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Errata

Page	Columm	Element	Printed:	Should be:
6	1	Figure 2	M Col 59	M Mex 59
6	2	Figure 3	M Col 59	M Mex 59
6	2	Figure 3	LSD ($P<0.05$)	LSD ($P<0.05$)
7	1	Figure 4	M Col 59	M Mex 59
60	2	Second para., line 8	more to growth	more top growth
61	2	Line 1	and K contents	and K concentrations
20	1	Figure 1	I - Tolerant III - Tolerant V - Tolerant	I - Intermediate-resistant III - Intermediate-resistant [illegible] Intermediate-resistant
62	1	Figure 3	Stems □	Stems △
64	1	Figure 5	5.0 4.0 % N	5.0 4.0 % N 3.0
66	1	Figure 8	Figure 44	Figure 8
93	2	Footnote	*Left during 1979.	*Left during 1980.

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The Physiology section has shifted emphasis from the ideal plant type for near ideal conditions towards identifying which characters are associated with high root yield and quality under stress conditions. Work in 1980 was directed to a detailed study of the plant's reaction to water stress.

Growth and Yield under Water Stress

Growth and yields of the vigorous (M Mex 59) and the low-vigor cassava variety (M Col 22) were studied with a period of artificial rain exclusion. Stress was obtained by covering the soil with plastic from 15 to 25 weeks after planting; control plots received the natural rainfall which was well distributed and totaled about 500 mm during the 10-week period. Due to a natural dry period (approximately 120 mm of rain during 11 weeks) just before the exclusion period, plots were already stressed before the treatment period. Plant growth and development were followed throughout the stress period and subsequent recovery.

Control plots of M Mex 59 were extremely vigorous with leaf area indices (LAI) above three for much of the growth period and above four for considerable periods (Fig. 1). These LAI values are well above the normal optimum of 2.5-3.5 for root yield. Control plots of M Col 22 never attained LAIs higher than three and were suboptimal for most of the growth period. In both varieties, water stress reduced LAIs markedly, although M Mex 59 maintained a LAI approximately twice that of M Col 22 during the stress period.

Changes in LAIs are determined by the initial LAI, the number and leaf area of leaves formed, and the area of fallen leaves. The decrease in LAI during water stress periods is frequently said to be due to increased leaf fall. In this experiment total leaf fall in the stress period was reduced in the stress plots (Fig. 2,a and b). Mean age of fallen leaves from M Col 22 was similar in control and stressed plants (Fig. 2,a). In M Mex 59, leaf life was slightly longer in stressed plots due to reduced shading of lower leaves which resulted from decreased leaf area production (Fig. 2,b).

Reduced leaf area during stress was due to reduced production of new leaves and reduced leaf size (Fig. 2,c). In turn, the decreased number of new leaves was due to both reduced branching (Fig. 3,a) and reduced leaf formation per apex (Fig. 3,b). Work with pot plants suggests that leaf expansion and, hence, leaf size are extremely sensitive to water stress.

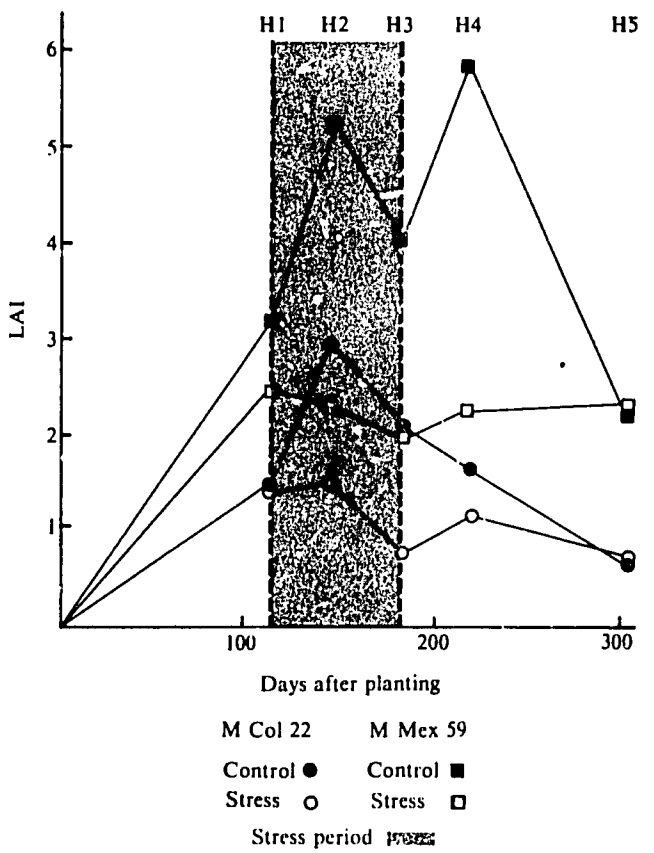


Figure 1. *Leaf area indices (LAI) of cassava cultivars M Mex 59 and M Col 22 during and after a water stress period. H= harvest.*

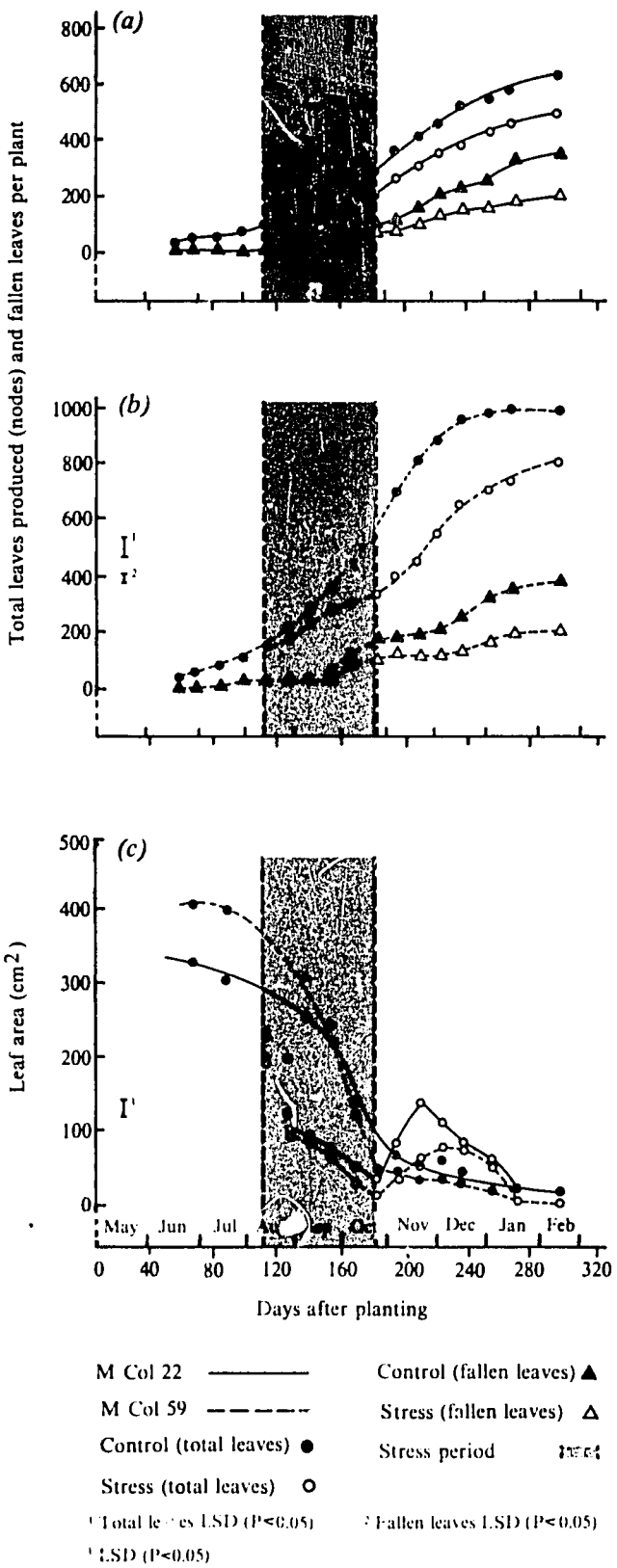


Figure 2. *Leaf production and leaf fall (a and b) and leaf size (c) of two cassava cultivars during and after a water stress period.*

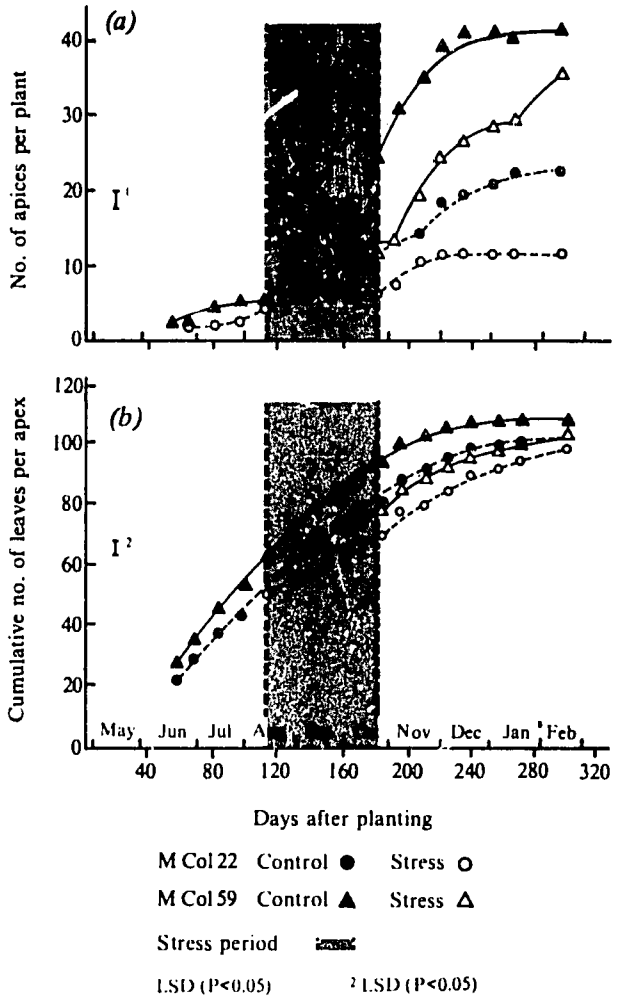


Figura 3. *Number of apices (a) and cumulative number of leaves per apex (b) of two cassava cultivars during and after a water stress period.*

The reduction in LAI and stomatal closure during the stress period caused a marked decrease in crop growth rate (Table 1). However, the percentage increase in standing biomass found in the roots greatly increased in the stressed plots, from 32 to 53% in M Mex 59 and from 70 to 87% in M Col 22. A direct result of this was that root yield of M Mex 59 was not significantly reduced in the stress period (Fig. 4) and that root yield was reduced proportionately less than crop growth in both varieties. Thus, during stress the crop tends to maintain root growth at the expense of top growth, utilizing reduced dry matter production extremely efficiently.

The marked decrease in LAI during the stress period is a mechanism to reduce transpiration (i.e., water loss) although loss of water was also controlled by stomatal closure. Leaves of plants in stressed plots had consistently

lower leaf conductance (a measure of stomatal opening) than did control plants. Leaf conductance of M Mex 59 was somewhat less than that of M Col 22, however, calculations suggested that total transpiration was similar due to the greater LAI of M Mex 59. Stomatal control was such that leaf water potential remained at similar levels in both stressed and control plots. The minimum leaf water potentials were approximately -1.5 MPa in both varieties.

Table 1. Crop growth rate of cassava cultivars M Col 22 and M Mex 59 during and after a water stress period.

Period[1]	Duration (days)	Mean daily solar irradiance (MJ/m^2)	Mean growth rate (kg/ha per day)			
			M Col 22		M Mex 59	
			Control	Stress	Control	Stress
PD - H1	109	17.3	27	27	39	30
H1 - H2	39	18.2	103	62	96	47
H2 - H3	33	19.3	112	14	74	51
H3 - H4	38	19.7	113	40	130	31
H4 - H5	87	20.3	17	35	61	115

[1] H = harvest; PD = Planting date

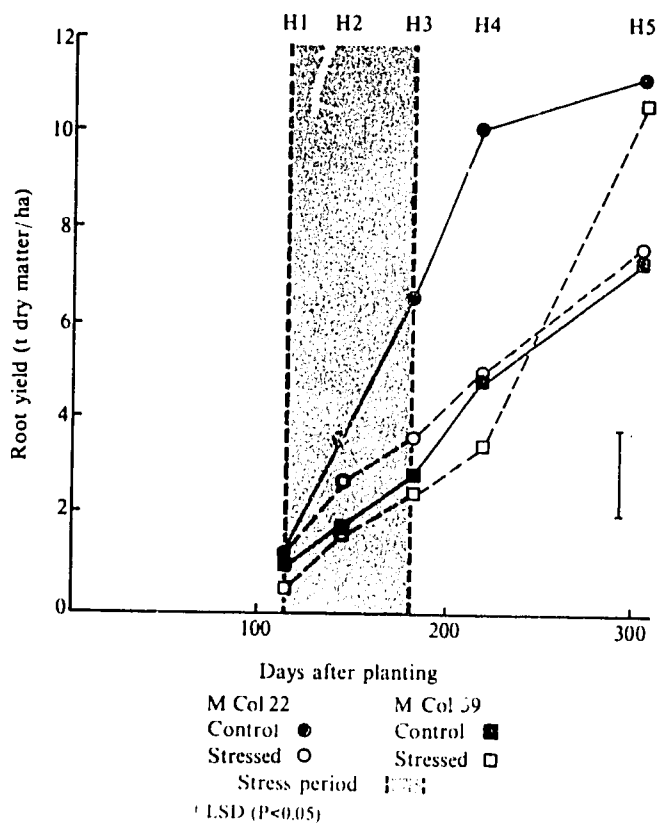


Figure 4. *Dry root yields of two cassava cultivars during and after a water stress period.*
H = harvest.

Both varieties also reduced average soil water potential to a depth of 2 m (maximum depth measured) to about -1.5 MPa, a level similar to that of the leaves. Soil water decreases were similar in both varieties, again suggesting similar transpiration rates for both varieties even with large differences in LAI.

At the second harvest, in the middle of the stress period, stressed plants of M Mex 59 had significantly more roots at greater depth than the controls. By the fourth harvest, roots were found 2.6 m deep, the greatest depth sampled. Although the cassava root system was quite deep it was also relatively sparse compared to many other crop plants. This rather sparse root system may well be a mechanism that leads to slow water use under drought and allows rather low levels of transpiration and growth to continue.

These data suggest that during a stress period the cassava plant can extract soil water to a depth of at least 2 m, to soil water potentials of -1.5 MPa. The sparse root system, reduced leaf area and partial stomatal closure all lead to a slow but prolonged water uptake during a stress period allowing continued but rather slow total growth. At the same time, the proportion of total growth used in root expansion increases under stress enabling the plant to minimize the reduction in root growth. This effect was particularly noticeable in the more vigorous variety M Mex 59.

After the stress period, a flush of new growth appeared. Pot trials show that leaves that pass through the stress period rapidly increase their photosynthetic rates when rewatered (Fig. 5), providing the plant with a positive carbon balance as soon as water becomes available. Root reserves are also apparently used for rapid regrowth of the tops (see next section). Leaf area indices in both varieties increased during recuperation, and by final harvest 10 months after planting, were similar in both control and stressed plants (Fig. 1).

Leaf area recovery was related to leaf formation rate per apex and branching; leaf formation rate per plant was similar in recuperating and control plants (Fig. 2). Leaves of recuperating plants were, however, much larger than those of the controls at similar node levels. Large leaf size during early recuperation allowed plants to rapidly increase LAI.

Total nodes produced in stressed plants were always less than in unstressed plants so stem weight increases were less in the former during recovery. LAI in M Mex 59 was sufficient to achieve reasonable daily growth rates of 89.5 kg/ha in recuperating plants, compared to 82.0 kg/ha in

controls; this coupled with decreased stem growth resulted in greater final yield (10.7 t dry roots/ha) in stressed plants than in the controls (7.6 t/ha). On the other hand, the LAI of previously stressed M Col 22 was so low that daily growth was reduced markedly (36.5 kg/ha) compared to the controls (46.2 kg/ha) and root growth rate was lower during recovery leading to a yield of 7.3 t/ha in the stressed plots compared to 11.2 t/ha in the controls.

These results suggest that when stress occurs in the middle of the growth period,a vigorous cassava variety may be preferable to a less vigorous type which may yield better under non-stress conditions.

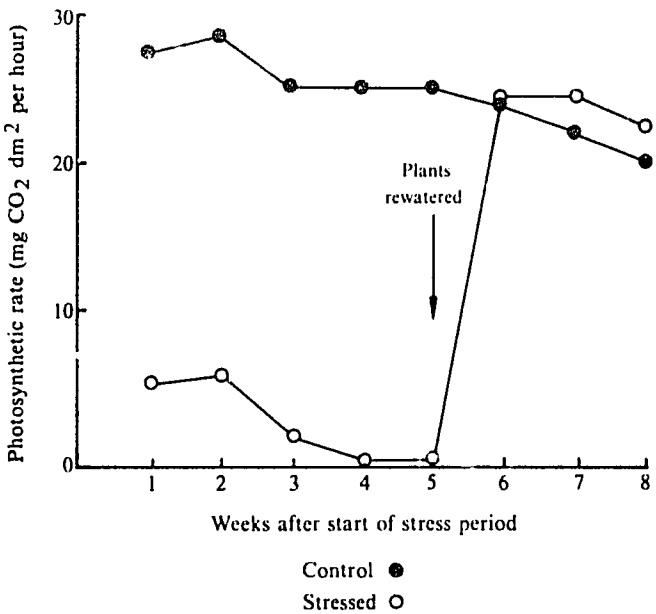


Figure 5. *Photosynthetic rate of the same leaf of pot-grown plants of cassava cultivar M Col 1684 during and after a water stress period.*

Root Quality under Water Stress

Root quality of cassava is closely related to dry matter content and starch content. Dry matter content of control plants in the experiment described above increased steadily with age of the crop until the final harvest 10 months after planting. Root dry matter of M Col 22 increased markedly during the first part of the stress period (Fig. 6); however, during recuperation, there was a marked decrease in dry matter that was maintained to a lesser extent by final harvest. This decrease in dry matter in the recuperation phase is consistent with the hypothesis that root reserves are used to produce the rapid flush of growth during recuperation.

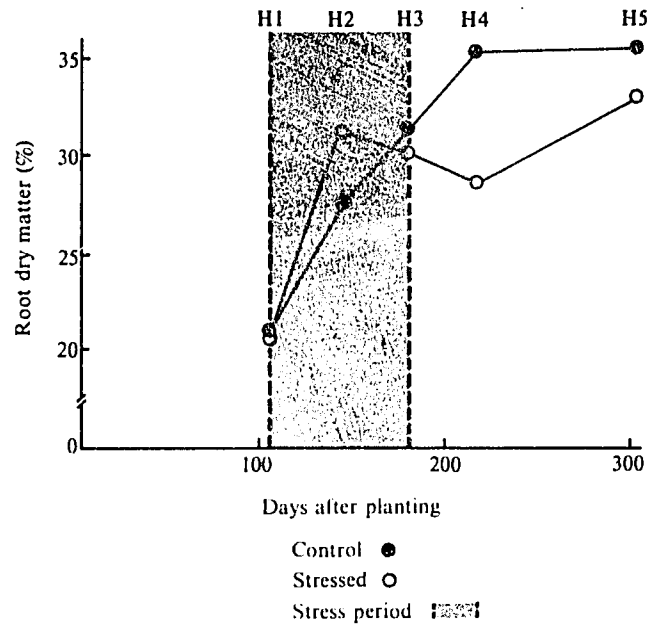


Figure 6. *Changes in root dry matter of cassava cultivar M Col 22 during and after a water stress period. H = harvest.*

Starch content increased slightly by the end of the stress period (20.1 versus 18.3%). However, by the end of the first recuperation phase starch content had risen to only 20.3% compared to 26.3% in the controls and this difference still existed at a reduced level by final harvest. Starch content (root quality) was, therefore, most affected by stress in the recuperation phase and was never completely recovered.

Growth Analysis

During recent years the clone M Col 1684 has consistently been one of the highest yielding varieties over a wide range of conditions in the regional trials network. Growth and development of M Col 1684 were compared to M Ven 77, M Ptr 26 and M Col 22 at CIAT-Palmira to determine if basic differences existed between M Col 1684 and the other clones. At final harvest one year after planting, yields ranged from 10.4 t dry roots/ha in M Ven 77 to 14.4 t dry roots/ha in M Col 1684. Total biomass (including fallen leaves) varied little (26.1-27.4 t dry matter/ha) and, hence, yield differences were mainly due to differences in harvest index, which ranged from 0.40 in M Ven 77 to 0.53 in M Col 1684.

The pattern of leaf area development in all varieties was similar, although M Col 22 developed more slowly but maintained a higher LAI during later growth stages.

M Col 1684 was by far the most profusive branching of the four clones tested. Whereas branch number of the other varieties increased in a phasic manner, the number of active apices of M Col 1684 fluctuated widely. These fluctuations are not due to a large variability in the data but, rather, due to a high mortality rate of apices at certain times. Apex mortality under stress conditions may allow M Col 1 to rapidly adjust its leaf area to stress conditions and this dieback may reduce the amount of dry matter required for node growth in the recovery phase.

Although early branching was much greater in M Col 1684, its LAI did not tend to be greater than that of the other lines due to a small maximum leaf size, a very early decline in leaf size with plant age, and a relatively low leaf formation rate per apex.

Other characters such as photosynthetic rate, water use efficiency of single leaves, root number, leaf inclination and the relation between crop growth rate and LAI showed no major differences that could be associated with higher yield in M Col 1684.

Entomology

Major studies were directed to accumulating information on the complex of insects that attack the cassava crop. Emphasis was on biological control studies of important pests, especially the cassava hornworm and mealybugs. Basic studies of the stemborer were conducted and reported for the first time. A new pest, a subterranean Hemiptera which causes considerable damage to cassava roots, is described.

Cassava Hornworm

The effectiveness of natural populations of the egg parasites *Trichogramma* sp. and *Telenomus* sp. were studied during two natural outbreaks (about one month apart) of the cassava hornworm, *Erinnyis ello*. These two parasites are an integral part of a pest management program being developed to combine utilization of natural enemies with chemical products to reduce and control hornworm populations.

During the first outbreak, egg parasitism increased from an initial 2% to 63%. In the second attack, initial parasitism was 35% and increased to 90%. Plant defoliation was heavy during the first outbreak but was only minimal in the second one. *Trichogramma* parasitized a greater percentage of eggs than did *Telenomus*. These findings indicate that damage currently may be reduced or repeated attacks averted when natural enemies increase during an initial attack.

A granulosis virus was discovered infecting natural populations of the hornworm. Virus-infected larvae were ground and diluted in water to a 30% concentration; rates of 5 cc and 10 cc of the viral solution per liter of water were applied to cassava foliage in the laboratory and in the field. In the laboratory, the 10-cc rate killed all larvae after 72 hours and the 5-cc rate gave 96% mortality after 96 hours. Three days after the field application larvae were collected and observed. Complete mortality was noted 120 hours after application, for both rates.

Difluron, an insect growth regulator that inhibits synthesis of chitin, was tested on first instar larvae and on hornworm eggs. Complete mortality was observed for emerging larvae feeding on cassava foliage treated at three rates, 2, 4 and 6 g/liter of water. Death occurred during the first larval molt between the first and second instars. Difluron was also effective when applied to hornworm eggs with mortality of emerging larvae observed during the first molt. This product appears promising and will receive further study.

Mealybug

The cassava mealybug *Phenacoccus* sp. (identified as near *P. manihoti)* was first identified in Colombia in 1978. *P. manihoti* causes considerable losses in Africa, and has not been studied previously in the Americas.

Male and female life cycles of *Phenacoccus* sp. were studied in the laboratory on cassava leaf disks (Table 1). The female passes through four instars before reaching the adult stage, whereas the male has five instars. The average life cycle of females was longer than that of males — 39 versus 23 days. Females began ovipositing seven days (range of 5-8) after fertilization. Parthenogenesis was not observed in isolated females, which lived for up to 23 days. When males were placed with unfertilized, 15-23 day-old females, the ovisac formed in 2-3 days. An average of 200 eggs per ovisac was produced and the resulting sex ratio was three females to one male.

Biological control. High populations of the dipteran predator *Kalodiplosis coccidarum* were observed in populations of *Phenacoccus* sp. and *Phenacoccus gossypii* in the greenhouse and in the field. *K. coccidarum* was initially observed predating on eggs within the ovisac but larvae have also been found predating on nymphs — especially adult females — when ovisacs were unavailable.

This predator remains in the ectoparasitic stage and seldom causes nymphal mortality until the ovisac is formed when it then predates on eggs until completing its life cycle. Its ectoparasitic stage is important for survival when host populations are low. A female:male ratio of 2:1 was observed.

The average number of *K. coccidarum* per ovisac varied depending on host availability; when ovisacs were numerous, an average of three predator larvae were found per ovisac (from 1-5) and higher predator populations resulted in five larvae per ovisac (range of 2-8) Initial studies of *K. coccidarum* indicated a life cycle of 12 days (at 28°C) to 16 days (at 22°C).

The effectiveness of several enemies on controlling *P. gossypii* was studied on cassava plants growing in field cages. When mealybugs became very numerous (about 26,000 nymphs and adults per cage) natural enemies were allowed entry. Predator and parasite populations were recorded for six weeks, by which time mealybug populations were almost zero.

In general there was a higher percentage of predation than parasitism with the latter never averaging over 10%. Predation of ovisacs, principally by *K. coccidarum*, reached 100% after five weeks, and predation of nymphs and adults reached 96%, primarily due to *Chrysopa* and Reduviids. Major predators were *Chrysopa*, *K. coccidarum*, several Coccinellids and Reduviids; *Anagyrus* spp. were the predominant parasites (Table 2). In cages where mealybugs were most numerous, *K. coccidarum* was the heaviest predator while *Chrysopa*, the Reduviids and some Coccinellids predominated in cages with lower mealybug populations. *K. coccidarum* is host-specific for *P. gossypii* while *Chrysopa* and the Reduviids are general predators.

Table 1. Duration of life cycle of **Phenacoccus** sp. near **P. manihoti** on cassava[1] leaves under laboratory conditions (26-28°C, RH 60%).

Instar	Female			Male		
	No. of observations	Mean duration (days)	Range (days)	No. of observations	Mean duration (days)	Range (days)
I	31	9	8 - 11	30	0.9	8 - 11
II	35	5	4 - 6	18	6.2	6 - 7
III	40	5	4 - 6	20	2.2	1 - 3
IV	25	20	18 - 25	18	2.5	1 - 4
V				23	2.0	1 - 4
Total		39	34 - 48		21.9	17 - 29

[1] Variety M Col 113.

Table 2. Numbers of natural enemies[1] observed to attack mealybug **(Phenacoccus gossypii)** populations over five consecutive weeks in the field in exposed cages[2].

Week after exposure to natural enemies	Average number of natural enemies per cage				
	Predators				Parasite
	Kalodiplosis coccidarum	*Chrysopa* sp.	Coccinellidae	Reduviidae	*Anagyrus* sp.
1	492.0	33.3	61.0	-	17.5
2	40.5	27.8	20.7	35.7	8.3
3	50.0	30.0	28.3	10.0	2.3
4	11.7	23.8	2.3	12.0	0.2
5	1.3	18.7	3.2	7.0	0.2

[1] Average per cage for six cages.
[2] Field cages 3 x 3 x 2 m.

Stemborers

The lepidopteran stemborer, *Chilomina clarkei* (Amsel), attacks cassava throughout the year in the Colombian Llanos and has been found in other areas as well. Studies were initiated to determine its economic importance as well as its biology and ecology.

Attacks begin around lateral buds where leaves have already fallen. During the first four instars, it feeds under a fine web around these buds; after the fifth instar, it penetrates the stem completing its life cycle in galleries within the stem. These galleries weaken the plant, often cause stem breakage and provide entrance points for plant pathogens.

Life-cycle duration (larval, prepupal and pupal stages) of *C. clarkei* was studied on six cassava varieties. Cycles varied depending on varieties and ranged from 62.2 days (on M Ven 77) to 68.4 days (on HMC 2). Differences were observed only during the larval stages with the greatest fluctuation occurring during the eighth instar. Generally, eight instars occurred but the number varied between six and eight, even within varieties. Durations of the prepupal and pupal stages were constant in all varieties.

In a field planting at Carimagua, damage from stemborer infestations was estimated for the treatments shown in Table 3. Actual and induced damage affected all yield variables except root starch content, which was slightly higher in Treatment 3 than in the others. About two-thirds of the weakened stems were broken in Treatment 1 and 2 due to natural causes such as winds. Stemborer infestations in Treatment 4 (control) was 1.06 perforations per plant.

Whiteflies

Previous studies have shown that high infestations of the whitefly, *Aleurotrachelus socialis*, cause considerable yield losses in cassava (CIAT Ann. Rept. 1978 and CIAT Cassava Prog. 1979 Ann. Rept.). Three trials were conducted at the Nataima station of the Instituto Colombiano Agropecuario (ICA), Tolima, to study cassava losses from whitefly attacks.

In one trial, one-month attacks by whiteflies were permitted over a 10-month growing cycle of the plant with plants protected by applications of dimethoate at 15-day intervals during all other times. A single one-month attack at any stage of plant growth did not reduce yields significantly. However, when whiteflies were not controlled, average yields decreased from 26 t/ha to only 9.7 t/ha. Likewise, production of planting stakes decreased sharply in uncontrolled plots, from 4.8 to 2.9 stakes per plant. Starch content did not differ significantly between controlled and noncontrol plots.

In a second trial, whiteflies were permitted to attack cassava for increasingly longer periods, up to 11 months of age. Results of this experiment are shown in Table 4. A significant correlation (r=0.9) was observed between attack duration and yield reduction, and the duration of attack and stakes produced per plant were negatively correlated (r=0.8). The effect of the duration of attack was significant after the third month of plant growth, indicating that spray applications (of, in this case, dimethoate) every three months may be sufficient to reduce whitefly attacks below the economic injury level.

Table 3. Economic damage caused to cassava by the stemborer, **Chilomima clarkei** (Amsel), at different levels of attack in Carimagua.

Treatment [1]	Foliage weight (kg/plant)	No. roots per plant	Weight of roots (kg/plant)	Commercial roots (%)	Starch content (%)	No. stakes per plant	Healthy stakes (%)	Broken stems (%)
1	1.0 b [2]	4.4 b	0.48 b	7.5 b	26.6 b	3.1 b	43.8 c	65.6 b
2	1.1 b	7.4 a	0.70 b	10.1 b	26.0 b	3.1 b	58.1 b	66.6 b
3	0.9 b	6.5 a	0.68 b	12.1 b	28.9 a	1.6 b	38.6 c	100 a
4	1.7 a	7.8 a	1.26 a	33.9 a	26.8 b	7.1 a	85.0 a	11.1 c

[1] Treatments: 1= 8-12 perforations per plant and infested with three larvae per plant at 4, 6, 8 and 10 months.
2= 16-20 perforations per plant and infested with five larvae per plant as above.
3= Infested with two larvae per plant at four months and all stems purposely broken at five months.
4=Control plants; no artificial infestation or damage.

[2] Values followed by the same letter within columns are not significantly different at the 95% level.

A third trial was planted to evaluate hybrids CM 489-1, CM 440-5 and CM 91-3 and the high-yielding, widely adapted variety CMC 40 for their resistance to whitefly attack. CMC 489-1 showed the least yield reduction from whitefly attack but it also had the lowest starch content. While the yield of CMC 40 decreased 46.5% due to whiteflies, it still had the highest yield and highest starch content (Table 5).

Table 4. Relationship between the duration of whitefly, **Aleurotrachelus socialis**, attacks and yield losses of the cassava line CMC 350-122.

Duration of whitefly attacks (months)	No. of insecticide applications[1]	Fresh root yield (t/ha)	Yield reduction (%)	Root starch content (%)	No. stakes per plant
0	22	42.1 a [2]	-	29.6 a	7.6 a
1	20	40.1 ab	4.8	29.5 a	7.5 a
2	18	36.1 abcd	14.3	28.7 a	5.4 bc
3	16	37.8 abc	10.2	29.4 a	6.3 ab
4	14	30.6 bcde	27.3	30.7 a	5.7 abc
5	12	29.8 cde	29.2	28.7 a	4.6 bcd
6	10	24.5 ef	41.8	27.2 a	4.7 bcd
7	8	26.7 de	36.6	29.4 a	4.1 cd
8	6	16.4 fg	61.0	27.8 a	4.1 cd
9	4	14.3 g	66.0	27.9 a	3.0 d
10	2	11.5 g	72.7	28.3 a	3.0 d
11	0	8.6 g	79.6	27.6 a	3.0 d

[1] Dimethoate applied at the rate of 0.8 g a.i. liter of water.
[2] Values within the same column followed by the same letter are not significantly different at the 95% level.

Table 5. Effects of whitefly, **Aleurotrachelus socialis**, attack on yields of three hybrids and one variety of cassava, in Tolima, Colombia.

Treatment	Cassava line	Whitefly population grade[1]	Whitefly pupal grade[1]	Commercial roots (kg plant)	Fresh root yield (t ha)	Yield difference (%)	Planting stakes per plant	Root starch (%)
Protected[2]	var. CMC 40	0.8	0.3	6.2	31.2	-	6.0	25.4
	hyb. CMC 489-1	0.6	0.2	2.0	20.7	-	4.0	21.1
	hyb. CM 440-5	0.7	0.2	0.4	3.5	-	4.0	20.3
	hyb. CM 91-3	0.9	0.3	1.7	14.0	-	2.7	24.7
Nonprotected	var. CMC 40	4.6	4.8	4.1	16.7	46.5	4.3	25.2
	hyb. 489-1	4.5	4.1	1.8	15.4	25.6	3.9	18.6
	hyb. 440-5	4.1	3.5	0.3	2.4	31.4	2.8	21.1
	hyb. 91-3	4.8	4.8	0.1	3.7	73.6	1.4	22.2

[1] Based on a scale of 0 to 5.
[2] Dimethoate applied at a rate of 0.8 g a.i. per liter of water.

Mites

Several species of mites, all previously unreported in Colombia, have been identified during recent surveys of cassava. They are *Allonychus braziliensis* (McGregor), *Atrichoproctus uncinatus* Flechtmann, *Aponychus schultzi* (Blanchard), *Eutetranychus banksi* (McGregor), *Oligonychus gossypii* (Zacher) and *Brebipalpus phoenecis*

(Geiysker). *Mononychellus caribbeanae* (McGregor) was found along the Atlantic Coast and in the Guajira region. High populations of a mite of the Eriophyidae family was also found, the first time mites of this family have been reported to attack cassava. Visual symptoms of high populations of this latter mite are a white to grey powdery effect caused by the mites' exudate.

Preference studies. Leaf preference studies were carried out with *Mononychellus tanajoa* and *Tetranychus urticae* in the laboratory. Field observations show that *M. tanajoa* prefers to feed on the upper or apical leaves while *T. urticae* prefers the lower leaves. Mites of both species were given a choice of feeding on leaf discs from the upper or lower areas of the plant for a three day period. Results with *M. tanajoa* show that 64% preferred feeding on the apical leaf discs and 36% on lower leaves of the variety M. Col 113. The *T. urticae* mite preferred the lower leaf discs: 78% vs 22% on the variety M Col 22 and 73% vs 27% on M Col 1434. These results indicate strong preference for mite feeding and leaf location.

Biology studies. Life cycle studies were realized with the mite *Oligonychus peruvianus*, an important species in many areas of Colombia. Laboratory leaf discs studies with this species have proven unsuccessful due to its behavior of forming a small web on the underside of the leaf, under which the developing stages feed. Studies were carried out in the greenhouse on growing potted plants; adults were allowed to form the protective web and oviposit before being removed. The developing life stages were studied. The egg stage is 4.5 days; the larvae, protonymph, and deutonymph are 2.7, and 1.5, and 2.5 days respectively. The average adult duration is 12.5 days and the preoviposition period is 1.7 days. Daily observations indicate that these mites spend their life cycle below the web and it is the female that has the capacity to form this web which it begins doing in the deutonymphal stage.

The life cycle of *T. urticae* was studied on three cassava varieties M Col 22, M Bra 12, and M Col 1434. M Col 22 is susceptible to *M. tanajoa* and M Col 1434 and Bra 12 are resistant (CIAT Cassava Prog. 1979 Ann. Rept.). Studies were carried out in the laboratory at 30°C day temperature and 28°C night, with 40-70% RH, using leaf discs on moist cotton in petri dishes.

Results show that the mites developed slower on the resistant cultivars, M Col 1434 and M Bra 12, than on the susceptible cultivar M Col 22 (Table 6). The longevity of the adult stage was shorter and fewer eggs were oviposited on the resistant cultivars. These studies indicate that there are resistance mechanisms in cultivars M Bra 12 and M Col 1434 that adversely affect the development of *T. urticae*. In addition these results coincide with results on resistance studies done with *M. tanajoa*.

Biological control. *Oligota minuta* and *Stethorus* sp. are active predators of mites on cassava. Preferences of these predators for *M. tanajoa* and *T. urticae* mites were studied in the field by surveying predator numbers during periods of high populations of mites. *T. urticae* was predated mainly (98%) by *Stethorus* sp. while *M. tanajoa* populations were predated by *O. minuta* (88%).

Table 6. Development of the **Tetranyhus urticae** mite on leaf discs of three cassava varieties under growth chamber conditions[1].

Life stage	Duration of life stage (days)					
	M Col 22		M Bra 12		M Col 1434	
	Females	Males	Females	Males	Females	Males
Egg	3.50	3.50	3.50	3.50	3.50	3.50
Larva	1.14 d [2]	0.88	1.31 d	0.75 d	1.01 d	1.53 cd
Protocrysalis	0.47 b	0.38 b	0.41 b	0.50 b	0.54 b	0.63 b
Protonymph	1.02 b	0.86 b	2.20 a	1.00 b	0.84 b	2.18 a
Deutocrysalis	0.61 a	0.61 a	0.61 a	0.50 a	0.69 a	0.60 a
Deutonymph	0.91 b	0.72 b	0.99 ab	1.50 ab	1.65 a	0.90 b
Teliocrysalis	0.78 b	0.88 b	0.85 b	0.50 b	0.78 b	0.80 b
Total of developmental stages	8.43 b	7.83 b	9.87 a	8.25 b	9.01 ab	10.14 a
Adult	17.52 a	5.00 c	14.17 ab	2.50 c	12.78 b	3.60 c

[1] Temperatures: 28°C, night; 30°C, day. Relative humidity: 40-70%.
[2] Figures within the same rows followed by the same letters are not significantly different at the 0.05 level.

Several predatory mites were found attacking *M. tanajoa* on cassava for the first time. Predators included mites of the Phytoseidae and Blattisocidae families and of family Tydeidae *(Tydeus,* prob. ne. *Californicus)* and *Typhlodromalus limonicus, Neoseiulu anonymus, Typhlodromina* sp., *Iphiseiodes zuluagai, Galendromus annectens* and *Proctolaelaps bickleji.*

Fruitflies

Cassava fruitflies *(Anastrepha manihoti* and *A. pickeli)* reduce the quality of planting material by boring throughout the pith of the stem and by transmitting the bacterial disease *Erwina caratovora* (CIAT Ann. Rept. 1977 and CIAT Cassava Prog. 1979 Ann. Rept.). Studies were done to determine the critical period of plant growth when fruitfly attacks cause heaviest damage to planting material. Bimonthly applications of dimethoate were used to protect plants from planting to 10 months.

Protecting plants during the first three months of growth produced 94% healthy planting material while unprotected plots produced only 35% healthy material (Fig. 1). There were no significant differences in root yield between treatments, corroborating previous studies which showed that fruitfly attacks did not directly affect yield, but that eventual yield losses are due to reduced quality of planting

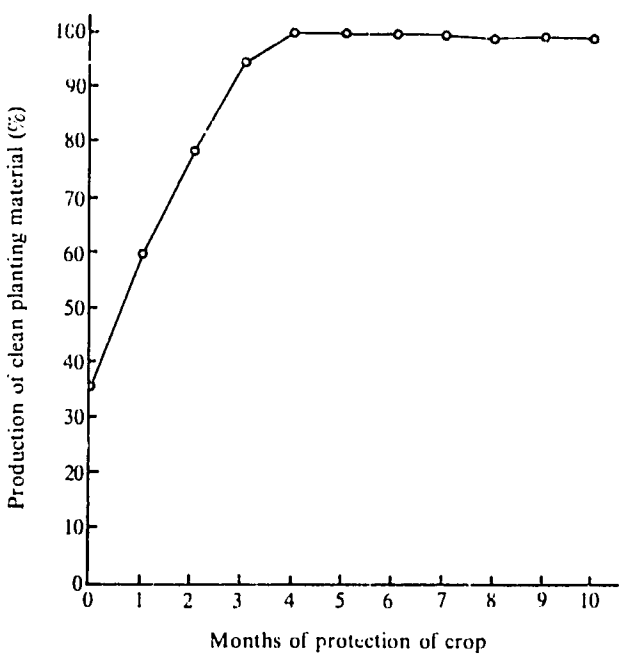


Figure 1. *Production of planting material free of fruitly* **(Anastrepha manihoti)** *damage by periodic applications of the insecticide dimethoate.*

stakes (CIAT Ann. Rept. 1977). Where high populations of fruitflies are present, high-quality planting material can be produced by protecting the crop for the first three months of growth.

Cassava Lacebug

The CIAT cassava germplasm bank was evaluated for resistance to the cassava lacebug *(Vatiga manihotae)* for the second time during 1980. Of 1865 lines screened, 527 (28%) were scored at 1 or lower on a 0-5 damage scale. Although the infestation this year was light and further screening will be done under heavier pressure, 131 lines among the 527 had received similar ratings in the first evaluation.

While no parasite of the lacebug has been observed, a hemipteran of the family Reduviidae has been identified predating lacebug nymphs and adults. During the predator's approximate 40-day nymphal cycle it will consume about 280 lacebug nymphs and adults.

Cydnidae

Nymphs and adults of a subterranean Cydnidae, *Cyrtomenus bergi* Froeschner, feed on the swollen roots of cassava by injecting their strong, thin stylets through the root peel into the parenchyma. This feeding habit causes small brown to black spots at the penetration sites. Several fungal pathogens are transmitted in this manner and their development causes a "smallpox" effect on the edible portion of the root. Commercial value of roots is reduced considerably, especially in those destined for human consumption.

Adult Cydnidae are black while nymphs have white-to creme-colored abdomens. Their legs are short with numerous small spines which facilitate insects' movement through the soil. When disturbed, the insects become immobile and appear dead, making them difficult to find. At harvest they occasionally are found adherring to roots by their stylets.

Severe attacks have been observed in plantations next to or on fields planted previously to sugarcane or pasture. An average of 32 nymphs per plant were counted during a harvest of the cassava variety Chiroza. In a preliminary laboratory study, 80% of a population of last instar nymphs preferred to feed on a sweet cassava variety instead of a bitter variety. Additional discussion of root damage is found in the Pathology section of this report.

Termites

Previous studies showed that control of termite damage was most effective if both a fungicide and a chlorinated hydrocarbon insecticide (aldrin) were applied to planting stakes (CIAT Ann. Rept. 1978). This year additional insecticides were evaluated and methomil (0.5 g commercial product of Lannate 90% per liter of water) and carbaryl (2.0 g commercial product of Sevin 80 OM per liter of water) were equally effective as aldrin. Vertically planted stakes also had better germination and less termite attacks than did stakes planted horizontally.

Pathology

Emphasis this year was on a study of disease presence, changes in severity and performance of cassava clones in each of five different environments. The identification of wide-type resistance to existing biotic problems as well as its durability in these ecosystems is being investigated. The relationship between plant reaction to cassava bacterial blight (CBB) in the greenhouse and field, and its stability through several continuous cycles was investigated. Field studies were begun to examine differences in the severity of CBB, superelongation and anthracnose in monoclonal and multiclonal plots at high and low inoculum levels. The sexual stage of the superelongation causal agent was found and its implication on pathogen-host interactions is being investigated.

Diplodia root-stem rot was identified at CIAT-Palmira. This disease, CBB, the frog skin and other viral diseases constitute the most threatening diseases of cassava in the production and distribution of vegetative planting material. Etiological studies were undertaken on the characterization of the frog skin disease causal agent.

Cassava Bacterial Blight

Screening for durable resistance. Plant reactions to cassava bacterial blight (CBB) infection under controlled conditions (by the clip inoculation technique, CIAT Ann. Rept. 1975) and in the first cycle of field testing were very similar. The pathogen was found invading the stem 5 cm above ground in cassava genotypes rated susceptible, intermediate-resistant and resistant, but the rate of pathogen recovery from susceptible genotypes was greater than from both the latter ones. Although bacterial invasion throughout the vascular system was positively correlated with the susceptible types as evaluated by external symptoms ($r = 0.914$ for greenhouse reaction and 0.927 for field reaction, both significant at the 0.1% level), several exceptions were observed.

Since the pathogen has poor pectinase activity, mature stem tissue may appear symptomless. Bacteria surviving in invaded xylem vessels of mature stems used as planting material spread systemically through young plants, which then serve as sources of inoculum in the next cycle. Consequently, the proportion of infected cuttings increases after several cycles of continuous cultivation of apparently intermediate-resistant or resistant genotypes when ratings are assigned after only one cycle of greenhouse or field evaluation. Using such "resistant" material continuously could result in a progressive decline in stand density due to lack of germination, decreased plant vigor due to bacterial root rotting, and earlier onset of more severe epidemics.

This was corroborated with results obtained after planting several genotypes at Carimagua for four cycles using planting material from that site (Fig. 1). Due to poor soil fertility in this region, production of planting material decreased about 60% compared with CIAT-Palmira. However, resistant genotypes (group I, Fig. 1) in which bacterial infection in the stem was very low or absent produced a constant number of cuttings during a four-cycle period, while other resistant or intermediate genotypes only survived for two or three cycles (groups II and III, Fig. 1). Susceptible genotypes were eliminated during the first or second cycles.

The data indicate the great importance of the sanitary condition of planting material on genotype stability, the existence of durable CBB-resistant genotypes in *Manihot esculenta*, and the need to evaluate testing material in the field for several continuous cycles in CBB-endemic areas, to identify accurately durable CBB-resistant genotypes. Planting material for each successive cycle must be produced in an endemic test area. Final resistance evaluation should result from integrating data on plant reaction, cutting production and quality of propagating material.

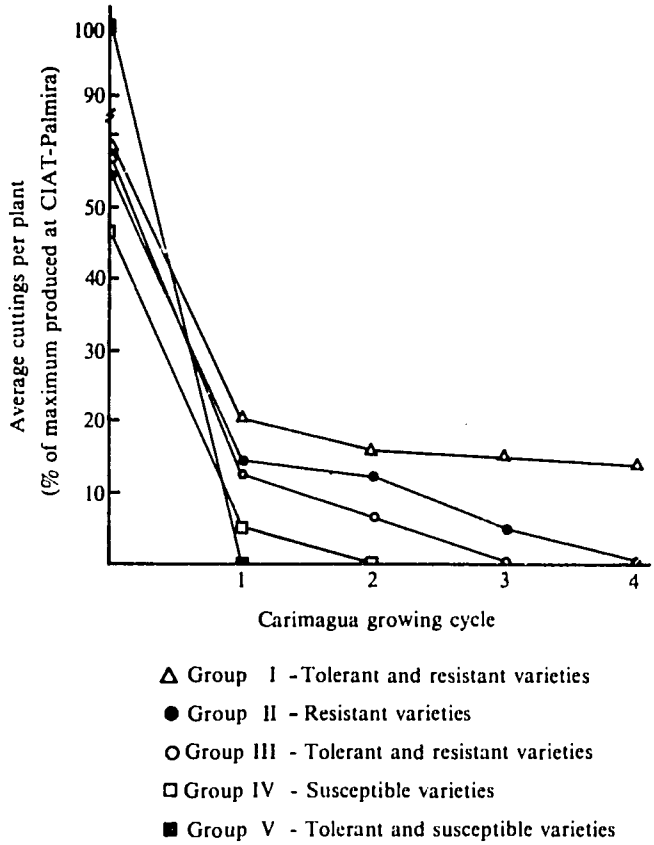


Figure 1. *Survival of cassava genotypes having differing reactions to cassava bacterial blight after cycles of continuous cultivation in the Carimagua environment, when utilizing locally grown planting material.*

Epidemiology. Considerable yearly fluctuations in CBB attack have been found in Carimagua and Media Luna. This suggests that continuous evaluations over a period of years may be necessary so as to identify sufficiently good levels of durable resistance.

Superelongation Disease

Causal agent. The sexual stage of the causal agent, *Sphaceloma manihoticola,* has been discovered and found to be abundant at a number of sites. Based on morphological studies of the fungus collected in Carimagua, CIAT-Quilichao, Media Luna and Mexico, it has been tentatively identified as a species of *Elsinoe,* a loculoascomycete. With one exception, all the known sexual stages of species of *Sphaceloma* are *Elsinoe.* A preliminary literature survey indicates that this may be an undescribed species. Growth stages of the fungus are shown in Figure 2.

Single ascospore isolations produced colonies typical of *S. manihoticola* and similar to those described for other members of the genus. Susceptible cultivars inoculated with these colonies showed characteristic superelongation symptoms and reisolation yielded *S. manihoticola.* That this sexual stage is so common suggests that the pathogen may be pathogenically variable. Preliminary field observations and previous laboratory experiments support the existence of physiological races (see below and CIAT Ann. Rept. 1977), and a thorough investigation is being undertaken.

Epidemiology. A multiclonal experiment was begun in Carimagua to test the influence of mixing resistant varieties on disease epidemic development and yield (root and stake production). Eight varieties were planted nonrandomly so that no two plants of the same variety were adjacent. Both next to the multiclonal plots and 2 km away each variety was planted in pure plots for comparison. Since the data are preliminary and incomplete only a few of the most interesting results will be presented.

Figure 3 shows that the varieties in the multiclonal plot had somewhat more superelongation disease than the same varieties had in pure plots. From field observations during the disease season, CMC 40 plants appeared to act as foci for sub-epidemics in the multiclonal plots. Thus interspacing a susceptible variety with more resistant varieties seemed to increase the total level of disease for all varieties rather than appreciably protecting the susceptible variety. This is contrary to what was expected based on epidemiological research with cereals. Investigations to clarify these results are being planned for the coming year.

It is interesting to compare the disease levels in CMC 40 and other varieties within the multiclonal site, between that site and the site 2 km distant where there was considerably more superelongation disease. At the multiclonal site, all varieties, which are considered resistant or intermediate-resistant based on data from recent years, showed more disease than they did in the remote site. This was extreme for CMC 40 (Fig. 3). Considering the level of disease in susceptible varieties planted adjacent to CMC 40 and the other resistant varieties, the low disease levels in these plots could not be due to escape. This difference in susceptibility within a clone under more or less uniform environmental conditions is consistent with the existence of physiological races within the pathogen.

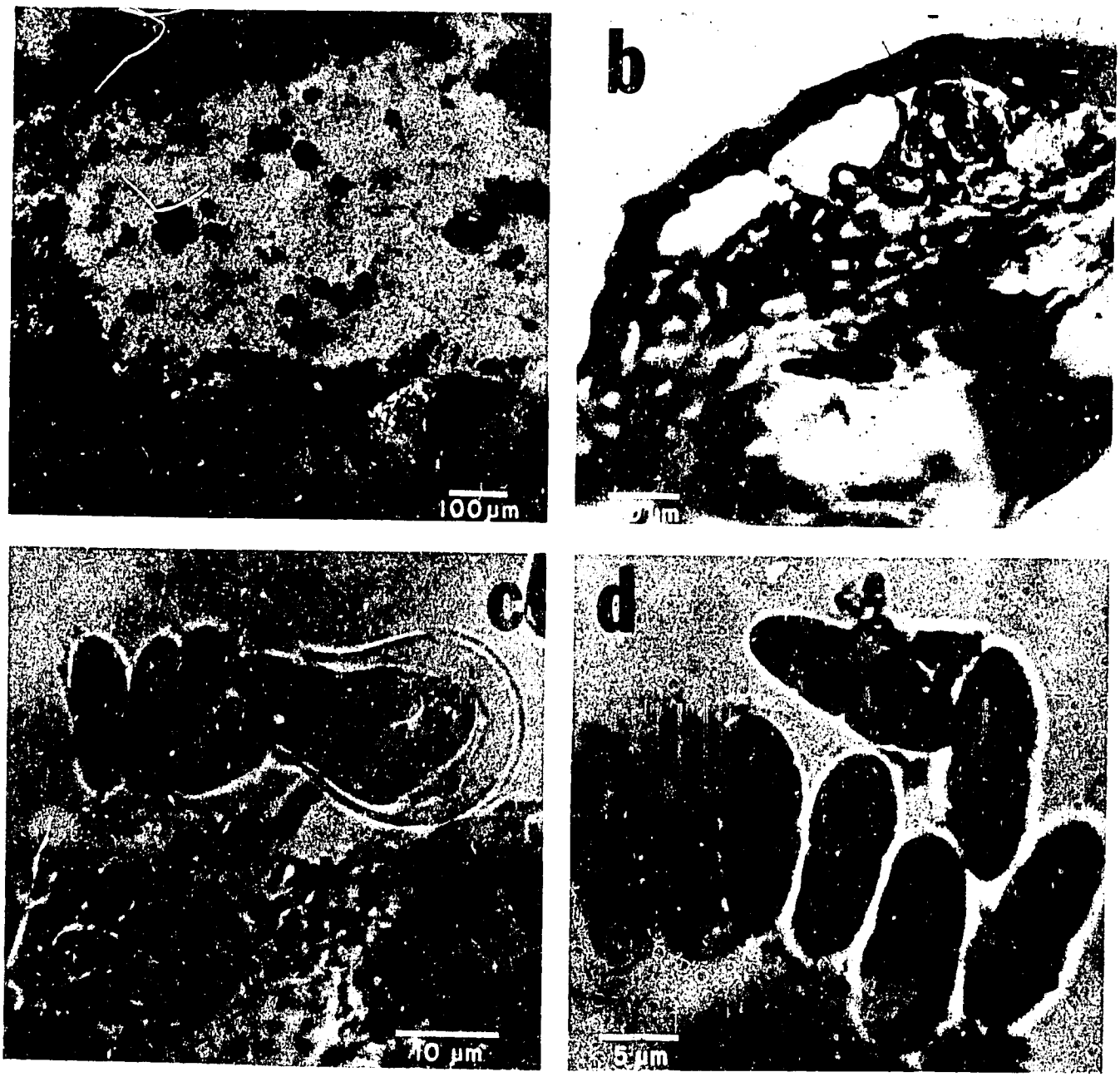


Figure 2. *Ascostroma, asci and spores of the sexual stage of* **Sphaceloma manihoticola**, *tentatively identified as a species of* **Elsinoe**. *a) Ascostroma on surface of a stem lesion; b) Section through an ascostroma showing well-defined locules with only one globose ascus per locule; c) Ruptured bitunicate ascus showing eight ascospores; c) Ascospores showing muriform character.*

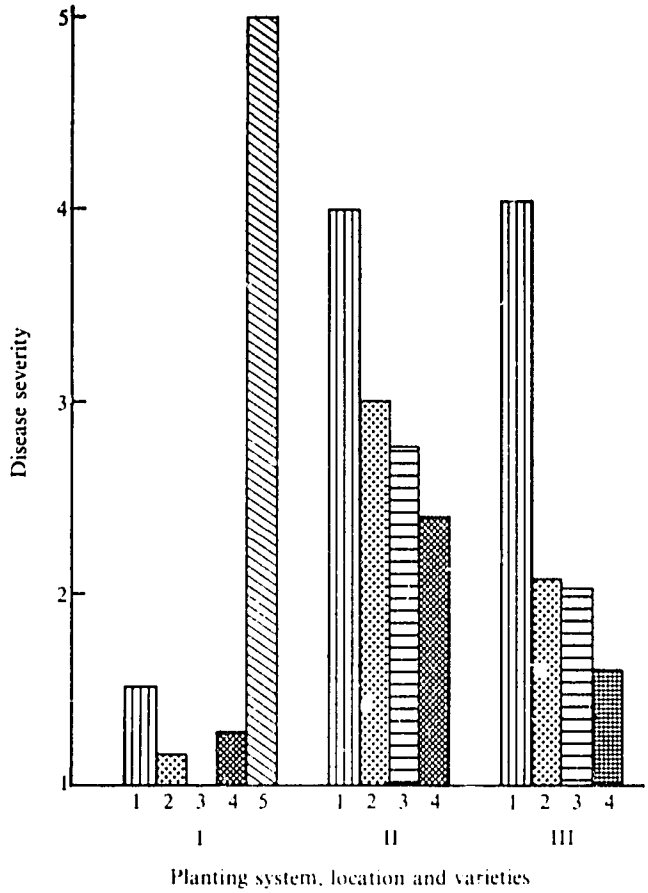


Figure 3. *Comparison of superelongation disease among varieties in a multiclonal experiment. Group I: varieties planted remotely (2 km from main plantings). Group II: varieties in a multiclonal pattern (see text) in an area of low inoculum pressure. Group III: varieties in multiclonal (pure) plots adjacent to multiclonal plots. Varieties: 1 = CMC 40; 2 = M Ecu 82, M Ven 77, M Pan 12B and M Pan 19; 3 = M Col 1914 and M Col 1916; 4 = M Col 638; S = several susceptible varieties in the remote site all killed by superelongation and included to demonstrate inoculum pressure at that site.*

located just beneath epidermal tissues of necrosed roots and stems. Immature picniospores are hyaline, but mature ones are dark, two-celled with thick walls. They are released through the picnidium, opening mostly during rainy periods. Penetration, fungal establishment and invasion are being investigated.

Epidemiology. There are two disease phases. The first is a root rot initiated by infection from infested soil or by using diseased cuttings taken from diseased plants. In this case, the fungus, which is a facultative parasite, could infest the soil and remain indefinitely as a saprophyte. Infected plants show root deterioration, sudden wilt and death. Symptoms are similar to those induced by other root-rot pathogens.

The second phase, a stem rot, is generally induced by systemic invasion from roots or picniospore infection of the stem. The fungus invades most of the stem tissues producing gumosis, sudden wilting, dieback and phloem and xylem rotting. Picnidia are produced readily on the stem epidermis of infected stems. During this phase, roots and mature stems may remain symptomless. Systemically infected stems may exhibit no external symptoms and appear to be suitable planting material. Symptoms can be confused with those caused by anthracnose, *Phoma* and superelongation dieback, CBB, drought stress, salinity, insects and spider mites. However, the fungus can be readily identified by the features of picnidia and picniospores produced.

The fungus is disseminated over long distances by infected cuttings taken as planting material. Within a plantation, wind and rain-splash dissemination of picniospores is probably most important, while land preparation machinery and irrigation water may also sometimes be important.

Diplodia Root and Stem Rot

Causal agent. Severe outbreaks of diplodia root and stem rot were observed in Colombia's Cauca Valley. This disease has been reported as one of the most serious ones in Brazilian cassava plantations, and in Africa, India and Cuba.

Its causal agent was isolated and identified as *Diplodia manihotis* Sacc., which could be synonymous with *Botryodiplodia manihoticola* Petr. Confirmation of this synonymy awaits further taxonomic study. The fungus produces clusters of picnidia on stromatal structures

Root "Smallpox" Disease

This disease has been found in Colombia associated with a subterranean sucking insect (Cydnidae) which causes the initial injury (other agents like nematodes can cause similar injuries and might initiate the same symptom development). This Cydnidae is described in the Entomology section of this report.

The insect introduces its stylet through the root epidermis and cortex injuring the root tissues and inoculating them with soilborne microorganisms (mostly fungi). Several fungal species have been isolated from these

lesions. Artificial inoculations simulating the insect damage have induced similar symptoms (Fig. 4). These microorganisms degrade the infected root tissues causing initial localized rots which can invade the entire root along the vascular system. Young lesions are pale to dark brown spots which show tissue degradations. Symptoms are most striking and lesions are most frequent in swollen roots and during harvest periods. A zone which fluoresces light blue under UV light occurs adjacent to the lesions, suggesting that the mechanism of discoloration could be related to that occurring in post-harvest physiological deterioration.

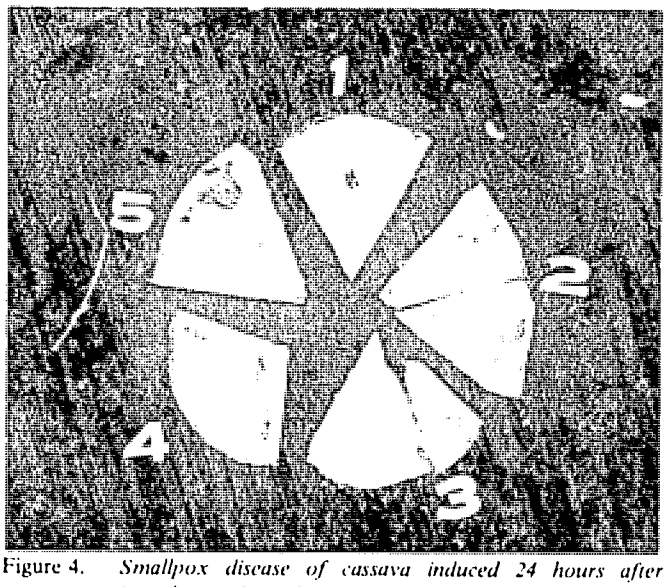


Figure 4. *Smallpox disease of cassava induced 24 hours after inoculating through the peel with an infested needle with spore suspensions of 2* = **Genicularia**, *3* = **Aspergillus**, *4*= **Fusarium**, *5* = **Pythium**; *1 = control.*

Frog Skin Disease

In 1980, characterization of the frog skin disease causal agent continued with emphasis on detection, transmission and isolation studies.

A cytological study revealed considerable degeneration of the phloem of young roots showing frog skin symptoms as well as the presence of massive inclusions blocking the phloem parenchyma in these tissues. Similar inclusions were occasionally detected in the phloem of petioles and midribs of diseased plants. No such inclusions were detected in the phloem tissues of healthy plants. Based on these observations, mycoplasma-like organisms or a phloem-restricted virus have been suggested as probable causal agents.

The possibility of a phloem-restricted virus such as those in the closterovirus class is currently being investigated. Preliminary results have shown the presence of long filamentous particles, similar to those of closteroviruses, in partially purified preparations from roots of frog skin-affected cassava plants. Whether these particles are indeed virions or artifacts is still unknown. The possibility of a mycoplasma-like organism as the causal agent of frog skin disease will be reinvestigated despite negative results in earlier tests.

Preliminary field results suggest that the disease is efficiently transmitted (up to 62%) by natural root grafts whenever stakes are planted closer than 1 m. Natural root injury or the existence of soil vectors, however, have not been discarded as possible transmission mechanisms.

No transmission via sexual seed was observed in 9-month-old plants grown from seed produced by 46 different cassava clones affected with the frog skin disease. So far, an alternative host has not been found among 50 other plant species following conventional mechanical inoculation experiments.

Fertilization with 200-200-100 kg/ha of N-P-K increased symptom expression, especially in cultivar M Col 22.

Environmental Studies

Screening for durable resistance to biotic problems. Germplasm evaluation in the past has shown that durable resistance to biotic problems of each environment exists although frequency is relatively low. Evaluations by Pathology and Entomology sections consist of growing accessions in each environment utilizing planting material produced in the same environment. Only those varieties which survive the season and produce adequate healthy planting material are carried over to the next year.

In Popayan, stable varieties could be identified after the fourth cycle, and in Carimagua, after the third. Up to the third cycle, the stability of the varieties has not been confirmed in Media Luna (Table 1). It is important to stress that resistance identified in these evaluations appears to include durable resistance to all biotic problems existing in the evaluation site and may also integrate resistance to abiotic problems.

Cassava environment relationships. Environment studies begun in 1978 (CIAT Cassava Prog. 1979 Ann. Rept.) continued during the 1979-80 season, when plants from the first cycle were harvested. Cultivars which produced planting material were continued in a second

cycle. All diseases and pests identified during 1979 in each of the five target environment were present in 1980, with the exception of the ash disease which was first detected this year in Caribia and Media Luna (Table 2). However, anthracnose (caused by different *Colletotrichum* spp. in each environment) was more severe in Caribia and Carimagua than the other environment this year; brown leaf spot was also very severe in Caribia and Media Luna, as was white leaf spot in Caribia.

The lace bug (*Vatiga* spp.), which was unimportant during the rainy season of 1979, caused severe damage during the same season this year at Carimagua.

Thrips were important at CIAT-Palmira, gall midges in Carimagua and scale insects in Popayan.

The populations and severity of spider mites (*Mononychellus* and *Oligonychus* species) have increased considerably in the CIAT-Palmira environment.

In general fluctuations in population dynamics and severities of disease and pest damage were observed for each environment between 1979 and 1980.

Differences within and between the five environments were considerable for the characteristics shown in Table 3. Yield range at CIAT-Palmira was similar to that at Caribia but means in these environment were notably larger than in the other three environments. Stake number and starch production also resemble yield in those respects.

Differences in ranges and means for harvest index and HCN content were similar in all environments. A wide range of deterioration susceptibilities was found only in CIAT-Palmira and Popayan; in the other environments most cultivars were markedly resistant.

In general, yield and especially the harvest index were well-correlated between all environments excluding Popayán, although CIAT-Palmira correlated with Carimagua only for harvest index. HCN content correlations were generally low and susceptibility to physiological deterioration and stake number showed no relationships between environments, apart from between Carimagua and Media Luna.

Popayan was obviously different from the other environments. The cultivars which did best in Popayan, namely local regional varieties, produced poorly in all other environments and especially so on the Colombian North Coast (Caribia). The local cultivars from the North Coast fared equally poorly in Popayan.

On the basis of these relationships, CIAT-Palmira and Caribia have some similarities, as does Media Luna, with both Caribia and Carimagua, but the differences between the environments are still substantial, e.g., yield, starch content, stake number, general evaluation and root deterioration susceptibility in CIAT-Palmira showed no significant correlation with Carimagua.

This demonstrates the importance of carrying out varietal selection at the environment level at the earliest possible stage of any breeding program. This is particularly true for Popayan and Carimagua.

Selection must continue until stability of yield and other selected traits has been achieved using planting material produced on-site. Nevertheless, the high correlation between many characters in Media Luna and Carimagua suggests that similar material may be useful across these environments.

Table 1. Results of screening for durable resistance to biotic problems of cassava in three environments.

Environment	No. of genotypes per continuous cycle evaluation [1]					
	1	2	3	4	5	8
Popayan	1708 (100)[2]	217 (12.7)	67 (3.9)	10 (0.6)	10 (0.6)	10 (0.6)
Carimagua	1379 (100)	65 (4.7)	13 (0.9)	12 (0.9)		
Media-Luna	391 (100)	116 (29.7)	29 (7.4)			

[1] 1st cycle planting at Carimagua and Media Luna: single rows with 5 plants/genotype; at Popayán: single rows with 11 plants/genotype. All replicated twice and using planting material from CIAT-Palmira. 2nd cycle: means of 15 plants/plot/genotype using locally produced stakes. 3rd and other cycles: mean of 30 plants/plot/genotype, replicated 3 times, using locally produced stakes.

[2] Values in parentheses are percentage of total number of genotypes planted in 1st cycle.

Table 2. Biotic negative production factors (BNPF) to cassava identified and evaluated in five environments in Colombia during 1979 (cycle 1) and 1980 (cycle 2).

BNPF	Environment									
	Caribia		Media Luna		Carimagua		CIAT-Palmira		Popayan	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
Diseases:										
Bacterial blight	M [1]	M	L	M	S	S	NP	NP	NP	NP
Superelongation	L	L	L	S	S	S	NP	NP	NP	NP
Concentric-ring leaf spot	NP	NP	NP	NP	NP	NP	NP	NP	S	M
Anthracnose	M	S	L	M	S	S	S	L	S	M
Brown leaf spot	M	S	S	S	M	L	L	M	NP	NP
Blight leaf spot	M	M	L	M	M	NP	L	M	NP	NP
White leaf spot	M	S	M	M	NP	NP	NP	NP	NP	L
Bacterial stem rot	L	L	L	L	L	L	M	M	NP	NP
Cassava ash	NP	L	NP	M	NP	NP	L	S	M	M
Cassava common mosaic	L	M	L	M	NP	NP	M	M	S	S
Frog skin	NE	L	NE	L	NE	NP	NE	M	NE	NP
"Smallpox" of root	NE	L	NE	M	NE	NP	NE	L	NE	NP
Root rots	NE	L	NE	L	NE	L	NE	M	NE	NP
Insects:										
Hornworm	L	L	L	L	S	L	L	L	L	L
Whitefly	M	L	M	L	L	L	L	L	L	L
Thrips	M	M	L	L	M	M	S	S	L	L
Lacebug	L	M	L	L	M	S	M	M	L	NP
Shoot fly	L	L	L	NP	L	L	M	L	NP	NP
Fruit fly	L	L	NP	NP	L	NP	L	L	L	NP
Leaf beetle	NP	NP	NP	NP	NP	NP	M	M	NP	NP
Gallmidge	L	L	L	L	M	S	L	NP	NP	NP
Termites	L	L	M	M	L	L	NP	NP	NP	NP
Stemborer	NP	NP	NP	NP	M	M	NP	NP	NP	NP
Leaf cutter ants	NP	NP	NP	NP	M	NP	NP	NP	NP	NP
Scales	NP	NP	L	NP	L	L	NP	NP	S	S
Mites:										
Monomychellus	L	L	M	M	L	L	M	S	L	L
Tetranychus	L	L	L	L	L	L	L	M	NP	NP
Oligonychus	L	M	L	L	M	NP	M	S	M	S

Ratings S = severe damage; M = moderate damage; L = light damage; NP = not present; NE = not evaluated.

Table 3. Ranges and average values for selected yield, quality and storage parameters of 31 cassava cultivars grown in five environments.

Environment	Yield (t/ha)		Root starch (t/ha)		Stake production per plant		Harvest index [1]		HCN content [2]		Root deterioration [3]	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
CIAT-Palmira	74.1 - 0.0	24.4	24.7 - 0.00	7.68	18 - 0.6	10.0	0.65 - 0.00	0.41	5 - 1	2.64	90.0 - 1.6	26.5
Media Luna	19.0 - 0.4	9.5	3.7 - 0.06	1.89	11 - 1.0	5.0	0.65 - 0.13	0.44	5 - 1	2.87	7.6 - 0.0	1.4
Carimagua	10.7 - 0.5	2.5	2.8 - 0.01	0.69	5 - 0.0	1.0	0.66 - 0.02	0.39	5 - 2	3.29	26.9 - 0.0	1.4
Caribia	55.9 - 2.4	23.2	16.3 - 0.33	6.43	16 - 2.0	8.2	0.61 - 0.12	0.40	5 - 1	2.99	28.1 - 0.0	3.6
Popayán	21.3 - 0.2	4.9	6.9 - 0.04	1.55	8 - 0.0	2.3	0.66 - 0.10	0.36	5 - 1	2.70	82.6 - 2.3	27.1

[1] Harvest index. [Root fresh weight/(Root fresh weight + Foliage weight)] x 100
[2] By picrate paper method: 5 = high and 0 = low HCN content.
[3] 100% = total and 0% = zero deterioration, three days after harvest.

Post-Harvest Deterioration

The two main areas of investigation this year have been the study of the variation encountered in the field within and among cultivars regarding their susceptibility to deterioration and the analysis of the biochemical processes which lead to the production of the blue-black pigments. Considerable progress was made in both areas.

Repeated evaluations of susceptibility to physiological deterioration showed that within one cultivar a wide range of susceptibilities can be encountered (CIAT Cassava Prog. 1979 Ann. Rept.). In the cultivar most studied, M Col 22, maximum and minimum deterioration values (Det. %, where 100% is total and 0% is no deterioration, after three days) were 98% and 18%, respectively at CIAT-Palmira, while even lower values were found at other sites (0% at Popayan and Carimagua). Values obtained from some other cultivars showed similar patterns.

The wide range of susceptibilities within one cultivar at one site makes the description of cultivars as "resistant" or "susceptible" to physiological deterioration difficult and of dubious validity.

Pruning studies. Pruning plants prior to harvest has been shown repeatedly to reduce susceptibility to physiological deterioration (CIAT Cassava Prog. 1979 Ann. Rept.). Experiments on M Col 22 plants have shown that this effect occurs regardless of the removal or supression of new regrowth from the pruned stump, although initially the loss of susceptibility is greatest in those treatments with less regrowth. The effect of pruning, regardless of regrowth removal, was also found to last considerably longer than previously reported. Plants still showed no signs of losing the resistance nine weeks or more after pruning. However, there is a loss of root quality (reduced starch content) associated with pruned roots which must be taken into account.

Environment studies. Evaluations of Det. % were done on 25 cultivars in the five sites of the environment experiment. Cultivar differences between the sites were large, and environment correlations were not significant. In Carimagua, Media Luna and Caribia, a majority of cultivars showed marked resistance, regardless of their susceptibility in CIAT-Palmira or Popayan, the two sites which did produce the expected range of Det. % scores. The correlation of Det. % with the starch content of the roots (CIAT Cassava Prog. 1979 Ann. Rept.) was significant only at CIAT-Palmira ($r = 0.680$, $P<0.001$) and Popayan ($r = 0.558$ $P<0.01$). In the other environments there was a wide range of starch contents although Det. % values were all low.

Plant defoliation caused by insects, diseases or water stress in the months preceeding harvest could have the same effect as pre-harvest pruning, leading to an induction of resistance to physiological deterioration. In the three environments where low Det. % values were found, substantial defoliation due to both biotic and climatic factors had occurred prior to harvest. Controlled experiments are in progress to see if resistance in the field is related to the severity of water stress and other factors.

Biochemical Studies

Examination of roots under UV light 24-48 hrs after harvest revealed the presence of a brilliant blue fluorescence in the parenchymal tissue which was not visible in freshly harvested roots. These fluorescent areas were the first to develop the vessel pigmentation characteristic of physiological deterioration. Roots with deteriorated vessels showed this blue fluorescence in the advancing front of deterioration. Similar observations at CIAT and Tropical Products Institute, TPI (J. E. Rickard) have been made during a microscopical study of primary deterioration in cassava roots.

Chromatographic studies by J. E. Rickard at TPI have shown the blue fluorescing compound to have retention times identical to scopoletin, a coumarin derivative. Independent studies at CIAT have agreed with this identification.

Exogenous applications of high concentrations (500 μg ml^{-1}) of scopoletin to freshly harvested root tissue induce rapid and intense vessel and parenchymal discoloration, identical to that found in naturally deteriorating roots. A range of related phenolic compounds had no effect. Applications of scopoletin to tissue from pruned roots produced an identical reaction to that of unpruned root tissue suggesting that resistance in pruned roots is not due to an inability to respond to scopoletin.

Roots attacked by various fungi (*Aspergillus* sp., *Fusarium* spp., etc) also had areas of blue fluorescence and vessel discoloration around the infected area, suggesting that scopoletin accumulation is a general response to stress in the root tissue.

Germplasm Development

The Germplasm Development section undertakes cassava germplasm collection and introduction, maintenance of the field collection of approximately 2600 clones, evaluation for a broad range of agronomic and morphological traits in diverse environments, and development of gene pools for adaptation in three high-stress environments.

CIAT has developed a multi-stage genetic improvement procedure involving: 1) evaluation of germplasm accesions in various environments for possible recomendation directly as new cultivars or for potential contribution as parents in a hybridization program; 2) formation of broad based gene pools with high levels of resistance and/or adaptation in specific environments; and 3) "fine tuning" of the final product in the varietal improvement stage to assure acceptability in all aspects by producers, processers and consumers. All stages involve inputs of the entire interdisciplinary team.

Germplasm Introduction and Maintenance

Introduction of cassava germplasm from outside Colombia is now limited to either meristems or to true seed, to minimize the possibility of introducing pests and diseases. The Genetic Resources unit this year transferred to CIAT some 150 selected clones from the Brazilian collection at Cruz das Almas, Bahia. This introduction helps alleviate a relatively minor representation of Brazilian material in our collection, and the exchange is expected to expand in the future. Previous introductions by meristems culture from Peru and the Amazonas region of Colombia are now planted in the field for multiplication and later evaluation.

A pathogen-free germplasm bank is being formed from clones which have passed through meristem culture and are free of systematic pathogenic infection. Utilizing isolation from other cassava fields and strict quarantine procedures, it is hoped this bank can continue to provide clean planting material for evaluation within and outside CIAT's facilities.

Germplasm Evaluation

Germplasm evaluation is proceeding along three principal routes: a) evaluation for adaptation, resistance, yield and root quality in moderate to high-stress environments in Colombia; b) evaluation of relatively stable morphological traits in CIAT-Palmira in order to eventually aid in defining similarly groups and duplications in the bank; c) special studies of selected groups of germplasm accessions for post-harvest root deterioration, early maturity, and root cyanide content.

Media Luna and Fonseca

Given the high priority of the North Coast environment representative of major cassava growing areas of the Americas and Asia, evaluation is carried out in two sites—Media Luna, Magdalena and Fonseca, the Guajira. Media Luna has moderate rainfall (800-1200 mm/year) with a long dry season. Fonseca has low rainfall (700-1000 mm/year) and a long dry season during which mites (*Mononychellus* sp.) are severe. In order to increase the probability of identifying promising material, the first accessions screened on the North Coast were preselected, based on mite resistance and/or origin in a similar environment.

Germplasm evaluations in Media Luna were begun in the 1978-79 cycle with about 400 accessions. In 1979-80, 103 of these were selected for further evaluation, and the 17 best planted this year in a replicated yield trial. At Media Luna the 17 clones have produced an average root yield of 10.5 t/ha (max. 21.7 t/ha), average dry matter of 31.8% (max. 36.8%) and average stake production of 7.9/plant

Table 1. Linear correlations among several traits in cassava germplasm evaluation at Fonseca, the Guajira (for May 1980 harvest).

	Pubescence[1]	Leaf retention[2]	Branching habit[3]	Mite damage[4]	Root weight per plant	Foliage weight per plant	Harvest index	Root density[5]
Pubescence	1.000	0.468**	- 0.082	- 0.579**	0.328**	0.286**	0.015	0.111
Leaf retention		1.000	- 0.362**	- 0.606**	0.094	0.057	0.039	0.138*
Branching habit			1.000	0.289**	0.074	0.217**	- 0.148**	- 0.197**
Mite damage				1.000	- 0.045	- 0.072	- 0.001	- 0.074
Root weight per plant					1.000	0.598**	0.391**	- 0.013
Foliage weight per plant						1.000	- 0.368**	- 0.162**
Harvest index							1.000	0.301**
Root density								1.000

[1] Subjective evaluation of density of pubescence of the apex: 1 = no pubescence; 3 = highly pubescent.
[2] Subjective evaluation of percent of stems retaining leaves at harvest.
[3] Number of levels of branching at harvest.
[4] Subjective evaluation of mite damage at peak of infestation: 1 = little damage; 5 = severe damage.
[5] By specific gravity method measuring root dry matter content.

(max. 14/plant.) These values equal or exceed those of the local check variety Secundina. An additional 240 clones have been planted in an observational yield trial.

In Fonseca 329 accessions were planted in an observational yield trial in May 1979 and harvested at 12 months. Under this high stress environment very striking differences among clones were noted. Good mite resistance (13% of the clones showed low damage levels), high root dry matter (11% gave above 33% dry matter) and high harvest indices (14% had indices above 60%) were measured. A few clones showed good levels of all of these variables. Fifty-seven accessions were selected and planted along with those selected in Media Luna. An additional set of 317 germplasm accessions were planted in an observational yield trial.

Phenotypic correlations among several traits indicate the interrelationships among traits and possible implications for breeding (Table 1). Of special interest is the high positive correlation between pubescence of the apex and *Mononychellus* mite resistance, also observed previously by the Entomology section. Pubescence can be easily selected for, with or without mite attack, and also confers resistance to thrips. Although other mechanisms are certainly operating to confer resistance to mites, pubescence may be the simplest to manage. Root yield was not correlated with mite damage, possibly because planting at the beginning of the rainy season permited good plant development before mite attack became severe. The data suggest that high yield potential and mite resistance may be combined to produce superior lines for these conditions. Mite attack tended to be more severe on highly branched types, although the reason for this is not clear. Root dry matter content was not related to severity of mite attack.

Selection for this environment will continue principally based on root yield, harvest index, root dry matter content, and moderate to high levels of mite resistance.

Carimagua

Most of the germplasm bank has been evaluated in Carimagua and superior accessions are being evaluated in the second year of a replicated yield trial. From data accumulated over several cycles, only a small percentage of accessions show stable adaptation in this high disease-stress environment (Table 2). These are being recommended as sources of CBB and superelongation resistance and yield potential in acid infertile soils. Since several of the accessions appear morphologically identical, a continuing search for germplasm adapted to this environment will be important.

A Cuban collection of 69 clones was planted in an observational yield trial and several show good levels of resistance to CBB, superelongation and anthracnose. Cuba has superelongation only in a few areas and CIAT assists in evaluating their lines so they can quickly take preventive measures should the disease become endemic in Cuba.

Table 2. Cassava germplasm accessions showing good adaptation in Carimagua according to their reactions to two major endemic diseases.[1]

Accessions	CBB resistance[2]	Superelongation resistance[2]
Group A		
M Bra 5, M Bra 22, M Bra 29, M Col 1940 and M Pan 51	MR	R
Group B[3]		
M Col 1894, M Col 1772 and M Col 1900	MR	R
Group C		
M Col 2052 and M Pan 12A	R	R
Group D[3]		
M Col 1914, M Col 1916, M Ecu 82, M Pan 12B, M Pan 19, M Pan 90, M Pan 101, M Pan 103, M Ven 38 and M Ven 77	R	R
Group E		
M Pan 97	R	MR

[1] Selected on the basis of 2-4 seasons of evaluation for disease resistance and 1-2 seasons evaluation for yield in a replicated trial.
[2] MR= moderately resistant; R=resistant.
[3] Accessions within each of the groups B and D appear very similar morphologically to all others within each group and may be genetically identical.

Popayan

In a yield trial of a collection of 18 clones from high-altitude areas of Southern Colombia, M Col 1522 (CMC 92), a regional variety of Popayan, gave the highest yield (12.8 t/ha, compared to 8.1 t/ha for the best accession). Several of the accessions, however, had higher dry matter content (up to 36.9%), compared to the 29.2% of M Col 1522. In all the regional trials planted at Popayán as well as in previous replicated yield trials, M Col 1522 has consistently been the highest yielder. This variety is very vigorous, highly branched, has moderate dry matter content, and is moderately resistant to *Phoma* leaf spot and *Oligonychus* mites. The goals for this environment are to improve upon the plant type (less branching), dry matter content, yield potential, and disease resistance of M Col 1522. Large-scale germplasm evaluation has begun with a planting of 438 accessions, mostly collected from areas above 1500 masl. In the overall germplasm improvement program, the high altitude areas are being given less emphasis than other environments.

CIAT-Palmira

Reevaluation of post-harvest root deterioration. In the preliminary germplasm evaluation at CIAT-Palmira from 1973-74, one of the evaluation parameters was post-harvest deterioration. In order to confirm sources of resistance to deterioration, a group of those accessions initially classified as grade 1 (139 accessions) were reevaluated in a replicated trial in CIAT-Palmira. Deterioration was measured by two methods: a) as in the original evaluation, by storing whole roots at ambient temperature for one week, then rating deterioration which included both physiological and microbial effects; and, b) by the method described by the Pathology section last year (CIAT Cassava Prog. 1979 Ann. Rept.) which determines only physiological deterioration. There was as wide a range in the reevaluation trial as in the original, and the mean rating for the two evaluations was practically equal (Table 3). These results illustrate a low consistency across years for root deterioration when measured on a single-row basis.

A highly significant correlation exists between the measures of physiological deterioration at three days, and physiological plus microbial deterioration at one week (Table 4). As previously observed in CIAT, deterioration was highly positively correlated with root density (dry matter content) and also with harvest index. Although no cause/effect relationships can be implied, selection for high root dry matter content and high harvest index will tend to increase deterioration problems.

Table 3. Comparison between preliminary evaluation of cassava germplasm bank accessions for post-harvest deterioration and reevaluation of clones selected for their resistance to deterioration.

Evaluation period	Rating class[1]	Frequency	Percent
Evaluated in 1973-74 in nonreplicated, single-row plots	1	169	9
	2	273	15
	3	480	26
	4	498	27
	5	405	22
Mean 3.4			
Evaluated in 1980 in two replications of single-row plots (all materials selected from within class 1 of 1973-74 evaluation)	1.0-1.9	10	7
	2.0-2.9	61	45
	3.0-3.9	49	36
	4.0-4.9	15	11
Mean 2.9			

[1] 1=little or no deterioration after one week storage; 5=high deterioration.

Table 4. Linear correlations among evaluations for cassava root postharvest deterioration, root density and harvest index.

	Physiological deterioration[1]	Physiological and microbiological deterioration[2]	Root density	Harvest index
Physiological deterioration	1.00	0.67**	0.78**	0.64**
Physiological and microbiological deterioration		1.00	0.42**	0.34**
Root density			1.00	0.58**
Harvest index				1.00

[1] Measured three days after harvest; 15-cm section of root with distal end covered with PVC film; 1=low deterioration; 10=severe deterioration.

[2] Physiological and microbiological deterioration measured seven days after harvest; roots stored intact under ambient conditions; 1=low deterioration; 5=severe deterioration.

Gene Pools for Environment Adaptation

Pool formation. Broad-based gene pools continue to be developed for adaptation in the environments represented by Media Luna and Fonseca, Carimagua, and Popayan. Initial parental components are selected from the germplasm bank based on environment performance. Emphasis is given to including a wide diversity of material having insect and diseases resistance, tolerance to soil and climatic stresses, high yield potential and good root quality. Since few accessions combine all these characteristics, others are included having less favorable expression of certain traits. Through recurrent selection, gene frequency for all traits can be increased.

Gene pool formation and improvement is a two-stage process. In the first stage, recombination is effected in open pollination blocks, each block representing selection for a particular environment. A polycross scheme is utilized where several replicates of each genotype are planted in random mixture to maximize the admixture of pollen among different genotypes. Individual polycross blocks are isolated from each other by at least 12 m by planting male-sterile filler rows. A study this year showed this isolation distance to be sufficient to prevent most contamination under conditions at CIAT-Palmira.

Cassava is not particularly well-adapted to the exploitation of open pollination crossing schemes, however, good management can overcome these problems, making open pollination an effective breeding tool. The advantage of open pollination is production of a large number of seeds with minimum labor requirements. A major difficulty is the great range in time to flowering and number of flowers produced among clones. Furthermore, the earliest and most prolific flowering types are less desirable from a plant type viewpoint since early flowering is associated with early and frequent branching. Branching is controlled on highly branched types to make flower production more uniform. There are no known effective means for increasing flower production of very late-branching types.

Individual plants are coded and each flower raceme tagged and covered after pollination to catch seeds at maturity. Seeds from the same clone among the various replications are combined and planted together as a half-sib family having a known female parent and a mixture of male parents. Family performance is a measure of general combining ability of the female parent.

The polycross blocks were modified this year to permit gradual incorporation of genes for characteristics occurring in a background basically unadapted to the environment in question. The unadapted genotypes were planted as borders surrounding each of the replicates of the polycross block. To avoid contamination of the basic gene pool with pollen of this unadapted germplasm, border plants were emasculated weekly. The progeny of the border rows will be backcrossed several times to the basic pool to combine the adaptation of the pool with the character being introduced.

The second stage of germplasm improvement involves selection of the best entries from the polycross blocks based on combining ability and performance within a given environment. The selected clones are recombined through controlled pollination. In this stage, more precise control of parentage is possible and specific combining ability effects can be capitalized upon.

Progeny evaluation. Progeny of gene pools are being evaluated in Media Luna, Carimagua, Popayán and CIAT-Palmira. Evaluation beginning at the F_1 stage (plants from true seed) within each environment has the potential advantage of a high selection efficiency since very large numbers of distinct genotypes are subjected to the particular characteristics of the environment. Further studies are needed however, to compare efficiency of F_1 selection first in CIAT-Palmira versus within the environment. Seedling plants are rather delicate during the first several weeks after sowing or transplanting, and large losses can easily occur from factors unrelated to the plant's

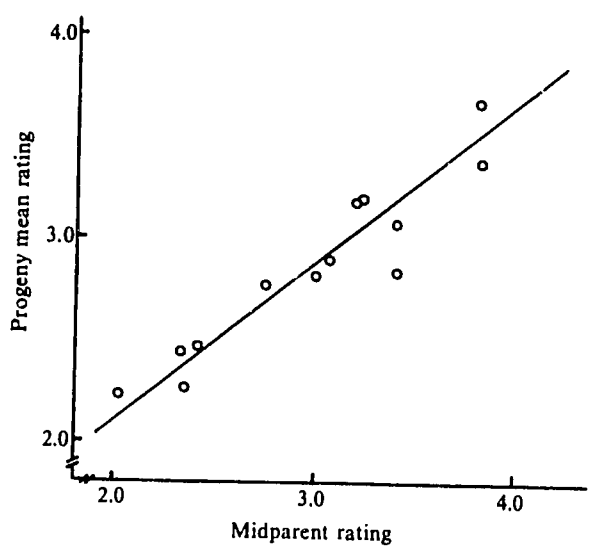
future potential (e.g., short drought period, weed competition, attack by chewing insects). A further problem is moving large amounts of clonal material back to a centralized location for crossing or stake multiplication. These problems are being investigated further to maximize the efficiency of F_1 selection. Superior hybrids will be tested through the replicated yield trial stage, then passed to the Varietal Improvement section as new gene sources.

Special Studies

Heritability of mite resistance. Mites have been identified among the important arthropod pests of cassava. Previous studies (CIAT Cassava Prog. 1979 Ann. Rept.) showed a high broad-sense heritability for *Mononychellus* resistance (high consistency across replications in a field, across sites, and across years).

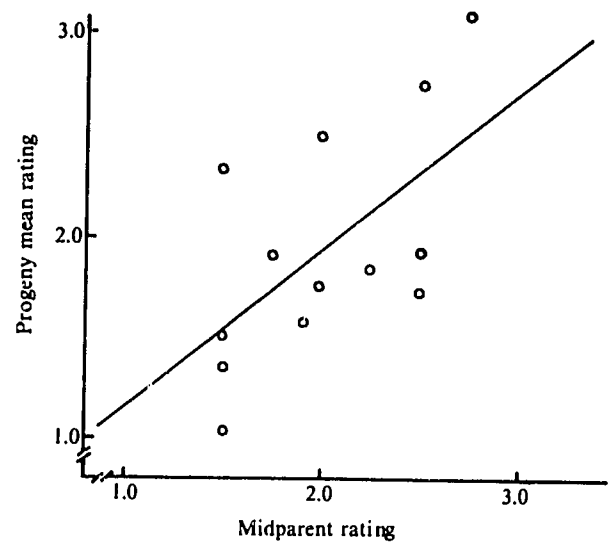
Studies in CIAT-Palmira this year in two F_1 hybrid trials showed high narrow-sense heritability ($h^2 = 0.78$) based on midparent-progeny regression, where the slope of the regression line is a direct estimate of h^2 (Figures 1 and 2).

This study also indicates that when medium to high mite infestation occurs at CIAT-Palmira, preliminary selection there of individual plants in a segregation population will probably be effective for North Coast conditions.



r = 0.95 Y = 0.78 X + 0.57

Figure 1. *Regression of F_1 progeny mean on midparent for resistance to the* **Mononychellus tanajoa** *mite under high population levels, at CIAT-Palmira, 1980.*



r = 0.62 Y = 0.78 X + 0.38

Figure 2. *Regression of F_1 progeny mean on midparent for resistance to the* **Mononychellus tanajoa** *mite under moderate population levels, at CIAT-Palmira, 1980.*

Heritability of adaptation in low temperature zones. Progeny from six cross combinations involving an adapted parent (M Col 1522) crossed with poorly adapted parents were grown in a replicated trial in Popayán, along with the parent clones. For all crosses, mean family yield, cold tolerance, *Phoma* and anthracnose resistance, and general evaluation was intermediate between the parents. A few hybrids yielded about the same as M Col 1522.

These data show that poorly adapted cultivars are generally unacceptable as parents for production of hybrids in this environment, as the proportion of well-adapted progeny is very low. Adaptation appears to be largely controlled by additive gene effects.

Early generation selection for root dry matter content. High root dry matter content is an important quality criterion for practically all uses of cassava. A study was concluded this year to determine whether selection for root dry matter content on an individual plant basis in a segregating F_1 population could be effective. Data from 260 individual plants grown from true seed were compared with the same clones grown in a single-row observational yield trial at CIAT-Palmira. Correlation between the two clonal generations was r = 0.48**, demonstrating the ability to measure a significant proportion of genetic control of dry matter production compared to environmental effects. CIAT does not presently intend to routinely evaluate F_1

progeny for dry matter content due to the huge number of samplings required; however, if at some point a rapid and intensive increase in dry matter content is desirable, F_1 evaluation would be justified.

Seed germination studies. Cassava seeds are known to have a dormancy period for several months after harvest. Decreasing the lenght of the dormancy period would significantly shorten the breeding cycle. For newly harvested seeds, a pregermination heat treatment in a dry oven at 60° C for 14 days was found to significantly increase total germination and decrease time to germination (Figure 3). For 3-6 month-old seeds, no improvement in germination was noted, but neither was the treatment detrimental to germination compared to the controls. Therefore, 0-6 month-old seed can safely be heat-treated with beneficial effects on the new seeds and no effect on the older seed. Results have been confirmed in the field at Carimagua, where germination of heat-treated seeds of 0-9 months was 47.2%, compared to 35.5% for nontreated seeds.

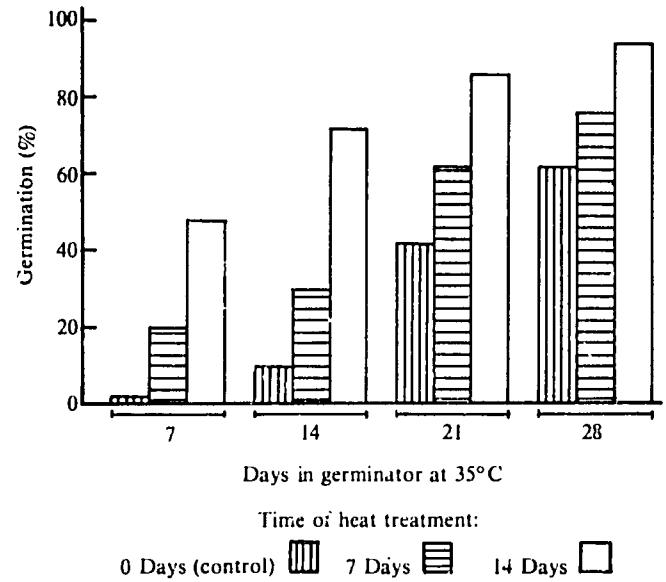


Figure 3. *Effect of a pregermination heat treatment (at 60° C, 150 seeds/treatment, composite from six varieties) on newly harvested cassava seed.*

Hybrid selections were continued at CIAT-Palmira, Caribia and Carimagua. Because of the importance of the Caribia and Carimagua environment, the relative importance of selection programs there was increased. Since considerable progress has been made in yielding ability and disease resistance through single-trait selection for harvest index, branching type, or CBB and superelongation resistance, selection emphasis has gradually shifted towards overall performance over several years at each selection site. Production of hybrid seeds by controlled pollination was quadrupled after critical pest problems were overcome.

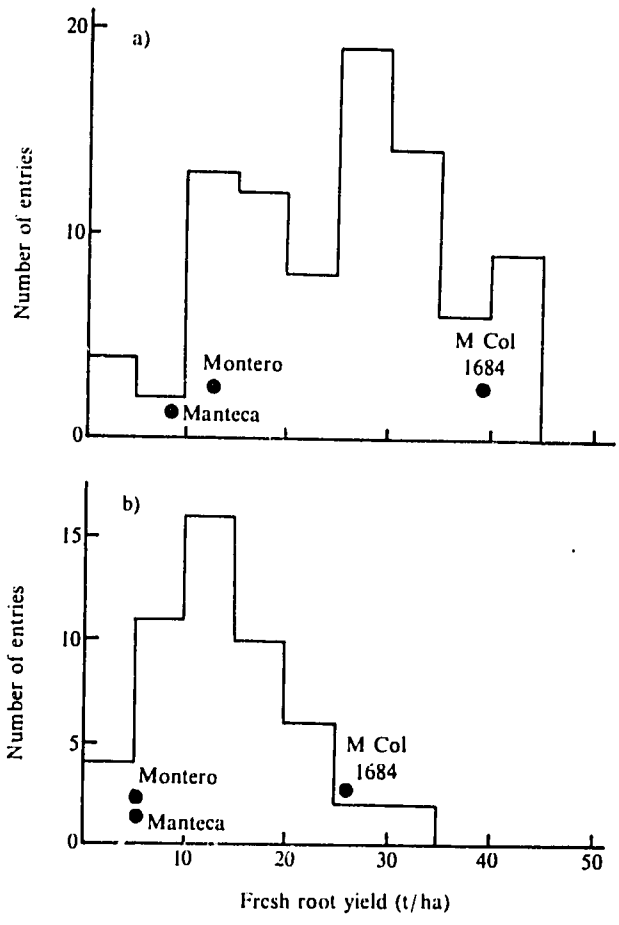


Figure 1. *Frequency distribution of CIAT cassava lines at different yield levels in replicated yield trials at Caribia, 1980.*
a) July and February plantings; b) May planting.

Selection at Caribia

CIAT hybrid selections and an outstanding germplasm accession, M Col 1684, continued to show good yielding ability (Fig. 1). One of the replicated yield trials (planted in May and harvested in February), planted on a poor soil spot without irrigation, suffered severely from drought and consequently yielded low. Yet, the superiority of CIAT selections over local cultivars (Montero and Manteca) persisted. However, only few CIAT lines exceeded the best

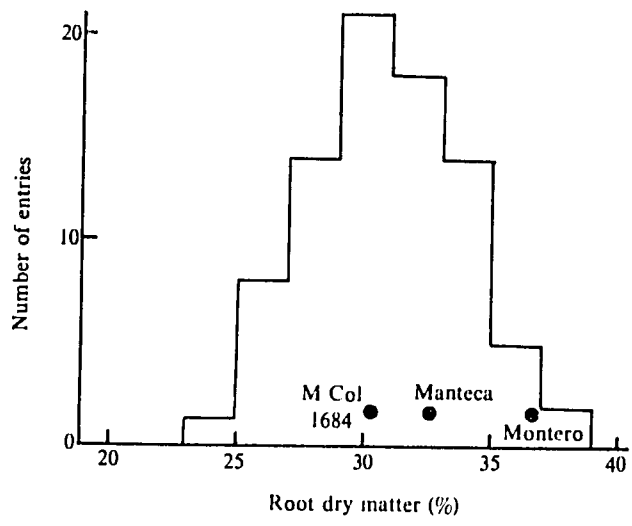


Figure 2. *Frequency distribution of CIAT cassava lines at different root dry matter contents in replicated yield trials at Caribia, 1980. (Average of three trials and including values only for higher yielding lines in terms of root production.)*

local cultivar in root dry matter content (Fig. 2). More selection efforts shall be directed to a good combination of high root dry matter content with high yielding ability.

Three new hybrid selections which seem to combine reasonably high yield with high root dry matter content and lodging resistance, were passed to the Agronomy section for evaluation in regional trials in the hot tropics.

Selection at Carimagua

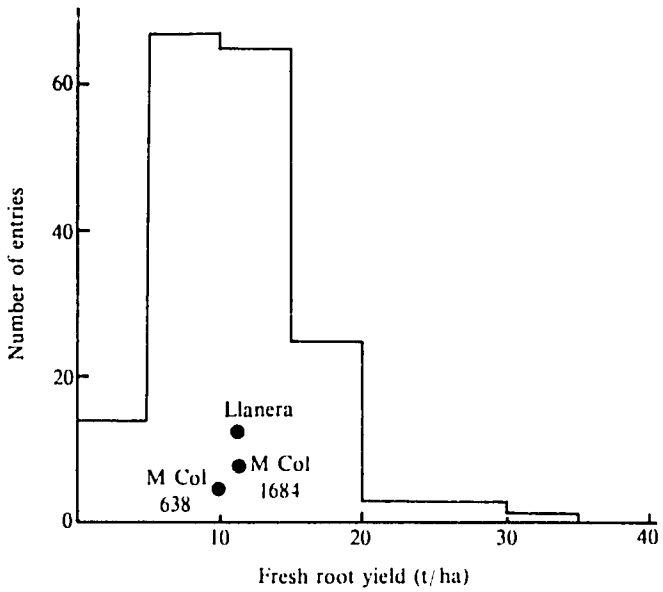


Figure 3. *Frequency distribution of CIAT cassava lines at different yield levels in replicated trials at Carimagua, 1980. (Average of two trials planted in May and October.)*

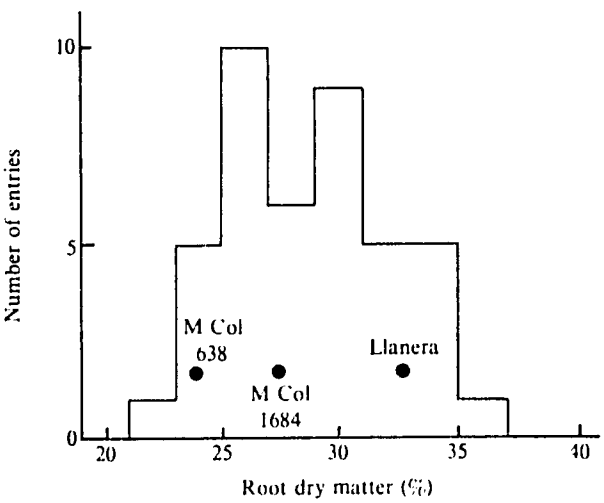


Figure 4 *Frequency distribution of CIAT cassava lines at different root dry matter contents in replicated yield trials at Carimagua, 1980. (Average of two trials and including values only for higher root yielding lines.*

Many CIAT lines outyielded local cultivars (Llanera and M Col 638) and M Col 1604 but yields were generally low (Fig. 3). All trials received a modest fertilizer application. The root dry matter content was generally very low but several lines, such as CM 523-7 and CM 723-3, consistently showed high root dry matter content (Fig. 4). Many new lines had good resistance to CBB and superelongation. Selection emphasis continues to be for a good combination of stable yield with high root dry matter content and disease and insect resistance.

Six new selections were passed to the Agronomy section for regional trials evaluations in tropical savanna conditions.

Selection at CIAT-Palmira

Many CIAT lines continued to show excellent yield and root dry matter content (Figs. 5 and 6). A good example is a new selection CM 849-1 which gave a root yield of 71 t/ha/year with 39% root dry matter content.

Twelve selections which seemed to combine high yield with high root dry matter content and high harvest index (thus lodging resistance) were passed to the Agronomy section. Many of these are expected to be adapted to the hot lowland tropics, thus, all of these are intensively evaluated at the Caribia station also. Ten selections which showed exceptionally high-yielding ability were also passed to the Agronomy section. These are the selections to be adapted to high-yielding environments.

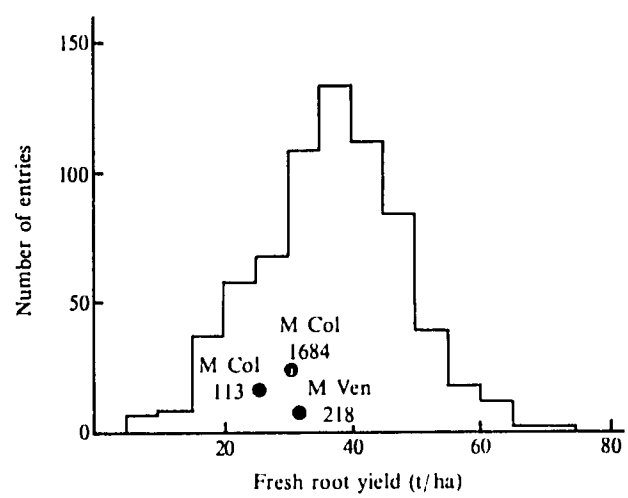


Figure 5. *Frequency distribution of CIAT cassava lines at different yield levels in replicated trials at CIAT-Palmira, 1980. (Average of three trials.)*

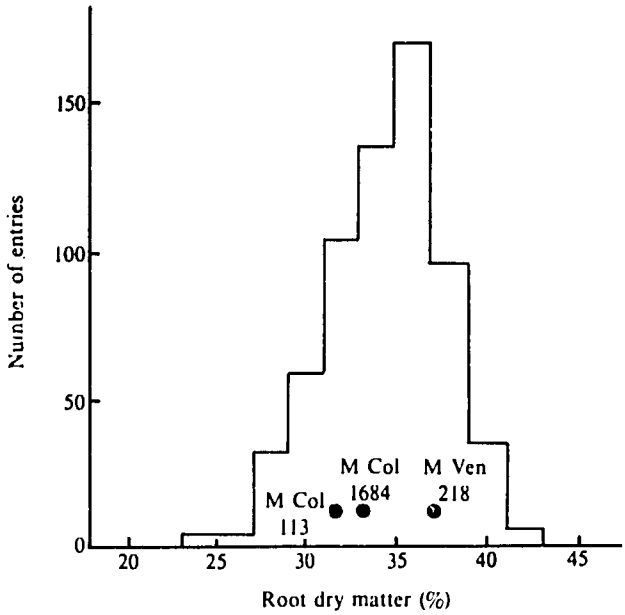


Figure 6. *Frequency distribution of CIAT cassava lines at different root dry matter contents in replicated yield trials at CIAT-Palmira, 1980. (Average of three trials.)*

Yielding Stability

Emphasis on varietal selection has shifted from absolute high yield to reasonably high yield that is stable over years and seasons in each representative enviroment. Treatment of selection fields is adjusted to realistic farm situations by eliminating heavy fertilizer applications, irrigation, and pesticides. Several factors affecting yield stability have been identified (see Agronomy-Regional Trials section). Thus, breeding for disease and insect resistance, good germination ability, and lodging resistance are among the important selection criteria. The final selection criterion in the Varietal Improvement section is stable yield over years and seasons. Yield stability over different sites within each macro-region is evaluated with a smaller number of promising materials in the regional trials. Numbers of new selections are evaluated in repeated seasons at each selection site.

A good example of high and stable yield was obtained with CM 342-170 at Caribia and CM 516-7 at CIAT (Fig. 7). At Carimagua, the number of abiotic and biotic factors which adversely affect cassava yield is much higher, so obtaining a stable yield is more difficult. Yet, CIAT lines such as CM 517-1 and CM 523-7 seem to show some promise.

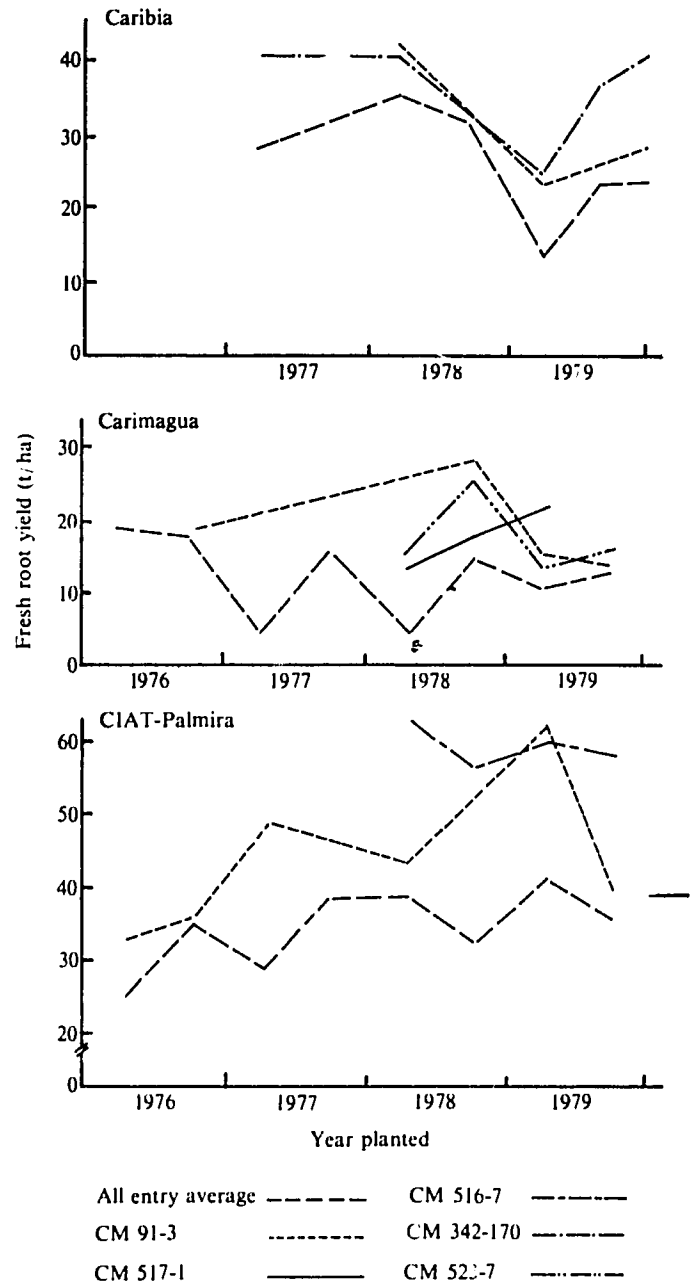


Figure 7. *Yield stability in selected cassava lines grown in three locations.*

Varietal Adaptation and Production of Planting Stakes

Production of good planting stakes is difficult under high-stress conditions such as those at Carimagua. CBB infection significantly reduces the root yield of susceptible cassava lines, particularly when early infection is produced

from CBB-infested cuttings (CIAT Cassava Prog. 1979 Ann. Rept.). Furthermore, CBB infection drastically reduced the quantity of planting stakes on susceptible lines. Unavailability of non-infested planting stakes is, therefore, a more acute factor than the reduced root yield in susceptible cultivars planted with uninfested stakes. This is especially critical when continuous cassava production has to be done using stakes produced locally.

Primary superelongation infection (self-infection within the same planting stake), which may cause complete crop failure, can be easily distinguished from ordinary or secondary infection coming from other plants. Primary infection is proportional to the superelongation infection in the previous planting from which the planting stakes were taken (Fig. 8). There are many more abiotic and biotic factors which should affect quantity and quality of planting stakes.

CIAT-Palmira is regarded as a low stress environment relatively free from disease problems for cassava production. Caribia is regarded as a medium stress environment where the dry season is long and CBB is always present during the rainy season and causes significant yield reductions occasionally. Caribia is, however, relatively free from other disease and insect problems. To compare the quality of locally produced planting stakes with those from CIAT-Palmira, several cassava lines have been planted in replicated yield trials with stakes from CIAT-Palmira and from Caribia and Carimagua.

At Caribia, both local and CIAT-Palmira stakes germinated well. Local stakes tended to yield slightly better but differences were generally not statistically significant. However, looking at individual lines, M Col 22 was a good yielder when planted with locally produced planting stakes but it was difficult to obtain a high yield using CIAT-produced stakes (Table 1). The same tendency was observed with CM 342-170, but M Col 1684 showed no clear tendency. There was no sign that stakes from Caribia were inferior to CIAT-produced stakes. There was, however, some delay in planting stakes from Palmira in Caribia due to transport problems. Nevertheless, CIAT-produced stakes were treated with fungicides to offset this effect while Caribia stakes were untreated.

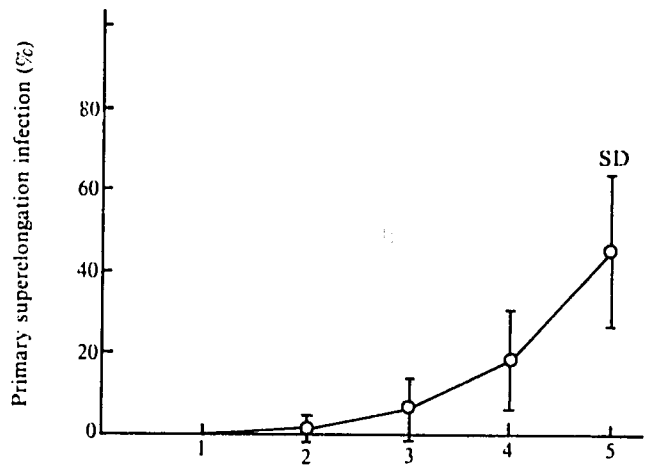


Figure 8. *Effect of superelongation infection in a previous planting on primary superelongation infection (May plantings in Carimagua)*
Superelongation rating: 1 = no symptoms; 2 = symptoms only on leaves; 3 = symptoms on leaves of all plants and occasional stem elongation; 4 = 50% of plants show stem elongation; 5 = leaves dying of disease infection.

Table 1. Yield comparisons for three cassava lines planted at Caribia, in relation to the source of planting stakes.

Cassava line	Source of planting stakes	Fresh root yield (t/ha) for crops planted in:				
		May 1978	May 1979	October 1979	February 1980	Average
M Col 22	Caribia	44.2	22.2	48.6	34.4	37.4
	CIAT-Palmira	20.0	16.1	29.2	15.0	20.1
CM 342-170	Caribia	51.4	25.2	-	41.9	39.5
	CIAT-Palmira	31.2	21.1	36.7	33.3	28.5
M Col 1684	Caribia	-	16.1	32.5	39.4	29.3
	CIAT-Palmira	50.8	25.6	56.9	27.2	36.6

At Carimagua, local planting stakes generally germinated poorly and yielded significantly lower. Yield differences between Carimagua and CIAT-Palmira stakes were greater in earlier days (1978 plantings); however, as selection intensified, differences narrowed to a negligible level (October 1979 planting). For those lines which gave reasonably high yields by planting Carimagua stakes, the yield difference between Carimagua and CIAT-grown stakes disappeared (Table 2).

Table 2. Yield comparisons for selected cassava lines planted in Carimagua, in relation to the source of planting stakes (for planting of October 1979).

Lines	Fresh root yield, Carimagua stakes (t/ha)	Fresh root yield, CIAT-Palmira stakes (t/ha)
New selections:		
CM 946-2	31.3	34.7
CM 996-6	29.9	23.6
CM 983-5	22.9	not planted
CM 951-6	20.8	29.2
CM 976-2	19.4	9.7
CM 854-21	18.8	19.4
CM 1012-2	18.1	13.2
CM 840-323	18.1	16.7
CM 869-4	18.1	12.5
CM 840-324	17.4	20.1
Average	21.3	19.9
Older selections:		
CM 430-37	18.2	13.9
CM 723-3	15.7	14.6
CM 523-7	15.3	12.5
CM 91-3	14.3	11.5
M Ven 77	11.9	7.7
Average	15.1	12.0

In older selections, whose adaptation to Carimagua has been well-confirmed, yield with Carimagua stakes tended to exceed that with CIAT stakes.

We can conclude that production of good quality planting stakes is difficult under high stress conditions. However, if the cassava genotypes are truly adapted locally, the quality of planting stakes produced is as good as or even better than stakes produced in other environments with less stress.

Hybrid Seed Production

As cassava breeding programs in certain key countries such as Brazil and Thailand gained strength, and the importance of decentralized varietal selection was widely recognized, demand for F_1 hybrid seeds has increased. Hybrid seeds had been produced at CIAT-Palmira with reasonably high efficiency (around 0.7 seed per each female flower pollinated) between 1974 and 1977. However, the efficiency dropped notably in 1978 and in 1979 when only an average of 0.28 seed per female flower was obtained. In 1979, the number of pollinations doubled but the actual hybrid seeds obtained decreased.

The primary cause of decreased seed production has been the increasing buildup of the cassava fruit fly (*Anastrepha* sp.), which feeds on developing seeds. In January 1980, biweekly applications of the systemic insecticide fenthion were begun. These treatments have not only effectively controlled *Anastrepha* sp., but also several other insect pests of cassava. A high efficiency of hybridization (0.82 seed per flower) has been restored and, because of the effective control of thrips, pollen and flower production has been improved. This has enabled massive pollinations to be made with such lines as M Ven 77 and M Pan 12B, which are known to be well adapted to the Carimagua environment.

Regional Trials

Results of sixth cycle. The sixth testing cycle for promising cassava varieties under uniform improved technology (CIAT Ann. Rept. 1974) was completed in 1980 with harvesting at eight locations in Colombia. Table 1 shows the edaphic and climatic conditions of the different sites.

Lime and fertilizer were used only at Carimagua and CIAT-Quilichao. At Carimagua, rates applied were 0.5 t/ha of lime, 1 t/ha of 10-20-20, 20 kg/ha of S and 5 kg/ha of Zn. At CIAT-Quilichao, where planting has been done in the same field for three years, 375 kg/ha of lime, 100 kg/ha of N and 50 kg/ha of P_2O_5 were applied; zinc was included in the stake treatments.

Principal problems in 1980 were heavy attacks of CBB and superelongation at Carimagua and superelongation, frog skin, *Cercospora* diseases, mites, white flies, white scale and thrips at CIAT-Quilichao. At Río Negro, 8 month-old plantings were completely defoliated by the cassava hornworm.

As in previous years, the best selected lines outyielded local materials an average of 37.5 t/ha to 18.5 t/ha. M Col 1684, CM 342-55 and CM 489-1 outyielded the best local clones in seven of eight sites; CM 308-197 and CM 462-6 surpassed local materials in six of eight sites; and CM 430-37, CM 321-188, CM 311-69, CM 451 -4, C71-4 and ICA-HMC-2 were outstanding in five of eight sites (Table 2). This again reflects the higher yield potential of selected improved material, compared to regional or local varieties.

Two new hybrids (CM 342-55 and CM 430-37) seem promising after their relatively high yields across several locations including Carimagua and CIAT-Quilichao. CM 342-55 is the result of crossing M Col 22 and M Col 1468 (CMC-40); the latter parent is widely adapted with good yield stability over time.

Overall six-year results. After six years of regional trials the three most promising cultivars at each site produced an average fresh root yield across all sites of 34.6 t/ha, compared to 20.1 t/ha for local varieties (Table 3). Moreover, at each site, promising materials substantially outyield local cultivars. This represents a tremendous increase in both types of materials compared with the Colombian average estimated yield of 9.7 t/ha.

Table 1. Main climatological and edaphic characteristics at sites of the 1979-80 regional yield trials for cassava, in Colombia.

Site	Altitude (masl)	Mean Temperature (°C)	Rainfall[1] (mm)	Days to harvest	Soil texture	Soil pH	Soil organic (%)	Soil P, Bray II (ppm)	Soil K (meq/100 g)
Media Luna	10	27.2	1190	328	Sandy loam	6.6	0.7	7.2	0.08
Chigorodó	28	28.0	1059	305	Silty clay loam	6.8	4.2	27.8	0.51
Carimagua	200	26.2	2867	398	Silty clay	4.7	3.2	1.9	0.14
Río Negro	250	27.0	2009	329	Sandy clay loam	4.4	2.1	4.0	0.11
San Martín	300	25.0	2373	332	Clay	4.2	3.2	7.4	0.16
CIAT-Palmira	1000	23.8	704	336	Clay	7.0	3.9	73.3	0.70
CIAT-Quilichao	1070	23.0	1233	310	Clay loam	3.6	6.7	40.5	0.35
Caicedonia	1200	22.2	1344	256	Sandy clay loam	5.5	3.2	40.5	0.35

[1] Total rainfall during cassava growing cycle.

Table 2. Yields of promising ICA-CIAT cassava varieties and hybrids at eight locations in Colombia during 1979- 80 regional trials.

Varieties and hybrids	Fresh root yield (t/ha)								Average yield (t/ha)
	Media Luna	Chigorodó	Carimagua	Río Negro	San Martín	CIAT-Palmira	CIAT-Quilichao	Caicedonia	
Best local[1]	10.1	28.9	4.5	13.6	15.7	25.5	22.1	27.7	18.5
M Col 1684	22.0	45.9	9.5	24.6	24.5	26.5	17.2	55.2	28.2
CM 309-41	10.7	-	3.8	13.8	-	30.4	-	44.5	20.6
ICA-HMC-1	11.8	47.5	-	12.5	-	40.2	-	42.7	30.9
CM 342-55	25.9	51.0	5.7	23.8	21.8	37.6	18.7	41.7	28.3
CM 430-37	9.5	-	18.2	13.6	20.4	48.0	22.0	40.9	24.7
ICA-HMC-2	11.5	41.2	15.4	-	20.1	22.9	-	40.6	25.3
CM 489-1	16.0	57.1	-	20.3	26.4	55.7	22.7	39.7	34.0
CM 308-197	16.0	45.0	1.5	23.8	16.7	36.9	-	37.8	25.4
CM 426-6	21.9	-	7.6	21.0	22.7	36.0	14.3	36.4	22.8
CM 440-5	9.1	-	4.1	13.2	13.4	29.2	9.5	35.2	16.2
CM 471-4	12.3	-	0.8	15.1	20.0	30.7	11.7	35.1	18.0
CM 451-1	14.0	-	3.5	16.1	18.2	31.2	16.2	34.7	19.1
CM 321-188	16.9	43.2	1.8	-	22.4	43.8	16.8	32.4	25.3
CM 305-120	-	-	-	-	-	-	-	38.8	38.8
CM 311-69	-	-	6.5	-	21.5	35.4	23.9	30.3	23.5
ICA-HMC-7	-	-	-	18.0	21.4	34.8	20.4	-	23.7
CM 344-71	-	-	-	-	20.7	30.5	32.0	-	27.7
CM 192-1	-	-	2.8	-	-	31.1	22.8	34.2	22.7
CMC 40 (M Col 1468)	-	58.2	6.9	-	-	-	-	33.7	32.9
CM 340-30	-	-	6.1	21.6	-	34.6	-	-	20.8
CM 305-41	-	-	-	-	-	45.3	28.4	-	36.9
M Ven 218	11.8	-	-	-	-	37.1	-	-	24.5
CM 323-375	18.1	-	-	-	22.2	32.9	-	-	24.4
CM 305-38	-	-	-	-	-	-	28.2	-	28.2
CM 323-87	18.8	-	-	19.2	-	-	-	-	19.0
Chiroza	-	-	-	8.6	19.2	-	-	-	13.9
CM 507-34	-	-	13.9	-	-	-	-	-	13.9
M Ven 77	-	-	12.5	-	-	-	-	-	12.5
CM 507-37	-	-	10.5	-	-	-	-	-	10.5
CM 430-9	-	-	7.1	-	-	-	-	-	7.1
CM 516-7	-	-	6.9	-	-	-	-	-	6.9
SM 1-150	-	-	4.9	-	14.0	-	-	-	9.5
CM 309-211	-	-	3.4	-	-	-	-	-	3.4
M Col 22	19.6	-	-	-	-	-	-	-	19.6
CMC 9 (M Col 1438)	-	-	-	-	11.0	-	-	-	11.0
M Mex 59	-	-	-	-	30.1	-	-	-	30.1
CMC 76 (M Col 1506)	-	34.5	-	-	-	-	-	-	34.5
ICA-HMC-3	-	31.7	-	-	-	-	-	-	31.7
ICA-HMC-53	-	64.2	-	-	-	-	-	-	64.2
Average, including local varieties	15.3	45.7	6.9	17.4	20.1	35.3	20.4	37.9	
Best promising hybrid or variety	25.9	64.2	18.2	24.6	24.5	55.7	32.0	55.2	37.5

[1] Best local varieties: for Media Luna, cultivar Secundina; for Chigorodo, CMC 84 (M Col 1513); for Carimagua, Llanera; for Rio Negro Venezolana; for San Martin, Tempranera; for CIAT-Palmira, M Col 113; for CIAT-Quilichao, M Col 113; for Caicedona Chiroza Gallinaza.

Table 3. Cumulative average fresh and dry root yields of the three best promising varieties compared with the best local variety, at nine sites of cassava regional trials.

Site	Yield (t/ha)											
	Average of five cycles[1]				1979-80 cycle				Average per site			
	Promising		Local		Promising		Local		Promising		Local	
	FRW[2]	DM[2]	FRW	DM	FRW	DM	FRW	DM	FRW	DM	FRW	DM
Media Luna	23.4	6.7	8.3	3.0	23.2	6.1	10.1	3.3	23.3	6.[illegible]	8.6	3.0
Chigorodó	-	-	-	-	59.8	16.4	28.9	8.6	59.8	16.4	28.9	8.6
Carimagua	20.4	6.7	13.3	4.2	15.8	4.9	4.5	1.3	19.6	6.4	11.8	3.7
Rio Negro	33.2	9.9	14.9	4.6	24.0	5.6	13.6	3.1	31.6	9.2	14.7	4.3
San Martin	-	-	-	-	27.0	9.3	19.2	6.2	27.0	9.3	19.2	6.2
Nataima	33.3	10.0	18.0	5.1	-	-	-	-	33.3	10.0	18.0	5.1
CIAT-Palmira	36.8	13.0	22.3	7.7	49.6	18.7	25.5	8.2	38.9	13.9	22.8	7.7
CIAT-Quilichao	37.8	12.0	31.4	9.9	29.5	8.8	22.1	5.7	35.0	10.9	28.3	8.5
Caicedonia	41.9	14.9	29.2	9.9	47.4	17.8	27.7	10.1	42.8	15.3	28.9	9.9
Average per cycle	32.8	10.8	21.6	7.2	34.5	10.9	18.9	5.8	34.6	10.9	20.1	6.3

[1] See CIAT Cassava Prog. 1979 Ann. Rept., for details.
[2] FRW=fresh root yield; DM=dry root yield.

Table 4 summarizes six years of yield data in regional trials and seven years of data for replicated yield trials in the Varietal Improvement section. In the regional trials, only varieties and lines that had outstanding performances against local varieties in each site have been included.

Varietal Adaptation and Yield Stability

Accumulated yield data in Table 4 enable some detailed analyses of cassava adaptation and yield stability. Varieties M Col 1468, M Col 1684 and M Col 22, tested for 45, 40 and 40 cycles respectively, have produced weighted average yields of 29.1, 30.8 and 22.0 t/ha, respectively. Yields of the first two are both high and relatively stable, while yields of M Col 22 are lower and unstable.

M Col 1468, a variety from Campinas, Brazil (located about 20°S latitude) has performed well as far as 22° N latitude. Based on good performance in Cuba, it was released for commercial production there; it was also outstanding in international yield trials this year in the Dominican Republic and Ecuador. These results confirm its wide range of adaptation. Variety M Col 1684 has also produced high yields and showed good adaptation in both Ecuador and the Dominican Republic. Its high yield at the Napo Station in Ecuador (Table 5) was produced on an acid infertile Oxisol soil.

Figure 1 shows yield data for M Col 1684 in seven Colombian locations below 1300 masl. While maximum yields were similar across locations, they were slightly lower at Media Luna and Río Negro where no irrigation was used. Yield variation within locations was very large, especially at Carimagua due to the very high soil, water, disease and insect stresses common there. These yield variations and high maximum yields suggest three conclusions relating to selected genotypes: a) genotype x location interaction is not so great if genotypes are planted under favorable conditions at each location; b) yield variation within a location is as great as or greater than yield variation across locations; c) an apparently large genotype x environment interaction is, in many cases, actually a genotype x within-location variation interaction.

Several factors influence within-location variation. Some such as land preparation, irrigation, soil fertility, weed control, and pesticide applications are controllable; others like temperature, rainfall, and disease and insect pest outbreaks are largely uncontrollable. Because cassava will continue to be produced primarily on marginal soils with animal or only modest input levels, understanding of within-location variation from uncontrollable factors is receiving major attention in the Cassava Program.

Several hybrid promising lines have been tested for more than 10 cropping cycles and have yielded well in several locations including the high stress sites at Carimagua and CIAT-Quilichao (Table 4). Performance of these crosses over time and locations indicates progress in finding superior germplasm through breeding manipulation.

Table 4. Yield performance and main characteristics of promising cassava lines and accessions during six years of regional trials.

Line or accession	Fresh root yield (t/ha)											Average	Dry Matter	Disease reactions[1]	
	Media Luna	Caribia	Chigorodó	Carimagua	Rio Negro	San Martín	Nataima	CIAT-Palmira	CIAT-Quilichao	Caicedonia	Pereira		(%)	CBB	Super-elongation
Promising lines															
CM 323-87	21.1 (3)				22.8 (3)							22.0 (6)	31	S	S
CM 308-197	17.0 (3)		45.0	11.6 (3)	26.7 (3)		34.4 (2)	33.9 (3)		41.1 (3)		28.8 (18)	32	S	S
CM 309-41	15.1 (3)			13.2 (3)	20.7 (3)			30.4 (3)	27.8 (3)	45.4 (3)		25.4 (18)	32	R	S
CM 192-1				12.8 (3)				29.3 (3)	29.9 (3)	40.2 (3)		23.1 (12)	31	S	S
CM 323-375	20.7 (2)	31.3 (3)				22.2 (1)		30.3 (3)				27.6 (9)	34	S	S
CM 480-1	16.0 (1)	27.7 (3)	57.1 (1)		20.3 (1)	26.4 (1)		62.5 (3)	22.7 (1)	39.7 (1)		37.8 (12)	29	S	S
CM 342-55	25.9 (1)		51.0 (1)		23.8 (1)	21.8 (1)		45.4 (4)		41.7 (1)		38.5 (9)	29	S	S
CM 451-1	14.0 (1)				16.1 (1)							15.1 (2)	30	MR	S
CM 344-71							27.6 (1)		29.0 (2)			28.6 (3)	30	S	S
CM 430-37		25.0 (2)		19.7 (3)		20.4 (1)		45.5 (3)		40.9 (1)		30.7 (10)	33	MR	MR
CM 342-170		38.6 (4)						24.7 (3)				32.6 (7)	34	S	S
CM 321-188	19.0 (2)	33.9 (3)					26.2 (1)	51.5 (5)	18.8 (2)	43.3 (2)		36.5 (15)	34	S	S
CM 462-6	21.9 (1)			7.6 (1)	21.0 (1)			36.0 (1)				21.6 (4)	26	MR	S
CM 91-3		25.8 (4)		20.0 (3)				44.3 (4)				30.9 (11)	33	MR	MR
CM 523-7		9.0 (1)		17.1 (2)				42.0 (2)				25.4 (5)	37	R	R
CM 430-9		20.5 (3)		13.9 (2)				42.0 (3)				26.9 (8)	28	MR	MR
CM 440-5		26.5 (3)		16.5 (2)				46.5 (3)				31.5 (8)	37	MR	MR
CM 323-403		46.8 (5)										46.8 (5)	30	S	S
ICA-HMC-2	15.6 (3)					20.1 (1)		26.0 (3)		33.4 (2)	37.2 (1)	24.9 (10)	32	MR	MR
ICA-HMC-7					18.0 (1)			36.2 (2)	32.2 (3)			31.2 (6)	40	-	MR
CM 311-69				10.5 (2)				35.4 (1)	23.7 (2)			20.8 (5)	34	MR	MR
CM 507-34		11.5 (2)		12.3 (3)				46.0 (2)				21.7 (7)	31	R	MR
CM 507-37		14.5 (2)		12.2 (3)				47.8 (2)				23.0 (7)	30	R	MR
CM 340-30					24.0 (2)			30.0 (2)				27.0 (4)	29	S	S
CM 305-41		24.0 (2)					26.6 (1)	46.2 (6)	26.9 (2)		30.9 (1)	36.4 (12)	33	S	S
ICA-HMC-1			47.5 (1)					35.5 (2)		50.5 (2)	38.1 (1)	42.9 (6)	37	S	S
CM 305-38									28.2 (1)			28.2 (1)	32	S	S
CM 471-4						20.0 (1)						20.0 (1)	31	S	S
CM 391-2		34.0 (2)		16.0 (1)				42.0 (3)				35.0 (6)	32	S	S
ICA-HMC-53			64.2 (1)									64.2 (1)	-	-	-
Weighted average	18.2 (20)	29.2 (39)	53.0 (5)	14.4 (31)	22.4 (16)	21.8 (6)	29.8 (5)	40.6 (66)	27.2 (19)	42.1 (18)	35.4 (3)	30.3 (228)			

Table 4. (continued).

Line or accession	Fresh root yield (t/ha)											Average	Dry Matter	Disease reactions[1]	
	Media Luna	Caribia	Chigorodó	Carimagua	Rio Negro	San Martin	Nataima	CIAT-Palmira	CIAT-Quilichao	Caicedonia	Pereira		(%)	CBB	Super-elongation
Outstanding accessions															
M Col 113				3.4 (3)				20.2 (6)			28.8 (2)	17.2 (11)	39	S	S
M Col 1684	29.4 (3)	36.2 (6)	45.9 (1)	20.1 (8)	35.2 (3)	24.5 (1)	27.2 (3)	29.1 (9)	31.4 (3)	50.5 (3)		30.8 (40)	31	MR	MR
M Col 22	19.6 (6)	28.7 (6)		10.8 (8)			26.0 (4)	26.2 (11)		30.9 (3)	8.8 (2)	22.0 (30)	34	S	S
M Col 1468 (CMC 40)	22.7 (5)	25.5 (4)	58.2 (1)	17.6 (8)	24.7 (5)		31.9 (5)	37.6 (9)		36.9 (4)	31.2 (4)	29.1 (45)	30	MR	MR
M Ven 218	14.7 (3)	29.3 (2)		9.5 (4)			24.2 (3)	36.1 (8)		32.4 (3)		26.1 (23)	33	S	R
M Col 1505 (CMC 76)			34.5 (1)		26.2 (3)			33.1 (3)			28.7 (3)	29.8 (10)	35	S	S
M Col 1513 (CMC 84)	13.1 (5)			17.0 (5)	29.9 (5)		26.9 (2)	35.0 (4)		31.5 (3)	24.2 (2)	24.5 (26)	34	S	S
M Mex 59	23.1 (5)			17.7 (4)	33.1 (5)	30.[illegible] (1)	29.6 (5)	24.8 (3)		32.7 (5)	16.4 (3)	24.6 (31)	32	S	R
M Col 1529 (CMC 99)					31.6 (3)							31.6 (3)	30	MR	S
M Ven 155	15.6 (3)				25.2 (3)			28.5 (3)				23.1 (9)	34	S	S
M Ven 77				16.9 (5)	27.7 (3)							21.0 (8)	28	R	R
M Col 673				9.3 (2)	29.0 (3)							21.1 (5)	36	S	MR
M Col 677					24.0 (3)			22.5 (2)		28.7 (8)		25.4 (8)	37	S	MR
M Col 1686							32.3 (2)					32.3 (2)	28	-	-
M Pan 70							23.5 (3)	28.5 (3)		34.3 (3)		28.8 (9)	33	S	R
Ptr 26							28.1 (3)	28.4 (3)				28.3 (6)	33	S	R
M Mex 17							24.8 (3)	25.7 (3)				25.3 (6)	34	S	S
M Mex 23				12.1 (2)				27.2 (3)		31.4 (3)		25.0 (8)	37	S	MR
M Col 1292										33.9 (3)		33.9 (3)	38	S	S
M Col 1488 (CMC 59)											41.3 (3)	41.3 (3)	40	-	-
Chiroza				17.9 (4)		19.2 (1)						18.2 (5)	32	S	S
Weighted average	19.8 (30)	30.6 (18)	46.2 (3)	14.9 (53)	28.8 (36)	24.6 (3)	27.7 (33)	29.6 (70)	31.4 (3)	34.3 (33)	26.7 (19)	26.3 (301)			
Weighted average of control cultivars	8.7 (6)	11.7 (9)	28.9 (1)	12.5 (11)	14.7 (6)	13.4 (2)	14.2 (4)	23.7 (12)	28.3 (3)	29.1 (6)	35.6 (4)	18.5 (64)			

[1] Reactions: S = Susceptible; MR = Moderately resistant; R = Resistant
[2] Figures in parentheses indicate number of cropping cycles.

Table 5. Fresh root yields of promising ICA-CIAT cassava lines and varieties harvested in international regional trials during the 1979-80 testing cycle.

Line or variety	Yield (t/ha)		
	Ecuador Pichilingue	Napo Station	Dominican Rep. San Cristóbal
Best local[1]	32.2	17.9	23.0
M Col 1468 (CMC 40)	30.4	14.0	42.5
M Col 1684	37.2	30.7	35.4
CM 305-41	42.0	9.0	37.1
ICA-HMC-1	26.5	21.5	31.6
CM 305-145A	33.2	15.6	18.9
M Ptr 26	32.1	17.3	
M Mex 17	23.7	19.4	
CM 321-188	46.6		
ICA-HMC-7	46.3		36.2
CM 323-142	38.5		
CM 305-120	35.4		
CM 309-163			
CM 344-27			
CM 192-1	29.1		
CM 305-122			
CM 340-30			
CM 344-71			
ICA-HMC-2		38.5	40.8
CM 308-197		15.2	35.4
CM 323-375		12.7	37.0
M Col 1513 (CMC 84)			33.8
CM 305-38			29.8
ICA-HMC-4			28.5
M Ven 218			27.9
CM 309-211			23.5
M Mex 59			23.1
M Col 22			21.7
Average yield, without local check	32.8	19.4	31.5

[1] Best local at Pichilingue: Yema de Huevo; at San Cristóbal: Zenon.

Yield variations at CIAT-Palmira, Caribia and Carimagua were analyzed for three germplasm accessions– Llanera, M Col 22 and M Col 1684 (Fig. 2). While M Col 1684 had the highest average yield at all locations, its yields were also the most unstable. Yields of Llanera and M Col 22 were similar at CIAT-Palmira although Llanera yields were stable. At Caribia, Llanera yielded poorly and unstably, and M Col 22 produced relatively high, stable yields. At Carimagua, yields of all three cultivars were unstable. These data suggest that wide adaptation and yielding ability are both independent of

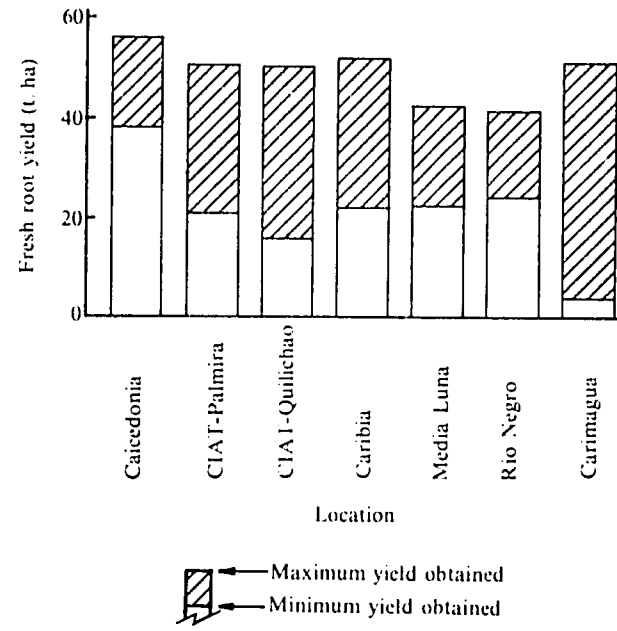


Figure 1. *Yield variation of variety M Col 1684 within and across seven locations. (Maximum yield at Carimagua from Soils and Plant Nutrition section, CIAT Cassava Prog. 1979 Ann. Rept).*

yield stability within a location. Since stable yield in one site does not guarantee stability in other locations, stable yield must be sought in each location.

Several factors affect yield stability. The following examples from regional trials testing show how some of the factors can influence cassava yields.

Cultivars M Ven 218 and CM 308-197 are high yielding selections although both are susceptible to CBB. At Carimagua they yielded well when CBB was controlled (1976 plantings) and when plantings escaped heavy infection from CBB (1977 plantings). However, yields were almost nil when CBB was present (Fig. 3). It is obvious that despite their high yield potentials, susceptible genotypes cannot provide stable yields in disease-endemic environments.

CM 507-34, CM 516-7 and CM 517-1 were selected at CIAT-Palmira between 1976 and 1978; all yielded more than 50 t/ha in 1978. CM 507-34 has produced stable yields up to now but yields of the other two have dropped markedly (Fig. 4). Over the years populations of thrips have been increasing at CIAT-Palmira and it was recently found that CM 507-34 and CM 517-1 were highly susceptible to this pest while CM 516-7 is tolerant.

Similarly, yields of CM 489-1, one of the highest yielding lines at CIAT-Palmira, have declined steadily. In this case, this line was tolerant to thrips but susceptible to mites and the lace bug, two other pests whose populations have increased over the years.

CM 430-9 and CM 440-5 had been high-yielding lines at Caribia. They were then found to be poor germinators (average 28%) when planted with stakes produced locally but not treated chemically (plantings of 1979 and 1980, Fig. 5). CM 342-170 on the other hand showed germination, regardless of the source of planting stakes. Thus, germination ability also affects yield stability and genetic variation for this factor can be hidden, especially when good-quality stakes are used.

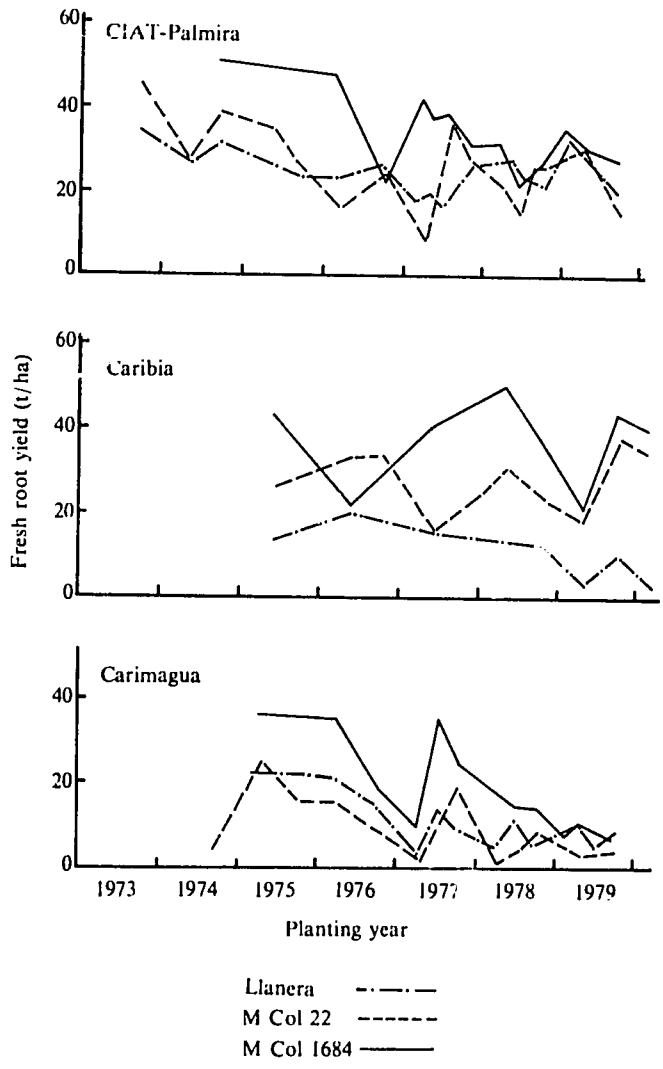


Figure 2. *Yield fluctuations of three cassava varieties at three locations.*

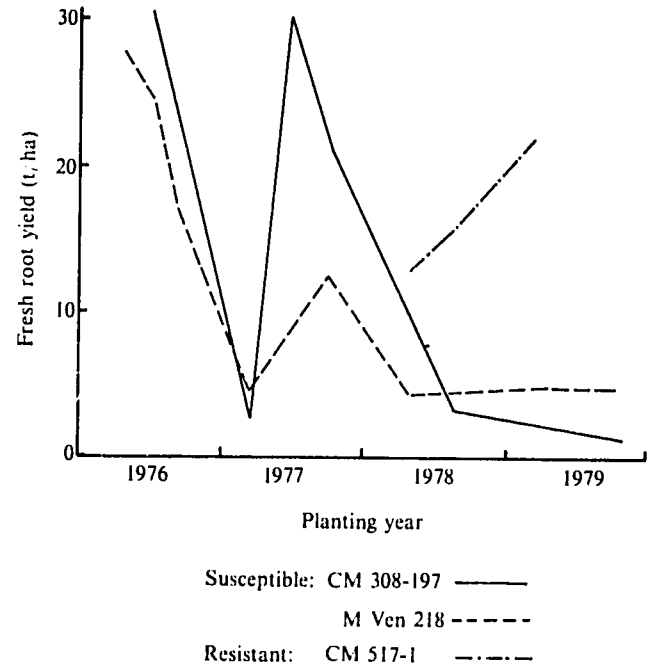


Figure 3. *Yield fluctuation of cassava lines having different resistance to cassava bacterial blight (CBB) at Carimagua.*

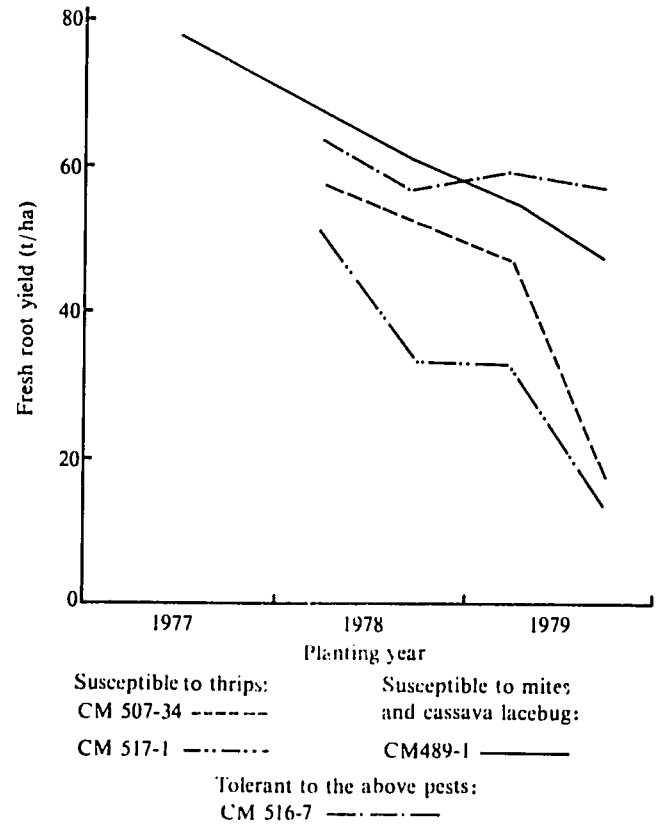


Figure 4. *Yield fluctuations of cassava lines having different resistances to insects, at CIAT-Palmira.*

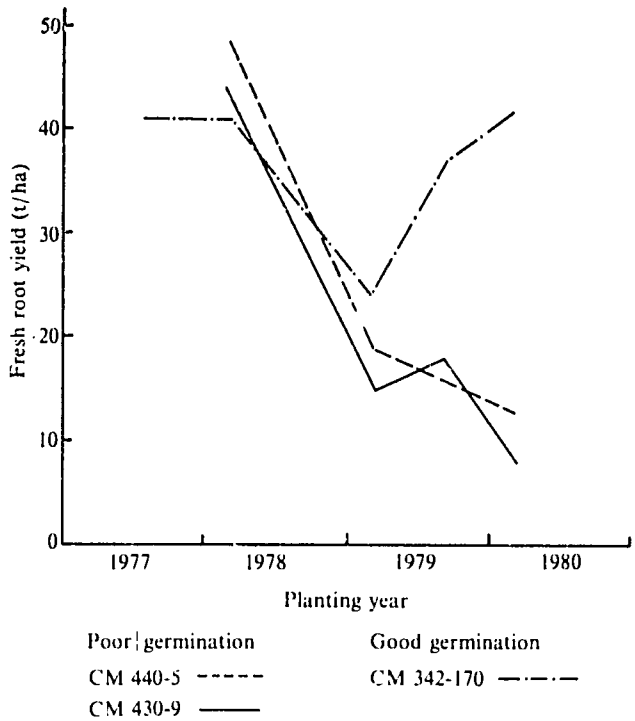


Figure 5. *Yield fluctuations of cassava lines having different germination habits, at Caribia.*

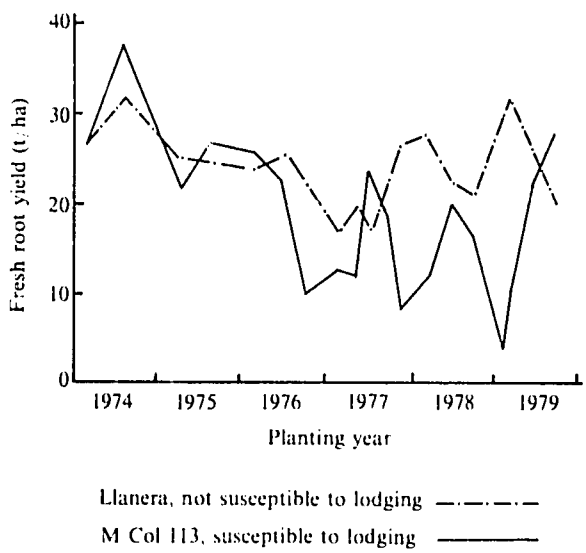


Figure 6. *Yield fluctuations of cassava lines having different lodging habits, at CIAT-Palmira.*

Finally, at CIAT-Palmira, Llanera and M Col 113 yielded similarly but M Col 113 was more unstable (Fig. 6). Severe lodging was observed in M Col 113 when its yields were measured below 15 t/ha. As in many other crops, lodging habit was a major cause of yield instability for this cultivar at CIAT-Palmira.

All of the factors mentioned above are genetically controlled so that each can be improved upon through breeding and selection. Repeated evaluation of cassava genetic materials in specific sites is mandatory to obtaining stable yielding cultivars. It is for this reason that the Varietal Improvement section does evaluations for three years in one site before releasing materials for regional trials another three years in various sites within similar ecosystems. Only then can selected materials be considered ready for possible varietal release.

International Yield Trials

Due to plant quarantine regulations in many countries the distribution of selected cassava germplasm as planting stakes is diminishing. This has caused a sharp decrease in the number of cooperative international regional trials planted. This trend will reverse as national workers are trained in the techniques of cassava tissue culture as a means of transferring germplasm without danger of pest and disease movement (see Tissue Culture section).

Three yield trials in two countries are reported this year (Table 5). In all locations the selected genotypes as groups outyielded local check materials.

Cassava Propagation from Leaf-Bud Cuttings

The international transfer of cassava varieties as disease-free meristem cultures requires a rapid multiplication technique for use in countries receiving the new introductions. The single leaf-bud cutting technique offers a means for producing a large amount of planting material from small numbers of imported clones.

The single leaf-bud cutting technique was created in 1972 by Kloppenburg and workers at the Department of Tropical Crops, Wageningen University, the Netherlands, and by Sykes and Harney at the University of Guelph, Canada. It was further improved and developed by Pateña and others at the Institute of Plant Breeding, University of the Philippines, Los Baños. The method has been tested and simplified at CIAT in a joint project with the Philippine workers to make it cheaper and more efficient for cassava. Operational details of the technique are available from the CIAT Cassava Program. On a conservative basis, the method has the potential for enabling production of 200,000 to 300,000 plants for commercial planting from a single mother plant after only one year.

Cultural Practices

Weed Control

Many cassava farmers agree that efficient, timely and economic weed control is possible with selective preemergent herbicides. Compared to hired labor for hand weeding, chemical control often gives more timely control because large areas can be treated in a short time before weeds begin to compete. Depending on labor cost, it may also be a cheaper option which even small farmers can afford. Furthermore, labor peaks at weeding time may limit the total cassava area; thus, herbicide use may allow the farmer to increase the area planted.

Preemergent herbicide mixtures

In Caribia where conditions favor a great variety of weed species and weed pressure on cassava is extremely heavy, several trials were conducted to study preemergent herbicides alone and in mixtures. Mixtures were tested to: a) increase the spectrum of weed species controlled; b) check on synergistic effects among chemicals; and c) identify cheaper mixtures having the same effectiveness as single products.

Preliminary results had shown that mixtures of oxyfluorfen and alachlor promised to fulfill these purposes. Therefore, several combinations of these two chemicals were tested along with other mixtures. Weed control efficiency and chemical injury ratings 29 and 57 days after application are given in Table 6.

Treatment No. 5 (0.5 kg a.i./ha of oxyfluorfen and 0.7 kg a.i./ha of alachlor) provided very effective and economical weed control; however, when purple nutsedge was a major problem, the rate was too low to give effective control. In this case, oxyfluorfen alone (No. 1) or combination treatments No. 7 or 8 suppressed growth of purple nutsedge better without being too expensive. Higher rates of oxyfluorfen alone or in mixtures with alachlor were not more effective than these treatments and were costlier. In addition, higher rates of oxyfluorfen may be detrimental to cassava particularly on sandy soils. Further testing on light soils is required.

Table 6. Weed control efficiency, chemical injury ratings and cost of preemergent herbicide mixtures tested on cassava, at Caribia, 1980.

Treatment	Product or mixture	Rate	Weed control (%)						Chemical injury to cassava [2]		Cost per ha
			Purple nutsedge DAA[1]		Grasses DAA		Broad-leaved weeds DAA		DAA		
		(kg a.i./ha)	29	57	29	57	29	57	29	57	($Col)
1	oxyfluorfen	0.75	38	1	92	90	90	85	1.5	0	1984
2	oxyfluorfen	1.00	44	5	- [3]	-	78	60	2.3	0	2646
3	alachlor	1.40	21	3	85	50	64	55	0.6	0	702
4	alachlor	2.10	44	23	71	10	51	0	0.6	0	1052
5	oxyfluorfen + alachlor	0.5 + 0.7	18	0	95	90	91	73	1.4	0	1673
6	oxyfluorfen + alachlor	0.5 + 1.4	28	0	91	-	85	75	1.5	0	2024
7	oxyfluorfen + alachlor	0.5 + 2.1	43	8	93	-	90	60	1.4	0	2374
8	oxyfluorfen + alachlor	0.75 + 0.7	55	8	91	90	70	60	1.6	0.4	2334
9	oxyfluorfen + alachlor	0.75 + 1.4	34	1	96	-	85	-	1.4	0.3	2686
10	oxyfluorfen + alachlor	0.75 + 2.1	39	1	93	-	89	-	2.0	0	3036
11	oxyfluorfen + alachlor	1.00 + 0.7	36	0	93	-	88	-	1.9	0.3	2996
12	oxyfluorfen + alachlor	1.00 + 1.4	39	10	94	85	80	60	1.8	0.3	3347
13	oxyfluorfen + alachlor	1.00 + 2.1	48	5	91	-	70	35	2.1	0.1	3698
14	fluridone + diuron	0.6 + 0.4	53	3	89	-	78	72	0.9	0	- [4]
15	fluridone + diuron	0.6 + 0.8	53	23	85	-	83	40	0.8	0.1	-
16	fluridone + diuron	0.9 + 0.8	43	4	85	80	80	80	0.9	0.1	-

[1] DAA = days after application.
[2] Chemical injury rating based on 0-10 scale where 0 is no injury and 10 is very severe injury leading to death of plants.
[3] No observations made due to absence of this weed.
[4] No commercial price could be obtained for fluridone.

An interesting result was obtained with fluridone and diuron, particularly because of its above-average, early control of purple nutsedge.

Strict observations of chemical injury in this trial, which was planted on a loam soil and received 541 mm of rain during the first 60 days after application, resulted in the readings in Table 6. In no case were symptoms stronger than a light yellowing of lower leaves without necrosis; this practically disappeared after 45 days. Earlier trials have shown that a low injury level does not affect cassava root yield, possibly due to the crop's long growth cycle and vigorous recovering ability.

Weed control in mixed cropping systems

For centuries traditional farming has followed the systems of growing two or more crop species simultaneously in the same field to gain food diversification, better distribution of work and risk aversion. Weed control was done manually by the farmer and his family. An increasing number of small producers are now interested in using herbicides to help with tedious hand-weeding. Since they would not like to abandon intercropping as their preferred production system, the need arises for chemicals with selectivity to a greater range of crop species.

Six preemergent herbicide treatments were tested on crop combinations including cassava, maize, the common bean, cowpea, mungbean, groundnut and the forage legume species *Desmodium heterophyllum*. Rates of 0.5, 1.0 and 2.0 times the commercial recommended rate of herbicides were applied with check plots left untreated. Overall efficiency of the herbicides and their selectivity levels in individual crops were assessed weekly during the first two months after application.

All treatments were chosen for their selectivity to cassava, however, only three combinations showed selectivity to other crop species.

The three promising treatments from the first trial together with two new combinations were tested in a follow-up trial with the same crop species as previously except that *Desmodium heterophyllum* was replaced by *Crotalaria* sp. Half of the trial was planted before herbicide application (i.e., in the traditional way for preemergence herbicides); the other half was planted the day following application, to hopefully obtain an additional selectivity advantage.

Combined results from the two experiments showed three mixtures to have good weed control effectiveness and selectivity to a wide range of crop species (Table 7). The linuron-metolachlor mixture showed a particularly high degree of selectivity, and there was no difference with respect to whether the crops had been planted before or after application. In contrast, the selectivity of the other two mixtures was markedly improved when they were applied prior to planting.

Table 7. Promising preemergent herbicide mixtures for use in cassava-based intercropping systems based on rates and time of application, effectiveness and selectivity in eight crops, at CIAT-Palmira, 1980.

Mixture and rate	Application time relative to planting	Weed control effectiveness[1]	Selectivity levels		
			Highly	Moderately	Nonselective
oxidiazon + alachlor (0.5 + 1.0 kg a.i./ha)	before	good	cassava groundnut mungbean	cowpea dry beans maize	*Crotalaria* *Desmodium*
oxidiazon + metolachlor (0.5 + 1.0 kg a.i./ha)	before	excellent	cassava groundnut mungbean	maize cowpea dry beans	*Crotalaria* *Desmodium*
linuron + metolachlor (0.25 + 1.0 kg a.i./ha)	after	good	cassava dry beans mungbean cowpea groundnut	maize *Crotalaria*	*Desmodium*

[1] Based on percentage reading of overall weed control 28 days after application, where: 100-95% excellent; 95-90% good; 90-70% fair; 70-50% intermediate and 50-0% poor.

Five conclusions are evident from results in the two experiments:

a) Chemical weed control in mixed cropping systems is feasible using an appropriate herbicide or herbicide combination at the correct rate of application.

b) Selectivity of herbicides to the different components of a cropping system should be tested in simultaneous plantings at one location since different planting seasons or soils may alter selectivities for the individual crops.

c) The selectivity of a herbicide to a number of crops can be increased by either lowering the application rate or by post-application planting. However, both practices may decrease weed control efficiency.

d) A herbicide with selectivity to a variety of crops may give less effective or less persistent weed control than one selective to a single crop. However, in mixed cropping systems, an earlier and denser cover by the crops shortens the period during which effective chemical control is required.

e) A mixture of 0.25 to 0.5 kg a.i./ha of linuron with 1.0 kg a.i./ha of metolachlor appears particularly suitable for weed control in cassava mixed croppings systems.

Purple nutsedge control

One of the more difficult weeds to control in cassava is purple nutsedge (*Cyperus rotundus* L.). The slow initial development and ground covering of cassava and the usual wide spacing provide ideal light, moisture and nutrient conditions for purple nutsedge at early growth stages. Preliminary studies on the Colombian North Coast showed that purple nutsedge can reduce cassava root yield up to 29%. Therefore, experiments were designed to evaluate the potential of an integrated control system based on those principles which take advantage of purple nutsedge's proven weaknesses, i.e., susceptibility to dehydration, shade and post-emergence herbicides.

Heavily infested plots at Caribia (2300 nutsedge tubers/m^2 to a depth of 25 cm) were treated with harrowing frequencies ranging from no harrowing to harrowing every ten days during the dry season. Treatments were stopped before rains started; after nutsedge sprouted, 50% of the plot area received an application of 4.5 liter/ha of glyphosate (commercial product). Four days later, plots were subdivided in quarters and planted either to cassava alone (M Col 22 in a 1 x 1 m arrangement), to a cassava-mungbean association (1.8 x 0.6 m arrangement) or to mungbean monoculture (cv. 1380 Mg 50-10A, 22 x 10^4 plants/ha at 0.6 m row spacing). The fourth quater was left uncultivated. A preemergent herbicide mixture (linuron + fluorodifen, 1 kg + 7 liter/ha commercial product) was applied to all cultivated and uncultivated plots to control all other weeds. Percentage ground cover achieved in the different systems, from planting to 6.5 months after planting, was recorded. Changes in tuber number of cyperus rotundus from before treatments to nine months after planting (cassava harvest) are shown in Table 8 along with yields for cassava and mungbeans.

In cassava monoculture, a ground cover of 80% or more was attained 60-90 days after planting and an 80-100% cover was then maintained until harvest. The canopy buildup was faster with than without glyphosate; the harrowing plus glyphosate treatment provided the earlier cover. The aim of intercropping cassava with mungbeans was to provide an earlier ground cover than is possible with cassava monoculture, to obtain shade before pre-planting treatments lost their effectiveness. A ground cover of 80-90% was obtained only 30 days after planting, irrespective of harrowing or herbicide treatments (Fig. 7).

Fast-growing mungbeans in monoculture quickly covered the ground but this cover was not maintained very long because of their short growth cycle.

The best and most stable control in cassava monoculture was obtained from the combined harrowing and glyphosate treatment, with control from the shade becoming effective before the preplanting treatments had lost their influence. The cassava-mungbean intercrop provided earlier and more effective control than the other systems.

Besides the visible effect of pre-planting treatments and crop cover on nutsedge growth, there was also a clear influence on the weed's subterranean propagation system and on crop yields (Table 8).

Although single effects of treatments were small, there was a strong aggregate effect when the different control principles were combined. Reducing viable nutsedge tuber number to 9% of the original infestation with the second system (no harrowing, glyphosate and intercropping) while producing good crop yields, was a promising result after only one crop cycle. This experiment will be continued to follow purple nutsedge infestation under the continued influence of the different treatments.

Figure 7. *Nearly complete ground cover was achieved with cassava-mungbean intercropping and other treatments to control purple nutsedge at Caribia in 1979. Cover was good as early as 30 days after planting (above); control was maintained later mainly through shading by the cassava (below).*

Table 8. Number of viable tubers of purple nutsedge and yields of cassava and mungbeans in different nutsedge control systems, at Caribia, 1979-80.[1]

Control system	Viable[2] tubers (per m²)	(%)[2]	Cassava yield (t/ha)	Mungbean yield (kg/ha)
No harrowing, no glyphosate; cassava-mungbean intercrop	1847	80	15.1	1115
No harrowing, with glyphosate; cassava-mungbean intercrop	208	9	18.5	1499
Harrowing every 10 days, with glyphosate; cassava-mungbean intercrop	557	24	7.8	1632

[1] Evaluated nine months after planting.
[2] Percentage based on a mean tuber number of 2300/m² representing the pretreatment infestation of plots.

Multiple Cropping

Trials to determine the agronomic management of grain legumes in association with cassava were conducted at CIAT-Quilichao. Studies on mineral nutrition aspects of cassava-legume intercrops both at CIAT-Quilichao and Caribia were begun.

Legume agronomy in cassava-legume intercrops

Groundnuts (*Arachis hypogaea* L., cv. ICA-Tatui 76) were planted as an intercrop with CMC-84 cassava at densities between 50,000 and 600,000 plants/ha. Three row spacings were used, 45/2, 70/2 and 60/3 (see CIAT Cassava Prog. 1979 Ann. Rept.). Cassava planting density was constant at 9259 plants/ha in a 1.8 x 0.6 m arrangement. The trial received a basal dressing of 0.5 t/ha of dolomitic lime preplanting incorporated and was bandfertilized at planting with 90-60-55-10-2 kg/ha of N, P, K, Zn and B, respectively.

Groundnut yields responded positively to planting densities of up to 250,000 plants/ha (Fig. 8). Cassava root yield was rather independent of groundnut planting density (Fig. 9), but showed a significant negative relationship to groundnut grain yield (Fig. 10). Although this yield relationship was expected and normal due to competition, cassava yield depression was not as severe as was observed last year with cowpeas intercropped at high planting densities.

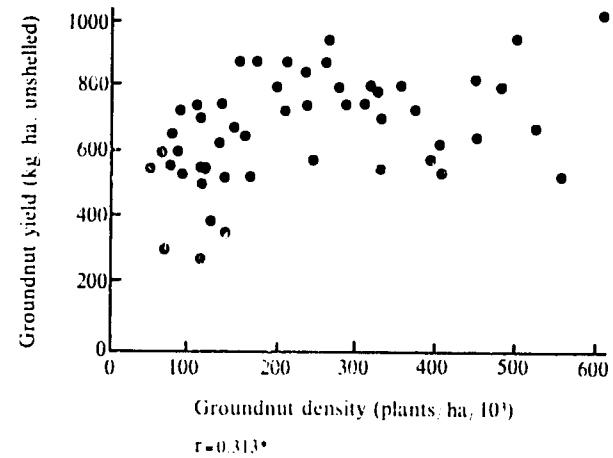


Figure 8. *Yield response of groundnut to planting density when intercropped with cassava cultivar CMC 84, at CIAT-Quilichao.*

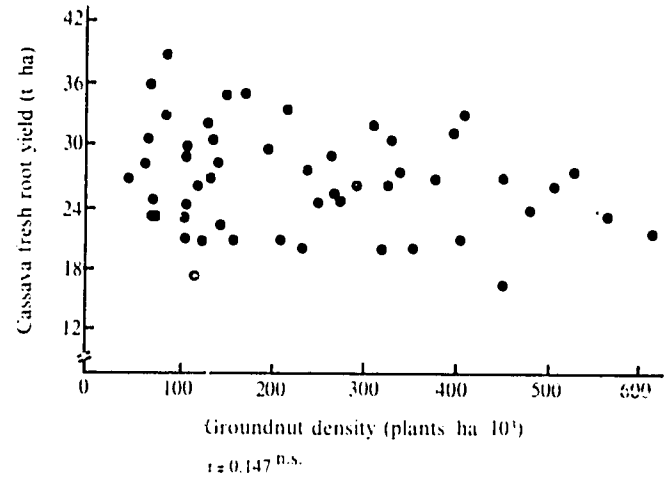


Figure 9. *Influence of groundnut planting density on cassava root yield in a groundnut-cassava intercropping system, at CIAT-Quilichao.*

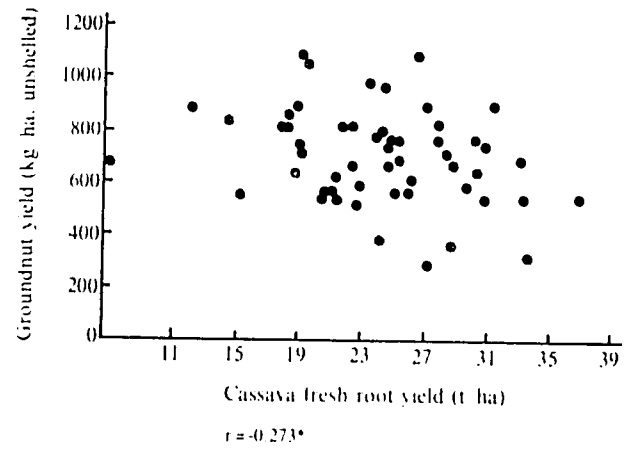


Figure 10. *Relationship between yields of groundnuts and cassava grown in an intercropping system, at CIAT-Quilichao.*

A similar experiment was conducted with cowpeas (*Vigna unguiculata*, cv. TVU 354-1B) and cassava (M Ven 218), using cowpea planting densities between 50,000 and 200,000 plants/ha in the three spatial arrangements mentioned above. The trial received 0.5 t/ha of dolomitic lime preplanting incorporated and band fertilization of 100-66-62-10-1 kg/ha of N, P, K, Zn and B, respectively.

Cowpea grain yield reached a flat peak at densities about 120,000 plants/ha and declined at higher densities. While cassava root yield was strongly depressed by cowpea densities above 200,000 plants/ha last year, the actual range of observed cowpea plant populations in this trial (55,000 to 190,000 plants/ha) had almost no influence on cassava yield (Fig. 11).

Data in Figures 8-11 are combined results from three different row arrangements of legumes. Although legume and cassava yield differences due to different competition situations induced by these three arrangements were observed, the agronomic behavior of groundnuts and cowpeas was not substantially altered, i.e., basic agronomic reactions such as yield response to planting density or the planting density/pods per plant compensation were the same for all three spatial arrangements.

Three conclusions are evident for the agronomic management of grain legumes as intercrops with cassava in simultaneous planting on acid, infertile soils:

a) Intercropped grain legumes react agronomically in the same manner as in monoculture.

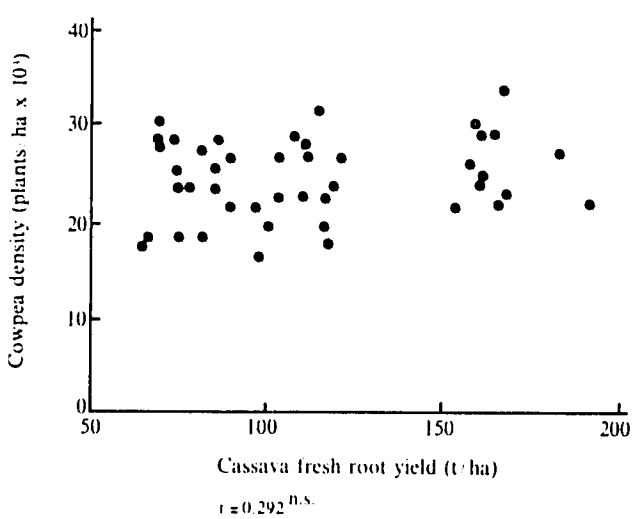


Figure 11. *Effect of cowpea planting density on yield of cassava cultivar M Ven 218 grown in an intercropping system, CIAT-Quilichao.*

b) Optimun planting densities for grain legumes intercropped with cassava are similar to those for monoculture, however, planting patterns must differ from monoculture to accommodate component crops in a way that minimizes competition and maximizes productivity.

c) A safe margin exists between compatible plant types within which optimum agronomic management can be sought for each crop individually, to maximize its yield without seriously affecting the yield of the companion crop. This is true both for excellent growing conditions on fertile soil (CIAT-Palmira) and also for suboptimal conditions on acid, infertile soil at CIAT-Quilichao where competition for nutrients and water are important.

Nutrient responses of cowpea-cassava intercrops

Three experiments were conducted to determine responses of a cassava cowpea intercrop and the respective monocultures to N, P and K. At CIAT-Quilichao where soil P levels are extremely low, cassava (M Ven 218) and cowpeas (cv. TVU 354-1B) were grown on previously uncultivated land, alone and in association at P levels of 0, 22, 44, 66 and 132 kg/ha, banded at planting as triple superphosphate. Nitrogen (as urea), K (as KCl), Zn (as $ZnSO_4$) and B (as Borax) were also applied in bands at 100, 62, 10 and 1 kg/ha, respectively; these rates were constant for all P levels. Fertilizer was divided equally between cowpeas and cassava. In the intercrop planting an all-fertilizer-broadcast treatment was added. A basal application of 0.5 t/ha dolomitic lime was incorporated before planting. Cassava was planted at 9259 plants/ha in a 1.8 x 0.6 m spacing with cowpeas intercropped at 110,000 plants/ha in a 60/3 arrangement. The cowpea monoculture spacing was 0.6 x 0.15 m.

Phosphorus. Leaves were sampled from the central portion of cowpea plants in the pre-flowering stage and the youngest fully expanded leaves of cassava were sampled after cowpea harvest. Leaf P concentration of cassava and cowpea are shown in Table 9. In cassava, leaf P levels were not affected by applied P levels, and in cowpea, an increase was noted only at the highest P rate in both monoculture and intercropping. P levels in leaves of both crops tended to be lower for the intercrops than in monoculture. While leaf P levels in cassava monoculture were already well below the normal of 0.3-0.5%, they were almost deficient (0.2%) in intercropped cassava. Cowpeas, both monoculture and intercropped, had considerably lower leaf P levels (0.5-0.9%) than those reported under normal growing conditions at the International Institute for Tropical Agriculture (IITA). Besides extremely low soil P and high P fixing capacity, the low P concentrations in the

Table 9. Effects of band-applied P rates on leaf P concentration of cassava and cowpeas grown in monoculture and intercropped, at CIAT-Quilichao, 1979.

P applied (kg/ha)	Leaf concentration of P (%)			
	Cassava		Cowpeas	
	Monoculture	Intercropped	Monoculture	Intercropped
0	0.26	0.26	0.26	0.23
22	0.25	0.22	0.29	0.28
44	0.27	0.19	0.26	0.27
66	0.25	0.21	0.28	0.24
132	0.27	0.24	0.39	0.34
Average as percent in monoculture	100	86	100	92

tissue of both crops may also be seen in relation to the dry spells acompanying the sampling period which possibly reduced P uptake.

Cowpea grain yield response to applied P levels showed two peaks, one at 22, the other at 132 kg/ha (Fig. 12) with intercropped cowpeas yielding more when fertilizer (including P) was broadcast. The relatively weak, non-linear yield response was unexpected on this highly P-deficient soil where a more linear response would seem likely.

Cassava in monoculture attained maximum root yield with only 22 kg/ha P whereas, in the cassava-cowpea association with banded fertilizer, maximum root yield was reached with 44 kg/ha P; with the broadcast application, 66 kg/ha P were needed to produce maximum root yield (Fig. 12). It appears logical that with greater demand for nutrients, in particular P, in association, peak yield should have been produced at a higher level of applied P than in monoculture. With competition for P in the association, 700 kg/ha more roots were obtained with 22 kg/ha P less, when fertilizer was banded instead of broadcast. Greatest root yield was never obtained with the highest P level, confirming that although cassava has a high external requirement of P for maximum growth, maximum root production is achieved at much lower P levels in the field.

These results show that competition for P in a P-deficient soil is more intense when cassava and cowpeas are intercropped than in monoculture. This is confirmed by foliar analyses and by crop productivity. In order to compensate for higher P demand in intercropping and avoid P deficiency, each crop in the intercropping should receive the amount of P which it requires for good production in monoculture.

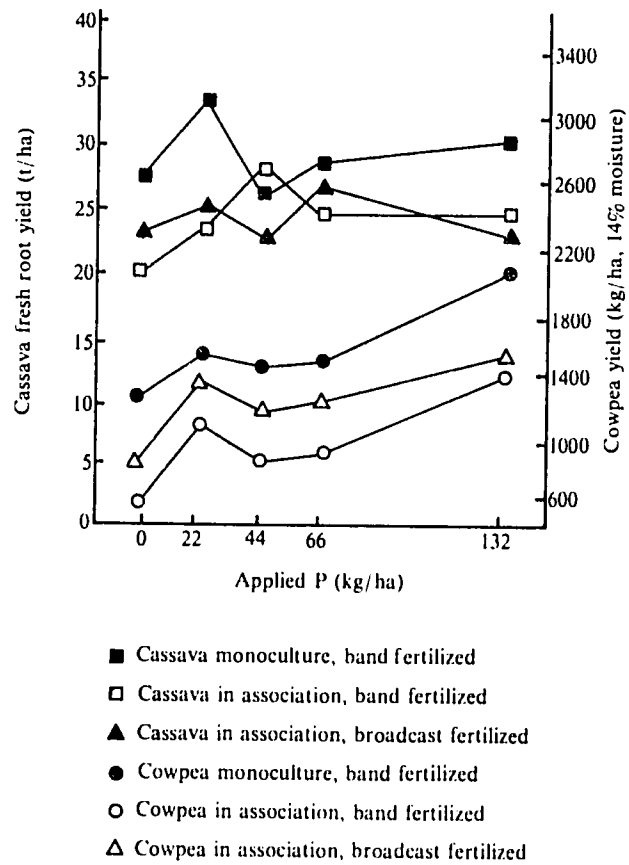


Figure 12. *Effects of rates and application methods of P on yields of cassava and cowpeas in association and monoculture, at CIAT-Quilichao, 1980.*

Table 10. Soil characteristics of the Caribia experimental site, 1979.

Sampling depth	Organic matter	P Bray II		Exchangeable cations (meq/100 g soil)			
(cm)	(%)	(ppm)	pH	Ca	Mg	K	CEC
0-20	1.4	89.4	5.7	3.4	0.6	0.12	4.3
21-40	0.6	105.5	5.8	2.3	0.4	0.10	2.5

Nitrogen and Potasium. The N and K response trials grown in Caribia on a soil with low organic matter and K but high extractable P levels (Table 10) were identical in design and agronomic practices to the P response trial. The cassava and cowpea cultivars were M Col 22 and TVX 1193-059 D, respectively. In the N response trial, nitrogen was applied as urea at rates of 0, 50, 100, 150 and 300 kg/ha N and a constant fertilization of 63 kg/ha K (as KCl), 10 kg/ha Zn (as $ZnSO_4$) and 1 kg/ha B (as Borax) were band applied at planting. The K response trial received rates of 0, 42, 84, 126 and 252 kg/ha of K and a constant fertilization of 100 kg/ha N, 10 kg/ha Zn and 1 kg/ha B, using the same sources as above. In both trials, all fertilizer was banded at planting, except in the intercropped all-fertilizer-broadcast treatments. Sampling of plant tissue and soil for analyses was done in the manner and at intervals described before.

Leaf N concentrations were not affected by applied N rates in either cassava or cowpea, however, intercropping reduced cassava leaf N from normal concentrations (4.7-5.4) to near deficient levels (4.5-4.8), whereas N in cowpea leaves was not influenced by intercropping (Table 11). Cassava root yield in monoculture responded positively to 50 kg/ha N (Fig. 13). When intercropped with cowpeas, cassava yields were lower than in monoculture up to an N level of 100 kg/ha. At higher N rates, cassava intercrop yields were greater than monoculture yields, with the increase being stronger with broadcast than with banded N. Although cowpeas did not respond with grain yield to N fertilization, they appeared to strongly compete for this element. Both the facts that leaf N concentration in cassava was reduced through intercropping, and that high N rates compensated for initially depressed cassava root yields in intercropping, point to a N competition situation in the mixed stand which was corrected by increased N fertilization.

Cassava's yield performance is understandable from the influence of N rates on top growth and harvest index. M Col 22, which is rather vigorous in the hot, humid environment of Caribia, showed excesive top growth at the higher N rates in monoculture; thus, harvest index and yield decreased. With intercropped cowpeas, cassava top growth without applied N was 19% less than in monoculture. However, higher N rates increased top growth of intercropped cassava, bringing about a better balance between top and root growth and resulting in root yields comparable to those obtained at low N rates in cassava monoculture.

In contrast to cassava, cowpea, with its aggressively growing and expanding root system, should have made use of most of the available N at zero and low rates of applied N. As a legume, it also should not have suffered from N deficiency due to rhizobial symbiosis. While the N-fixing activity may have been reduced at higher N rates, this was apparently nearly compensated for by a greater N uptake from fertilizer in these treatments. As a result, both leaf N and grain yield were stable over all N rates.

In the K response trial, cassava petiole K concentrations clearly increased according to applied K rates, both in monoculture and intercropped cassava (Table 12). Petiole K was slightly lower in intercropped than in monoculture cassava, but in both systems, K concentration was well above the normal range of 1.5-3.0%. In contrast, cowpea leaf K concentration was not affected by either K rates or cultivation system.

Table 11. Effects of band-applied N rates on leaf N concentration of cassava and cowpeas grown in monoculture and intercropped, at Caribia, 1979-80.

N applied	Leaf concentration of N (%)			
	Cassava		Cowpeas	
(kg/ha)	Monoculture	Intercropped	Monoculture	Intercropped
0	5.04	4.82	4.76	4.51
50	5.35	4.84	4.54	4.62
100	5.24	4.54	4.34	4.45
150	4.73	4.54	4.23	4.51
300	5.24	4.82	4.82	4.56
Average as percent in monoculture	100	92	100	100

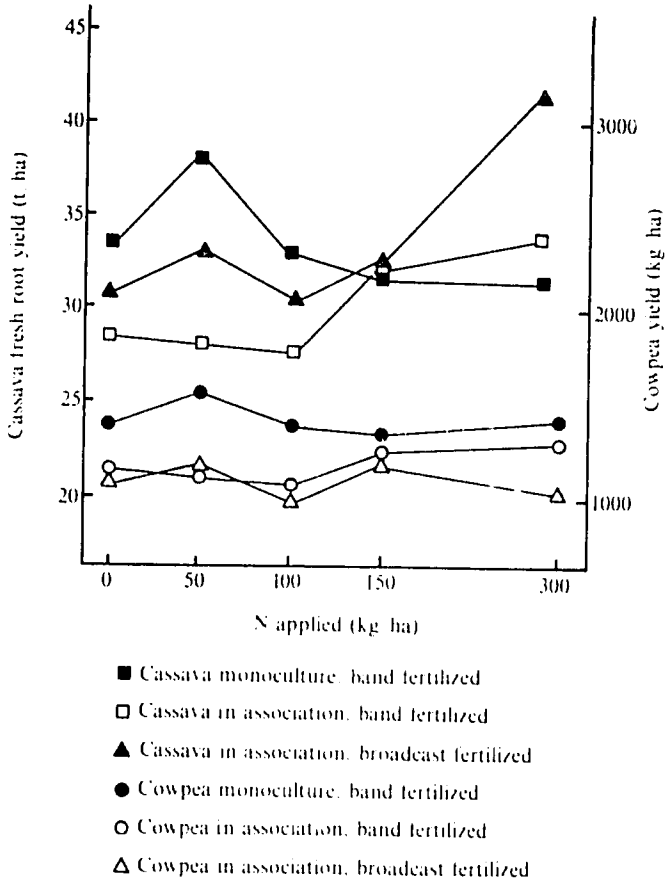


Figure 13. *Effects of rates and application methods of N on yields of cassava and cowpeas in association and monoculture, at Caribia, 1980.*

Table 12. Effects of band-applied K rates on petiole K concentration of cassava and leaf K concentration of cowpeas grown in monoculture and intercropped, at Caribia, 1970-80.

K applied	K concentration (%)			
	Cassava		Cowpeas	
(kg/ha)	Monoculture	Intercropped	Monoculture	Intercropped
0	3.23	3.27	2.13	1.93
42	3.51	2.92	1.84	2.19
84	3.67	3.55	1.78	1.78
126	4.23	4.01	1.87	1.93
252	4.41	3.88	2.29	2.29
Average as percent in monoculture	100	93	100	102

Similar to the N trial, monoculture cassava root yield responded positively up to 42 kg/ha, and yields declined at the higher K rates (Fig. 14). Yield of intercropped cassava was lower than the monoculture yield at the low K rates but increased to the maximum monoculture yield at the highest K rate, with no significant difference between banded and broadcast applications. Cowpea yields were not influenced by either the cultivation system or method of application and yield was stable over all K rates.

Competition for K was probably the least of the three major elements examined at CIAT-Quilichao and in Caribia, although some may have occurred in intercropped cassava as the positive yield response to the highest K rate may suggest. However, petiole K concentrations were high enough to indicate that cassava, even when intercropped, was far from a deficiency situation. Cowpea nutrition with K was apparently also adequate as both the lack of differences in leaf K concentrations of monoculture *vs* intercropped cowpea and the absence of yield response to higher K rates would indicate. K fertilization in cassava-cowpea intercropping systems should, therefore, be directed mostly to the needs of cassava which extracts greater amounts of this element whereas the removal by cowpea when only seed is harvested, is rather low.

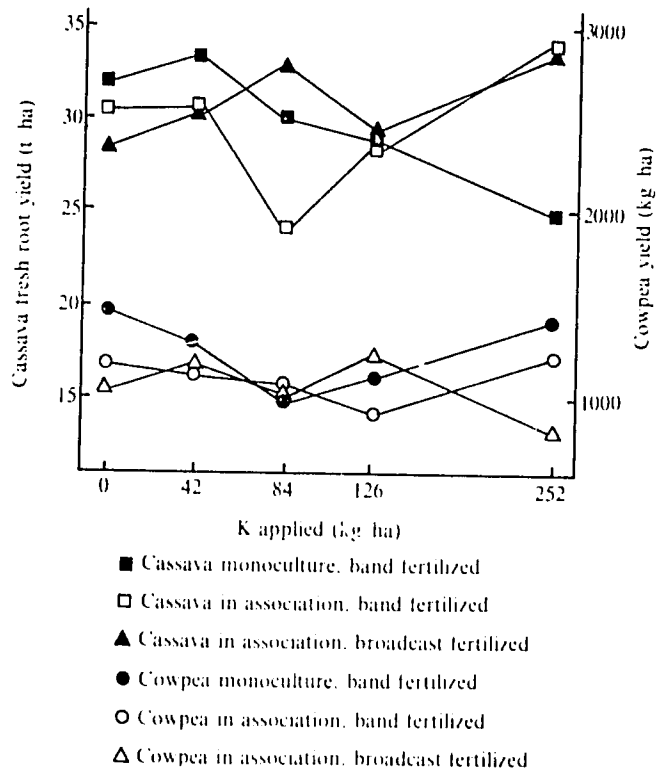


Figure 14. *Effects of rates and application methods of K on yields of cassava and cowpeas in association and monoculture, at Caribia, 1980.*

Storage of Planting Material

Cassava planting material undergoes a variety of transformations during storage which may seriously affect its value for future plantings. It has been shown previously that fungal infestation is probably the most detrimental factor for stake preservation. Besides being attacked by pathogens, stored cassava stems lose moisture, and the dehydration of living stake tissue leads to irreversible loss of bud viability. The loss of moisture is related to both storage duration and conditions and may be considerable. When 1 m cassava stems were stored for 201 days in an open-air, bamboo shade environment, weight loss was almost 40%.

Another change during storage occurs in the soluble-nonsoluble carbohydrate concentration of the stakes. The former increases and the latter decreases during storage, with the new carbohydrate loss possibly due to respiration and rooting and sprouting. During 201 days of storage, the soluble fraction increased from 3.5 to 5.0% while nonsoluble carbohydrates decreased from 26.6 to 8.4%. Roots and sprouts were removed from the stored material before analyses. As a consequence of these processes, the amount of useful planting material diminishes with storage.

When the same stake selection criteria were applied to stakes from 1-m stems which were chemically treated and stored for different intervals, the useful amount of planting material obtained from these stems was reduced over 180 days from 98 to 59%. While a pre-storage treatment with fungicides (BCM and captan at 3000 ppm each) can reduce pathogenic deterioration of the stakes, storage conditions influence the degree of dehydration and loss of carbohydrate reserves.

Stems 1 m long of variety CMC-40 were stored for 60, 120 and 180 days under either dry room or bamboo-shade field conditions with and without adding sodium alginate for protection against dehydration to the standard fungicide treatment. After storage all materials were planted together with fresh stakes at 1 x 1 m in a preirrigated field. Sprouting, early growth and canopy formation were monitored to determine whether early crop development was affected by storage intervals or treatments, and how an influence on early crop development would affect final productivity.

Neither storage sites nor chemical treatment with sodium alginate influenced sprouting and early development. Storage intervals did not affect final sprouting percentage (Figs. 15 and 16) but clearly influenced early growth and canopy formation (Table 13).

Correlations between these early growth parameters and final root yield were not all significant and rather low (Table 14). Nevertheless, more vigorous early growth and canopy expansion appeared positively related to high final yield. This was particularly true for plant height at 45 days, mean leaf size and light interception.

The inverse was true when top growth during later stages was related to root yield. Weight of tops at harvest was reduced by storage, with reduction proportional to the length of the storage interval. The reduction in top weight appeared to be directly related to an increase in harvest index which was highest at the 60 and 180-day storage intervals and lowest with fresh stakes. Total and commercial root yields in turn showed the same ranking as did harvest index (Table 15).

Table 13. Effects of storage duration of cassava planting material on growth parameters during the firts 10 weeks after planting, at CIAT-Palmira, 1979.[1]

Storage duration (days)	Sprouting rate (plants day/plot)	Final sprouting, 31 DAP[2] (%)	Plant height, 45 DAP (cm)	Mean number stems plant, 60 DAP	Mean leaf size, 60 DAP (cm^2)	Light interception, 76 DAP (%)
0	1.73 a[3]	100 a	26 a	2.66 a	278 ab	77 a
60	1.83 a	100 a	27 a	2.73 a	282 ab	78 a
120	1.59 ab	100 a	2[illegible] b	2.36 b	253 b	72 a
180	1.40 b	98 b	25 ab	2.23 b	296 a	75 a

[1] Variety CMC-40; treated with BCM and captan (3000 ppm each) before storage; means of two storage sites and two chemical treatments (with and without sodium alginate).
[2] DAP = days after planting
[3] Values within the same column and followed by the same letter are not significantly different at the 5% level.

Figure 15. *Sprouting and crop establishment when fresh cassava stakes are planted after chemical treatment.*

Figure 16. *Sprouting and crop establishment when cassava stakes are planted after chemical treatment and up to 180 days storage in adequate conditions, showing no difference from fresh stakes.*

Table 14. Correlations between early growth parameters and final root yield in cassava grown from stored and fresh planting material, at CIAT-Palmira, 1979.

Root yield	Sprouting rate	Final sprouting percentage	Plant height, 45 DAP[1]	Number of stems/plant, 60 DAP	Mean leaf size, 60 DAP	Light interception, 76 DAP
Total fresh root yield	0.237	- 0.025	0.331**	0.181	0.324**	0.460***
Commercial root yield	0.216	- 0.044	0.253*	0.132	0.216	0.366**

[1] DAP = days after planting.

Table 15. Effects of storage duration of planting material on yield parameters of cassava cultivar CMC 40, at CIAT-Palmira, 1979.

Storage duration (days)	Weight of tops (t/ha)	Harvest index	Root production (t/ha)	
			Commercial	Total
0	33.0 a[1]	0.43 b	22.0 b	25.4 b
60	31.7 ab	0.49 a	26.8 a	30.3 a
120	29.6 b	0.45 b	20.3 b	24.1 b
180	29.1 b	0.48 a	23.9 ab	27.4 ab

[1] Means within the same column followed by the same letter are not significantly different at the 5% level.

These results indicate that:

a) Cassava planting material can be kept viable under CIAT-Palmira conditions for up to six months as 1 m stems and when treated with fungicides.

b) Numbers of useful stakes obtained from stored planting material decreases with time, even when stems are chemically protected and kept under adequate storage conditions.

c) The use of sodium alginate in dip treatments, together with fungicides, to reduce moisture loss from stored planting material, does not appear to provide any additional advantage.

d) The transformation of part of the nonsoluble carbohydrate fraction (starch) into soluble carbohydrates (sugar) during storage of cassava stems appears to enhance early growth and canopy formation in the young crop when storage has been for two months or less. Vigorous early growth and establishment seems to be positively related to final root yield. With longer storage intervals, loss of carbohydrates from stored stems—principally due to respiration, rooting and sprouting— may be considerable and cause depressed growth of the crop during early and later stages.

e) Reduced top growth of cassava raised from long-stored planting material may cause an increase in harvest index and, thus, in total and commercial root yields. This should apply in particular to vigorous, leafy types of cassava.

Efforts to develop cassava technology for the vast areas of acid infertile soils continued along the strategy outlined last year (CIAT Cassava Prog. 1979 Ann. Rept.). The screening of cassava germplasm in nutrient solution was discontinued, partly because of difficulties in reproducing results due to plant variability, and partly because nutrient solution screenings do not account for the differential ability of varieties to form mycorrhizal associations that are so essential for P uptake.

Large-scale field screenings were begun in Carimagua for P and acidity tolerance, and in CIAT-Quilichao for P tolerance. The second aspect of improving the efficiency of nutrient absorption and fertilizer application involved various fertilizer trials to determine: a) nutrient absorption and distribution within the plant during a 12-month growth cycle; b) the long-term effect of N-P-K applications on soil fertility and yield of continuously grown cassava; c) the residual effect of various sources of P; d) the lime x P interaction; and e) the effect of mycorrhizal inoculation on P absorption.

Screening for Low-P Tolerance

A small-scale screening for P tolerance in CIAT-Quilichao continued. Thirty-two cultivars from the germplasm collection were planted without P and with 44 kg P/ha (100 kg P_2O_5) applied as triple superphosphate in plots that previously had received 88 and 44 kg P/ha in two preceeding years, respectively. Leaf samples were taken at three months. At 12 months plants were harvested.

Table 1 shows P content of leaves, fresh root yields, starch content, P tolerance index and percentage

Table 1. Effect of P fertilization on leaf P content, root yield, starch content and mycorrhizal infection of the 10 most low-P-tolerant cassava cultivars, at CIAT-Quilichao.

Cultivar	P content in YFEL [1] (%)		Root yield [2] (t/ha)		Root starch (%)		Mycorrhizal infection [3] (%)		P-tolerance index [4]
	P applied (kg/ha)								
	0	44	0	44	0	44	0	44	
ICA-HMC-2	0.36	0.35	37	33	22	19	45	44	86
M Col 1226	0.39	-	48	56	26	24	25	56	85
M Mex 59	0.40	0.38	44	49	28	29	35	34	83
M Col 1879	0.28	0.32	37	36	26	27	37	30	80
M Col 1684	0.31	0.29	36	39	25	25	34	24	70
M Col 113	0.30	0.40	42	58	26	25	39	37	63
M Col 131	0.26	0.28	31	32	-	-	40	36	62
M Ven 83	0.30	0.35	36	49	30	31	40	26	57
M Col 88	0.33	0.41	32	39	-	-	22	39	55
Llanera	0.36	0.42	24	23	-	-	43	50	54

[1] YFEL = youngest fully expanded leaves at three months after planting.
[2] Single row yield, average of three plants, four replications.
[3] % of total root observations having hyphae, vesicles or arbuscles.
[4] P-tolerance index: $\frac{\text{Yield (O P)}}{\text{Yield (44 P)}} \times \frac{\text{Yield (O P)}}{\text{Max. Yield (O P)}} \times 100$

mycorrhizal infection of 10 of the most P-tolerant cultivars. The P tolerance index of the 32 cultivars ranged from 11 to 86 with an average of 43. Leaf P content at three months and the varieties' P tolerance index were not related as P content reflects both P uptake ability and plant size, which is highly variable among cultivars. Average root yields of the ten most tolerant cultivars increased only 10% by the application of P. Starch content increased in some cultivars and decreased in others by P fertilization, but differences were not significant at the 5% level for any of the seven cultivars studied; starch content varied significantly among cultivars.

Mycorrhizal infections, especially vesicle numbers, were higher in P-fertilized plants than in those without P. However, there was no correlation between percentage infection of roots at harvest, and root yield or P tolerance index. Changes in root infection during the growth cycle will have to be determined in order to establish whether early infection is essential for obtaining high yields in low-P soils.

Nutrient Absorption and Distribution

To determine the effect of fertilizers on the rate of nutrient absorption during different stages of plant development and nutrient distribution within the plant (nutrient profile), two cassava cultivars were planted in CIAT-Quilichao in large plots with and without applied fertilizer. Cultivars were M Col 22 and M Mex 59, the former a non-vigorous plant type and the latter a very vigorous one. All plots were limed with 500 kg/ha of dolomitic lime and the fertilized plots received 1 t/ha 10-30-10. 20 kg S/ha as elemental sulphur, 10 kg Zn/ha as $ZnSO_4.7H_2O$. and 1 kg B/ha as Borax, all applied broadcast and incorporated before planting; another 50 kg N/ha as urea was applied at 60 days. Two plants per plot were harvested monthly and separated into upper, middle, and lower leaf blades ("leaves"), petioles and stem, as well as roots. Samples were dried, weighed and analyzed for all macro- and micronutrients. Soil samples were also taken monthly and analyzed.

Figure 1 shows the rate of total dry matter (DM) production for the two varieties. Fertilizer had no significant effect on M Mex 59 (a variety highly tolerant to low P and not responsive to high levels of fertility—CIAT Ann. Rept. 1977.1978 and CIAT Cassava Progr. 1979 Ann. Rept.). M Col 22, on the other hand, produced significantly more DM when fertilized, especially during the last six months. Effects were similar for dry root yields (Fig. 2). In M Mex 59 root yields were highly variable during the last three months with no apparent response to fertilization, while M Col 22 yielded similarly without fertilizer, but produced much higher yields with fertilization.

In both varieties fertilization stimulated top growth more than root growth, decreasing harvest index about 10-15%. Unfertilized M Col 22 had a final harvest index of about 0.70-0.75, which remained constant during the last five months, while the harvest index of M Mex 59 continued to increase until the 10th month, but reached only 0.55. Thus, the more vigorous M Mex 59 produced relatively more to growth, while the nonvigorous M Col 22 produced more roots and at an earlier stage. At six months, M Col 22 had produced about 50%, while M Mex 59 had produced only about 25% of its final root yield.

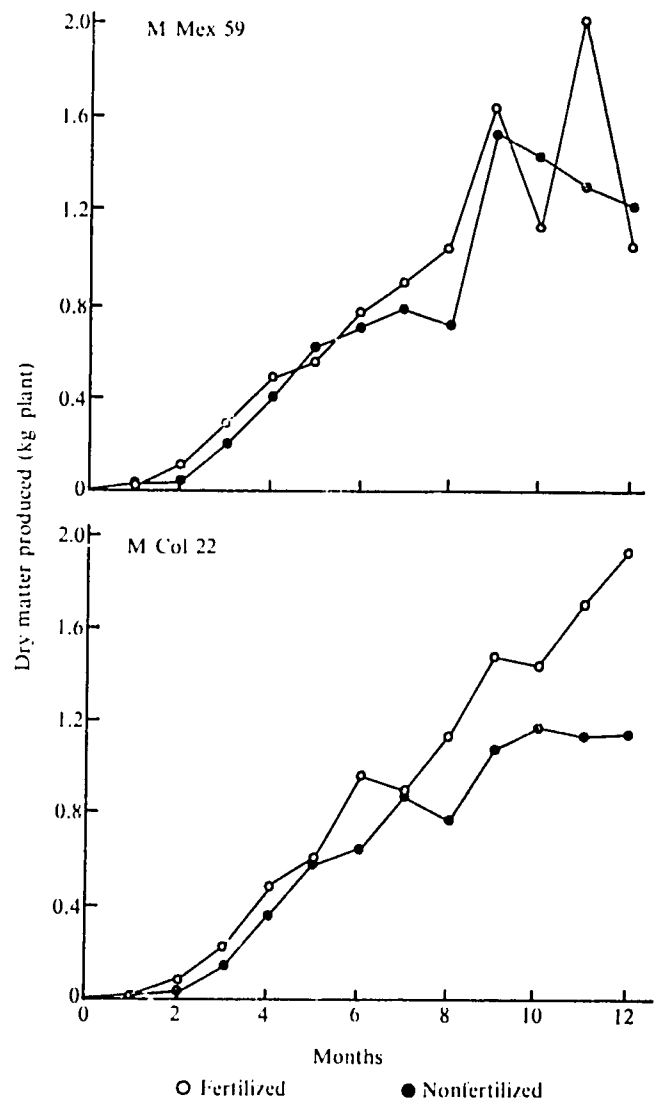


Figure 1. *Cumulative total dry matter production over 12 months for two cassava cultivers grown with and without fertilizers, at CIAT-Quilichao.*

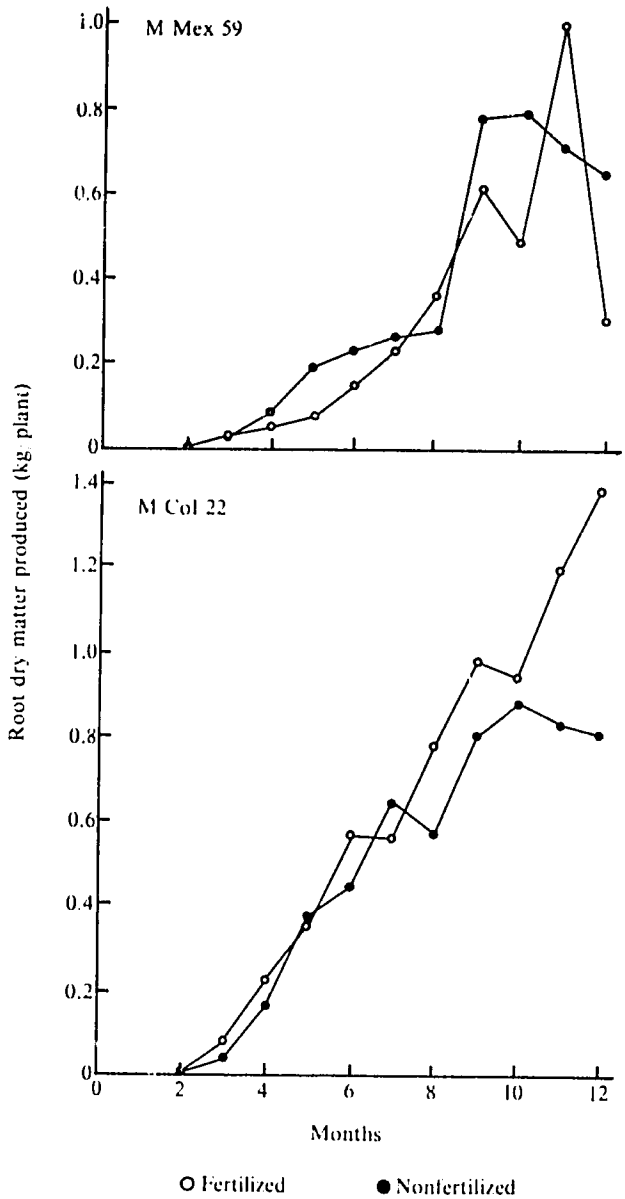


Figure 2. *Cumulative root dry matter production over 12 months for two cassava cultivars grown with and without fertilizers, at CIAT-Quilichao.*

Figure 3 shows the distribution of DM between roots, stems, leaves and petioles during the cultivars' growth cycles without fertilization. Roots started to accumulate DM after two months, and reached a maximum at 10 months in both cultivars; however, these cultivars varied markedly in their DM distribution with M Col 22 translocating most DM to roots after the third month while M Mex 59 did so only after the eighth month. The DM distribution in fertilized plants followed essentially the same pattern, except that in M Col 22 roots continued to accumulate DM up to the 12th month.

In general, N, P and K contens of the various plant parts decreased with time, especially in the upper stem tissue. Nutrient contents of upper leaves also decreased with time but not to the same extent as those of stems, petioles or roots, making this tissue more suitable for diagnostic purposes. For most elements, sampling at three months is recommended, while at a later date of sampling the critical levels should be reduced. The contents of most other nutrients also decreased with time, except Fe and Mn which remained constant in upper leaves, and Ca which increased in upper leaves and in petioles. Nutrient contents of roots decreased markedly for all elements as starch increased with time. It is clear that roots are relatively high in N and K, and these elements are removed in greatest quantities in each root harvest.

The nutrient contents of all plant parts at 2-4 months of age are shown in Table 2, both for fertilized and non-fertilized plants. Fertilization had mainly increased the nutrient content of all tissues without significantly changing the distribution pattern. Nitrogen and P contents followed similar distributional patterns and decreased in all plant parts from the top to the bottom of the plant. Potassium was highest in upper stems followed by petioles and leaves, however, the K gradient from upper to lower stem was much greater than for leaves. Leaves were more indicative of K status than the upper stem or petioles; the lower stem or the petioles might also be good indicator tissue for K although the former would destroy the plant during sampling. Data for other nutrients (Table 2) indicate Ca and Mg were both about equally high in leaves, petioles and stems, and low in roots. Unlike N, P and K, lower leaves and petioles were higher in Ca and Mg than upper leaves. Sulphur was high in leaves, extremely low in petioles and intermediate in stems; B was rather uniform throughout the plant; Cu was high in stems; Fe was high in leaves, especially lower leaves; while Mn and Zn were high in petioles especially lower petioles. The Fe, Mn and Zn contents all increased from upper to lower leaves and petioles. In this extremely acid (pH 3.9-4.1) soil, tissue concentrations of Fe and Mn were very high, probably above the critical level for toxicity.

Figure 4 shows the cumulative N, P, K profiles in M Col 22. Plants continued to accumulate nutrients throughout the growth cycle, but the greatest rate of absorption occurred from the second to the fifth month, especially for K. After the fifth month all these elements had accumulated mainly in the roots of this early root bulking cultivar. At harvest, quantities of N, P and K were greatest in roots (66% for K) followed by stems, leaves and petioles. However, Ca, Mg and Mn accumulated more in the stem than in the roots.

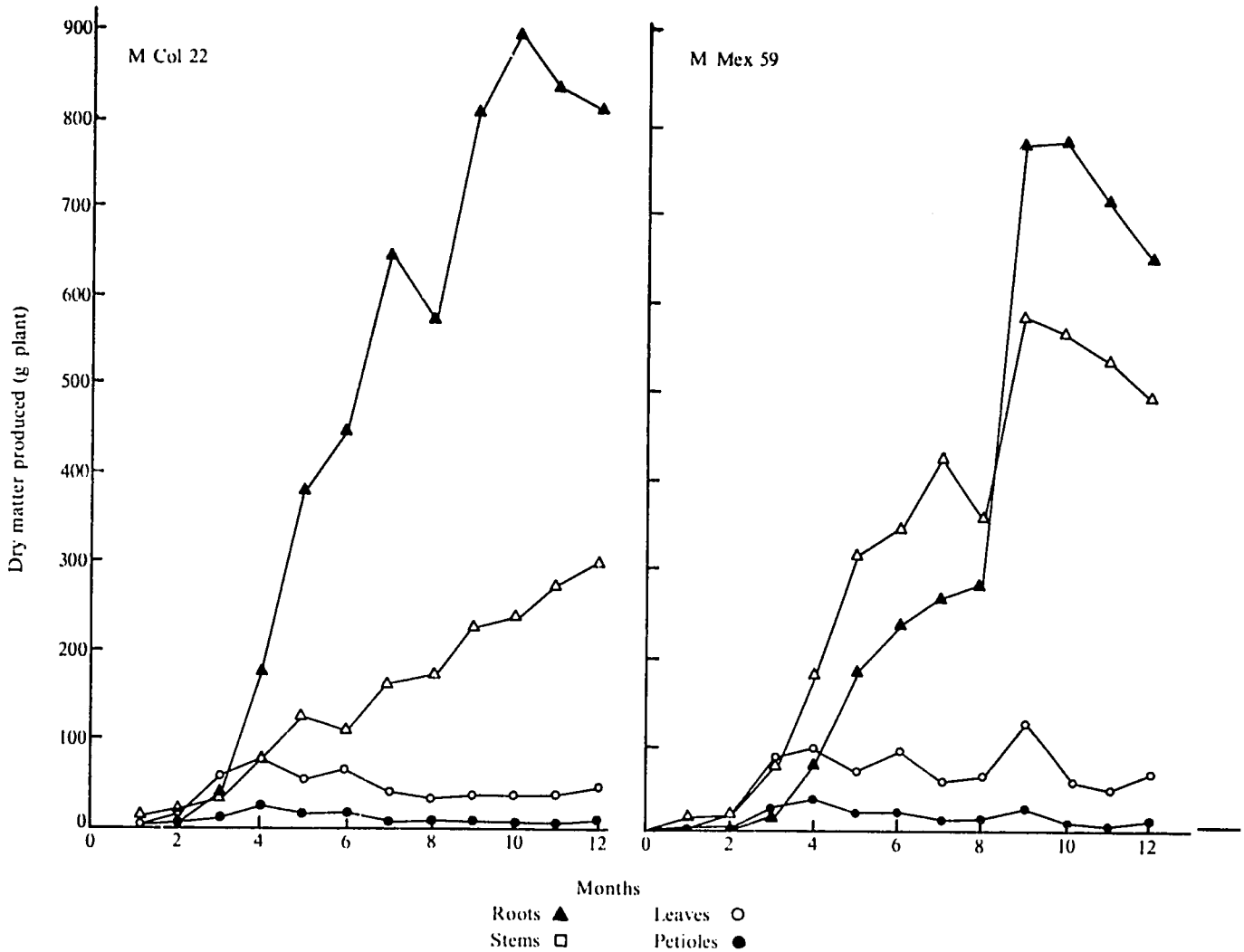


Figure 3. *Distribution of dry matter among roots, stems, leaves and petioles in two cassava cultivars grown without fertilizer over 12 months, at CIAT-Quilichao.*

Table 2. Concentration of nutrients in cassava upper, middle and lower leaves, petioles and stem, and roots[1].

Plant part		Nutrient content (%)						Nutrient content (ppm)				
		N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
Leaves	upper	5.75	0.42	1.98	0.72	0.34	0.30	11.1	12.2	176	400	107
	middle	5.18	0.27	1.80	1.01	0.38	0.28	11.9	12.1	237	523	119
	lower	4.40	0.20	1.58	1.34	0.49	0.22	11.7	11.1	386	697	137
Petioles	upper	2.25	0.22	2.93	0.90	0.38	0.06	10.6	9.0	66	533	90
	middle	1.41	0.14	2.35	1.13	0.39	0.02	9.9	7.1	56	835	127
	lower	1.35	0.12	2.23	1.54	0.48	0.01	10.9	7.5	123	1470	190
Stem	upper	2.73	0.30	3.15	0.82	0.37	0.18	10.5	18.1	133	339	86
	middle	2.21	0.27	2.21	1.02	0.38	0.16	8.6	22.7	107	379	120
	lower	1.28	0.22	1.14	0.65	0.31	0.09	6.4	23.6	225	170	97
Roots		1.52	0.18	1.56	0.24	0.14	0.05	6.0	10.7	508	178	66

[1] Averages of samples taken at two, three and four months, for fertilized and unfertilized cultivars M Col 22 and M Mex 59

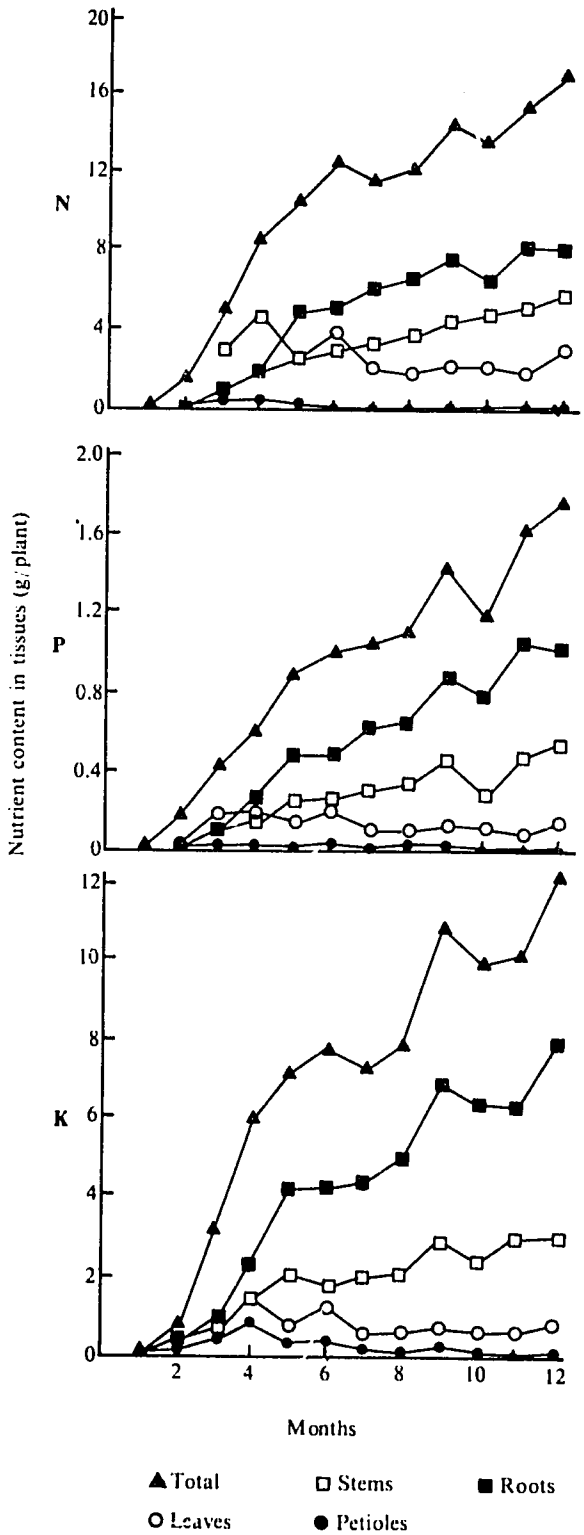


Figure 4. *Total uptake and distribution of N, P and K among plant parts of cassava cultivar M Col 22 over 12 months, at CIAT-Quilichao. (Averages from fertilized and nonfertilized* plants.)

Monthly analyses of unfertilized soils showed no significant changes in pH and Ca content, a slight increase in exchangeable Al from 2.5 to 3.5 meq/100 g; a slight increase in available P from 4 to 6 ppm, possibly due to leaf fall and decomposition; a slight decrease in exchangeable Mg; and a significant decrease in exchangeable K, from 0.4 to 0.2 meq/100 g. In fertilized plots, exchangeable K decreased from 0.60 to 0.25 meq/100 g, and increased again during the final month. The marked decrease in soil K is the cause of soil exhaustion after cassava cultivation and the reason why cassava responds more to K fertilization after several consecutive cassava crops. If each plant of a cassava crop removes about 10 g of K (see Fig. 4) and all was absorbed from the top 20 cm of soil without replacement, this decrease is as much as 0.17 meq K/100 g of soil; additional K may be lost by leaching and erosion. Thus, adequate K fertilization is essential to obtain high yields while maintaining soil fertility (see next section).

Long-Term Fertility Trial

Objetives, experimental treatments and results of the first planting with cultivar Llanera were described last year (CIAT Cassava Progr. 1979 Ann. Rept.).

In the second year, cultivar CMC 40 was planted in the same plots without additional fertilizer, except the eight additional plots receiving fertilizers annually. Figure 5 shows response to residual effects of N, P and K for root and foliage yield, harvest index, and N, P, K contents of leaves of three-month-old plants. Despite no additional application of fertilizers, root yields were very high with the lowest yield (31 t/ha) obtained with an absolute zero fertilization of N, P and K. In general, plants responded to fertilization more in terms of foliage than root yields but unlike the first year, there was no significant decrease in harvest index due to fertilization.

Figure 6 shows the root yield response to zero, medium and high fertilization both for the single and annual applications. Although there was a significant residual effect from the initially applied fertilizers, root yields increased another 5-6 t/ha from reapplication of these fertilizers. This would have been economical at the intermediate level of application, but not at the highest level.

After two years of cassava cropping the available P content of the soil had decreased from 7.8 to 2.3 ppm without applied P and from 41.8 to 6.9 ppm with 175 kg P/ha applied. Similarly, without additional K the

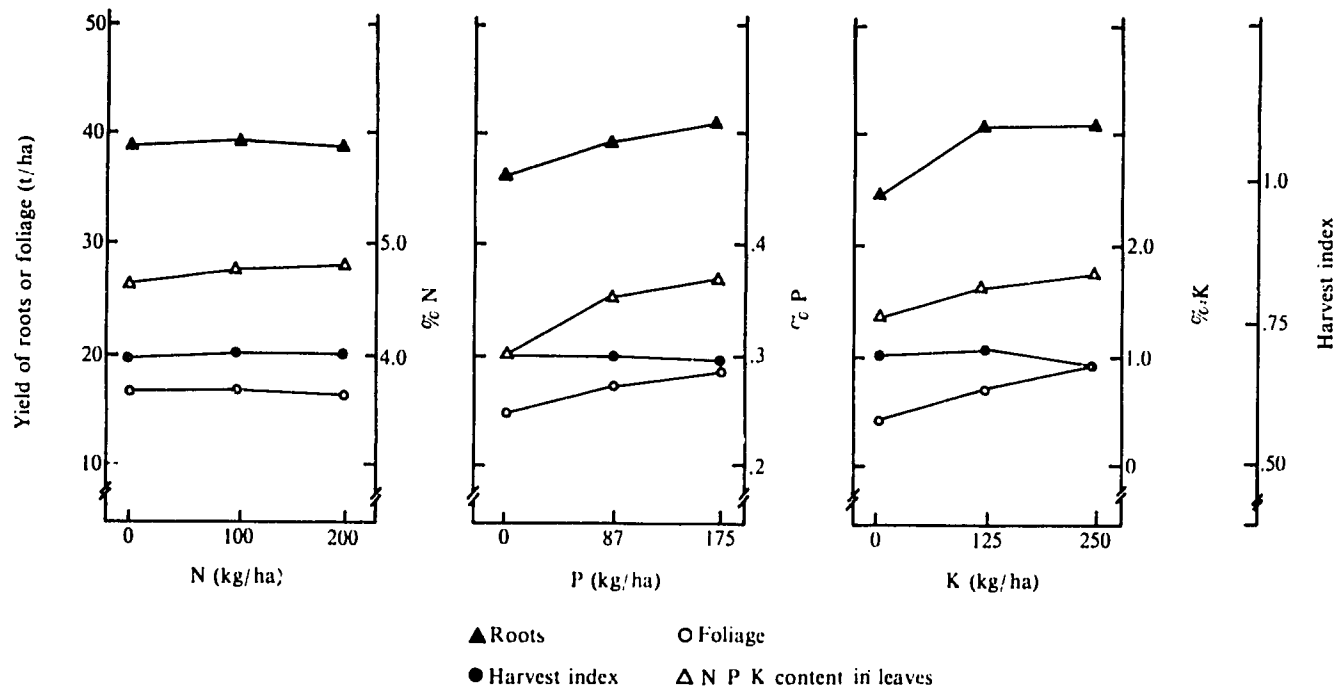


Figure 5. *Residual effects from three levels of N, P and K applied to a previous cassava crop on nutrient contents of upper leaves, at three months, and on root and foliage yields and harvest index of 12-month-old cultivar CMC 40, at CIAT-Quilichao.*

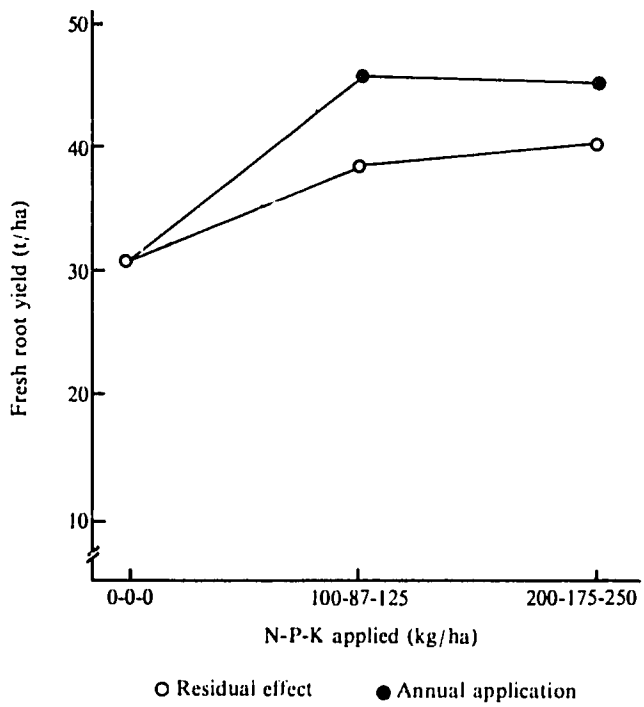


Figure 6. *Root yield response of cultivar CMC 40 to zero, medium and high levels of N, P and K applied only to the preceding crop (residual effect) or when applied annually, at CIAT-Quilichao.*

exchangeable K content of the soil decreased from 0.20 to 0.12 meq/100 g, and with the initial application of 250 kg K/ha, K content decreased from 0.48 to 0.14 meq/100 g. Only with annual reapplication of 250 kg K/ha could the soil K content be maintained at 0.21 meq/100 g after the second cropping, while an annual application of about 90-100 kg P/ha would be required to maintain an available P content of 7 ppm in the soil.

Sources of P

Two experiments to study the effect of various P sources, levels and methods of application on cassava yields in CIAT-Quilichao were initiated in 1978 (CIAT Cassava Prog. 1979 Ann. Rept.), and repeated in 1979 to study the residual effect. In the first year root yields of Llanera cassava varied from 20 to 25 t/ha, without a significant response to P application. In the second year, without additional P applied, root yields of cultivar M. Col 1684 varied from 42 to 51 t/ha, again without a significant response to P. Phosphorus contents of upper leaves at three months varied from 0.38 to 0.42% in the check plots; this is at the critical level of 0.4%, indicating an adequate P status of the plants. In the P check plots the average yield was 46 t/ha.

This high yield was attained in a soil with an initial P content (Bray II) of only 3 ppm, which increased to 5-6 ppm due to organic matter mineralization even before the first planting, and had remained at that level at the second planting. Plants in all treatments were highly infected (48-83%) with mycorrhiza, resulting in an efficient uptake of P even from a very low-P soil. Mycorrhizal infection was particularly evident in plots receiving no or only small amounts of soluble P, or high amounts of rather insoluble phosphate sources; infection decreased with increasing amounts of soluble P applied. Starch content of roots varied from 26 to 28% with P application having no significant effects. These trials suffered a 30-50% defoliation at eight months due to a severe hornworm attack, followed by three months of extreme drought (total of 57 mm rainfall) without any apparent detrimental effect.

Lime x P Interaction

An experiment has been conducted for two consecutive years in Carimagua to determine the interaction between lime and P applications on an acid infertile soil (CIAT Ann. Rept. 1976).

Lime applications from zero to 4.8 t/ha increased soil pH from 4.15 to 4.75, decreased exchangeable Al from 3.5 to 1.3 meq/100 g and decreased Al saturation from 88 to 27%. Root yields of M Col 638 ranged from 7 t/ha without lime and P to 25 t/ha with a combination of 3.6 t/ha of lime and 380 kg/ha of P_2O_5.

Figure 7 shows root yield and foliage growth responses to several rates of P and lime applications. On the average, near maximum root yields were obtained with 210 kg P_2O_5 /ha (92 kg P) and 1.1 t lime/ha. While root yields showed a more or less quadratic response, foliage yields showed a nearly linear response to P, as was also reported in 1976. Harvest index was highest (0.65) with 0.3 t lime and 210 kg P_2O_5 and decreased to 0.50 at the highest lime and P rates.

In Carimagua, near maximum yields can apparently be obtained with the application of 90-100 kg P/ha and 1 t/ha of dolomitic lime, which produced a pH of 4.3 with 2.75 meq Al/100 g or 76% Al saturation. These data indicate that cassava is extremely tolerant of low pH and high Al, but also illustrate the beneficial effect of small lime applications.

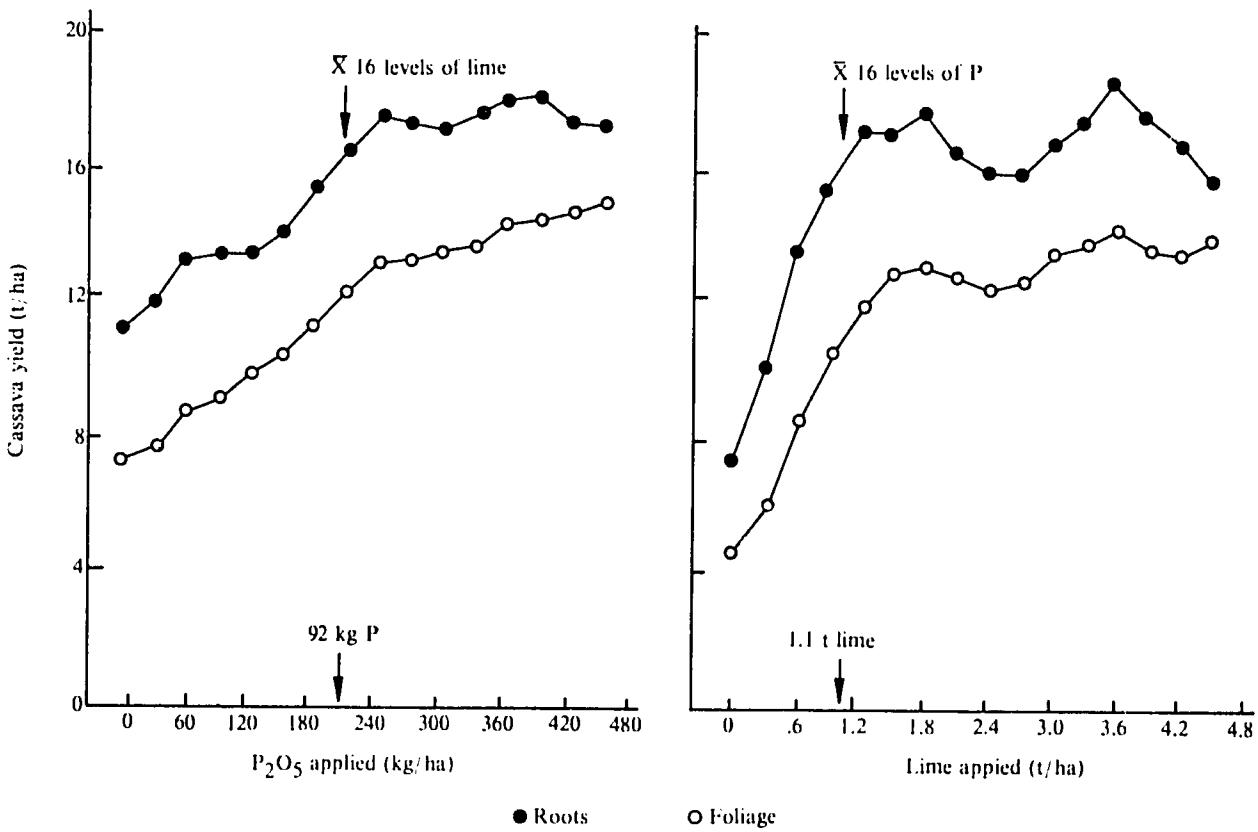


Figure 7. *Effect of increasing levels of applied P and lime on root and foliage yields of cultivar M Col 638, in Carimagua. Arrows indicate rates required for 95% of maximum yield.*

Response to Mycorrhizal Inoculation

In many cassava growing areas of Latin America, P deficiency is the main limiting nutritional factor. Inoculation with mycorrhizal fungi has been shown to improve cassava's ability to absorb P from low P concentrations in both soils and nutrient solutions (CIAT Cassava Prog. 1979 Ann. Rept.). Cassava plantlets produced in a misting chamber were planted in pots with sterilized soil from CIAT-Quilichao to which nine levels of P had been applied. Plantlets were either noninoculated or inoculated with mycorrhizal spores or infected roots. A clear P response could be observed after two weeks and a response to root inoculation after three weeks, the latter becoming more pronounced with time. The dramatic response to inoculation can be seen in Figure 8.

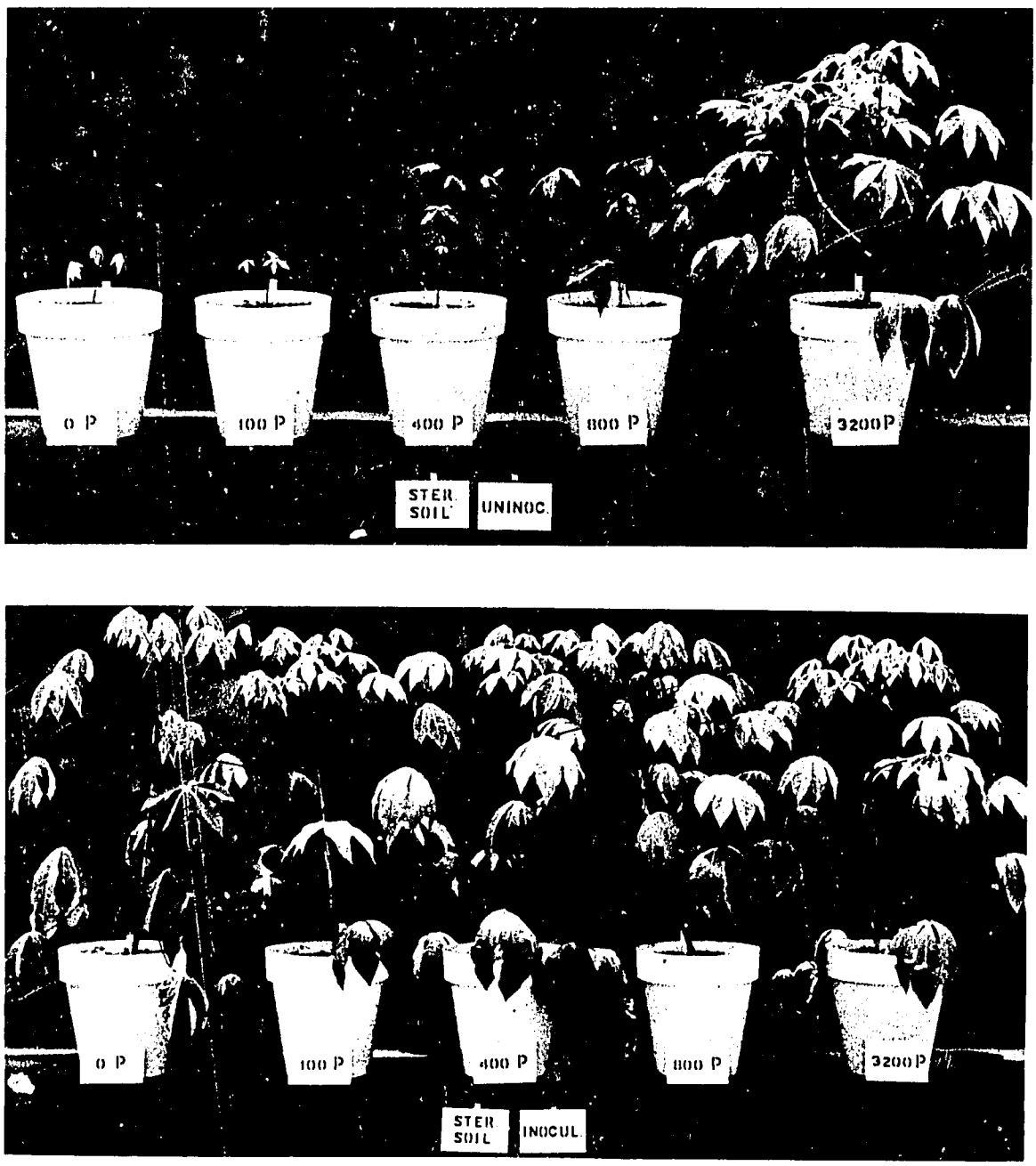


Figure 44. *Response of cassava cultivar M Mex 59 to mycorrhizal inoculation and several levels of applied P, in a sterilized soil from CIAT-Quilichao.*

Without inoculation plants remained P-deficient even with 800 kg P/ha applied, and reached near-maximum growth only with 1600 and 3200 kg P/ha. With root inoculation, plant growth was very good even without applied P; response to P-application was small initially and had nearly disappeared by harvest. The response to spore inoculation was essentially zero.

Inoculation with 2 g of infected roots in the P check increased top growth over 80 fold compared with the noninoculated treatment, and was about equally effective as the application of 1600 kg P/ha (Fig. 9). Without mycorrhizal infection, plants absorbed very little P from a soil to which 800 kg P/ha had been applied.

In the CIAT-Quilichao soil, mycorrhizal inoculation was highly effective even without any P applied, althouth infection and the P concentration of the tops were relatively low at this level (Table 3). Maximum infection occurred at intermediate P levels corresponding to 50 and 100 kg P/ha applied (levels used in field-grown cassava). Without P applied, total uptake was over 100-fold higher in mycorrhizal than in non-mycorrhizal plants; even at the highest levels of applied P, mycorrhizal plants had higher P concentrations and absorbed more P than non-mycorrhizal plants.

Figure 10 shows the relation between DM production and available P content (Bray II) of the soil after harvest, both for inoculated and noninoculated treatments. Curves were drawn visually through the points and arrows indicate "critical" P contents, defined as 95% of maximum yield. Although inoculated and non-inoculated plants reached the same maximum yield, it is clear that the presence of mycorrhiza markedly reduced the "critical" soil P-content. The critical level of 15 ppm for mycorrhizal plants is only slightly above the level of 8-10 ppm obtained from field experiments, while the level of 190 ppm for non-mycorrhizal plants is unrealistically high.

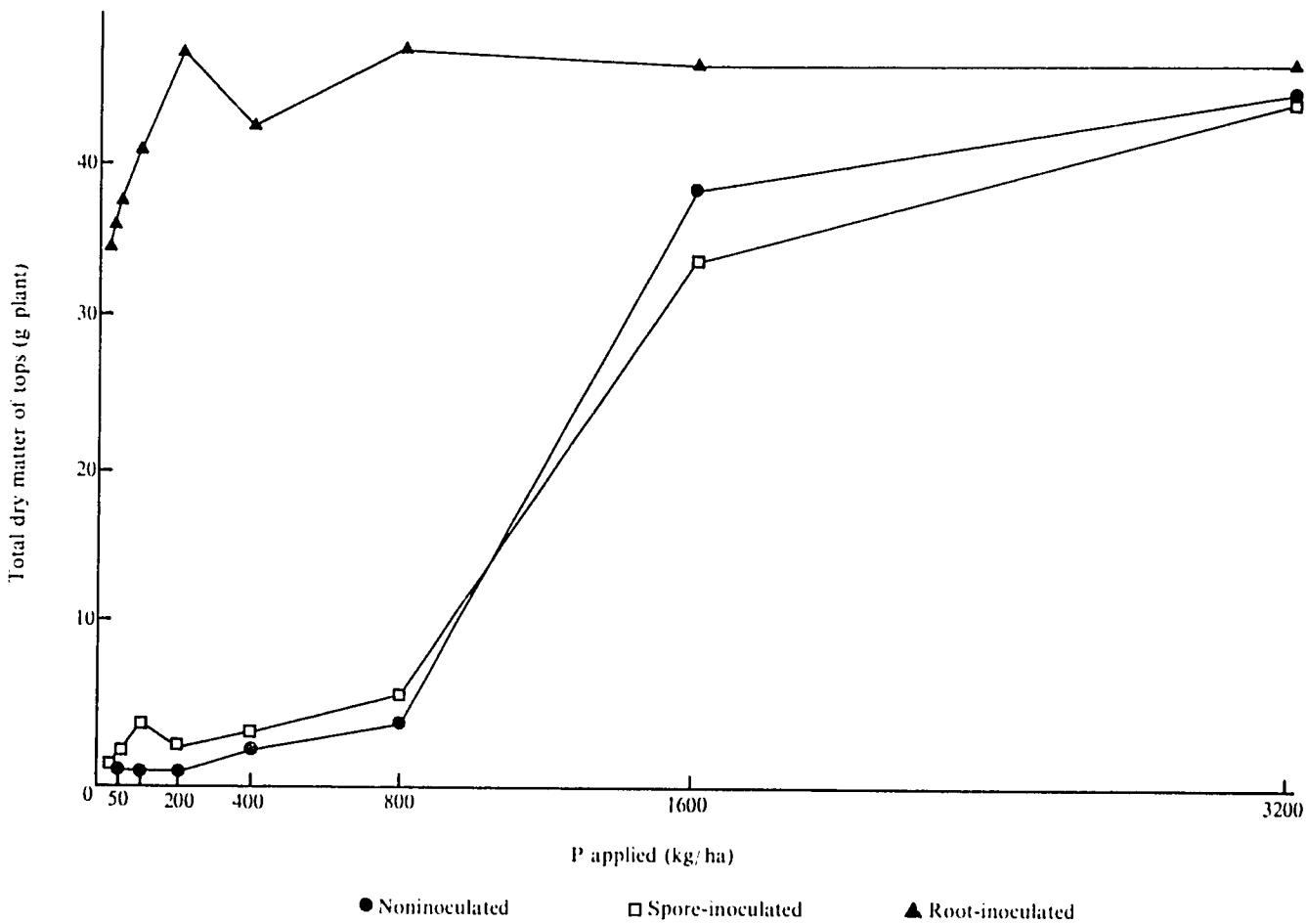


Figure 9. *Effect of mycorrhizal inoculation and several levels of applied P on dry matter production in tops of cultivar M Mex 59, in a sterilized soil from CIAT-Quilichao.*

Table 3. Effect of mycorrhizal inoculation and P levels applied on mycorrhizal infection of cassava roots, P concentration of tops and total P uptake by tops[1].

P applied	Degree of infection [2]			P concentration in tops (%)			P uptake by tops (mg/plant)		
(kg/ha)	NI[3]	RI	SI	NI	RI	SI	NI	RI	SI
0	0	1.7	0	0.05	0.08	0.05	0.2	27.7	0.3
25	0	2.2	0	0.07	0.07	0.05	0.5	25.5	0.6
50	0	2.6	0	0.04	0.11	0.08	0.3	41.3	1.5
100	0	2.6	0	0.05	0.12	-	0.3	49.4	-
200	0	2.4	0	-	0.17	0.09	-	81.0	2.0
400	0	2.0	0	0.06	0.17	0.09	1.2	73.0	2.8
800	0	1.5	0	0.09	0.18	0.06	3.4	86.0	3.4
1600	0	1.0	0	0.15	0.16	0.08	58.3	75.3	27.5
3200	0	1.0	0	0.20	0.25	0.21	90.5	118.3	93.5

[1] Cultivar M Mex 59 grown on sterilized soil from CIAT-Quilichao, in the greenhouse.
[2] Degree of infection. 0 = none, 3 = high number of hyphae and vesicles in roots.
[3] NI = noninoculated, RI = root-inoculated, SI = spore-inoculated.

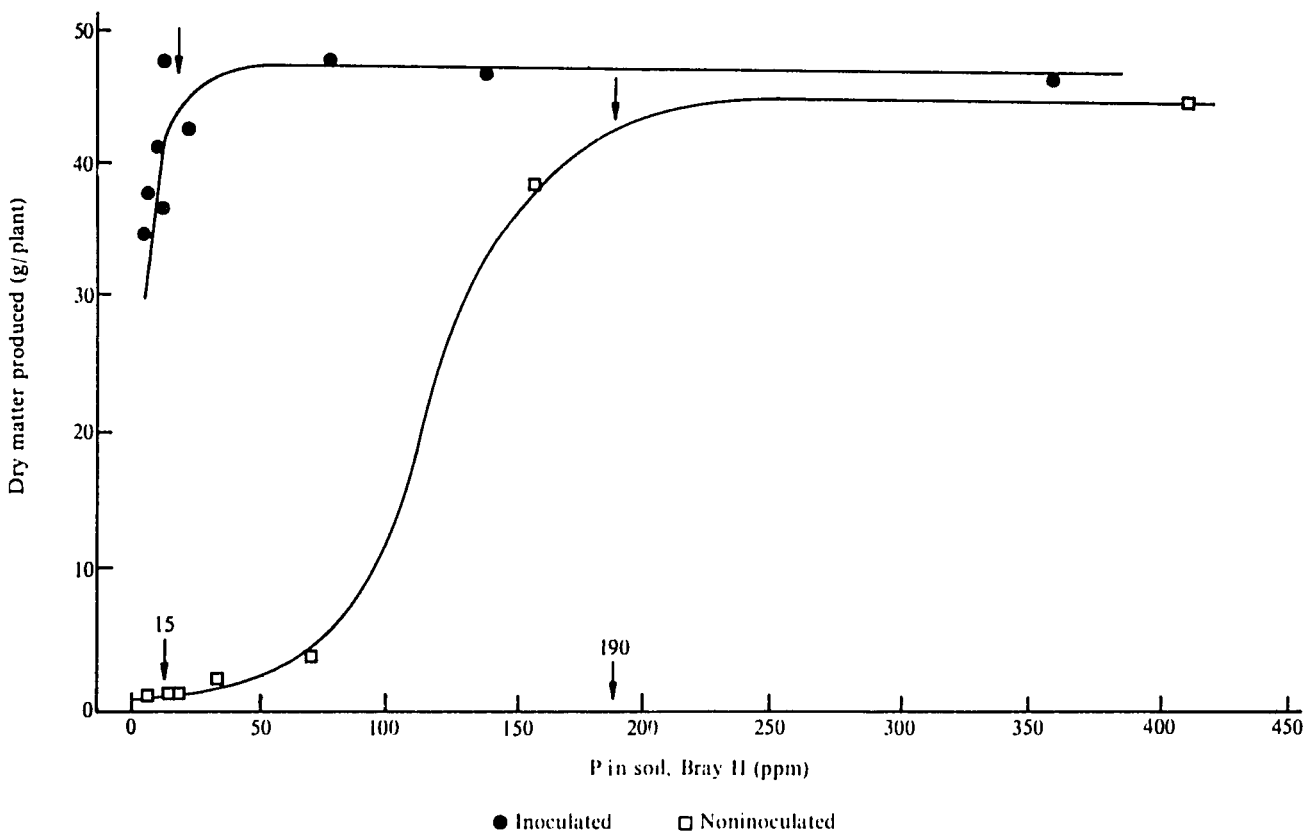


Figure 10. *Relation between dry matter yields of three-month-old inoculated and noninoculated cassava cultivar M Mex 59, and soil P content after harvest. (Arrows indicate critical P levels for 95% of maximum yield.)*

Spore inoculation did not result in an apparent root infection, nor in an improvement in plant growth, but inspection of the soil after harvest revealed a large spore population. Replanting cassava in these pots resulted in a marked improvement of growth at intermediate P levels. While infection from spore inoculation was much slower than from root inoculation, with time these methods will probably be equally effective.

The results of this experiment corroborate the conclusion (CIAT Cassava Progr. 1979 Ann. Rep.) that without a mycorrhizal association cassava roots are extremely inefficient in P uptake, and indicate the great dependence of the crop on mycorrhiza when grown on low-P soils. Practical implications of these findings are, however, not yet clear. First, in a nonsterilized soil the native mycorrhizal population may be highly efficient, reducing the beneficial effect of inoculation unless more efficient species and strains can be identified. Secondly, cassava is normally grown from stakes with a considerable reserve of nutrients (25-50 mg P/stake but less than 1 mg in rooted cuttings), which it can utilize to grow an efficient root system before having to rely on that system for P uptake. Initial responses to inoculation in cassava grown from stakes were small compared with those in cassava from rooted cuttings. It remains to be seen what the long-term effect of inoculation is once the stake reserves are exhausted.

Host specifity. To determine the degree of host specificity, mycorrhizal-infected cassava roots were used to inoculate seven species: maize, beans, cowpeas, rice, *Andropogon gayanus, Stylosanthes guyanensis* and cassava hybrid CM 91-3, all grown in sterilized soil from CIAT-Quilichao with 0, 100, and 500 kg P/ha applied.

Table 4 shows the response to inoculation and P application of these species. All species except rice benefited markedly from inoculation at the levels of 0 and 100 kg P/ha, while cassava, beans, cowpeas and *Stylosanthes* sp. also responded at 500 kg P/ha. The lack of response in rice may indicate some host specificity, but is more likely due to the extremely fine and highly branched root system of this species. The lack of response to inoculation of *Andropogon* sp., and maize at 500 kg P/ha also reflects a well developed, highly branched and dense root system.

As was observed in nutrient solutions (CIAT Cassava Progr. 1979 Ann. Rept.), without mycorrhizal infection cassava required much higher rates of P to attain normal growth than even such P-demanding species as beans. Using the ratio of DM obtained without inoculation over that obtained with inoculation as a measure of mycorrhizal dependence (Table 4), considering all P levels, cassava was the most mycorrhizal-dependent species, followed by *Stylosanthes guyanensis*. Without applied P, these two species again were most mycorrhizal dependent, although in reverse order; at 100 kg P/ha, *Stylosanthes, Andropogon* and cowpeas were even more mycorrhizal-dependent than cassava. On the other hand, with a mycorrhizal association, cassava was more P-tolerant (DM_{P_0} / $DM_{P_{500}}$) than any of the species including rice. Thus, cassava's well-known ability to grow on low-P soils is due to a large P reserve in its planting piece as well as to an effective mycorrhizal association in many (but not necessarily all) low-P soils.

Table 4. Effect of mycorrhizal inoculation and P application on dry matter in tops of seven crop species[1].

Species	Dry matter in tops (g/pot)						Mycorrhizal dependence ratio [2]			
	Noninoculated			Inoculated						
	P-0	P-100	P-500	P-0	P-100	P-500	P-0	P-100	P-500	Mean
Cassava	0.34	0.72	0.54	4.33	14.21	16.36	0.08	0.05	0.03	0.05
Beans	1.11	3.44	8.29	3.08	18.79	25.01	0.36	0.18	0.33	0.29
Cowpea	0.96	0.64	13.65	2.60	20.68	36.32	0.37	0.03	0.38	0.26
Stylosanthes sp.	0.08	0.08	2.74	1.25	9.33	12.20	0.06	0.01	0.22	0.10
Andropogon sp.	0.15	0.39	34.24	1.26	16.67	32.18	0.12	0.02	1.06	0.40
Maize	1.19	8.74	59.35	4.84	34.75	53.57	0.25	0.25	1.11	0.54
Rice	3.79	26.63	30.60	3.83	22.36	31.23	0.99	1.19	0.98	1.05

[1] Crops grown in sterilized soil from CIAT-Quilichao, in the greenhouse. Fertilized with either 100 or 500 kg P/ha.

[2] Mycorrhizal dependence is in terms of the ratio: $\frac{\text{Dry matter produced without inoculation}}{\text{Dry matter produced with inoculation}}$

Economics

The long-term objective of the Economics section is to analyze the potential impact of improved cassava technology in Latin America. This objective defines a relatively broad research program, since the adoption potential of new technology is determined both by the characteristics of the technology and the access of increased production to markets. Output price becomes a key parameter in the analysis. On one hand, it determines the profitability of the technology at the farm and, on the other hand, it determines cassava's competitiveness (and thus its potential) in alternative markets. For most of the other crops within the mandate of the Consultative Group for International Agricultural Research (CGIAR), demand is not a critical factor influencing technology adoption; in the case of cassava, both economic research on production and demand are essential inputs into the Cassava Program's research strategy.

Production Economics

Media Luna on-Farm Trials

Last year cassava production systems in the Media Luna zone were described and results were reported from farm trials comparing the local variety with introduced cultivars (CIAT Cassava Progr. 1979 Ann. Rept.). Among the issues raised was that of root quality; while yields between the cultivars did not differ substantially, the local variety produced higher quality roots.

Given cassava's perishability and indeterminate harvest period, storage in the ground is a principal means for regulating market supplies, especially if there is a critical planting period. Since cassava cannot be stored after it enters urban fresh market channels, consistent flows of the product onto the market through the year depend on staggered harvesting. If farmer risk is to be minimized and farmers are to be assured access to the fresh market, yield and quality must be maintained throughout this storage period.

To evaluate potential future hybrid introductions and to develop a methodology within the farm trials for evaluating cassava storage, the local variety Secundina was compared to three new lines at an early stage of selection. Trials were established in the primary planting season and harvested monthly from 10 to 15 months of age. This harvest period extended from the dry season through initiation of the rains and through three months of high rainfall. This duplicated the actual pattern of the local area for about 70% of all cassava produced over the seasons. Results of the trial are shown in Table 1.

Data for Secundina confirm why this variety dominates in the Media Luna area. First, it matures early but still continues to yield when left in the ground for several more months. Secondly, it maintains its high quality, especially in terms of starch content and low fiber, over the storage period. Finally, it resists root rotting well. These characteristics minimize production and marketing risks, insure farmer access to markets and provide an adequate return to land and labor.

Results for the other lines suggest that a single evaluation for yield and quality characteristics will often be misleading, for example, in the case of CM 391-2 after 12 months. Such evaluations should be based on how the farmer adapts his farming system to requirements of the market, the rainfall pattern and, in some areas, to temperatures, since evidence suggests starch content is inversely correlated with temperature (CIAT Ann. Rept. 1978).

Mondomo on-Farm Trials

Farming System. Environmental and economic characteristics of the farming system in Mondomo, Departament of Cauca, Colombia, differ completely from those in Media Luna. Rainfall averages about 400 mm annually and is relatively well-distributed. There is no critical planting season, and time of planting is determined by labor availability and market requirements. The 1500 m altitude and average temperature of 19°C result in a significantly longer growing season of 14 to 18 months.

Table 1. Yield characteristics of four cassava lines as a function of different harvesting times, at Media Luna, 1979-80[1].

Yield characteristics	Harvest period (months after planting)					
	10	11	12	13	14	15
	Rainfall in harvest month (mm)					
	0	3	50	170	240	180
Dry matter content (%)						
Secundina	36.6	33.1	32.3	32.2	41.4	35.5
CM 323-375	28.5	22.5	23.6	23.1	25.6	23.7
CM 305-38	28.9	27.3	25.9	24.6	28.0	22.7
CM 391-2	29.8	26.8	27.2	21.1	33.2	30.2
Root rotting (% of total roots)						
Secundina	0.8	1.0	0.7	0.3	1.1	0.4
CM 323-375	4.1	13.3	6.3	2.8	4.5	4.5
CM 305-38	4.8	10.4	10.9	4.1	3.0	5.6
CM 391-2	2.2	18.3	14.1	5.8	4.3	1.0
Fiber content (%)						
Secundina	2.8	2.6	4.8	na	3.4	4.0
CM 323-375	3.1	3.6	5.3	na	3.9	3.3
CM 305-38	3.2	4.1	na	na	4.4	6.4
CM 391-2	3.3	3.4	6.4	na	4.5	3.3

[1] Cassava was planted in May 1979.

Soil factors are the principal constraints on the system. Phosphorus (Bray II) varies from 0.8 to 2.7 ppm, well below critical levels; potassium also varies substantially, from 0.10-0.78 meq/100 g. Soils are very acid with levels of Al reaching 4.7 meq/100 g. Fertilizer use is increasing but still is not widespread.

For cassava cultivation, farmers manage soil fertility through a fallowing system with variety selection based on relative responsiveness to fertility conditions. Optimally, farmers fallow for at least six years and then plant three or sometimes four successive cassava crops. This system is, however, dependent on farm size (ranging from 4 to 40 ha and averaging 15 ha) and farmers with smaller areas must reduce their fallow period. Four cassava varieties are commonly planted and each responds differently to existing soil fertility.

Although its yields are rather low, coffee is the only competing crop as it produces adequately under the local conditions. The average cropping pattern is 2.1 ha of coffee, 3.6 ha of cassava, 1.6 ha of other crops (principally plantain), and 8 ha in fallow. Critical labor demand peaks for the two coffee harvests determine scheduling of cassava activities. The amount of labor devoted to weeding is lower than in other zones due to this competition for labor.

Market restrictions are not so severe as in the Media Luna case. Cassava goes almost exclusively into a small-scale starch industry which, in turn, sells exclusively to the bakery industry. Prices received are slightly lower than those from the wholesale urban market; however, the high-quality variety suitable for the urban market does not yield well under the low fertility conditions. Supply continuity is maintained by staggered plantings. Starch content determines prices received and the market discriminates between local varieties as follows: Valluna, Col.$7.3/kg; Americana, $5.0/kg; and Algodona, $4.0/kg. Farmers claim yield potentials of the three varieties are inversely related to starch content.

Farm Trials. A complete factorial fertilizer treatment involving 500 kg/ha of lime and 500 kg/ha of 10-30-30 fertilizer was utilized on the two local varieties Algodona and Americana and a hybrid introduction CM 323-375. The latter had yielded consistently high across the regional trial sites at somewhat lower altitudes, and produced 19 t/ha under similar soil conditions at CIAT-Quilichao. Local average yields in the Mondomo area were about 6.7 t/ha.

Table 2 shows results of the trials. Algodona yielded more than either of the other two varieties, which is consistent with its local dominance. On the other hand, varieties did not differ significantly in dry matter content. This was inconsistent with the price discount applied to Algodona, unless another factor is causing differences in starch extraction rates between the two varieties. Such a factor, called simply latex, has been reported in Australia.

Table 2. Fresh root yield and dry matter contents for cassava tested in on-farm trials, at Mondomo, 1979-80.

Yield parameter and fertility treatment [1]	Cassava variety		
	Algodona	Americana	CM 323-375
Fresh root yield (t/ha)			
Lime + fertilizer	10.3	6.3	5.5
Fertilizer only	10.4	4.9	6.2
Lime only	[illegible]	4.8	4.7
Control	[illegible]	4.9	3.1
Dry matter content			
Lime + Fertilizer	36.8	35.9	37.6
Fertilizer only	36.6	33.7	36.2
Lime only	36.1	35.1	36.4
Control	35.4	34.3	37.5

[1] Lime treatment was 500 kg/ha, fertilizer treatment was 500 kg/ha of 10-30-10.

Differences between fertilizer treatments were not significant but differences between farmers were, that is, variations between farms (replications) were greater than between treatments. This is not unusual and, as was the case in Media Luna, confirms the substantial micro-variation between farm trial sites. Table 3 gives average yields for Algodona on each farm along with the plot cropping histories.

A crop rotation index was also calculated. While somewhat arbitrary, the index is basically adapted from the proportion within the farmers' normal rotation scheme of six years of fallow and three successive crops of cassava. Remarkably, the index gives a virtual exact ordering of yields.

The sample was stratified according to the rotation index with 6 used as the dividing point, i.e., the implicit point in the rotation system at which soil fertility was declining. Table 4 shows that for all three varieties, yield and dry matter content differed significantly between the two groups (except for dry matter of CM 323-375).

There was also a significant and economic response to fertilizer in the case of Algodona on critical fertility plots and no significant response on plots where a sufficient rotation period was being maintained (Table 5).

The critical influence of the fallow system, and the differential response to a fertilizer based on how much the fallow system was shortened, define the requirements for new technology in this zone.

Table 3. Yields of two local cassava varieties on individual farms, as related to plot history and farm size, at Mondomo.

Farm size (ha)	Previous	Rotation index[1]	Fresh root yield Americana (t/ha)	Fresh root yield Algodona (t/ha)
44.8	1 year cassava, 15 years fallow	13	8.5	16.6
12.6	2 years fallow, 1 year cassava, 10 years fallow	10	[2]	13.7
19.2	10 years fallow	10	[3]	11.4
4.5	8 years fallow	8	6.6	8.7
5.8	6 years fallow	6	6.2	6.9
15.1	2 years fallow	2	3.5	6.5
5.0	2 years cassava, 8 years fallow	4	4.6	4.7
12.6	2 years cassava, 2 years fallow	-2	2.7	[2]

[1] Rotation index = number of years in fallow minus 2 times number of previous years in [illegible]

[2] [illegible] different plot histories for the two varieties

Table 4. Fresh root yield and dry matter content of three cassava varieties, in relation to length of previous fallow period, at Mondomo[1].

Rotation strata	Cassava variety		
	Algodona	Americana	CM 323-375
Fresh root yield (t/ha)			
Adequate rotation	11.5	7.1	7.3
Shortened rotation	5.6	3.6	2.5
Dry matter content (%)			
Adequate rotation	37.2	37.5	37.6
Shortened rotation	34.0	32.[illegible]	36.6

[1] Except in the case of dry matter content of CM 323-375, there were significant differences at the 5% level between the two rotation groups for all other values.

Table 5. Yield response of the cassava variety Algodona to fertilizer treatments, in relation to the length of the rotation period, at Mondomo.

Fertility treatment [1]	Fresh root yield (t/ha) according to rotation strata	
	Adequate	Shortened
Fertilizer + Lime	11.3 a[2]	7.7 a
Fertilizer	11.1 a	8.9 a
Lime	12.1 a	2.5 b
Control	11.0 a	4.2 b

[1] Lime treatment was 500 kg/ha, fertilizer treatment was 500 kg/ha of 10-30-10.

[2] Values within column followed by the same letter are not significantly different at the 5% level.

Cassava Intercropping Trials

Cassava is grown principally by small farmers, for whom land is usually a constraining resource and cash flow through the crop year is a principal concern. Intercropping permits intensifying land use and, where different maturity crops are used, can help stabilize income flows. Cassava is well suited to multiple cropping, but given its wide ecological range, the best potential intercrop will vary across ecological zones. On-farm intercropping trials were done in two locations by the Cultural Practices section; budgeting analyses of these trials are reported.

Media Luna. In Media Luna maize is the principal crop associated with cassava (for a discussion of environmental conditions and farming systems, see CIAT Cassava Progr. 1979 Ann. Rept.) Maize has no marketing problems; it is a short-season crop, and, while it has low productivity under existing conditions, it provides an adequate return on investment when grown with cassava. Farmers in the zone use a low-plant population system which seemingly minimizes light competition between the tall maize and slower growing, shade-sensitive cassava (Fig. 1). A trial was designed to compare the farmer's system using the local variety Secundina in both monoculture and intercropped, with an improved system in which plant densities of both cassava and maize were increased while the spatial arrangement of the cassava was modified (Fig. 1). An N treatment was added as one additional component, primarily to benefit the maize.

Four conclusions are evident from the yield results (Table 6): a) changing either the plant population or the spatial arrangement in monoculture, cassava did not increase yield; b) under the farmer system, maize did not suppress cassava yields; c) the higher maize population in the improved system produced a slight decline in cassava yields but almost tripled maize yields; and, d) there was no economic response to fertilizer.

Net income calculations (excluding land and management costs) at varying cassava:maize price ratios (Table 6) demonstrated that the improved intercropping system without fertilizer was the most profitable up to the very highest price ratio (Col. $4.0/kg for cassava: $5.0/kg for maize). At low cassava prices, the income gain was substantial, with only very marginal increases in costs. The experiment will be continued at least three years to evaluate the stability of the systems, especially those without applied fertilizer.

Caicedonia. Compared to the marginal agricultural conditions of Media Luna, Caicedonia is prime coffee land where cassava must compete with high-value crops. In this case, beans — the highest value intercrop — was selected for study. Cassava can compete economically due to the very high yields obtained, because of the preferential price received for the high-quality variety grown in the zone (usually more than double farm prices on the North Coast), and due to the generally high level of prices for cassava nationally.

Three basic agronomic changes were made in farmers' cassava-bean intercropping systems. First, plant populations of both crops were increased (beans by a factor of 10). Secondly, a preemergent herbicide was used instead of two hand weedings and fertilizer (100-100-80 kg/ha of N-P-K) was applied. Finally, changing from horizontal to vertical planting of cassava stakes allowed both crops to be planted simultaneously because cassava germinated faster and thus minimized interspecies competition.

Table 6. Yields and net incomes from various cassava and maize intercropping systems, at Media Luna.

Crop system and (spacing)	Mean yields (t/ha)		Net income per hectare; cassava price in $Col/kg[1]			
	Cassava	Maize	1.0	2.0	3.0	4.0
Farmer system						
Cassava monoculture (1.2 x 1m)	14.3	-	1944	16,244	30,544	44,844
Cassava (1.2 x 1m)/maize (2 x 1.2m)[2]	15.7	0.7	5256	20,956	36,656	52,356
Improved system without fertilizer						
Cassava monoculture (1 x 1m)	15.0	-	2644	17,644	32,644	47,644
Cassava monoculture (1.6 x 0.6m)	14.1	-	1744	15,844	29,944	44,044
Cassava (1.6 x 0.6m)/maize (1.6 x 0.3m)	13.9	1.9	9506	23,406	37,306	51,206
Improved system with fertilizer						
Cassava (1.6 x 0.6m)/maize (1.6 x 0.3m)	13.6	1.9	8661	22,261	35,861	49,461

[1] Maize price was held constant at $Col 5.0/kg.
[2] Maize population was determined by planting pattern and number of plants per hill (farmer: 3; improved: 2)

Figure 1. *(Above) typical farmers' cassava/maize intercropping system employed in the Media Luna zone. (Below) improved system developed by CIAT.*

As in Media Luna, there was no apparent competition in the intercropping system, and even some tendency was evident for increased cassava yields (Table 7). There was no apparent response by cassava to fertilizer, with the impact on beans being inseparable from the impact of increased density. Again, as in the Media Luna case, the improved system's principal advantage was in improved yields of the intercrop, with bean yields increasing fivefold.

A simple budgeting analyses of the results revealed that the intercropping systems were more profitable than monoculture and that the improved system was most profitable (Table 7). Nevertheless, cassava dominates in the economics of the association, and the beans only contribute marginally to total profitability of the system. Returns to land and management in Caicedonia were larger than returns to cassava systems in Media Luna by a factor of 10. If such profit differentials are necessary to bring prime agricultural land into cassava production, such zones will continue to supply only preferred, high-priced markets like the fresh cassava market of Bogotá.

Table 7. Yields and net income from various cassava and bean intercropping systems, at Caicedonia.

Crop system	Mean yields		Net income from system ($Col/ha)			
	Cassava	Beans	Gross income[1]		(Variable cost)	Net income
	(t/ha)	(kg/ha)	Cassava	Beans		
Farmers' system						
Cassava monoculture	31.7	-	253,600	-	(11,090)	242,510
Cassava/beans	37.5	210.0	300,000	6300	(14,727)	291,573
Improved system						
Cassava monoculture	36.0	-	288,000	-	(14,920)	273,080
Cassava/beans	37.4	1022.0	299,200	30,660	(20,499)	309,361

[1] Prices received were cassava, $Col 8.0/kg and beans, $Col 30/kg.

Demand and Marketing Economics

Successful diffusion of new agricultural production technology is critically dependent upon the increased output reaching profitable markets. While in the past cassava has performed well as a basic food crop in many zones of Latin America, future yield-increasing technology will be adopted only if the additional production can be readily marketed.

Cassava is suitable for use in several distinct markets of which five are outstanding: a) fresh for human consumption; b) processed for human consumption; c) as an animal feed; d) as an industrial starch; and, e) as a feedstock in the distillation of fuel. Knowledge of the price at which cassava must be sold in order to compete in each of these markets not only indicates which markets cassava is most likely to enter, but also gives an estimate of the level of productivity which new production technology must attain if cassava is to compete in each market.

Colombian Case Study

Because CIAT's mandate emphasizes increasing the availability of food supplies, primary focus is placed on analyzing cassava markets where it is used directly or indirectly as a food. The poultry industry in Colombia was selected for study because of the extremely rapid growth rates in this and the related feed concentrate industry. Cassava might well find an important market in this latter industry as a substitute for one or more feed grains. It is also thought that any results from this industry-wide model could be adapted easily to other countries of the region.

A linear programming model was constructed for the poultry feed industry to provide a least-cost feed ration for broilers. Two levels of increased cassava production were assumed -- a 15 t/ha low-input technology suitable for production regions with moderate stresses, and the other a 24 t/ha model for the same production regions but employing higher fertilizer levels and appropriate weed control measures.

Percentage cost reductions in the least-cost, nutritionally adequate rations are shown in Table 8, for cassava produced at three technology levels. The model assumes cassava is available at prices associated with these potential

technologies and that alternative feed materials are available at prices prevailing at the time of study. Given the high national price for sorghum (about double world market prices), cassava completely replaced that grain in the least-cost ration calculated. Although the economic optimum where cassava could be substituted for other grains was at 43% of the broiler diet, poultry performance on cassava meal at that high level has yet to be fully defined. Therefore, the cassava level was also constrained to form no more than 10 and 20% of the rations.

The impact of reduced prices for feed concentrates on consumer welfare can be traced through a supply and demand model of the poultry sector. This influence was calculated for this case study and the results, in terms of gross benefits derived at the different technology levels and cassava substitution levels, are shown in Table 8. The magnitude of these benefits in Colombia alone compares favorably with total research expenditures being made on cassava.

It is also important to note that the benefits from the 15 t/ha techonology are about two-thirds those from the 24 t/ha technology although the yield increase required to attain 15 t/ha is only 40% that involved in reaching 24 t/ha, using current Colombian national average yields for comparison. This pattern of benefits tends to support the research strategy of the CIAT Cassava Program which emphasizes low input technology.

While the gross benefits indicated in this study are only those attributable to the increased consumption and lower price for poultry, when cassava substitutes for other feed ingredients, other social and political benefits would also accrue. For example, if cassava completely replaced sorghum in poultry rations, Colombia could realize an annual foreing exchange saving of US$12.7 million, based on 1979 prices and the average level of sorghum imports. Moreover, at the 20% inclusion level and with 15 t/ha technology, an additional 4.2 million mandays of employment would be created in producing the additional cassava required.

Table 8. Estimated percentage cost reductions and gross benefits from substituting cassava produce at three technology levels into commercial poultry feed concentrates, in a Colombian industry model.

Cassava substituted into concentrate (%)	Percentage reduction in feed costs, at cassava production of:			Gross benefits (US$ '000) realized by substitution, at cassava production of:		
	12 t/ha	15 t/ha	24 t/ha	12 t/ha	15 t/ha	24 t/ha
10	0.4	1.3	1.9	208	658	973
20	0.7	2.6	3.8	353	1320	1941
43 [1]	1.06	5.5	8.2	808	2795	4151

[1] Economic optimum at all levels of technology.

During 1980 the Tissue Culture section focused on the utilization of meristem culture methods for disease eradication, germplasm conservation and international exchange. Research also continued to refine techniques now used as well as to develop new applications.

Cassava Meristem Culture

The successful regeneration of cassava plants from meristem cultures depends on the interaction of the genotype with the chemical composition of the culture medium (CIAT Ann. Rept. 1978). Under meristem culturing, cassava varieties responded differently in forming shoots and roots simultaneously in a given medium (Fig. 1); most varieties tended to differentiate shoots more consistently than roots. An improved two-step system was devised that permits the regeneration of complete plants regardless of the cassava variety.

The technique is shown in the lower portion of Figure 1. Within 4-5 weeks, every meristem gives rise to three plantlets; thereafter each culture can be multiplied again through nodal cultures by a factor of 5, monthly. Furthermore, every shoot as differentiated on multiple-shoot cultures (CIAT Cassava Progr. 1979 Ann. Rept.) can be multiplied by nodal cultures as well. Over 600 cassava varieties have been processed successfully in this manner.

Disease Eradication

Frog skin disease. The method for cleaning up cassava materials infected with the frog skin disease consists of culturing 0.5-0.6 mm meristem tips excised from stake sprouts grown 3-4 weeks at 40°C (day) and 35°C (night). The effectiveness of the technique was proven by propagating stakes from meristem-derived plants for consecutive cycles in the field. In experiments carried out with 13 cultivars, eight resulted 100% disease-free while five had 82 to 90% disease-free plants at the end of the first cycle; however, all cultivars resulted 100% disease-free after the second cycle of propagation.

Following the success in controlling frog skin disease using the thermotherapy-meristem culture methodology, routine work was begun in 1980 to clean cassava materials from diverse origins. About 300 cultivars were treated, recovered from meristem cultures, potted and handed over to the Cassava Program. Materials included both some infected with frog skin disease, others without apparent infections and collected materials brought to CIAT either as stakes or in meristem cultures.

Grafting studies. The frog skin disease is 100% transmitted downwards through a graft union (CIAT Ann. Rept. 1977). Understanding the extent of its upward transmission could be relevant to studies on the mode of translocation of the causal agent and its dissemination. Using disease-free plants derived from meristem cultures along with their diseased counterparts, reciprocal grafts (i.e., diseased scions onto healthy stocks and *vice versa)* were made with four cassava varieties.

All roots of normal grafts and those of the reciprocal ones (healthy scions onto diseased stocks) showed disease symptoms 3-4 months after grafting. Stem cuttings were made from various heights along the scion of each reciprocal graft, rooted and grown in the greenhouse for three months.

The greatest relative degree of symptoms and the largest number of roots with symptoms were on stem cuttings closest to the graft union; fewest symptoms were observed on cuttings originating at the top of the shoot (Table 1). Surprisingly, when cultivar M Col 721 was the disease-free scion, no symptoms were detected in any plants from its stem cuttings, even though disease symptoms were present when the same clone acted as the stock. This may suggest that structural factors are preventing translocations of the disease upwardly, although it may move downwards freely.

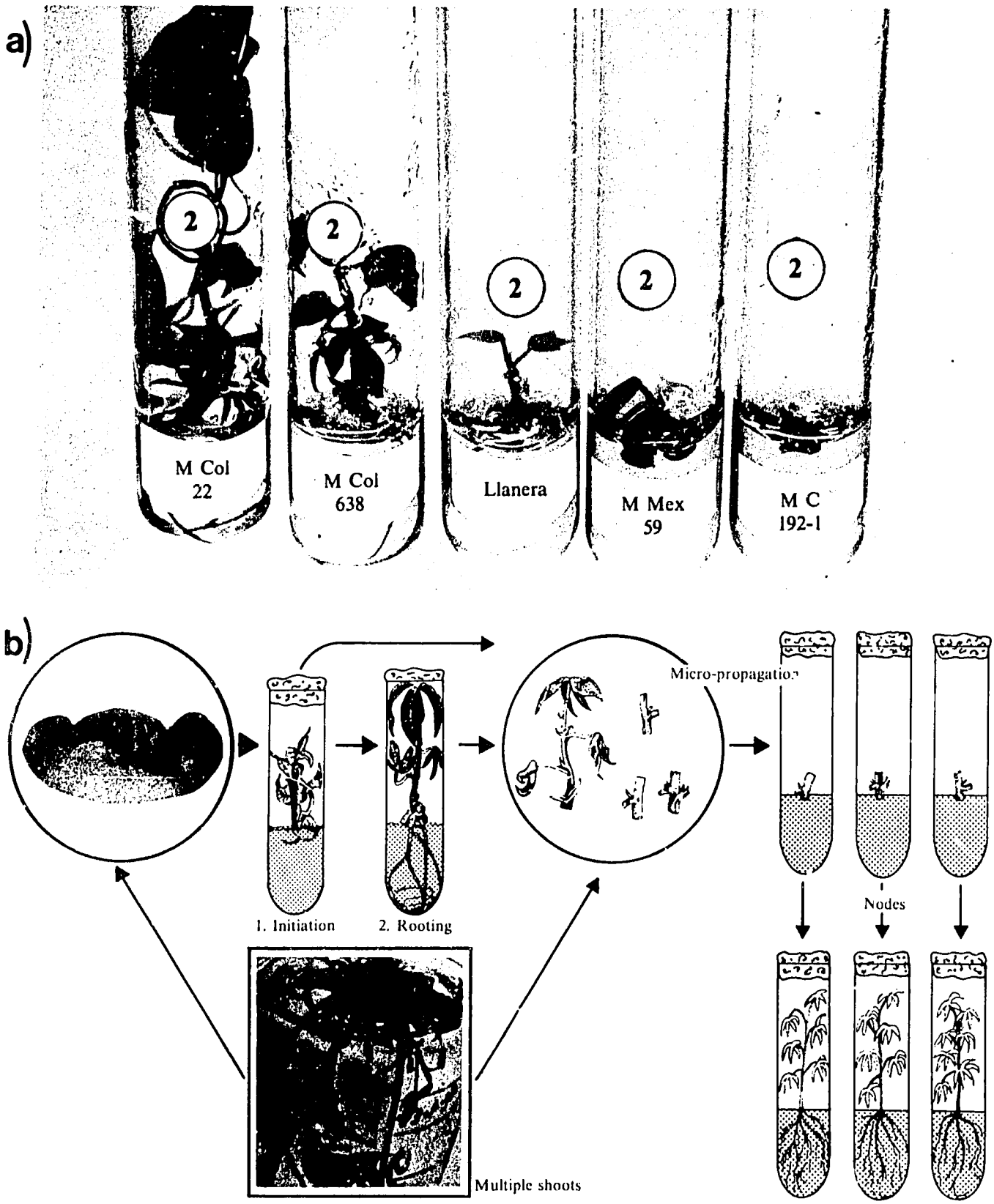


Figure 1. a) *Simultaneous development of shoots and roots in a single medium is influenced by the genotype.*
b) *Two-step technique to regenerate plants from meristem cultures regardless of the cassava variety.*

Table 1. Transmission of the frog skin disease through reciprocal graft unions of various cassava varieties.

Graft [1]		Downward transmission	Upward transmission		
Scion	Stock		Stem cut position [2]	Relative symptoms	No. roots with symptoms [3]
M Col 67(+)	M Col 67(-)	100%			
M Col 67(-)	M Col 67(+)		1	+	2/6
			2	++	2/4
			3	+++	8/8
			4	++++	10/10
M Col 67(+)	M Col 33(-)	100%			
M Col 33(-)	M Col 67(+)		1	+	3/6
			2	+	4/8
			3	++	10/10
			4	+++	8/8
M Col 67(+)	M Col 721(-)	100%			
M Col 721(-)	M Col 67(+)		1	-	0/6
			2	-	0/5
			3	-	0/10
			4	-	0/8
M Col 329(+)	M Col 721(-)	100%			
M Col 721(-)	M Col 329(+)		1	-	0/6
			2	-	0/8
			3	-	0/10
			4	-	0/12

[1] (+) diseased plants, (-) meristem culture-derived, disease-free plants.
[2] Stem cuttings obtained above the graft union from plants showing root symptoms. 1 = top shoot; 4 = shoot closest to graft union.
[3] No. of roots with symptoms / Total no. of roots thicker than 0.5 cm.

Germplasm Conservation

Conditions have been devised to maintain meristem-derived cassava cultures *in vitro* for protracted periods. Objectives are to slow the growth rate of cultures to a minimum while increasing viability to a maximum. The work has demonstrated the importance of storage temperature and illumination, as well as the composition of the culture medium.

Shoot growth rate of meristem cultures was directly related to storage temperature, within the relative limits of 15°-35°C and depending upon the materials. Growth temperatures below 18°C were detrimental to most varieties, especially after 3-5 months of exposure.

The amount of rooting during storage is also important. Rapid rooting shortened the transfer period of the cultures due to deterioration following the oxidation of phenolic-type exudates to the medium from the old roots. Low temperature, which retards shoot growth, tended to promote rooting; high illumination (about 4000 lux) also favored rooting. When illumination was lowered and composition of the culture medium altered by adding a high level of cytokinin and a low concentration of sucrose, not only rooting was delayed, but cultures remained nearly 100% viable so that the transfer period was extended to at least two years.

Therefore, conditions established for the storage of meristem-derived cassava cultures *in vitro* are:

Temperature:	20°-22°C
Illumination:	1000-1500 lux
Photoperiod:	12 hours

Culture medium: Mineral salts of Murashige-Skoog (full strength, with inositol and thiamine-HCL)
low sucrose
high cytokinin
high gibberellin
agar

Type of culture: Nodal cultures and multiple-shoot cultures in 18 x 150 mm test tubes

Transfer period: At least two years.

In order to establish CIAT's cassava germplasm bank *in vitro*, a room (3 m wide x 4 m long x 2.5 m high) was set up this year with the above conditions. The room can store more than 14,000 test tubes of cultures (Fig. 2).

Cassava materials from different sources are being transformed routinely into meristem cultures for storage. Priority for storage is given to materials cleaned of frog skin disease, to clones from the germplasn bank and advanced hybrid lines, and to materials recently introduced to CIAT.

Up to November 1980, materials have been maintained for over two years without replenishing the culture medium; others have been kept for 15-18 months and most varieties maintained for up to one year. Throughout storage, the cultures produce new axillary buds. The average number of axillary buds per variety is directly related to the capability of plant regeneration upon retrieval from storage; thus, it is a measure of the culture's viability. On the average, cassava varieties stored have produced at least three axillary buds during storage periods of 3-24 months, and the variability of response between different varieties is low enough (0.12-0.17 C.V.) so as to provide confidence in the application of the technique.

In order to test whether varietal characteristics of materials have remained stable during long-term storage, cultures have been retrieved every six and 12 months, propagated and transplanted to the field for comparison with stake-propagated materials. In terms of the general growth and morphology of tops and roots, plants stored *in vitro* remained true to type. However, meristem-derived materials showed less variation in yield between plants than did stake-derived ones. This work is continuing.

Figure 2. *Light- and temperature-controlled storage room for cassava meristem-derived cultures* **in vitro**, *in CIAT's Genetic Resources Unit. The room has a capacity of more than 14,000 test tubes, each containing a single plant.*

International Exchange of Germplasm

During 1980, 61 cassava varieties were shipped from CIAT to eight countries as aseptic meristem cultures.

As a follow-up to a training course on cassava meristem culture, 18 varieties were delivered on a trial basis to five Southeast Asian countries. Preliminary results showed that successful use of the method depended mainly on two factors -- the arrival conditions of the cultures, which in turn depend on the lenght of transit, and on the effectiveness of handling the cultures after arrival. Handling success of 45-70% was obtained in the first shipment, prepared and hand-carried by the trainees themselves; later shipments to Thailand and Malaysia were handled with greater success (85-95%), as estimated from information provided from trainees (Table 2). Although some cultures arrived showing deterioration due to etiolation and phenolic-type browning in protracted darkness — from air mail shipments of 25-30 days — these gave rise to plants after proper handling.

Another 43 cassava varieties sent in a total of nine shipments to Brazil, Costa Rica and the United States all arrived in good condition after both hand-carried and air-mailed trips of 3-12 days.

In order to minimize the detrimental effects of long trips on cultures, work is being conducted for conditioning the materials to stand long periods of darkness without irreversible damage, as well as to implement rapid propagation methods of recovered materials after their distribution from CIAT. A multiplication technique that utilizes single leaf-bud cuttings, developed in the Philippines, is being adapted to conditions at CIAT, to rapidly build up materials from importation of a few cultures (see discussion in Agronomy section).

Because of their disease-free condition, meristem cultures can be utilized not only to distribute cassava materials from CIAT to other countries, but to enrich CIAT's germplasm bank with new introductions. This method of germplasm transfer provides adequate safeguards to minimize the risks of disease dissemination existing when cassava stakes are moved.

The transfer to Colombia of cassava collections from Peru and Brazil has been prevented previously due to the presence of coffee rust in those countries. Under arrangements made with the Colombian plant health authorities, nearly 200 cassava varieties, as aseptic meristem cultures, have been introduced to CIAT in December 1979 and October 1980, from Peru and Brazil, respectively (Fig. 3).

Table 2. Distribution of cassava materials as meristem cultures from CIAT to various locations in Southeast Asia.

Destination	Method of shipment	No. tubes/ No. varieties	Trip duration (days)	Condition of cultures upon arrival	Tubes handled successfully after arrival (%) [1]	
					recovery	propagation
Thailand	1. hand-carried [2]	16/8	10	good	65	75
	2. air-mailed	8/4	30	etiolated, brown	85	85
	3. hand-carried	4/2	8	good	90	-
Malaysia	1. hand-carried [2]	18/9	7	good	70	70
	2. air-mailed to Kew					
	Gardens, UK; Kew	10/2	10	good		
	Gardens to Malaysia	10/2	15	etiolated	95	-
Philippines	1. hand-carried [2]	8/8	8	good	45	80
	2. air-mailed	4/2	25	etiolated, brown	50	-
Sri Lanka	1. hand-carried [2]	9/9	8	pale green	60	-
Indonesia	1. hand-carried [2]	8/8	10	pale green	70	-

[1] Estimated on the basis of information received from trainees.
[2] Cultures prepared and carried by trainees attending course at CIAT, November 1979.

Figure 3. *A) More than 130 varieties of cassava were brought to CIAT from Brazil in this single package (45 x 25 x 22 cm). B) Plants derived from meristem cultures brought from Peru are maintained under quarantine in this greenhouse before incorporation into CIAT's germplasm bank.*

Other Tissue Culture Systems in Cassava

Anther culture. The microspores, being the direct product of meiosis, are haploid cells which under appropriate conditions can be shifted to perform an entirely new role, namely, the development of tissues and plants instead of the male gametes. The number of species which have yielded to androgenesis is considerable; however, no results have been obtained with cassava as yet. Under a training scholarship, work has been initiated at CIAT in anther culture of cassava. So far, a strong varietal influence was observed in the development of macroscopic structures (i.e., callus cells) in anther cultures as a response to the factors of the medium. Work is underway to ascertain the conditions conducive to organogenesis in anther-derived callus cultures. Although the techniques are still in their infancy, the incorporation of haploids into specific cassava breeding programs could be useful since genes in these materials segregate in gametic rather than zygotic proportions and could be linked to somatic fusion and operate in conjunction with conventional breeding. A possible practical use of haploids may be the production of hybrid cassava seed.

Protoplast cell cultures[1]. The ability to regenerate plants from individual cells now exists for a limited number of species. This new techonology can assist in the identification, assembly, recombination and selection of novel forms of genetic variability.

With the support of a grant from the Rockefeller Foundation to Dr. J. Shepard, work was done at Kansas State University, Kansas, U.S.A., by Drs. E. Shahin and D. Bidney which involves the enzymatic isolation of large numbers of cassava leaf cells without their walls, called protoplasts, followed by the incubation of these protoplasts in a medium of complex formulation. The protoplasts will undergo a series of cell divisions to form multicellular colonies and unorganized callus tissue. By the implementation of several more media, shoot development has occasionally been observed. Work is currently underway to define the proper conditions for routine single cell regeneration techniques.

Similar work, though on a limited scale, was also initiated by Dr. R. Litz at the Agricultural and Research Center, University of Florida, Homestead, U.S.A.

Using callus cultures induced on various type of tissues, Drs. G. G. Henshaw and J. Stamp are working under a grant from the British ODM, at the University of Birmingham, England. Here, attention is paid to those cultural conditions which favor the development of meristematic "nodules" in the callus mass. Further work will place emphasis on the use of embryonic tissues and sequential culture regimes.

CIAT has provided selected materials for use in the studies referred to above.

Freeze preservation[1]. Research continued at Saskatoon, Canada (Dr. K. Kartha) and Birmingham, England (Drs. G.G. Henshaw and J. O'Hara) to store cassava meristems in liquid nitrogen (-196°C). In both laboratories, meristem cultures subjected to an array of freeze-thaw protocols have showed low survival with callus formation, but no organogenesis has been obtained from the callus cells as yet.

[1] This work, although not carried out at CIAT, is reported here because it directly relates to tissue culture work done at CIAT. The Center collaborates with these efforts by providing selected materials and by discussing with the authors of this work the orientation and methodology of the research.

Training at CIAT

The Cassava Program's training activities played an important role in the substantial progress achieved this year in Latin America and Asia. Several countries of Oceania are developing more positive links with CIAT in cassava research and transfer of technology, with the assistance of the United Nations Development Programme (UNDP) for the South Pacific islands.

In cooperation with CIAT's Training Office, the Cassava Program trained 38 professionals from 15 countries at CIAT in 1980. Participants came from the following countries: Brazil and Colombia, 8 trainees each; Mexico, Bolivia and the United States, 3 each; Thailand, the Dominican Republic and South Africa, 2 each; Ecuador, Haiti, Honduras, West Germany, the Netherlands, Great Britain and Italy, 1 each. The 21 students from 6 Latin American countries attending the 1980 intensive special training course are included in these figures.

Activities in Latin America

Several Latin American countries, including Brazil, Cuba, the Dominican Republic, Ecuador, Haiti, Honduras, Mexico and Paraguay, were visited by Program scientists to follow up the development of national cassava programs and to strengthen cooperation. More emphasis has been given to visiting countries without established cassava programs that have good possibilities of starting programs. While other new national programs for cassava continue to develop, the cases of Cuba and Ecuador illustrate how these typically came about.

Cuba. Of particular interest was the eight-day visit to the Cuban Cassava Research Center (Centro de Mejoramiento de Semillas Agámicas - CEMSA), located at Santo Domingo, Villa Clara province. Before establishing a cassava program four years ago, Cuba had a national average cassava yield of 7 t/ha per year. The country has made tremendous progress; provisional estimates suggest that average production has increased to 25 t/ha per year over large areas. The way this happened was simple.

Three cassava researchers trained at CIAT validated and adapted the technology recommended for Cuba. Two outstanding Cuban varieties were selected for testing under CIAT technology; results were so good that officials decided to promote the improvements over the whole country. Groups of agronomists from the 1900 state agricultural enterprises were trained during three-day sessions at CEMSA.

The basic technology they were taught included:

a) Good soil preparation with construction of ridges taller than those used for sugarcane;

b) selection and treatment of 30-cm stakes from the basal part of mature plants, to reduce the problem of CBB;

c) planting vertically on top of the ridges;

d) timely weed control; and

e) reduced irrigation.

Before the training, Cuban farmers had planted short stakes horizontally on the bottom of small ridges and irrigated heavily.

The Cuban experience reflects the fact that simple technology can make an impact if it is properly conveyed to farmers.

Ecuador. Based on the agro-economic description of cassava by Luzuriaga in 1975, indicating that Ecuadorian cassava yield was low (10t/ha), the CIAT Cassava Program started cooperation with this country by setting up an international cooperative trial at Pichilingue Experiment Station near Quevedo. This trial, planted with promising material, has completed four cropping cycles.

The Pichilingue trial and those planted in other cassava-growing regions by the National Agricultural Research Institute (Instituto Nacional de Investigaciones Agropecuarias—INIAP) have served to measure the potential yield of the selected germplasm. Using improved agronomic practices, yields of promising material have surpassed those of local varieties. This led INIAP directors to launch a formal cassava program this year. This was the result of INIAP's interest and desire to offer a cheaper source of carbohydrates to the poultry and swine industries and to have cheaper commercial starch.

CIAT's Cassava Program will continue to assist the organization and development of this new program.

Cultural practices workshop. A great amount of research has been done on cultural practices for cassava production in different environments. To consolidate existing information into one document for use by national cassava programs in developing further research, research priorities and technology transfer, a Cassava Cultural Practices Workshop was held in Salvador, Brazil, March 18-21, 1980. The workshop was sponsored by the International Development Research Centre (IDRC) and organized by the Empresa Brasilera de Pesquisa Agropecuária (EMBRAPA), CIAT and IDRC. Thirty-five cassava scientists from i4 countries participated.

Within-country training. CIAT has assisted in training personnel within those countries having strong national cassava research programs linked to a well developed extension program and those having the goal of increasing national cassava production. Short intensive courses were given this year in Mexico and the Dominican Republic.

In the Mexican course, organized bv the Secretaría de Agricultura y Recursos Hidráulicos (SARH), the Instituto Nacional de Investigación Agropecuaria (INIA) and CIAT, 11 researchers, 8 extension workers and 1 farmer were trained. The course in the Dominican Republic, organized by the Centro Norte de Desarrollo Agropecuario (CENDA) with CIAT cooperation, trained 1 researcher and 24 extension agents. Extension participants were important components of both courses because these countries realize that the generation of technology must be linked closely to an effective transfer of technology to the client farmers who are the ultimate users. These two courses focused on field practices.

This type of training may prove to be a very appropriate method to more quickly reach a larger critical mass.

Activities in Asia

This continent, excluding the Republic of China, has one-fourth of the world's population and produces 36% of the world's cassava, mostly in Thailand, India and Indonesia. These countries and Malaysia, the Philippines and Sri Lanka are paying considerable attention to strengthening research capabilities in cassava production systems.

Of the 316 persons receiving cassava training from CIAT to date, 70 have been Asians. The 70 included 24 from Thailand, 13 from Malaysia, 12 from Indonesia, 11 from the Philippines, 5 from India, 4 from Sri Lanka and 1 from Japan.

Seven CIAT cassava scientists visited five Asian countries during 1980 to become acquainted with Asian cassava production, research and extension, to formulate new approaches for program development and to teach in the First Asian Training Course.

First Asian cassava course. With the participation of six CIAT cassava staff including the outposted staff member for Asia and members of Asian national programs, the First Asian International Training Course on Cassava Production was held at Visayas State College of Agriculture (VISCA), Baybay, and South East Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Los Baños, the Philippines. This course was organized by CIAT and financed by IDRC. The June 2-30 course was attended by 24 professionals; 6 each from Thailand, the Philippines and Indonesia; and 3 each from Malaysia and Sri Lanka.

Activities in Oceania

Although this continent produces only 0.2% of the world's cassava, the UNDP established a Root Crops Project two years ago, with headquarters in Apia, Western Samoa. The project leader had received training at CIAT earlier. The main interest in increasing cassava production is its use for animal feed, starch extraction and alcohol fuel. In this region, cassava is used only to a limited extent for human food because the sweet potato, taro and yams are the major staple root crops.

Two CIAT cassava scientists visited the project this year and offered to assist with the training course next June.

Adoption of Selected Germplasm

Table 1 shows the cassava varieties and hybrids selected and distributed by CIAT that are now or soon will be in commercial production. It is noteworthy that seven hybrid lines from CIAT's breeding program have been adopted in eight countries.

Table 1. *Cassava varieties and hybrids selected and distributed by CIAT and now being planted commercially or being multiplied for commercial use.*[1]

Countries	M Col 1468	M Col 1684	M Mex 59	M Col 22	M Ven 218	M Pan 51	SM1-150	CM 309 165	CM 323 375	CM 308 197	CM 192 1	CM 407 7	CM 305 13
Brazil	*	**											
Colombia	*	*		*									
Cuba	*												
Dominican Republic	*	*											
Ecuador	*	*		*									
Honduras		*	*						*				
Mexico			*			*		*					
Venezuela	*	*			*		*			*	*		
Australia			*		*		*						
Philippines		*											
Thailand												**	**

[1] * Planted commercially; ** under multiplication.

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* Left during 1979
** Assigned to Training and Conferences.