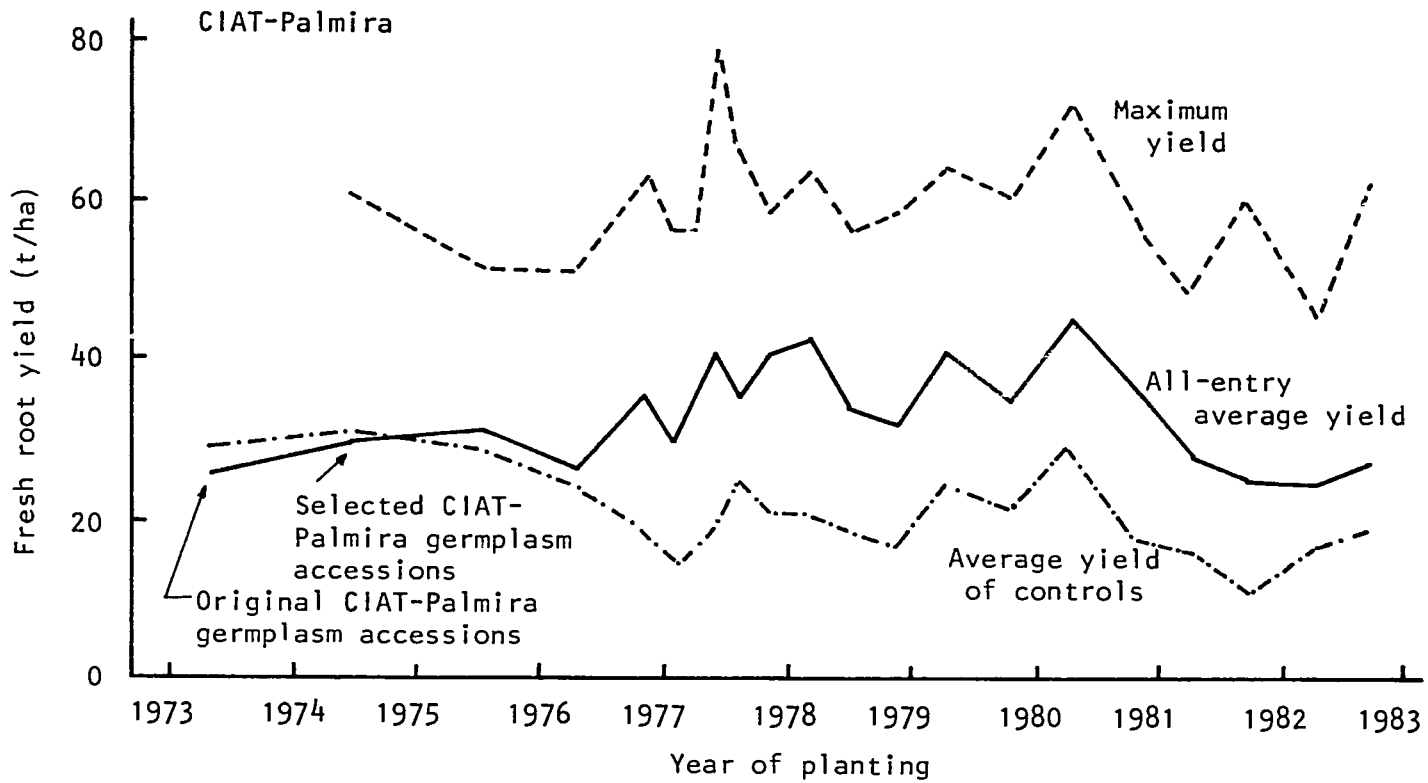


Figure 10. Change in average yields of yield trial and control cassava genotypes from 1973 to 1982 (control genotypes: M Col 1438, M Col 22, M Col 113).

Tissue Culture

In 1983, the work on tissue culture continued to help to alleviate problems associated with (a) the production of healthy clones from diseased varieties; (b) the international exchange of germplasm in clonal form, to prevent the introduction of undesirable pests and pathogens; (c) the long-term conservation of germplasm, in a small area and protected from disease outbreak, pest infestation and climatic and soil problems which often result in the loss of valuable genetic materials.

Production of Healthy Clones

Cleaning process

Generation of clean stocks from infected varieties continued (Table 1). The frog skin disease singly or associated with bacterial blight were the two main infections cleaned by the use of thermotherapy followed by meristem culture. Including materials processed this year, 745 cassava varieties were rendered free of diseases over the last few years.

Important regional cassava cultivars were processed through the *in vitro* cycle, thermotherapy and meristem culture to improve their general vigor and yield. A list of the regional cultivars cleaned and delivered to the Cassava Program for testing is as follows:

Name	Source
Quilcace	Cauca
Popayan	Cauca
Secundina	Caribia (North Coast)
Satadovio	Cauca
Regional Amarilla	Cauca
Regional Morada	Cauca
Llanera	Carimagua
Valluna	Valle
Varejona	Caqueta
Venezuela Regional	Tolima
Blanca Mona	Media Luna (North Coast)
Venezuela Regional Rionegro	Rio Negro (Antioquia)
Colombiana	Rio Negro (Antioquia)
Chiroza	Caicedonia (Valle)

Attempts to clean several segregating lines from a new viral disease, called ET, by means of the techniques previously used successfully for the frog skin and the Caribbean mosaic diseases, resulted in very low cleaning rates. Work is underway with more stringent thermotherapy, both on infected stakes and on shoot tips *in vitro*, and chemotherapy treatments prior to the excision and culture of meristems.

A gradual integration of pathogen testing techniques with *in vitro* cleaning procedures was initiated this year.

Recovery of yield and vigor. The use of clean planting material, produced through *in vitro* techniques, from frog skin and Caribbean mosaic-diseased cultivars has resulted in very high yield increases (see "Thermotherapy" in the Tissue Culture Section of the Cassava Annual Report, 1982). A thesis research was initiated two years ago to find out

whether in vitro processing of cassava varieties without any apparent disease would result in increases of plant vigor and yield. Two varieties, Llanera and CMC 40, were processed through thermotherapy and meristem culture and grown in the field along with their conventionally propagated (stake control) counterparts. Stakes taken from these plants, and the controls were grown for a second year in the field. The results of the field and laboratory tests are now available.

(1) Compared to the stake propagated plants (control), the yield of roots and the amount of planting material increased dramatically following in vitro culture in both cultivars. Similarly, there was a clear net increase in the height of the stem prior to the formation of the first branching, i.e. flowering. This difference may account for the higher quantity and quality, i.e. vigor of the stakes that were obtained from the meristem-derived plants. The gains in yield and vigor continued to be manifiested during the second year of the field test but at a lower level than in the first year (Table 2). The magnitud of increments over the control were always higher in Llanera than in CMC 40. (Llanera represents the case of an old cassava cultivar that has lost preference among farmers due to gradually poorer yields. On the other hand, CMC 40 is known for its outstanding performance in recent years).

(2) In addition, the leaves of the meristem-derived plants of Llanera but not of CMC 40 became twice as long, narrower, and thicker than the control leaves. The increase in thickness of the meristem-derived leaves was only due to the formation of a thicker spongy mesophyll (Table 3).

(3) Although no changes in starch or sugar content in the roots were evident, the in vitro processed plants of Llanera had twice high cyanide content (HCN) and 4% more dry matter content in their roots than the control; however, no changes occurred in CMC 40 (Table 4).

The dramatic changes observed in yield, vigor and morphology are diagramatically represented in the Figure 1. A gradual accumulation of negative factors, e.g., latent pathogens, may possibly explain the changes described in Llanera; but these may not fully explain the response of CMC 40. Whether the in vitro state per se may have a residual effect on the regenerated plants, lasting for several years of field propagation, cannot be proved at this stage.

The "elimination or dilution of negative factors" effect can account for the increase in yield and amount of planting material obtained through meristem propagation. However, the changes in leaf morphology, late branching habit, and higher HCN content in the roots require additional explanation. Because the leaf length/width ratio appears to be under the control of a single gene in cassava, one may speculate that the factors in question may alter the expression of that gene to produce a wide-lobed leaf in their presence; dilution or elimination of such factors by means of meristem culture would then give rise to the narrow-lobed leaves. Such factors either move very slowly within the plant or require a minimum threshold titer to express the wide lobe syndrome. This can be inferred from the failure to reproduce the changes

in leaf form in reciprocal grafts, even after six months in the field; furthermore, the fact that second year plants still showed the narrow lobed leaves supports this concept. The increase in HCN content in Llanera may also result from a cleaning of the negative factors, as was reported for African mosaic. The extension of this experiment to a third and fourth year in the field should provide additional valuable data.

The possibility that narrow-lobed leaves, with a thicker spongy mesophyll, may confer to the cassava plant a higher photosynthetic efficiency will be evaluated. Symtomatically, the change in leaf shape was predominantly evident from the third to the sixth month in the field, the period within which the cassava plant produces most of its potential storage roots.

International Exchange of Germplasm

Distribution from CIAT

In 1983, a total of 104 cassava varieties were sent *in vitro* to 12 countries (Table 5) using procedures developed previously. The number of clones shipped per variety has been variable, 3 to 33 depending on the request.

Following recovery and propagation of the *in vitro* cultures in recipient institutions, clones have been moved to the field for testing in Mexico, Costa Rica, Cuba, Panama, Brazil, Malaysia, Thailand, and Indonesia.

This year, a set of 42 elite cassava varieties have been made available *in vitro* for distribution to institutions which solicit them. Every year, this group will be updated with new promising materials. The application of pathogen testing techniques should provide additional protection against the risks of disease dissemination.

Introduction to CIAT

The transfer of cassava germplasm to CIAT using meristem culture techniques continued. In collaboration with the International Board for Plant Genetic Resources (IBPGR) and the national programs of four countries, a total 524 cassava varieties were introduced *in vitro* to CIAT in 1983, as follows:

Source	Collaborating institutions	Country	No. varieties
Tarapoto, Chiclayo	INIPA, UNPRG	Peru	105
Sta. Catarina	IPAGRO/CENARGEN	Brazil	249
Eastern & Southern Paraguay	IAN, Caacupe	Paraguay	149
Corrientes	Inst. Bot. Nordeste	Argentina	20
		Total	503

With the exception of Argentina, the germplasm transferred to CIAT this year was gathered through collecting expeditions in 1981-82 with the collaboration of the IBPGR.

With the addition of the 1983 transfer, the total number of cassava varieties introduced to CIAT using *in vitro* techniques amounts to 1,348. With these, CIAT's cassava collection has increased to over 3,400 varieties.

The integration of *in vitro* techniques with conventional collection methods has resulted in the following scheme for the transfer of cassava germplasm: stem cuttings 0.3 - 0.5 length, obtained at the collection site are moved to a collection center (national program), located in the area of genetic variability where the collection takes place. Here, 5-10 stakes, 0.15 - 0.20 m in length, are cut from the stems, desinfested and planted both in sterilized soil contained in pots, and in the field. The pots are placed within a protective housing made of plastic or mesh. Following phytosanitary evaluations, meristem tip samples are taken from the potted plants and explanted in sterile culture media. (The pre-made media has been carried over from CIAT.) Normally, 3-6 test tubes are prepared with the meristem samples per variety and transferred to the germplasm center (CIAT). Here, *in vitro* micro-propagation, potting in a phytosanitary greenhouse, indexing, and finally field transplanting is carried out. Duplicate samples of the germplasm are maintained in the *in vitro* gene bank of cassava.

Wild Manihot species. Various constraints currently limit the adequate handling of wild *Manihot* germplasm: the availability of seeds and/or stem cuttings at the site of collection very frequently can be limited or nil. In addition, the seeds of wild species normally germinate very poorly (if at all) and the stakes are often difficult to establish in soil once they have been moved from their natural habitat. Therefore, *in vitro* methods for transfer and propagation of wild species becomes a valid alternative.

Both, meristem tip and embryo culture techniques have been studied this year in a collaborative project with the IBPGR and the national programs of Mexico, Brazil and Colombia.

While the wild *Manihot* species did not respond well to the meristem culture technique of cassava, recent results with embryo culture are quite promising for handling wild species. Plants of nine species have been regenerated *in vitro*. Pre-treatment of seeds with 60°C for two weeks and the inclusion of a high sucrose level in the medium have been beneficial. Microbial contamination of the seed was reduced with rigorous chemical desinfestation; however, microwave treatment though effective in desinfesting the seed reduced embryo germination.

Germplasm Conservation

As of this year over 2,000 cassava varieties, representing 58% of CIAT's germplasm collection, have been put into the *in vitro* gene bank (Table 6). The *in vitro* culture collection, five test tubes per variety, is maintained under reduced growth conditions, which result in one transfer to fresh medium every 18 to 24 months.

Minimim growth storage Research further extended the period between transfers of the cultures during storage. Previous work (see "Minimum Growth Conditions for Storage" in the Plant Tissue Section of Cassava Annual Report, 1982) showed the detrimental effect of temperatures lower than 20°C on the viability of cassava cultures stored at 1500-2000 lux of illumination. It was found this year that meristem-derived cultures could be maintained at temperatures lower than 20°C as long as the illumination were were kept low (100 to 500 lux). The viability of cultures stored for five months at 20°C day and 10°C night, was higher at 500 lux than at 1500 lux. At the higher illumination the cultures exhibited generalized bleaching which led to their death. Green tissues could be maintained even at 10°C day and night, if the illumination were lower than 200 lux; however, the viability of these cultures was drastically reduced following retrieval to a higher temperature and illumination. Work along these lines should soon provide the means to double the transfer period of the cultures.

Evaluation of phenotypic stability The reliability of an *in vitro* conservation system depends to a large extent on the maintenance of maximum phenotypic trueness in the materials during storage.

A study was initiated this year to evaluate the degree of stability of several cassava varieties stored *in vitro* for 12, 24, 48, 52, and 60 months. Sample cultures have been retrieved from the *in vitro* bank, micro-propagated, potted and transplanted to the field in experimentally designed plots, along with their stake-propagated counterparts (control). Both morphological parameters (through the use of a minimum set of descriptors) and agronomic criteria will be used to monitor the phenotype of the varieties. In addition, preliminary studies to develop electrophoretic finger printing techniques to characterize the materials has been initiated this year. Out of 20 enzyme systems, the following seven have been identified for use in the evaluation: , -esterase, glutamateoxaloacetate-transaminase, alcohol dehydrogenase, phosphogluco-isomerase, acid phosphatase, peroxidase and malic enzyme.

Cryogenic storage Research continues at the PRL, Saskatoon, Canada, in collaboration with CIAT and under IBPGR support, to develop liquid nitrogen storage of cassava meristems. Plants have been regenerated from cassava meristems stored in liquid nitrogen though still at variable and low rates. Further work should be addressed to improve regeneration rates, to test viability and phenotypic stability of the plants and finally to simplify procedures.

Table 1. Number of cassava varieties cleaned of diseases by meristem culture in 1983.

Diseases	Materials	No. varieties
Preventive cleaning[a]	M Col cvs.	28
Frog skin + CBB	M Col, M Mex, M Ecu, M Per, M PR cvs.	127
Frog skin	M Col, M Bra, M CR, M Dom, M Ecu, M Mex, M Per, M Ven cvs.	34
	Total	189

[a] Cultivars without apparent disease symptoms.

Table 2. Increase in yield and vigor of two cassava cultivars as a result of propagation by meristem culture. Measurements were made at harvest: 12 months (1st year) and at nine months (2nd year).

Cultivar	Parameter		Percent increase over control[a]	
			1st year[b]	2nd year[c]
Llanera	Fresh root yield		52.9	24.8
	Planting material		47.1	46.3
	Plant height	a.[d]	2.8	0.0
		b.	25.0	
	Height to 1st branching	a.	66.6	25.7
		b.	76.6	
CMC-40	Fresh root yield		42.8	28.7
	Planting material		18.2	22.7
	Plant height	a.	5.8	5.4
		b.	0.7	
	Height 1st branching	a.	15.4	14.4
		b.	19.1	

[a] Control was propagated only through stakes without meristem culture.

[b] 1st year at CIAT: plants derived directly from meristem cultures; Llanera 57 plants, CMC-40 30 plants.

[c] 2nd year at CIAT and ICA-Palmira: stakes obtained from the 1st year plants. 30 plants each variety.

[d] a and b: two sites in the plot.

Table 3. Changes in leaf morphology as a result of propagation by meristem culture.

Cultivar	Propagation	Ratio leaf[a] length/width	Total	Palisade	Spongy
Llanera	Stakes	6.50	120	70.0	30.0
	Meristems	12.25	140	69.5	47.0
CMC-40	Stakes	4.60	140	66.0	41.0
	Meristems	4.50	141	65.5	42.0

[a] Average of 10 plants per treatment, five months old, 5th expanded leaf.

[b] Average of five leaf measurements at the lobe's median transverse axis, 0.5 cm from the main vein.

Table 4. Changes in the content of dry matter, starch, sugar and high cyanide content (HCN) in the roots of two cassava cultivars as a result of meristem culture propagation.

Cultivar	Propagation method	Root sample	Percentage			ppm	
			Dry matter	Starch	Sugars	Total HCN	Free HCN
Llanera	Stake	Unpeeled	38.4	87	4.58	67	7
		Peeled	41.0	91	3.43	38	7
	Meristem	Unpeeled	42.1	90	3.12	96	14
		Peeled	42.4	90	3.65	77	11
CMC 40	Stake	Unpeeled	35.1	86	4.44	342	119
		Peeled	40.4	92	3.10	139	19
	Meristem	Unpeeled	35.9	87	4.73	203	76
		Peeled	40.4	88	3.48	136	15

Table 5. Distribution of cassava germplasm *in vitro* from CIAT to other countries in 1983.

Country	Institution	No. of varieties	No. clones per variety
Mexico	INIA	12	4
Panama	IDIAP	22	8
Trinidad & Tobago	Univ. West Indies	5	3
Honduras	Min. Agricultura	10	5
Brazil	CENARGEN/CNPMF	9	6
Ecuador	INIAP	8	33
Argentina	Est. Exp. Obispo Colombres	5	2
China[a]	SChATC	7	3
Philippines	Univ. Philippines	7	5
Indonesia	CRIFC, Bogor	5	8
France	INRA	6	7
U.S.A.	Epcot	6	5
	Univ. Minnesota	2	5
	Total	104	

[a] In addition, five wild *Manihot* spp. were shipped *in vitro* to China.

Table 6. No. of varieties, duration of storage, and frequency of transfers of cassava germplasm stored *in vitro* under limited growth conditions through December, 1983.

No. of varieties	Duration of storage (months)	X No. of transfers
1,106	0 - 12	0.0
145	13 - 18	0.6
287	19 - 24	1.0
367	25 - 36	1.5
103	37 - 48	2.3
9	49 - 66	2.8
2,017		

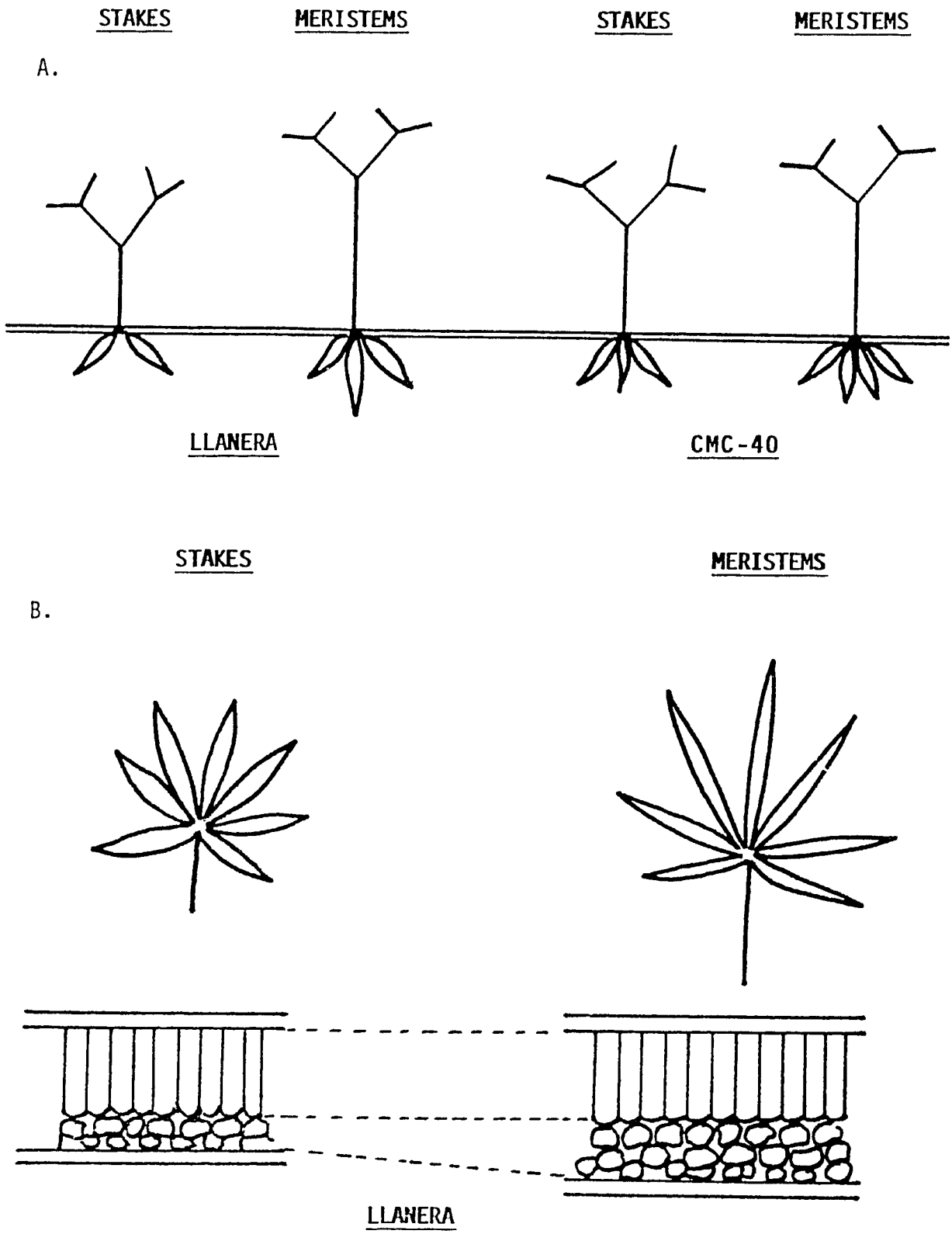


Figure 1. Diagrams representing the changes in plant and branching height (A) and leaf morphology (B) in two cassava cultivars as a result of propagation by meristem culture.

Cultural Practices

The Production of Planting Material in Cassava

There are several ways to propagate tropical root and tuber crops. Roots or root cuttings are used in yams (Dioscorea sp.), rhizomes in Cocoyams (Colocasia sp., Xanthosoma sp.), and both tubers and vines are used for planting material in sweet potato (Ipomsea batatas). In cassava, however, only stem cuttings are currently used to propagate the crop in any situation from subsistence to large commercial farming. As cassava stems age, leaves are abscised, but in each site of petiole abscission, an axillary bud develops providing a new growing point for the regeneration of a plant. The quantity and quality of stems and buds, their vigor and endurance under adverse soil and climatic conditions after planting is the result of both genetic factors and the management of mother plants before stake cutting. A careful evaluation, and, where possible, quantification of genetic and management influences on stake production was attempted in the past. It is the objective of this text to make researchers and extensionists aware of the results of this investigation and provide them with guidelines for further adaptive research and practical information useful in the initiation of scientifically oriented, effective cassava planting material production programs.

Genotypic Influences

The two varietal characteristics which potentially most affect stake production of a cassava genotype, are its general vigor and its branching habit. While overall vigor decides on the amount of top growth and consequently the number of stems available for stakes, the branching habit determines the availability of primary and secondary stems which are the principal parts used for planting material. In the case of a vigorously growing but early branching cultivar, there may actually be little stem material suitable for stake production since parts of the plant may be either too lignified or too young and stem lengths between one branching and the next are rather short. On the other hand, a less vigorously growing, late branching genotype may offer more stem material for stake production due to good primary and secondary stem lengths even if total top dry matter production is not very large. Thus, with the exception of drastically reduced vigor or extremely vigorous vegetative development, stake production may be relatively independent of total top growth.

An in-depth study of the growth habit, stake number and stake production efficiency of four contrasting cassava genotypes corroborated the previous observations. Total top growth at 12 months after planting was low with non-vigorous, late branching M Col 22, intermediate with two, more or less erect, vigorous hybrids (CM 516-7 and CM 849-1) and high with a very vigorous, early branching cultivar, M Mex 59 (Figure 1)

There were also large differences in the efficiency of the different genotypes to produce stakes, as measured by the stake production index (SPI = stake fresh weight over total top fresh weight multiplied by 100). The two erect growing genotypes (M Col 22 and CM

Previous Page Blank

849-1) showed greater efficiency than the non-erect genotype M Mex 59. The hybrid CM 516-7 which is also more or less erect has an enormous foliage retention capacity leading to a low SPI compared to CM 849-1 and M Col 22. With regard to the total number of stakes produced per plant, it is thus clear why M Col 22 with over 16% of its total top growth useful for stake production was able to produce almost as many stakes per plant as did M Mex 59 with only 12%, although the former produced only about half the total top growth of the latter. It can thus be concluded that there is a large difference among cultivars in their ability to produce planting material. This ability is, within certain limits, rather independent of total top growth but is influenced greatly by the distribution of the total top dry matter among parts not useful for stake production such as foliage and young, herbaceous branches as well as overly lignified stems, and stems suitable for stake production.

The ratio of suitable stem material to total top fresh weight is particularly high in cultivars with a late branching, erect growth habit since in these cultivars, primary and secondary stems mostly used for stake production make up a large proportion of total top growth. Thus, cultivars with the characteristics of high root yield are at the same time most efficient in stake production.

Climatic Environment and Soil

The vegetative growth of cassava is modified greatly by different climatic and soil conditions. A variety which shows fast and vigorous growth in a high temperature environment usually grows much slower and stays smaller under lower temperature conditions. Similarly, cassava growing on a highly fertile soil normally produces more stems and branches than when grown on soils with low fertility. Climatic factors may also have an influence on the flowering and branching habit of cassava and thus modify the growth habit, affecting the production of stem and branch material suitable for stake production.

The growth and stake production characteristics of cultivar M Col 22 were compared in three environments with large differences in climatic and soil conditions, making observations at all three sites when the plants were 10 months old. On the highly fertile mollisol at CIAT headquarters in Palmira, plants grew well but the intermediate temperature (annual average 24° C) limited top growth somewhat compared to the much hotter site Caribia (annual average 28°C) where soil is also fertile and thus total top growth was very heavy. However, in the hot and humid site of Caribia, branch and foliage growth not useful for planting material increased more than stem growth, resulting in a slightly lower plant efficiency to produce stakes (lower stake production index) and a small reduction in stake number per plant compared to the Palmira conditions (Figure 2).

At Media Luna, (despite a hot climate similar to that of Caribia), top growth of cassava was drastically reduced when grown on the white, sandy, low fertility soil of this site with a serious drought during part of the season. Plants had only small quantities of thin branch and foliage tissue. This lead to a high stake production efficiency but to a very low stake production in absolute terms. These data clearly

reveal the strong influence that climatic and soil environments can have on the cassava growth habit and stake yield. However, observations were made only at one plant age with no opportunity to observe how growth and stake production developed in different sites over a longer period of time and whether low productivity at an early stage might be overcome later. Additional research was, therefore, conducted with the same cultivar at two sites, Palmira and Media Luna, to follow stake production over 10 months of the plants' life span (Figure 3).

Data show that stake production followed a very different course at the two sites. At Media Luna, vegetative development was poor throughout the season with the exception at 14 months when the third rainy season improved stake production somewhat. However, the maximum production of two stakes per plant was never exceeded. On the other hand, stake production at Palmira increased steadily through 14 months and an adequate number (5-8 stakes per plant) was available at any time between 8 and 16 months.

These data emphasize the strong influence of environmental conditions on the production of planting material in cassava. Sites with optimum growing conditions may show high root yield potential not only because conditions are favorable for root production but also because a sustained production is feasible of high quality planting material in sufficient quantity. Where a site does not meet this requirement, not only will stake production be difficult but also root yields will be low. Where even a minimum number of good stakes cannot be obtained, a variety may eventually even disappear completely from the cultivation system.

Age of the Plant.

The effect of plant age as a determinant of planting material production in cassava is still largely unknown. For this reason, a study was carried out at CIAT, harvesting four genotypes at bimonthly intervals during a ten month period, 6-16 months after planting. Total top growth continued to increase in all four genotypes over the observation period, greatest amounts of stems and foliage being produced by M Mex 59 and the smallest amounts by M Col 22, the two hybrids CM 516-7 and CM 849-1 showing intermediate growth (Figure 4).

The Stake Production Index (SPI) indicating the efficiency with which cassava tops could be used in stake production, increased up to 12 months and declined thereafter. While this pattern was shown by M Col 22, CM 516-7 and CM 849-1 in a similar fashion, M Mex 59 reached maximum efficiency at eight months after which the SPI declined. The latter cultivar also showed the lowest SPI on the average whereas CM 849-1 had the highest stake production efficiency over the 10 month observation period (Figure 5). As a result of a continuously increasing top growth and an initial increase followed by a decrease in the SPI, the stake number per plant initially increased and then stagnated (Figure 6). The hybrid CM 849-1 which demonstrated outstanding stake production efficiency, also produced the greatest amount of stakes in absolute terms whereas the other three genotypes did not differ greatly in stake numbers produced per plant.

When both stake and root production are considered, under the experimental conditions, stake production efficiency and starch percentage in the roots (data not presented) showed optimum values at 12 and 10 months, respectively, whereas both stake and root production continued to increase beyond that age in 2 of 4 cultivars examined (Figure 7).

It may thus be concluded that stake production increases with plant age reaching an optimum in some cases but continuing to increase in others. There does not appear to be limiting maximum plant age for stake production. Stake production efficiency also increased with plant age under CIAT conditions showing an optimum at 12 months. The greatest increase in stake production efficiency occurred between 6 and 8 months, rising from low levels at six months to rather high levels at eight months which were not much different from those observed at later stages. Thus, it appears that under CIAT conditions, a minimum plant age for stake production of eight months should be reached. On the other hand, the hybrid CM 849-1 demonstrated that a very early stake and root production is possible with some cultivars. With only six months age, this hybrid reached a stake production of almost four stakes per plant and a stake production efficiency of over 10% together with a fresh root yield of 27.3 t/ha containing 37% starch. This shows that there are cassava clones with sufficient earliness to produce acceptable stake and root yields with less than the previously mentioned minimum age.

Tissue Age within the Plant

The stems resulting from the initial sprouts of the planting piece are called primary stems and represent the oldest tissue of the plant whereas secondary, tertiary etc. stems resulting from the branching process are formed later and represent younger tissue.

An experiment was conducted to evaluate the influence of tissue age (stakes from primary and secondary stems) on sprouting and yield of a subsequent cassava crops. There was a considerable difference in speed of sprouting among the stakes of different ages, stakes from the middle and lower part of the primary stems, i.e. the older stakes sprouting much faster and more vigorously than stakes from the upper portion of primary stems and from secondary stems, i.e. the younger stakes. While no difference existed between the four groups of stakes with regard to the percentage of the final stand at harvest, plant height or total top fresh weight, there was a large difference among commercial root weights, stakes from the secondary stems, i.e. the youngest stakes giving a significantly greater commercial root yield, than the oldest stakes (Table 1). The same tendency was observed with regard to total root yield, however, differences among treatments were not statistically significant.

Besides plant age per se, the age of tissue within the plant thus appears to influence the performance of the stakes in a subsequent crop. Old stakes from the lower and middle portion of primary stems are normally thick and have a large carbohydrate reserve. This leads to fast sprouting and vigorous early growth. Younger stakes, on the other

hand, show slower sprouting. However, with regard to root yield, younger stakes produce greater numbers of commercial roots per plant and higher commercial and total root yields. While this is not well understood, it seems possible that plants from younger stakes distribute more efficiently dry matter to the roots resulting in higher harvest indices and root yields.

Stake Length and Stake Position

The influence of these two factors on planting material production was tested using cultivar M Col 22 in trials conducted at Caribia, on the Colombian north coast. When stakes of 10, 20, 30 and 40 cm lengths were planted vertically at a 1 x 1 m spacing, small but significant differences were observed in early crop establishment, growth and development. Besides resulting in a slightly reduced stand, short stakes also produced significantly fewer primary stems, shorter plants at harvest and an overall lower top weight (Table 2). As a consequence of reduced vegetative development, a significantly lower stake number per plant and per hectare was obtained when planting was done with short stakes. On the other hand, mean stake weight was not affected, possibly as a result of the very strict, standarized stake selection procedure. Also, the stake production index was not altered by varying the stake length, the efficiency of the plant to produce stakes being approximately the same whether the crop had been raised with long or short stakes (Table 3). No significant differences between total fresh root yields were obtained in this trial highlighting the ability of cassava to compensate under good growing conditions.

It may be concluded from these results that the use of planting materials too small in size can noticeably reduce establishment and vegetative development of the subsequent crop, thus affecting stake production significantly. Stakes slightly longer than those recommended for commercial root production (20 cm) may be best to ensure good vegetative growth and high stake production. Furthermore, the use of longer sized stakes is not likely to be detrimental to root production.

Under similar conditions, stakes of 20 cm length were planted in a horizontal, inclined and vertical position, and the establishment, growth, stake and root production of the different treatments were recorded. In this case, only root production showed significant differences between planting positions; vertically planted cassava yielded 22% more than horizontally planted cassava. Although parameters of vegetative growth and stake production were not significantly different, appreciable numerical differences were found with regard to stake number and stake production efficiency, being clearly in favor of the vertical planting position (Tables 4, 5). These data suggest that vertical planting of stakes results in somewhat taller plants with heavier tops than the horizontal planting. Also, the efficiency of the plant to produce stakes appears favorably influenced by the vertical planting. These factors together account for a greater stake number per plant and per hectare in vertical as opposed to horizontal planting.

Plant Population in a First Planting and a Ratoon crop

When the original cassava planting piece is placed in the ground vertically, it will produce 1-2, and in rare cases three or more sprouts which form the primary stems. In first plantings, the number of sprouts seems to be determined by varietal characteristics as well as the vigor of individual stakes and the condition of buds. Early interference among cassava plants affecting sprout number appears unlikely due to wide spaces between plants to accommodate future growth, even if higher than normal planting densities are used. At later growth stages, however, higher planting densities giving more primary stems per unit area lead to increased competition among these stems. As a result, individual stems stay thinner and a lower production of stakes per plant with adequate size, maturity and bud number is obtained (Figure 8A). On the other hand, higher planting densities increase the total number of plants per unit area sufficiently to more than compensate for the decrease in number of stakes per plant. In the end, higher planting densities do increase the total amount of stakes produced per unit areas, although the mean stake fresh weight is somewhat adversely affected (Figure 8B). Similar experiences with the use of increased planting densities for the production of quality planting material in cassava have been reported from India.

When a cassava crop is ratooned, i.e. roots are not harvested and resprouting is allowed after stem cutting, many more sprouts per plant develop than in the first planting. This leads to an excessive competition among stems most of which stay thin and never reach the degree of maturity necessary for good quality stakes. Therefore, in a ratoon crop, the sprout number needs to be reduced manually, mechanically or by other means to allow a normal development of the remaining sprouts.

In a trial with planting densities ranging from 5,000 to 40,000 plants/ha, plants were thinned to three sprouts per plant, two months after the first stake harvest was taken, and produced a ratoon crop, taking the second stake harvest 12 months after the first cut.

In general, second harvest data corroborate the findings of the first harvest; the stake numbers per plant decreased and stake numbers per hectare increased as plant population increased. However, a slight difference was observed in the second crop in comparison to the first: with sprout number per plant at a much higher level in the second than the first crop (even after thinning), competition was higher in the second crop, particularly at higher plant populations. This lead to sprout mortality and a reduction of the number of primary stems per plant at the higher plant population (20 and 40 x 10^3 plants/ha), a phenomenom not observed at the generally lower sprout number level in the first crop (Figure 9A). As a result, stake numbers per hectare, which were higher in the second than in the first crop at planting densities of 5, 10 and 20 x 10^3 plants/ha, declined noticeably at 40 x 10^3 plants/ha in the second crop whereas they had reached their greatest number at this high plant population in the first crop (Figure 9B).

From this data it may be concluded that to obtain large stake numbers per unit area, planting densities of up to 40 x 10^3 plants/ha may be used, however, if a crop with such a high plant population is ratooned for further stake harvests sprouts must be thinned down to 1-2 sprouts/plant. This ensures normal development of the remaining stems and an abundant stake production of good quality.

If, on the other hand, an increased combined stake and root harvest is desired, densities of around 20 x 10^3 plants/ha may be preferable to avoid a severe reduction in root size while still reaching a stake production which is significantly greater than that obtained with normal planting densities. To date there is no information comparing the performance of stakes from high density to low density plantings. However, in the light of results discussed in relation to tissue age within the plant, the use of somewhat thinner, lower weight stakes coming from high density plantings should not be detrimental to root production in subsequent crops, if agronomic growing conditions are adequate.

Spatial Arrangement and Intercropping

The way in which cassava plants are arranged in the field, at equal distances on all sides in a square planting or in rectangular arrangements with large distances between rows and short ones between plants, can influence top growth and stake production. Spatial arrangement is often modified when other crops are grown in association with cassava. Intercropping *per* se influences the vegetative development of cassava which is normally reduced due to the competition imposed by the intercrop. The effect of spatial arrangement and intercropping on planting material production was examined in the field using the erect growing cultivar M Ven 77 in three planting arrangements - 1 x 1 m, 1.4 x 0.7 m, and 1.8 x 0.55 m, growing cassava as a solo crop and intercropped with cowpea.

When cassava was grown as a solo crop, a change in spatial arrangement from square to rectangular did not produce any important change in either plant height or number of primary stems per plant (Table 6). While total top weight was slightly reduced it was mostly tissue not suitable for stake production (such as leaves, petioles and herbaceous, young stems). This lead to a small increase in the efficiency of plants to produce stakes as well as stake production itself.

A different situation was observed in cassava intercropped with cowpea. As expected, intercropping reduced top growth of cassava significantly as seen by a lower plant height at harvest and an overall lower top weight. This resulted in a lower number of stakes per plant in intercropped as compared to solo cropped cassava, even though the stake production efficiency increased slightly because the weight of those vegetative plant parts not suitable for stake production was more affected than the weight of stems useful for stake production.

However, within the intercropping system, the competitive effect on cassava was highly dependent on the spatial planting arrangement

adopted. It has been shown that in an intercropping situation, changing the square planting arrangement of cassava to a rectangular arrangement can increase the competitiveness of cassava markedly bringing about a better competitive balance between cassava and the intercrop. The use of the rectangular planting pattern in this trial alleviated the competitive pressure on cassava and improved top growth as demonstrated by taller plants with heavier tops. This in turn resulted in more stakes per plant while at the same time a slight increase in stake production efficiency was observed. It may thus be concluded that single row cassava grown in a pure stand does not suffer a fundamental change in its stake production potential when a spatial arrangement change from square to rectangular and planting density are maintained.

Neither in this nor in other trials was a significant negative or positive effect observed of the rectangular planting pattern on stake production. On the other hand, when cassava is grown in association with an aggressive competitor such as cowpea, a planting pattern which minimizes intercrop competition such as the rectangular pattern used in this experiment can be decisive in maintaining an adequate level of vegetative growth and stake production in cassava.

Plant Nutrition

When cassava grows in a beneficial climate on a soil with good fertility, vegetative growth and stake production are only limited by varietal characteristics such as growth habit and vigor. However, these optimal conditions are seldom encountered in a real production situation where soil fertility may limit growth of cassava drastically and inhibit the production of the planting material necessary for sustained crop production.

On a low fertility soil in Quilichao, five cassava cultivars and one hybrid were grown without fertilizer and with 150, 132, 125 and 10 kg/ha of N, P, K and Zn respectively. With fertilizer, both the number of stakes per plant and the stake weight, increased noticeably, stake number in one case showing a 100% increase (M Col 1684). Even the hybrid which did not produce more stakes when fertilized, showed a clear increase in stake weight when fertilizer was applied (Table 7). These figures show how decisive good plant nutrition can be for the production of quality planting material in sufficient quantity.

A more detailed analysis of the effect of single elements on stake production was also undertaken, applying varying levels of N, P, and K to cassava and measuring parameters of vegetative growth as well as stake and root production.

As expected, increased N applications promoted the formation of stems and foliage (total top weight) which almost doubled in weight when the 300 level was compared with the zero N level (Table 8). However, stake number per plant was only slightly increased up to 150 kg N/ha and showed a decline at 300 kg N/ha. Similar to stake number per plant, the stake production efficiency increased from 50 to 150 kg N/ha and decreased when more N was applied. No such variation of the above parameters was observed as a response to K fertilization. Total top

weight, stake number per plant and the stake production index were stable across all K levels showing that K does not normally modify strongly the vegetative growth of cassava, even on a soil without very high levels of exchangeable K (Table 9).

The trial with P was conducted on the low-P soil of Quilichao, where P application stimulated vegetative growth, stake and root production in a similar manner as did N on the low-N site of Caribia.

Data from these experiments show that applications of N and P up to intermediate levels have a positive influence on stake yield whereas K appears to have very little influence on either efficiency or quantity of stake production. The reason for this positive influence of N and P is that the proportion of stems useful for stake production balances favorably with total top growth as long as growth is only supported by good natural soil fertility or stimulated slightly by low to intermediate fertilization. On the other hand, at very high rates of applied nutrients, the efficiency of the plant to provide propagative material diminishes due to higher foliage production, a higher proportion of thinner branches with longer internodes leading to stakes with less than the minimum of five buds per 20 cm stake (which is recommended to ensure plant establishment).

Under limited soil fertility conditions, the shift in top growth is promoted first of all by N, or, if the soil is low in available P, by P whereas K appears to have a smaller influence. On the other hand, the high stake production efficiency observed in all three trials at the zero level may be explained by the lesser elongation of stems without the applied nutrient which selected for a higher proportion of the entire top as planting material with adequate bud number and the production of less foliage, petioles and thin branches.

It was also suspected that the nutritional level under which mother plants are raised influenced the nutritional status of the stakes harvested from these plants and their performance in the subsequent crop. Therefore, stakes were harvested from the previous trials, keeping the planting material obtained in the different N, P and K levels separate. These materials were then planted at the same site where they were produced, without application of any fertilizer nutrient.

Stakes from mother plants that had received N rates between 0 an 300 kg/ha, did not show a clear influence of N rates on N concentrations in the stakes whereas P, Ca and Zn concentrations showed a significant reduction when more N was applied (Table 10). The same tendency toward decline was noted with K and Mg concentrations, however, this was not significant. Looking at cassava growth data (Table 8) it is clear that the principle of dilution (which normally acts when vegetative plant growth is stimulated more than nutrient uptake) was responsible for this reduction in the concentration of some of the elements in this case since total vegetative growth was increased by 77%, when the 0 level was compared with the 300 N level. Also, there may have been a shift in the quality of cassava tissue from a more lignified to a more herbaceous, tender condition. These two reasons together may have led to a higher water and a lower mineral element concentration in the stakes as a

result of higher N application to mother plants. However, cassava plant height, top weight and root yield obtained with the crop grown from these stakes was in no way affected by this condition, as shown in the previously mentioned figures (Table 11).

In a simultaneous trial with K levels ranging from 0 to 252 kg/ha, stakes did show an increase in K concentration from 0.73 to 0.95% but this increase was not significant. No other element was affected in any noticeable proportion nor was vegetative growth or root yield of the crop grown from these stakes.

In contrast to the results obtained with N and K, a strong carry-over effect of mother plant nutritional status into the following crop by means of planting material was found with P fertilization. A cassava crop of hybrid CM 523-7 was raised on the low P soil of CIAT-Quilichao and P rates of 0, 44, 132 and 264 kg/ha were applied as triple superphosphate (TSP) at planting. Stakes from these different treatments were harvested separately and planted in a uniform field without P fertilization. At planting, stake samples were taken and analyzed for P. Results show that P fertilization applied to mother plants significantly increased P concentration in the stakes from 0.07% with 0 P to 0.14% with 264 P.

Initial growth of plants raised from stakes with high P concentration was visibly more vigorous than that of plants raised from stakes with low P concentration, the latter showing P deficiency symptoms early on. The positive response of the crop to P fertilization of the mother plants was still observable at the end of the growth cycle when plant height, total top weight, number of commercial roots per plant and total root yield all showed a more or less positive reaction to P reserves in the stakes, root yield parameters reflecting the advantage of high P stakes most clearly (Table 12),

In order to demonstrate that differences in the stake P status and not soil variation had caused this yield response, correlations were calculated between cassava root yield and both soil P at harvest and stake P concentration at planting. The correlation between root yield and soil P ($r = 0.25^{n.s.}$) shows that variation in root yield could not be explained by differences in soil P and correlations with other soil parameters such as Al ($r = 0.18^{n.s.}$) or the pH ($r = -0.13^{n.s.}$) were also low and nonsignificant. On the other hand, stake P concentration was closely related to cassava root yield, explaining almost 50% of the yield variability (Figure 10). These data suggest that P nutrition of mother plants could play an important role in the production of high quality stakes, in particular if these stakes are to be planted on acid, low P soils which are frequently found in the tropics.

Plant Protection

All types of pests, i.e. diseases, insects and weeds may be detrimental to the production of planting material in cassava. In the case of diseases and insects the concern is twofold since both can not only reduce the production of stakes, they can also be transmitted from mother plants to new crops resulting in a high risk for productivity.

Weeds which are among the agronomic aspects discussed in this text, compete with cassava for light, nutrients and water, growth depression in cassava being particularly strong when competition occurs at early growth stages.

A direct response of cassava to different weed control levels during the first two months of growth was observed in a trial conducted at Media Luna, on the Colombian north coast. According to the weed control efficiency of different systems, products and doses, there were varying levels of competition between weeds and cassava, the lower the control percentage 50 days after application, the higher the competitive effect, reflected by a reduction in total top fresh weight as weed control percentage decreased. Stake production per plant was proportional to total top fresh weight. Uncontrolled weeds reduced top growth to a very low level and under these conditions, only every third plant produced one stake of acceptable size and quality. On the other hand, without competition in the hand weeded treatment, almost six stakes per plant were obtained. The mean stake fresh weight was rather constant, mainly as a result of the uniform selection criteria (Table 13). These data suggest that with regard to weeds, the effect on cassava planting material production is less complex than with diseases and insects since there is only a direct influence and no stake-transmission of the problem occurs. Data presented here show that stake and root production is affected by deficient weed control in similar proportions. It is therefore of dual interest to maintain a good control level of this pest when both root and stake production are to be optimized.

Table 1. Effect of stake age within the plant on sprouting, growth and root yield of a subsequent crop.

Stake age and origen	Final sprouting (%)	Plant height at harvest (cm)	Total Fresh Weight		
			Total tops (t/ha)	Total roots (t/ha)	Commercial roots (t/ha)
Very old lower part primary stem	100 a*	234 a	34.3 a	15.9 a	11.2 b
Old middle part primary stem	100 a	239 a	32.3 a	16.7 a	12.0 ab
Intermediate upper part primary stem	100 a	241 a	32.9 a	17.5 a	12.3 ab
Young lower part secondary stem	100 a	240 a	32.9 a	21.3 a	16.9 a

* Means in the same column followed by the same letter(s) not significantly different at P = 0.05, according to Duncan's multiple range test.

Table 2. Effect of stake length on crop establishment, and growth and development parameters in cassava M Col 22, at Caribia, 1983.

Stake length cm	Crop stand %	No. of primary stems/plant	Plant height cm	Total top fresh weight t/ha	Total root fresh weight t/ha
10	83 b*	1.4 c	293 b	31.9 b	26.6 a
20	91 ab	2.1 b	318 ab	33.7 b	25.5 a
30	97 ab	2.6 a	336 a	45.0 a	26.5 a
40	99 a	2.8 a	323 a	46.4 a	28.2 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05.

Table 3. Effect of stake length used for mother plant establishment on stake number, mean stake weight and stake production efficiency of M Col 22 at Caribia, 1983.

Stake length cm	Stake number		Mean stake fresh weight (g)	Stake production index (%)
	Per plant	Per ha		
10	5.0 b*	42.268 c	101 a	13.9 a
20	5.3 b	48.468 bc	99 a	14.5 a
30	6.3 ab	61.000 ab	100 a	13.5 a
40	7.4 a	72.600 a	98 a	15.4 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05.

Table 4. Effect of the planting position of stakes on crop establishment, and growth and development parameters in cassava M Col 22 at Caribia, 1983.

Planting position	Crop stand (%)	No. of primary stems/plant	Plant height (cm)	Total top fresh weight t/ha	Total root fresh weight t/ha
Horizontal	95 a*	1.7 a	278 a	30.0 a	26.1 b
Inclined	93 a	1.6 a	277 a	34.1 a	30.1 a
Vertical	93 a	1.7 a	288 a	32.7 a	31.9 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05.

Table 5. Effect of the planting position of stakes used for mother plant establishment on stake number, mean stake weight and stake production efficiency of M Col 22, at Caribia, 1983.

Planting position	Stake number		Mean stake fresh weight (g)	Stake production index (%)
	Per plant	Per ha		
Horizontal	5.4 a*	51.268 a	90 a	15.7 a
Inclined	7.0 a	65.400 a	87 a	17.1 a
Vertical	7.2 a	66.868 a	87 a	18.0 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05.

Table 6. Effect of spatial arrangement of M Ven 77 on planting material production under solo crop and intercrop conditions, at Quilichao, 1982.

Planting arrangement	Plant height (cm)	No. of stems per plant	Total top weight t/ha	No. of stakes per plant	Stake production index
Solo crop					
1.0 x 1.0 m	229 a	2.1 a	28.6 a	4.8 a	10.3 a
1.4 x 0.7 m	232 a	2.0 a	29.0 a	4.9 a	11.7 a
1.8 x 0.55 m	226 a	2.2 a	27.0 a	5.2 a	12.8 a
Intercrop					
1.0 x 1.0 m	182 a	2.2 a	14.5 a	3.5 a	13.3 a
1.4 x 0.7 m	185 a	2.2 a	14.9 a	3.3 a	12.1 a
1.8 x 0.55 m	200 a	2.2 a	18.8 a	4.4 a	14.0 a
Cultivation system (average of arrangement)					
Solo crop	229 a	2.1 a	28.2 a	5.0 a	11.6 a
Intercrop	189 b	2.2 a	16.1 b	3.7 a	13.1 a

Table 7. The effect of fertilization and genotype on stake production in cassava grown on an inceptisol (typic dystropept) of low fertility in CIAT-Quilichao.

Variety or hybrid	Fertilizer level	No. of stakes/plant	Mean stake fresh weight (g)
M Mex 59	without	6.3	58
	with [a]	9.4	68
M Ven 218	without	8.9	67
	with	11.3	70
M Col 638	without	4.9	46
	with	6.7	53
M Col 22	without	5.2	57
	with	6.2	59
M Col 1684	without	4.2	53
	with	8.4	63
CM 91-3	without	4.9	46
	with	4.4	61
LSD 5% varieties or hybrids		2.1	15
LSD 5% fertilization		1.1	6

a. Complete fertilization consisted of 0.5 t/ha dolomitic lime and 150, 132, 125 and 10 kg/ha of N, P, K and Zn, respectively.

Table 8. The influence of N fertilization on quantity and efficiency of stake production and on other growth and yield parameters,

N level (kg/ha)	Stakes/plant	Stake production index (%)	Total fresh weight Tops (t/ha)	Total fresh weight Roots (t/ha)	Harvest index (%)
0	3.9 ab*	8.5 a	26.5 c	28.5 b	52 ab
50	3.1 b	5.6 a	30.1 bc	33.0 ab	52 ab
100	3.3 ab	7.5 a	28.9 bc	39.0 ab	57 a
150	5.3 a	8.0 a	40.1 ab	40.6 a	50 ab
300	2.7 b	4.0 a	46.9 a	41.3 a	47 b

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05 according to Duncan's multiple range test.

Table 9. The influence of K fertilization on quantity and efficiency of stake production and on other growth and yield parameters.

K level (kg/ha)	Stakes/plant	Stake production index (%)	Total fresh weight Tops (t/ha)	Total fresh weight Roots (t/ha)	Harvest index (%)
0	3.8 a*	7.6 a	29.3 a	38.8 a	57 a
42	3.4 a	7.8 a	25.2 a	37.5 a	59 a
83	3.6 a	7.6 a	29.4 a	37.4 a	57 a
125	3.8 a	7.3 a	29.0 a	40.3 a	58 a
250	4.0 a	7.5 a	27.2 a	40.9 a	60 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05, according to Duncan's multiple range test.

Table 10. Effect of N levels applied to mother plants on the concentration of the elements in stakes harvested from these plants.

N level kg/ha	Concentration in stake (DM)[a.] (%)					Zn (ppm)
	N	P	K	Ca	Mg	
0	0.67 a*	0.36 a	1.17 a	1.23 a	0.38 a	46 a
50	0.65 a	0.29 abc	1.02 a	1.14 ab	0.35 a	31 b
100	0.64 a	0 31 ab	0.95 a	0.92 b	0.32 a	33 b
150	0.60 a	0.24 bc	0.92 a	1.02 ab	0.35 a	25 b
300	0.75 a	0.23 c	0.98 a	0.89 b	0.28 a	27 b

a. DM = Dry Matter

* Means in the same column followd by the same letter(s) are not significantly different at P = 0.05.

Table 11. Effect of N levels applied to mother plants on the growth and yield performance of a cassava crop grown from stakes on these plants.

N application to previous crop kg/ha	Plant height (cm)	Total top weight (kg/plant)	Total root yield (t/ha)
0	251 a*	3.16 a	34.3 a
50	243 a	2.97 a	31.5 a
100	256 a	3.06 a	32.4 a
150	242 a	2.76 a	31.0 a
300	235 a	2.66 a	33.5 a

* Figures followed by the same letter(s) are not significantly different at 0 = 0.05 of the Duncan multiple range test.

Table 12. The effect of P nutrition of cassava mother plants on stake P concentration, and on growth and yield parameters of the subsequent crop.

P level kg/ha	P in stakes (%)	Plant height at harvest (cm)	Total top weight (t/ha)	Number of commercial roots per plant	Total fresh root yield t/ha
0	0.08 c*	224 b	15/2 a	5.0 c	26.3 b
44	0.10 b	236 a	17.2 a	6.0 b	32.4 a
132	0.13 a	231 ab	15.7 a	6.1 b	33.0 a
264	0.14 a	231 ab	17.9 a	7.0 a	34.8 a

* Means in the same column followed by the same letter(s) are not significantly different at P = 0.05.

Table 13. The effect of weed competion on growth and stake production in cassava.

Control systems Products - Doses[b]	Weed control 59 DAA[a] (%)	Stakes/plant	Mean stake Fresh weight (g)	Total fresh weights Tops (t/ha)	Total fresh weights Roots (t/ha)
Frequent manual control	100	5.9 a*	70 a	18.8 a	28.4 a
Oxifluorfen 4 lt/ha	70	4.1 a	71 a	17.4 ab	24.6 ab
Oxifluorfen 2 lt/ha	67	3.5 ab	64 a	14.3 ab	22.8 ab
Diuron + Alachlor 1 kg + 2 lt/ha	62	4.9 a	63 a	16.7 ab	19.2 b
Oxifluorfen 1 lt/ha	51	3.3 ab	63 a	13.8 ab	21.9 ab
Oxadiazon 2 lt/ha	30	1.1 bc	69 a	9.4 bc	16.9 b
No weed control	0	0.3 c	90 a	2.6 c	3.5 c

a. DAA = Days after aplication.

b. Amounts in liters or kilograms of commercial product per hectare.

* Means in the same column followed by the same letter are not significantly different at P = 0.05.

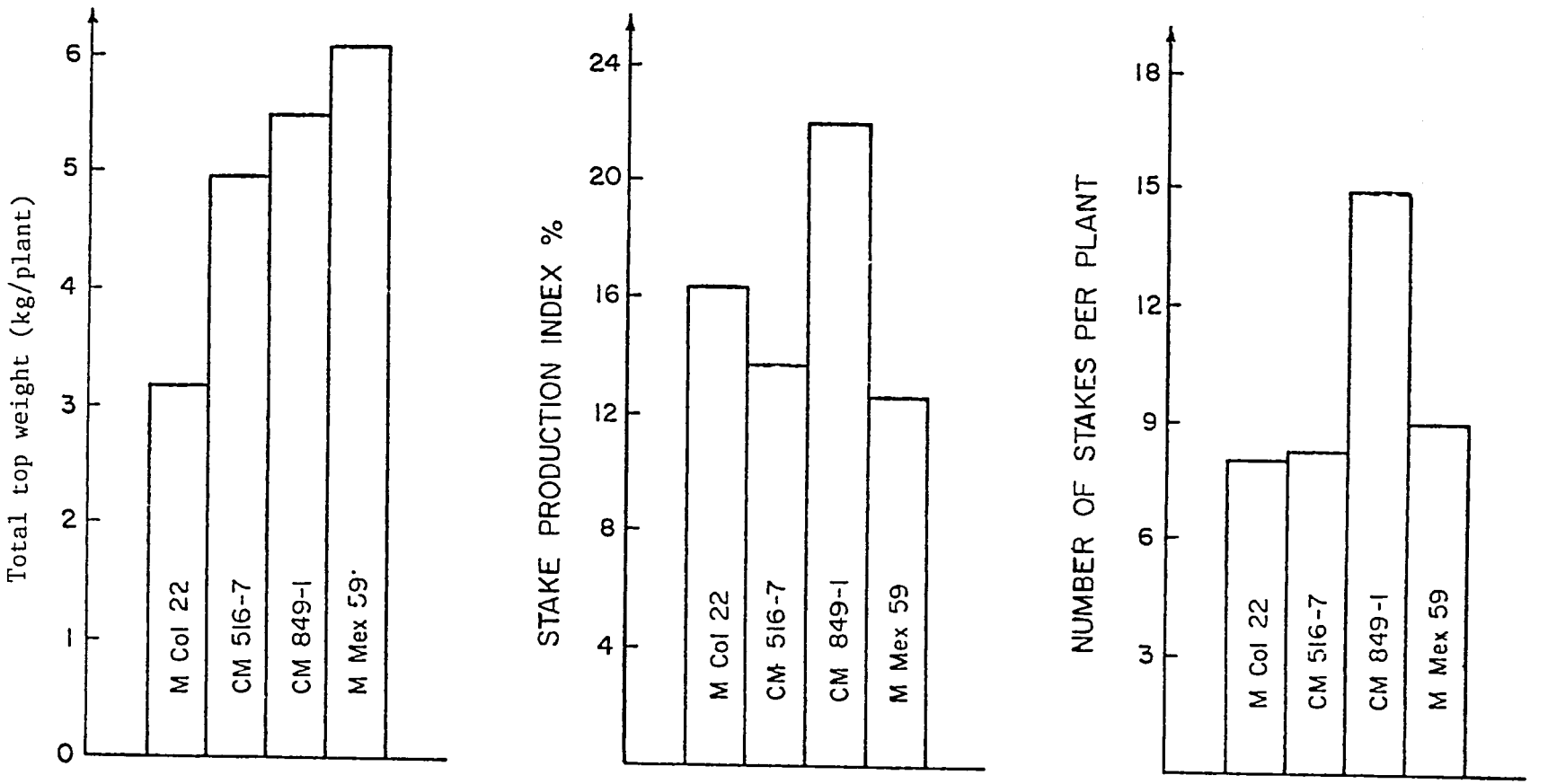


Figure 1. Total top growth, stake production index and total number of stakes per plant of four contrasting cassava genotypes at 12 months after planting in CIAT- Palmira.

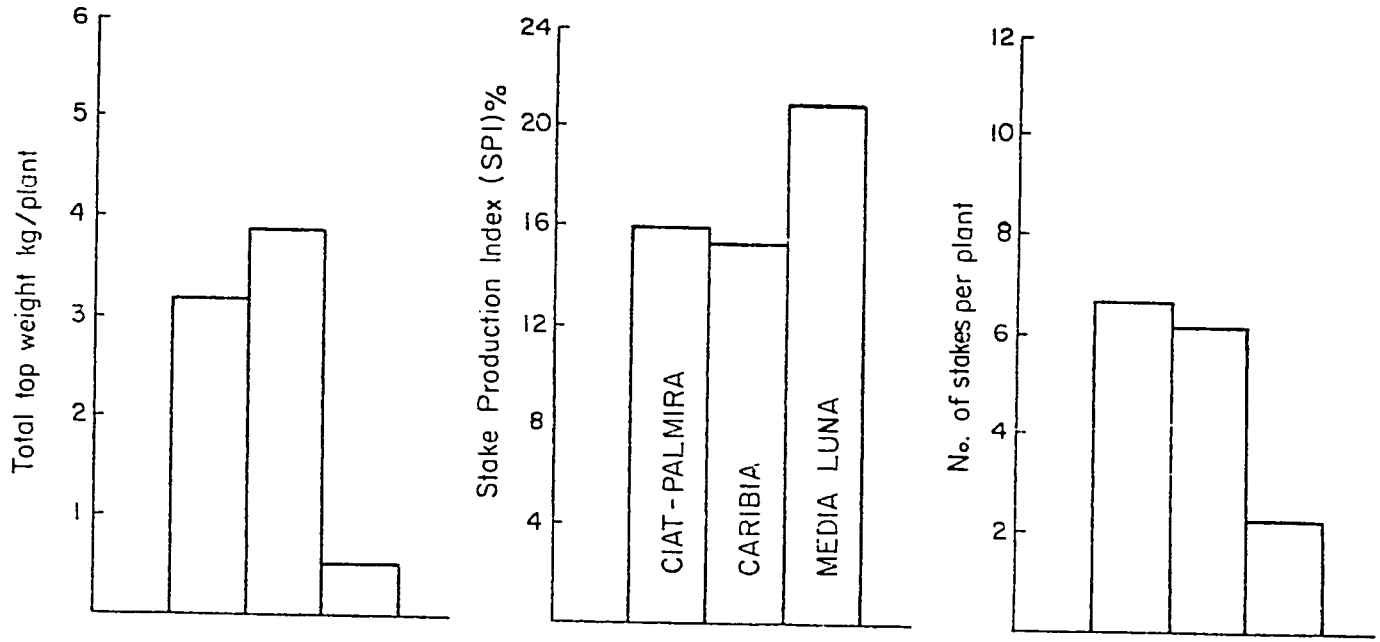


Figure 2. Total top weight, stake production index and number of stakes per plant of 10 month old cassava M Col 22 as influenced by different climatic and soil conditions.

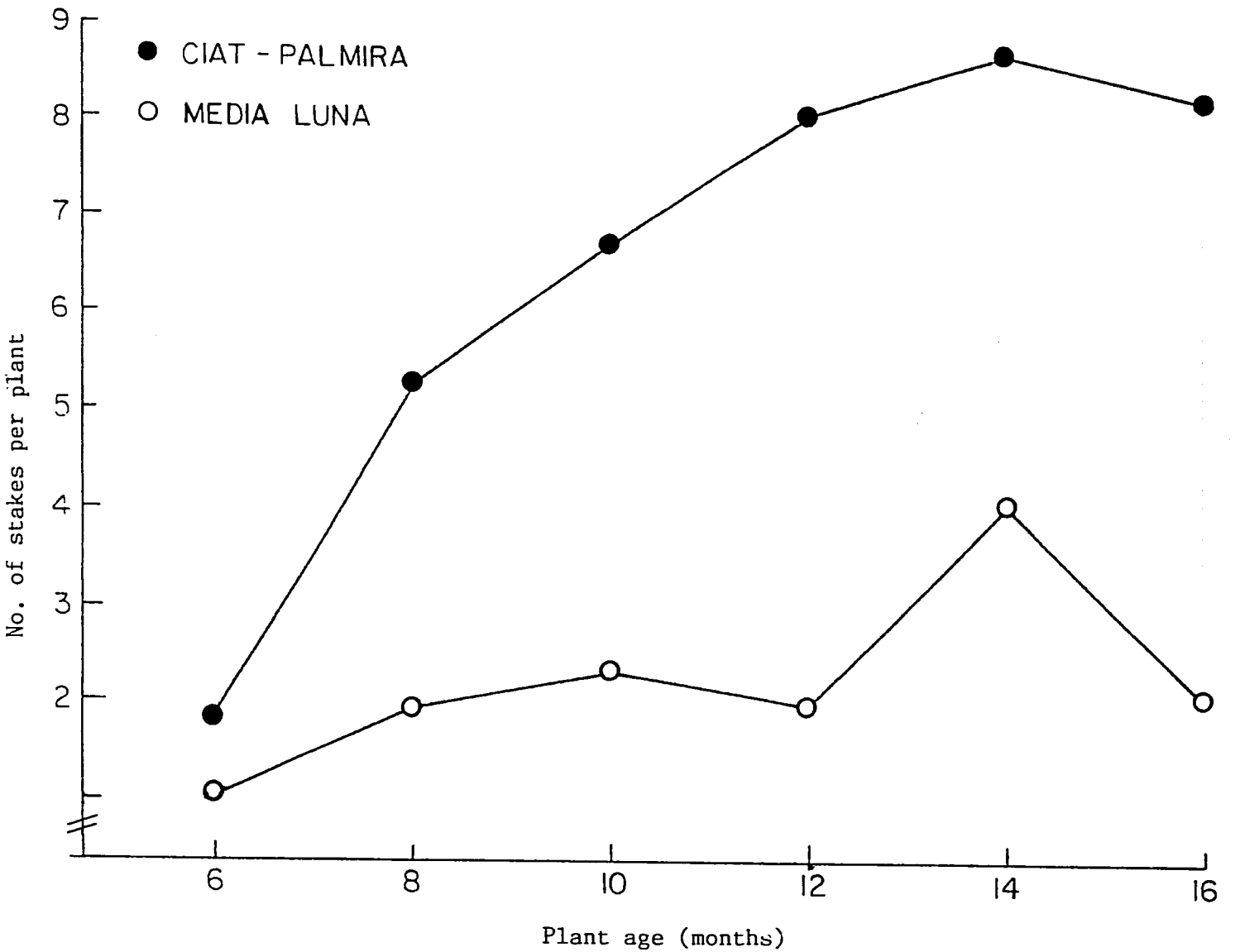


Figure 3. The effect of plant age of M Col 22 on stake production in two environments.

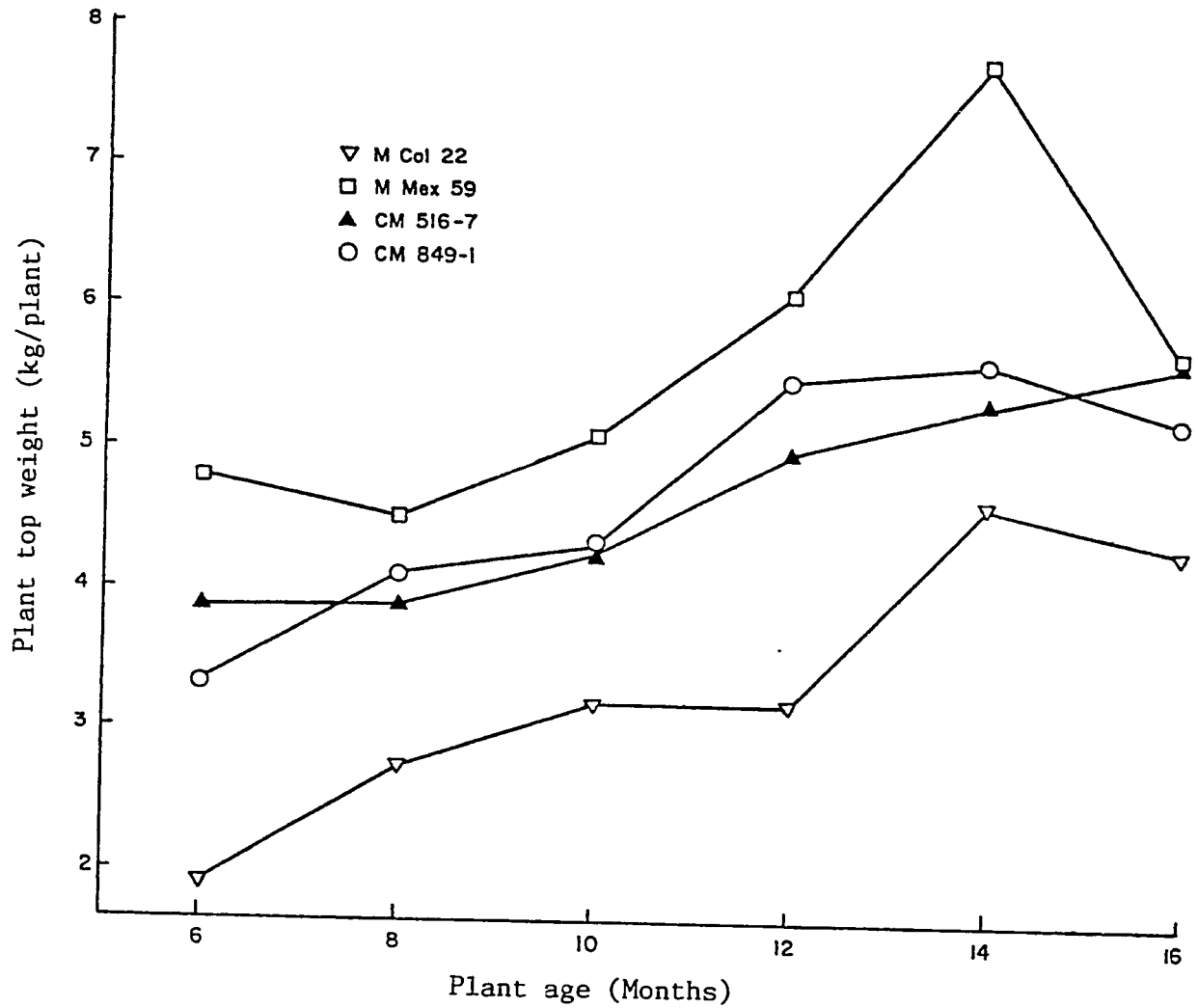


Figure 4. The effect of plant age of four cassava cultivars on total top growth at CIAT- Palmira

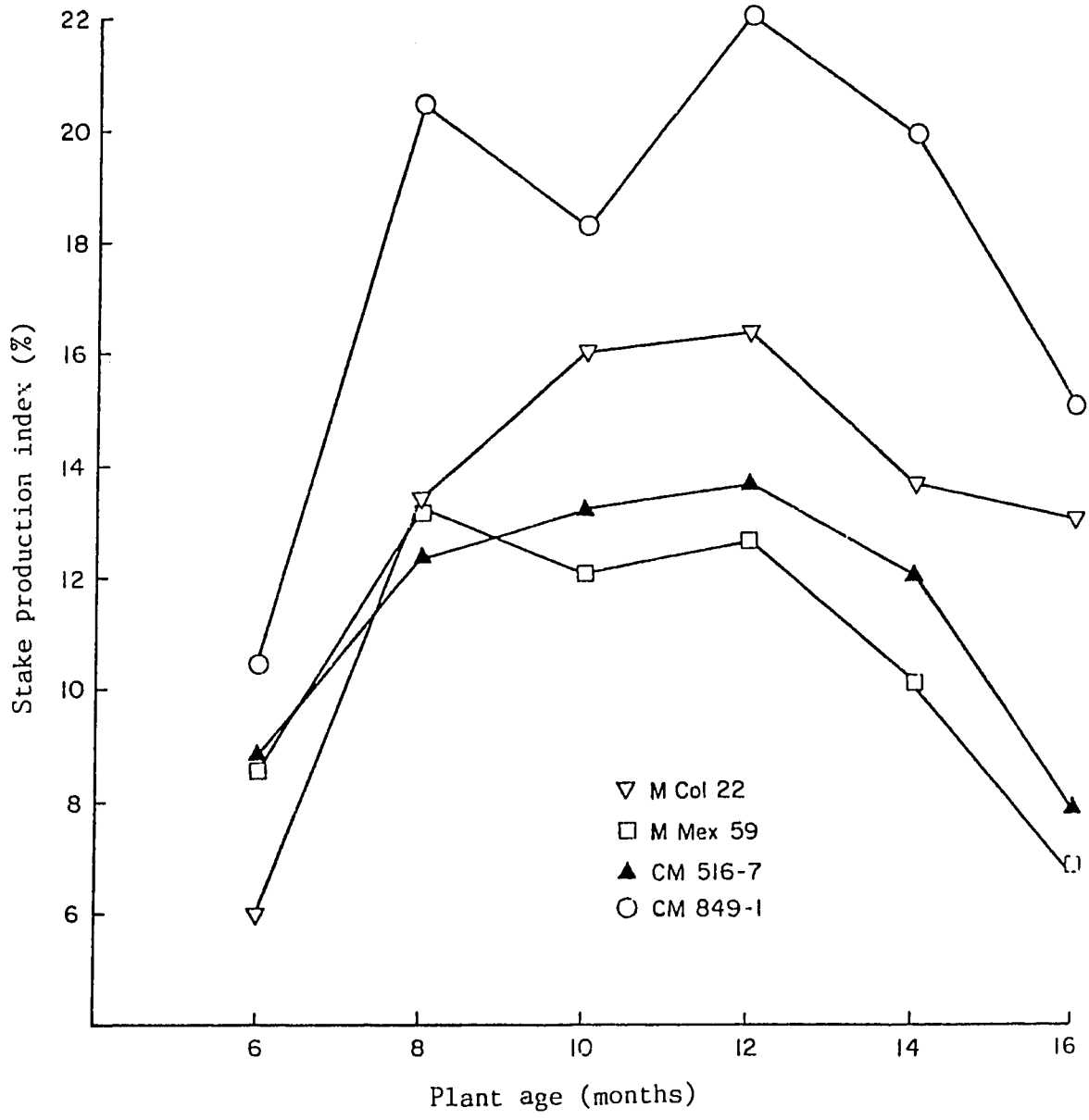


Figure 5. The effect of plant age of four cassava cultivars on the stake production index (SPI) (stake fresh weight over total top fresh weight x 100) at CIAT- Palmira.

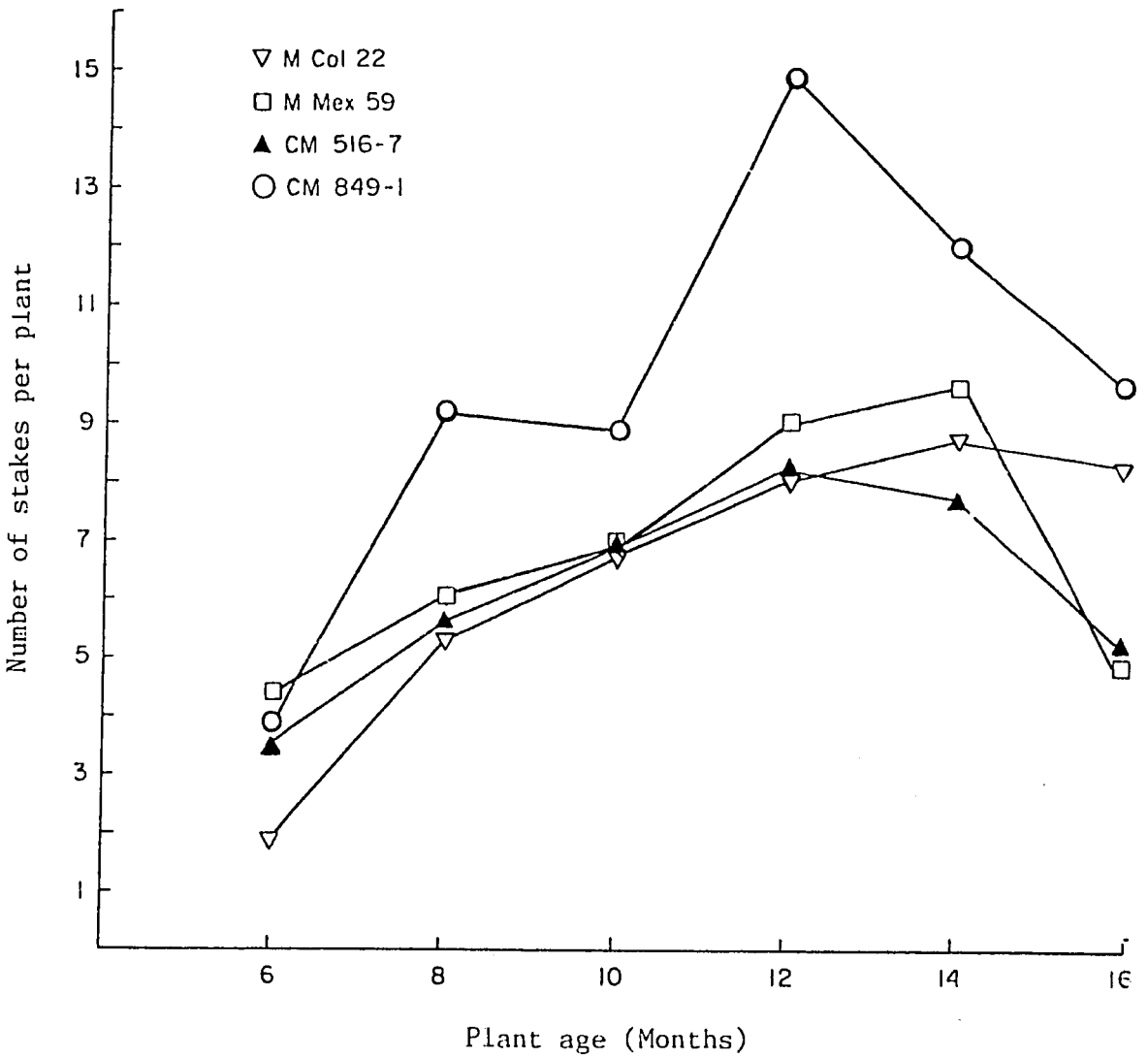


Figure 6. The effect of plant age of four cassava cultivars on stake production per plant at CIAT- Palmira.

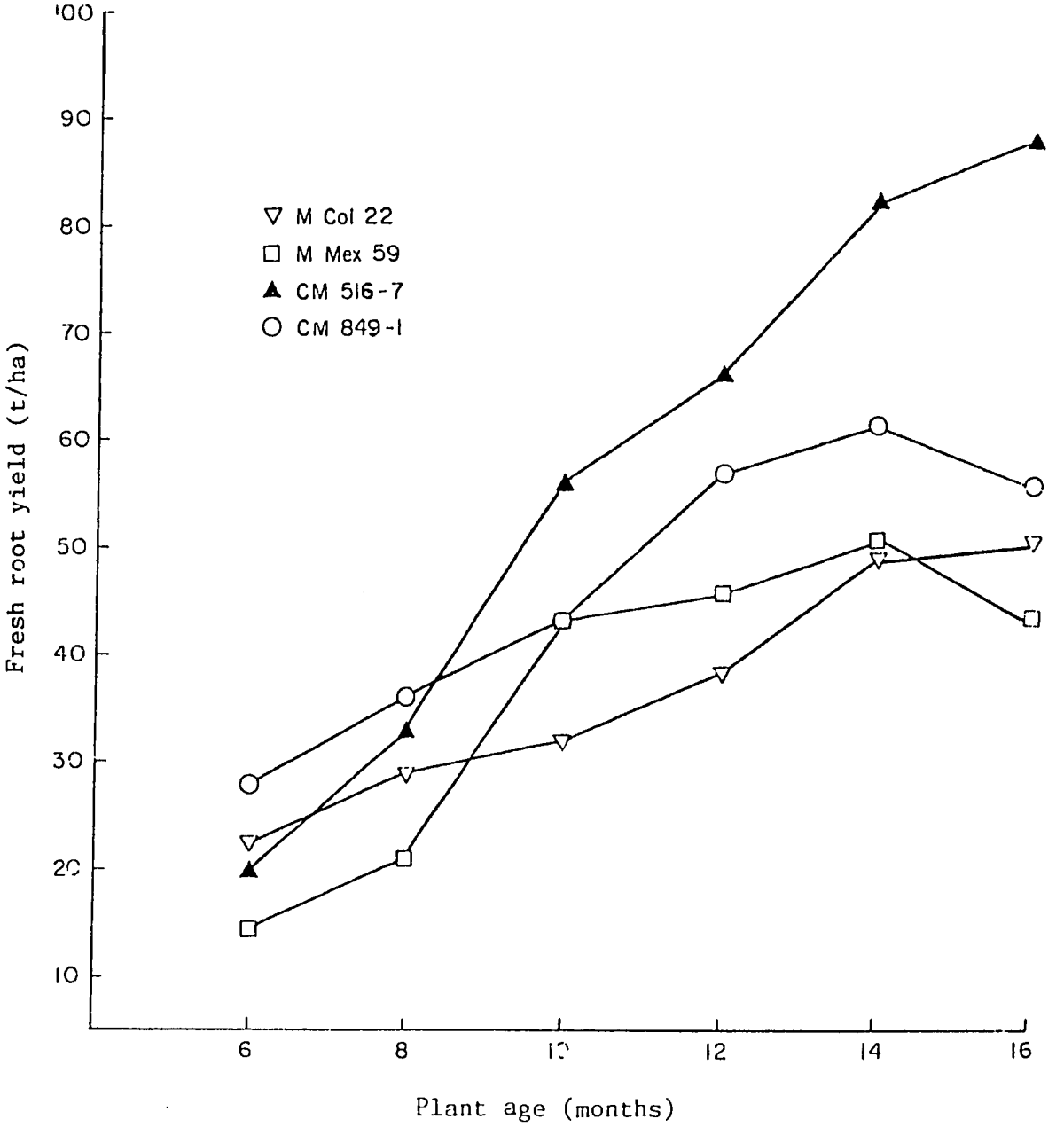


Figure 7. The effect of plant age of four cassava cultivars on total fresh root production at CIAT- Palmira.

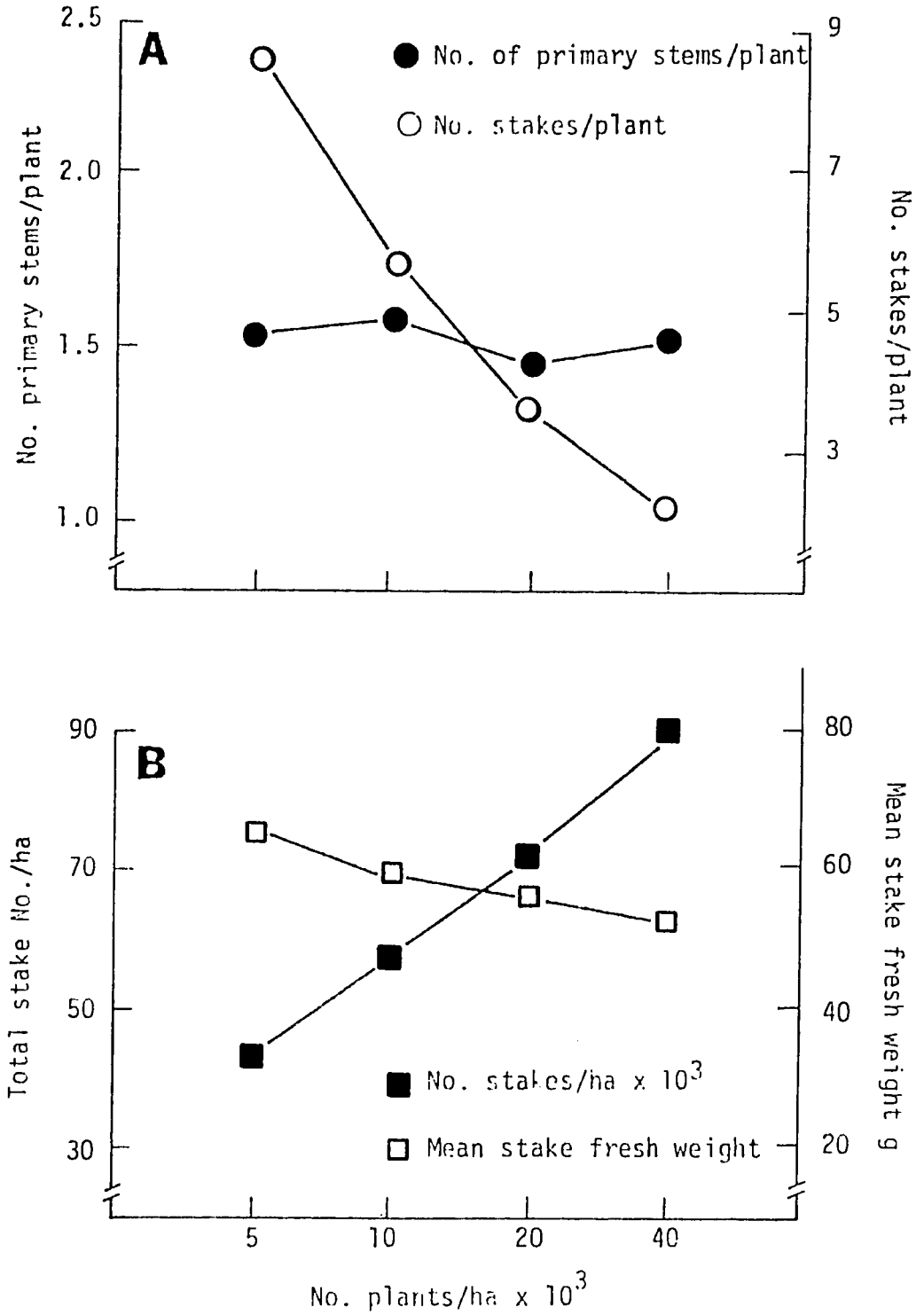


Figure 8. Effect of planting density on number of primary stems, stakes and stake weight in M Ven 77 at Carimagua, 1982.

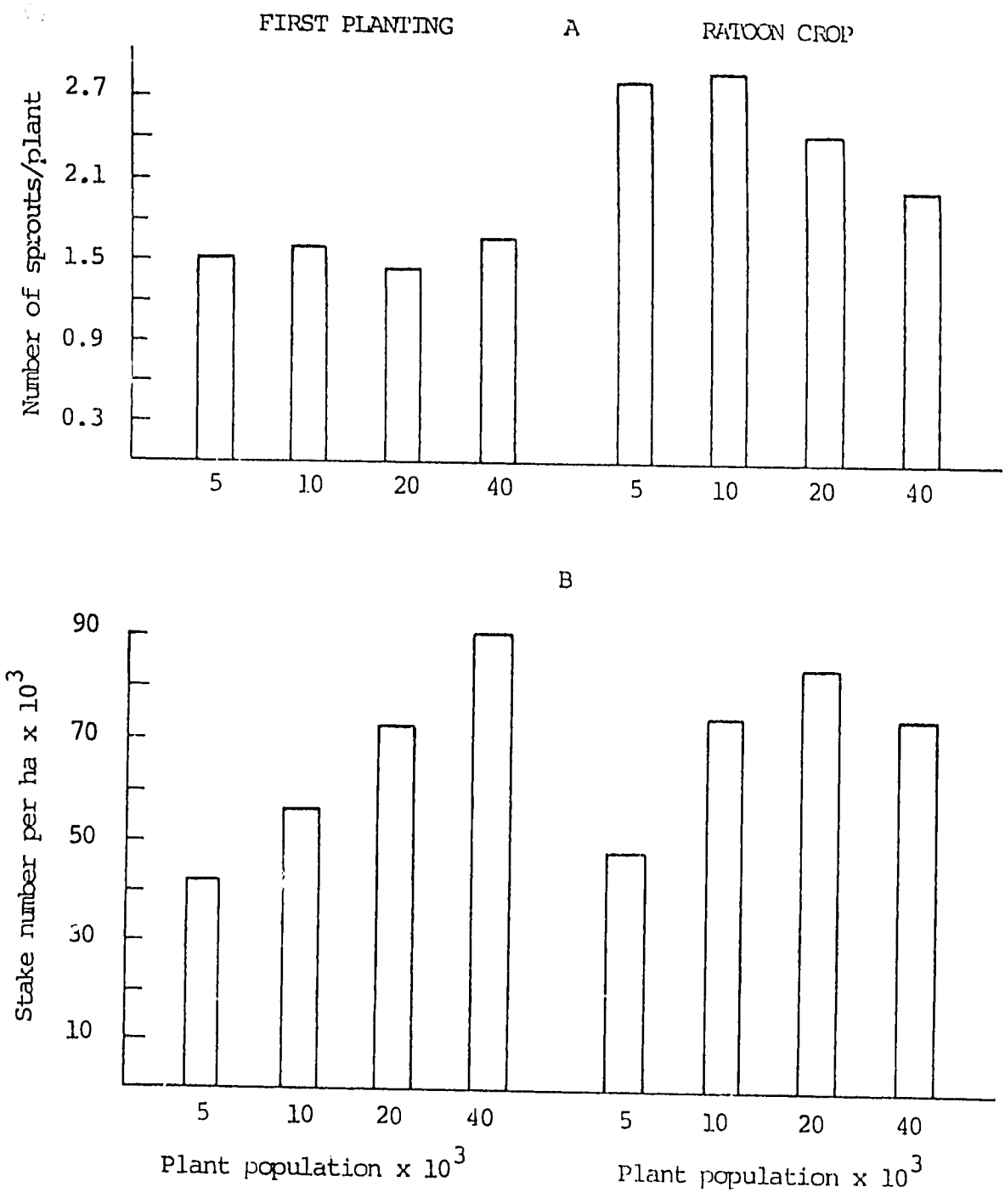


Figure 9. Influence of plant population on the number of sprouts per plant and stake number produced per ha in a first planting and a ratoon crop of M Ven 77.

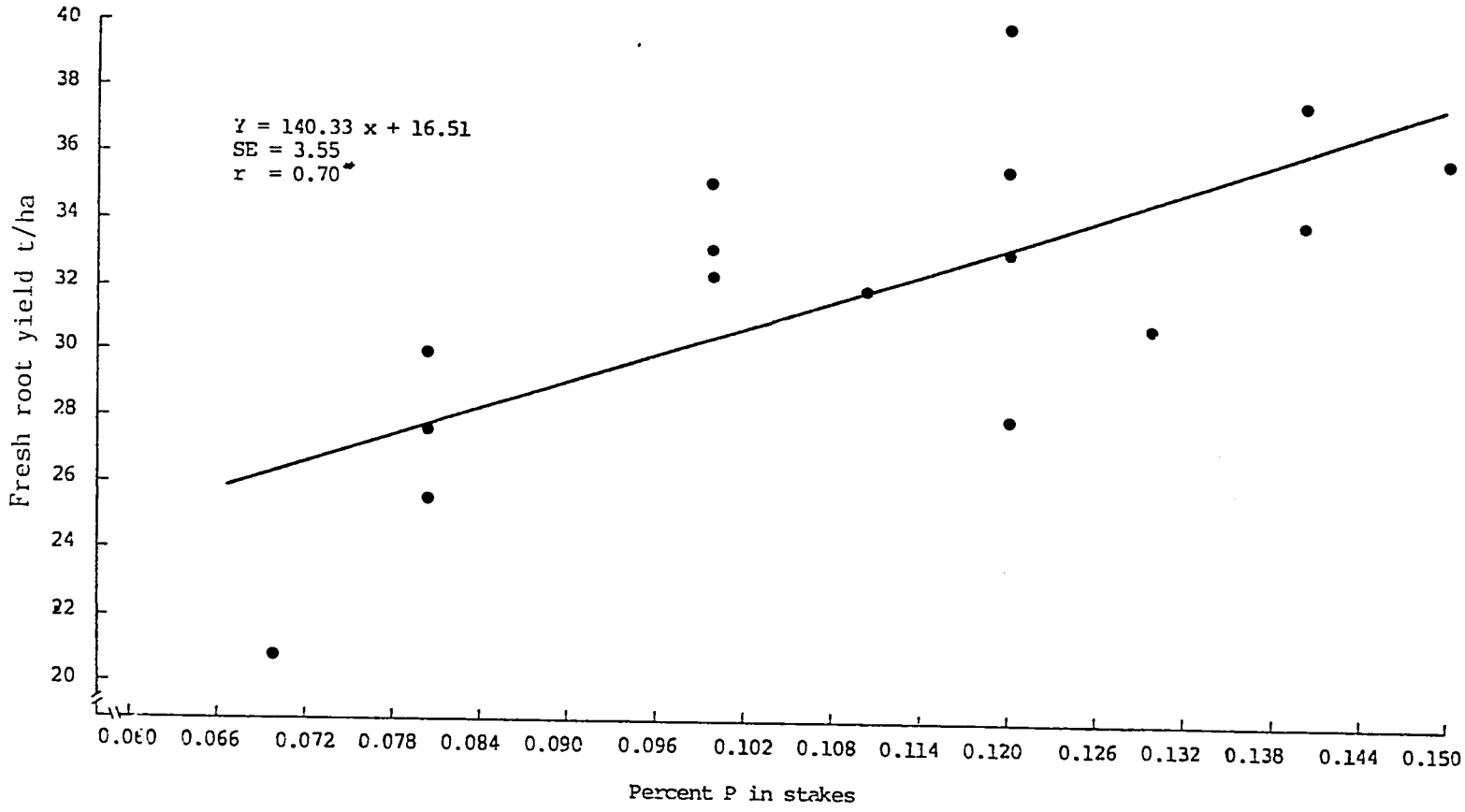


Figure 10. The effect of P concentration in cassava stakes on fresh root yield of the hybrid CM 523-7 grown from these stakes on a low P soil without P fertilization.

Cassava Utilization

During 1983, the cassava utilization section worked in the following two areas: (a) fresh cassava deterioration and storage; and (b) cassava drying. The studies on quality evaluation and the animal feeding trials, reported in previous years, were phased out during 1983.

Cassava Deterioration and Storage

In last year's Cassava Annual Report the promise of plastic bag storage of fresh cassava roots was reported (See "Storage System", Cassava Utilization). This year's research concentrated on further improving this system under experimental conditions at CIAT as well as testing the methodology at the farm level.

Repeated experiments at CIAT with a number of different clones have shown that storage for short periods in plastic bags is possible. The high humidity and temperature conditions which develop within the sealed bag enable root curing (wound healing) to occur and prevents rapid post-harvest physiological deterioration. However, the microclimate inside the bag is also ideal for the proliferation of micro-organisms in and on the roots. This can be avoided by adopting one of two strategies: (a) using perforated bags; (b) treating roots with a fungicide before packing.

Perforations reduce the humidity to a level sufficient for curing but less than that required for rapid fungal growth. However, curing is not 100% effective (normally there are 5-10% losses from physiological deterioration) and roots tend to dry out after more than one week (fresh weight losses of 2.5% after one week and 6% after two compared with 0.5% losses after two weeks in unperforated bags). Therefore, greater emphasis has been put on fungicide treatments and storage in sealed, unperforated bags, under which conditions root curing is completely effective and storage for two weeks with minimal losses is possible. The best results have been obtained with a thiabendazole based product, Mertect 450FW, which has fewer toxicity problems than the previously recommended fungicide, Manzate. Residue analyses of thiabendazole - treated roots are in progress, but this is not envisaged as a major constraint on the use of this fungicide, since it is a common post-harvest practice for both potatoes and bananas.

Typical results of experiments at CIAT-Palmira after root storage for two weeks are shown in Table 1. The evaluation of losses during storage was based on two parameters: (a) external microbial growth, scored on a subjective scale of 0-5 proportional to the surface area covered by micro-organisms (fungi and bacteria). From this, a percentage loss was calculated; and (b) a composite index of internal root deteriorations, both physiological and microbial rots, each scored on a separate 0-5 subjective scale, proportional to the volume of root affected. These two scores were combined and a percentage loss calculated.

Previous Page Blank

Roots without fungicide treatments invariably showed very high percentage losses from both external fungal growth and internal (microbial) rots were low after two weeks of storage, although occasionally after only one week losses. All Mertect-treated roots, however, were consistently in acceptable condition after two weeks of storage, with losses below 5%.

One important parameter affecting the success of storage experiments was found to be the time between harvest and packing of the roots in the plastic bags. In one experiment (Table 2) roots were treated and packed within two hours of harvest, while other roots were left for four hours before being treated and packed. The differences between treatments after one week of storage were remarkable. The roots packed rapidly after harvest had zero physiological deterioration (ie. root curing was 100% effective), whereas roots packed after a delay had between 30 and 40% losses, due entirely to physiological deterioration. This suggests that the biochemical phenolic reactions which produce the discoloration characteristic of physiological deterioration start almost immediately after harvest. It is thus essential that all storage treatments should be carried out on or near the farm, thus avoiding delays which will reduce the effectiveness of storage. (Between harvest and packing, roots should be maintained in shady areas.)

Analyses of the quality of stored roots show that changes during the two week storage period are minimal. Roots look fresh, starch contents are similar, cooking times and root parenchyma hardness are all essentially unchanged (Table 3). Informal tasting of roots suggests that taste and texture are also unaltered, although when storage times exceed two weeks some starch to sugar hydrolysis takes place, which gives the roots a sweet taste.

Given the promising results achieved in these experiments at CIAT, it was decided to initiate on-farm trials in a region where cassava was produced for the fresh market (storage would also be on-farm) and to assess the reactions of the farmer and intermediary. The area chosen for this study was centered on Rozo, Valle del Cauca, Colombia, 25 km from the CIAT-Palmira station. A preliminary survey of the 60 cassava farmers of this region gave the following picture of their production and marketing characteristics.

The 60 farmers surveyed had a total of 274 ha of agricultural land of which 70.5 ha was devoted to cassava production. Each farmer had an average of 1.6 plots of land, totaling 1.2 ha per farmer planted with cassava. The average yield of the cassava (in monoculture) was 22 tons/ha with a mean age at harvest of 7.9 months. (This is double the Colombian national average and is due to the good soils of this region and the easy access to irrigation facilities during the dry season which permit harvesting at such an early age). Some 95% of the farmers grow variety CMC-40, 5% grow HMC 1. Roots are sold in equal quantities to the fresh market in Palmira and to the starch processing market in nearby Potrerillo.

Farmers complained that both of the varieties grown deteriorated quickly (within 24 hours) which made marketing difficult. Generally,

they did not know anything about the causes of deterioration or how to prevent it. All expressed interest in storage treatments for cassava.

To date, six storage experiments have been carried out in Rozo with the active cooperation of the farmers. The results of one experiment are shown in Table 4. They were comparable with those obtained at CIAT, both as regards absence of deterioration and maintenance of root quality. Farmers have expressed considerable interest in commercializing the method. It is hoped that next year some commercial application of this storage method will occur, that a consumer acceptability survey will be carried out and that storage experiments and demonstrations will be done in other cassava production regions of Colombia where different climatic conditions could necessitate modifications in the methodology.

Economic analysis of the storage method has proved favorable. The cost of the fungicide treatment plus the plastic bags totals only Col.$2 pesos per kg of roots of the current marketing margin of Col.$30 pesos. If this storage technology were widely adopted the cost of fresh roots could be expected to drop by 11-22% in urban areas, which it is calculated should produce an increase in consumption of between 18-30%. In addition, due to the decrease in marketing margins caused by loss reduction and risk avoidance, farm-gate prices should rise by 23-47% thus benefiting producers as well as consumers. Overall, it is estimated that the Colombian fresh cassava root market would benefit by US$27-37 million per year if the storage technology were integrated into the system.

Cassava Drying

During 1983, the work on cassava drying continued in (a) the replication of the natural drying plants on the Atlantic coast of Colombia; and (b) the development and evaluation of a through circulation dryer at CIAT.

Replication of the plants on the Atlantic Coast

In the first trimestre of the year, six additional cassava natural drying plants, with drying floor areas varying between 400 and 600 m^2 were constructed on the Atlantic coast and the capacity of the pilot plant at Betulia was increased from 300 to 1000 m^2.

At Betulia it was intended to extend the drying plant with a soil-cement mixture to reduce the investment cost of the plant. The results of the granulometric studies of the soil samples from the Montanitas farm, undertaken by the Infrastructure Section of the Instituto Colombiano Agropecuario (ICA) at Tibaitata, gave the following composition: sand: 50.96%, clay 20.0% and silt 29.04%. Consequently, an 8:1 soil-cement mixture was recommended at six parts soil and two parts sand to one part cement.

In practice, it was not possible to implement this recommendation because the construction of soil-cement floors requires certain machinery for land preparation and mixing the soil-cement that was not available at the time. Due to this unforseen logistic difficulty and the poor weather conditions prevailing at the time the scheme was abandoned. This

experience suggests that the use of soil-cement mixtures for relatively small drying floors (500-1000 m^2) may not be practically or economically feasible due to the difficulty and cost in obtaining the necessary machinery.

The construction of the six additional drying plants went according to schedule and considerable experience has been accumulated with regard to the factors to be taken into account in designing and constructing a natural drying plant. (A construction guide for the modified Thai type chipping machine is already available.)

Last year it was reported that during the semi-commercial phase of operation of the pilot plant the average drying time per batch was 54.6 continuous hours (approximately 28 daylight hours) to reach a moisture content of 10-14%. During commercial operation in 1983, when almost 218 tons of fresh cassava were processed, the average drying time was reduced to around 40 continuous hours (approximately 24 daylight hours). This reduction is attributed to the better organization of the working groups so that the cassava was chipped between 4-6 A.M. thus making better use of the daylight drying hours, and turning the chips more frequently during drying.

Another important feature of plant operation during the semi-commercial phase has been an increase in the capacity of the chipping machine, brought about principally by redesigning the feed hopper to give a more even flow of roots to the cutting disc. This modification increased the output from 1.3 to 2.4 tons per hour.

In terms of conversion of fresh cassava to dry chips the results of the three years of operation are presented in Table 5. The variations between years could be due to a number of factors such as the improved quality (dry matter content) of the fresh roots or the recollection of the dry product at a higher moisture content or even reduced handling losses. Periodic sampling of the predominant regional variety Venezolana indicates that its dry matter content is on the order of 36% which would give theoretical conversion ratios of between 2.39 and 2.50, corresponding to dry cassava moisture contents of 14 and 10%, respectively. The data, therefore, suggest that the efficiency of the plant operation has been improving. It is worth noting that to date there has been no problem in satisfying the quality requirements (principally a moisture content level less than 14%) set by the concentrate manufacturer buying the dry cassava produced at the pilot plant.

Development of the through circulation drier

The work of developing and evaluating through circulation drying systems using ambient, solar-heated and fuel-heated air has continued using the experimental plant described in the 1982 Cassava Annual Report.

The results of a series of trials to determine the optimum loading density with and without the use of the solar collector are shown in Table 6. As had been determined previously the optimum loading density using the solar collector is 125 kg/m^2. This loading density not only

gave the highest rate of production of dry cassava but also gave a drying time within 48 hours thus ensuring production of one batch every two days. Without the use of the collector the possible loading density for a two day per batch cycle was reduced to 75 kg/m^2 which represents a 40% reduction in dryer capacity. Both with and without the use of the solar collector it was found that drying times in excess of 48 hours gave a distinctly discoloured product and a strong odour of fermentation during the drying process.

The solar collector was originally constructed using massive concrete blocks especially designed to maximize the absorption of solar radiation (see the Cassava Annual Report 1982, Cassava Utilization Section, Figure 2). Preliminary cost calculations on the collector revealed that using the blocks was hardly likely to be an economic proposition and it was therefore decided to evaluate the performance of the collector using different collecting materials. The materials employed included (see Table 7): (1) the bed of gravel alone (on which the concrete blocks had been supported); (2) the 108 concrete blocks supported on the gravel bed; (3) 230 kg of large river boulders supported on the gravel bed; and (4) corrugated iron sheets. The results of the evaluation show that replacing the concrete blocks by an equivalent weight of river boulders had a beneficial effect on the collector efficiency, which was in turn reflected by a greater increase in air drying temperature (2.6°C as against 1.9°C) over ambient temperature. Given the poor showing of both the gravel alone and concrete block treatments at the high airflow rate, these were eliminated from further evaluation at flowrates of 20 m^3/min and 13 m^3/min.

The efficiency of the collector using either river boulders or corrugated iron sheet was very similar at all three airflow rates, with correspondingly similar increases in air drying temperature over ambient temperature. Despite this similarity in overall efficiency, the behavour of the two materials in terms of the increase in air drying temperature over ambient temperature throughout the day and night was markedly different, Figure 1.

As might be expected, the corrugated iron sheets gave greater ΔT during the hours of peak solar radiation while the river boulders, through their capacity to absorb heat and then release it during hours of low or nil solar radiation, gave a lower ΔT but maintained temperature differences for longer periods. There is a definite effect of the boulders releasing their absorbed heat throughout the night. Trials are underway to determine which collector material is most suitable from the drying point of view. It is conceivable that a higher daytime air drying temperature, and lower relative humidity, obtained using the corrugated iron sheets could accelerate the final stage of drying.

In terms of cost the two alternatives appear to be similar although the cost of transport of the river boulders could make their use location specific.

Over the last year the design and construction of a prototype Brazilian type chipper which produces rectangular bars has been concluded and the machine is under evaluation. Initial results suggest that the

geometry of the chips is a great improvement over that of the chips produced by the Thai type machines.

Table 1. Evaluation of roots of M Col 22 stored for one and two weeks in two sizes of plastic bags with and without fungicide (Mertect) treatment.

Treatment		Storage time			
		1 Week		2 Weeks	
Bag size (kg roots)	Mertect (0.4%)	Micro-bial growth	Deterioration	Micro-bial growth	Deterioration
20	-	65 [a]	11	80	36
20	+	5	4	16	4
5	-	29	17	84	39
5	+	1	2	11	2

[a] Numbers refer to percentage losses due to exterior microbial growth (fungi + bacteria) and to interior deteriorations.

Table 2. Effect of a delay between root harvest and packing in plastic bags on the development of deterioration during one week's storage. All roots were treated with Mertect (0.4%) prior to packing.

	Time between harvest and packing	
	2 h	4 h
Perforated bags	2.8[a]	43.6
Unperforated bags	0.0	28.8

a Numbers refer only to percentage root losses from physiological deterioration. There was no microbial deterioration.

Table 3. Comparision of some quality characteristics of eight month old fresh roots of CMC 40 with roots stored in five kg size plastic bags after Mertect treatment.

Storage time (weeks)	Losses due to: Exterior microbial growth %	Losses due to: Interior deterioration %	Root starch content %	Cooking time (min)	Parenchyma hardness penetration (mm)	Cooked root taste and texture
0	-	-	34.3	36	2.04	good/soft
1	2.2	1.4	34.4	33	1.94	good/soft
2	7.2	4.6	33.4	38	1.82	good/soft

Table 4. Results of on-farm fresh root storage in plastic bags for one and two weeks, using CMC 40, eight months of age.

Storage time (weeks)	Mertect	Exterior microbial growth % loss	Interior deterioration % loss
		5 kg size bags	
1	+	2.2	1.4
1	-	22.5	2.1
2	+	7.2	4.6
2	-	24.2	7.7
		0.5 - 1 kg size bags	
1	+	0.2	1.5
1	-	4.6	6.2
2	+	0.2	3.1
2	-	6.9	4.0

Table 5. Conversion of fresh cassava to dry chips at the pilot plant, Betulia, Sucre, 1981-1983.

Year	Tons fresh cassava processed	Tons dry cassava produced	Ratio fresh/dry cassava
1981	18.0	6.7	2.69
1982	100.9	38.3	2.63
1983	217.6	89.6	2.43

Table 6. Drying time and rate of production of dry cassava with and without the use of the solar collector.[a]
Air flow 14.5 m^3/min. m^2. Drying started at 1700 h

Loading density kg/m^2	With collector		Without collector	
	Drying time h	Rate prod. dry cassava $kg/h.m^2$	Drying time (h)	Rate prod. dry cassava $kg/h.m^2$
50	33	0.56	44	0.42
75	42	0.66	48	0.59
100	44	0.84	62	0.59
125	47	0.99	-	-
150	65	0.85	-	-

[a] Using a ratio of solar collector area: dryer floor area of 10:1 which gave an overall increase in air drying temperature of 3.8°C.

Table 7. Evaluation of the 10 m^2 solar collector using different collecting materials.

Collector material[a]	Airflow rate					
	39 m^3/min		20 m^3/min		13 m^3/min	
	ΔT^oC[b]	E%[c]	ΔT^oC	E%	ΔT^oC	E%
Gravel alone	1.9	63.5	-	-	-	-
108 concrete blocks on gravel	1.9	62.8	-	-	-	-
230 kg river boulders on gravel	2.6	85.4	3.2	51.2	4.0	45.4
Corrugated iron sheet	2.7	85.0	3.3	59.5	4.0	45.1

[a] All materials painted mat black.

[b] ΔT^oC represents increase in air drying temperature over ambient temperature during a 24 hour period, 10 replications.

[c] E%, the collector efficiency is given by: radiation received x collector area/mass of drying air x air specific heat x ΔT.

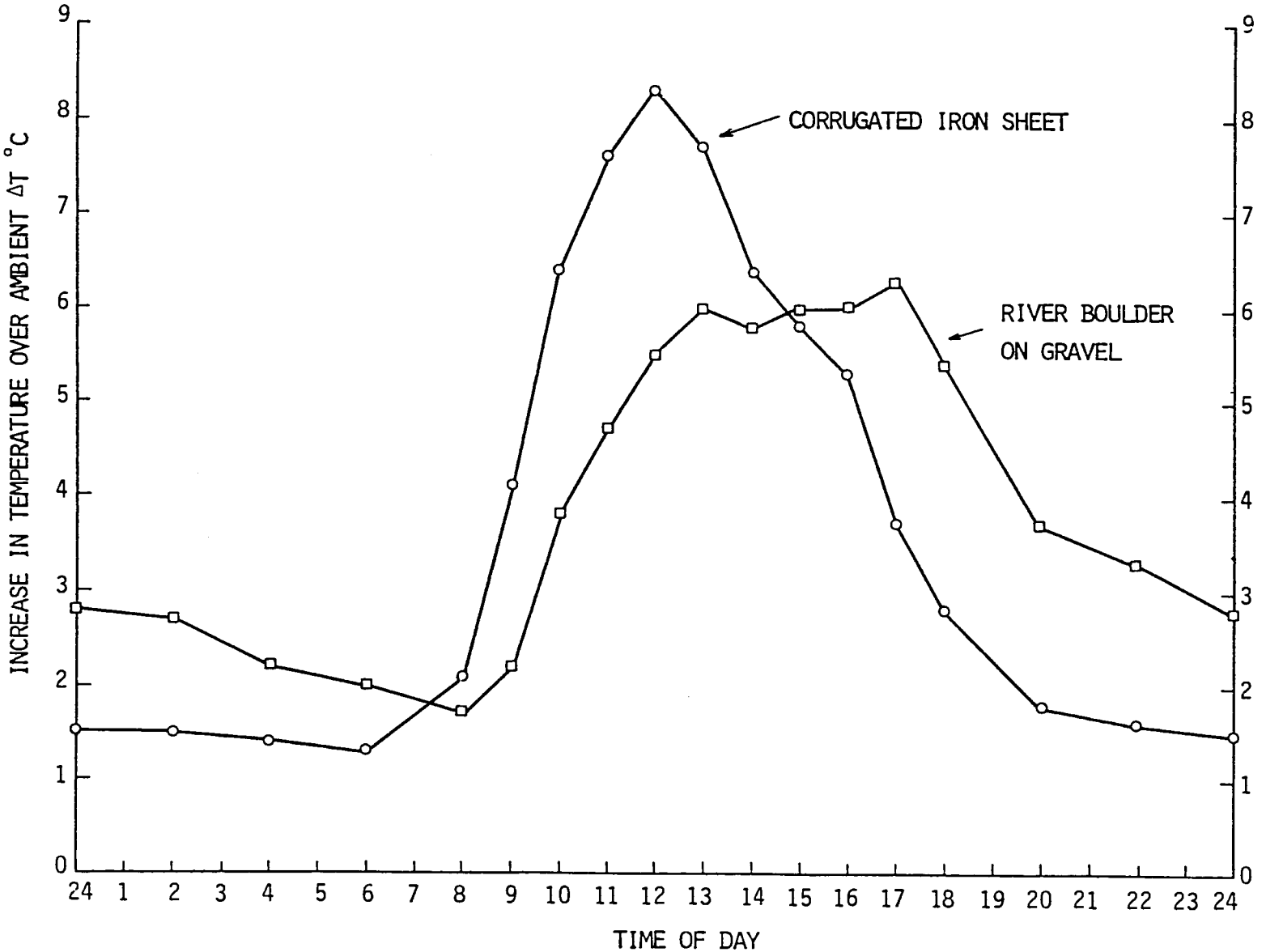


FIGURE 1. SOLAR COLLECTOR EVALUATION: DRYING AIR TEMPERATURE VARIATION OVER 24 HOUR PERIOD FOR TWO COLLECTING MATERIALS.

Economics

1. Methodology Development for the Planning and Evaluation of Integrated Cassava Development Projects.

1.1 Objectives and constraints in cassava development in Latin America

Latin America economies in the last two decades have undergone very significant structural change, of which the most important components are substantial expansion in the industrial sector, even higher growth in the service sector, and extremely rapid urban growth, caused by high rates of rural-urban migration and an overall population growth rate that was about 2.8% per year. While the weight of the agricultural sector in total GNP naturally declined in this period, substantial demands were nevertheless made upon it. Rising income and urbanization created a rapid increase in demand for food products, of which an increasing percentage had to be commercialized. Moreover, the structure of food demand changed, as consumption patterns shifted from a rural to an urban setting.

In the period between 1961-79 agricultural production grew at an annual rate of 3.1% per annum, a rate above population growth but below demand growth. Such an imbalance between demand and supply either puts upward pressure on food prices or results in a deteriorating agricultural trade balance. Both have serious ramifications on policy issues. Rising food prices obviously have implications for the nutritional situation of the lower income strata. A deteriorating trade balance, on the other hand, puts strains on the ability of Latin American countries to meet their very severe debt repayment requirements. This growing trade imbalance is most critical in the area of cereals. All countries in tropical Latin America are net importers of cereals and the ability of these countries to produce their cereal needs have deteriorated over time (Table 1).

While governments have tried to curb this cereal deficit through price policy intervention, investment in research and extension, and subsidized production credit, governments have almost never looked beyond the cereals themselves to supply this increasing demand for carbohydrates. Moreover, because of this oversight, traditional starchy staples, such as cassava, have had to compete with grains at a substantial disadvantage, and as a result such crops have stagnated, due to both traditional production techniques and the declining importance of traditional markets.

Cassava's center of origin is Latin America and historically the crop has played a fundamental role in supplying the carbohydrate requirements of the human population of the lowland tropics. The crop's advantages -high carbohydrate production per unit of land and labor; adaptation to soil and climatic stresses; and its indeterminate harvest period, were all efficacious in supplying the needs of a rural population. However, as the economy urbanized, the crop's production advantages were neutralized by marketing disadvantages, particularly bulkiness and rapid perishability, and the crop not only failed to

respond to but also was retarded by the structural change occurring in Latin American economies.

In the 1971-81 period, cassava production in Latin America declined at an annual rate of 1.3%. The reasons for this lie more on the demand side than in constraints on production. Cassava production goes into three principal types of end utilization (Table 2). First, is human consumption of fresh roots. In this, fresh market demand is limited by the declining rural population and the very high cost of marketing cassava roots in urban areas. Second, a large portion of cassava is consumed in traditionally processed forms, particularly farinha in Brazil and cassabe in the Caribbean. In these markets consumption is already relatively high and consumers would rather consume other carbohydrate sources with increases in income; demand is thus inelastic and limited by consumer preferences. Thirdly, the remainder of the crop is principally fed fresh to swine in on-farm feeding systems. Apart from the relatively technified systems in Paraguay and southern Brazil, this use is generally limited by extensive management systems for swine and the lack of a cheap protein source. Overall, demand in these traditional markets is either static or declining.

While there are structural reasons why cassava has not developed, there are as well economic and social policy reasons why cassava development should be encouraged. First, cassava is one of the few remaining crops where new technology can be utilized as a means to increase the incomes of small-scale farmers. It is expensive to mechanize cassava production. Thus, small-scale farmers are the principal producers of cassava, and considering the soil and moisture stresses under which many of these farmers must produce, cassava is their most productive and least risky alternative. Providing productive employment in the rural sector is a potential solution to the unemployment and high cost of social infrastructure in the urban sector.

Second, when cassava is properly processed, it has the potential of entering a multiplicity of end markets -such as starch, composite flour, and animal feed concentrates. All enjoy rising internal demand, and moreover increased cassava production could reduce the imports of grains, which are increasingly being used to meet growing domestic requirements. The linkage of small-scale producers to these expansive growth markets would help to meet several social policy objectives without transferring land and labor resources from other productive activities in the economy.

While the creation of this linkage offers substantial benefits, it will not occur spontaneously. For cassava to compete in these alternative markets will generally require lower farm-level prices in addition to the investment costs in new processing capacity. Moreover, improved production and utilization technologies *per se* are not sufficient to induce a coordinated expansion in production, processing and utilization.

There are many reasons for this but what may be termed a high price illusion is probably the principal factor. In a great many cassava producing areas outside Brazil, farm-level prices are substantially

above production costs; so much so, that an incentive to plant an increased area to cassava should be operative. Farmers do not do so partly because of the known marketing risks, of either lower prices or, more often, the inability to sell the cassava. Also, the high farmgate prices reflect a price premium for quality characteristics, since often a significant percentage of the cassava roots are not saleable. Additionally, the structure of a marketing chain for a highly perishable crop induces a high price level. The result of this high price illusion is that potential end users will not invest in cassava processing, because cassava prices appear noncompetitive. On the other hand, cassava farmers will not expand production without the guarantee of a more expansive market. The development of the organizational intervention by which small-scale cassava farmers are linked to high growth markets is the principal objective of integrated cassava development projects.

1.2 Integrated cassava development projects

Many small farm development projects have not succeeded because the focus has been only on increasing crop productivity and/or access to production credit. In a Latin American setting, one of the principal problems faced by small-farm crops is inelastic demand, so that any gains made by new technology are negated by a fall in price. Because of cassava's multiple end uses, it is not only possible but necessary to attack the demand problem jointly with the development and release of new technology.

Conversely, for new cassava technology to have any beneficial impact, market/consumption studies and related development of processing capacity are integral parts of the technology transfer process. Moreover, there must be an institutional capacity to adapt production and processing technology to local conditions, to provide extension, credit, and other production support services, to promote investment in processing capacity and to develop the required market channels. These activities must be phased in a coordinated manner, and the means of integrating these activities is best done in a project framework. In a sense such projects extend the farming systems methodology (now so much in vogue in small farm development) one step further by coordinating changes in the farming system with changes in the marketing system.

The set of activities required in the successful execution of integrated cassava development projects have not yet been worked out to a sufficiently detailed level. Nevertheless, the development of a sufficiently generalizable methodology for such projects is currently seen to involve six principal activities, each of which will be briefly described.

1.3 Development of a macro planning frame

The activities in this section focus on defining the most appropriate alternative market, identifying the initial target region, and providing a first approximation of the cost structure in each subsystem. Characterization of present production and utilization

patterns of cassava provides the starting point. An evaluation of growth prospects, substitution possibilities, and competing prices of grain substitutes in alternative markets provides a first assessment on which market to focus. Government policy objectives are also essential determinants of this choice. Finally, the target region is selected. The principal criteria in this choice are: the capacity to expand cassava production; the potential level of profitability of cassava production; and regional development priorities on the part of the government.

1.4 Assessment of institutional capacity

There is a large institutional component in the initial phases of project development. It is assumed that at a critical point growth in cassava production and utilization will be self-sustaining and institutional support will then decline. The pilot projects at their inception involve a multifarous set of activities, usually outside the scope of any one institution. The institutional assessment will encompass three principal components: (1) identification of a coordinating institution; (2) designation of the necessary functions between existing institutions; and (3) development of a coordinating mechanism at the project, regional and national level.

1.5 Project financing

Pilot projects, in order that they have a certain degree of autonomy in decision making and planning, should have a certain level of independent financing, principally for the core, coordinating staff. These projects are not a short-term activity and financing for a five-year period would probably be the minimum acceptable.

1.6 Phasing of activities in project execution

Once the target region has been selected, it is still necessary to screen production systems and sites within the region (see "The screening Process" section in this report.)

The idea is to start where the constraints on system profitability are least binding. A pilot processing plant is then constructed to ascertain any adaptation necessary in processing technology, to work out the management of the processing, and to develop an accurate account of investment and operating costs. At the same time a survey is made of the production systems and a first set of technology adaptation trials are designed. These will include necessary adjustments in production systems to meet the needs of the new market. The more experimental results there are to draw on, the easier this process is. Particularly important, however, is the requirement for some previous capacity to multiply and screen varieties. The project necessarily relies on a link to a system for varietal introduction, usually in the form of a regional trial of 12 to 20 varieties. The on-farm research then feeds into, but is not a substitute for, a production expansion program. Critical issues in this program are seed multiplication, monitoring of labor or machinery constraints, extending the planting and harvest season, and

the phasing of production expansion with increases in processing capacity.

1.7 Support activities

There are critical support activities which usually must be coordinated between institutions. The principal activities are:

(1) Opening of credit lines: a special type of credit line must be found or created for the financing of the processing plants; moreover, there are many cases where production credit for cassava is not an established credit line.

(2) Farmer organization and training: whether and how to organize small-scale farmers into associations to finance and manage the plants is a key issue; a procedure for farmer screening and organization needs to be elaborated. Additionally training in plant management, in basic accounting, and in production technology is critical.

(3) Opening market channels: identifying buyers for the processed cassava, occasionally motivating investment in equipment to utilize the processed cassava (eg. mixing of composite flour), defining the mode and costs of transport, and working out sales and payment arrangements are key activities.

(4) Policy intervention in factor and output markets: these activities focus on relieving constraints on cassava expansion due to lack of access to labor, tractors or land and price policy intervention for cassava where grain subsidies are particularly large.

1.8 Replication and monitoring

The project should focus on maximizing the demonstration effect of the plants, to reduce investment of institutional resources. Site screening is again a key to this objective. Production and processing costs and the profitability of the whole system must be monitored carefully in the initial phases, especially where the success of the project is dependent on yield-increasing technology. Also, the interaction between traditional cassava markets and the new market should be monitored. Especially important in this context is whether to introduce an industrial variety as the basis for the project and the impact this has on food markets.

1.9 The Colombian Cassava Development Project

The CIAT Cassava Program is currently assisting the Colombian Integrated Rural Development (DRI) program in setting up the first such integrated cassava project. This project is in full measure an exercise in learning by doing and it is on the basis of the experience in this project that a generalized methodology will be developed.

The overall project design is based on two basic objectives: (a) to develop a dried cassava industry in a region which has a comparative advantage in cassava production; and (b) to ensure that small-scale cassava producers are the principal beneficiaries of the project. These objectives led to the basic structure of the project. First, the project focuses on developing the market for dried cassava chips or pellets for the expanding animal feed industry in Colombia. Second, the project is located on the Atlantic Coast and will eventually encompass the five principal departments. The area is characterized by high temperatures, a long dry season and relatively infertile soils but has relatively good infrastructure and underemployed land and labor resources. Third, the organization of the project is based on farmer associations (FA), a group of 15 to 30 small-scale farmers which are organized by institutions within the DRI program, The associations have legal status and can act as an entity in obtaining credit.

1.10 The Integrated Rural Development Program (DRI)

The Integrated Rural Development Program (DRI) was started in 1976 and set out as its objectives the increase in the production of basic food staples, improvement in the employment and income of small-scale farmers, and better linkage of small-scale producers to input and output markets. DRI was conceived of as a coordinating institution, which would bring together various other institutions in a particular region, together with a certain amount of financial resources to improve the welfare of the small-scale farmer in that region. The program at its inception focused only on a limited number of well-defined regions. It was thought that if development would not respond to generalized policies, then it must be susceptible to an intensive concentration of institutional resources in limited areas. As such, the DRI program was seen as an alternative strategy and replacement for the agrarian reform program.

In what was called the first phase of the DRI program (1976-80), parts of the departments of Sucre and Cordoba were selected as project areas for the Atlantic Coast. Most of what came out of that phase was institutional: a mechanism for coordination of institutions working in the region, organization of farmer associations, and experience in problem identification. However, what was lacking was the identification of a means of increasing farmer incomes. Credit programs and a yam storage project had limited success, but the creation of a credit line to expand cassava production failed completely. Cassava production increased substantially, but this coincided with a relatively good year for cassava on the coast in general, and farmers could find no market for their cassava. In many cases it was turned back into the soil. Since cassava was the principal crop for most of these farmers, means of increasing farmer income appeared limited indeed.

The problem of marketing small-farm crops thereby became a dominant concern and a post-harvest committee was created to develop marketing projects. In 1981, CIAT was contacted by this committee for advice on how to resolve the marketing problem in cassava. At the same time the

DRI program entered phase two in which the coverage of the program was extended, and for the Atlantic Coast all the principal departments were brought under the DRI umbrella.

Because of the structure of the DRI program, institutional support is wide-ranging. ICA is responsible for production technology and testing. SENA is responsible for training, both for professionals involved in the project but also for the farmer associations. The Caja Agraria is responsible for agricultural production credit. CECORA is responsible for organization of the farmer associations and FINANCIACOOP provides credit for the processing plants. Institutional coordination is achieved through the post-harvest committee and the departamental directors of the DRI programs. Also, since the participating institutions are organized hierarchically, DRI also provides a coordinating role at the project, the regional, and at the national level. This coordinating function at various hierarchical levels is critical to effective functioning of the local projects.

1.11 Socio-economic characteristics of the target region

The Atlantic coast of Colombia provides the target region for the integrated cassava development project. The region has an extremely skewed land distribution, with close to 80% of the farms being less than 20 ha in size and making up less than 10% of the land in farms. The region is characterized by large, extensive cattle operations interspersed with small-scale farming. Tenants form a significant portion of small-scale farms and land invasions are a common occurrence in the region.

Cassava is the principal crop of small-scale producers in the region, making up almost half of cultivated land of farms less than 20 ha in size (Table 3). Nevertheless, rarely does the area planted to cassava average over 1 ha and a substantial portion of these small-scale farms remain uncultivated. Since there is surplus rural labor in the region, this underutilization of land and labor can be attributed to marketing constraints. Planting other crops is not a solution because of the stresses of temperature, rainfall, and in some areas, soils. Means of increasing farmer income are few and cassava is viewed as one of the principal means. Moreover, these characteristics are generally typical of the major cassava producing areas in much of Latin America, i.e. where cassava is grown, it is the major crop and access to markets limits its expansion.

1.12 The screening process

The Atlantic coast of Colombia was selected as the primary target region because it was the major cassava producing area, agro-climatic stresses limited other crop production and made for low cassava production costs, small-scale producers were a large component in crop production, and marketing was the major constraint on cassava production. In the present cassava system of the Atlantic coast most production is destined to fresh consumption. A small part ($\pm$10%) is processed into a number of products (bollo, casabe, starch) that have different markets. A study of market potential suggested that dried

cassava for the animal feed market had the largest capacity to absorb increased cassava production. Preliminary economic analysis suggested that chip production would be economically feasible at a raw material price of 4-5 pesos/kg of cassava, a price well within existing production costs. To diminish supply problems and transport costs it was decided to locate plants in their immediate production region. The issue was how to select the production system and site on which to focus.

Appropriateness of production systems were defined by two factors:

(1) The potential to increase cassava production for utilization by the feed concentrate industry. This production potential is determined by underutilized land availability, possibility to mechanize land preparation, low competition with the fresh market, the possibility to increase productivity, presence of a good dry season and of good institutional support.

(2) The impact that a project would have on the income of cassava farmers in the region. The potential impact will be larger when crop alternatives are few, when other employment is lacking and when infrastructure and institutional support is limited.

To determine which sites are best suited for the establishment of drying plants, a screening procedure was developed, that takes into account production potential as well as possible impact on farmers' incomes. Data were gathered by surveying the spectrum of potential target sites in the departments of Atlantico, Bolivar, Sucre y Cordoba. (Target sites were zones of influence of the DRI program.). Some H_2O farmers distributed through these zones were surveyed in this screening procedure. Some of the results of this screening are shown in Table 4.

Screening results can be interpreted in two ways:

(1) The screening results identify the appropriateness of different zones. Sucre and Cordoba appear to be the zones where the project would best succeed at present. Mechanization opportunities are reasonable to good, and competition with the fresh market is limited. Sucre has a tenancy and farm size problem that could limit expansion of cassava production. A reflection of the appropriateness of the different zones was found when farmers were asked whether they would start growing cassava at a fixed price of $5 pesos per kilo (see Table 5).

In Cordoba, 38% of the farmers would grow more cassava at such a fixed price. In Sucre, this was 24%. In Bolivar, as well, 38% of farmers were interested in a fixed, $5 peso price, but the area is hardly appropriate to extend cassava cultivation because of the severe slopes. In Atlantico, only 12% of the farmers would be interested in a guaranteed price of $5 pesos. The impact of the project would be slightly less in Bolivar and Atlantico. In Atlantico, the institutional support is

quite good and employment is a less severe problem than in Sucre and Cordoba. In Bolivar maize is a very good cropping alternative and people often find employment in other activities (eg. the tobacco industry).

(2) The screening results indicate institutional support activities within the whole target region. In Cordoba and Sucre, a major effort has to be made to change the cropping system (presently cassava/yam/maize) to one more qualified for industrial use. In Cordoba, a credit line for tractors might well be useful. In Bolivar, the institutional support in the zone should be upgraded. One of the biggest constraints, as much in Sucre as in Atlantico, is the size of small farms, which limits the potential expansion in the area in cassava. A well functioning land rental market would relieve this constraint. However, this is a problem which cannot be solved within the framework of an integrated cassava project and this criterion must weigh heavily in the final decision of where to locate plants.

The screening process was developed in the context of choosing seven sites in the departments to construct drying plants. As the project expands further the screening process will be used much more systematically in both site selection and provision of support services.

1.13 Progress of the project to date

Project implementation is now in its fourth year and the project can be viewed as having passed through three phases. The first stage or experimental phase involved the selection of a single farmer association, the construction of a pilot plant,the development of an operational drying scheme adapted to local conditions and the monitoring of the reaction of potential buyers to the product. In the second, or demonstration phase, the plant was run by the farmer association on a commercial basis and a preliminary economic feasibility study of the plant was done. This stage established the commercial viability of investment in the plants, supplied the data for credit lines for additional plants, and provided a demonstration model for introducing the idea to other farmer associations. The third, or replication phase, has focused on building plants in other areas, and in the past year six additional plants in four different departments were established and are operating. Plans in 1985 call for an increase in the number of plants to 24.

The impact on cassava production is also being noted. Farmers in the original farmer association have increased their area in cassava by more than four-fold. Farmers have also intensified management of the crop; greater attention is given to weed control, seed selection and plant population. Also, there is a tendency as area expands to move more to monoculture systems. On-farm research trials have been established. To date these have focused on varietal evaluation trials, evaluation of monoculture and intercropping systems, and trials to determine an optimum system of planting and harvesting dates to ensure a continuous supply of cassava.

The plants to date have been based on solar drying in the four month dry season from December to mid-April. Extending the root production and drying through the year would insure that there were fewer peaks in demand for labor and tractor resources and a more continuous supply of dried cassava to feed the concentrate plants. Research is now underway at one of the plants to develop through-circulation bin drying of cassava chips for drying during the rainy season. This will then be followed by development of the most appropriate management system for combining solar and bin drying.

1.14 Potential economic benefits

The viability of an integrated cassava project obviously depends on whether cassava can compete in alternative markets. In the Colombian case the issue was dried cassava's ability to compete with sorghum in the animal feed concentrate industry. Sorghum prices determine the price of dried cassava and because of the difference in protein content, cassava chips are discounted in price, in this case by 20%. This factory price must then cover the costs of transport and handling, processing, and root production. As shown in Figure 1, the project was economically viable at existing yield levels of about 8 t/ha. However, while the margin was positive, it was not large. Nevertheless, it provided a starting point.

The income generating potential of the project is located at the level of the cassava producer. The project both allows expansion of cassava area and motivates adoption of improved technology. However, it is the cost reductions that come from yield-increasing technology that produce the principal gains in income (Table 6). Net margins are increased up to 3.7 fold by increasing yields from 8-16 tons, a level which the farm trials suggest is imminently feasible.

Given the economic viability, the succeeding question is the capacity to expand cassava production and to utilize the dried cassava. If a 25% yield increase is assumed for farms between 10 to 20 ha (it is assumed that cassava is planted on 25% of the land) and for farms of less than 10 ha that half the fallow land is planted to cassava, the production can be expanded by 640,000 tons, or 1.6 times the present production level (Janssen, 1983). This amounts to 259,000 tons of dried cassava. As shown in Tables 7 and 8, this level of dried cassava production is equivalent to 17% of total concentrate production and would effectively replace sorghum and maize imports. The project in effect balances production and utilization capacity and would markedly contribute to national policy objectives.

1.15 CIAT and Integrated Cassava Projects

CIAT is an applied agricultural research center, of which the cassava program has been a functioning component since 1972. As such, the progress of the CIAT cassava program is measured less by the research performed and published than by the technology being utilized at the farm level, The cassava program since its inception has faced two interrelated constraints in its international cooperation and technology transfer activities. First, when the CIAT cassava program

started, there were no functioning national cassava programs to do the adaptive research and varietal testing so necessary for effective technology transfer to the farm level. Second, there were no institutional mechanisms for linking the production technology to growth markets.

Initial international cooperation activities focused on the traditional activities of training and assistance in the development of cassava research programs. There has been modest success in creating national programs in Mexico, Cuba and Brazil and to date over 300 professionals from almost all the cassava-producing countries in Latin America have been trained. Yet national programs have been marked by a rapid turnover in personnel and instability in program planning and research. Moreover, a large percentage of trainees were not retained in cassava research. The reason for this limited progress is simple; there was not effective demand for cassava research in most Latin American countries and those researchers that worked on the crop were continually frustrated by the lack of interest in new cassava technology, extending from farmers up to policy makers.

Demand for cassava research will only arise as the result of an effective demand for cassava. In this regard integrated cassava development projects are seen as integral to an international cooperation strategy for Latin America. Within the scope of the project there is a clear mechanism for varietal evaluation and adaptive research on production technology. If necessary, adaptive research on processing technology can also be accommodated. But the projects, in integrating the components necessary to expand both production and utilization, in themselves generate the demand for more generalized applied research in cassava. This, in turn, gives the national cassava research program a clearer focus, with a clearer definition of objectives.

The integrated cassava project on the Atlantic Coast of Colombia is seen as something of a prototype. The project will serve three primary purposes in regard to CIAT's objectives. First, is the mere demonstration effect that cassava can be a basis for the regional development of the small farm sector, especially in more marginal production areas. The project moves the discussion with other Latin American countries from the possible to actual tangible benefits. Second, the project provides the opportunity to develop the methodology required for establishment of similar projects in other countries. In this regard, the focus will be on maintaining a certain level of generality in the methodology and on identifying the principal issues affecting the potential success of such projects. Third, the project site can be used as a training vehicle both for CIAT scientists and for professionals involved in similar projects in other countries.

CIAT would potentially act as a catalyst in the development and financing of these projects outside Colombia. A network consisting of such projects would be a more effective means of testing and adapting new production and utilization technologies and in providing the impetus for eventual investment in national cassava research programs. Mexico and Panama have just started developing such projects and the Dominican Republic has expressed strong interest.

2. On-Farm Research on Rotation Systems in Mondomo.

Introduction

The accumulated evidence suggests that cassava producers in Latin America very rarely utilize fertilizer on cassava but rather rely on fallow or rotation systems in order to maintain soil fertility and yields. This type of land use pattern may be rational, even for small-scale producers, where farmers have few other cropping alternatives and where farmers face severe marketing constraints. However, with the expansion of market opportunities, the expectation is that farmers will substantially intensify their land use by bringing into production the fallowed land. The traditional avenue of maintaining adequate plant nutrition in such a process of intensification is through chemical fertilizer application. The on-farm trials attempt to understand this substitution process.

Two years of trial results

The farms or plots are stratified by the length of time in fallow and four different fallow states are defined. Two sources (TSP and rock phosphate) and four levels of phosphorous (0, 25, 50, and 100 kg/ha) are tested, with and without a base application of 50 kg/ha of nitrogen and 50 kg/ha of potassium. Moreover, in the second year there was a division of replicates to evaluate residual response. The trial is planned for three years and the first two years of data are summarized (see Cassava Annual Report "Economics Section" for more detail).

The farmer check and the absolute check provide a very clear validation of the stratification by fallow state and the second year results show very little change from the first year (Table 9). The second year results also demonstrate again that there is little response to N and K without P application and also very little response to P without N and K. But these are the only similarities between the results of the two years.

First, in the second year there is a large and consistent decrease in yields in the long-term fallow, even with application of fertilizer. This tendency has been observed in plantation systems in Asia, where virgin land is newly opened for cassava.

Second, there is a distinct increase in yields in the degrading fallow system with the second year of fertilizer application. Yields in this system approached those of the long-term fallow. It could be said that yields in all systems were approaching about 15 t/ha with fertilizer application, were it not for the anomaly of the 3-5 year fallow system, where another factor appeared to be operative.

Third, where there was no basal application of N and K, there was a consistent decline in yields with increasing application of phosphorous (i.e., in relation to the 25 kg/ha level) except in the degraded fallow where there was no response to phosphorous. This was not due to excess top growth, as top weight declined in the same manner. Yields appear to be very sensitive to low levels of phosphorous application in these

soils, given some level of N and K. This is confirmed by evaluation of the residual response (Table 10). In the long-term fallow and the 8-10 year fallow there was a higher yield on residual phosphorous than with phosphorous reapplication. There was a residual response in the other two fallow states as well, but reapplication gave a higher yield, particularly in the degrading fallow.

These results are suggestive that the immobile nutrient, phosphorous can be applied at very low levels (25 kg/ha) to achieve economically optimum yield (or at least at this level of potassium application), even in soils such as these where Bray II phosphorous rarely exceeds 2.0 ppm. In fertility trials in these types of soils reported in the literature, cassava has always shown a dramatic yield response between zero and the first level of application. The farm trial results are only suggestive, but would argue for closer scrutiny of yield response at very low levels of phosphorous application.

Responsiveness to low levels of P leads to a final observation. Sampling of mycorrhiza in the trials led to no conclusion except that there was a large degree of variation. This occurred in most measures of mycorrhiza infection: percentages of root with hypha infection, vesicular infection, soil spore count, and strain identification. What was most noticeable was that over twenty races of mycorrhiza were identified and the population distribution was significantly different between plots and even between treatments. How effective each of these races is remains to be determined. Nevertheless, if an effective mycorrhiza association is so critical to cassava yield in these low phosphorous soils and if mycorrhiza is so variable is this zone, is it possible to interpret yield differences between fertilizer treatments and what should be the relative weight between managing phosphorous levels and managing mycorrhiza populations ?

Farm model

A linear programming model of the farming system in Mondomo was constructed with a particular focus on the fallow system. The four fallow states defined in the farm trials were utilized as the cassava activities, i.e. maintenance of a certain yield level through time required the allocation of a requisite amount of land to fallow. A brief summary of the results are shown in Table 11. What the model suggests is that where fertilizer is not utilized, the optimal strategy for the farmer independent of farm size is to use the long-term fallow system. Such a strategy for a six hectare farm implies a stable but very small net income of about $28,000 pesos, an income well below subsistence requirements. Farmers have thus adopted a short term strategy of sowing larger areas in cassava at the expense of equilibrium fallow, with the result that incomes will decline over time. Thus, in a non-random sample of plots in the area, of 28 plots that had just come out of fallow 39% had been in long term fallow, 32% had been in fallow 6-10 years, 25% in fallow 3-5 years, and 4% in fallow less than three years. As production in the region has expanded in relation to market possibilities, farmers are increasingly having to shorten fallow periods and future incomes will decline as a result of declining fertility.

Introducing fertilizer into the fallow system (i.e. under the assumption that fallow is still necessary even with fertilizer) raises potential incomes in the six hectare farm by 43% as a result of needing less fallowed land in equilibrium and by raising average yield levels. However, incomes are still not large due to the substantial amount of land devoted to fallow, However, introducing a continuous cropping system would have the potential of increasing annual incomes by over a factor of four. Such a continuous cropping system would require improved methods of erosion control, fertilization, and possibly a rotation system with a green manure or grain crop, given that such a crop can be identified. The next phase of on-farm research in the zone will focus on adapting such a system to local conditions.

Table 1. Self-sufficiency ratios for agricultural commodities in Latin America.

	Cereals (%)	Other food (%)	Other non-food (%)	Livestock (%)	Total (%)
Mexico and Central America					
1961/65	100	115	324	104	123
1975	86	115	274	100	113
1980	80	117	227	100	110
Caribbean countries					
1961/65	36	222	163	83	139
1975	35	194	198	79	120
1980	39	199	158	81	122
Andean countries					
1961/65	75	108	277	92	110
1975	71	107	271	96	107
1980	63	103	256	92	102
South cone					
1961/65	158	112	71	119	121
1975	147	110	98	110	113
1980	173	138	98	115	124
Northeast Atlantic					
1961/65	91	108	193	101	114
1975	95	124	217	101	117
1980	85	129	192	101	115
Total region					
1961	102	116	202	105	118
1975	97	121	166	101	114
1980	91	127	156	102	114

SOURCE: FAO, Agriculture Toward 2000, 1981.

Table 2. Utilization of cassava in Latin America, 1971-76

Region and country	Human consumption: Fresh (metric tons)	Human consumption: Processed (metric tons)	Starch (metric tons)	Animal feed (metric tons)	Total utilization (metric tons)
Argentina (75/76)	78,000	44,000	15,000	88,000	225,000
Brazil (75)	687,730	6,553,457	411,000	4,020,552	11,672,739
Paraguay (76)	299,825	136,998	38,500	361,617	836,940
Venezuela (75)	119,917	42,606	24,064	130,806	317,392
Andean					
Bolivia (72)	68,923	-	4,800	128,493	202,216
Colombia (70)	466,470	-	29,200	186,486	682,156
Ecuador (74)	124,109	195	2,850	9,640	136,794
Peru (76)	173,708	750	2,500	125,208	302,166
Central America					
Costa Rica (73)	10,960	925	1,000	-	12,885
El Salvador (71)	16,470	-	-	-	16,470
Guatemala (72/74)	4,488	-	2,512	-	7,000
Honduras (74)	11,284	-	-	-	11,284
Nicaragua (74)	22,108	-	2,500	-	24,608
Panama (70)	28,803	300	3,633	5,900	38,636
Caribbean					
Cuba (76)	179,414	-	13,000	61,586	254,000
Dominican Rep. (75)	169,205	?	2,880	4,050	176,135
Haiti (79)	-	246,083	-	7,610	253,693
Jamaica (75)	5,426	13,725	2,554	-	21,705
Total Latin America	2,466,840	7,039,039	555,993	5,129,948	15,191,819

SOURCE: CIAT data files.

Table 3. The importance of cassava in farms of 20 hectares or less, Atlantic Coast, 1982.

	Atlantico	Bolivar	Sucre	Cordoba
% of farms less than 20 ha.	79.6	69.0	75.0	77.0
% of land in farms less than 20 ha.	14.2	7.6	6.0	6.2
Average farm size of farms less than 20 ha.	5.5	7.1	6.0	6.5
Area in cassava (ha)	1.1	0.7	0.9	0.6
% of cultivated land in cassava	48	20-44	50	42
% of farm area in crops	40	51	30	23
Most common cassava system[a]	C/M	C/M	M/Y/C	M/Y/C
% of cassava in most common system	82	N.A.	61	80
Yield of cassava in cropping system (t/ha)	8.3	8.0	6.0	6.0
Yields of cassava in monoculture (t/ha)	N.A.	12.0	11.0	7.4

[a] C= cassava, M = maize, Y = yam

SOURCE: W. Janssen, unpublished survey data.

Table 4. Screening of production zones on the Atlantic coast for their appropriateness in establishing a cassava-drying industry (scale 0 to 4, 0 = unappropriate; 4 = very appropriate).

		Atlantico	Bolivar	Sucre	Cordoba
Production potential					
Land availability	- size of the farms	0	4	1	3
	- tenancy of the land [a]	3	2	3	4
Mechanization possibilities	- tractor availability [b]	3	0	4	2
	- mechanization feasible [c]	1	0	3	3
Fresh market competion	- present market access [d]	1	3	2	3
	- cassava quality [e]	2	2	2	2
Dry season [f.]		3	1	2	2
Productivity increase	- soil quality [e]	2	2	2	2
	- crop systems [g]	3	3	1	1
Institutional support [h.]		3	1	3	2
Project impact					
Crop alternatives [i.]		3	2	1	1
Available employment [j.]		2	1	3	4
Available institutional assistance [k.]		1	3	2	2

Notes: a) share of land in property. b) % of farmers who say they can rent tractors. c) % of farmers who say their land can be mechanized. d) average sales per farm between May'82 and May'83. f) weather-maps Agustin Codazzi. g) ease in increasing present cropping system productivity and area. h) subjective analysis of the author. i) indicated importance by farmers of cassava. j) weighted average of off-farm income and wages. k) subjective analysis of the author. e) too variable within zones to form a conclusion.

SOURCE: Farm survey in the ICA-DRI zones among 420 farmers, March to May 1983.

Table 5a. % of farmers that would grow more cassava at a fixed price of:

	4 pesos	5 pesos	6 pesos	7 pesos
Atlantico	12%	12%	30%	72%
Bolivar	26%	38%	60%	74%
Sucre	8%	24%	59%	77%
Cordoba	37%	39%	61%	77%

Table 5b. % of farmers that would grow less cassava at a guaranteed price of:

	4 pesos	5 pesos	6 pesos	7 pesos
Atlantico	58%	40%	22%	10%
Bolivar	58%	42%	24%	6%
Sucre	46%	31%	6%	2%
Cordoba	37%	25%	9%	5%

SOURCE: CIAT/ICA/DRI-farm survey, March-May 1983.

Table 6. Relationships between yields per hectare, costs, and margins per ton of dried cassava in Sucre.

Yield (t of fresh roots/ha)	Production costs ($ pesos/t of dried cassava)[a]	Margin ($ pesos/t of dried cassava)
8	9563	1749
10	7650	3662
12	6375	4937
16	4781	6531

[a] Based on land costs of $7,000 pesos per ha.

Table 7. Production of animal feed concentrates in Colombia 1960-82.

Year	Total (000 t)	Poultry (000 t)
1960	125.7	87.8
1965	216.1	151.1
1970	563.1	395.0
1975	970.3	730.7
1976	978.2	714.1
1977	1085.8	722.7
1978	1205.3	872.9
1979	1386.1	1011.8
1982	1509.8	1146.7

Table 8. Area and production of sorghum and imports of coarse grains in Colombia, 1970-1981.

	Sorghum			Imports	
Year	Area (000 ha)	Yield (t/ha)	Production (000 t)	Sorghum (000 t)	Maize (000 t)
1970	53.6	3.1	165.0	-	6.6
1972	84.0	2.8	238.0	-	0.6
1975	134.0	2.5	335.0	-	3.1
1976	173.6	2.5	427.7	-	16.2
1977	189.5	2.1	406.2	126.8	100.7
1978	224.8	2.3	516.7	50.6	66.2
1979	221.2	2.3	501.3	4.8	60.0
1980	206.0	2.1	430.5	176.9	192.6
1981	231.3	2.3	532.0	11.0	79.6

Table 9. Root yield of different fertilizer treatments by fallow state and by year in Mondomo.

Fertilizer treatment [a]	Degrading		3-5 years		8-10 years		Long-term	
	1st year (t/ha)	2nd year (t/ha)	1st year (t/ha)	2nd year (t/ha)	1st year (t/ha)	2nd year (t/ha)	1st year (t/ha)	2nd year (t/ha)
Farmer check	3.8	4.3	1.7	5.8	6.7	7.4	10.5	10.2
Without base nutrients								
0 kg/ha P	3.8	3.4	4.5	3.7	3.8	6.2	15.1	12.2
25 kg/ha P	5.6	3.2	9.9	13.5	6.8	8.0	19.3	12.3
50 kg/ha P	5.5	2.5	9.7	12.4	7.6	6.5	15.8	10.1
100 kg/ha P	5.6	4.1	8.3	7.8	8.6	7.4	19.7	7.5
With base nutrients [b]								
0 kg/ha P	4.0	5.0	3.8	4.8	4.1	7.7	14.3	12.2
25 kg/ha P	6.2	10.6	16.7	21.3	12.9	12.3	20.2	12.7
50 kg/ha P	7.3	12.6	19.2	24.5	15.1	14.6	21.1	14.8
100 kg/ha P	8.3	12.7	17.9	12.4	14.3	11.3	24.3	15.1

[a] All phosphorous band applied in the form of triple superphosphate

[b] 50 kg of N and 50 kg of K as elemental nutrients.

Table 10. Residual response to phosphorous in second year in Mondomo.

Fertilizer treatment [a]	Degrading		3-5 years		8-10 years		Long-term	
	Reapply (t/ha)	Residual (t/ha)	Reapply (t/ha)	Residual (t/ha)	Reapply (t/ha)	Residual (t/ha)	Reapply (t/ha)	Residual (t/ha)
Farmer check	4.3	-	5.8	-	7.4	-	10.2	-
Without base nutrients								
0 kg/ha P	3.4	3.4	3.7	3.7	6.2	6.2	12.2	12.2
25 kg/ha P	3.2	4.7	13.5	11.7	8.0	9.9	12.3	10.0
50 kg/ha P	2.5	7.0	12.4	12.4	6.5	7.7	10.1	8.1
100 kg/ha P	4.1	4.1	7.8	9.1	7.4	6.0	7.5	7.7
With base nutrients [b]								
0 kg/ha P	5.0	5.0	4.8	4.8	7.7	7.7	12.2	12.2
25 kg/ha P	10.6	7.9	21.3	16.1	12.3	15.3	12.7	16.1
80 kg/ha P	12.6	7.3	24.5	20.2	14.6	15.4	14.8	16.6
100 kg/ha P	12.2	8.0	12.4	16.9	11.3	17.7	15.1	15.4

[a] All phosphorous applied banded in the form of triple superphosphate.

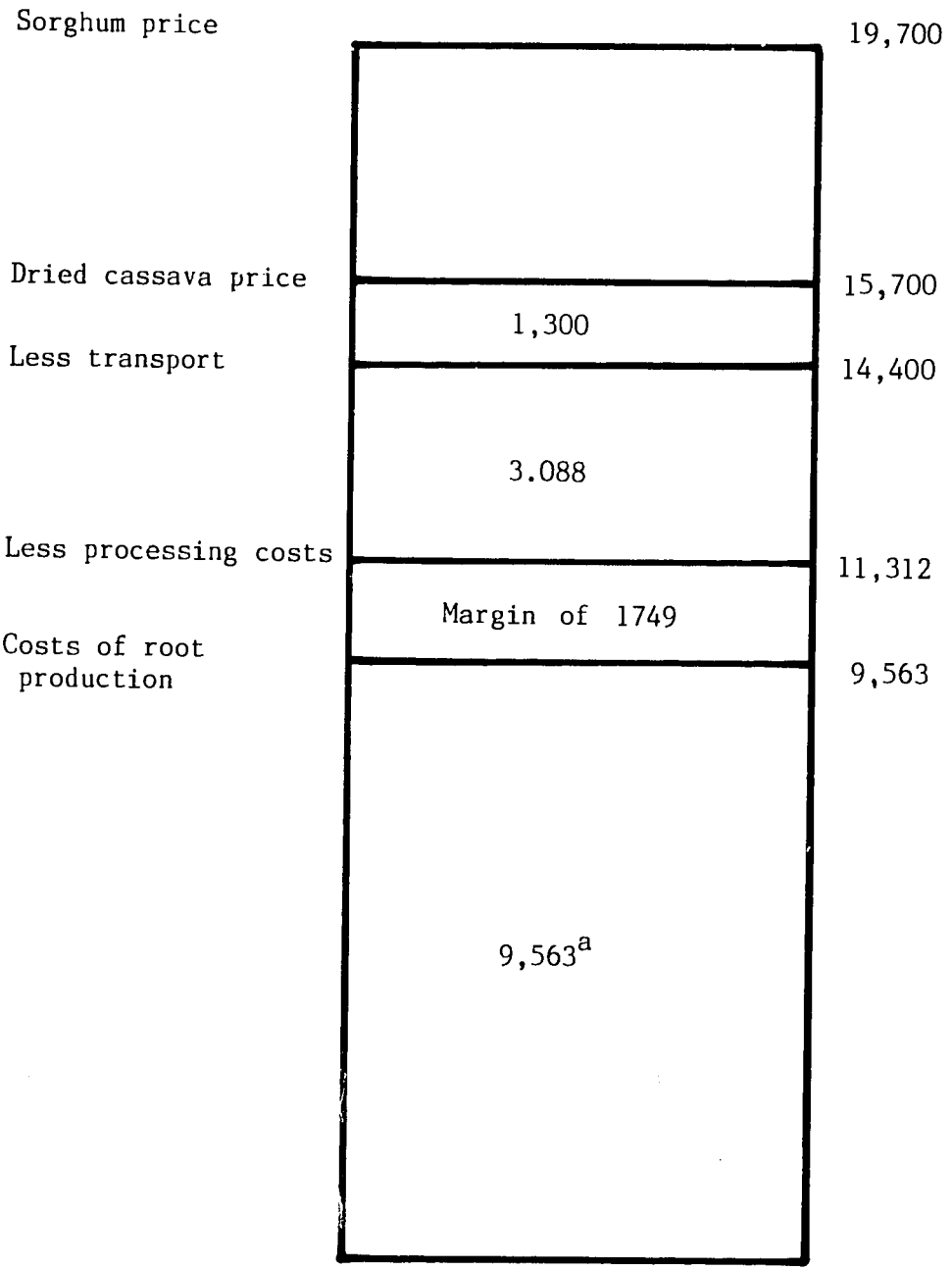
[b] 50 kg of N and 50 kg of K as elemental nutrients.

Table 11. Optimum land allocation strategies in equilibrium as derived from a farm model for Mondomo.

Land allocation and income	Farm size (ha)			
	6.1	11.1	16.1	21.1
Without Fertilizer				
Cassava (ha)	.37	.78	1.20	1.62
Fallow land (ha)	4.03	8.62	13.20	17.78
Fallow state	Long-term	Long-term	Long-term	Long-term
Net income (pesos)	28,388	35,140	37,397	38,950
With Fertilizer				
Cassava (ha)	.67	1.34	1.63 [a]	1.62
Fallow land (ha)	3.77	8.06	12.77	17.78
Fallow state	8-10 years	8-10 years	8-10 years Long-term	Long-term
Net income (pesos)	40,524	49,158	55,241	59,717

[a] 1.01 ha in 8-10 year fallow and .62 in long-term fallow.

Figure 1. Determination of the price and cost per ton of dried cassava in Colombia.



[a] Based on yield of 8t/ha and conversion rate of 2.5:1

Scientific Training and Conferences

Introduction

In 1983, the Cassava Program continued to collaborate with national programs in Latin America and Asia in the training of their scientific personnel and in the dissemination of technologies favoring the production of cassava in those countries where there is an interest and a potential for this crop. As of 1983, 430 professionals from 38 countries have been trained (Table 1).

The most outstanding aspects of this year can be summarized as follows:

- National programs were offered a training program with four options: support for in-country courses; advanced studies in research related to postdoctoral studies; advanced studies in post-master's or postdoctoral research and postgraduate specialization.

- The book, "Cassava: Integrated Control of Pests", was compiled and published under the financial auspices of the United Nations Development Programme. This book constitutes the most important reference material on the subject. It is being distributed to visiting researchers working in this area and is on sale at CIAT.

- Continued support was given to Colombia and Cuba for courses organized by the different national programs. This year the technical seminars were better organized to optimize the time required to transfer specific information to groups of Colombian professionals associated with those institutions responsible for agricultural development.

- The first intensive course on the establishment and operation of cassava drying plants was carried out with the participation of 10 professionals from five countries.

- In collaboration with CIP and IITA, a workshop was held on the propagation of root and tuber crops with the participation of scientists from Latin America, Asia and Africa.

Training Activities at the CIAT Headquarters

During 1983, 21 visiting researchers and three associate researchers were trained at CIAT (Table 2) from 10 countries and 18 different institutions (Table 3). Two visiting researchers and two associated researchers worked on their master's and doctoral theses, respectively. Ten of the 24 trainees participated in the intensive course on the establishment and operation of cassava drying plants. This course ran for four weeks of which two were devoted to theoretical/practical instruction at the CIAT headquarters while the other two weeks were spent in intensive practice on the North Coast of Colombia. The participants lived with the farmers and actually managed

the drying plants already established. Of the 10 course participants, 5 came from Colombia, 2 from the Dominican Republic, 1 from Mexico, 1 from Panama, and 1 from the Bahamas (Table 4).

Fourteen of the 24 professionals trained had 58 months of training in such disciplines as: entomology (4), genetic resources and breeding (5), phytopathology (2), soils and nutrition (3).

The number of training participants at CIAT was less than that of 1982. However, emphasis was placed on those processing aspects of the crop in the hope that participants from the different countries will have a tool with which to solve storage and marketing problems - an important consideration with a product as perishable as cassava. Due to the experience acquired by the program in this course, the processing aspect of cassava will be offered in the future as another specialization of the program.

Training related to academic degrees

Four students - two Colombians and two from the United States began work on their theses leading to postgraduate degrees (Table 5), three of them in entomology and one in phytopathology.

The subjects of their theses are:

(1) The effect of associated crops on cassava pests (Cliff Guld).

(2) Evaluation of the importance of predators of mites in cassava (Ann Braun).

(3) Etiological research on the E.T. virus in cassava (Nancy Barrera).

(4) The Phytoseiidae mites in cassava in the Cauca Valley (Nora Mesa).

In the same vein, contacts were established and two scholarships were awarded contemplated in the project financed by the UNDP. One was assigned in Mexico to an entomology student, Jose Antonio Urias, and the other in Paraguay to a breeding student, Luis Alberto Caceres, who has been accepted at the Universidad de Lavras in Brazil. These two researchers had previously participated in specific training programs at CIAT.

In-Country Training Support

The training program gave support to Colombia and Cuba in 1983.

To support the pilot project for cassava drying contemplated in the DRI-ACDI-CIAT agreement, two courses were given on the production and processing of cassava with the participation of 69 professionals -one course was held in Sincelejo and the other in Barranquilla. These courses corresponded to a training program initiated in 1981 through which activities related to the drying plants were reinforced on the

North Coast of Colombia. The success of this program as measured in the possible proliferation of plants similar to these not only on the North Coast but also in the interior of the country, envisions CIAT's participation in similar courses in the future.

In Armenia, Colombia, an important course was carried out on the production of cassava emphasizing soil conservation in cooperation with the Federacion de Cafeteros and the participation of 39 professionals from different organizations related to agricultural development in the zone.

In this course, important aspects of the technology of cassava production in the coffee-growing zone of Armenia were discussed. Also, a document was produced containing basic recommendations on management of the crop.

In Manizales, Colombia and in cooperation with the Universidad de Caldas, a course was offered on the integrated control of pests for 25 agronomists from the university and other regional institutions. Two of the instructors for this course had participated in a course on the same subject held at CIAT, the previous year. The university will offer this course on an annual basis.

In Cuba and in collaboration with CENEVIT (Centro Nacional de Investigaciones de Viandas Tropicales) the first postgraduate course on cassava production was carried out. Forty-one agronomists participated in the two week course in which 40 hours of theoretical instruction were given and 48 hours of practice. The Cassava Program participated with four members of its staff and CEMSA provided seven technicians of which six had received training at CIAT in previous years. CENEVIT requested that this course be repeated in 1984.

Technical Seminars

During 1983, three technical seminars were organized, two of them for 30 agronomists of the Caja Agraria in Colombia on the agronomy of cassava, and one for 32 agronomists from ICA on pest management in cassava. These technical seminars have the advantage of providing in an organized fashion the transfer of information to a large group of professionals interested in specific subjects.

Conferences

In cooperation with CIP and IITA and under the financial auspices of the UNDP, a working seminar was held on the propagation of root and tuber crops, September 12-16, 1983. The objectives of this seminar were: (1) to review the actual state of technology on the propagation of root and tuber crops in tropical countries; (2) discuss the available techniques and identify the most critical problems in the propagation of these species; (3) discuss and come to an agreement on the required strategies for the multiplication of good quality seeds for these cultivars.

Thirteen scientists from three international centers participated in this meeting and 16 scientists from 12 countries were invited. During this meeting four topics were discussed: the importance of good quality planting material on the production of root and tuber crops; the production situation of sexual and asexual seeds; phytosanitary and physiological problems in seed production; special techniques for the production of high quality seed and their storage. Readings from the seminar are in the process of publication.

Table 1. Training participants from 1968-1983 by countries.

Country	No. Participants
Bolivia	5
Brazil	94
Colombia	86
Costa Rica	9
Cuba	12
Dominican Republic	20
Ecuador	12
Guiana	4
Haiti	4
Honduras	5
Mexico	31
Nicaragua	3
Panama	7
Paraguay	3
Peru	10
El Salvador	2
Trinidad and Tobago	1
Venezuela	14
United States	12
West Germany	6
Italy	1
Holland	8
United Kingdom	5
Indonesia	12
Malasia	14
Japan	1
Philippines	11
Thailand	24
India	5
Sri Lanka	6
Seychelles	1
Cameroon	3
Kenya	1
Nigeria	2
South Africa	3
Tanzania	1
Zimbabwe	1
Bahamas	1
	430

Table 2. Training of visiting researchers and associates in 1983 in the cassava program.

Discipline	Visiting Researchers		Associate Visiting Researchers		Total [b]
	For MSc	non-thesis	For Ph.D	Non-thesis	
Entomology	1 (3[a])	1 (2)	2 (9[a])		4
Genetic Resources, breeding		4 (12)		1 (3)	5
Phytopathology	1 (10[a])	1 (5)			2
Soils, Nutrition		3 (14)			3
Processing		10 (10)			10
TOTAL	2 (13)	19 (43)	2 (9)	1 (3)	24 (68)

[a] Continue in 1984; ( ) = months of training

[b] Total until 1983

Table 3. Professionals trained in the cassava program by countries and institutions.

Country	No.	Institutions
Colombia	11	Universities (3), ICA (2), SENA (1), DRI (1), CECORA (2), SEC. AGR. (1)
Brazil	2	EMBRAPA CAMARAGIBE
Cuba	2	CEMSA, MIN. OF AGRICULTURE
U.S.A.	2	UNIV. CALIFORNIA
Thailand	1	MINAGRIC.
Zimbabwe	1	UNIVERSITY
Dominican Republic	2	SEC. OF STATE FOR AGRIC.
Mexico	1	SARH, DIST. TEMPORAL
Panama	1	IDIAP
Bahamas	1	MINIAGRIC.
	24	

Table 4. Participants in the course on the establishment and operation of cassava drying plants.

Name	Country	Institution
Rafael A. Rodriguez	Colombia	FINANCIACOOP
Regis M. Benicez	Colombia	CECORA
Balmiro A. Donado	Colombia	CECORA
Ubaldo Villacob	Colombia	DRI
Alvaro E. Mozo	Colombia	SENA
Kenneth Vincent A. Richardson	Bahamas	MIN. AGRIC.
Jose A. Aguilar	Panama	IDIAP
Jorge E. Martinez T.	Mexico	SARH
Rogelio A. Fernandez	Dominican Republic	SEC. AGRIC.
Luis J. Almanzar	Dominican Republic	SEC. AGRIC.

Table 5. Professionals trained in the cassava program at CIAT during 1983.

	Discipline	Country	Institution	Months
Visiting researchers				
Quintana B. Jorge A.	Ent. cassava	Brazil	CAMARAGIBE	2
De Goes A. Marisa	Genetic Resources	Brazil	EMBRAPA	4
Sanchez Marino	Soils	Colombia	U. NACIONAL	6 ½
Lopez M. Antonio	Breeding	Colombia	ICA	4
Martinez P. Servio	Phytopathology	Colombia	SEC. AGRIC.	5
Alvarez S. Andres	Breeding	Colombia	ICA	3 ½
Ruiz M. Luis Alberto	Soils	Cuba	CEMSA	4
Alguacil B. Juan Luis	Soils	Cuba	MIN. AGRIC.	4
Rowe Alan	Germplasm	Africa	UNIV. ZIMBABWE	1
Visiting researchers for MS thesis				
Barrera Nancy	Phytopathology	Colombia	U. NACIONAL	Continues
Mesa Nora	Entomology	Colombia	U. NACIONAL	Continues
Visiting associate researchers for PhD. thesis				
Braun Ann	Entomology	U.S.A.	U.California	Continues
Gold Clifford	Entomology	U.S.A.	U.California	Continues
Non-thesis Visiting associate researchers				
Tongglum Anuchit	Breeding	Thailand	Dept. Agric.	3 months

Table 6. Courses and technical seminars held in 1983 in cassava.

Country	Mode	Discipline	Coordinating institutions	Length days	No. participants
COLOMBIA					
Sincelejo	Course	Production-processing	DRI	5	31
Barranquilla	Course	Production-processing	DRI	5	38
Manizales	Course	Integrated control	UNIV. CALDAS	4	23
Armenia	Course	Soil conservation	FEDECAFE	4	39
Armenia	Technical Seminar	Pest management	ICA	1	32
CIAT	Technical Seminar	Production	CAJA AGRARIA	1	16
CIAT	Technical Seminar	Production	CAJA AGRARIA	2	14
CIAT	Course	Drying	CIAT	28	10
CUBA					
Santo Domingo	Course	Production	CENEVIT	10	41

Personnel
(as of December 1983)

Senior staff

James H. Cock, Ph.D., Physiologist, Coordinator

Anthony C. Bellotti, Ph.D., Entomologist, Entomology

* Guillermo G. Gómez, Ph.D., Nutritionist/Biochemist, Utilization

Clair Hershey, Ph.D., Plant Breeder, Plant Breeding

Reinhardt Howeler, Ph.D., Soil Scientist, Plant Nutrition and Soils

Kazuo Kawano, Ph.D., Plant Breeder, Plant Breeding (stationed in Rayong, Thailand)

Dietrich Leihner, Dr.agr., Agronomist, Cultural Practices

J. Carlos Lozano, Ph.D., Pathologist, Plant Pathology

John K. Lynam, Ph.D., Agricultural Economist, Economics

* Julio César Toro, Ph.D., Agronomist, Agronomy

Visiting scientists

Rupert Best, Ph.D., Utilization

Mabrouk El-Sharkawy, Ph.D., Physiology

* Marta Rojas de Hernández, Ph.D., Entomology

Postdoctoral fellows

* Upali Jayasinghe, Ph.D., Virology

Ewald Sieverding, Dr.agr., Soil and Plant Nutrition

Christopher Wheatley, Ph.D., Utilization

Research associat

Rafael Orlando L[illegible], M.S., Economics

Rafael Alberto Laberry, M.S., Plant Pathology

Bernardo Ospina, Ing. Agric., Utilization (stationed in Sincelejo, Colombia)

Benjamín Pineda, M.S., Plant Pathology

Octavio Vargas, M.S., Entomology

Research assistants

Lisímaco Alonso, Ing. Agric., Utilization

Bernardo Arias, Ing. Agr., Entomology

Darío Ballesteros, Ing. Agr., Soils (stationed in Carimagua)

Eitel Adolfo Burckhardt, Lic. Biol., Soils

Luis Fernando Cadavid, Ing. Agr., Soils

Fernando Calle, Ing. Agr., Germplasm

José Aquileo Castillo, Biol., Entomology

Carolina Correa, Econ., Economics

Miguel A. Chaux, Tec. Ing. Ind., Office of the Coordinator

Diego Izquierdo, Econ., Economics

Gustavo Jaramillo, Ing. Agr., Agronomy

Javier López, Ing. Agr., Cultural Practices

Jorge Orrego, Ing. Agr., Utilization

Germán E. Parra, Ing. Agr., Physiology

José Antonio Puente, Ing. Agr., Cultural Practices

Edgar Salazar, Ing. Agr., Cultural Practices

* Mauricio Valdivieso, Zoot., Utilization

Ana Cecilia Velasco, Lab. Clin., Plant Pathology