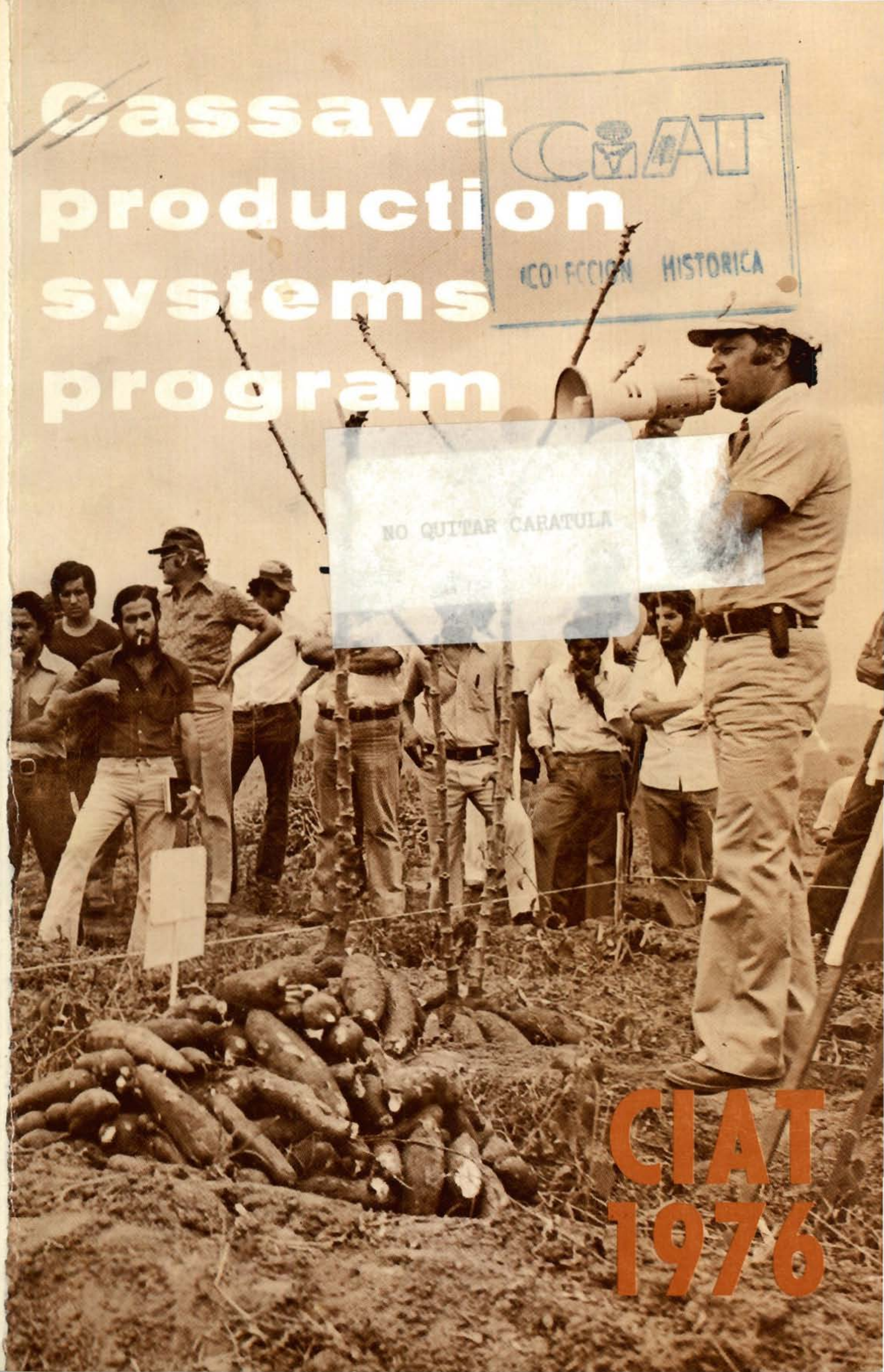
Cassava production systems program



CIAT
1976

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out on several of its experimental stations and similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research. During 1976 these donors were the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the W.K. Kellogg Foundation, the Canadian International Development Agency (CIDA), the International Bank for Reconstruction and Development (IBRD) through the International Development Association (IDA), the Inter-American Development Bank (IDB) and the governments of Australia, Belgium, the Federal Republic of Germany, the Netherlands, Switzerland and the United Kingdom. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada and the International Board for Plant Genetic Resources (IBGPR). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

Cassava production systems program

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Cables CINATROP

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* Left during 1976
** Assigned to more than one program.

CONTENTS

Climatic and edaphological data for locations where CIAT's Cassava Program has done research work in 1976

(Most research projects were carried out with the cooperation of ICA)

Locations*	Altitude (meters above sea level)	Mean temperature (0C)	Rainfall (mm|year)	Organic matter (%)	pH	P (Bray II) (ppm)	K (meq|100 g)	Soil texture
CIAT, Palmira (Valle)	1,000	24	1,000	6.8	6.9	46.3	0.44	Clay
Carimagua (Meta)	200	27	2,031	4.3	4.7	1.6	0.08	Clay loam
Turipaná (Córdoba)	13	28	1,200	3.1	6.8	13.0	0.68	Clay
Loboguerrero (Valle)				4.6	7.3	35.0	0.85	Sand loam
Caicedonia (Valle)	1,000	22.5	1,900	5.3	5.5	70.0	0.68	Silt loam
Media Luna (Magdalena)	10	27.2	1,486	0.65	6.3	8.2	0.056	Sand
Nataima (Tolima)	430	27.8	1,479	1.30	6.2	24.7	0.22	Sand
Villavicencio (Meta)	450	26.3	4,306	2.80	4.3	4.22	0.08	Clay loam
Florencia (Caquetá)	450	25.0	3,475	2.30	5.5	18.9	0.19	Sand loam
El Nus (Antioquia)	847	23.7	1,875	2.80	5.0	4.3	0.11	Loam
Rio Negro (Santander del Sur)	480	26.6	1,594	1.50	5.1	3.9	0.16	Silt loam
La Zapata (Valle)	1,100	22.7	1,219	6.77	5.2	5.03	0.14	Clay loam
El Darién (Valle)	1,450	19.5	1,500	15	5.1	1.9	0.14	Silt loam
Pereira (Risaralda)	1,480	19.0	2,000	8.25	5.13	8.28	0.08	Clay loam
Popayán (Cauca)	1,760	18.0	2,500	7.56	5.00	2.40	0.44	Clay loam
La Unión (Nariño)	1,800	17.0	1,844	12.25	5.7	6.13	0.43	Clay loam
(Quilcacé) (Cauca)	920	28.00	2,250	6.0	5.3	2.5	0.33	
Boliche**	17	26.0	1,200		6.8			

* These locations are all found in Colombia; the name of the corresponding departamento is given in parentheses. There are no data for the Caribia station, located in the Departamento del Magdalena, where research was conducted in 1975 to evaluate new cassava progenies.

** The Boliche Experimental Station is located in the Province of Guayas, Ecuador.

Cassava production systems program

HIGHLIGHTS IN 1976

The development of many aspects of cassava production technology has now reached the stage when it can be used by farmers with only minor changes to adapt it to regional conditions. Although major emphasis is placed on development of new technology more emphasis than before has been placed in training and cooperative projects with agencies from other countries.

The ideal plant phenotype for cassava production appears to be similar for different temperature zones, however, when average temperature is below about 22ºC special genotypes are needed.

The spider mites that attack cassava can cause severe yield reductions in areas with long dry seasons. Low to intermediate levels of resistance, depending on the mite species, have been found. Efficient biological control methods for the hornworm are being tested on farmers fields and this system seems to be highly effective.

The "Frog Skin" disease of cassava was shown to reduce yields considerably, however, it can easily be controlled by selection of healthy planting material. Superelongation disease causes extreme yield losses when attacks occur early in the growth cycle. However, planting material can be disinfected by stake fungicide treatments, delaying the onset of the attack. This treatment coupled with tolerant varieties should greatly reduce yield losses.

In order to combine high yielding ability with desirable characters such as disease and pest resistance, ease of harvest, high starch content and long post-harvest shelf life, tens of thousands of hybrids have been made and evaluated. The variety M Col 1684 has exceptional stability with high yields of over 50 t/ha in CIAT, 44 t/ha in Caribia and 36 t/ha in Carimagua. These zones have pH's ranging from 4.5-7.8, mean temperatures from 24-28ºC and vary from extremely low fertility to very fertile. It is therefore feasible to obtain broadly adapted high-yielding types.

what are they

The yield of over 36 t/ha with low levels of fertilizer input in Carimagua confirms cassava's ability to grow on poor acid soils which are generally underutilized. Good yields (more than 20 t/ha) were obtained on these soils with moderate levels of fertilizer input in several trials.

In other areas selected lines have consistently outyielded local lines by 75 percent with extremely low input levels. The local lines yielded 16 t/ha—about double the national average—due to improved selection of planting material and good cultural practices, suggesting that average yields can be increased to this level by optimizing plant population and level of inputs such as weed control.

The agro-economic study shows that cassava is frequently produced in associated cropping systems which can reduce average yields by about 30 percent. The basic response of cassava in competition with beans is being studied to design more efficient associations.

not a relevant system

The development of new production technologies makes it essential that post-harvest handling for the increased production also be improved. Natural drying methods are being developed which appear to improve efficiency over traditional methods by using a modified Malaysian chipper followed by drying on inclined trays.

The movement of new technology to other countries is based on cooperation with national agencies through (1) training, (2) technical advice, (3) germplasm exchange and (4) conferences. The cassava Program was active in each aspect during the year.

A short intensive cassava production course was held at CIAT for 32 agronomists from nine Latin American countries. More than 60 percent of the course was devoted to practical aspects of production including on-site evaluations of production methods used by farmers in different zones of Colombia.

Furthermore, long-term training in research is given to students from Latin America, Africa and Asia. Groups are invited from each country and trained so that they can return to form an effective research team. Eight Mexicans and three Thais are now forming multidisciplinary research teams in their respective countries. Similar training plans are in progress with Brazil and Malaya. Seven of eight professionals at the recently formed Cassava Center in Brazil have received some training at CIAT.

Both the Mexican and Brazilian cassava research and development programs requested technical advice on research and production strategies and CIAT staff has responded to these requests. Similarly, the Indian and Malaysian programs are in close contact with CIAT and their program directors visited CIAT for short periods in 1976.

Most national programs have not been in progress long enough to develop their own genetically superior material and breeding programs. As a result CIAT sent seeds and planting material to 28 countries this year. Regional trials using CIAT and local varieties are being established in Guyana, Mexico, Brazil, Venezuela and Ecuador. The only trial already harvested showed a CIAT line to be the highest yielder of both fresh roots and starch.

Germplasm movement details and the methodology of the international yield trials were determined in a special workshop held in 1975. Cassava researchers from all over the world had the chance to meet and discuss common problems at IV Symposium of the International Tropical Root and Tuber Crops Society held at CIAT in August 1976.

PHYSIOLOGY

Introduction

The factors controlling leaf area development and maintenance so as to define and ideal plant type as well as the existence of an optimum leaf area index (LAI) of about 3 were presented in CIAT's 1975 Annual Report. This year these results have been confirmed and used to construct a plant ideotype. In addition, relations between source and sink have been further studied.

In previous years results have been presented mainly for CIAT conditions; this year responses of different clones have been observed under different temperature regimes to better understand the mechanism of temperature adaptation. The effects of different photoperiods have also been investigated. Work has also been initiated on varietal differences in photosynthetic rate to see if new yield levels can eventually be reached.

Since the understanding of the crop in monoculture is well-developed, emphasis is now being placed on designing efficient mixed cropping systems, which comprise a major part of the world's cassava production.

Leaf Area Development

In 1975 it was shown that in three varieties leaf size reached a maximum about four months after planting and then declined. This was confirmed for ten varieties all of which showed the same trend, irrespective of branching habit. It was also suggested last year that leaf formation rate per apex showed little genetic variability. However, this year one variety, M Col 1120, showed a consistently greater leaf formation rate than nine other varieties. Leaf formation patterns of four of these varieties are shown in Figure 1.

Leaf life was also measured on ten varieties and large varietal differences were observed; leaf lives of three are shown in Figure 2. It is interesting to note that these varietal characteristics were maintained throughout a prolonged dry spell and that maximum leaf life recorded was 18 weeks in M Col 72. The longest and shortest leaf lives were in M Col 72 and M Col 1120, respectively; neither variety produces branches suggesting that leaf life is independent of branching habit.

Leaf life is a varietal characteristic; the differences being maintained even under

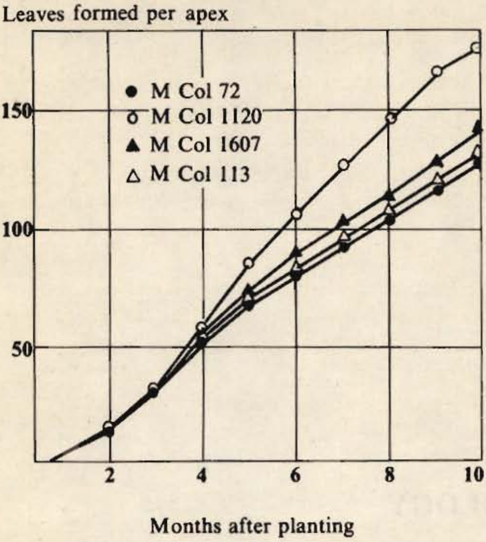


Figure 1. Leaf formation per apex of four cassava varieties.

dry conditions. Leaf formation rate per apex shows little genetic variability but one variety with a substantially higher rate than that previously found was identified. Rate of leaf formation declines as plants grow older in all varieties.

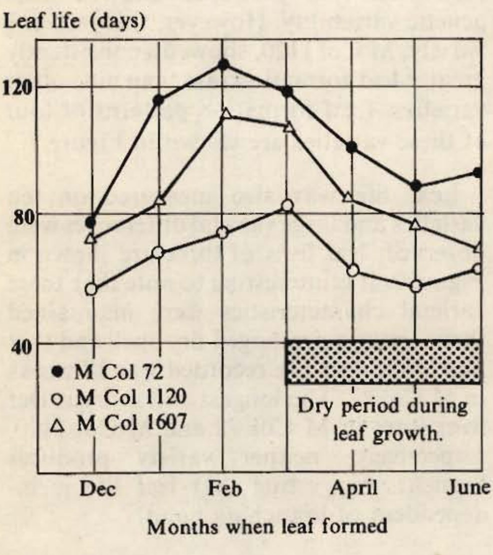


Figure 2. Leaf life of three selected cassava varieties.

Relation between LAI and Yield

LAI of M Col 113 increased rapidly after planting reaching a value of more than 5 after six months, after which it declined until the final harvest at 15 months. In CMC 84 and M Mex 11, LAI reached a maximum after four months of 4 and 2.9 repectively, and then declined (Fig. 3). M Col 113 reached its maximum rate of root bulking (7.6 g dry matter/m^2/day) during the period of 9-12 months when its leaf area index showed little change and was equal to about 3 (Figs. 3 and 4). During this same period both CMC 84 and M Mex 11 were increasing their leaf area index and although total dry matter weight increased (Fig. 5) root weight showed a very small increase. This trend is particularly noticeable in M Mex 11 where total dry weight increased by 515 g/m^2 while root weight only increased by 125 g/m^2 but LAI increased from 0.9 to 2.7. When a high LAI is maintained, as in M Col 113, from 4-9 months root weight increase is small as all available carbohydrate is directed to formation of leaf and stem. Also, when LAI increases rapidly as in M Mex 11 from 9-12 months, there is little root weight increase. These data demonstrate the balance between root production and stem production.

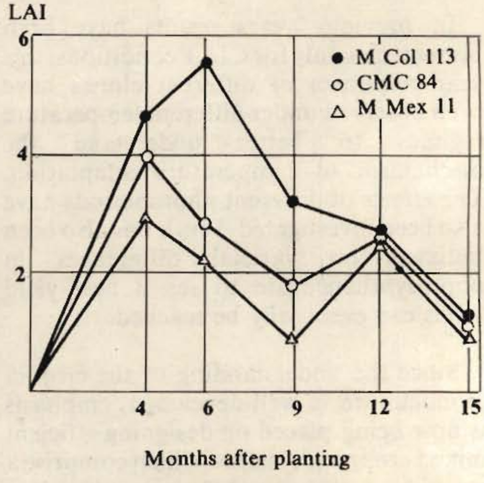


Figure 3. Development of LAI of three cassava varieties.

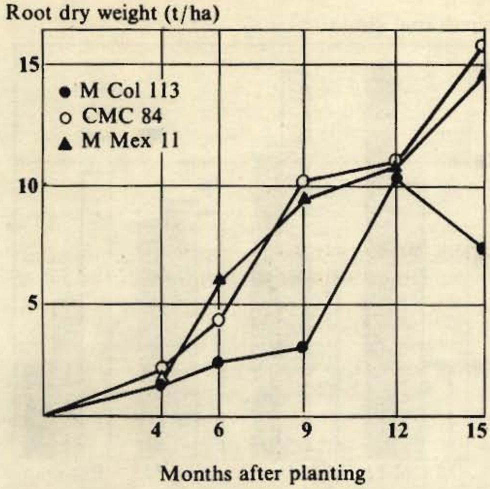


Figure 4. Changes in dry root yield of three cassava varieties.

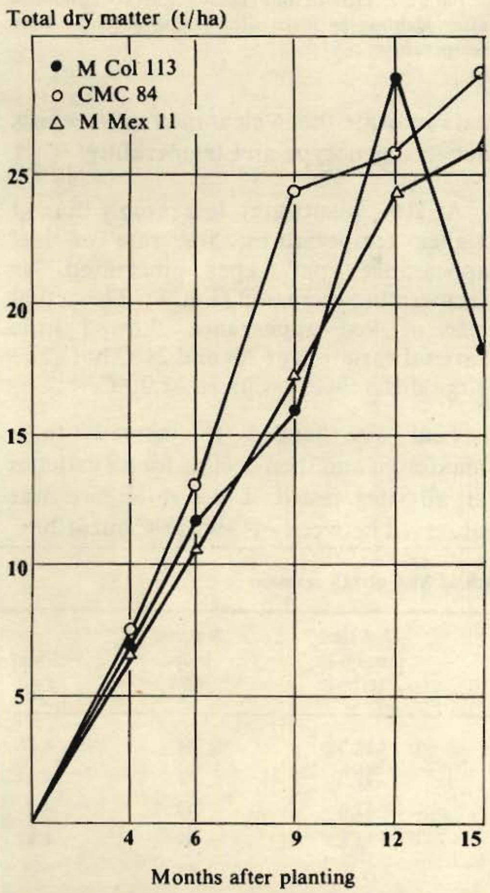


Figure 5. Changes in total harvestable dry matter of three cassava varieties.

In results in 1975, the optimum LAI for root growth of M Col 113 was determined as 3-3.5. Data collected this year using three varieties show the same tendency for an optimum LAI of about 3 during the period 4-9 months after planting (Fig. 6). The data for 9-15 months showed the same trend with rather large experimental error due to the unexplained decrease in root weight on M Col 113 from 12-15 months. This confirms that the optimum LAI for cassava is about 3 and that when this is maintained yields will be maximized. When LAI is increasing rapidly, root growth is reduced even though LAI may be optimal.

M Col 113 tends to have excessive LAI during much of its growth cycle leaving little carbohydrate available for the roots, and reducing leaf life by shading. When plants were five months old branch apices were cut so as to reduce the leaf production. The treatments were such that total number of active apices were reduced by 0, 25, 50 and 75 percent. This treatment significantly increased yield from 33 t/ha 10 months after planting to 41 t/ha when active apex number was reduced by 75 percent.

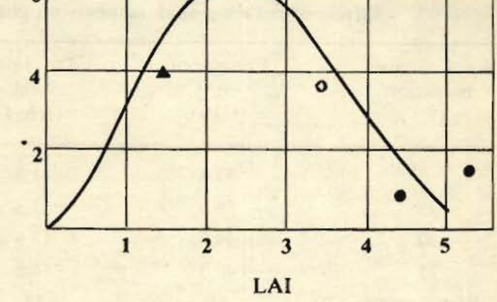


Figure 6. Changes in root dry weight as related to mean LAI 4-6 and 6-9 months after planting.

The final LAI was not reduced by this treatment as leaf life was increased. Total dry matter production was not significantly reduced by the treatments but harvest index was markedly increased to give the higher yield (Table 1). Hence control of branching habit appears to be a useful means of controlling LAI, and by breeding for the ideal branching pattern yields can be increased.

Temperature Effects on Cassava Growth

Four varieties of low, medium, high and very high vigor (M Col 22, M Col 113, M Mex 59 and Popayan, respectively) were planted in three sites; one a short distance from CIAT (called Km 27), CIAT and Caribia with mean temperatures of 20°, 24°, and 28°C, respectively. All plots received 300 kg/ha NPK so as to give a high fertility level in all sites. Phoma leaf spot is normally a problem in cooler areas and fungicidal applications were used in Km 27 to control this disease.

At Caribia, a high temperature environment, M Col 22, gave the highest yield followed by M Mex 59 and M Col 113 with Popayan yielding by far the lowest (Fig. 7). However, at Km 27, a low temperature environment, Popayan gave the highest yield and M Col 22, the lowest. The results at CIAT fell somewhere between the two extreme locations but showed more similarity to Caribia than to Km 27. The data indicate that a clear interaction exists between genotype and temperature.

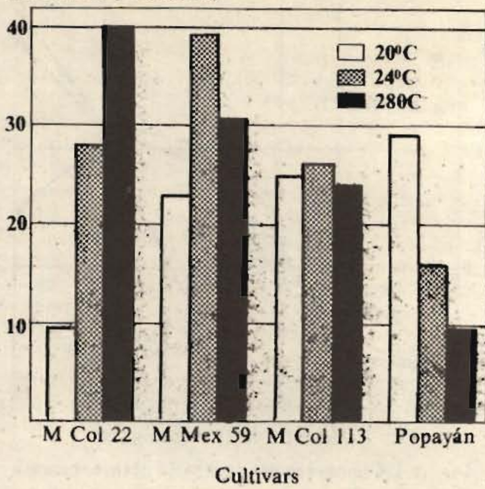


Figure 7. **Yield of four cassava cultivars 12 months after planting at three sites having different mean temperatures.**

At 20°C plants grew less rapidly than at higher temperatures; the rate of leaf appearance per apex increased as temperature increased (Fig. 8). The actual rate of leaf appearance showed little varietal variation at 28° and 24°C but quite large differences occurred at 20°C.

Leaf size tended to increase to a maximum and then decline for all varieties at all sites tested. Little difference was observed between 24° and 28°C but at 20°C

Table 1. **Effects of reducing apex numbers on growth of M Col 113 cassava.**

Apex number reduction (%)	Fresh root yield (t/ha)	Dry root yield (t/ha)	Dry stem weight (t/ha)	Harvest index (%)	Final LAI
0	33.6	11.3	12.5	44	4.86
25	38.5	13.3	12.7	47	4.44
50	39.7	13.6	12.0	49	4.28
75	40.3	14.0	11.8	49	4.92
Significant differences	**	**	N.S.	**	N.S

** Means a significant difference at the .01 significance level.

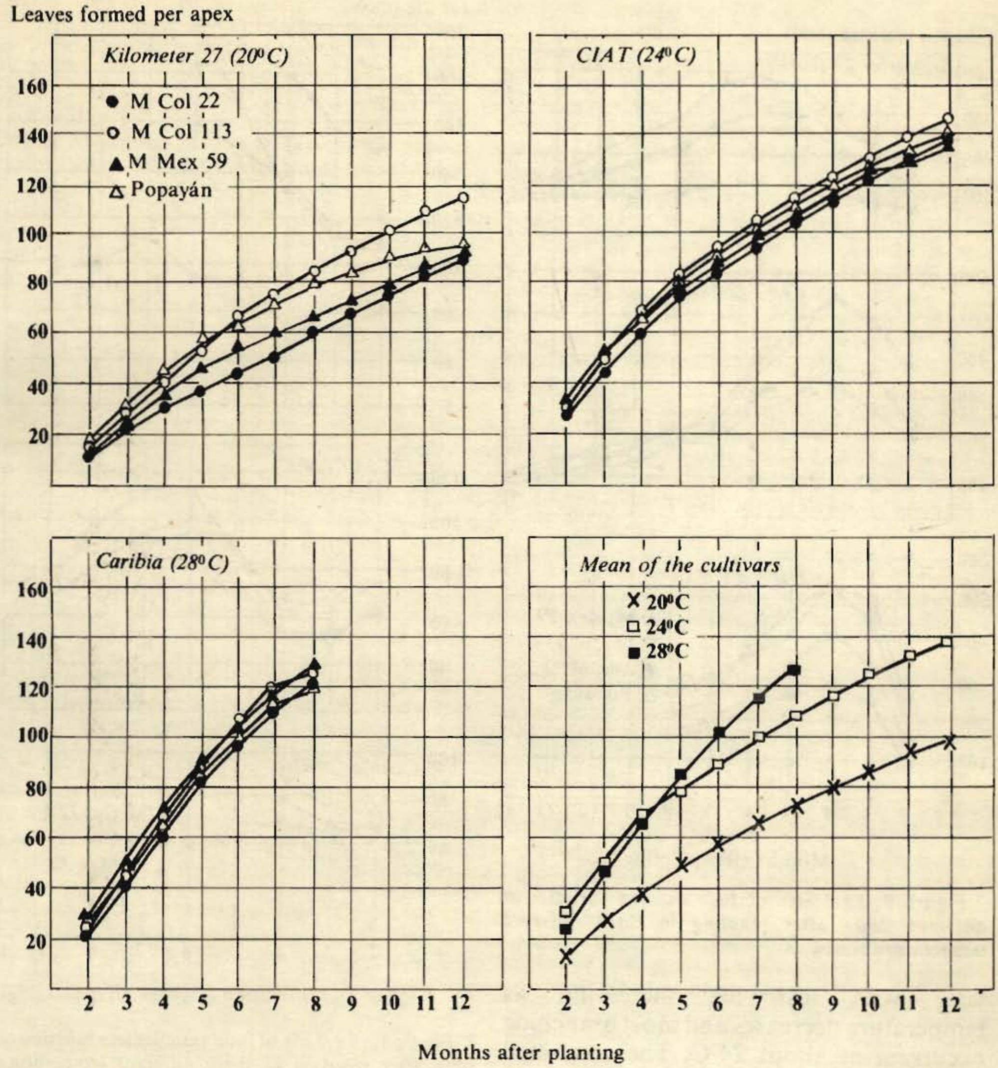


Figure 8. Total leaves produced per apex by four cassava varieties at three temperature zones.

maximum leaf size was reached later and was smaller (Fig. 9).

Although leaf size and leaf formation rate were smaller at lower temperatures, leaf life was markedly increased in all varieties (Fig. 10). At 20°C leaf lives of up to 200 days were recorded whereas at 24°C and 28°C maxima of 115 and 90 days respectively were observed.

The number of functional branches per plant did not show a consistent trend with temperature. M Col 22 and M Col 113 produced the same number of branches at 28° and 24°C and fewer at 20°C whereas Popayan and M Mex 59 peaked at 24°C, suggesting that maximum branch production occurs at about 24°C (Fig. 11).

In summary, leaf formation rate per apex and maximum leaf size increase as temperature increases while at lower temperatures maximum leaf size is reached

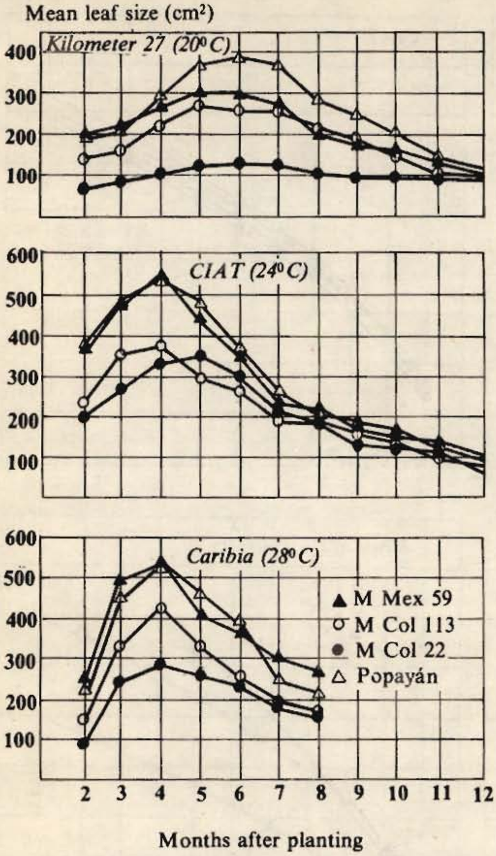


Figure 9. Leaf size of four cassava varieties at different times after planting in three different temperature zones.

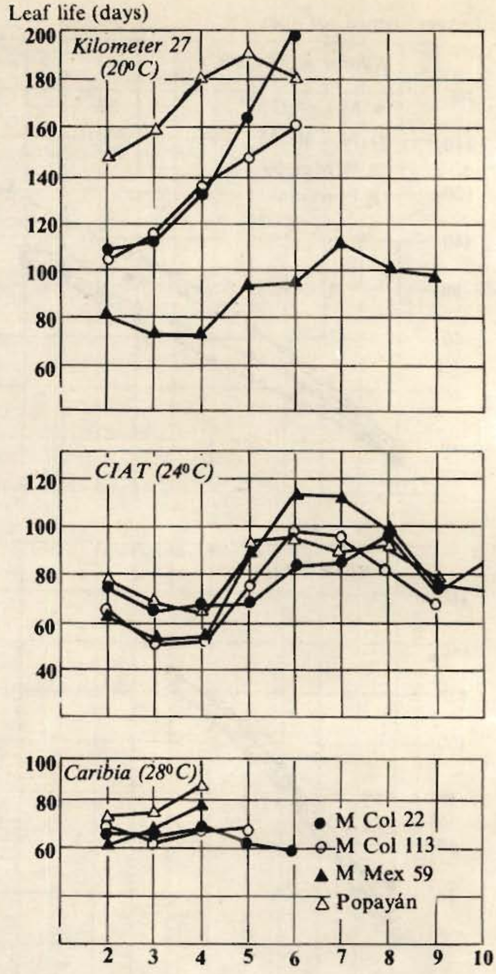


Figure 10. Leaf life of four varieties as a function of time after planting in three different temperature zones.

later with leaf life increasing as temperature decreases and most branching occurring at about 24°C. The combined effect of these factors on LAI is shown in (Fig. 12). As temperature increases LAI increases, except in the case of M Mex 59 where less branching and short leaf life at higher temperatures reduced LAI.

Analyzing the LAI at the most crucial period of yield formation (8-12 months), M Col 22 had an LAI nearest to the previously determined optimum LAI of 3 at Caribia, while all the others had LAI's far exceeding 3 (Fig. 12). At Km 27, Popayan maintained an LAI of nearly 3 during the 8-12 month period while the others failed to reach the LAI of 3. The relation between root growth rate and mean LAI (Fig. 13) suggests that the optimum LAI of 3-3.5 is valid over a wide range of temperatures and that the varietal interaction with different temperatures is demonstrated primarily through effects on leaf area formation under different temperatures.

Source-Sink Relations

Previous results on the effects of the root sink capacity on both yield and total dry

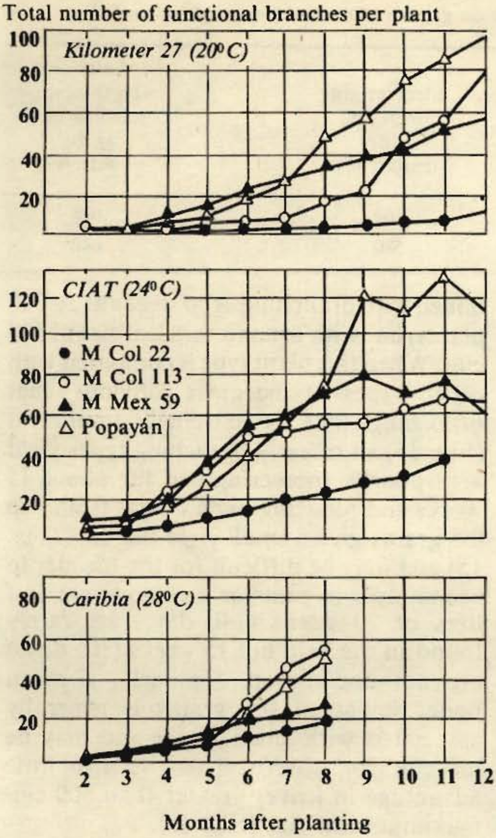


Figure 11. Total number of functional branches per plant of four cassava varieties at three different temperature zones.

matter production were somewhat equivocal (CIAT Annual Report, 1974). This year two varieties, M Col 22 and CMC 84, were girdled at five months after planting and harvested three and a half months later. No variety by treatment interactions were observed and data are presented as the mean for the two varieties. Root weight showed no significant increase in the treated plants, as would be expected, but increased in the controls (Table 2). LAI and area per leaf were not affected by the girdling treatment. Stem weight was, however, markedly affected by the treatment increasing from 0.4 kg/plant in the controls to 0.7 kg/plant in the treated plants (Table 2). The total dry weight of the plants was not affected

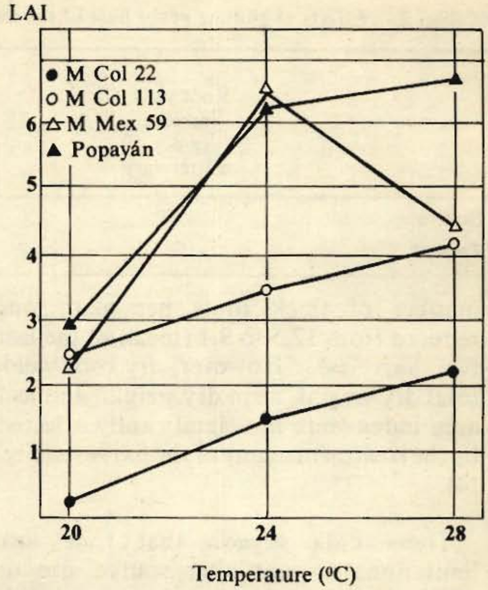


Figure 12. LAI of four cassava varieties eight months after planting at different temperatures.

suggesting that reducing the root sink does not affect the efficiency of the source nor its size. Elimination of the root sink does, however, cause more carbohydrate to be stored in the stem.

M Col 22 was grown in the field and three months after planting six roots per plant were cut. Harvests were taken at 3, 6, and 12 months after planting. The total

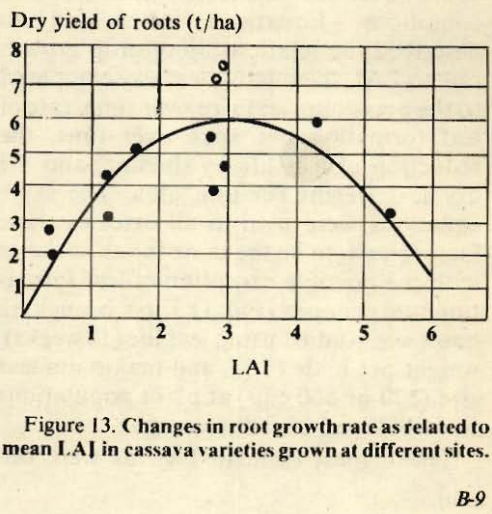


Figure 13. Changes in root growth rate as related to mean LAI in cassava varieties grown at different sites.

Table 2. **Effects of girdling at the base of the stem on growth of cassava (mean of two varieties).**

	Root yield increase (g dry matter/m²)	Stem weight increase (g dry matter/m²)	Total dry weight increase excluding leaves (g dry matter/m²)
Control	456	162	618
Treated	60	580	640

number of thick roots per plant was reduced from 12.5 to 9.1 (mean of the last two harvests). However, dry root yield, total dry weight, stem dry weight, and leaf area index were not significantly affected by the treatment at any of the harvests (Fig. 14).

These data suggest that root sink limitations do not alter source size or efficiency and that when root number is reduced to nine roots per plant their capacity to expand is greater than the carbohydrates available but when the root sink is isolated from the source the stem accepts the extra carbohydrate.

A Cassava Ideotype

This and last year's data suggest that the ideal cassava plant for maximum yield would rapidly reach LAI of about 3 and then maintain that level. A computer model was developed to define how this could best be achieved under CIAT conditions. Equations were used to described the relationship of crop growth rate to LAI, the relative leaf size compared to the maximum leaf size over time, rate of leaf formation per apex over time, the reduction of leaf life by shading, and the dry leaf weight per unit area. The same equations were used in all cases as these factors seem to be the same for all varieties with the possible exception of leaf formation rate per apex (Fig. 1). First, branching habit was studied using leaf life (10 weeks), weight per node (1 g), and maximum leaf size (300 or 500 cm²) at plant populations of 10,000 and 20,000 plants/ha.

The highest simulated yields were obtained with branching at 30 weeks at 20,000 plants/ha with a maximum leaf size of 500 cm². When this plant type is compared with other types it becomes obvious that branching time is extremely important (Fig. 15) since early branching types yield very poorly. Increasing leaf life above 15 weeks and reducing node weight from 1 to 0.5 grams give a small yield increase (Fig. 15) and may be difficult for the breeder to accomplish in practice as maximum leaf lives of 20 weeks (140 days) are rarely found in the field but 15 weeks (105 days) are not uncommon. Similarly, a mean node weight of 0.5 grams is generally associated with small leaves and may be difficult to achieve. There is also little advantage in leaves greater than 500 cm² maximum leaf size (Fig. 15).

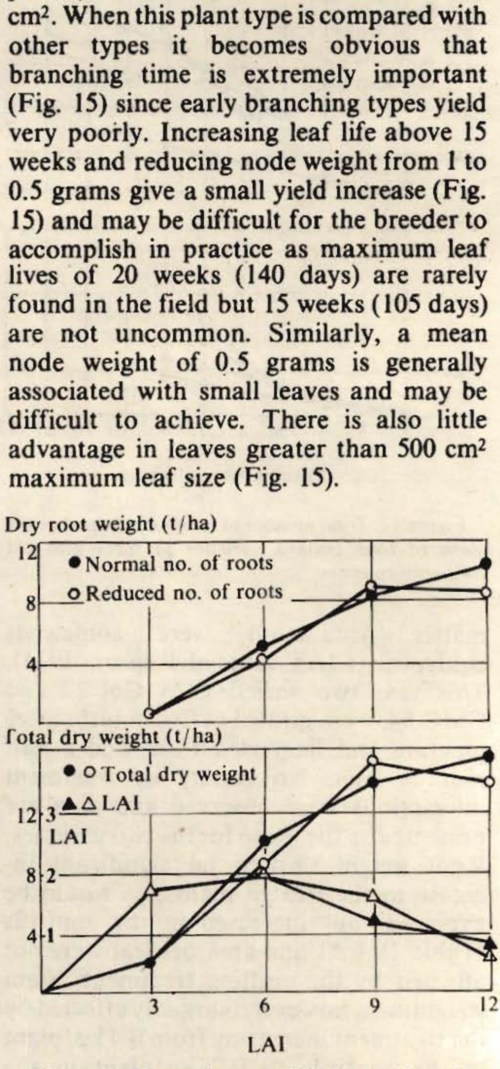


Figure 14. Change in root yield, LAI and total dry matter of M Col 22 with normal and reduced numbers of thickened roots.

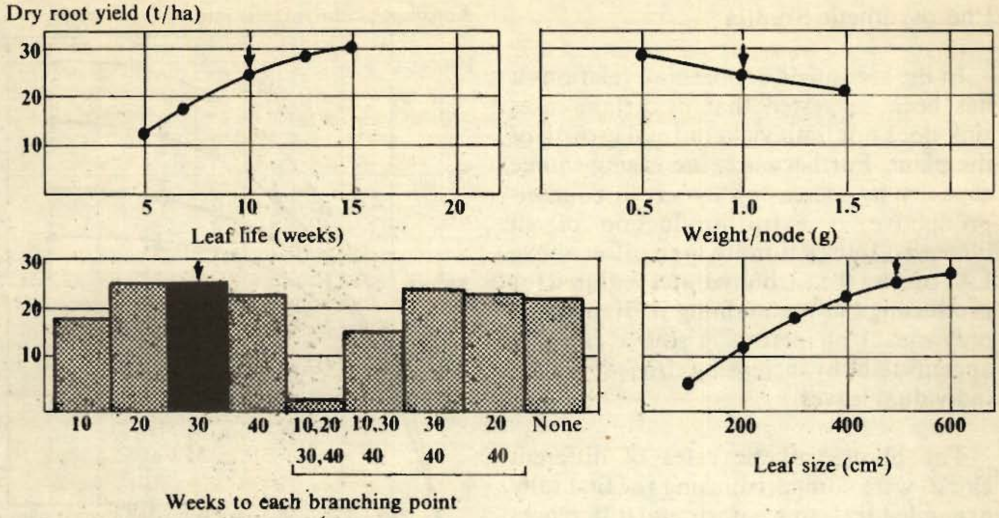


Figure 15. Simulated effects on yield of varying one character in a cassava plant with the following standards: branching at 30 weeks, leaf life of 10 weeks, population of 2 plants/m², maximum leaf size of 500 cm², and node weight of 1.0 gram. Arrows indicate standard type.

These simulated data suggest that high yields can be obtained by searching for types that branch about six months after planting, have large leaves and a long leaf life.

Photoperiod Effects

Two varieties, M Col 22 and Llanera, were planted in rows leading away from incandescent lights in the field. The lights were used to increase day length to 18 hours during the period from planting to three months, 3-6 months and 6-9 months after planting. No effect on yield per plant was noted when long days were given to plants older than three months. However, long days for the first three months after planting reduced yield in Llanera but had no effect on M Col 22 (Fig. 16), suggesting that long days during the early growth period may reduce yield and that varieties vary in their sensitivity to photoperiod.

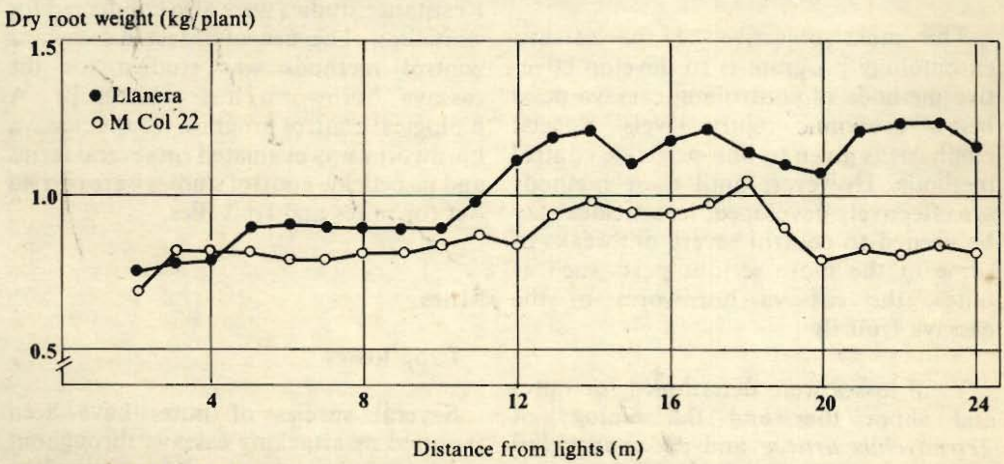


Figure 16. Effect of 18-hour days during the first three months after planting on the yields of two cassava varieties.

Photosynthetic Studies

In the section on source-sink relations it has been suggested that in certain cases sink does not limit yield or total growth of the plant. Furthermore, increasing source capacity by increasing its size is counterproductive as extra production of an increased source is more than offset above LAI of 3 by the carbohydrates required for producing and maintaining it. Hence, the only means of increasing source capacity appears to be by increasing efficiency of the individual leaves.

The photosynthetic rates of different clones were compared, using the first fully expanded leaf, to see if varietal differences occur. Cultivar M Col 72 had the highest photosynthetic rate at all light intensities, being 63 percent greater than M Mex 11 at 1,600 microeinsteins/m^2/sec and 57 percent greater at 700 microeinsteins/m^2/sec (Fig. 17). Relative values are shown as calibration problems occurred. However, rates of over 40 mg $CO_2/dm^2/hr$ have recently been obtained with M Col 72 using air of about 350 ppm. These differences are large and suggest that there may be possibilities of breeding for increased photosynthetic efficiency.

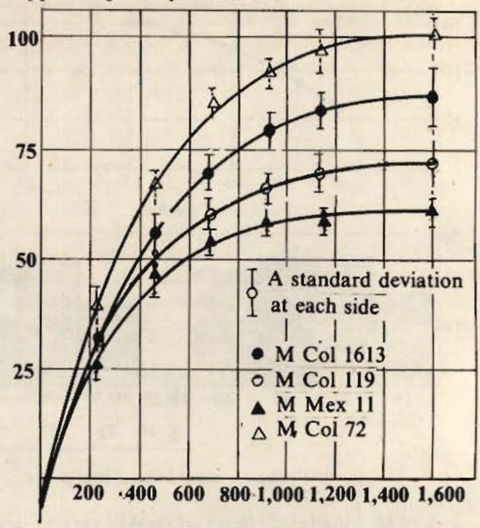


Figure 17. Photosynthetic rates of four different cassava clones.

ENTOMOLOGY

Introduction

The main objective of the cassava entomology program is to develop effective methods of controlling cassava pests below economic injury levels. Special emphasis is given to non-pesticide control methods. However, until these methods are effectively developed, insecticides may be needed to control severe outbreaks of some of the more serious pests such as mites, the cassava hornworm of the cassava fruit fly.

Yield losses were determined for mites and shoot flies and the biology of *Tetranychus urticae* and *Mononychellus tanajoa* was also studied. An extensive program to identify resistance to these mite species was continued throughout the year. Resistance studies were also conducted for whiteflies. The use of insect diseases as control methods was studied for the cassava hornworm and whitegrubs. A biological control program for the cassava hornworm was evaluated on several farms and insecticide control studies were carried out for mites and fruit flies.

Mites

Crop losses

Several species of mites have been reported as attacking cassava throughout many of the cassava growing regions of the world. Recent reports from Africa and

Venezuela indicate that the green mite *(M. tanajoa)* causes crop losses ranging from 30-40 percent. It has long been considered that mites may cause serious crop losses in cassava but until recently there was only minimal experimental data to support this claim.

Four species of mites, *M. tanajoa, M. mcgregori, T. urticae* and *Oligonychus peruvianus,* from Colombia were described in the CIAT Annual Report of 1975. The high mite populations coincide with prolonged dry periods in cassava growing regions. (Dry seasons in many areas of Colombia range from 2-3 months; this normally does not allow mite populations to build up and remain at high enough levels to cause serious crop losses.) To determine the yield loss potential due to mites, cassava plants were artificially infested with *T. urticae* from a screenhouse colony at the onset of the short dry season at CIAT. A natural infestation of *Mononychellus* spp. and *O. peruvianus* occurred in the experimental plots. However, artificial mite infestation allowed for more rapid buildup of mite populations.

Yield losses due to mite attack ranged from 20-53 percent depending upon the age of the plants when the attack occurred, and the duration of the attack (Table 3).

The biology of *T. urticae* and *M. tanajoa* were studied under controlled conditions in an environmental growth chamber (Tables 4 and 5). The female *T. urticae* mite passes from egg to adult in approximately nine days and the female *M. tanajoa,* in eight days. The males complete this phase in slightly less time. Oviposition by *T. urticae* begins during the second day as an adult and each female is capable of ovipositing an average of 40 eggs. Of this total, nearly 29 eggs, or 72 percent of the total during the 20-day adult life, are deposited during the seven-day period between the third and ninth day of oviposition (Fig. 18). Egg viability and the sex ratio were also studied for *M. tanajoa* under growth chamber conditions. Sex ratio studies with 1,186 adults resulted in 62 percent females and 38 percent males. Egg viability for 289 eggs was 92 percent. This data, and the fact that these mites are parthenogenetic, indicates that buildup of mite populations may be very rapid during favorable environmental conditions.

Two predators of mites were identified during the past year. The predatory mite *Typhlodramales peregrinus* Muma (Phytoseiidae) and Coleoptera, *Stethorus* sp. (Coccinellidae) were collected at CIAT.

Resistance studies

Screening of cassava varieties for resistance to *Tetranychus* and *Mononychellus* mites continued under controlled conditions in the screenhouse and greenhouse (CIAT Annual Report, 1975). A major objective of this initial phase of screening is to select about 10-15

Table 3. **Effects of mites *(Mononychellus* spp., *Oligonychus peruvianus* and *Tetranychus urticae)* on cassava yields (var. M Col 22) with artifical infestations of *T. urticae* and biweekly applications of monocrotophos for mite control in treated plots.**

Planting number	No. of artificial infestations	Age of plant when infested (mo.)	Duration of infestation (mo.)	Mites per leaf		Production (t/ha)		% yield loss
				treated	untreated	treated	untreated	
I	1	6	3	110	425	21.8	17.3	21
II	2	4 and 10	4	77	349	16.4	12.3	25
III	2	2 and 8	6	60	263	27.9	13.1	53

Table 4. **Life cycle of *Tetranychus urticae* on excised cassava (var. M Col 420) leaves under growth chamber conditions.**[1]

Developmental stage	No. observed	Range in days	X̄ (days)
Female [2]			
Egg	44	3.0- 4.0	3.09
Larvae	27	2.0- 5.0	2.85
Protonymph	23	1.0- 2.0	1.65
Deutonymph	22	1.0- 3.0	2.04
Egg to adult	22	7.0-11.0	9.27
Longevity of adult	20	8.0-22.0	15.05
Egg to death of adult	20	17.0-32.0	24.35
Male			
Egg	6	3.0- 4.0	3.18
Larvae	6	2.0- 4.0	2.66
Protonymph	6	1.0- 2.0	1.33
Deutonymph	6	1.0- 3.0	1.66
Egg to adult	6	7.0-10.0	8.83

1 Temperature: 28°C day (12h); 25°C night (12h); R.H. 60-70%

2 Average number of eggs oviposited per female = 40.0

Table 5. **Life cycle of *Monychellus tanajoa* on excised cassava (var. M Col 17) leaves under growth chamber conditions.**[1]

Developmental stage	No. observed	Range in days	X̄ (days)
Female[2]			
Egg	35	4.0-5.0	4.14
Larvae[3]	35	1.0- 2.0	1.22
Protonymph	35	1.0- 2.0	1.17
Deutonymph	35	1.0- 2.0	1.60
Egg to Adult	35	7.0-10.0	8.14
Male[2]			
Egg	21	3.0-5.0	4.19
Larvae[3]	21	1.0-2.0	1.14
Protonymph	21	1.0	1.0
Deutonymph	21	1.0-2.0	1.33
Egg to Adult	21	6.0-9.0	7.66

1 Temperature: 30°C day (12h); 27°C night (12h); R.H. 60-70%.

2 Sex ratio - female (62%), male (38%).

3 Percentage egg viability: 92%.

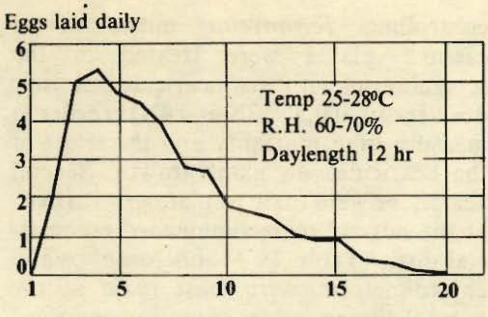


Figure 18. Daily oviposition by 20 female *Tetranychus urticae* mites on excised cassava leaves (var. M Col 420) in growth chambers.

percent of the germplasm for further testing. Of 1,973 varieties screened for resistance to the *Tetranychus* mite only low levels of resistance have been found (Table 6). This was expected since this mite is a very general feeder with over 400 host plants. Although most varieties are classed as susceptible, 270 were selected as showing some low levels of resistance. One hundred and eighteen of these were re-evaluated and 12 varieties were selected as promising for resistance to *T. urticae*. These include M Col 310, 288, 289, 230, 395, 282, 256, 560, 371, 674, 624 and CMC 39.

Among 1,349 cassava varieties evaluated for resistance to *M. tanajoa,* there are some showing moderate or intermediate resistance but none with high resistance or immunity has been selected. Forty varieties have been selected for intermediate resistance and 210 have been selected for future testing.

Based on a 0-5 resistance rating scale only 0.4 percent of the varieties evaluated for *T. urticae* received a rating of 3.5 or less. Of the 1,349 varieties evaluated for *M. tanajoa* resistance, 14 percent received a rating of 3.5 or less. In addition, 86.7 percent of the varieties tested received an evaluation of 5.0 for *T. urticae* while only 7.7 percent received a similar rating for *M. tanajoa*. This indicates that there is more

Table 6. Evaluation of cassava germplasm for resistance[1] to *Tetranychus utricae* and *Mononychellus tanajoa*.

Mite	No. of varieties evaluated	Varieties in each resistance class			Varieties selected as promising
			(No.)	(%)	
Tetranychus urticae	1,973[2]	5.0	1,711	86.72	270
		4.5	214	10.85	
		4.0	40	2.03	
		3.5	7	0.35	
		3.0	1	0.05	
Mononychellus tanajoa	1,349[3]	5.0	104	7.71	210
		4.5	501	37.14	
		4.0	555	41.14	
		3.5	149	11.05	
		3.0	36	2.67	
		2.5	4	0.30	

1 Resistance scale: 0-1, resistant; 2-3, intermediate resistance; 4-5, susceptible.

2 Artificially infested in screenhouse.

3 Artificially infested in greenhouse.

resistance to *M. tanajoa* than to *T. urticae* in the cassava germplasm bank and that there is little cross resistance between the two species.

In addition to these studies at CIAT, 101 varieties of cassava were randomly selected for mite resistance in the field at Maracay, Venezuela (Fig. 19). High mite populations occurred when the plants reached about six months of age and continued for about five months. Although both *Mononychellus* mite species were present on the plants, *M. tanajoa* was predominant. Many varieties were completely defoliated and terminal and lateral buds were killed. However, several varieties did show intermediate levels of resistance.

Insecticide control

Six acaricides were studied under screenhouse and field conditions for controlling *Tetranychus* mites. Young cassava plants were treated in the screenhouse with six acaricides at four dosis (normal 0,5N, 2N and 4N) in order to measure mite mortality and the effect of the acaricides on plant growth. Several acaricides were toxic to plant growth even at the normal or recommended commercial dosis (Table 7). Monocrotophos and chlordimeform were least toxic at the normal dosage and monocrotophos caused only slight toxicity even at 4N dosis. Both acaricides were also effective in causing mite mortality; effects of the monocrotophos treatments are shown in Figure 20.

These same six acaricides were tested in the field for their effectiveness in mite control. The mite species present were *T. urticae*, *Mononychellus* spp. and *O. peruvianus*. Monocrotophos, chlordimeform and RH218 effectively con-

Figure 19. *Mononychellus* mite damage in a field at the Centro Nacional de Investigaciones Agropecuarias (CENIAP) at Maracay, Venezuela. Observing the damaged plants are (on the left) Dr. Carlos Arias, of CENIAP, and Dr. Ernesto Doreste S., of the Faculty of Agronomy, Central University of Venezuela.

Table 7. **Toxicity effects of several acaricides on cassava (var. Llanera) under screenhouse conditions for control of *Tetranychus urticae*.**

	Average grade[1] of toxicity for each application dosis			
Acaricide	.5 x N[2]	N	2 x N	4 x N
chlordimeform	0.1	0.5	1.3	2.3
dicofol	1.3	1.6	2.1	2.4
monocrotophos	0.0	0.1	0.5	0.8
binapacryl	2.5	3.0	3.0	3.0
RH - 218	0.8	1.5	2.4	2.8
Atellic	0.0	1.1	1.3	2.1

1 Toxicity grades: 0 = No leaf damage; 1 = Upper leaves with light localized damage and lower leaves undamaged; 2 = Upper leaves heavily damaged and lower leaves with some damage; 3 = Plant totally damaged, causing death of leaves and/or plant.

2 N = Normal or recommended commercial dosis.

trolled mites up to eight days after application (Table 8). In a second trial at ICA, Palmira six acaricides were evaluated for control of natural mite populations of *M. mcgregori*. Again, monocrotophos, chlordimeform and RH218 were the most effective acaricides tested. Monocrotophos still gave good control 24 days after treatment. However, since mite populations were not high applications did not significantly increase yield.

Cassava Hornworm

Observations of heavy hornworm *(Erinnyis ello)* outbreaks with populations reaching 90 larvae per plant on cassava farms this past year indicate that high hornworm populations will consume not only 100 percent of the foliage but larvae

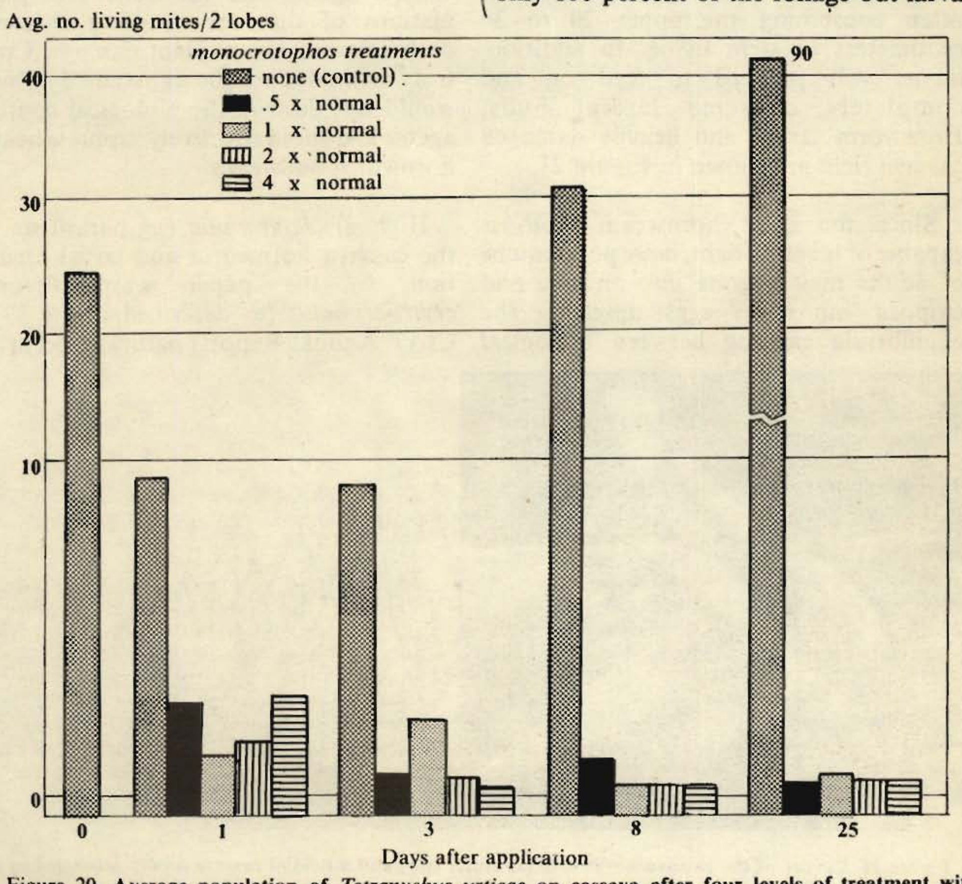


Figure 20. **Average population of *Tetranychus urticae* on cassava after four levels of treatment with monocrotophos, with observations at four periods after treatment.**

Table 8. **Effects of the application of several acaricides on mortality of mites (*T. urticae*, *Mononychellus* spp. and *O. peruvianus*) at one, three and eight days after application (var. M Col. 22).**

		Mites per leaf and % mortality at days:						
		0	1		3		8	
Acaricides	Dosis	Mites (control)	Mites	% Mortality[1]	Mites	% Mortality	Mites	% Mortality
chlordimeform	800 cc/ha	780	346	53	207	72	156	79
dicofol	1000 cc/ha	648	354	43	279	55	306	50
monocrotophos	1000 cc/ha	430	336	18	152	63	106	74
binapacryl	250 cc/ha	369	420	0	124	65	453	0
RH 218	250 cc/ha	593	207	63	87	85	210	63
Actellic	250 cc/ha	448	384	9	144	66	225	47
Control		517	487	0	481	0	453	0

[1] % mortality calculated by Henderson and Tildon method.

will also feed on tender parts of the stem often consuming the upper 20 to 30 centimeters of stem tissue. In addition, larvae will proceed to feed on and completely consume lateral buds. Hornworm larvae and heavily damaged cassava field are shown in Figure 21.

Since the adult hornworm moth is capable of lengthy flight, large populations of adults may migrate into an area and oviposit numerous eggs upsetting the equilibrium existing between biological control agents and the hornworm populations of that area causing a heavy outbreak and severe plant damage. Control methods are being studied which would not destroy the biological control agents and could effectively suppress heavy hornworm outbreaks.

High *Trichogramma* egg parasitism of the cassava hornworm and larval predation by the paper wasp *Polistes erytrocephalus* (as described in the 1974 CIAT Annual Report) naturally occur in

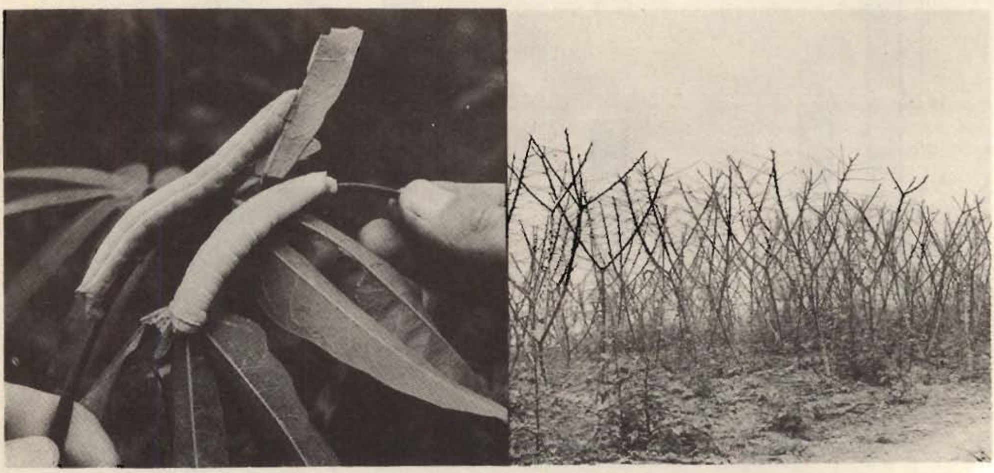


Figure 21. **Larvae of the cassava hornworm (*Erinnyis ello*) and a field of cassava totally defoliated by the hornworm.**

many cassava fields. In order to determine the effectiveness of this biological control system, *P. erytrocephalus* were released on cassava farms and biweekly evaluations are being made of hornworm oviposition, egg parasitism, larval populations and wasp populations.

Bacillus thuringiensis, a commercially available bacterial disease of many Lepidopterous larvae, was studied for cassava hornworm control. In a cassava field with heavy hornworm attack, 50-plant plots were sprayed with a suspension of *B. thuringiensis* and the larval population was measured before application and three days after application. Results showed that the larval population was reduced by 68 percent (Table 9), *B. thuringiensis* being most effective against the first three larval instars and least effective against the fourth and fifth instars.

Table 9. **Number of cassava hornworm (*Erinnyis ellos*) larvae before and three days after application of *Bacillus thuringiensis* on two-month cassava plants (var. Chiroza gallinaza).**

Developmental stage	No. larvae per instar[1] Before application	3 days after aplication
I Instar	1,520	114
II Instar	4,449	982
III Instar	3,375	1,207
IV Instar	1,192	850
V Instar	320	298
Total	10,856	3,451

Eight plots of 50 plants with center 15 plants of each plot sampled (total of 120 plants sampled).

One half of a five-hectare field was sprayed with *B. thuringiensis* and 50 plants were randomly sampled before application and at three and six days after application. The larval population in the treated field was reduced from more than six larvae per plant to one, while in the untreated field the larval population increased to more than 13 larvae per plant (Table 10).

Trichogramma egg parasites were released into treated and untreated fields prior to *B. thuringiensis* application and egg parasitism was recorded at seven and 10 days after release to determine the effect of the application on parasitism. Egg parasitism remained equally high in the treated and untreated fields (Table 11)

Table 10. **Effects of an application of *Bacillus thuringiensis* on a population of cassava hornworm (*Erinnyis ello*) after three and six days.**

	Days after application	No. of larvae[1] Instar I	II	III	IV	V	Total larvae	Larvae/ plant
With *B. thuringiensis*	0	159	97	56	—	—	312	6.24
	3	84	80	39	1	—	204	4.08
	6	7	19	21	3	4	54	1.08
Without *B. thuringiensis*	0	311	160	63	—	—	534	10.68
	3	141	287	100	1	0	529	10.58
	6	127	254	227	51	20	679	13.58

[1] Based on a 50 plant random sample.

Table 11. **Percentage of cassava hornworm (*Erinnyis ello*) eggs parasitized by *Trichogramma* sp[1] seven and ten days after application of (*Bacillus thuringiensis*).**

Treatment	% Parasitism[2] at 0	7	10
	days after application		
With *B. thuringiensis*	76	98	100
Without *B. thuringiensis*	76	93	97

[1] Approximately 98,000 *Trichogramma* adults released in each treatment plot of 2.5 hectares.

[2] Samples of 100 eggs.

indicating that application of *B. thuringiensis* will not adversely affect *Trichogramma* sp. egg parasitism.

A common complaint of many cassava farmers is that *B. thuringiensis* does not rapidly kill hornworms and that they continue to consume foliage for several days after its application. Therefore, a laboratory study was designed to measure the foliage consumed after leaves had been sprayed with *B thuringiensis*. Larvae were also allowed to feed on untreated leaves to compare leaf area consumption between the *Bacillus* infested larva and healthy larvae. Results showed that larvae can survive for 1-4 days after they begin to consume treated foliage. However, the leaf tissue they are able to consume during this period is greatly reduced (Table 10).

Cassava Fruit Flies

Two species of fruit flies have been identified as attacking cassava in Colombia. *Anastrepha pickeli* has been collected at the CIAT farm in the Cauca Valley (altitude 1,000 m) while *A. manihoti* was collected from the coffee growing regions of Colombia (1,200 m) where cassava is also widely grown. Stem and fruit damage due to the fruit fly and the bacterial disease associated with it (see CIAT Annual Report, 1975) have been observed in several cassava growing regions of Colombia. These range from coastal area where there is minimal and sporadic rainfall to mountainous areas where rainfall is well dispersed throughout the year.

The *Anastrepha* female oviposits in the fruit of mature plants or in the tender stem, just below the growing point of younger plants. The larvae may bore upward or downward in the stem causing extensive tunneling. This provides and entrance for a bacterial pathogen (see Plant Pathology Section) which can cause severe stem rotting. The rotten stem is not a favorable environment for the larvae and can cause larval mortality (see control treatment of Table 14). This also indicates that the major population increase of the fruit fly may result from the cassava fruit or an

Table 12. **Average leaf consumption (cm²) of cassava hornworm (*Erinnyis ello*) feeding on leaves treated with *Bacillus thuringiensis* and untreated leaves, under laboratory conditions.**

Developmental stage (Instar)	Avg. untreated leaf consumption/ larvae[1] (cm²)	Treated with *B. thuringiensis*: Avg. leaf consumption/ larvae (cm²)	% reduction of control	Larval duration (days)
III	347.2	48.0	86.10	2.7
IV	273.8	19.2	93.0	2.3
V	345.3	7.11	97.96	2.11

[1] Sample of 10 larvae in each treatment.

alternate host. The fruit of several other plants commonly found in areas of high fruit fly populations have been examined but no additional host to these species has yet been identified. It appears that cassava plants can recuperate rapidly from fruit fly damage given adequate, well-distributed rainfall. Plants that have been severely attacked when three months old, resulting in dead or rotted growing terminals, were compared to healthy plants over a six-month period. Plant height measurements showed that within five months the damaged plants recuperate and attain the same height as non-damaged plants (Fig. 22).

Damage to planting material

Cuttings selected from planting material that has been damaged by the fruit fly and invaded by the bacterial rot have a rotten pith area. As a result, germination of damaged cuttings is reduced by 5 percent and may be delayed by several weeks (Table 13).

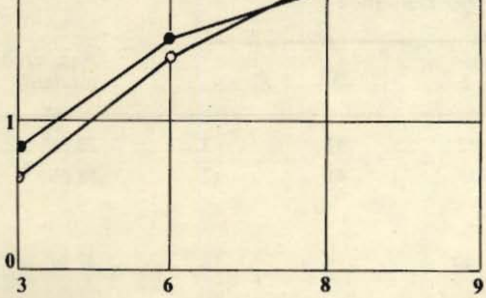


Figure 22. **Recuperation of cassava plants severely damaged by the cassava fruit fly (*Anastrepha* sp.) and bacterial rot (*Erwinia* sp.).**

Table 13. **Influence of cassava fruit fly (*Anastrepha* sp.) damage on the germination of planting material (var. Chiroza gallinaza).**

Treatment	No. of cuttings	% germination at 14 days	% germination at 28 days
Cuttings infected	100	76.8	94
Cuttings uninfected	100	84.4	99

Chemical control

Control methods using insecticide applications for both the larval and adult stage of the fruit fly were studied. For larval control, carbofuran was applied at three different doses in the soil around each plant and fenthion, in solution, was applied at three different doses to the foliage. Percentage of larval mortality caused by each systematic insecticide was recorded at 3, 8 and 16 days after application.

Results showed that fenthion gave good control three days after application and at eight days there was 100 percent larval control at all three doses (Table 14). After 16 days control was still 90-100 percent effective, depending upon the dose. Control by carbofuran was much less effective reaching only 69 percent at 16 days. Meanwhile, larval mortality in the control plants reached 40 percent, supporting the observation that the rotting stem is not a favorable medium for larval development.

Attractants

Adult fruit flies are highly mobile and difficult to control. However, trapping of adult fruit flies with the appropriate bait or attractant could result in an effective means of control, or of measuring adult fruit fly populations to determine when control measures should be employed. A

Table 14. **The effect of carbofuran and fenthion on the control of cassava fruit fly larvae (*Anastrepha* sp.) in stems of cassava (var. M Mex 23).**

			% mortality of larvae at.		
Treatment	Dosis	Application	3 days	8 days	16 days
Carbofuran	10 g/plant	Soil	9.7	45.0	69.0
Carbofuran	20 g/plant	Soil	23.0	64.0	50.0
Carbofuran	30 g/plant	Soil	24.0	53.0	20.0
Fenthion	1.5 cc/liter H_2O	Foliage	76.0	100.0	95.0
Fenthion	2.0 cc/liter H_2O	Foliage	97.0	100.0	91.0
Fenthion	2.5 cc/liter H_2O	Foliage	77.0	100.0	100.0
Control			22.0	24.0	40.0

trial was designed to study baits or attractants that would increase the effectiveness of insecticide application. The insecticide EPN was used because of its quick knockdown effect which was necessary to get an accurate mortality count. Three bait combinations were studied—yeast, molasses, and yeast plus molasses. Yeast alone proved to be the most effective bait causing more than double the adult mortality of the insecticide used alone (Table 15). The addition of molasses had no effect on mortality and when molasses and yeast are combined mortality was greatly reduced.

In preliminary experiments, brewers yeast and hydrolized protein gave the best results as attractants for the capture of fruit flies. These were compared to three additional attractants—hydrolized yeast, hydrolized corn, and hydrolized soybean, using the McPhail trap. The hydrolized corn gave nearly three times greater capture of fruit flies than any of the other attractants (Table 16).

Table 15. **Evaluation of yeast and molasses as baits mixed with the insecticide EPN for control of cassava fruit fly (*Anastrepha* sp.) adults in field trials.**

	Adult mortality per replication				
Treatment and dosis	1	2	3	4	Avg. adult mortality
EPN (12 cc/12 liters H_2O)	25	42	43	3	28.3a[1]
EPN (12 cc/12 liters H_2O) + yeast (0.5 kg)	71	103	41	17	58.0b
EPN (12 cc/12 liters H_2O) + molasses (0.5 liter)	49	49	18	14	32.5a
EPN (12 cc/12 liters H_2O) + yeast (0.5 kg) + molasses (0.5 liter)	34	79	24	3	35.0a

[1] Averages followed by different letters are significantly different at .05.

Table 16. **Comparison of five attractants in capture efficiency of the adult cassava fruit fly (*Anastrepha manihoti*) using McPhail traps.**

Attractant	Dosis	Average no. of *Anastrepha* captured/week
Brewers yeast	40 g brewers yeast, 6 g sugar, 1 g Borax 400 cc H_2O	23.1
Hydrolized protein	50 cc/1,000 cc H_2O	17.1
Hydrolized corn	20 cc/1,000 cc H_2O	60.7
Hydrolized yeast	20 g/1,000 cc H_2O	21.9
Hydrolized soybean	20 g/1,000 cc H_2O	18.4

Biological control

Fruit fly larvae in cassava fruit are attacked by the parasite *Opius* sp. (Hymenoptera, Brackonidae). A study on the CIAT farm showed a 4.9 percent level of parasitism, while in the coffee growing region of Colombia, where fruit fly populations and damage are high, parasitism levels were 16 percent. There have been no observations of parasitism of the larvae in cassava stems.

Cassava Shoot fly

The metallic blue adult shoot fly oviposits its eggs between the unexpanded leaves in the growing terminals or in a small cavity in the tissue made by the ovipositor. After hatching, the young larvae tunnel in the soft tissue and eventually kill the growing point.

In a field where numerous plants were attacked by shoot flies yield was recorded on an individual plant basis. On plants where the attack occurred at 4.5 months of age yield reduction was 15.5 percent and when the attack occurred at 5.5 and 6.5 months there were 16.7 and 34.1 percent yield reductions, respectively. Control plants (sampled at random) yielded an average of 4.19 kg/plant as opposed to 3.54, 3.49 and 2.76, respectively, for the damaged plants. Affected plants were also shorter and may have been shaded by their healthy neighbors, hence yield losses are probably overestimated.

White Grubs

White grubs *(Phyllophaga* sp.) can cause considerable damage to planting material and roots of young plants. Germination of cuttings can be reduced by more than 90 percent under heavy attack by the grubs. In previous experiments aldrin (2.5% at 60 kg/ha) and carbofuran (3 g/m^2) applied below the cutting in the soil were found to give the most effective control.

A Muscardine fungus, *Metarrhizium anisopliae,* is pathogenic to the grubs and preliminary laboratory experiments indicate that this can be an effective control method. This fungus has been found attacking grubs in their natural state in cassava fields in Colombia.

Mealybugs

Cassava plants infested with mealybugs have masses of cottony appearing insects clustered on the stem and leaves (Fig. 23). The species *Phenacoccus gossypii* has been identified as attacking cassava. There is no information available as to the extent of damage by these insects but mealybugs have been known to cause serious losses to other crops and could represent a serious

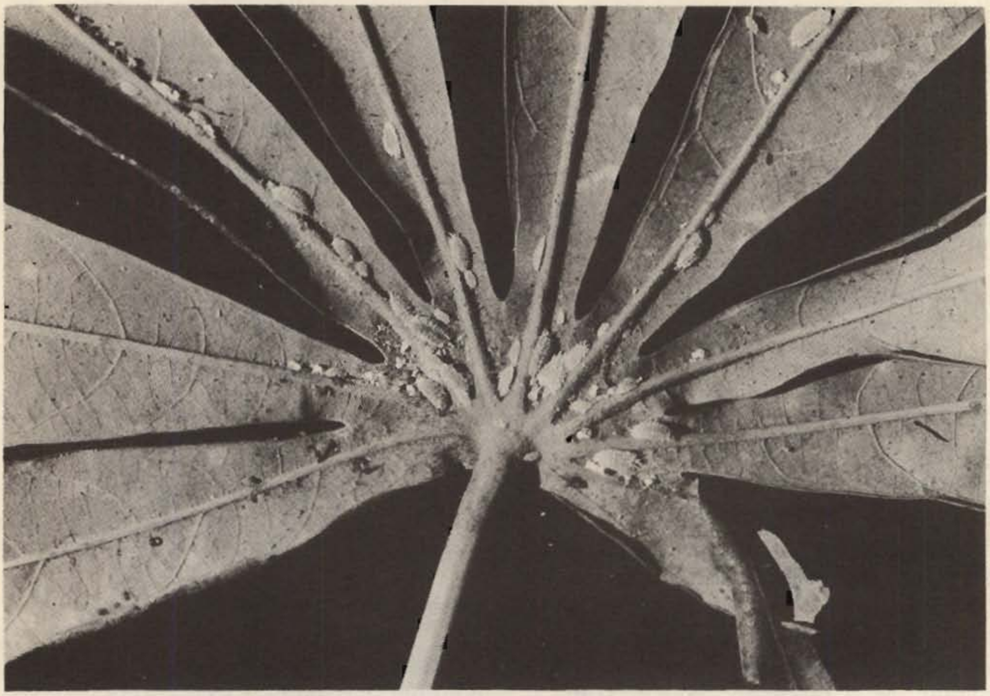


Figure 23. An infestation of mealybugs (*Phenacoccus gossypii*) on cassava.

pest of cassava. Communications from Brazil and Africa indicate that mealybugs severely defoliate cassava in these areas. They have been observed in increasing numbers this year on the CIAT farm causing defoliation and the drying of stem tissue.

Whiteflies

Very severe infestations of whiteflies (*Aleurotrachelus* sp.) were observed at the ICA experiemnt station at Nataima (Espinal) in Colombia. Leaf damage from heavy whitefly attack was observed as severe mottling or curling on susceptible varieties. These leaves had a mosaic-like effect with splotches of light green leaf tissue on the dark green leaves. The presence of sooty mold was also evident on the lower leaves of those plants with heavy infestation.

The black pupae covered with a white waxy excretion was easily observed on the

Table 17. Evaluation of 12 varieties of cassava for resistance to the whitefly *Aleurotrachelus* sp.

	Resistance grade[1]			
	Replicate			
Variety	1	2	3	Avg.
CMC 40	3	3	3	3
CMC 72	1	1	2	1.3
M Col 673	3	3	3	3
M Mex 52	1	2	2	1.7
CMC 86	3	3	3	3
M Ven 119	2	3	2	2.3
CMC 84	3	3	3	3
CMC 137	2	3	2	2.3
M Ecu 159	1	3	2	2
CMC 57	1	1	1	1
M Mex 59	2	2	3	2.3
M Col 22	3	3	3	3

Grade 1: Few or no pupae on leaves, no mottling of leaves;
Grade 2: About one half of leaves with many pupae and some mottling of foliage but no curling;
Grade 3: Most leaves with pupae and severe mottling and curling of leaves.

leaf undersides. The undersurface of heavily infested leaves were almost completely covered with pupae, giving a glistening white effect. Infestation was observed on nearly all leaves (upper as well as lower ones) but mottling and curling were primarily present on upper leaves.

A preliminary evaluation of 12 varieties was made for resistance/susceptibility to the whitefly.

The variety CMC 57 appeared to have good resistance in all three replicates. CMC 72 and Mex 52 gave moderate resistance while CMC 40, M Col 22, M Col 673, CMC 86 and CMC 84 were highly susceptible (Table 17).

PATHOLOGY

During 1976 emphasis was placed on research related to selecting and protecting vegetative propagating material. Losses caused by some major diseases were also determined, as well as new methods for a more accurate evaluation of resistance to certain diseases. Evaluations of resistance to cassava bacterial blight (CBB), Phoma leaf spot, *Cercospora* spp. leaf spots and the superelongation disease were done routinely on the promising material produced by the breeding program. Furthermore, the investigation related to identifying the causal agent of some syndromes observed in several commercial plantations was continued.

Bacterial Diseases

To date, three bacterial diseases of cassava have been defined according to the symptomatology, cultural and taxonomic characteristics of their causal agents. These are bacterial blight *(Xanthomonas manihotis),* bacterial stem rot *(Erwinia cassavae)* and bacterial angular leaf spot *(Xanthomonas cassavae).* However, the etiological and epidemiological knowledge of *X. cassavae* and the disease it causes is still in the preliminary phase.

Cassava bacterial blight (CBB)

Research on this disease was concentrated on: (a) determining those factors that may induce variability in the reaction of cassava cultivars inoculated by the clipping method for resistance screening to CBB (CIAT Annual Report, 1975); (b) determining the pathogenic variability of the causal agent; (c) evaluating resistance of F_1 hybrids obtained by controlled pollination; and, (d) determining losses caused by the disease on plantations infected monthly after germination, under conditions of the Cauca Valley of Colombia.

Inoculation procedure. Various trials were done to establish the optimum inoculation procedure for CBB screening. This procedure is summarized as follows. Plants should be grown in 11-cm diameter x 10-cm high pots since bigger pots do not allow plants to express symptoms as strongly as do smaller ones. Six young leaves around the stem should be inoculated using 10^8 cells/ml or more in sterile distilled water when the plants are 45-70 days old. Inoculation is best done on cloudy days or in the evening. Relative humidity should be greater than 70 percent and plants kept in pots at field capacity. This may require twice daily watering when temperatures are above 25°C since higher temperatures accelerate symptom formation. Final evaluation, on five plants 45 days after inoculation, can be made visually.

Pathogenic variability. The virulence of 52 strains of *X. manihotis* collected from plantations in Africa, Asia, and America during the last four years was determined.

Why not do them all t on a bigger scale? As in beans Pathology is spread very thin-

The cultivars M Col 113, Llanera, and M Col 647, previously rated as susceptible, tolerant and resistant, respectively, to certain Colombian strains were clip-inoculated with each of these strains. The 52 strains were classified into four virulence groups as shown in Table 18.

These results suggest the presence of groups of the pathogen differing in virulence. Of particular importance to CIAT's breeding strategy is whether these groups interact differently with various cassava genotypes. If so, the screening system should include as much diversity of pathogen groups as possible. If, on the other hand, the groups do not include interaction with cassava genotypes, screening by using the most virulent strains would be the most efficient, although less virulent strains (groups 1, 2 and 3) are more common. empirical basis for this.

Table 18. **Evaluation of virulence of 52 CBB strains from Africa, America and Asia, using the clip inoculation technique.**

		Virulence[1]			
Source of strains	No. of strains tested	Group 1	Group 2	Group 3	Group 4
Africa	13	2	8	2	1
America	35	8	12	10	5
Asia	4	2	1	1	—
Total	52	12(23%)	21(41%)	13(25%)	6(11%)

Group 1: Low virulence; it was able to induce lesions only on the clip inoculated leaves of the three cultivars.

Group 2: Induced dieback and/or death of susceptible cultivars. Tolerant and resistant cultivars showed lesions only on the inoculated leaves.

Group 3: Induced dieback or death of susceptible and tolerant cultivars. The resistant cultivar showed only foliar lesions.

Group 4: Induced death of the susceptible and tolerant cultivars and dieback (80%) and/or death (20%) of the resistant cultivar.

Disease losses related to crop age. The evaluation of losses caused by CBB in plantations infected at different ages was determined by monthly plantings of the cultivars Llanera (tolerant), and M Col 113 and M Mex 23 (susceptible). Yields were not reduced when plots were infected between the seventh and the tenth month of growth (Fig. 24), but in plots infected between the first and the sixth month, yield was significantly reduced in the two susceptible cultivars. Yield of the tolerant cultivar was only reduced when CBB infection occurred between the first and third month of growth. No correlation was found between yield and rainy or dry periods during this experiment.

These results suggest that disease losses may be reduced with disease-free planting material in areas where the disease is endemic. When "clean seed" (produced to insure that it doesn't carry CBB) is planted in an affected area, the plantations will be clean initially if the land has not been planted to cassava previously or has been rotated for a six-month period (CIAT Annual Report, 1973). Since CBB dissemination over short distances is generally related to environmental conditions and insect populations, the possibility that these plantations become fully infected within 3-4 months is low. Consequently, the risk of losses caused by CBB could be reduced by using clean propagating material or minimized if clean material of resistant or tolerant cultivars is used.

Evaluation for resistance. Evaluation of promising high-yielding material produced by the breeding program was of high priority. Other nonpromising lines were also included to obtain more information on the genetic control of this disease. Results (Table 19) were similar to those found previously (CIAT Annual Report, 1975). Selfing of resistant cultivars produc-

Not very far in this though as pathology is overloaded.

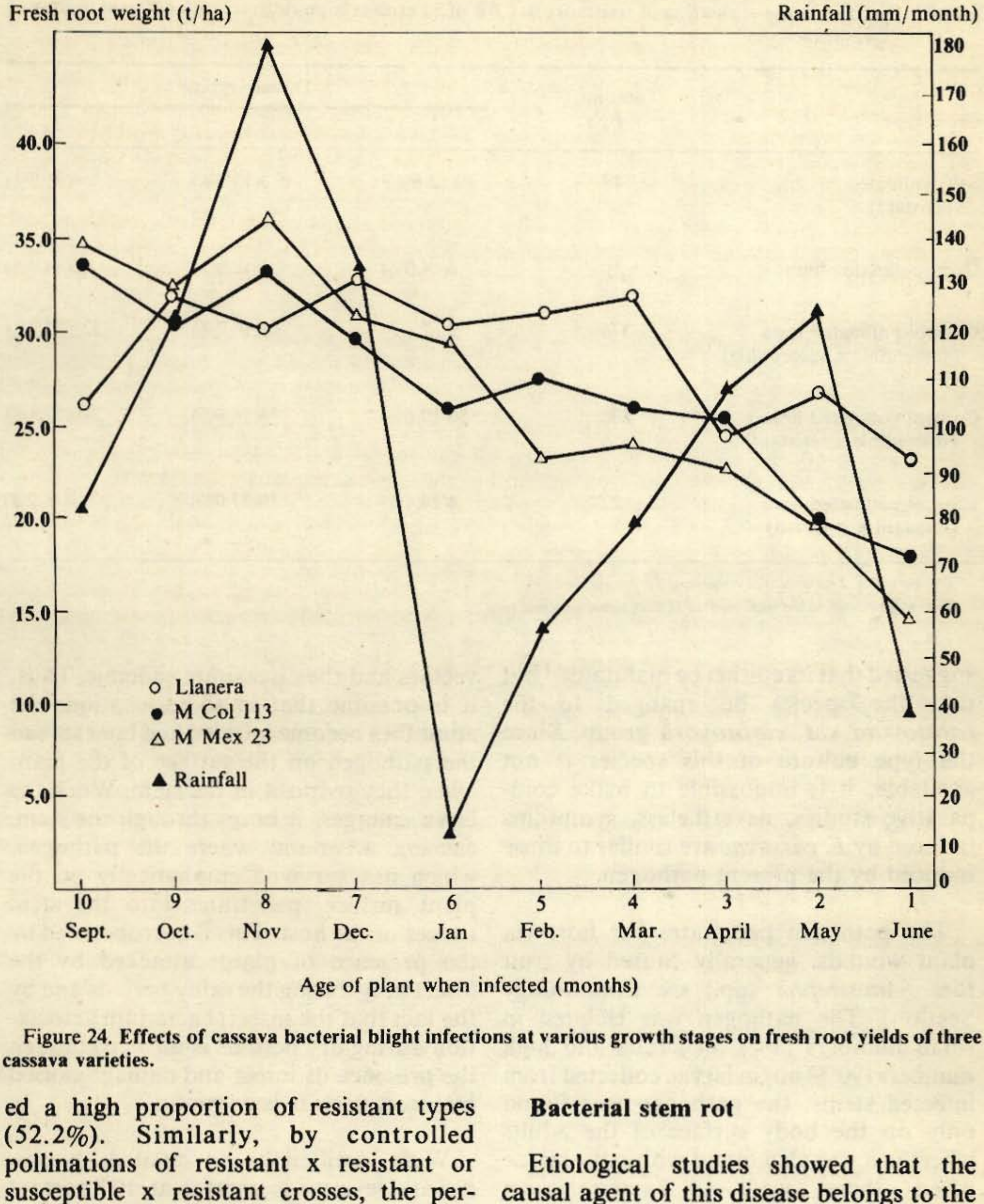


Figure 24. Effects of cassava bacterial blight infections at various growth stages on fresh root yields of three cassava varieties.

ed a high proportion of resistant types (52.2%). Similarly, by controlled pollinations of resistant x resistant or susceptible x resistant crosses, the percentage of resistant hybrids was considerably higher (14.8% and 10.6%, respectively) than crossing susceptible cultivars (2.1%) or by using open pollination (4.0%). With controlled hybridization resistant hybrids with other desirable characters can be obtained. Based on these methods, promising hybrids resistant to CBB have already been identified.

which strains

Bacterial stem rot

Etiological studies showed that the causal agent of this disease belongs to the *carotovora* group of the genus *Erwinia*. This pathogen also seems to belong to the variety *carotovora*. Taxonomically, therefore, this organism appears to belong to *Erwinia carotovora* var. *carotovora*. Erwinia *(E. cassavae* [Hansford] Burkholder 1948) is included in Bergey's *Manual of Determinative Bacteriology* (8th ed.) in the *herbicola* group. It is

Table 19. **Greenhouse evaluation of resistance to CBB of F_1 crosses from cultivars with different degrees of resistance.**

Cross type	Total no. of F_1's	Disease rating[1] 1	2	3
Self-pollinated (resistant)	19	10(52.6%)[2]	3(15.8%)	6(31.5%)
Open-pollinated lines	50	2(4.0%)	6(12.0%)	42(84.0%)
Control pollinated lines (susceptible x susceptible)	375	8(2.1%)	40(10.7%)	327(87.2%)
Control pollinated lines (susceptible x resistant)	530	56(10.6%)	194(36.6%)	280(52.8%)
Control pollinated lines (resistant x resistant)	27	4(14.8%)	10(37.0%)	13(48.2%)

1 Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

2 Percentage related to the total number of lines tested per cross type

suggested that its epithet be maintained but that the species be changed to the *carotovora* var. *carotovora* group. Since the type culture of this species is not available, it is impossible to make comparative studies; nevertheless, symptoms induced by *E. cassavae* are similar to those induced by the present pathogen.

The pathogen penetrates the host via plant wounds, generally caused by fruit flies *(Anastrepha* spp.; see Entomology Section). The pathogen was isolated in small numbers (1%) on adults and high numbers (90%) on/in larvae collected from infected stems; the pathogen was found only on the body surface of the adults whereas it was also found within the larvae when there was a bacteria/insect relationship in the stem. The pathogen was able to survive epiphytically for 132 hours, when relative humidity was near 100 percent and its concentration increased more than 100-fold.

Insect adults generally live and feed on fermenting organic debris, common in those cassava-growing areas where the vectors and the disease are endemic. Thus, it is possible that in these locations the adult flies become infested and later spread the pathogen on the surface of the plant when they oviposit in the stem. When the larva emerges, it bores through the stem, causing a wound where the pathogen, which has survived epiphytically on the plant surface, penetrates into the stem tissues of the host. This is corroborated by the presence of plants attacked by the insect only during the rainy periods and by the fact that the insect/bacterium association during dry periods is nil, even though the presence of insect and damage caused by insect vectors is common.

With artificially inoculated plants, disease severity is greater at 100 percent relative humidity than at 70 percent relative humidity during incubation (Fig. 25). In the field, disease incidence (infected plants/total plants) and severity are high during the rainy season. During the dry season, external symptoms (total stem rot) disappear, but the pathogen continues to invade the pith tissues of the infected plants. Since no significant differences in

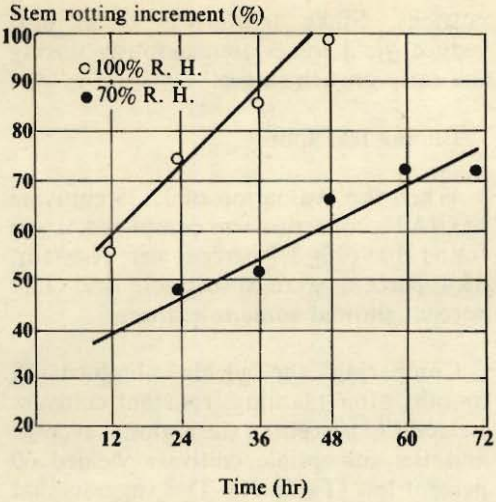


Figure 25. Disease progress of bacterial stem rot of cassava at two humidity levels.

the degree of stem rotting were found among artificially inoculated cultivars, best control is to identify cultivars resistant to the insect or direct control of insects.

or could combine breeding

Bacterial angular leaf spot

This disease was described in Africa (Uganda) in 1956, but no other report of the disease has been published. This year, some cultivars were found to be affected by the disease in Carimagua (Llanos Orientales, Colombia) during the rainy season. The disease, caused by *X. cassavae* (a parenchymatous pathogen), is observed only on the foliar system of cassava as angular, water-soaked lesions, very similar to those induced by CBB. The angular spots, however, are smaller, with a pale yellowish exudation in the center of the lesions on the leaf undersurface. The spots are surrounded by a diffuse pale yellow halo, which eventually extends over the whole leaf lamina, causing leaf abscission within 20 days after infection.

The pathogen grows well but slowly in sugar media, producing yellow colonies; these two characteristics (slow growth and yellow colonies) separate it from *X. manihotis,* which is a fast-growing organism producing white mucoid colonies on sugar media. First symptoms appear 8-9 days after spray inoculation with a bacterial suspension of 10^9 cells/ml, followed by 24 hours of incubation at 100 percent relative humidity and 25°C. Small, swollen, water-soaked, reddish brown dots appear, which enlarge and become surrounded by a yellow halo as described above.

Fungal Diseases

Superelongation disease

Cultural studies on *Sphaceloma manihoticola,* the causal agent of superelongation, and on *S. poinsettiae* (CIAT Annual Report, 1975) showed that these two organisms can mutate on artificial media relatively easily, producing colonies phenotypically different from the original cultures. Frequently, black, mucoid colonies appear which can sporulate more intensely than the original ones and remain stable even after inoculating/isolating several times on a susceptible cassava cultivar. Such mutants were observed to be more virulent than the original cultures affecting the same cultivar. This suggests the possible existence of physiological races in nature and/or the possibility of forming new biotypes or races in relatively short periods, an important point for a breeding program to control this disease.

In general, three field-resistant types have been observed: (a) complete immunity, characterized by the absence of disease lesions on certain cultivars; (b) disease occurrence with foliar lesions in a 12-month cycle, but without elongation and/or leaf distortion; and, (c) complete immunity during the first four months of plant growth and then tolerance, shown by the presence of lesions on leaves, petioles and green stem, and elongation only on the very young portions of branches.

Pathology issues are fairly complicated

The severity of this disease depends on the occurrence of prolonged periods of rainfall but yield reduction is almost nil when plantations are infected after five months of growth (CIAT Annual Report, 1975). Since it is likely that physiological races exist which interact with different cassava genotypes, especially in the case of type (a), importance will also be given to other types of resistance.

Disease resistance evaluation is carried out using plots surrounded by heavily attacked susceptible cultivars. From the results it is evident that there are very good sources of resistance to this disease in CIAT's germplasm bank (Table 20). The resistant cultivars have remained resistant for a year under continuous exposure to high inoculum potential.

Dissemination. The effect of the causal agent of this disease on germination of cuttings, as well as its dissemination by the use of infected cuttings, was determined by planting cuttings (var. M Col 310) taken from clean and infected plantations. Of cuttings from infected plantations 50 percent did not germinate, and all sprouts were infected.

When diseased cuttings were treated with the fungicide captafol (80%) at 8,000 ppm the disease was eradicated. Captafol (80%) at this concentration did not show any inhibitory or toxic effect on the treated cuttings. Stake treatments could also reduce yield losses tremendously during the early growth stages.

Phoma leaf spot

When the evaluation of 1,139 cultivars of CIAT's collection was completed, it was found that only 1.7 percent were resistant, 85.4 percent were susceptible and 12.9 percent showed some tolerance.

Comparing the yields obtained 15 months after planting, resistant cultivars yielded 190 percent of the regional average and the susceptible cultivars yielded 60 percent less (Table 21). This suggests that in areas where the disease is endemic (areas with low temperatures and high relative humidity), growers have unconsciously selected cultivars resistant to the disease and to the environmental conditions. If this resistance is increased, yields could be doubled in these areas (Table 21). However, the resistance evaluation of the first 200 hybrids showed that the heritability of resistance to this disease is quite low (Table 22).

***Cercospora* spp. leaf spots**

The effect of *Cercospora henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot) on leaf longevity and yield of the susceptible cultivar Llanera was determined under CIAT environmental con-

Table 20. **Field evaluation of 488 cultivars and F crosses for resistance to *Sphaceloma manihoticola* (superelongation disease of cassava).**

No. of cultivars or hybrids tested	Disease rating[1]		
	1	2	3
418 cultivars	7.2[2]	24.9	67.9
70 hybrids	10.0	18.6	71.4
Avg.	7.6	24.0	68.0

1 Disease rating: 1=resistant, 2=tolerant, 3=susceptible
2 Percentage of the total number tested.

Table 21. **Average yield (at 15 months) of 1,139 cassava cultivars grouped according to their reaction to Phoma leaf spot.**

Disease reaction	Average yield (kg/plant)	% yield related to regional yield
Regional yield	1.2	100 a[1]
Resistant	2.3	190 b
Tolerant	1.0	80 a
Susceptible	0.5	40 b

1 Numbers followed by the same letter were not significant at .01 level (F test).

Table 22. **Field evaluation of resistance of F_1 crosses to *Phoma* sp. from cultivars with different degrees of resistance.**

Pollination system	Total F_1 crosses	Disease rating[1]		
		1	2	3
Self-pollinated (resistant)	26	1(3.8%)[2]	15(57.7%)	10(38.5%)
Open pollinated	52	0(0.0%)	6(11.5%)	46(88.5%)
Control pollinated:				
(susceptible x susceptible)	81	0(0.0%)	2(2.5%)	79(87.5%)
(resistant x resistant)	41	2(4.9%)	31(75.6%)	8(19.5%)

1 Disease rating: 1 = resistant, 2 = tolerant, 3 = susceptible

2 Percentage related to the total number of lines tested per cross type

ditions by applying fungicides and stickers at 1, 2 and 3 week periods in a split-plot design.

Longevity of healthy leaves was 85 days and for infested leaves untreated with fungicide, 68 days (Table 23). Fungicide treatments reduced infected leaf numbers by 60 percent but only increased leaf life of infected leaves by two days. The fungicide treatment every week reduced the level of infestation and increased leaf life. Yield was increased by 14 percent (Table 24) by this treatment at CIAT. It is interesting to note that increased leaf life is suggested (Physiology Section) as a means of increasing yield. Higher yield in this case is apparently associated with greater leaf longevity.

Field evaluation for resistance to *C. henningsii*, *C. vicosae* and *C. caribae* (Table 25) showed results similar to those reported previously (CIAT Annual Report, 1975). A high percentage of F_1 lines showed resistance to *C. henningsii* and *C. caribaea*, but resistance to *C. vicosae* was very low. Resistance to *C. henningsii* and *C. vicosae* together was even lower (Fig. 26) with the resistance to each *Cercospora* species being independent and not correlated.

Table 23. **Longevity of healthy leaves of Llanera and those infected with *Cercospora henningsii* and/or *C. vicosae*.**

Sanitary condition	Longevity (days)	No. of leaves
Infected leaves, no fungicide treatment	68	367
Infected leaves treated with fungicide	70	4,732
Healthy leaves, treated every week	85	2,062

Table 24. **Yield of cassava (var. Llanera) according to the frequency of application of either mancozeb, Vitigran, benomyl and Macuprax plus sticker (Triton or Tween 20).**

Frequency of application	Yield (t/ha)
Every week	33.1 a[1]
Every two weeks	28.1 b
Every three weeks	29.2 b
Control	28.5 b

1 Numbers followed by different letters were significantly different at the .05 level.

Table 25. **Field evaluation of resistance to *Cercospora henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot) in F_1 crosses from cultivars with different degrees of resistance.**

	Disease rating[1]		
Cercospora spp.	1	2	3
C. henningsii	616(46%)[2]	210 (15%)	518 (38%)
C. vicosae	53(4%)	208 (15%)	1,083 (81%)
C. caribaea	141(34%)	154 (37%)	118 (29%)

1 Disease rating: 1=resistant, 2=tolerant, 3=susceptible
2 Percentage related to the total number of F_1 lines evaluated/cross type.

Cassava rusts

The studies on cassava rusts in cooperation with ICA, the Universidad Nacional and CIAT (1975 Annual Report), were continued. A taxonomic analysis was made of *Uromyces* spp., pathogenic to *Manihot* spp. A total of 72 samples were analyzed after being obtained from the following European and American herbaria and/or museums: Royal Botanic Gardens, Kew; Naturhistoriska, Riksmuseet, Stockholm; Botanischer Garten und Botanisches Museum, Berlin-Dahlem; Instituto Agronomico, Campinas; Micoteca Nacional, ICA.

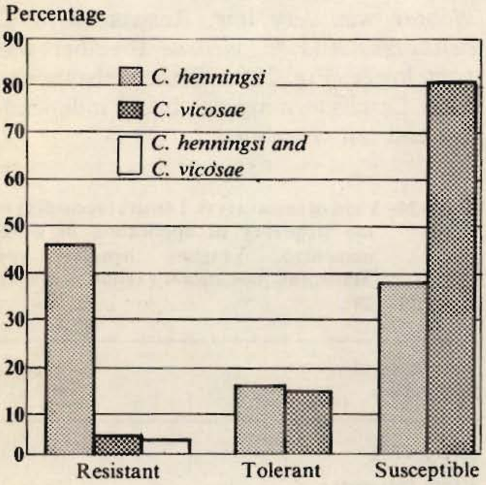


Figure 26. **Field resistance to *Cercospora henningsii* and *C. vicosae* of F_1 crosses from cassava cultivars with different degrees of resistance.**

As a result 42 samples were reclassified. The samples were characterized by comparing each sample with the type or isotype species. The identification of rust species included studies on: ornamentation and thickness of the cell wall, color, size and shape of teliospores and uredospores, and the pedicel characteristics of the number and position of the germinative pores on uredospores.

Six *Uromyces* spp. have been reported pathogenic to *Manihot* spp. in Latin America, of which *U. manihotis* Henn. is most widely distributed (Fig. 27).

The highest percentage of germination of uredospores of *U. manihotis* takes place at 20-25°C, 36 hours after incubation on agar. At 1°C and 35°C uredospores do not germinate. Germination is delayed when light intensity is greater than 12,917 lux (1,200 ft-c). When relative humidity is lower than 81 percent, uredospores do not germinate but when relative humidity was between 95 and 100 percent, germination was 18 and 68 percent, respectively. Satisfactory infection was obtained when plants were spray inoculated and incubated for 12 hours at 100 percent relative humidity. The optimum concentration of inoculum was 25 mg of uredospores/40 ml of water plus Tween 20 at 0.1 percent; first symptoms appeared 12-15 days after inoculation. The highest disease rating was obtained on four-week-old plants. The pathogen penetrates the host via stomatal cavities, 4-5 hours after inoculation.

Under field conditions (at Mondomo, Cauca, Colombia) *U. manihotis* produced only uredospores. After evaluating 72 cultivars, it was found that only 8 percent appeared to be susceptible, but the disease incidence was only moderate. However,

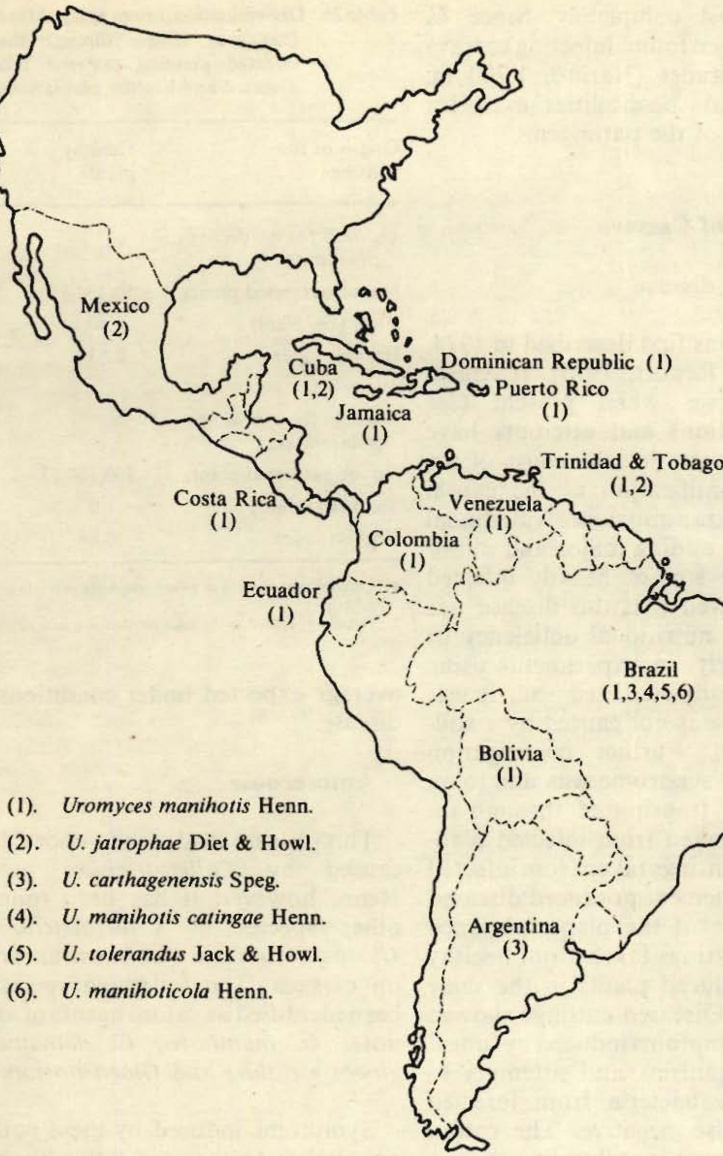


Figure 27. Geographical distribution of *Uromyces* spp. in *Manihot* spp.

after inoculation under greenhouse conditions, M Col 113 and 146, which showed high tolerance under field conditions, were rated as susceptible. It appears that the high incidence of the microparasite *Darluca filum* (Biv.) Cast. on pustules of *U. manihotis* in Mondomo plantations restricts the dissemination and incidence of this cassava rust and limits the production of uredospores because it invades the entire fruiting structure of the rust.

When the pathogenicity of *D. filum* was tested under controlled conditions, it was found that after 10-12 days of incubation at 70 percent relative humidity and 25⁰C, the parasite invades rust lesions. *D. filum* on mature sori restricts sporulation of *U.*

manihotis almost completely. Since *U. manihotis* has been found infecting cassava at different altitudes (Nariño, 1,700 m; CIAT, 1,006 m), possibilities exist for ecological races of the pathogen.

Other Diseases of Cassava

The frog skin disease

This disease was first described in 1974, (CIAT Annual Report, 1975). It causes tremendous losses when present (see Economics Section) and attempts have been made to determine the cause of the disease, the identification of the causal agent and its transmission. Nutritional studies made by adding major and minor elements to the soil of heavily infected plantations showed that this disease was not due to any nutritional deficiency or toxicity. Similarly, in experiments using heat- or chemically-sterilized soil, it was found the disease is not caused by a soil-borne pathogen. Further investigation showed that the syndrome was due to an infectious agent transmitted through infected cuttings taken from infected plantations. Of the cuttings taken from infected plantations, 87 percent produced diseased plants, but none of the plants obtained from healthy cuttings taken from healthy plantations produced plants in the same site (Table 26). Diseased cuttings showed no necrosis or symptoms induced by fungal or bacterial organisms and attempts to isolate fungi or bacteria from infected cuttings were also negative. The causal agent of this disease is still unknown.

Yields of plants infected with this disease may decrease by 50 percent; the harvest index of diseased plants is extremely low because they produce few swollen roots and aerial development is more vigorous than in the healthy plants. By using healthy plant propagating material taken from diseased or healthy plantations, the disease can be eradicated and yields can be increased more than three times the average expected under conditions of the disease.

Table 26. **Dissemination, losses and yield index of the frog skin disease through the use of infected planting material taken from diseased and healthy plantations.**

Origin of the Cuttings	Healthy plants	Diseased plants
Cuttings from infected plantations: [1]		
No. of harvested plants	50(13%) [2]	326(87%)
Yield (kg/plant)	1.40	0.70
Harvest index	0.63	0.33
Cuttings from healthy plantations: [1]		
No. of harvested plants	360(100%)	0.0(0.0%)
Yield (kg/plant)	1.0	—
Harvest index	0.84	—

1 Cuttings were planted in a field where the previous crop was 92% infected

2 Percentage related to the total number of plants harvested.

Anthracnose

This disease had been reported to be caused by *Colletotrichum manihotis* Henn; however, it has been found that other species of *Colletotrichum* and *Gloeosporium* can also cause anthracnose on cassava. The following species have been identified as causal agents of anthracnose: *C. manihotis, C. dematium, C. gloeosporioides* and *Gloeosporium* sp.

Symptoms induced by these pathogens are similar to those of foliar blight, butt rotting, die-back and stem cankers. However, specific symptoms have not yet been identified to specific pathogens. Generally, these pathogens attack more frequently during prolonged periods of rainfall.

Periconia leaf spots

In some cassava plantations necrotic leaf spots different from those induced by

Cercospora caribaea and other known foliar pathogens of cassava were observed. They are of variable sizes, light brown in color, with well-defined margins. They commonly coalesce, forming large irregular necrotic lesions frequently found at the end of the rainy season. The lesions are induced by a fungus of the genus *Periconia*. Taxonomic studies show that the fungus may belong to the species *P. shyamala* because the conidophores are similar to *P. byssoides* but its conidia are only 17.5u (16 to 20u) in diameter. So far the disease is unimportant because of its low severity and incidence.

Selection and Treatment of Planting Material

Losses almost always occur during the establishment of cuttings due to the attack of soil-borne pathogens (CIAT Annual Report 1972, 1973). These losses were reduced by a five-minute dip treatment of cuttings in some fungicide solutions.

Thirty-five fungicides and mixtures were tested (Table 12) and the following conclusions were reached: (1) Some fungicides are effective in protecting the cuttings against most of the soil-borne

Table 27. **The effect of five of the most promising fungicides or mixtures on early performance of cassava propagation material using a five-minute dip treatment of cuttings in the fungicide suspension.**

		Greenhouse test [2]		Field test [2]	
Treatment [1]	Rate (ppm)	Shoot height [3] (cm)	Germinated buds (%)	Shoot height [3] (cm)	Wt/plant (g)
chlorothalonil	2,000	14.4	44.4	12.7	251
	4,000	12.4	57.1	12.2	215
	8,000	11.6	44.4	12.2	213
maneb	2,000	11.7	61.7	12.6	242
	4,000	12.1	56.6	12.2	225
	8,000	14.3	62.2	12.0	212
captan	1,000	11.7	56.2	12.3	232
+ BCM	2,000	14.8	58.5	13.8	261
	4,000	14.5	67.6	12.7	246
	8,000	12.2	54.0	12.8	231
chlorothalonil	4,000	14.4	40.0	11.9	211
+ maneb	8,000	12.0	68.4	12.1	207
chlorothalonil	4,000	12.9	47.8	12.2	210
+ captafol	8.000	12.5	65.7	12.6	215
Control		7.8	40.6	10.6	160

1 Treatments consisted of a five-minute dip of cuttings in the fungicide suspension
2 Average data of three replications with nine cuttings each
3 A significant difference (at the .01 level) existed between treatments and the control.

pathogens of cassava and their effect can last up to 60 days; (2) By treating the cuttings with certain fungicides, bud germination takes place more quickly and is higher than in the untreated controls; and, (3) Some fungicides induce faster rooting and growth of sprouts than the control.

Even though the effect of fungicide treatment of cuttings on yield has not been determined, these promising results and the low cost of the treatments suggest that it is wise to treat the cuttings with fungicides before planting. Moreover, strict selection and care during preparation, handling and planting must be given to the cuttings to assure good establishment and to avoid further disease problems.

It was also demonstrated that by selecting healthy cuttings taken from plantations free of systemic causal agents (causal agents of bacterial blight, bacterial stem rot, the superelongation disease, the frog skin disease, viruses and mycoplasma, and of cankers, rotting and/or any vascular or epidermal necrosis) it was possible to avoid disease dissemination and to assure a high percentage of germination and crop development.

VARIETAL IMPROVEMENT

During the past year CIAT lines, both selected germplasm materials and hybrids, outyielded local cultivars both in and outside CIAT. Results indicate that high yielding genotypes can be produced relatively easily by hybridizations and selections. Tens of thousands of hybrids were made and evaluated in observational yield trials and replicated yield trials in and outside CIAT. Thousands of hybrid and open-pollinated seeds were distributed to breeders in Latin America, Asia and Africa. Several lines were passed for multiplications and regional trials (Table 28).

It was determined that root starch content and post-harvest root durability

Table 28. Cassava genotypes produced, evaluated and selected at four sites in Colombia during 1976.

	Site			
	CIAT	Carimagua	Caribia	Popayán
Germplasm collection	2,269			
Hybrid seeds produced (not including open-pollinated seeds)	30,007			
Hybrid seeds sown	22,482			
Hybrid plants harvested (planted in 1975)	16,196			
Hybrid plants selected	1,558			
Lines planted in observational yield trial	2,057	490	463	230
Lines harvested in observational yield trial (planted in 1975)	1,268	300	370	388
Lines planted in replicated yield trial	483	78	90	
Lines harvested in replicated yield trial (planted in 1975)	63	20	36	
Lines selected for multiplication	30			
Hybrid seeds distributed to other programs	6,628 (+ some 30,000 open-pollinated seeds)			

demand considerations prevailing in breeding

are highly heritable characteristics whose relative genetic values are stable over a wide range of environmental conditions. Groups of valuable genotypes were newly identified for CBB, superelongation, and Phoma leaf spot resistance. It was also found that high cassava yields can be obtained even on very acid infertile soils such as those of the Llanos Orientales of Colombia. Finally, the same high yielding genotype can give good yield over environmental variations of soil pH 4.5-7.8 and annual average temperatures of 24^{0}-28^{0}C.

no systematic parent identification

Yield Trials

Several thousand hybrids were developed in 1973 with little knowledge as to which parents were useful. The resulting hybrids were planted in the observational yield trial of 1974 with no selection at the seedling stage. The hybrids were first selected at this stage, and therefore, passed only one step of selection before they entered replicated yield trials. (Presently new hybrids pass three steps: selection of parents, selection at seedling stage, and selection in observational yield trials).

Of these hybrids, 150 were planted in replicated yield trials in CIAT during 1975. However, only 58 were harvested during 1976 because the others were lost as a result of salt spots and poor drainage of the field.One hybrid yielded more than 50 t/ha and eight yielded more than 40 t/ha. Many outyielded the local cultivar (Table 29). Results have been promising and suggest that by simple selection high yielding hybrids can be produced relatively easily.

In Carimagua, in the Llanos Orientales, M Col 1684 yielded 36.8 t/ha (11.8 t/ha in dry matter) and many yielded more than 20 t/ha (Table 30). The soil in this area is very infertile and acid (pH 4.5) and the level of aluminum is so high that most field crops simply cannot grow even with a fairly heavy application of fertilizers. This indicates that cassava is a highly efficient crop in producing carbohydrate on poor acid soils. There is an immediate possibility of varietal selection of cassava for this kind of soil.

In Caribia, (pH 6.5, mean temperature 28^{0}C) M Col 1684 was again the top yielder with 44.2 t/ha (Table 31). Seven cultivars

Table 29. **Results of Replicated Yield Trial during 1975/76 crop year at CIAT.**[1]

Line	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yield (t/ha/yr)
SM1-150	52.2[2]	.310[2]	16.2[2]
SM1-162	45.8	.326	14.9
CM192-1	45.3	.358	16.2
SM1-211	44.4	.324	14.4
CM104-3	43.6	.332	14.5
CM156-3	42.5	.356	15.1
SM1-193	41.9	.322	13.5
SM1-223	40.3	.346	13.9
CM192-5	38.9	.350	13.6
CM208-10	38.3	.318	12.2
M Col 22 (control)	35.3	.372	13.1
M Col 113 (local)	27.2	.306	8.3
Llanera (control)	25.3	.304	7.7

1 Soil pH 7.8; annual average temperature 24^{0}C; no fertilizer applied

2 All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 spacing, eliminating two rows of borders.

Table 30. **Results of Replicated Yield Trial during 1975/76 crop year at Carimagua.**[1]

	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yield (t/ha/yr)
M Col 1684	36.8[2]	.320[2]	11.8[2]
CM 180-5	26.1	.358	9.3
M Col 710	25.0	.353	8.8
M Mex 59	24.8	.357	8.9
M Col 1468	24.7	.310	7.7
M Col 638	24.3	.324	7.9
M Ven 326	23.4	.350	8.2
M Col 22	23.2	.349	8.1
M Col 655A	23.2	.373	8.7
M Col 5	23.1	.342	7.9
Llanera (control)	23.0	.339	7.8

[1] Soil pH 4.5; annual average temperature 26°C; fertilizer applied 100 kg/ha N, 200 kg/ha P_2O_5, 200 kg/ha K_2O, 115 kg/ha Ca, 52 kg/ha Mg.
[2] All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 m spacing, eliminating two rows of borders.

selected at CIAT and ICA yielded more than 30 t/ha and many outyielded the local cultivars quite significantly. M Col 1684 was also one of the 11 cultivars yielding more than 50 t/ha in 1975 at CIAT. The pH of CIAT's soil is around 7.8 and the soil is generally regarded as highly fertile. This suggests that a wide range of soil pH's (from 4.5 to 7.8), temperature's (24°-28°C) and fertility can be covered by the same high yielding genotype. The major part of the world's cassava grows within these

Table 31. **Results of Replicated Yield Trial during 1975/76 crop year at Caribia.**[1]

	Root yield fresh wt. (t/ha/yr)	Root dry matter content	Root dry matter yield (t/ha/yr)
M Col 1684	44.2[2]	.296[2]	13.1[2]
M Ven 307	37.5	.344	12.9
M Col 1468 (CMC 40)	35.0	.269	9.4
M Mex 59	32.8	.337	11.1
CMC 180	32.2	.315	10.1
CMC 144	30.6	.302	9.2
CMC 151	30.6	.315	9.6
M Ven 326	29.4	.306	10.0
M Ven 318	29.2	.344	10.0
CMC 74	27.2	.357	9.7
M Col 22 (control)	26.9	.350	9.4
Majetera (local)	23.1	.360	8.3
Llanera (control)	19.4	.291	5.6
Manteca (local)	17.5	.350	6.1
Montero (local)	13.6	.370	5.0

[1] Soil pH 6.5; annual average temperature 28°C; no fertilizer applied
[2] All the yield data are the average of two replications and come from the nine plants planted at 1 x 1 m spacing eliminating two rows of borders.

What is the harvest index?

ranges. Thus, the data suggest not only that cassava can be grown successfully under wide range of environments, but also that a single high yielding genotype can cover the major part of this wide range.

In CIAT, there was a highly significant correlation between harvest index and root yield with a slight tendency for the types with too high a harvest index to yield less (Fig. 28). This correlation was also significant both in Carimagua (Fig. 29) and Caribia (Fig. 30). Last year (CIAT Annual Report, 1975) it was demonstrated that the harvest index was a highly efficient and reliable character in selection for root yield throughout the selection of cross parents and the selections at seedling stage and in single-row trials. Results this year further suggest the validity of harvest index as a selection character for high yield over a wide range of environmental variation.

Evaluation of Hybrids

About 16,000 hybrids from several hundred crosses were harvested during the year. From this population, about 1,500 hybrids were selected and planted in observational yield trials and some 500 selected lines are being evaluated in replicated yield trials in CIAT and in observational yield trials outside CIAT (Table 28).

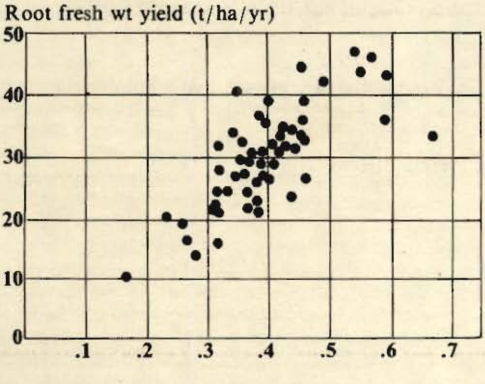


Figure 28. **Relationship between harvest index and root yield of cassava at CIAT, 1976.**

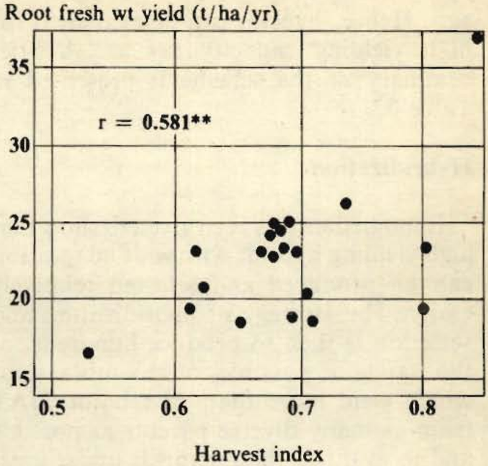


Figure 29. **Relationship between harvest index and root yield of cassava at Carimagua, 1976.**

All the hybrid seedlings at CIAT are selected for productivity mainly using harvest index. At this stage, stem cuttings of some genotypes are prepared for disease evaluation. After the observational yield trial is harvested at CIAT the superior lines are screened for different characters. The CIAT farm is kept free from two of the most important diseases, i.e., CBB and superelongation since the pathology group eradicated CBB from the farm four years

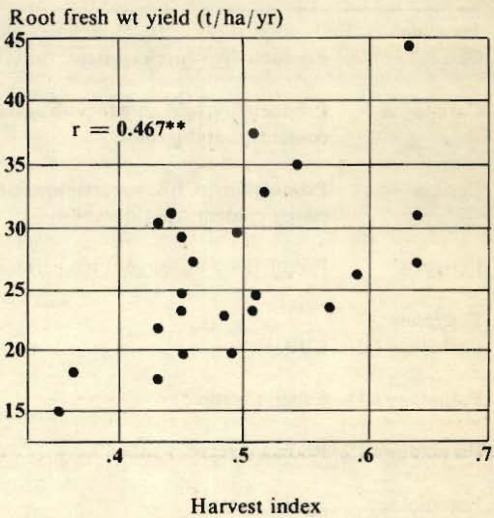


Figure 30. **Relationship between harvest index and root yield of cassava at Caribia, 1976.**

Is this sufficient exposure + realistic. Depends up the incidence levels.

ago. Hence, hybrids can be evaluated for high yielding capacity *per se*. A brief summary of the scheme is presented in Table 32.

Hybridization

Enough data has been given to show that high yielding hybrids with wide adaptation can be produced and selected relatively easily. The strategy of hybridization and selection is then to produce hundreds, or thousands, if possible, of recombinations which yield more than 50 t/ha at CIAT from as many diverse parents as possible and to evaluate these hybrids under great environmental diversity, and at the same time, incorporating as much disease and pest resistance as possible into the whole population.

A moving target

General productivity and wide adaptation.

From the original germplasm collection, such cultivars as M Col 655A, M Col 1292, M Col 1684, M Mex 17, M Mex 59, M Ven 168, M Ven 185, M Ven 218, M Ven 270, M Pan 70 and M PTR 26 remain as important parents in the list of hybridizations. After one cycle of hybridization and selection, high harvest index genotypes with other favorable agronomic characters are available by the hundreds. All these materials were crossed among themselves and with disease resistant genotypes, etc.

An example is given by the case of M Col 1684. Due to the extremely high harvest index of M Col 1684, it was decided to include this cultivar in hybridizations more than a year ago, so that some 5,000 hybrid seeds of M Col 1684 have been produced up to now.

CBB resistance

Among the four CBB resistant genotypes, i.e., M Col 197, M Col 638, M Col 647 and M Col 667, which have been used as sources of resistant genes M Col 647 has proven to be outstanding. After

Table 32. **Scheme of cassava hybrid evaluation according to locations and research discipline.**

	Major characters being evaluated
Location	demand
CIAT	Productivity, starch content, root durability, HCN content, thrips.
Carimagua	Productivity, tolerance to poor acid soil, superelongation, CBB, tolerance to dry season, starch content, root durability.
Caribia	Productivity, CBB, superelongation, *Cercospora* diseases, growth under hot dry climate, starch content, root durability.
Popayán	Productivity under cool temperatures, Phoma disease.
Discipline	
Pathology (I)	CBB
Pathology (II)	Superlongation
Pathology (III)	Phoma disease
Entomology	Spider mites
Physiology	Photosynthetic activity

Figure 72 shows the distribution of scores on the two tests.

These newly trained agronomists will form important links between their respective countries and CIAT's expanding cassava outreach activities.

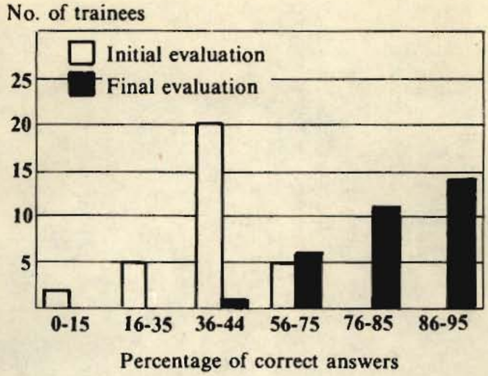


Figure 72. Comparison of initial and final knowledge evaluation of 32 trainees participating in the CIAT Cassava Production Course, 1976.

PUBLICATIONS

COCK, J.H. Characteristics of high yielding cassava varieties. Expl. Agric. 12:135-143. 1976.

LOZANO, J.C. and TERRY, E. Enfermedades de la yuca y su control. Noticias Fitopatológicas 1:38-44. 1976.

NESTEL, B. and COCK, J.H. Cassava: the development of an international research network. IDRC º59e. Ottawa, Canada, International Development Research Centre, 1976. 69 pp.

ROSAS, C., COCK, J.H. and SANDOVAL, G. Leaf fall in cassava. Expl. Agric. 12:395-400. 1976.

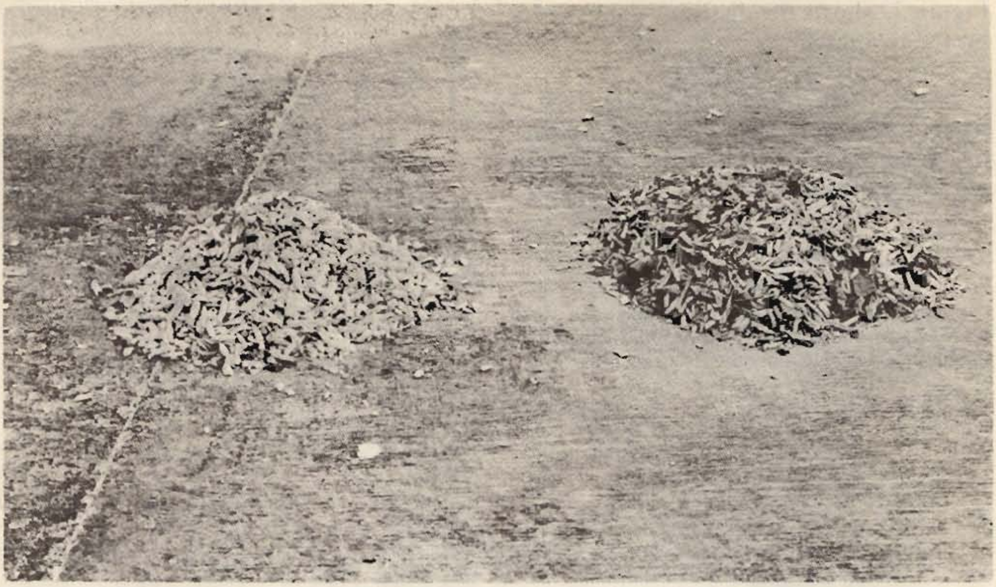


Figure 71. Chips on the left were dried under good conditions and have an excellent appearance; those on the right have deteriorated in quality during extended drying periods.

floor, these being the major disadvantages of this method of drying.

The visual quality of cassava chips depends on the drying rate, Chips dried rapidly under good conditions either on concrete at 5 kg/m² or in trays at 10 kg/m² are a brilliant white. When the drying period extends for two or more days the quality of chips produced by both methods deteriorates and there is a greater proportion of dust and fine particles in the concrete dried product due to repeated sweeping up and spreading of the cassava (Fig. 71).

TRAINING

Intensive Course on Cassava Production

Thirty-two agronomists from nine Latin American countries participated in a 31-day Intensive Course on Cassava Production funded by the Canadian International Development Research Center. During the 24 instruction days, 176.5 hours of training were given with 37.4 percent devoted to theory and 62.6 percent to practice.

Twenty-nine CIAT technicians, assistants and senior staff provided the direct instructional input. Teaching materials were compiled and printed as preliminary editions of two books in Spanish: "Course on Cassava Production" (432 pages) and "Management and Control of Weeds in the Tropics" (132 pages).

Effectiveness of the course and progress of the trainees were measured by two examinations — at the beginning and at the end of the course. Every student improved his knowledge; the average score of the initial test was 44 percent while the group averaged 79 percent on the final test.

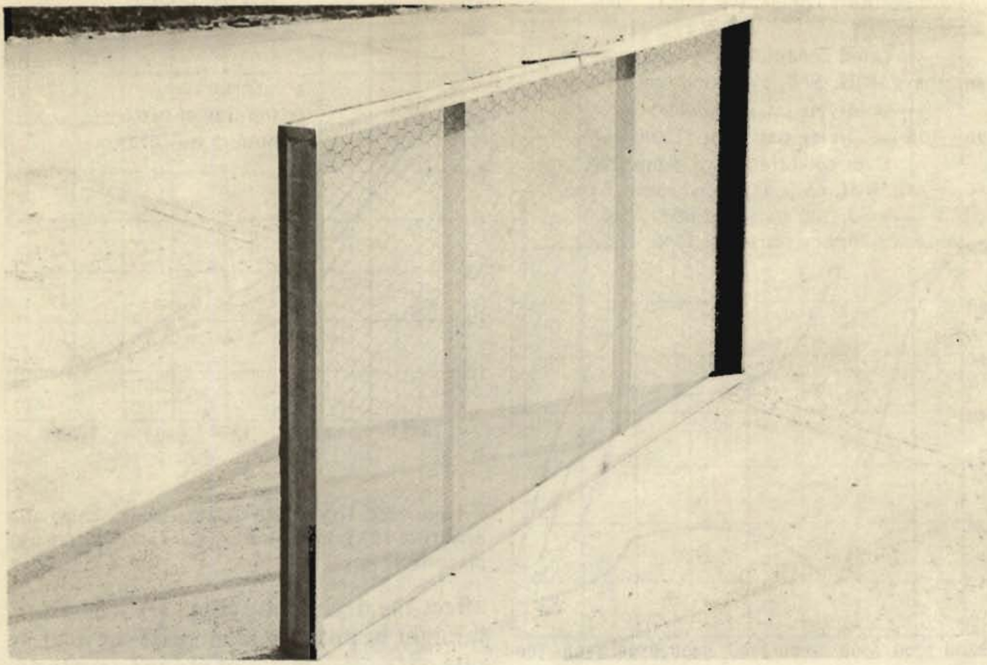


Figure 70. Drying trays constructed in this manner are sturdy and can carry 15 kg of moist chips m².

Various materials are being tested for constructing the drying trays and their supporting frames. The latter can be made simply from bamboo posts and rails arranged to support the trays at an angle of 25-30° and positioned to make the greatest use of the prevailing wind. Wooden framed trays, 0.90 x 1.70 meters by 5 centimeters deep with a base of plastic mosquito screen supported by chicken netting have proved sturdy and capable of carrying 15kg/m² (Fig. 70); higher densities require deeper frames and a more substantial mesh.

The material costs per square meter of drying area are given in Table 46. Labor costs are not included as a farmer could build the trays or lay the concrete himself. The trays may be built of readily available materials and the cost of transporting them may not be as great as compared with cement, sand, gravel and hard-core. However, trays will have a shorter life and need greater maintenance than a concrete

Table 46. **Material costs for tray and concrete drying of cassava.**

	Col. $/m²
Trays	
Bamboo frame	15
1" chicken netting, 0.90 m wide	22
Plastic mosquito netting, 0.90 m wide	16
Wood frame for trays 0.90 x 1.70 m	45
Total cost of materials:	98
Concrete	
10-cm thick concrete floor	45
Foundation	15
Black pigment or paint	10
Total cost of materials:	70

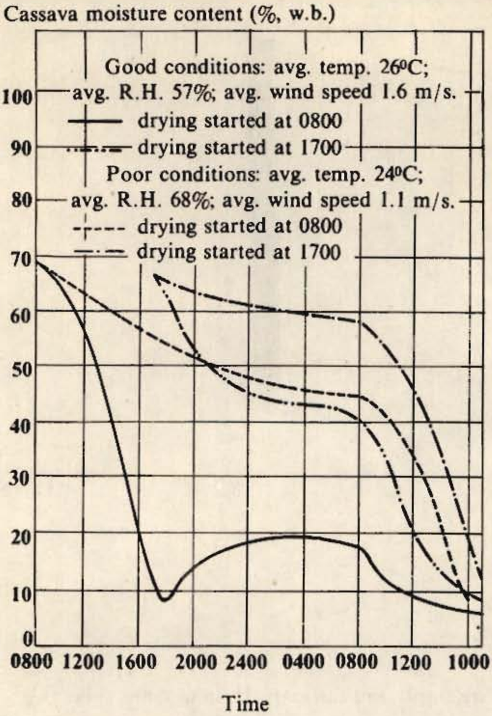


Figure 67. **Drying curves for cassava at a density of 10 kg/m² in inclined trays according to weather conditions.**

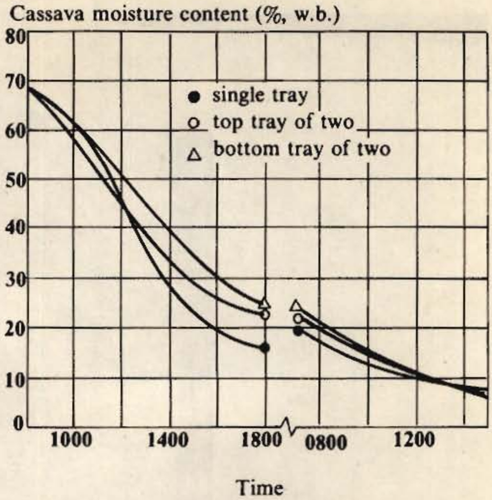


Figure 69. **Drying curves for cassava chips at a density of 10 kg/m² in inclined trays according to tray placement.**

affect the drying rate (Fig. 69). Therefore, it might be possible to increase the loading rate per square meter of ground area to 40-60 kilograms by placing 3-4 trays on top of each other, thereby justifying a roof or cover to protect the cassava at night and during rain.

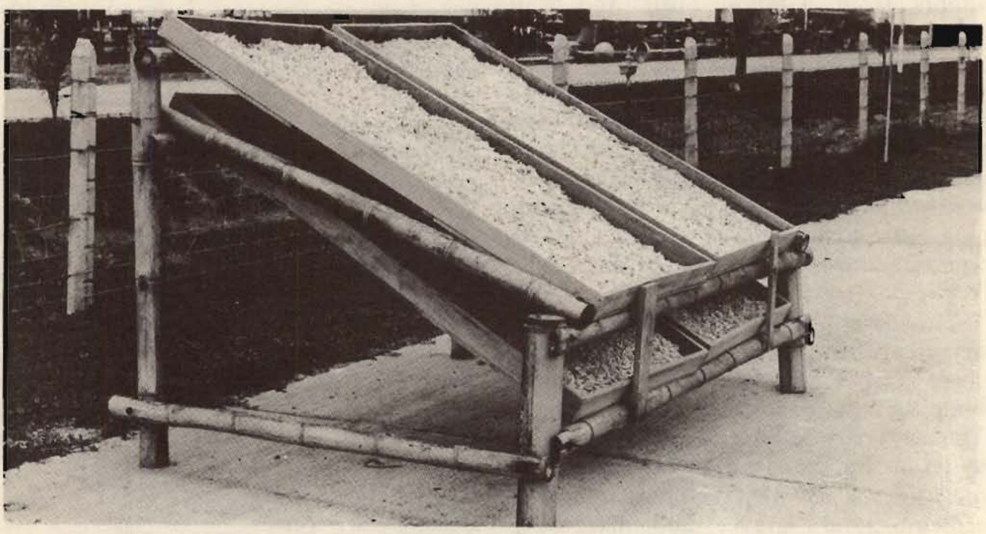


Figure 68. **When inclined trays are stacked in this way with a 30-centimeter space between them, drying rates for the chips are not appreciably affected.**

shows being sound fresh + greater preservation

'the cassava skin together with particles smaller than the chips. The fine material mixed with the chips apparently doesn't affect the drying rate, either on concrete or in trays, but does cause losses of up to 8 percent dry matter during drying and storage in fiber sacks. Modifications are being made to the blades and feed hopper to try to reduce the production of fine material.

Trials over a three-month period at CIAT have shown that the traditional method of drying cassava on concrete can be improved by placing the chips in horizontal or inclined mesh trays (Table 45). The increased drying rate is achieved by better circulation of air around the chips and, in inclined trays, better usea is made of the drying power of the wind. The maximum angle of inclination of a tray has been found to lie between 25 and 30º.

Drying on black concrete gives a marked improvement over plain concrete at a fresh cassava loading of 5 kg/m², but at 10 kg/m² the layer of chips is too thick and the black surface is almost totally obscured. The higher loading rate does not require a proportionally greater number of drying hours and hence gives a greater capacity per unit area of drying surface. In practice it is difficult to achieve loading rates higher than 7 kg/m² using wooden rakes to spread and turn the chips; in this respect the design of the rake is important and requires more attention. Drying on black concrete has the disadvantage of cassava dust collecting in the cracks and reducing the absorption of solar radiation; therefore the concrete should have a smooth finish with a black pigment incorporated into the final layer to give a permanent color. For the same number of drying hours the capacity of inclined trays is double that of concrete, and if the cassava is spread evenly over the trays no turning is necessary, thus cutting labor costs during drying.

If inclined trays are used a further reduction in drying time is achieved by starting chip drying in the late afternoon. Cassava chipped at 0800 hours and placed in inclined trays at 10 kg/m² does not always dry below 14 percent moisture content, wet basis (w.b.) in one day. If the moisture content of the chips falls below 20 percent absorption of moisture can occur during the night. However, cassava chipped at 1700 hours continues to dry throughout the night and heat of the next day reduces the moisture content to below 14 percent. Figure 67 shows typical drying curves for sunny and cloudy days. Even under poor conditions, when drying starts at 1700 hours the chips reach 14 percent moisture in one complete day thus allowing the trays to be loaded again.

Stacking inclined trays one on top of the other with gaps of 30 centimeters between the trays (Fig. 68) does not appreciably

Table 45. **Hours required to dry cassava to 14 percent moisture (wet basis), at CIAT, June-August 1976.**[1]

Method of drying	Density of chips (kg/m²)	Number of trials	Drying time (hrs) Total hours	Hours between 0800-1800
Plain concrete	5	6	26	12
Black concrete	5	6	20	10
Plain concrete	10	4	34	19
Black concrete	10	4	32	18
Horizontal trays	10	5	29	15
Inclined trays	10	8	20	11

[1] Drying conditions: horizontal trays 30 centimeters above ground; inclined trays at 28º. Drying began at 0800 and chips were covered between 1600 and 0800.

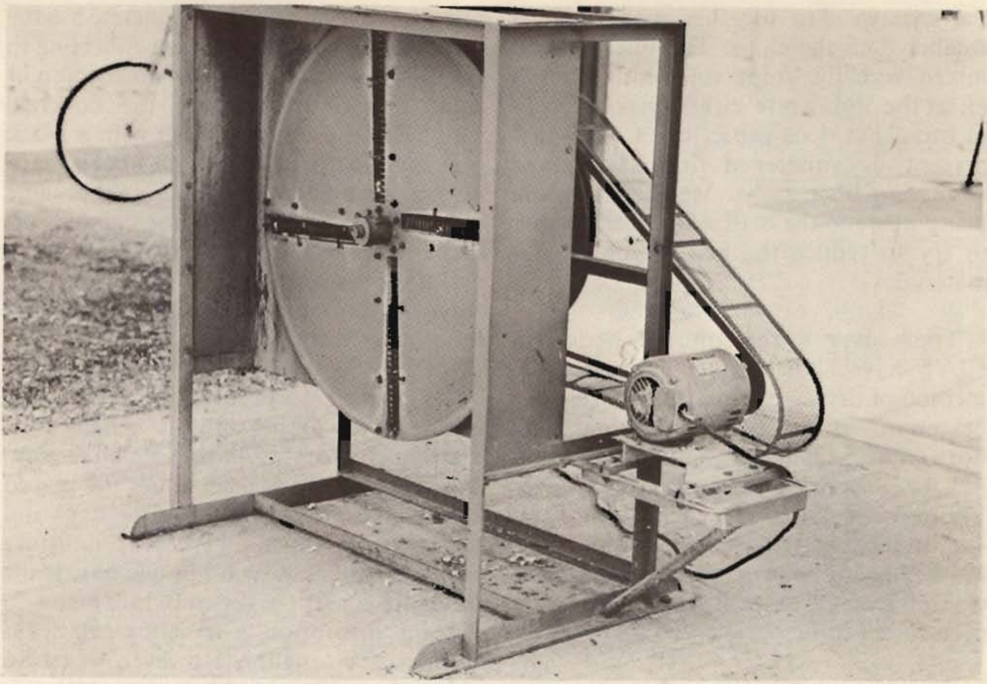


Figure 65. Malaysian type cassava chipper used in CIAT's studies of cassava drying.

Figure 66. Different treatments used in cassava drying studies at CIAT.

Table 44. Yield losses due to different factors affecting cassava production in Colombia.[1]

	Loss in affected plot (t/ha)	Total area affected (%)	Avg. yield loss over total area (t/ha)
Phoma	3.45	4	0.13
Superelongation	3.45	4	0.13
Low phosphorus	2.21	63	1.39
Associated crops	1.89	31	0.59
High pH (>5.5)	1.74	58	1.01
Ants	1.20	2	0.02
CBB	0.75	5	0.04
Total			3.31
Excessive rain	0.77	48	0.37
Heavy soil texture	1.46	75	1.09

[1] Calculated on basis of an average yield of 6.2 t/ha.

$19,000/ha in zone II but returns were negative in zone V.

Share-cropping occurs in some zones with farmers giving one-third of the production to the owner. In zones III, IV and V net returns to the share-cropper were negative. nonsense

The average price received by farmers was Col. $1,540/t, however prices in zones II, and III were almost double those of zone V. The difference is probably due to the proximity of large fresh markets in zones II and III. Although individual farmers received very different prices, there was no tendency for the large farmer to obtain better prices.

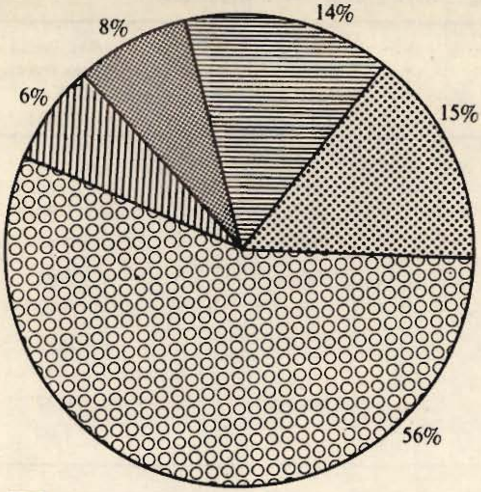
Yield Losses

A multiple regression analysis was used to analyse limiting factors on yield. When Phoma and superelongation were present yield losses were tremendous (Table 44); superelongation was present on only a small area of the total but potential losses are tremendous if this disease spreads. Using associated cropping systems also markedly reduced yields (see Multiple Cropping Section). Low phosphorus in the soil was also apparently a major limiting factor on cassava production. High soil pH (>5.5) also apparently reduced yield, although other factors are likely to be involved. Excessive rain and heavy soil texture are also associated with reduced yields, however, unlike the other factors, it is difficult to see how these can be ameliorated. The correction of the other limiting factors would increase yields by 3 t/ha (35%).

CASSAVA DRYING

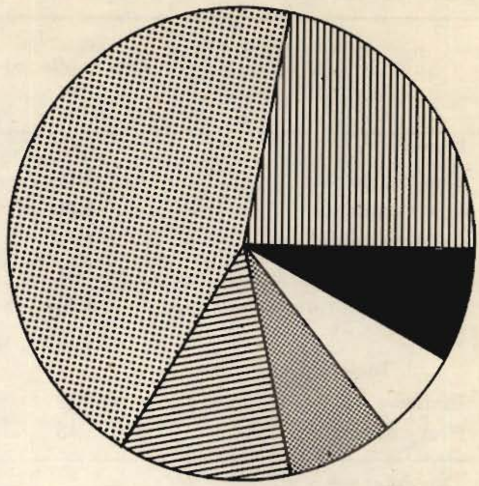
Following earlier studies (CIAT Annual Report, 1973) work has been continued on improved methods of drying cassava naturally. Cassava chips produced by a Malaysian type chipper (Fig. 65) have been dried in horizontal and inclined mesh trays raised above the ground (Fig. 66) with comparative trials on plain and black concrete.

The Malaysian chipper produces moderately uniform chips, 0.4-0.6 centimeters thick and 1-8 centimeters long, and separates from the chips a large part of



Land preparation
Harvesting
Weeding
Hilling, irrigating, draining, pruning, applying fertilizers and pesticides.
Planting, replanting

Figure 63. **Estimated percentages of the total labor required for producing cassava that are allocated to the various production activities.**



Land preparation
Harvesting
Weeding
Inputs
Planting, replanting
Hilling, irrigating, draining, pruning,. applying fertilizers and pesticides

Figure 64. **Estimated percentages of the total variable production cost per hectare of cassava that are allocated to the various production activities.**

greatest yields, cost per ton was lowest (Col. $850/t).

The total value of the production was greatest in zone II, over Col. $25,000/ha. and lowest in zone V, about Col. $4,000/ha. The net return to farmers after paying for estimated rent was Col.

Table 43. **Average total production costs of cassava per hectare and per ton in each of two zones in Colombia.**

	Zone I		Zone II		Total	
	Col. $/ha	Col. $/t	Col. $/ha	Col. $/t	Col. $/ha	Col. $/t
Average variable costs	3,068	694	5,019	397	3,968	640
Administration			199	16	62	10
Technical assistant	8	2	9	1	4	1
Surveillance	39	9	263	21	96	15
Packing	52	12	126	10	123	20
Interest (12% of variable cost)	368	84	602	48	476	77
Total cost excluding land rent	3,535	803	6,218	494	4,729	763
Land rent (10% of land value)	278	63	4,511	358	1,318	212
Total cost	3,813	866	10,733	852	6,047	975

Not an interesting crop combination

(CIAT Annual Report, 1973) was again proven; the later the bean was planted the greater the cassava yield. The 80 days between the first and the second cassava harvest gave time for the cassava to recover, especially when the total biomass was low at the 100 days harvest (Fig. 61).

These preliminary results suggest that by planting beans 0-2 weeks after the cassava, 75 percent of the bean monoculture level can be obtained and after 180 days an average of 50 percent of the cassava monoculture level can be obtained (Fig. 62). From 100-180 days the intercropped yield of cassava relative to control increased so that by 300 days the relative yields may be even more promising.

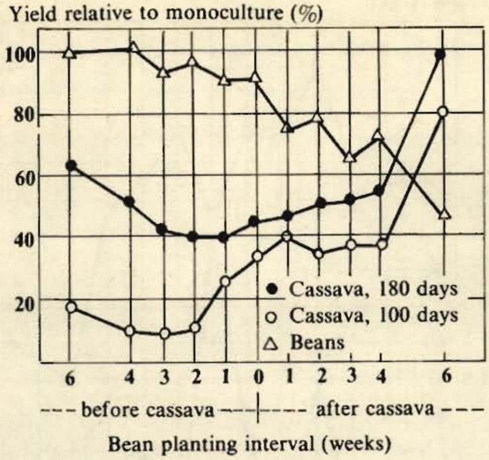


Figure 62. **Root dry matter yield of cassava at 100 and 180 days and yield of beans at maturity when beans were planted before, at the same time and after cassava.**

weeding as the barrier to output increase

ECONOMICS

In the 1973, 1974, and 1975 CIAT Annual Reports the methodology and preliminary results of an agro-economic survey were presented. The survey was made in five zones of Colombia: (I) Cauca, (II) Valle and Quindio, (III) Tolima, (IV) Meta and (V) Magdalena and Atlántico. Analyses of all data have now been completed.

However family labor costed? All this is worthless

Economic Data

Average yields from the survey were less than 7 t/ha although a great range was observed from near zero to more than 40 t/ha. Yields tended to be greater on large farms than on smaller ones, 7.9 and 4.3 t/ha, respectively. The effect was particularly noticeable in Valle and Quindio zone with 14 and 8 t/ha for large and small farms, respectively.

Although yields are low, very much labor is used to produce cassava an average of 86 man-days/ha and varying from 66 in zone IV to 106 in zone I. About half this labor input was for weed control with land preparation, planting and harvesting using another 30 percent of the total (Fig. 63).

The variable cost of cassava production was estimated as almost Col. $4,000/ha or Col. $640/t of cassava produced. The variable production costs per hectare varied from Col. $3,000/ha in zone I to Col. $ 5,000/ha in zone II. The weeding of the crop accounted for about 50 percent of the variable costs while purchased inputs accounted for only 8 percent of variable costs (Fig. 64).

The average total costs are about Col. $6,000/ha or Col. $1,000/t (Table 43). The costs on large farms are greater per hectare due to higher land value (rent estimated at 10 percent of land value), administration costs, security and packing. Nevertheless, cost per ton of cassava is lower as a result of greater production. In zone III, with lowest yields, costs per ton were greatest, (slightly greater than Col. $1,600/t) and in zone II with highest cost and

don't include the fixed costs. Too arbitrary

Wrong place
Not relevant experiments

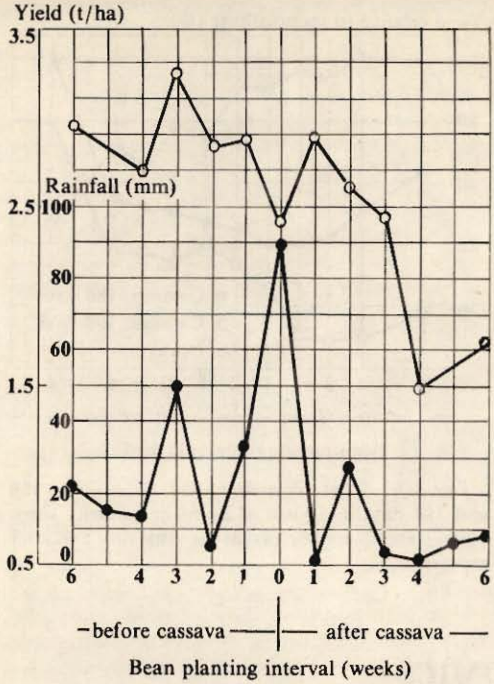


Figure 58. **Monoculture yields of beans showing influence of rainfall patterns on yields in intercropping experiment with cassava and beans.**

yield was still 2.9 t/ha (Fig. 58). Bean yields were not severely reduced when beans were planted earlier than the cassava but yields decreased when planted after the cassava

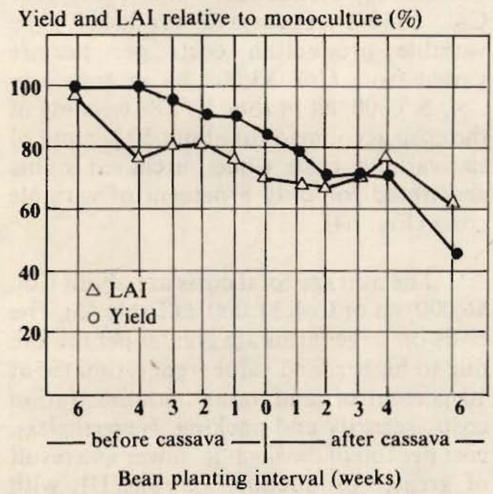


Figure 59. **Yields and leaf area index (LAI) maximum of intercropped beans planted before, at the same time and after cassava.**

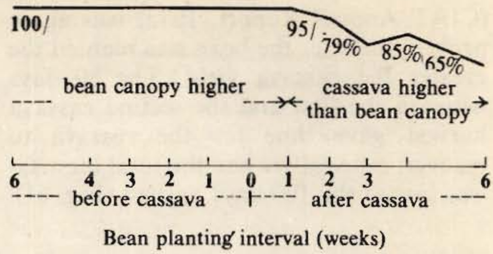


Figure 60. **Percentage of light available to beans intercropped with cassava and planted before, at the same time and after cassava.**

(Fig. 59). When cassava was planted six weeks before beans, bean yields were reduced to 53 percent of their monoculture level.

about the same as with corn. Not useful experim

The light intensity at the top of the bean canopy five days after maximum LAI is shown in Figure 60. Marked yield depression only occurs when the cassava canopy is above the beans suggesting that the main competition is for light.

Cassava has been harvested at 100 and 180 days and there will be further harvests at 260 and 340 days. Figure 61 shows the total biomass curve of cassava as affected by the different bean planting dates. The fact that cassava does not tolerate any competition during the early growth stages

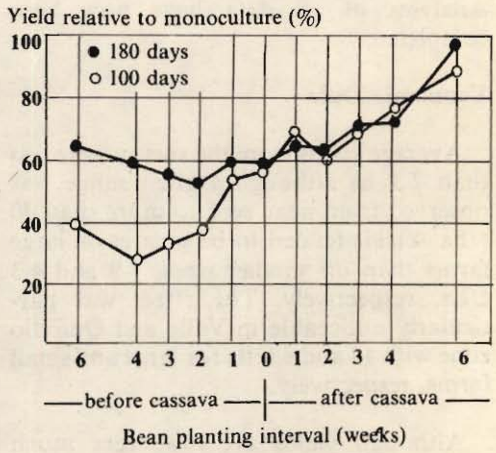


Figure 61. **Biomass yield of cassava at 100 and 180 days when beans were planted before, at the same time and after cassava.**

be recommended to select a highly tolerant cultivar of cassava rather than modify the soil with rather expensive acidifying agents.

MULTIPLE CROPPING

Multiple cropping is widespread throughout the world and it is commonly practiced in Latin America by small farmers who grow cassava. Beans, maize, yams, potatoes, tomatoes and other crops all are frequently grown with cassava. The multiple cropping methods used appear to be based on tradition and the criteria for agronomic decision-making are poorly understood. It is known that intercropping cassava with beans, for example, will reduce yields of both crops. But, on the other hand, multiple cropping may be an efficient way to reduce weeds, diseases and insects and hence increase farmers' net returns (CIAT Annual Report 1975). During its early growth cassava does not tolerate shading, however, neither does it intercept much light. Hence, much light apparently is not utilized by the cassava. This light could be used for another crop such as beans.

Experiments on intercropping cassava with beans were begun early in 1976. The main objective of these experiments was to understand crop interactions so as to define more efficient multiple cropping methods.

Planting Date Experiment

The cassava variety M Mex 11 and the bean variety P302 were planted with 11 different bean sowing dates relative to a single planting date for the cassava. Beans were sown at 250,000 plants/ha and cassava at 10,000 plants/ha according to the pattern shown in Figure 57. Control plots of beans only and cassava only were also planted.

Due to climatic conditions the bean yield in monoculture tended to decrease with advancing planting dates but the mean

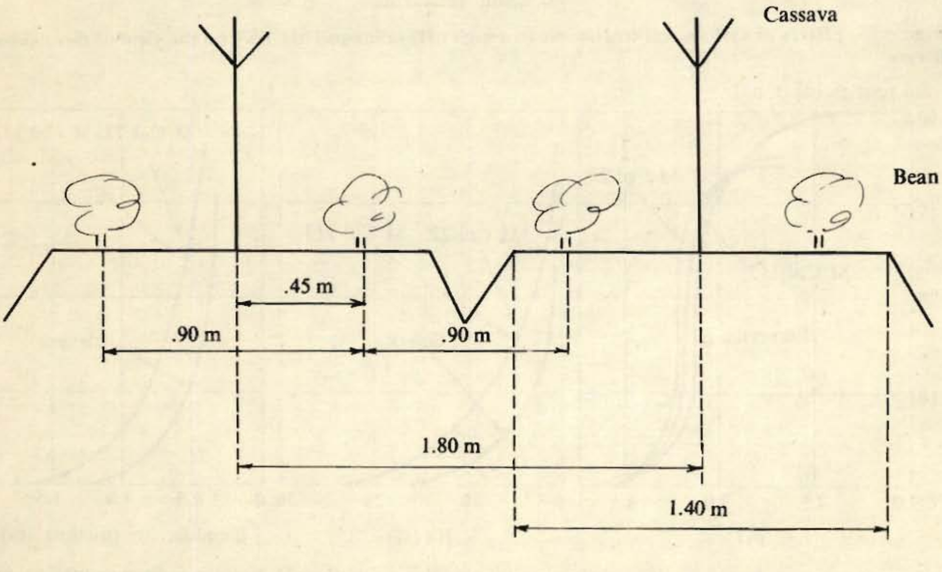


Figure 57. **Planting pattern for intercropping studies of cassava and beans.**

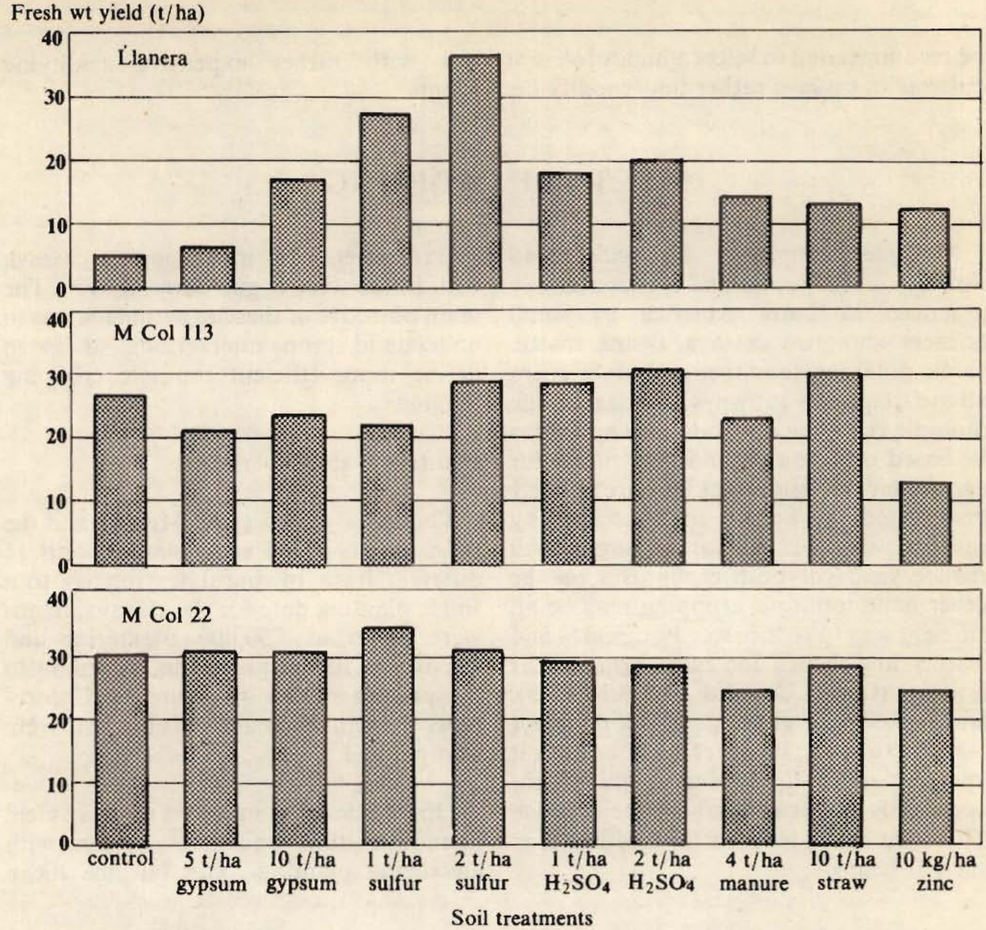


Figure 55. Effects of various soil treatments to a high pH, saline soil in CIAT on the yield of three cassava cultivars.

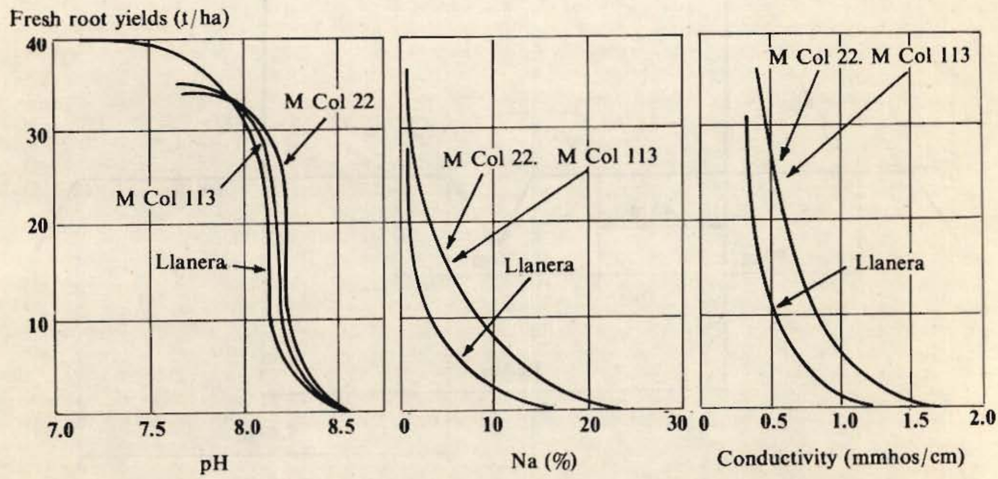


Figure 56. Relation between yields of three cassava cultivars and the pH, percent sodium saturation, and electrical conductivity of the soil, at CIAT.

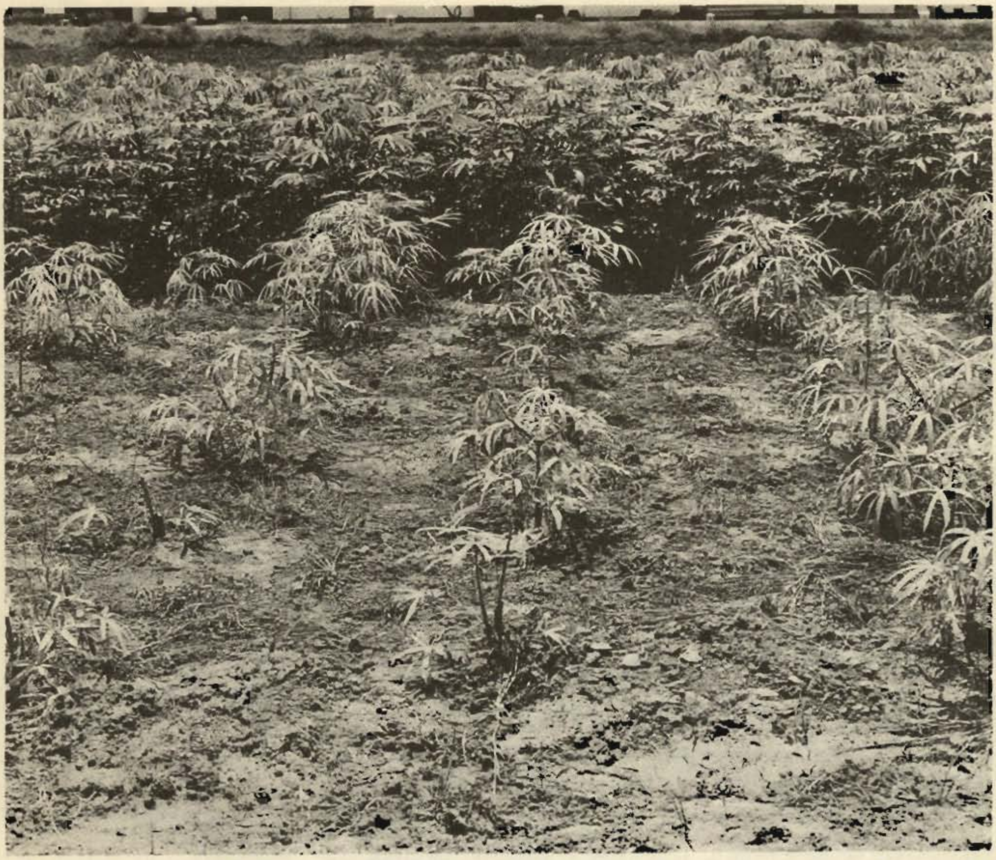


Figure 54. Effect of soil salinity on cassava growth; in the foreground is the susceptible cultivar Llanera, in the background, the tolerant cultivar M Col 22.

grown in each treatment. Figure 55 shows the effect of soil treatments on cassava yield. It is clear that the treatments had little effect on the yield of the two tolerant cultivars M Col 22 and 113. However, in the susceptible cultivar, Llanera, whose yields increased from 5 to 35 t/ha with the application two tons of elemental S/ha. The application of 1 or 2 t/ha of sulfur or sulphuric acid increased yields considerably. However, soil treatment effects were greatly masked by extreme soil variability within the lot and results must be considered as preliminary.

Figure 56 shows the relationship between yield and pH, percent sodium saturation and electrical conductivity of the soil. The critical pH for Llanera was 7.8 and for M Col 22 and 113 between 8.0 and 8.1. Above these pH's yields declined markedly. Similarly, yields were severely affected by excess sodium when the percent of sodium saturation was above 1 percent for Llanera and 4-5 percent for the other varieties. Yields were affected by salinity when the conductivity was above 0.5 mmhos/cm for Llanera and 0.7 for M Col 22 and 113. Thus, while many other crops are not affected by excess sodium until the percentage saturation is above 15 percent and by salinity until the conductivity is above 2 mmhos/cm, cassava is seriously affected at much lower values, and thus more susceptible to soil salinity and alkalinity. Under these conditions it would

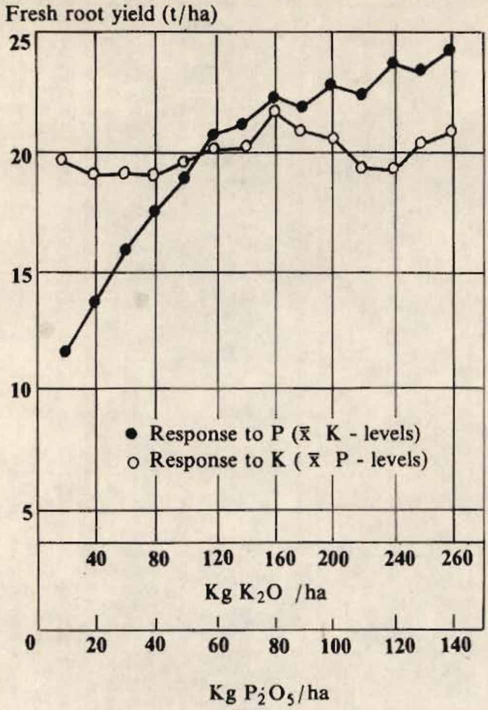


Figure 52. **Average response of cassava to the application of phosphorus and potassium, in Carimagua.**

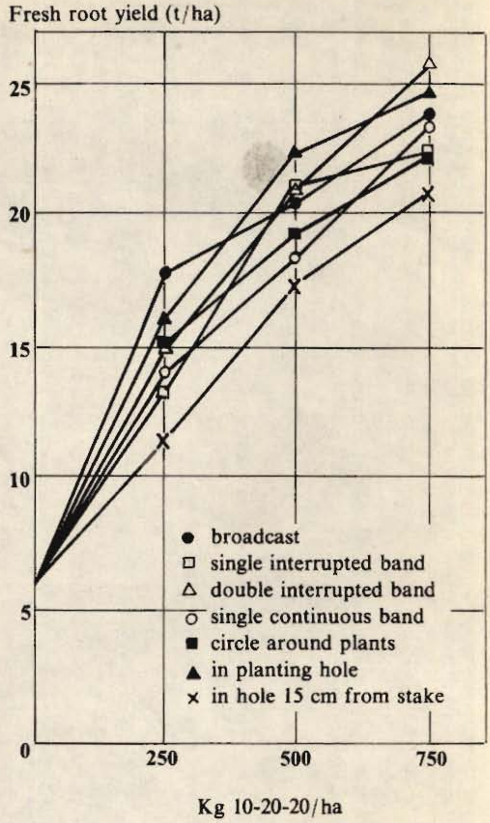


Figure 53. **Effects of various levels and methods of 10-20-20 fertilizer application on yields of cassava, in Carimagua.**

Although there were no significant differences among methods of application ($P = 0.05$), placement of the fertilizer in the planting hole gave a slightly higher average yield but also the greatest variability in yield, due to loss of stand caused by fertilizer burn of the stake. This effect was most pronounced when the dry season followed planting, but when planted before the wet season no loss of stand occurred. During dry season planting, broadcast application was comparable to other methods (Fig. 53), while in the wet season planting this method reduced initial plant growth and encouraged excessive weed growth. The commonly used and very labor intensive circle application was equal or less effective than other methods. Fertilizer application in a hole 15 centimeters from the stake was the least effective method.

Management of Saline/Alkaline Soils

Although cassava is well adapted to acid soils, it appears quite sensitive to high pH and saline soil conditions. Large varietal differences in sensitivity have been observed on the high pH soils of the CIAT farm (Fig. 54). The uniform yellowing of leaves and die-back of the growing point is generally due to a combined effect of high pH, salinity, alkalinity, poor drainage, and sometimes deficiency of minor elements, especially zinc.

Various soil treatments to overcome one or more of these problems were established in a field of high pH, and three cassava cultivars of different sensitivities were

Kg P_2O_5/ha   23-25 t/ha   > 25 t/ha

Kg P_2O_5/ha	20	40	60	80	100	120	140	160	180	200	220	240	260	280	$\bar{X}$
$\bar{X}$	20	19	19	19	20	20	21	22	21	21	19	19	20	21	
140						20	22					22			
130		22	21	22	22	20	20								
120			21	21	22										
110		21	20	21	21		22		22		21				22
100	22	21	22	22							20	21	22		
90	19	19	20	21	22		21				21	21			22
80	19	20	22				22				21			22	2
70	19	18	20	19	20	22	22		20	22	21				21
60	21	20	20	19	20				21	19	18	20	21	21	21
50	19	19	17	16	17	20	22	22	19	17	17	18	19	20	19
40	19	19	18	18	17	17	19	20	19	16	16	16	16	17	18
30	16	17	17	16	16	15	17	16	16	14	16	15	15	16	16
20	14	15	15	14	14	14	15	14	14	13	13	13	13	13	14
10	11	12	13	11	12	12	13	12	12	11	11	10	13	13	12

Kg K_2O/ha

Figure 51. Root yields of cassava (t/ha) in Carimagua as affected by the interaction of various levels of applied phosphorus and potassium.

of the soil was extremely low (0.24 meq/100g after liming).

Method of fertilization

The efficiency of fertilizers depends to a great extent on methods of application. Fertilizers of low water solubility are generally more effective when broadcast and incorporated to secure good soil-fertilizer contact, while highly soluble fertilizers are more efficiently used when banded or otherwise placed in concentrated form.

Without N-P-K fertilization (only lime and zinc applied) cassava yielded 5.8 t/ha. Yields increased to 14.7, 20.0 and 23.4 t/ha after applying 250, 500 and 750 kg/ha of complete fertilizer (10-20-20). Since the response curve did not reach a maximum it is likely that higher yields could be obtained with higher rates.

The use of TSP gave the highest return at the 200 kg P_2O_5/ha level but the lowest return at the highest application rate. SSP was the least economic source, but broadcast application might improve this.

Nitrogen fertilization

The best level and time of applying nitrogen was studied in Carimagua, using levels of 0, 50, 75, 100 and 150 kg N/ha, band placed as urea in various fractions at 0, 30, 120 and 150 days after planting. Because of dry weather no fertilizer could be applied between 30 and 120 days. The treatment with zero nitrogen still yielded 16.4 t/ha, indicating that of the three major elements, nitrogen, phosphorus and potassium, lack of nitrogen is of least importance in limiting yield (see Soils Section in CIAT Annual Report, 1975). Nevertheless, there was a definite response to nitrogen rates as high as 150 kg/ha (Fig. 50). Only when all nitrogen was applied at planting was there a negative response to the highest application rate, probably because of fertilizer burn during the dry season following planting.

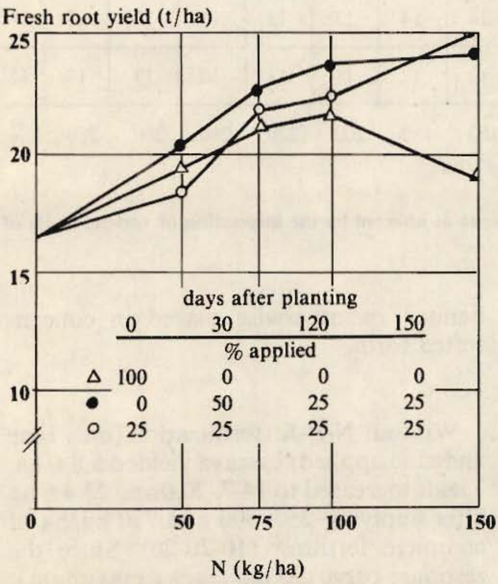


Figure 50. **Response of cassava to various levels and times of application of nitrogen, at Carimagua.**

The best fractionation was that of 50 percent applied at 30 days and 25 percent each at 120 and 150 days. There was no significant difference between other fractionation methods used. However, a similar trial planted at the begining of the rainy season (destroyed at two months because of CBB) showed a definite lack of vigor at two months in any treatment in which the initial nitrogen application was delayed to 30 days after planting. Thus, it appears that nitrogen should be fractionated with the initial doses at planting if this occurs at the beginning of the wet season or at 30 days if planting occurs at the end of the wet season.

Phosphorus x potassium interaction

To determine the interaction between phosphorus and potassium a systematic design experiment was established with 15 levels of each element in all possible combinations. Levels of the two elements increased in increments of 10 kg P_2O_5/ha and 20 kg K_2O/ha in perpendicular directions. Each plant was one treatment, and treatments were replicated four times. The yield of each treatment was considered to be the average yield of the plant with the treatment and its eight surrounding neighbors. Figure 51 shows the effect of phosphorus and potassium on yield. Highest yields were obtained with 140 kg P_2O_5/ha and 180-200 kg K_2O/ha. At lower levels of P_2O_5 the optimum K_2O application was about 140-160 kg K_2O/ha. Figure 52 shows the average phosphorus and potassium response. It is clear that cassava responds markedly to phosphorus and that maximum yields were not yet obtained with the highest application rate of 140 kg P_2O_5/ha. There was relatively little response to potassium but maximum yields were obtained with 160 kg K_2O/ha, above which yields declined. Since potassium was applied as K_2SO_4, the decline was not due to sulfur deficiency (CIAT Annual Report 1975), but was possibly due to a potassium induced calcium deficiency, since the calcium level

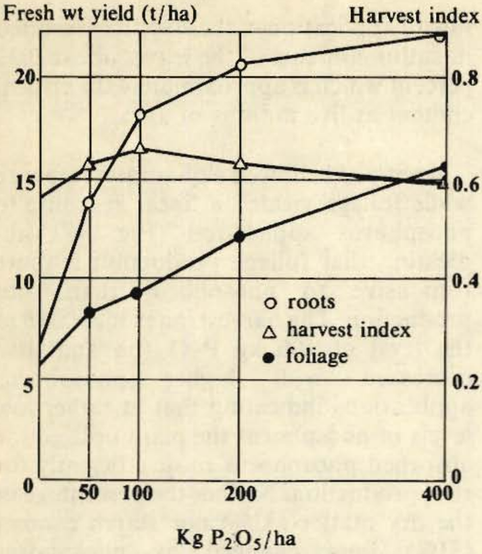


Figure 47. Effects of phosphorus (avg. of six sources) on yields of cassava roots and foliage and on the harvest index.

cassava production is directly correlated with leaf phosphorus content and that plants require at least 0.35 percent phosphorus in the leaves for optimum yield. Since the curve does not reach a maximum, it is likely that elements other than phosphorus limited yield (zinc content was depressed from 47.6 to 37.2 ppm by high phosphorus-application) and the critical phosphorus content is above 0.4 percent.

The net return from applying phosphorus at current fertilizer prices and a value of Col. $2,000/t cassava for a starch extraction plant is shown in Figure 49. Highest returns were obtained with basic slag due to its high agronomic effectiveness and low cost. Production of this material is limited but the rock phosphates-sulfur mixture would be a good alternative source (Fig. 49).

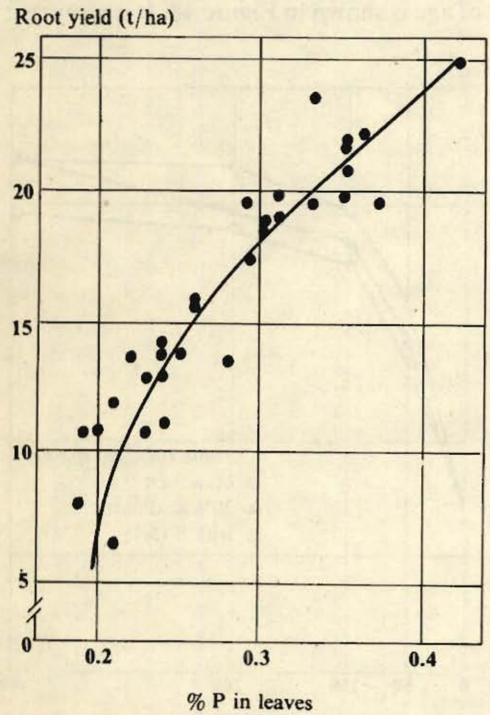


Figure 48. Relation between cassava yield and phosphorus content of leaves five months after planting.

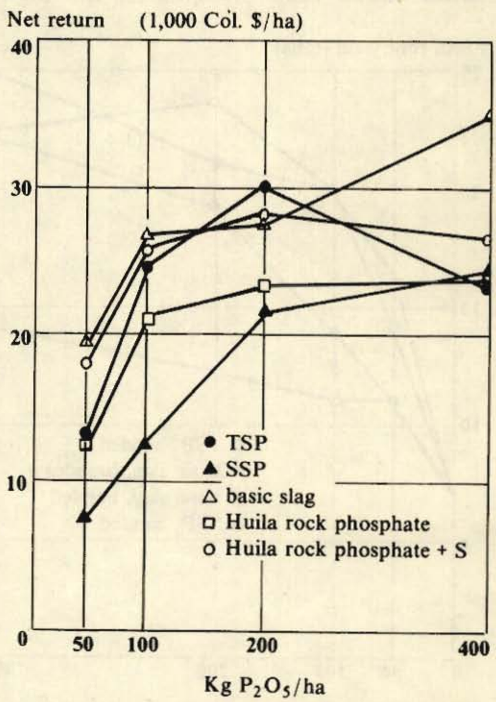


Figure 49. Net return from fertilizing cassava with various levels and sources of phosphorus, at Carimagua.

and Huila rock phosphate, either by itself, mixed with elemental sulfur or sulphuric acid (20% acidulated). The highest yields were obtained with band-placed TSP and broadcast basic slag (Fig. 46). When the basic slag was band-placed plants suffered from severe phosphorus deficiency and yields were about half those obtained with broadcast basic slag. The SSP of local manufacture was only 43 percent citrate soluble (% of total phosphorus) and when band-placed was much less effective than TSP and slightly inferior to broadcast rock phosphate. The Huila rock phosphate was a good phosphorus source for cassava, but its effectiveness was considerably improved by partial acidulation or mixing with elemental sulfur (Fig. 46); the latter mixture gave yields equal to TSP. Although 37 kg/ha of sulfur had been applied to all treatments in the form of K_2SO_4, plants may have responded to the sulfur in SSP, and in the acidulated or sulfur-mixed rock phosphates; the high rate of application of these sources resulted in sulfur contents of the leaves above 0.32 percent which is approximately the critical content at five months of age.

Root yield showed a quadratic response while foliage yielded a linear response to phosphorus application (Fig. 47), indicating that foliage production is more responsive to phosphorus than root production. The harvest index increased to the level of 100 kg P_2O_5/ha and then decreased with higher phosphorus applications indicating that at rather low levels of phosphorus the plant utilized the absorbed phosphorus most efficiently for root production. Neither the percentage of the dry matter (33%) nor starch content (31%) were changed by phosphorus application.

The relation between cassava yield and phosphorus in the leaf blade at five months of age is shown in Figure 48. It is clear that

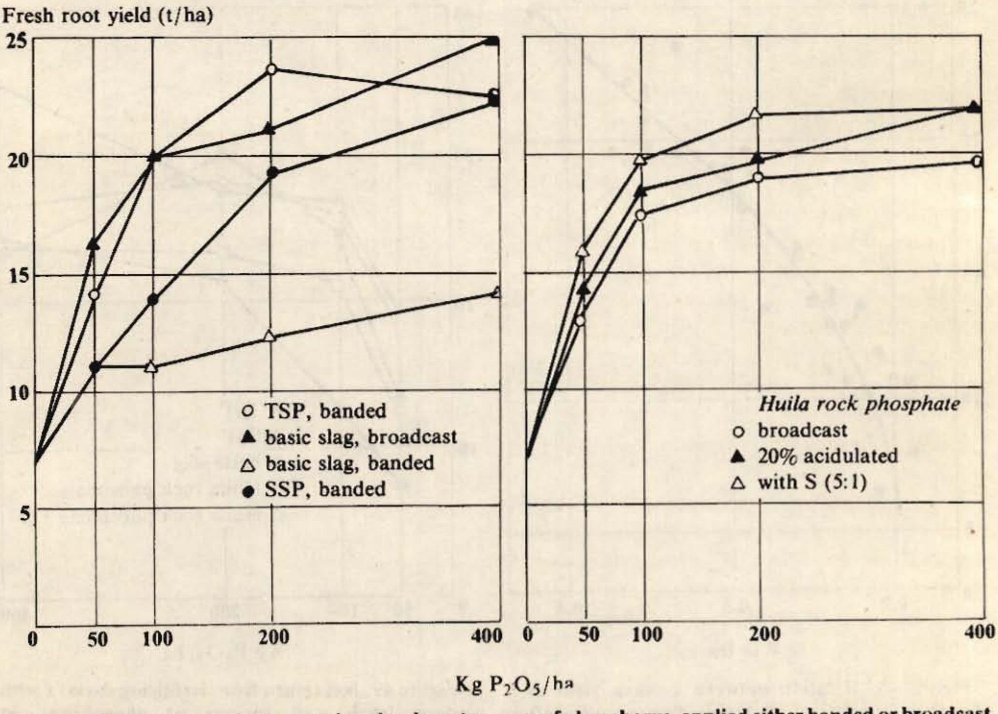


Figure 46. Cassava response to various levels and sources of phosphorus, applied either banded or broadcast, at Carimagua.

frequently grown in Latin America. Under these conditions cassava response to nearly all essential elements as well as to their interactions could be studied. The most economic levels, sources, times and methods of application were also determined.

The 1975/76 cassava trials in Carimagua suffered considerably from CBB infections. Eight trials seeded in early 1975 became infected and all were destroyed. In late 1975 many of these were replanted at an isolated location (Tabaquero), 17 kilometers from the main Carimagua headquarters site. These trials remained free of CBB and only at a later stage were they affected by superelongation, which seemed to have a minor effect on yield (see Pathology Section). The highest yield obtained was 36 t/ha with the variety M Col 1684, while most trials with the variety Llanera gave top yields between 20 and 25 t/ha.

All trials received a uniform lime application of 500 kg/ha as dolomitic limestone (115 kg Ca and 52 kg Mg/ha). Except for the elements under study the constant fertilization consisted of 100 kg N/ha as urea (50 kg at seeding, 50 kg at 120 days), 100 kg P_2O_5/ha as triple superphosphate (TSP) at seeding, 100 kg K_2O/ha (50 kg as K_2SO_4 at seeding, 50 kg as KCl at 120 days) and 10 kg Zn/ha as $ZnSO_4$, all applied in short bands 5-10 centimeters from the stake. All trials used Llanera as the test variety, and were harvested at 11.5-12 months after planting.

Phosphorus fertilization

To establish the phosphorus requirement of cassava and the most economical method of applying it, two trials were planted in Carimagua using different levels and sources of phosphorus. In the first trial (conducted in cooperation with the International Fertilizer Development Center), six rock phosphates from various parts of the world and of highly variable citrate solubility, were compared with TSP and basic slag at four levels of phosphorus application: 0, 50, 100 and 400 kg P_2O_5/ha. Average yields increased from 7.5 t/ha without applied phosphorus to 13.9, 17.1 and 19.9 t/ha with applications of 50, 100 and 400 kg P_2O_5/ha.

The most soluble phosphorus sources, TSP and basic slag, gave highest yields (Fig. 45). However, the more soluble rock phosphates from Gafsa (Morocco) and North Carolina (U.S.A.) also gave very good responses, while the less soluble rocks from Huila and Pesca (Colombia) and Florida (U.S.A.) gave lower but not significantly different yields. Only yields obtained with the least soluble rock from Tennessee (U.S.A.) were significantly lower from those obtained with TSP and basic slag.

In the second trial the effectiveness of TSP was compared with that of a number of other phosphorus sources including simple superphosphate (SSP), basic slag,

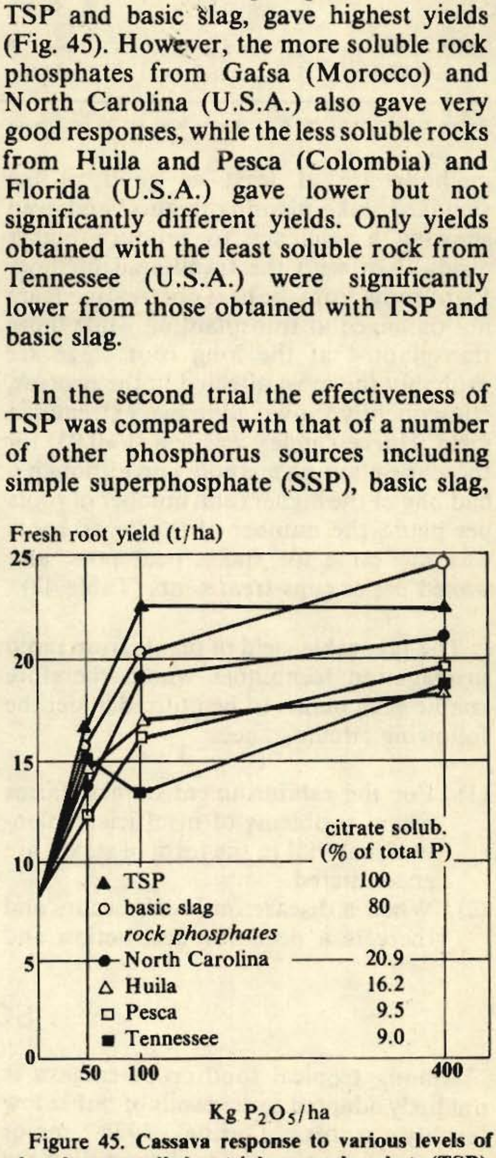


Figure 45. Cassava response to various levels of phosphorus applied as triple superphosphate (TSP), basic slag and various rock phosphates, in Carimagua.

Table 42. Yield and yield components of cassava plants planted by five systems and harvested at 10 months, CIAT, 1976.

Treatment	Root yield (t/ha)	Total plant fresh wt. (t/ha)	Harvest Index	Total roots /plant	Thickened roots/ plant
Peat pots	29.2 a[1]	73.7 a	0.40 a	10.5 c	7.3 ab
Waxed paper cups	26.3 a	63.9 a	0.41 a	11.2 bc	7.1 abc
Long roots	20.8 a	59.6 a	0.34 a	12.8 ab	5.8 c
Callus	22.7 a	57.5 a	0.40 a	9.5 c	6.1 bc
Stakes	21.1 a	81.2 a	0.26 b	13.6 a	7.4 a
C.V. (%)	25.0	18.0	13.0	11.4	8.0

[1] Values in the same column with the same letter are not significantly different at the .05 level according to Duncan's new multiple range test

methods are at least as good as the standard stake planting method and even showing a tendency to produce higher yields than with the traditional method. Plant roots from the peat pot treatment are not damaged at transplanting while those transplanted at the long root stage are probably the most affected in the process, consequently showing the two extremes in yield. Harvest index was less (P=0.05) for the stake planting method, and although it had one of the higher total number of roots per plant, the number of thickened roots was the same for stake, peat pots, and waxed paper cups treatments (Table 42).

The favorable yield of plants from rapid propagation techniques would therefore enable such plants to be utilized under the following circumstances:

(1) For the establishment of new farms where problems of insufficient planting material in the form of stakes are encountered.

(2) When a disease outbreak occurs and there is a need for destruction and elimination of diseased plants, replanting can then be done with disease-free material.

(3) Rapid propagation techniques save the time required in the multiplication of plants to be used as stakes when releasing new varieties or evaluating new varieties in regional trials.

Improved Rapid Propagation

The CIAT rapid propagation system for cassava as developed and recommended called for shoots growing on the two-node stem sections to be cut and rooted in flasks containing sterile water. The rooted cuttings were then planted in the field. An improved technique is now being used at CIAT and a few other locations. Shoots are cut at the same stage as previously (when they are about 8 centimeters long) and planted directly into the field. Water is supplied to provide adequate moisture during the first two weeks. This improvement makes the system even simpler, faster and less expensive, however losses can be great if management is not first class.

SOILS

Among tropical food crops cassava is uniquely adapted to acid soils of rather low fertility status. During 1976 major emphasis was directed to determining the crop's nutritional requirements under these conditions.

Fertilization of Acid Soils

Fertilizer experiments were conducted in Carimagua, which has an extremely acid and infertile soil representative of many oxisols and ultisols where cassava is

Table 41. Fresh root yield and dry matter production of 12 cassava varieties grown in Guyana.

Anira Peat No. 20				Inki Clay No. 100			
Variety	Ranking	Fresh wt. yield [1] (t/ha)	Dry matter (kg/ha/day)	Variety	Ranking	Fresh wt. yield[1] (t/ha)	Dry matter (kg/ha/day)
M Mex 59	1	30.5	25.2	M Mex 59	1	23.0	21.3
M Mex 23	2	19.3	16.7	Uncle Mack	2	22.0	21.4
Del Pais	3	19.3	18.6	Del Pais	3	22.0	18.1
M Col 673	4	18.2	19.5	M Mex 23	4	17.6	16.8
Twelve Month	5	16.4	16.5	Four Month	5	17.4	15.1
Llanera	6	15.2	14.9	Llanera	6	16.8	18.3
Uncle Mack	7	15.2	15.6	M Col 673	7	16.4	19.6
Brancha Butterstick	8	14.2	14.8	Brancha Butterstick	8	15.2	15.1
R. Singh	9	13.0	14.6	R. Singh	9	14.7	15.5
Four Month	10	12.0	11.3	Twelve Month	10	12.3	12.0
Bitter Stick	11	11.7	11.2	Bitter Stick	11	11.0	9.5
Chinese Stick	12	7.6	6.0	Chinese Stick	12	9.0	7.0
Avg. introduced varieties		20.5	18.9			19.1	18.8
Avg. regional varieties		12.8	12.9			14.5	13.6
Avg. best introduction		30.5	25.2			23.0	21.3
Avg. best regional		16.4	16.5			22.0	21.4

[1] Harvested at 12 months.

system was compared to yields from plants started as stem cuttings as normally used, after a similar growth period.

These five cassava propagation techniques were tested:

(1) Rooting in peat pots (8-cm diameter) filled with clay loam soil for 18 days and subsequent transplanting to the field without removal of the pots.
(2) Rooting in waxed paper cups (5-cm diameter) filled with clay loam soil for 18 days and subsequent transplanting to the field after careful removal of the cups
(3) Rooting in flasks (25-ml glass flasks) filled with sterile water for 18 days and subsequent transplanting to the field at the long root stage (1-cm long).
(4) Rooting in flasks (25-ml glass flasks) filled with sterile water for 8-10 days and subsequent transplanting to the field at the callus formation stage.
(5) Planting 20-cm long stem cuttings directly to the field as a control treatment.

Planting distance in the field was on 1 x 1-meter ridges. The plantules were transplanted into holes and buried to the base of the lowest leaf, taking care not to damage the roots. Plants were watered daily for the first 27 days.

Yield, and components of yield of the cassava plants harvested at 10 months are shown in Table 42. Fresh root yield of the five treatments was not different at P=0.05, proving that root yield of plants originating from the rapid propagation

Input use was too high

Table 39. **The effect of rainfall on cassava fresh root yield at five locations[1] in Colombia during two growing cycles.**

Cycle	Mean rainfall (mm/cycle)	Yield average (t/ha)
1974/75	1,502	26.4
1975/76	1,162	18.1

[1] Locations: Media Luna, Rionegro, Nataima, CIAT and Caicedonia..

Abdul Wahab, of the Guyana Sugar Corporation. They have kindly made their data available to CIAT.

Both trials were planted at Enmore, one on Anira peat No. 20 and the other in Inki clay No. 100. Both soils are extremely acid, pH 3.4 and 4.1, respectively. The main edaphic and climatological data of the site are shown in Table 40.

Of the 12 varieties tested, seven were from Guyana, one (Del Pais) was introduced from Puerto Rico, and four (Llanera, M Col 673, M Mex 23 and M Mex 59) came from CIAT's cassava collection.

Standard cultural practices were used. Plant population was about 12,000 plants/ha. Lime was applied in the form of aragonite at 6.7 t/ha. Nitrogen, P_2O_5 and K_2O, at rates of 200, 67 and 134 kg/ha, were split-applied in bands. Secondary and micronutrients were also applied to prevent any possible deficiencies. Weeds were controlled manually and hornworm and shoot fly attacks were chemically controlled.

Yield data of both trials are shown in Table 41. On Anira peat, M Mex 59 yielded 30.5 t/ha, significantly higher than all other varieties. However, on Inki clay No 100, M Mex 59 produced a fresh root yield (23 t/ha) which was similar to Uncle Mack and Del Pais, which yielded 22 t/ha. On both soils, the average of the introduced varieties was significantly higher than the average of the regional varieties.

Highest producer of root dry matter was M Mex 59 with 25 kg/ha/day on Anira Soil, and both M Mex 59 and Uncle Mack on Inki Clay soil with 21 kg/ha/day (Table 41).

Rapid Propagation

The vegetative cassava propagation method used commercially gives a slow rate of plant multiplication. Development of techniques for rapid propagation initiated at CIAT in 1971 have shown that it is possible to produce more than 36,000 normal plant cuttings after one year from one adult plant. However, it has been pointed out that this method is mainly suitable for use at research stations producing planting material.

This year, a root yield of plants originating from the rapid propagation

Table 40. **Main edaphic and climatological characteristics for two Guyana sites used in International Yield Trials for cassava during the 1975/76 cycle.**

Soil type	Altitude (m above msl)	Mean temperature (°C)	Rainfall (mm/year)	Relative humidity (%)	Soil classification	pH	Organic matter (%)	P ruog (ppm)	K (meq/100 g)
Anira Peat No. 20	0	26.4	3,310	82.9	Silty clay	3.4(VA)[1]	32.0(H)	26.3(M)	0.45(H)
Inki Clay No. 100	0	26.4	3,310	82.9	Clay	4.1(VA)	7.5(H)	1.1(L)	0.3(M)

[1] Fertility codes: (N) neutral; (A) acid; (VA) very acid; (L) low; (M) medium; (H) high.

Input use info

Table 38. Fresh root yield of the ICA-CIAT promising varieties from nine locations in Colombia.

Locations	Media Luna	Carimagua	Nataima	Rionegro	El Tambo	CIAT	Caicedonia	Pereira	Popayán
Days to Harvest	333	335	337	326	335	367	363	400	428
Varieties	Root yield fresh weight (t/ha/yr)								
M Mex 59	18.8**	25.6*	26.7**	24.5**	18.7	—	23.7**	10.5*	0.9
CMC-40 (M Col 1468)	19.2**	23.2*	35.3**	16.1**	22.8*	35.5**	—	16.7*	3.8
CMC-84 (M Col 1513)	15.0**	26.8*	16.3**	18.2**	25.9*	24.6**	—	18.1	1.0
CMC-76 (M Col 1505)	—	21.8	—	20.5**	17.1	29.7**	—	20.8*	0.5
M Col 22	10.5**	15.5	23.2**	—	11.1	25.1**	—	8.8	0.3
M Col 113	—	21.9	—	—	—	—	—	20.7*	5.0
M Col 673	—	13.8	4.8	20.1**	10.3	—	22.2	—	—
M Ven 119	8.5	18.4	16.9	14.3	15.3	23.7	—	—	—
M Ecu 159	—	—	15.9	—	—	22.8	18.3	—	—
M Mex 23	—	18.3	—	—	10.4	24.5**	17.3**	17.0	1.0
M Mex 52	4.6	19.8	16.8	11.1	13.0	23.0	20.7	—	—
M Col 677	8.4	—	6.3	20.8*	—	27.5*	29.2*	—	—
Other varieties									
Maximum	—	24.4 (1)	23.4*(2)	—	9.6(4)	—	11.0(3)	13.1(4)	23.8*(5)
Minimum	—	—	4.7 (3)	—	—	—	—	—	0.8(4)
Regional varieties									
Maximum	4.0(9)	22.9(4)	—	11.7 (8)	22.3(6)	22.1(6)	15.8(1)	16.9(6)	14.5(7)

* & ** Respectively, varieties approved for second and third year evaluation at the same location

(1) Chiroza Gallinaza. (2) CMC 57, (M Col 1486). (3) CMC 72, (M Col 1501). (4) CMC 9, (M Col 1438). (5) CMC 92, (M Col 1522). (6) M Col 113. (7) Amarilla. (8) Colombiana and Torama Negrita. (9) Blanca Mona.

Isn't necessary to produce cassava in cold climatic conditions

Table 37. **Some agronomic and commercial characteristics of the promising varieties used in regional trials during 1975/1976 cycle.**

Varieties	Plant height[1] (m)	Ease of harvest[1]	Starch[2] (%)	Dry matter[2] (%)
M Col 22	1.50	easy	31.9	34.0
M Col 113	1.98	difficult	31.1[3]	33.2[3]
M Col 673	2.00	moderate	32.1	34.2
M Col 677	2.00	moderate	31.2	33.3
M Mex 23	2.23	difficult	36.2	38.4
M Mex 52	2.20	moderate	32.0	34.1
M Mex 55	1.70	easy		
M Mex 59	1.85	moderate	31.5	33.7
M Ven 119	2.00	moderate	30.5	32.5
M Ecu 159	2.20	moderate	26.0[3]	28.0[3]
CMC 9 (M Col 1438)	2.00	moderate	33.1[3]	35.3[3]
CMC 40 (M Col 1468)	2.35	easy	29.8	32.0
CMC 57	2.50	moderate	27.8[4]	29.8[4]
CMC 72	2.80	moderate	27.1[3]	29.1[3]
CMC 76 (M Col 1505)	2.25	easy	34.5	36.7
CMC 84 (M Col 1513)	2.35	easy	33.8	35.9
CMC 86	3.00	easy	24.8[4]	26.7[4]
CMC 92	3.00	easy	—	—
CMC 137	3.00	easy	19.5[4]	21.4[4]
Chiroza Gallinaza	—	—	34.4[4]	36.6[4]
Best Regional[5]	—	—	36.1	38.3

1 Under CIAT's conditions
2 Average of 1976 regional trials.
3 Mean value from less than five location
4 Data from only one site
5 Among all regional varieties used as the controls in all trials.

wide range of soil and climatic conditions when temperature is above 22ºC.

In the two cooler sites, Popayán and Pereira, the highest yields were obtained by CMC 92 and M Col 113 respectively. CMC 92 is very tolerant of Phoma and M Col 113 is reasonably tolerant of cooler conditions when Phoma is not present. The yield of 24 t/ha after 14 months in Popayán suggest that with carefully selected lines high yields can be obtained in cooler areas (Table 38).

This year was much drier than the previous one and yields in many sites were reduced; the overall mean yield of the same five trials was reduced from 26.4 to 18.1 t/ha as rainfall decreased from 1,502 to 1,162 mm/yr. (Table 39).

International Regional Trials

Yield data from the first two international regional trials has been collected. These were planted in Guyana by Dr.

Pulking

Table 36. **Resistance of promising cassava varieties to some important insects and diseases in regional trials during 1975/76 cycle.**

	Resistance to[1]						
					Leaf spots		
Varieties	Thrips	White fly	Bacteriosis	Super-elongation	*Phoma* sp.	*C. henningsii*	*C. vicosae*
M Col 22	T	S	S	R	S	R	T
M Col 113	R	—	S	S	S	T	S
M Col 673	S	S	S	T	S	R	S
M Col 677	S	S	S	—	T	T	T
M Mex 23	R	—	S	T	S	T	S
M Mex 52	R	T	S	T	S	T	T
M Mex 55	T	—	S	S	S	S	S
M Mex 59	S	S	S	T	S	R	R
M Ven 119	S	T	S	S	S	T	T
M Ecu 159	S	T	S	S	—	—	—
CMC 9 (M Col 1438)	T	—	T	R	S	S	S
CMC 40 (M Col 1468)	S	S	S	S	S	R	T
CMC 57	T	R	S	S	S	—	—
CMC 72	T	R	S	S	S	—	—
CMC 76 (M Col 1505)	S	—	S	S	S	R	T
CMC 84 (M Col 1513)	S	S	S	S	S	R	T
CMC 86	T	—	S	S	S	S	S
CMC 92	T	—	S	S	R	S	S
CMC 137	T	T	S	S	S	S	S

[1] (R) Resistant; (S) Susceptible; (T) Tolerant; (—) Not evaluated.

lines have continued to outyield local lines in Colombia and the first results from outside Colombia have shown these selected lines to be superior in Guyana.

Regional Trials

The regional trials test new selected lines under technology which demands low cost inputs and which farmers can readily accept. Special emphasis is placed on low levels of chemical inputs. The details of this "low level technology" were described last year (CIAT Annual Report, 1975). This year two trials were planted in cooperation with ICA, three with Federación Nacional de Cafeteros, two with Integrated Rural Development Projects, and three with local Secretariats of Agriculture, with the remaining nine trials being under CIAT's direct supervision and control.

The major problems experienced in the field this year were a heavy attack of CBB and superelongation disease in Media Luna, a severe white fly attack in Nataima, and very heavy infestations of thrips in Caicedonia.

Table 36 shows the resistance of the promising varieties to some important insects and diseases. Because of the susceptibility of many varieties to a few of these pests, the improved cultural practices discussed below should be used.

Some agronomic and commercial characteristics of these varieties are shown in Table 37. Plant height and strong winds may affect lodging, while ease of harvest affects labor efficiency.

Mean starch content of the promising varieties varied from 30 to 36 percent with a minimum of five trials for variety mean. Furthermore, site means varied from 22 to 36 percent. However, the relative varietal values to the site mean were stable (see Varietal Improvement Section). Where the best regional variety produced 36 percent starch in one site, the best promising line produced 38 percent. In all trials, except for the Media Luna site, the starch content of the best promising line was greater than that of the best local variety.

A similar analysis can be done regarding dry matter content. The mean dry matter content of the promising varieties varied from 32 to 38 percent with a minimum of five trials for variety mean. Furthermore, site means varied from 24 to 38 percent. However the relative varietal values to the site mean are stable. Where the best regional variety produced 38 percent dry matter the best promising had 40 percent. In all sites, except Media Luna, the best promising cultivar had a greater dry matter content than the best regional line.

Of the nine trials so far harvested, the average of the best local line in all sites was 16.3 t/ha (Table 38), or nearly double the national average yield of 8.5 t/ha. These results suggest that simple improved cultural practices can considerably increase yields. The most important practices are: (a) using selected stakes free of CBB and superelongation; (b) good soil preparation; (c) timely weed control; and, (d) adequate plant population at harvest (10,000 plants/ha).

When the best promising line in each site is used, the yield shows a further increase up to an average of 26.8 t/ha (Table 38), showing that the combination of improved cultural practices with selected varieties can increase national average yield 3-4 times. The two varieties M Mex 59 and CMC 40 consistently yield more than the local varieties in all sites below 1,200 m msl. CMC 40 showed tremendous yield stability over a very wide range of soil conditions giving 35.5 t/ha in the fertile soils of CIAT and 23.2 t/ha in the infertile Llanos Orientales. This variety, however, is very susceptible to thrips and has very low starch content (Tables 36 and 37). Nevertheless the data support the hypothesis presented in previous sections that a single genotype may be adapted to a

Table 35. Sites in Colombia and their main soil and climatic characteristics where the second cycle of promising ICA-CIAT varieties were planted during the 1975/76 cycle.

Locations	Altitude (m)	Mean temperature (°C)	Rainfall (mm)[1]	Relative humidity (%)	Soil type	pH	Organic matter (%)	P (Bray II) (ppm)	K (meq/100 g)
Media Luna (Magdalena)	10	27.2	887	77.6	Sandy	6.6 (N)[2]	0.7 (L)[2]	4.8 (L)[2]	0.08 (L)[2]
Carimagua (Meta)	200	26.1	2,323	75.2	Sandy Loam	4.9 (VA)	1.9 (M)	1.1 (L)	0.04 (L)
Nataima (Tolima)	430	27.8	1,064	69.0	Loam	7.1 (Al)	1.2 (L)	77.5 (H)	0.23 (M)
Rionegro (Sant. del Sur)	480	26.6	1,746	79.5	Clay Loam	5.1 (A)	2.0 (M)	4.9 (L)	0.17 (M)
El Tambo (Cauca)	900	26.0	850	75.0	Clay	4.9 (A)	6.0 (H)	1.8 (L)	0.15 (M)
CIAT (Valle del Cauca)	1,000	23.5	901	74.5	Clay	6.4 (N)	3.3 (M)	36.2 (H)	0.47 (H)
Caicedonia (Valle del Cauca)	1,100	22.7	1,214	80.7	Silt Loam	5.6 (A)	2.9 (M)	7.1 (L)	0.20 (M)
Pereira (Risaralda)[3]	1,480	19.0	3,817	80.0	Silty Clay	5.1 (A)	8.2 (H)	8.2 (L)	0.08 (L)
Popayán (Cauca)[3]	1,760	18.0	2,998	85.0	Loam	5.0 (A)	7.5 (H)	2.4 (L)	0.44 (H)

1 Rainfall data corresponds to actual rain during growth period
2 Fertility codes: (N) neutral; (Al) alkaline; (VA) very acid; (A) acid; (L) low; (M) medium; (H) high.
3 Pereira and Popayán sites correspond to 1974/75 cycle.

from many parts of the world. A total of 21,750 hybrid seeds and 50,100 open-pollinated seeds have been distributed to 28 countries (Table 34).

Table 34. **Summary of the distribution of cassava genetic materials, 1973-76.**

Country	Hybrids	Open-pollinated seeds	Stakes
Brazil	4,400	2,000	20
Mexico	200		160
Venezuela			200 (Entomology)
Ecuador			20 (Agronomy)
Nicaragua			6
Dominican Republic			6
Trinidad	600		6
Jamaica			6
Bahamas			6
India	1,300		
Thailand	3,900	4,500	
Malaysia	900		
Philippines	1,450		12
Indonesia	900		
Taiwan	1,200		6
Japan	2,000		12
Australia	900		50
New Zealand	300		
IITA (Nigeria)	1,550	41,500	
Kenya	400		6
Tanzania	1,000		
Tonga	350		
Samoa	350		
Seychelles	250		6
Hawaii			6
United States		1,000	
Canada		100	
United Kingdom		1,000	
Total	21,750	50,100	528

AGRONOMY

The agronomy program has continued to emphasize the propagation and testing of promising lines over a wide range of ecological conditions (Table 35). Selected

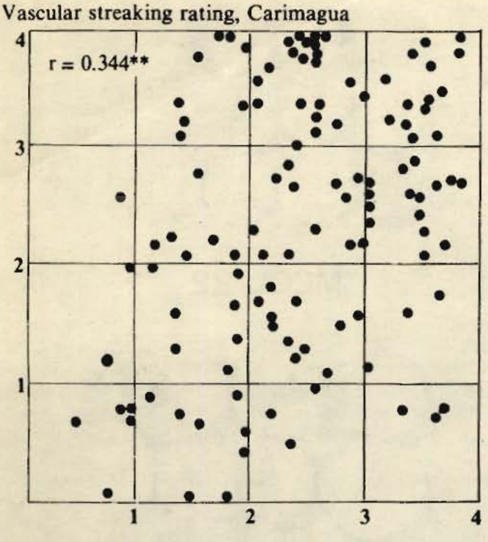


Figure 41. Relationship between vascular streaking of cassava in CIAT and Carimagua.

positively correlated with the root dry matter content (Fig. 44). Athough there is a fair amount of variability left after the limitation imposed by the correlation, there may be some difficulty in combining good root durability with high dry matter content.

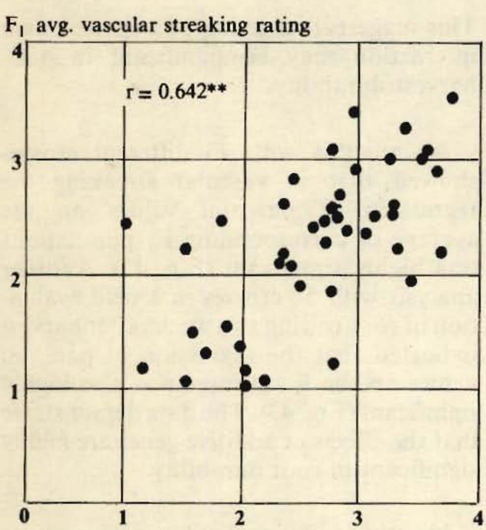


Figure 42. Regression of F_1 average on the parental value for vascular streaking of cassava, 1976.

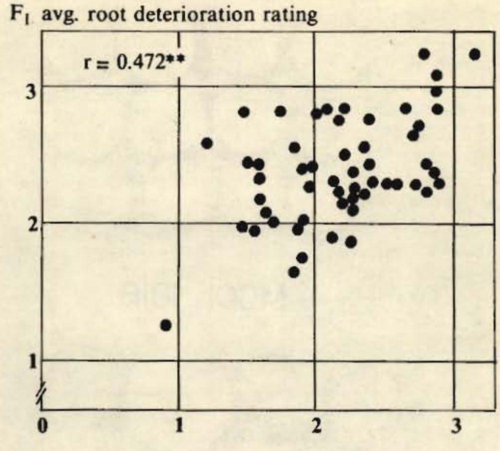


Figure 43. Regression of F_1 average on the parental value of cassava root deterioration in the field.

Nine genotypes have been identified as sources of genes for good root durability and are actively used in hybridization.

Distribution of Genetic Material

Since the beginning of the cassava breeding program, there have been numerous requests for genetic materials

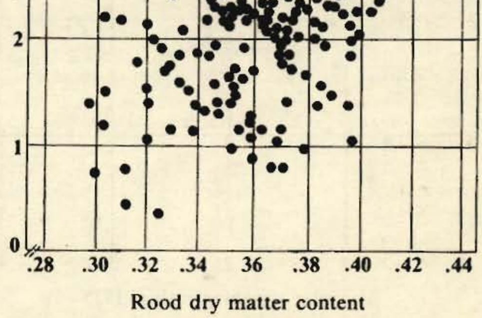


Figure 44. Relationship between root dry matter content and root rotting in cassava.

Since does the correlation coefficients

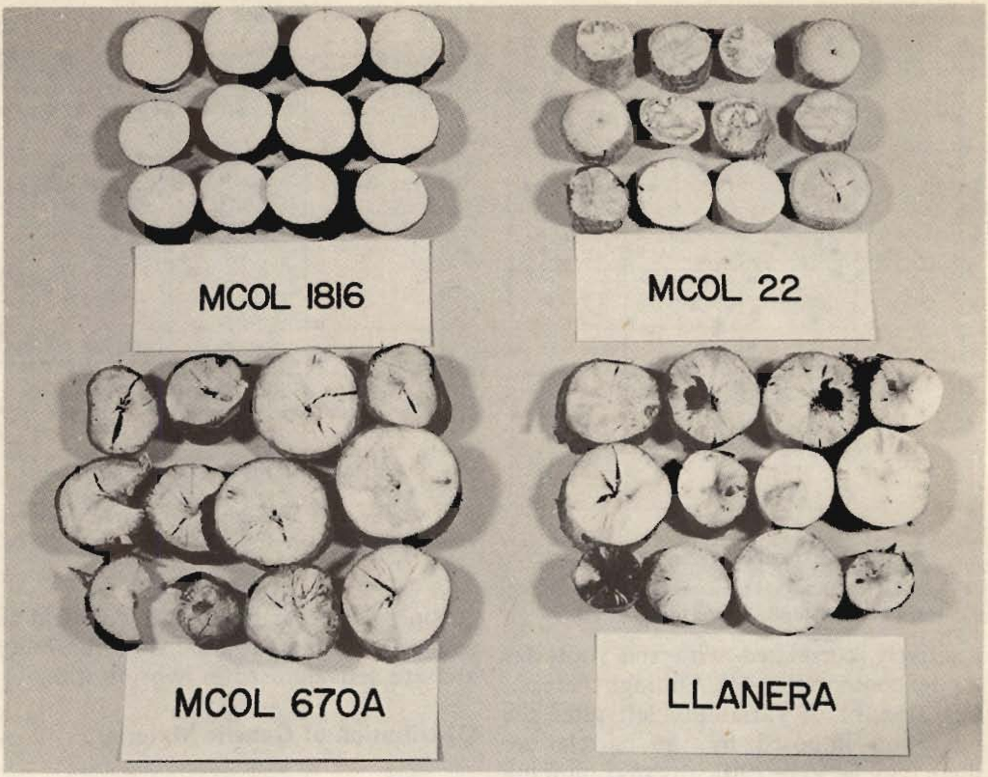


Figure 39. **Roots of four cassava cultivars three weeks after harvest.**

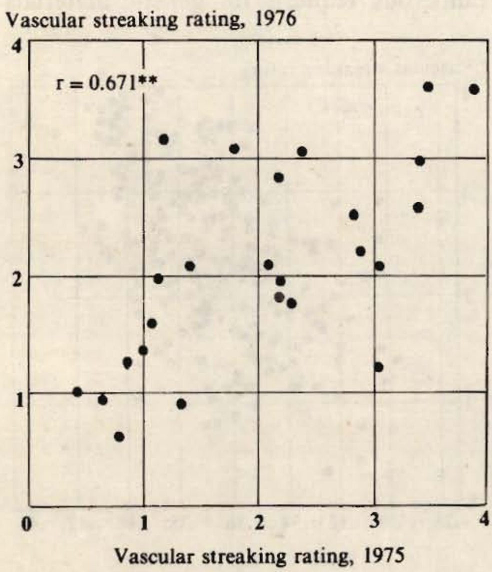


Figure 40. **Relationship between varietal vascular streakings of cassava in 1975 and 1976.**

This suggests that genotype x environment interaction may be significant in post-harvest durability.

An analysis with 43 different crosses showed that in vascular streaking the regression of parental values on the average of corresponding F_1 populations was highly significant (Fig. 42). Another analysis with 56 crosses in a field evaluation of root rotting two weeks after harvest indicated that the regression of parental values on the F_1 average was also highly significant (Fig. 43). The data demonstrate that the effects of additive genes are highly significant in root durability.

weak stat.

In one of the varietal experiments at CIAT, an analysis was made on the correlation of root durability with yield characters. The vascular streaking was

Table 33. HCN content in cassava roots and root dry matter content.

HCN rating (at 12 months)	No. of cultivars	Average root dry matter content (at 12 months)	Minimum root dry matter content within rating class	Maximum root dry matter content within rating class
1	5	.369	.349	.387
2	32	.362	.243	.417
3	87	.370	.302	.455
4	82	.362	.295	.406
5[1]	10	.356	.319	.395

[1] Usually unfit for direct human consumption.

Two ways of evaluating genotypes for root durability were adopted: (a) a quantitative rating of vascular streaking on the roots kept under shade for a week after harvest, and (b) a quantitative rating of the combination of vascular streaking and general rotting of the root kept under the sun in the field for two weeks after harvest.

Varietal rating in vascular streaking was fairly constant in 1975 and 1976 (Fig. 40, r=0.671**). The CIAT rating was significantly correlated with Carimagua (Fig. 41) and Caribia. However, the correlations were rather low between CIAT and Carimagua (r = 0.344**) and between CIAT and Caribia (r = 0.262**).

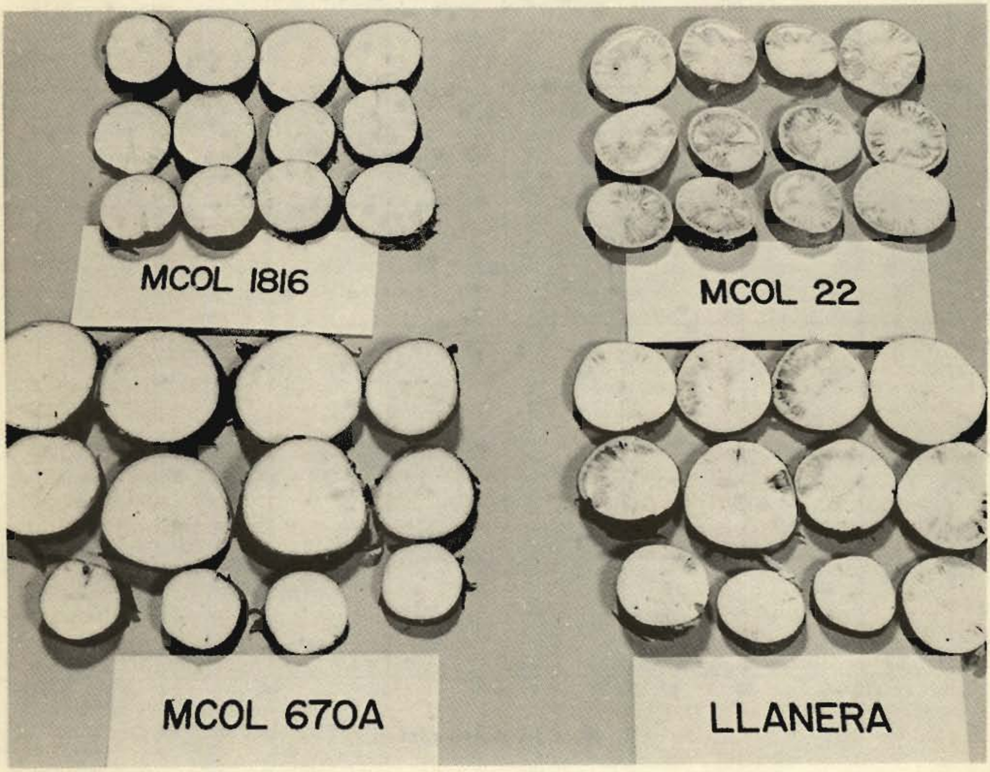


Figure 38. Roots of four cassava cultivars one week after harvest.

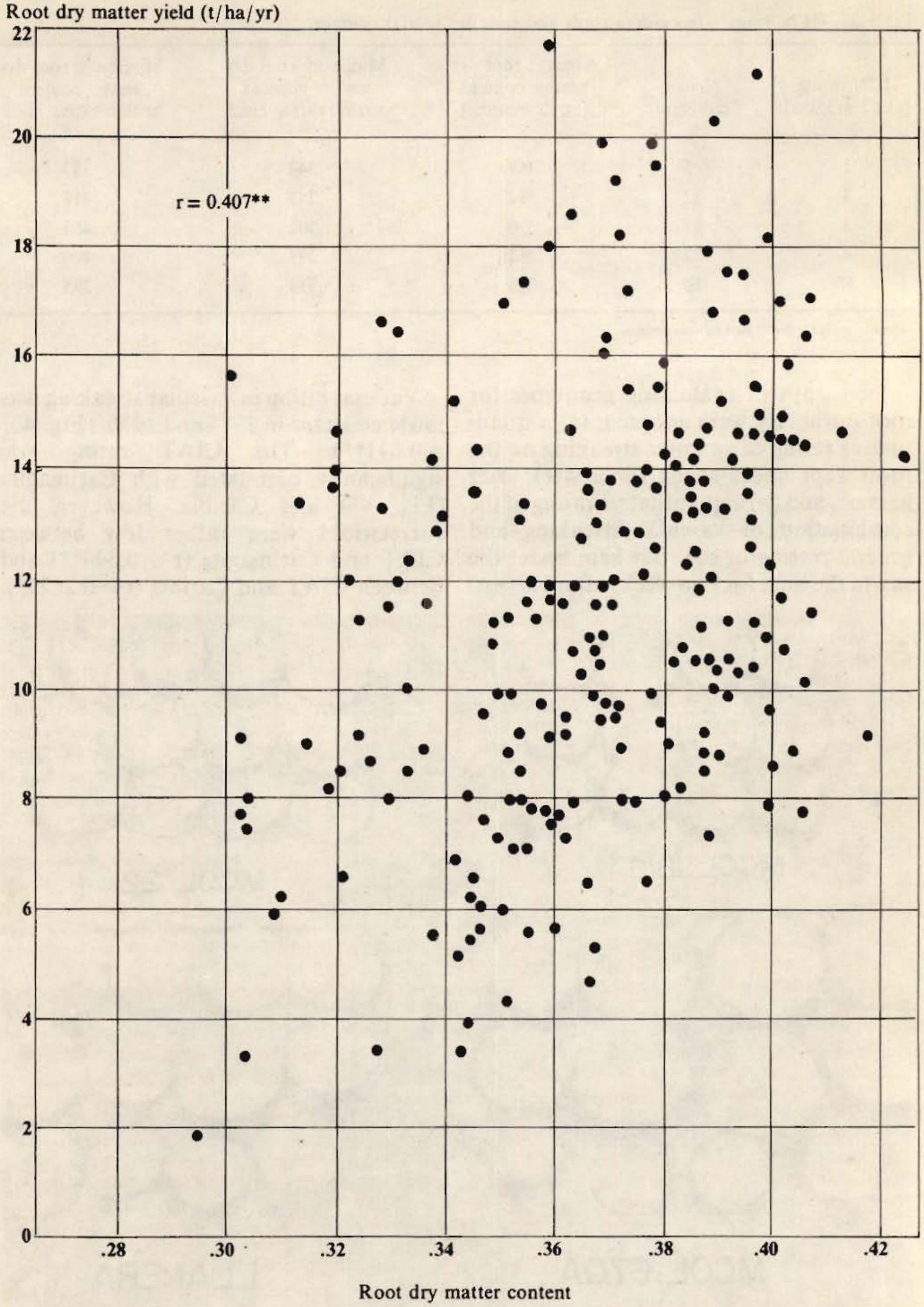


Figure 37. Relationship between root dry matter content and dry matter yield of cassava.

of corresponding F_1 population was highly significant (Fig. 36). The effect of additive genes must be significant and high dry matter content of some genotypes is expected to be transferred to other favorable genotypes without much difficulty.

In one of the varietal experiments in CIAT, the relationship of root dry matter content with root fresh weight yield, root dry matter yield and HCN content of the roots were analyzed. The root dry matter content was not correlated with the root fresh weight yield but significantly correlated with the dry matter yield (Fig. 37, $r = 0.407^{**}$). The same analysis was also made with F_1 populations of several crosses. In all of these populations, the correlation between root dry matter content and dry matter yield tended to be positive, although in some of these populations, the correlation was not as strong as in the varietal population. Nevertheless, the data indicate that improvement in root dry matter content never leads to a reduction in root yield both in fresh weight

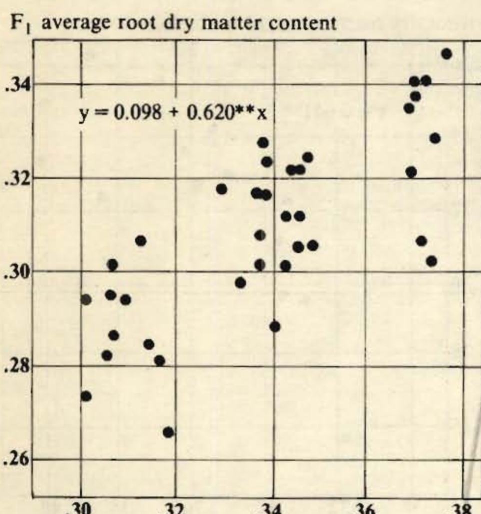


Figure 36. Regression of F_1 average (measured at 10 months) on the parental average root dry matter content of cassava.

very important results

and dry matter basis. There was no sign that root dry matter content was associated with HCN content (Table 33). It is known (CIAT Annual Report, 1973) that HCN content is not correlated with insect resistance (thrips and hornworm), with disease resistance (Cercospora leaf spot) or starch content; the popular legend that bitter cassava is disease and insect resistant, and good for starch production has to be challenged.

Twelve new hybrid lines have been included in the list of hybridizations for higher dry matter content.

Post-Harvest Durability of Roots

Observations of harvested cassava roots reveal that there are at least two phases of root deterioration after harvest, a vascular streaking and a general, total root decay. The vascular streaking occurs 2-7 days after harvest. This does not necessarily lead immediately to the total rotting of the root. However, there is no doubt that the vascular streaking drastically affects the quality of the roots especially when cassava roots are consumed directly as human food. The general and total decay usually occurs 1-2 weeks after harvest on roots already affected by vascular streaking when the internal root condition turns from anaerobic to aerobic.

M Col 22 is highly susceptible to vascular streaking (Fig. 38) but fairly resistant to general rotting (Fig. 39). M Col 670A is resistant to vascular streaking (Fig. 38) but susceptible to general rotting (Fig. 39). Llanera, like the majority of genotypes, is susceptible to both (Fig. 38 and 39). M Col 1816 is resistant to both (Fig. 12). The root of M Col 1816 can be eaten even two weeks after harvest. These suggest that root durability is a genetic character and that vascular streaking and general rotting are independent of each other.

why the Brazilian Indian processing innovation

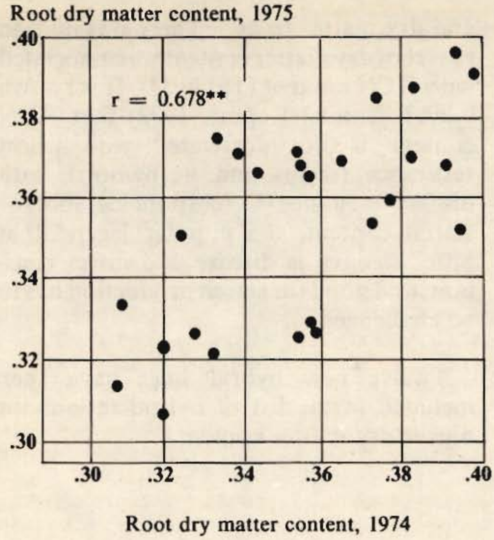


Figure 32. **Relationship between cassava root dry matter contents in 1974 and 1975.**

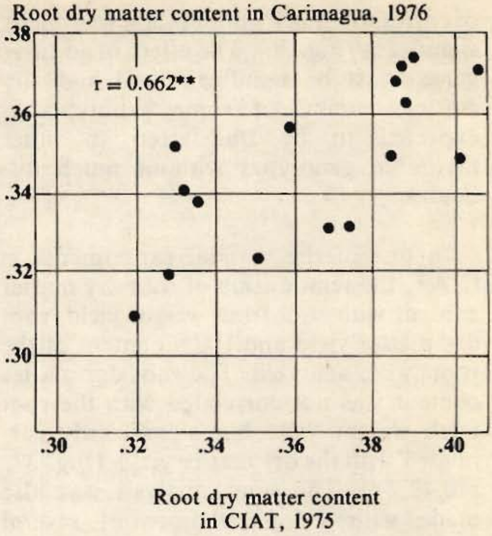


Figure 34. **Relationship between root dry matter contents of cassava at CIAT and Carimagua.**

r=0.678**) which was highly correlated with the 1976 experiment (Fig. 33 r = 0.695**). The varietal root dry matter content in CIAT was highly correlated that in Carimagua (Fig. 34, r = 0.662**) and Caribia (Fig. 35, r =0.641**). These data indicate that root dry matter content, which is almost parallel with starch content (CIAT Annual Report 1975) is a genetic character which is highly stable over a wide range of environmental conditions.

An analysis with 37 different crosses showed that in root dry matter content the regression of parental value on the average

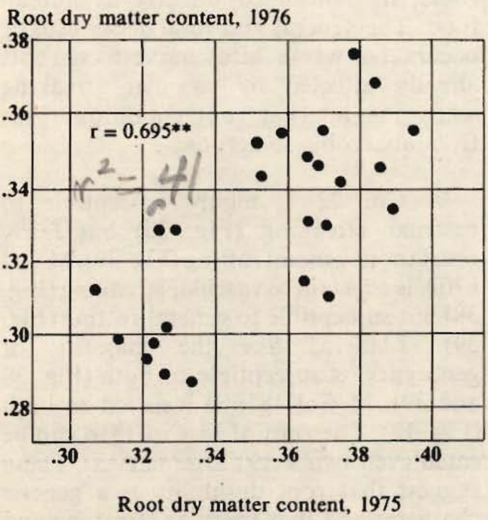


Figure 33. **Relationship between root dry matter content in cassava in 1975 and 1976.**

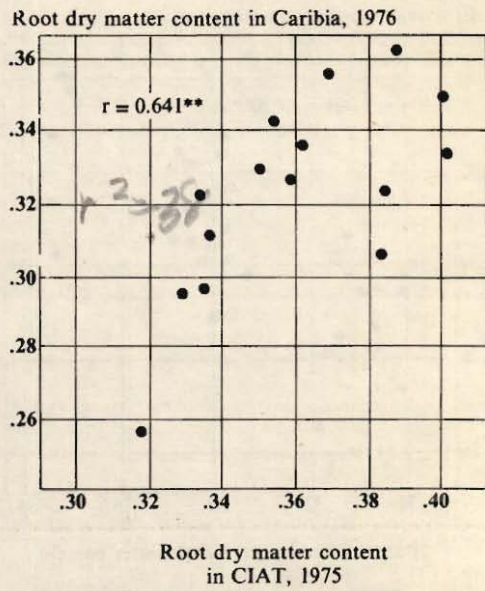


Figure 35. **Relationship between root dry matter contents of cassava at CIAT and Caribia.**

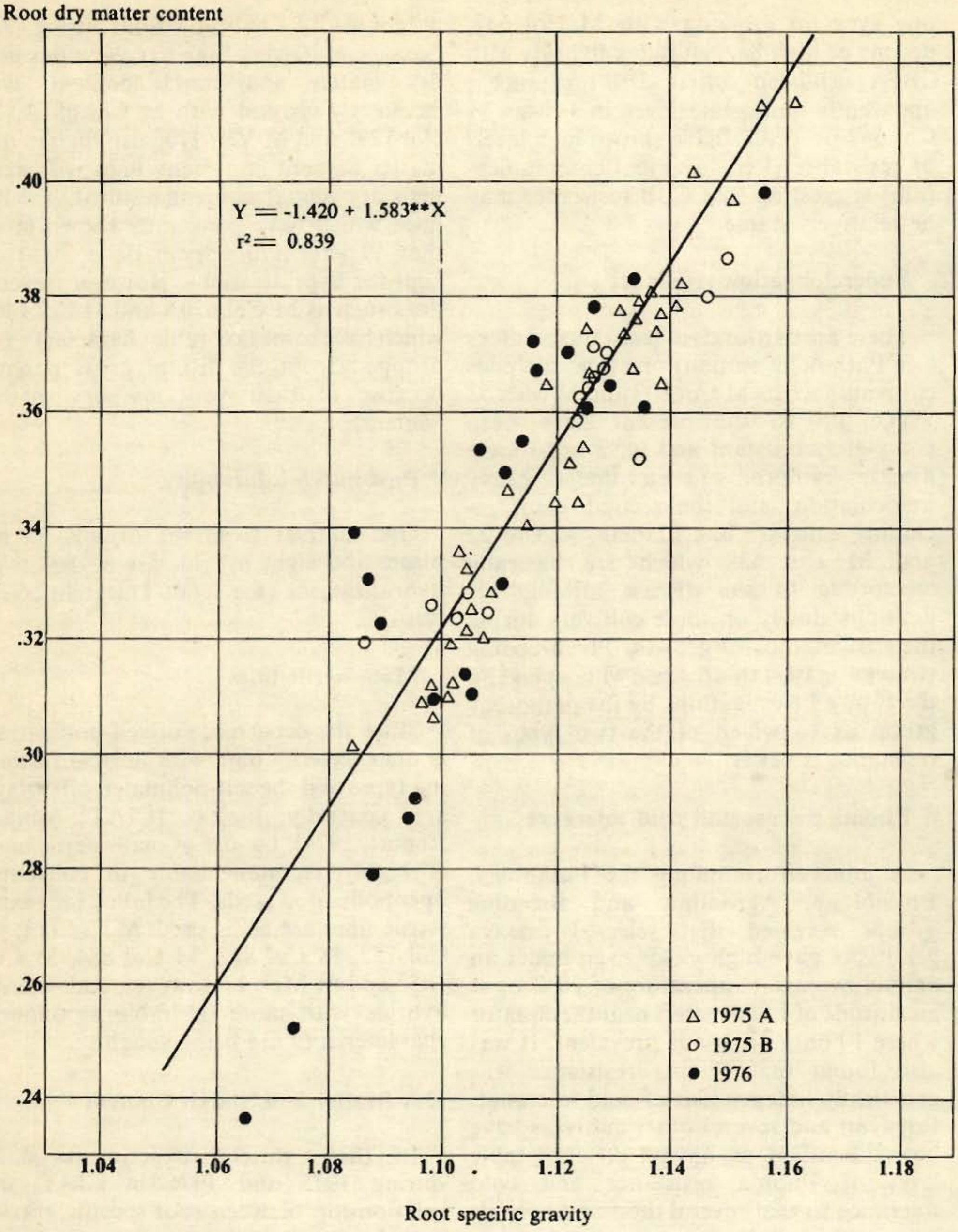


Figure 31. Regression of cassava root specific gravity and dry matter content of the root in three trials.

0.23-0.41 found in CIAT collections. Hence, this method can safely be used for selection.

Varietal root dry matter content in the 1974 experiment showed high correlation with that in the 1975 experiment (Fig. 32,

one cycle of crossing with M Col 647, dozens of high harvest index hybrids with CBB resistance resulted. CBB resistance is apparently multigenic. Even in Taiwan M Col 647 progenies have shown high levels of resistance (Leu, personal communication) suggesting that CBB resistance may be relatively stable.

Superelongation resistance

There are two kinds of resistance sources (see Pathology section) one kind includes cultivars such as M Col 803 and M Mex 52 which up to the present have been completely resistant and have not shown disease symptoms even under heavy innoculation, and the second kind, including cultivars like Llanera, M Col 22 and M Col 638 which are basically susceptible to the disease although it develops slowly on these cultivars during the first months of growth. The breeding strategy against this disease will depend on the future investigations by the pathology group as to which of the two types of resistance is better.

Phoma disease and cold tolerance

A joint effort among the Pathology, Physiology, Agronomy and Breeding groups revealed that selected cassava genotypes gave high yields even under an annual average temperature of 20ºC or at an altitude of 1,800 meters near the equator where Phoma disease is prevalent. It was also found that Phoma resistance was genetically independent of cold tolerance. Popayan and several other cultivars have been identified as having an acceptable level of Phoma resistance and cold tolerance so that several thousand hybrids were made with Popayan in an attempt to combine high harvest index and other desirable agronomic characters with Phoma resistance and cold tolerance.

Higher dry matter content

M Col 22, the most frequently used parent in CIAT hybridizations during 1973 because of its very high harvest index and dry matter and starch content, was frequently crossed with M Col 655A, M Col 1292 and M Ven 270, also high in dry matter content and many lines with very high dry matter content, resulted. Twelve lines which have constantly shown more than 40 percent root dry matter content are kept for hybridizations. However, several lines such as M Col 670A and M Col 1468 which have some favorable characters were dropped from the list of cross parents because of their very low dry matter content.

Post-harvest durability

One cultivar from the original germplasm and eight hybrids are in the list of hybridizations (see Root Durability Section).

Male-sterile lines

Since the occurrence of self-pollination is unexpectedly high with normal flowering types and the self-pollinated offsprings are generally useless (CIAT Annual Report, 1974), the use of male-sterile lines is highly recommendable in collecting openpollinated seeds. The following male-sterile lines are being used: M Col 113, M Col 755, M Col 882, M Col 884, M Col 1052 and M Mex 1. However, male-sterile hybrids with more desirable agronomic characteristics are being sought.

Dry Matter and Starch Content

In three varietal experiments done during 1975 and 1976 in CIAT, the relationship between root specific gravity and dry matter content of the roots was analyzed (Fig. 31). The regression of root dry matter content on the specific gravity was highly significant ($r^2 = 0.839^{**}$)and there was not much difference between different years. The deviation from the regression is considerable but is small when compared to the dry matter variation of