Cassava program

1977/CIAT

Cover: Harvesting of replicated yield trials of hybrid cassava lines

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. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT the 184 hectare substation of Quilichao, situated near Santander de Quilichaó, Departamento del Cauca. 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 (CGIAR). During 1977 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, Japan, 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 United Nations Development Programme (UNDP). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

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Cassava Program 1977 Report

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* Left during 1977
** Assigned to two programs

CONTENTS

Cassava Program

During 1977 the Cassava Program continued its efforts to reach its objectives of: (1) producing a low-input technology for increased cassava production in areas where it is presently grown; (2) developing technology for cassava production of the infertile acid soil areas of the tropics; and (3) diffusing these technologies to national and local agencies and assisting them where possible.

A multidisciplinary team works as a group to resolve problems associated with meeting these objectives. Of primary importance in the program strategy is to have a plant that is *per se* efficient in converting solar energy to carbohydrates. The characters of a plant to achieve this were described last year on the basis of a computer model. Experiments this year have confirmed the importance of long leaf life and late branching. Furthermore, efforts to seek variability in photosynthetic rate, which may ultimately be used to increase yield potential, showed that variation in this character is considerable.

Different genotypes were grown at three sites with average temperatures of 20°, 24° and 28°C. The same plant type yielded best in all sites; however, for the coolest site, which is at the lower limit of cassava's range of adaption, a different, more vigorous genotype was required.

Cassava is frequently found on the acid infertile soils and tremendous potential exists for increased production in these zones. Cassava will give good yields at low levels of lime (0.5 t/ha), however, new trials this year have shown that there is scope for selecting lines that do exceptionally well at this level or with even lower lime levels. Similarily lines were identified with good potential yields at very low levels of applied phosphorous.

Although the technology being developed aims to use the lowest possible fertilizer levels, fertilizers yield a high rate of return on investment. The use of rock phosphates show particular promise as a source of cheap fertilizer. With moderate fertilizer levels yields of 25-28 t/ha can be obtained on acid infertile soils.

A major problem in these low-fertility areas and the regions where cassava is already widely grown is the control of diseases and pests. Poor germination is often due to a number of organisms that attack the planting piece, especially if it is not planted immediately after cutting. A simple fungicidal and insecticidal dip that costs only 3US$ per hectare was found extremely effective in eliminating this problem.

The emphasis of disease and pest control is, however, not chemical. The extremely devastating disease cassava bacterial blight can be controlled by planting resistant varieties. Many of the new hybrids from the program have been tested for resistance and have shown acceptable levels even when infected with the most virulent strains.

The superelongation disease, first reported in 1974, was identified in several countries of Latin America where it causes severe losses. Although it can be disseminated by infected planting material, the fungicidal dip described above eliminates the diseases thus preventing early infection. Unfortunately, different races of the causal organism, *Sphaceloma manihoticola* exist. A small number of cultivars showed high tolerance to all known races.

One of the most widespread problems in cassava in the Cercospora diseases. These often cause yield losses of 20 to 30 percent but resistant lines were found which were not affected.

During the dry season severe attacks of thrips and mites occur and cause yield losses of up to 50 percent. The cassava germplasm at CIAT was screened for resistance to thrips and more than half the material showed high levels of tolerance. In the case of mites, high levels of resistance have not been encountered, nevertheless, massive screening showed that a number of varieties are tolerant to both *Mononychellus* and *Tetranychus* mites.

No varietal resistance to the hornworm has been found, however, biological control can be based on maintaining *Polistes* populations in the field, with strategic release of *Trichogramma* and applications of the bacterial disease *Bacillus thuringiensis*. These techniques are being tested on a commercial scale; early results suggest that the system is effective.

The cassava fruitfly *Anastrepha* spp. bores in the stem and allows the entry of *Erwinia caratovora* var. *caratovora*, which causes rotting of the interior stem parts. Stakes taken from damaged plantations and used for planting material give poor stands and reduced yields. Merely by proper selection of planting material, yields can be increased by up to 20 percent.

Although the desirable characters of an efficient plant type, lines tolerant to the acid infertile soils and resistant to major diseases and pests exist, they have yet to be combined in a single line. The breeding section tests more than 20,000 hybrids, from controlled crosses, each year in order to obtain new varieties with most of the desirable characters. New hybrids have good yield potential, 60 t/ha under the fertile CIAT conditions, 40 t/ha in Caribia with less fertile soils and a very pronounced dry season and 30 t/ha in the acid infertile soils of the Llanos Orientales. Disease and pest problems are still serious but progress was made this year to combine resistance with high yield potential.

Promising selections from the germplasm bank and the new hybrids are multiplied with the rapid propagation technique. This system was further refined and simplified and is now used routinely. The promising material after multiplication, promising materials are planted in regional trials throughout Colombia. No fertilizer or post-emergence applications of insecticides or fungicides were used except for an intermediate application of fertilizer in the trials on the acid infertile soils. Carefully selected plant material is treated with fungicides and insecticides and planted, good weed control is practices but otherwise, no special care is given to the trials.

The year 1977 provided the third year of results from these trials. In the first two years when only preliminary selections were used, the advantage of selected lines over the best local lines was quite small. However, with the final selections from the germplasm a tremendous advantage was evident from combining good cultural practices and selected material.

Previously, all work at CIAT has been on cassava as a monoculture crop. Much of the world's cassava is grown as a mixed culture. Cassava was grown in association with beans to test the potential of cassava grain legume association. Very high Land Equivalent Ratios were obtained — greater than 1.7 when cassava and beans were planted at the same time, and at their normal plant population. Yields of both crops were high at 34 t/ha and 2.9 t/ha of fresh cassava and dry beans, respectively.

A major problem faced by all cassava producers is the difficulty involved in handling the crop due to its extreme perishability after harvest. The perishability is due to physiological deterioration which often occurs within 48 hours of harvest and microbial deterioration which occurs five to ten days after harvest. It was found that the physiological deterioration can be prevented by either pruning the tops three weeks before harvest or by putting roots in to polyethylene lines\papar bags directly after harvest. Microbial deterioration was prevented by treating the roots with a broad spectrum fungicide.

The international cooperation activities markedly increased in the Cassava Program in January 1977 with the assignment of two staff possitions — one based at CIAT to coordinate Latin American activities and the other, posted at SEARCA, the Philippines, to coordinate outreach activities in Asia.

Physiology

Temperature Effects on Cassava Growth

Preliminary results reported last year (CIAT Annual Report, 1976) suggested that different genotypes of cassava are required below about 24°C. These results have now been confirmed. The variety Popayan was the highest yielding at 20°C (Table 1) and by 16 months had produced 39.7 t/ha. On the other hand, at 24° and 28°C Popayan was the lowest yielding variety tested. M Col 22 was the lowest yielding line at 20°C at all harvests but showed good yield potential at 24° and 28°C.

Temperature adaptation of a variety appears to be directly related to its vigor. Popayan is very vigorous while M Col 22

Table 1. **Fresh and dry root yield of four contrasting cassava genotypes at different times after planting at altitudes with three different mean temperatures.**

	Avg. mean temperature								
	20°C Harvest date (months)			24°C Harvest date (months)			28°C Harvest date (months)		
	8	12	16	8	12	16	8	12	16
Fresh yield[1] (t/ha)									
M Col 22	2.7	9.3	13.3	22.1	22.7	48.3	23.9	39.4	53.1[2]
M Mex 59	9.2	22.8	32.8	25.3	38.8	57.0	21.3	30.4	60.3
M Col 113	14.2	24.2	28.6	16.4	26.1	51.3	20.2	23.9	55.0
Popayan	10.7	28.9	39.7	6.3	15.7	13.3	4.6	9.4	13.2
Dry yield[1] (t/ha)									
M Col 22	0.9	3.3	5.6	8.4	11.5	18.0	8.8	14.2	18.4
M Mex 59	3.0	8.2	12.9	8.2	14.2	18.1	7.5	10.1	19.7
M Col 113	4.5	8.4	15.6	5.4	10.0	19.1	6.2	7.5	17.0
Popayan	3.1	10.7	16.2	1.9	5.1	2.6	1.1	2.2	3.0

[1] For fresh and dry root yields temperature x variety interaction was significant at P = 0.01

[2] This yield was reduced due to robbery in the experiment plot.

has very low vigor. In general, vigor at 20°C was lower than at 24° and 28°C, as measured by leaf area index (LAI) (Fig. 1), and root bulking is maximized only over a small range of LAI (Fig. 2). The vigorous variety, Popayan, reaches its optimum LAI at a lower temperature than M Col 113 and M Mex 59 that in turn reach optimum LAI at lower temperatures than M Col 22. It follows that more vigorous varieties must be selected for maximum yields at lower temperatures and less vigorous varieties for higher temperatures.

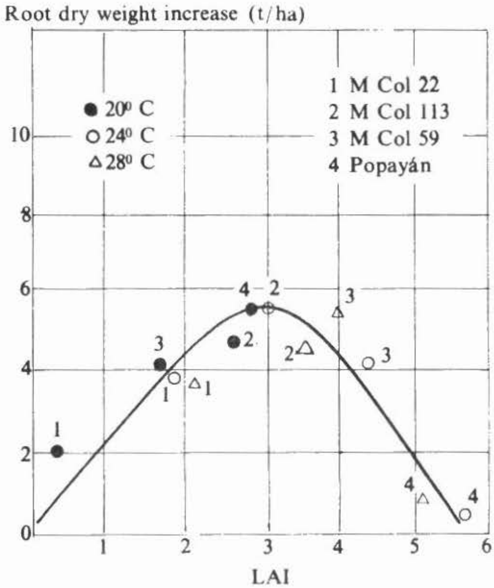

Figure 2. **Root dry weight increase as related to mean Leaf Area Index (LAI) of four cassava varieties at 8-16 months after planting in locations having three mean temperatures.**

Leaf Life

Simulation results suggest that increased leaf life should be a useful character for improving yield. The simulation model used assumed that older leaves were photosynthetically efficient. The older leaves are always lower in the canopy and receive less light than the upper ones. Photosynthetic rate of leaves of different ages was measured at 1500 μ Em^{-2} sec^{-1} and 500 μ Em^{-2} sec^{-1} (about three-quarters and one-quarter full sunlight, respectively). At 500 μ Em^{-2} sec^{-1}, the photosynthetic rate of leaves up to 56 days after emergence was very little less than that of younger leaves (Fig. 3) suggesting that even these older leaves can contribute actively to total plant photosynthesis.

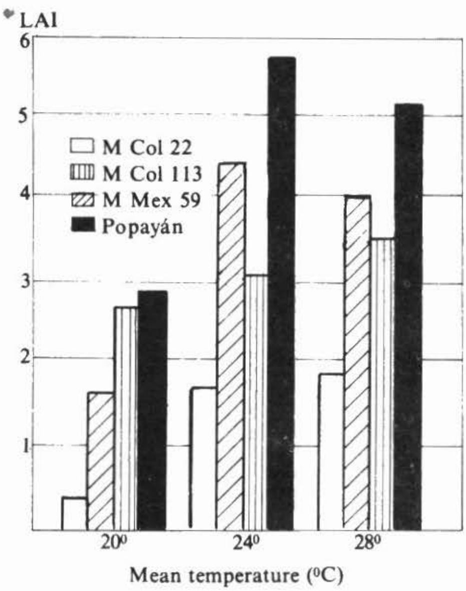

Figure 1. **Mean Leaf Area Indices (LAI) from 8-16 months after planting for four cassava varieties grown in locations having three mean temperatures.**

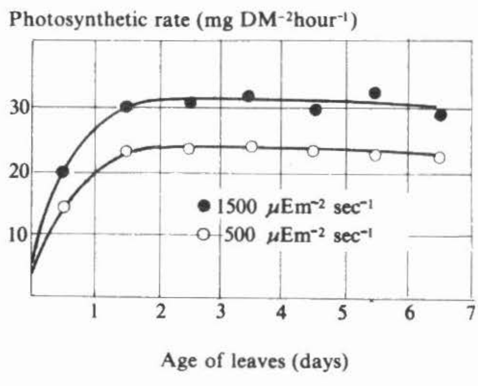

Figure 3. **Effect of leaf age on photosynthesis of leaves of cassava variety M Col 72.**

Rather than depend entirely on simulation data to assess the effects of leaf life on yield, M Col 72 with a leaf life of 120 days or more was planted at 20,000 plants/ha and leaf life artificially reduced to 49 or 84 days or left at its natural level. The natural leaf life was no greater than the 84-day treatment for leaves tagged up to two months after planting and therefore yields were similar for the 84-day treatment and control at the six month harvest but the plots with the 49-day leaf life had markedly reduced yields. By nine months after planting, leaf life of the controls was considerably greater than either treatment and yield was also greater when leaf life was longer (Fig. 4).

To obtain varieties with a long leaf life, a suitable screening technique was needed. Leaf life was measured on more than 200 new hybrid lines by tagging newly formed leaves at two, three and four months after planting. Only a small variation was found between varieties when leaves were tagged at two months after planting. However, when leaves were tagged at either three or four months large differences were found, ranging from 60 to 150 days. The high correlation between the two observations suggested that screening for different leaf lives can be done by tagging leaves at three to four months. In another trial where leaf life was measured, little difference was found in leaf lives of early-formed leaves but later-formed leaves showed large differences depending on the variety (Fig. 5). This confirmed that leaves formed in the first two months after planting are not suitable for screening for varietal differences in leaf life.

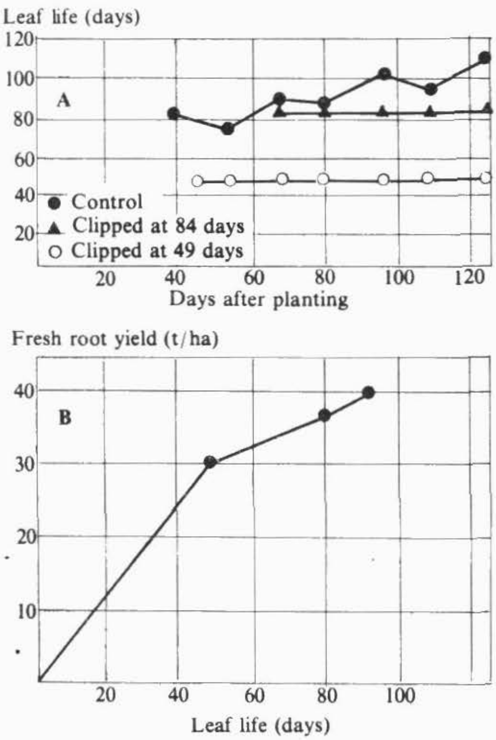

Figure 4. **Leaf life of cassava variety M Col 72 with two clipping treatments (A), and effect of leaf life on fresh root yields nine months after planting (B).**

Leaf Size

Leaf size in most varieties increases with increase in canopy height and then declines (Fig. 6). However, the leaf size of M Col 72, a non-branching variety, shows a much smaller decline than other varieties which have varying degrees of branching. When branching was restricted in M Col 113, a branching variety, the decline in leaf size did not occur, at least up to seven months after planting when the experiment terminated, while in natural branching plots leaf size at seven months was less than half that at four months (Fig. 7). This suggests that maximum leaf size is not affected by branching habit but that leaf size decline after four months is greater when branching occurs.

Last year (CIAT Annual Report, 1976) a computer simulation model was used to predict yields of cassava lines with different branching habits on the assumption that leaf size declines with time in all types. This would indicate that predicted yields of single stem types would be slightly lower than can be expected when leaf size decline does not occur.

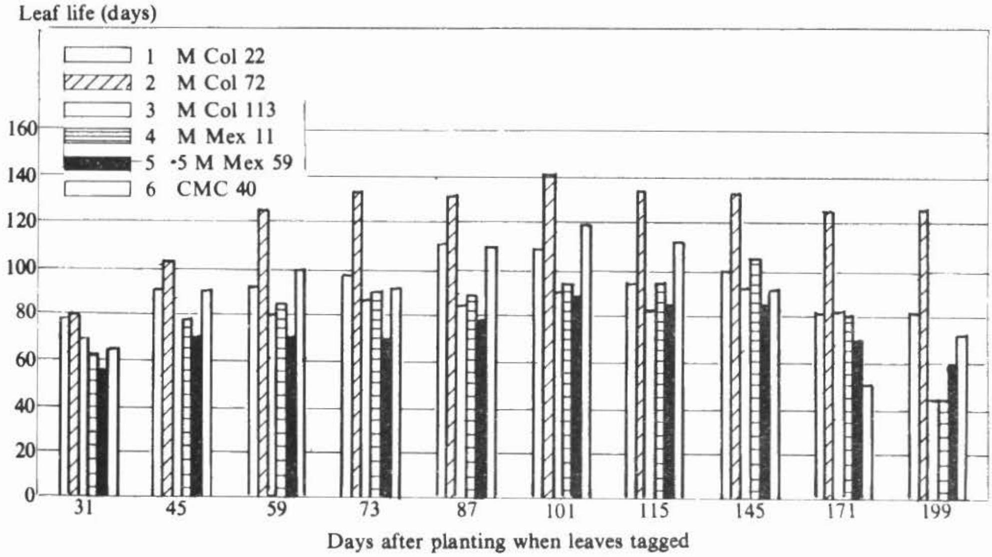

Figure 5. **Leaf life of six cassava varieties at different times after planting.**

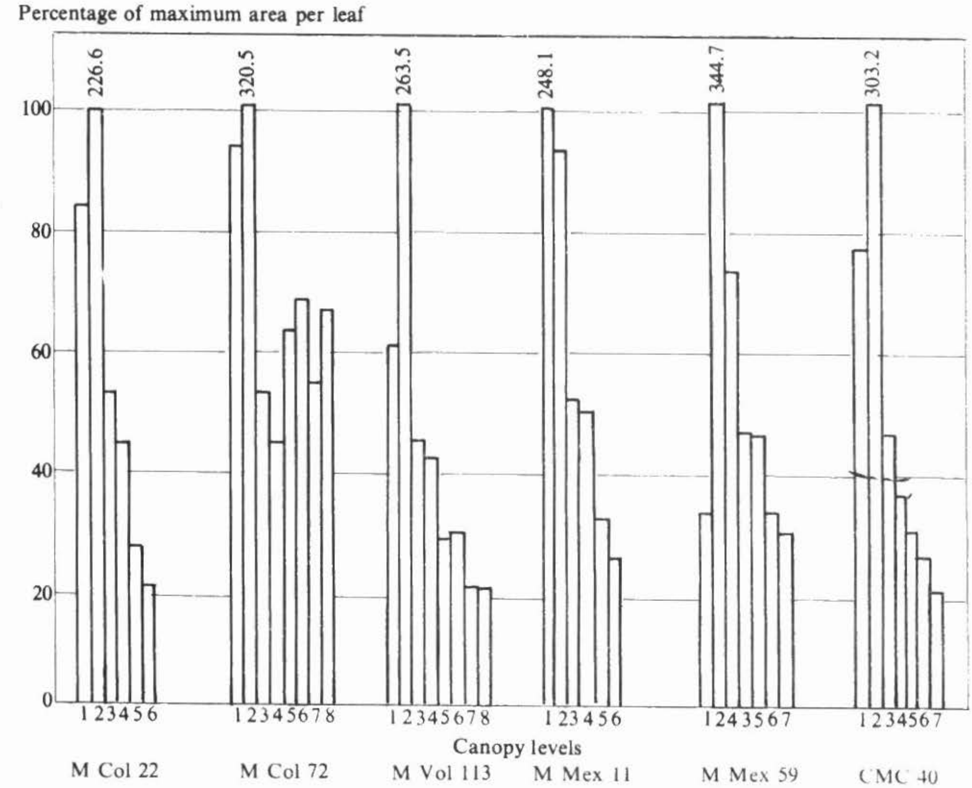

Figure 6. **Leaf size as affected by canopy level of six cassava varieties.**

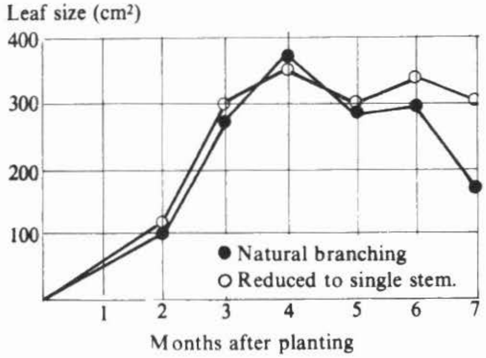

Figure 7. **Interactions of branching pattern and leaf size of cassava variety M Col 113.**

Root Sink Capacity

In previous reports, experiments to reduce root numbers by clipping suggested that the remaining roots have the capacity to accept more carbohydrate than is available (CIAT Annual Report, 1976). However, when root number was decreased there was always a slight decrease in total root yield, suggesting a sink limitation on root expansion.

During the early growth phase of cassava top growth is very vigorous and roots do not normally swell rapidly. It is not certain whether the roots do not expand due to inability to accept carbohydrates or to lack of available carbohydrate. Similarly, vigorous top growth at this period may be due to lack of alternative sinks (i.e. roots).

When top growth was reduced by apex removal total crop growth rate (as a function of LAI) was not affected (Fig. 8), demonstrating that top sink did not limit total photosynthesis and crop growth rate. Additionally, while LAI (and hence crop growth rate) was reduced, root growth rate was increased (Table 2). The roots clearly can accept more carbohydrate than is normally available in the early growth phase. These results also indicate that top growth has preference over root growth and that roots accept carbohydrate in excess of the needs of the tops.

The data demonstrate that top growth is a strong attractant of carbohydrates and in previous reports (CIAT Annual Report, 1976) it was suggested that in certain cases limitation of top growth could be used to increase yield. In fact, yield was increased 25 percent by restricting top growth. The vigorous variety M Col 113 was planted and different branching patterns were produced by clipping (Table 3). The most effective treatment increased yield 70 percent showing that the branching habit is extremely important for yield. There was also a close relationship between the actual yield obtained in the field and simulated yields (Fig. 9) suggesting that the simulation model described last year (CIAT Annual Report, 1976) can be used to predict high-yielding types.

Photosynthetic Rate

The simulation model was used to predict the effects of increased crop growth rate on yield. The model suggested that very small increases in crop growth rate should lead to large increases in yield (e.g. a

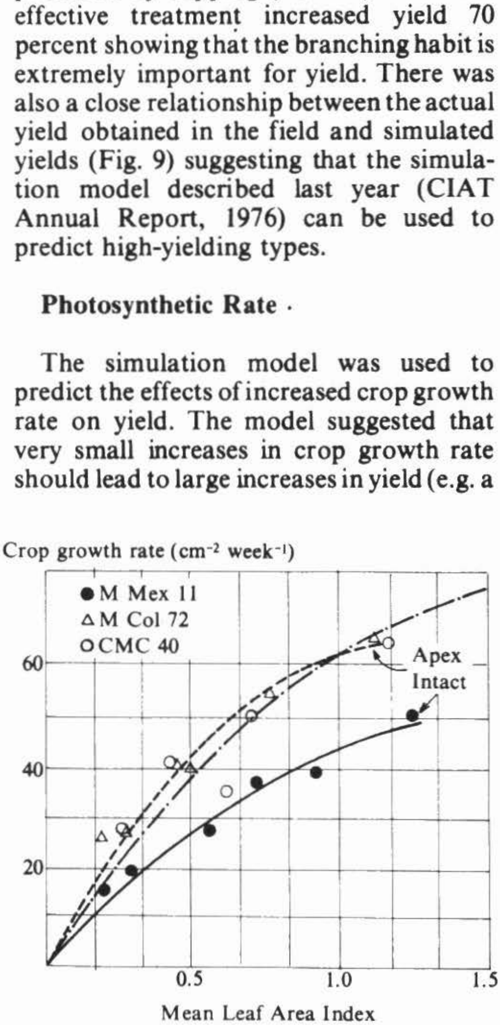

Figure 8. **Crop growth rate as a function of Leaf Area Index of three cassava varieties.**

Table 2. **Effects of apex clipping on crop growth rate and root growth rate of three varieties of cassava.**

	Crop growth rate (gm^{-2} wk^{-1})	Root growth rate (gm^{-2} wk^{-1})	$\frac{\text{Root growth}}{\text{crop growth}}$ x 100 (%)
M Col 72			
Control	67	18	28
Apex-clipped	54	23	42
CMC 40			
Control	77	18	23
Apex-clipped	64	21	33
M Mex 11			
Control	49	7	13
Apex-clipped	38	10	25
Mean			
Control	64	14	22
Apex-clipped	52	18	34

10 percent increase in crop growth rate at all LAI's should result in a yield increase of slightly more than 20 percent). Several varieties were screened for photosynthetic rate of individual leaves and large, consistent differences were found between varieties (Table 4). (It remains to be seen whether these differences can be related to differences in crop growth rate in the field.) Large differences in crop growth rate between three varieties were encountered and these differences maintained over a range of LAI's (Fig. 8). The cause of these differences has not been determined but the data suggest that yield may be increased via increased crop growth rate.

Harvest Index

In the CIAT Annual Report, 1974, it was suggested that the harvest index is a useful selection tool for cassava breeders. It has also been frequently noted that harvest indices in cassava are very high which is

Table 3. **Fresh and dry root yields of cassava variety M Col 113 with different branch controls.**

Branch time (weeks after planting)	No. of branches at each branch point	Dry root yield (t/ha)	Fresh root yield (t/ha)
12, 19, 27, 40	3 - 4	5.5	17.6 (100)[1]
14, 20, 28, 38	3	7.3	22.3 (127)
13, 20, 24, 33	2	10.3	29.6 (168)
No branching	1	8.4	26.9 (153)
26	3 - 4	8.5	25.4 (144)
27, 33	3 - 4	9.8	30.0 (170)
26, 32, 39	3 - 4	9.3	27.6 (157)

[1] Figures in parentheses are percentages of control.

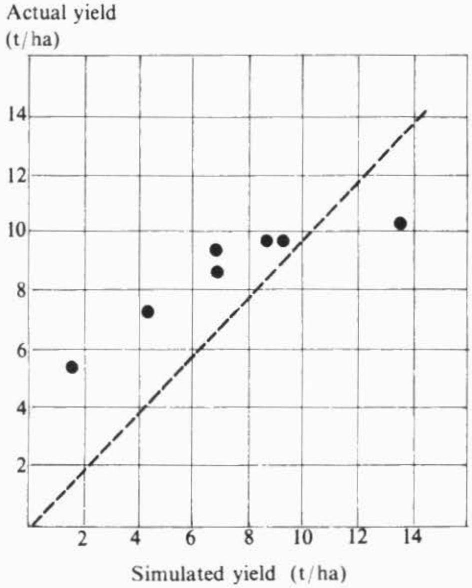

Figure 9. **Relation between actual yield and simulated yield of cassava variety M Col 113 with branch control (yield in terms of root dry matter).**

one of the reasons for its high yield potential.

The measured harvest index of cassava does not usually include fallen leaves. Nevertheless, when fallen leaves are included, real, high harvest indices of over 50 percent are still obtained. The relationship between real and measured harvest indices is consistent and therefore, measured harvest index is still a valid selection index although it has a systematic bias (Fig. 10).

INTERCROPPING

Relative Planting Dates

As cassava is slow to establish and form a canopy, it may be possible to intercrop cassava with a short-season crop such as beans. It was thought that one of the most important factors in determining the success of intercropping would be the

Table 4. **Photosynthetic rate of individual cassava leaves of 15 varieties at 100 uE $m^{-2}sec^{-1}$ of light intensity. (Mean of nine replicates).**

	DM Rate (mg dm^{-2} hr^{-1})	Standard Deviation	Percentage of maximum
M Col 72	33.2	2.6	100
M Col 22	32.1[1]	3.3	96
M Col 1292	31.5	2.9	95
"	31.5	2.8	95
CMC 40	31.0	3.3	93
M Col 113	30.9	2.7	93
M Col 946	30.9	2.5	93
M Mex 17	30.8	3.2	92
M Col 12	30.7	3.1	92
"	29.4	3.7	88
M Col 667	30.5[1]	2.6	92
CMC 84	29.7	2.1	89
M Col 638	29.8	3.9	89
M Mex 11	28.5	2.5	86
M Col 119	28.4	2.3	85
"	26.8	2.3	80
Popayan	27.1	2.1	81
"	26.7	3.2	80
M Mex 59	26.8	2.4	80

[1] Only six replicates compared to nine in the experiment.

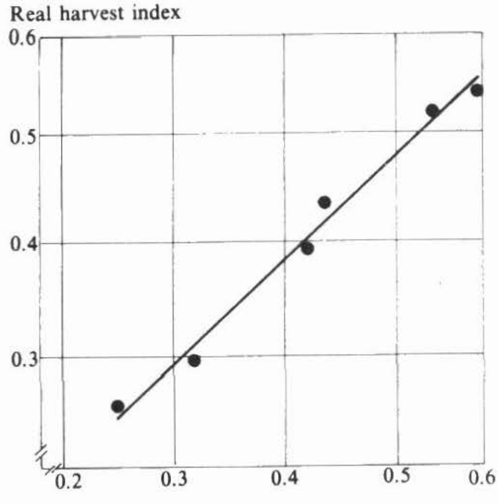

Figure 10. **Relation between measured and real harvest index of cassava.**

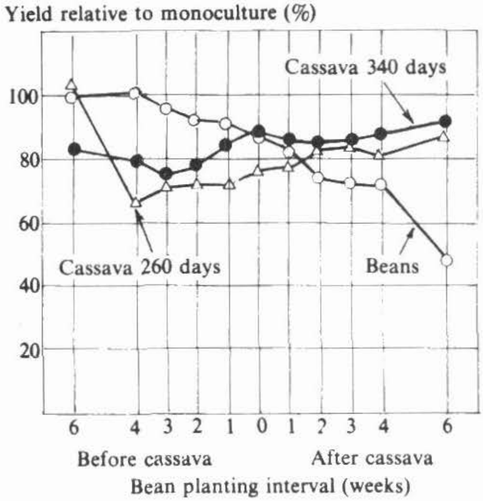

Figure 11. **Root dry matter yield of cassava at 340 and 260 days and yield of beans at maturity when beans were planted with different planting dates.**

relative planting dates of the two crops so that neither suffers from excessive competition.

When cassava and *Phaseolus* beans were intercropped at CIAT, cassava root yield was little affected by the planting date of the beans (Fig. 11) compared with monoculture cassava harvested at 340 days. When intercropped cassava was harvested earlier at 260 days, the effects were more pronounced with cassava yields being markedly reduced when the beans were planted four weeks before the cassava.

Bean yields were not reduced by intercropping with cassava when the beans were planted from four to six weeks before the cassava. However, bean yields showed a marked decline when beans were planted from three weeks before to six weeks after the cassava (Fig. 11).

When beans were planted six weeks before the cassava, total land use time for the two crops was 382 days. However, when they were planted at the same time or later, total land use time was 340 days when the cassava was harvested 340 days after planting. The Land Equivalent Ratio (LER) of the various planting dates was calculated as the ratio of the land area needed in intercropping/monoculture for both crops. (The land equivalent ratio was corrected so that all comparisons were made on equivalent total land use time.) The most efficient biological land use measured by the LER was 1.7 when crops were planted at the same time, or beans one week earlier (Fig. 12). This very high LER suggests that there is great potential for intercropping with cassava. Yields indicated that one hectare of land can

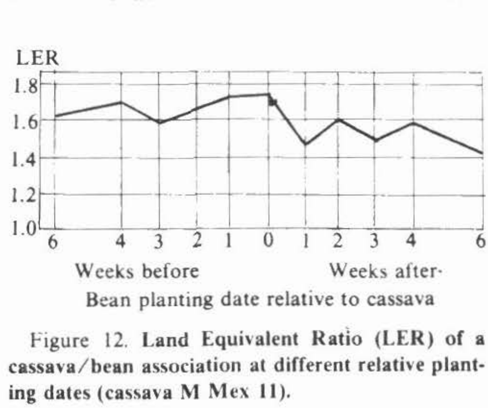

Figure 12. **Land Equivalent Ratio (LER) of a cassava/bean association at different relative planting dates (cassava M Mex 11).**

optimally produce 34 t/ha of fresh cassava and 2.9 t/ha of beans in less than one year.

Intercropping did not affect root dry matter percentage but the starch content on a dry matter basis was markedly reduced when beans were planted before cassava.

Plant Populations

When two different crops are planted together they compete for light, nutrients and water. As the density of each crop increases, competition increases. As the cassava density is increased in monoculture root yield either reaches a plateau or a marked optimum, depending upon the variety. As bean populations increase yields also increase and then reach a plateau. However, optimum plant populations for yield in intercropping may be different from those in monoculture.

Two varieties of cassava, M Mex 11, a non-leafy, late-branching type, and M Col 113, early-branching, leafy type, were planted at different population densities with P302, a bush bean with few branches, and Puebla, a prostrate, heavy-branching bean type. There was no obvious interaction of increasing densities of bean populations x cassava populations on yield of beans or cassava.

Since cassava was planted two weeks before the beans, yields of intercropped beans were low due to the bean planting date. Yield of Puebla in monoculture tended to increase slightly as density increased but no effect was observed in intercropping. However, the yield of the intercropped bush bean P302 increased with population density (Fig. 13). Bean yield was more severely reduced over all population densities when intercropped

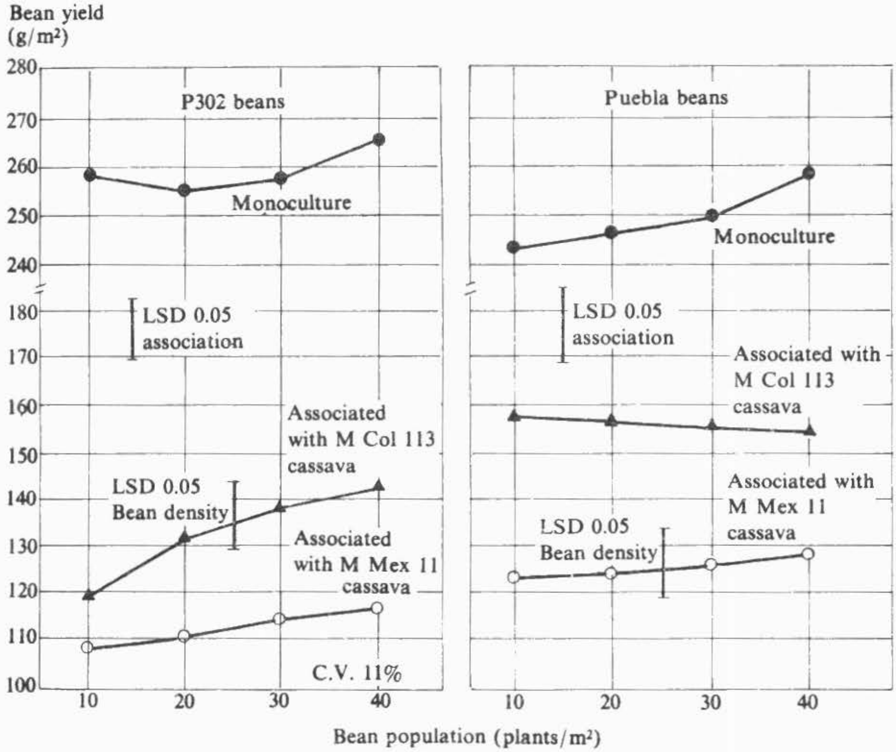

Figure 13. Dry bean yield of two varieties as affected by plant density of beans alone and in association with two cassava varieties.

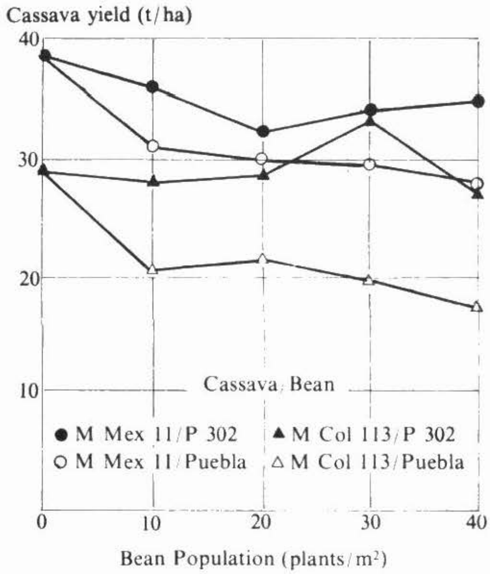

Figure 14. **Cassava yields as affected by intercropping with two bean varieties at varying densities.**

with M Mex 11 than with M Col 113. (M Mex 11 has more early vigor than M Col 113 and emerged above the bean canopy two weeks earlier.) However, bean density above 10 plants/m² did not affect cassava yields (Fig. 14).

When cassava density was increased bean yield was markedly reduced (Fig. 15). However, yield of M Mex 11 increased with plant population in both monoculture and intercropping. Yield of M Col 113 in monoculture reached a maximum at about 5000 plants/ha and then declined. When M Col 113 was planted at more than 6900 plants/ha and intercropped with P302, the cassava yield was superior to the monoculture level at any density. This suggests that intercropping beans with cassava in certain cases may increase the yield of M Col 113 above the monoculture level although yield never reached that of

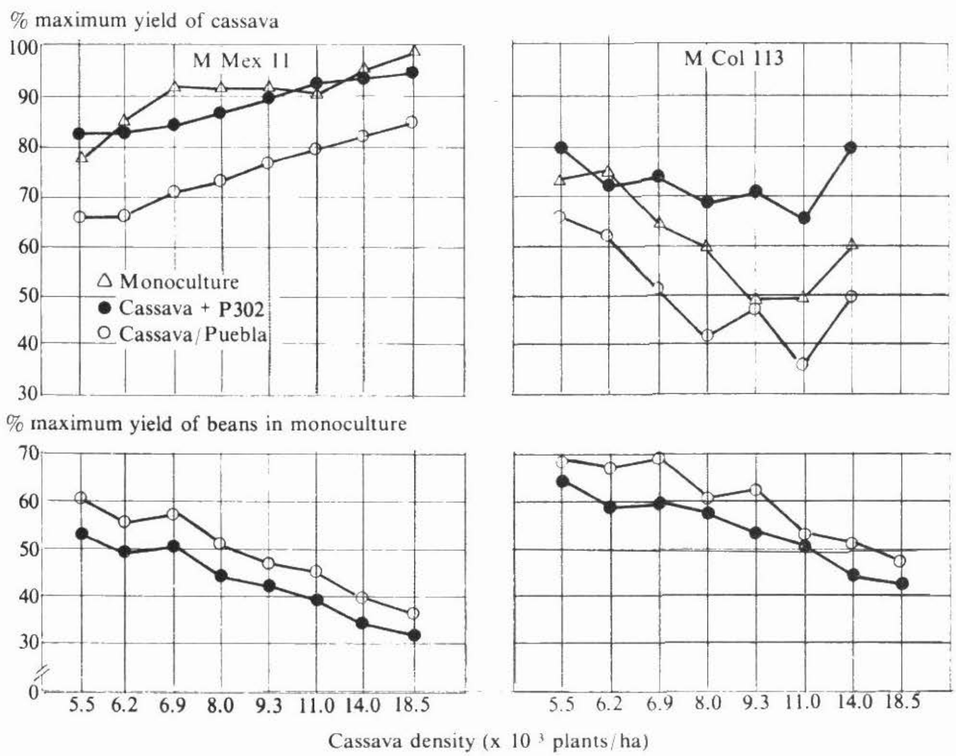

Figure 15. **Cassava yields and bean yields as percentage of maximum yield as affected by cassava plant densities in association with beans and in monoculture.**

M Mex 11 in monoculture. While the yield increase of M Col 113 may appear anomalous, early competition may have lowered early growth vigor reducing the later LAI to near optimum; consequently, yield improved in a process similar to that which occurs when apices are removed.

These data suggest that it may be difficult to breed for high yield in intercropping systems without depressing the yield of the associated crop. Nevertheless, when the best monoculture yields of 39.4 t/ha by M Mex 11 and 2.6 t/ha by Puebla were used as a reference, LER's of greater than 1 were consistently obtained in this trial (Fig. 16). As cassava density increased when M Col 113 was planted with Puebla, Land Equivalent Ratios declined but remained fairly constant in other combinations. Yields in this experiment were lower than those of the planting date trial; this may have been due to Problem X in the beans. The highest yields of cassava (M Mex 11) were obtained at the highest plant population (18,500 plants/ha) whereas the highest LER's were obtained at much lower plant populations of cassava. This suggests that optimum cassava populations may be different for intercropping cassava and beans, however, bean populations commonly employed can be used.

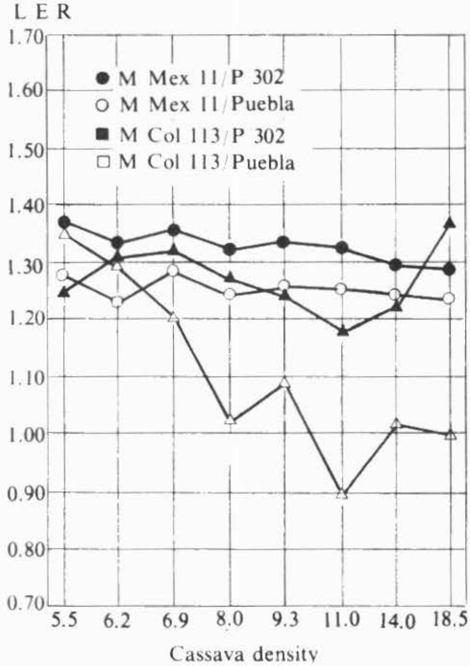

Figure 16. **Land Equivalent Ratio (LER) of different cassava/bean associations compared to best monoculture yield of cassava and beans.**

Pathology

Special emphasis was placed on research to determine losses due to *Cercospora* leaf diseases and the use of cassava bacterial blight (CBB) infected planting material. The efficacy of greenhouse and field screening evaluations for resistance to CBB were also determined and studies were done on the variability of the causal agents of CBB and superelongation.

Varieties, from the CIAT germplasm bank, and promising hybrids were evaluated for resistance to CBB, superelongation, *Cercospora* leaf diseases and Phoma leaf spot. Preliminary etiological studies were also undertaken on an unreported bacterial species that induced stem galls on several cassava clones. The effect of protectant fungicides on storage and germination of cuttings was also determined under field conditions to evaluate losses caused by the lack of sanitary precautions for planting material.

BACTERIAL DISEASES

Cassava Bacterial Blight (CBB)

Studies on pathogenic variability of the causal agent continued this year with 29 cassava varieties with different degrees of resistance and using two strains representative of each of the virulence groups 1, 2, 3, and 4 reported last year (CIAT Annual

Report, 1976). Ten 45-day-old plants/variety/strain were clip-inoculated. Results confirmed differences in virulence among the strains of this pathogen, but the strains did not interact differently with the cassava genotypes tested. Consequently, the existence of distinct races of the CBB pathogen has not been determined; the most virulent strains must be used for screening purposes.

Field *vs.* greenhouse screening methods. The efficacy of greenhouse screening for resistance to CBB (CIAT Annual Reports, 1975 and 1976) was determined by comparison with field evaluations in areas with high rainfall (2200 mm/year) for prolonged periods (nine months). Some 109 varieties were evaluated in the greenhouse and in Carimagua, using a highly virulent Carimagua strain. Twelve plants/variety were planted in Carimagua, at the beginning of the rainy season and six months after planting, naturally infected plants were evaluated.

Results showed a statistically significant correlation between greenhouse and field evaluations for identification of resistant varieties (Fig. 17). Even though some varieties showed moderate resistance in the greenhouse evaluation and susceptibility in the field, it was concluded that the greenhouse technique is useful as a rapid method of screening for CBB resistance, but later testing for resistance under field conditions is required.

When the same varieties were evaluated in the Cauca Valley (400 mm of rainfall scattered over six months), the most susceptible varieties in both the greenhouse and the Carimagua trials were only moderately infected eight months after planting. Therefore, it appears that field evaluation for CBB resistance requires: (1) initial inoculations; (2) several months of host exposure to the pathogen during rainy periods; (3) heavy rainfall (minimum of 120 mm/month) for at least four months; and, (4) evaluation at the end of rainy

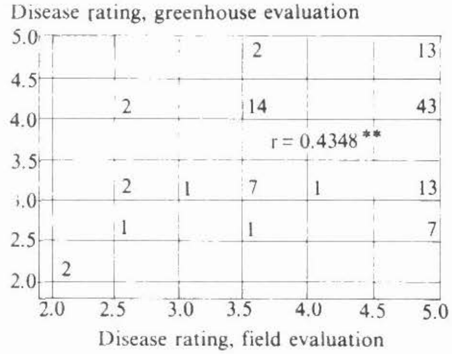

Figure 17. **Relationship between greenhouse and field evaluations (at Carimagua) for resistance to cassava bacterial blight (CBB) of 109 cassava varieties. (Resistant = 2.0; Susceptible = 5.0).**

(Figures within the matrix are the number of varieties for each pair of ratings.)

periods to avoid confusion with symptoms induced by other factors (insects, drought, etc.) and plant recovery due to the effect of dry periods on disease development.

Field losses due to cutting infection. Disease losses caused by CBB in plantations infected at monthly intervals were determined last year (CIAT Annual Report, 1976) under Cauca Valley conditions, using the moderately resistant variety Llanera and the susceptible M Col 113 and M Mex 23. This year, three replicated plots of these varieties (36 plants/plot) were planted with cuttings taken from 10-month-old plants that had been infected at monthly intervals. No artificial inoculation was done and the rainfall was scattered, totaling only 688 millimeters.

When yields of plants from cuttings infected at nine months were compared with yields of controls (Fig. 18), yield reductions were 27, 29 and 31 percent, respectively, for Llanera, M Col 113 and M Mex 23. Cuttings taken from plants infected at two months yielded 38, 34, and 46 percent less than the disease-free controls. This suggests that CBB can seriously reduce yield when planting material is taken from infected plantations

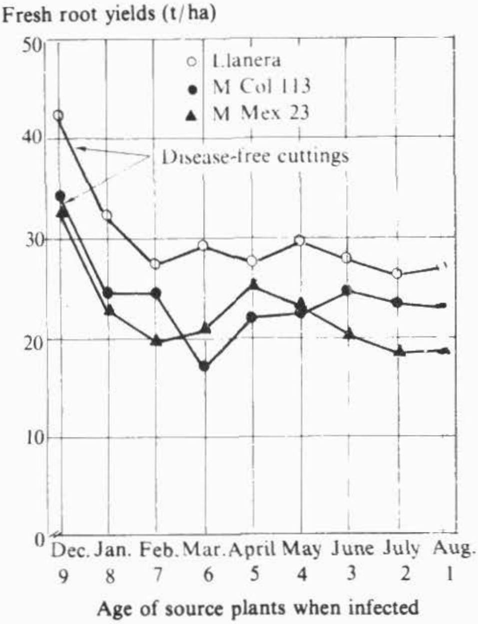

Figure 18. Yield losses of cassava when cuttings were taken from plants infected with cassava bacterial blight (CBB) at montly intervals.

of susceptible or even moderately resistant varieties.

As rainfall was low and scattered during the experiment, yield losses can be principally attributed to the effect of primary CBB infections, reflected in reduced establishment and death of young plants during the first two months. In areas with periods of higher rainfall, disease losses could be considerably higher due to secondary infections.

Evaluation for resistance. To identify new sources of resistance to CBB 328 varieties were evaluated under greenhouse conditions; two were resistant, 90 tolerant, and 236 susceptible. Another 585 varieties were evaluated under field conditions at Carimagua; 5 were resistant, 31 moderately resistant and 549 susceptible. Additionally, 668 high-yielding hybrids developed by the Varietal Improvement section were evaluated under greenhouse conditions (Table 5).

Bacterial Stem Gall

A previously unreported bacterial disease of cassava has been found affecting three-year-old cassava plants. Infected plants are stunted and have large galls on the nodes of the most lignified part of the stem (Fig. 19). The galls are characterized by the presence of several germinal buds.

Isolation of the pathogen was made by grinding surface-sterilized tissues taken from galls, suspending them in sterile distilled water and streaking on Schroth's and Clark's media in petri dishes. Well-developed, white, mucoid bacterial colonies developed after two days incubation at 28°C. Pathogenic tests by direct stem inoculation with a needle prick were done on one-month-old plants of different varieties. Thirty days after inoculation symptoms appeared as normal tissue proliferation around the inoculation site; fifteen days later, galls were clearly formed; two months afterward, plants were weak and stunted; and three months after the inoculation over 90 percent of the plants showed dieback. However, the new shoots which developed below the galls were apparently healthy.

Galls were induced by this bacterial species on 30-day-old tomato plants by direct stem inoculation during a 20-day period. Also, galls were produced on young freshly sliced carrots on the secondary phloem two weeks after inoculation with cotton saturated witha heavy suspension of bacterial isolates.

Pathogenicity results and preliminary physiological and biochemical tests suggest that this pathogen belongs to the genus *Agrobacterium*.

Diseased cuttings produced 13 percent diseased plants in sterile soil under greenhouse conditions, but when apparently healthy cuttings were taken from diseased plants, no diseased plants were produced. Apparently, this bacterial

Table 5. **Greenhouse evaluation of resistance to cassava bacterial blight (CBB) of F_1 crosses from cultivars with different degrees of resistance.**

Cross combination	Reaction of parents	Reaction of hybrids[1] (%) R	MR	S	No. of hybrids
M Col 22 x M Mex 59	S x S	7.4	42.6	50.0	68
M Col 22 x M Ven 318	S x S	-	81.2	18.2	11
M Col 22 x M Ven 307	S x ?	-	70.0	30.0	10
M Col 22 x M Col 647	S x R	26.8	42.1	31.6	19
M Col 113 x M Col 22	S x S	-	43.8	56.2	16
M Col 113 x M Mex 55	S x S	-	66.7	33.3	18
M Col 113 x Llanera	S x MR	-	8.3	91.7	12
M Col 113 x M Col 638	S x R	18.5	22.2	59.2	27
M Col 113 x M Col 647	S x R	7.1	42.9	50.0	16
M Col 755 x M Ven 143	S x S	-	27.8	72.2	18
M Col 755 x M Col 655A	S x S	13.2	5.3	81.6	38
M Col 755 x M Col 690	S x S	20.0	30.0	50.0	10
M Col 755 x M Col 1684	S x MR	9.5	19.0	71.5	21
M Col 755 x M Col 647	S x R	6.9	41.4	51.7	29
Llanera x M Col 690	MR x S	-	12.5	87.5	16
Llanera x M Col 1684	MR x MR	6.7	6.7	86.6	15
Llanera x M Col 647	MR x R	7.8	23.5	68.6	51
M Col 647 x M Ven 143	R x S	10.0	30.0	60.0	10
M Col 882 x 7 varieties	S x [2]	17.6	26.5	55.9	34

[1] R= resistant; MR= moderately resistant; S = susceptible
[2] Susceptible: 5, Moderately resistant: 1, Resistant: 1.

pathogen can be disseminated by planting infected cuttings, but healthy planting material can be obtained from diseased plantations if stem pieces are carefully selected and sterilized knives are used.

FUNGAL DISEASES

Superelongation Disease

Pathogenic variability. Studies continued on the variability of *Sphaceloma manihoticola,* the causal agent of superelongation disease (CIAT Annual Report, 1976). Fourteen varieties, selected for their reaction to this pathogen in field and greenhouse inoculations, were artificially inoculated with 1.5 x 10^6 spores/ml with seven strains, from different geographical areas, under controlled environmental conditions.

Groups of strains of *S. manihoticola* interacted differently with cassava genotypes (Table 6). Of the cassava varieties, four differential groups were identified that showed resistance to three physiological races among the seven

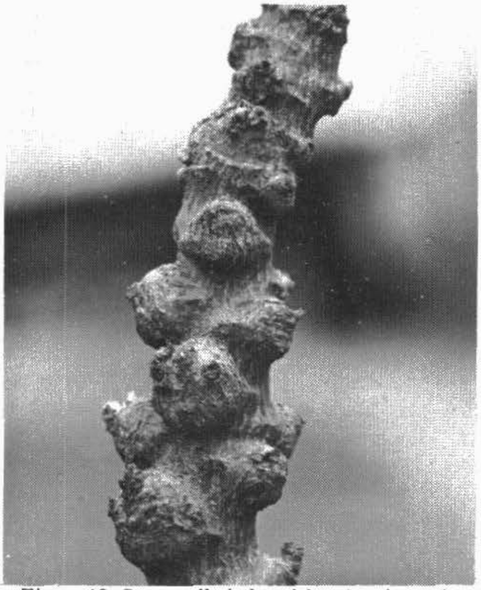

Figure 19. Stem galls induced by *Agrobacterium* sp. on a 2.5-year-old cassava plant growing in the field. Galls are on the stem portion nearest the ground.

strains of *S. manihoticola* tested. These physiological races have the following pathogenic characteristcs: Race 1 produces a susceptible reaction on differential groups of varieties I and II and a resistant or tolerant reaction on differentials III and IV; Race 2 produces a susceptible reaction on differentials I and III and a resistant or tolerant reaction on differentials II and IV; Race 3 produces only a susceptible reaction on differential group I.

The existence of physiological races of *S. manihoticola* was confirmed during field evaluations. Some 297 cassava varieties were planted at Quilichao and Carimagua, where Races 1 and 3, respectively, were detected. Some of the resistant varieties at Quilichao were susceptible at Carimagua and vice versa (Table 7). Consequently, disease reaction was interacting differently with genotypes at both locations. Seven of these varieties showed field resistance at both Quilichao and Carimagua. Further-

Table 6. **Reactions of 14 cassava varieties to seven strains of *Sphaceloma manihoticola* from different geographical areas.**

Differential group	Variety	Strain group, number[1] and varietal reaction[2]						
		Group 1			Group 2		Group 3	
		1	2	3	4	5	6	7
I	M Col 126	S	S	S	S	S	S	S
	M Col 115	S	S	S	S	S	S	S
	M Col 113	S	S	S	S	S	S	S
	M Col 61	S	S	S	S	S	S	S
	M Col 22	S	S	S	S	S	S	S
	M Col 23	S	S	S	S	S	S	S
	M Col 19	S	S	S	S	S	S	S
	M Col 133	S	S	S	S	S	S	S
II	M Col 39	S	S	S	R	T	R	T
	M Col 907	S	S	S	R	R	T	R
III	M Col 148	T	R	R	S	S	T	R
	M Col 645	R	T	T	S	S	R	T
IV	M Col 33	R	R	T	R	R	T	R
	M Col 96	R	R	T	R	R	T	R

1 Area of strain collection: 1 = Jamundí (Col.), 2 = Pance (Col.), 3 = Santander (Col.), 4 = Quilcacé (Col.), 5 = CIAT (Col.), 6 = Costa Rica; 7 = Carimagua (Col.)

2 Disease rating: R = resistant (immune reaction), T = tolerant (leaf and petiole cankers), S = susceptible (elongation, leaf, petiole and stem cankers).

Table 7. **Reactions of 297 cassava varieties to *Sphaceloma manihoticola* in the field at Carimagua and Quilichao.**

Location	Reaction	
	Susceptible	Resistant, Moderately Resistant
Carimagua	284	13
Quilichao	270	27
Quilichao/Carimagua	290[1]	7[2]

1 Varieties susceptible in either one or both sites.
2 Varieties resistant at both sites.

more, they have shown the same disease reaction in the Quilichao area over a three-year period of continuous planting.

S. manihoticola also attacks the following perennial and annual alternate host species: *Manihot* spp., *Euphorbia pulcherrima, E. heterophylla,* and *Euphorbia* sp.

Pathogen survival. When samples were stored at 23°C (+ 8°C) and 70 percent relative humidity, the fungus was isolated from diseased stems, petioles and leaf tissues for up to six months. This indicates that the pathogen can survive long dry seasons.

Pathogen eradication from cuttings. As reported, the pathogen was eradicated from cuttings dip-treated for three minutes in captafol at 8000 ppm a.i. (CIAT Annual Report, 1976) which was confirmed this year. Also, copper hydroxide and captan reduced infection, but eradication was not complete (Table 8). Consequently, cuttings should be treated with captafol when material is taken from areas where superelongation is present.

Evaluation for resistance. Evaluation of selected varieties and promising, high-yielding hybrids was done at Carimagua and Quilichao. Of 1027 and 297 varieties and hybrids evaluated at Carimagua and Quilichao, respectively, 5.1 and 16.5 percent showed resistance. The varieties, M Col 19 and 258 were resistant to superelongation at both locations. Both varieties were also highly resistant to CBB in both greenhouse and field evaluations at Carimagua. M Ven 39 was resistant to superelongation and CBB in the greenhouse at CIAT and at Carimagua. It was not evaluated for resistance to superelongation at Quilichao.

Some 16.5 percent of 175 high-yielding hybrids were resistant to superelongation at Quilichao. The same material will be evaluated at Carimagua.

Phoma Leaf Spot

Of 260 varieties evaluated for Phoma leaf spot under field conditions at Popayan, only 2 percent showed any resistance to the pathogen. An evaluation of 343 hydrids from crosses between susceptible parents showed no resistance; 3.2 percent tolerance; and 96.8 percent susceptibility. This confirmed last year's results that the frequency of resistance to this disease is low (CIAT Annual Report, 1976) and that resistance can only be achieved with controlled hybridization using resistant sources.

Resistant varieties—CMC 92, Popayan, M Col 712, M Col 303 and Dovio—were

Table 8. **Control of *Sphaceloma manihoticola* on cassava cuttings by dipping for three minutes in fungicides.**

No. of Treatment[1]	No. of healthy plants	No. of diseased plants	Percentage of infection
Control	30	95	76
captafol	44	0	0
copper hydroxide	23	8	26
captan	38	4	10

1 All solutions with chemicals contained 8000 ppm a.i.

planted continuously for the past four years in areas where this disease is endemic and epidemic (on susceptible varieties). These varieties have shown stable reactions which may indicate that resistance to this disease is stable. Similar results were obtained following artificial inoculations under controlled environmental conditions.

Cercospora Leaf Spots

Studies were done on the epidemiological aspects of brown leaf spot *(Cercospora henningsii)* and of leaf blight *(C. vicosae)* and the yield losses they cause. Five varieties and four hybrids were planted in a split plot design at Caicedonia (to study brown leaf spot) and Quilcacé (to study leaf blight). One-half the plots at each location were sprayed weekly with benomyl (150 ppm a.i./100 liters) for disease control. The development of each disease and its effect on leaf fall and yield losses were compared for the sprayed and unsprayed plots. Disease development was assessed at three-week intervals, based on percentage of diseased leaf area and number of lesions/leaf.

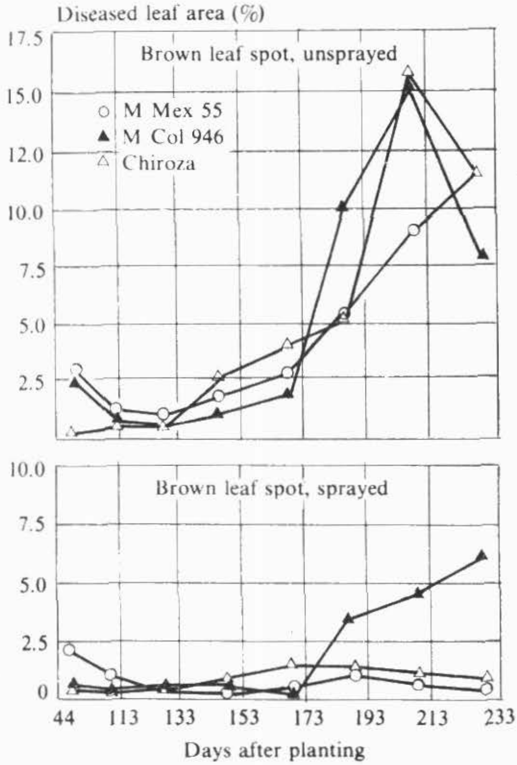

Figure 20. **Percentage of diseased leaf area in cassava plots infected with brown leaf spot.**

Brown leaf spot. Disease development with time is shown for three susceptible varieties in Figure 20. Results indicate that the lag in the inoculum build-up phase of this disease occurred during the first 183 days of planting, followed by an exponential phase (epidemic stage) of approximately 20-60 days which varies according to variety. The long time period required for the exponential phase indicates that it might be possible to prevent or reduce the exponential phase by programming planting with the rainy seasons. In areas with only one annual rainy season, planting at thz end of the rainy season can reduce the inoculum potential during the dry season, avoiding or reducing epidemics during the rainy season. In areas with bi-modal rainfall patterns, it might be better to plant at the beginning of the heaviest rainy period so that inoculum build-up would be reduced by the next dry period; if the second rainy period were mild the chances of an epidemic would thus be reduced.

Leaf fall was assessed as the inverse of leaf retention percentage. Differences were highly significant (P = 0.01) between sprayed and unsprayed plots. Similarly, the variety/disease interaction in percentage of defoliation was highly significant (P = 0.01) (Fig. 21).

The disease reduced fresh root yield significantly in susceptible varieties but not in resistant varieties (Table 9). Root starch content was also reduced 7.3 percent in the susceptible variety M Mex 55. These results indicate that fresh root yield and

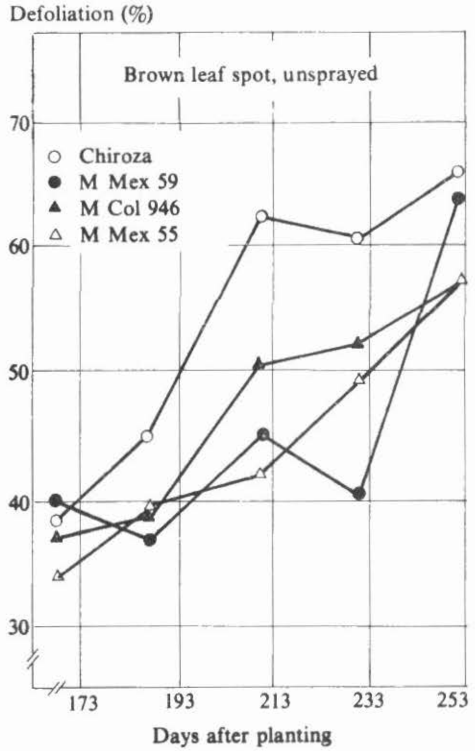

Figure 21. **Relative defoliation of resistant and susceptible cassava varieties infected with brown leaf spot.**

starch content are reduced on susceptible genotypes attacked by brown leaf spot.

Cercospora Leaf Blight. The development of this disease with time is shown in Figure 22. Apparently, the lag phase for this disease is shorter than that of brown leaf spot. This may indicate (as shown by yield assessments in Tables 9 and 10) that yield reductions caused by leaf blight could be higher than those for brown leaf spot; consequently, control by varietal resistance is more important for this disease. However, since the lag phase is long, programmed planting according to rainy/dry seasons should reduce epidemics.

Disease attack caused severe defoliation, as shown in Figure 23. M Col 803 showed relatively low leaf infection (Fig. 22), and hence, considerable defoliation (Fig. 23), possibly indicating this variety is highly sensitive to fungal infection (i.e. sensitivity to fungal toxin production). Similar data were obtained with other varieties. Yield was significantly reduced by the disease (Table 10) and root starch content was also reduced (Table 11).

Table 9. **Fresh root yield of cassava genotypes infected with brown leaf spot (*Cercospora henningsii*).**

Genotype	Reaction[1]	Yield (t/ha) Sprayed[2]	Unsprayed	Increase	Percentage increase in yield
Varieties					
M Mex 55	S	27.96	23.79	4.17	14.91
M Col 946	S	29.70	26.65	3.05	10.27
Chiroza	R	29.13	29.57	-0.44	- 1.51
M Mex 59	R	32.72	32.95	0.23	- 0.70
Hybrids					
CMC-323-334	S	31.89	26.73	5.16	16.18
CMC-323-497	S	23.21	17.83	5.38	23.18
CMC-323-178	R	22.33	20.70	1.63	7.30
CMC-323-492	R	15.58	15.70	-0.12	- 0.77

1 S = susceptible; R = resistant; T = tolerant

2 Sprays were applied weekly; benomyl at 150 ppm a.i. 100 liters was the fungicide.

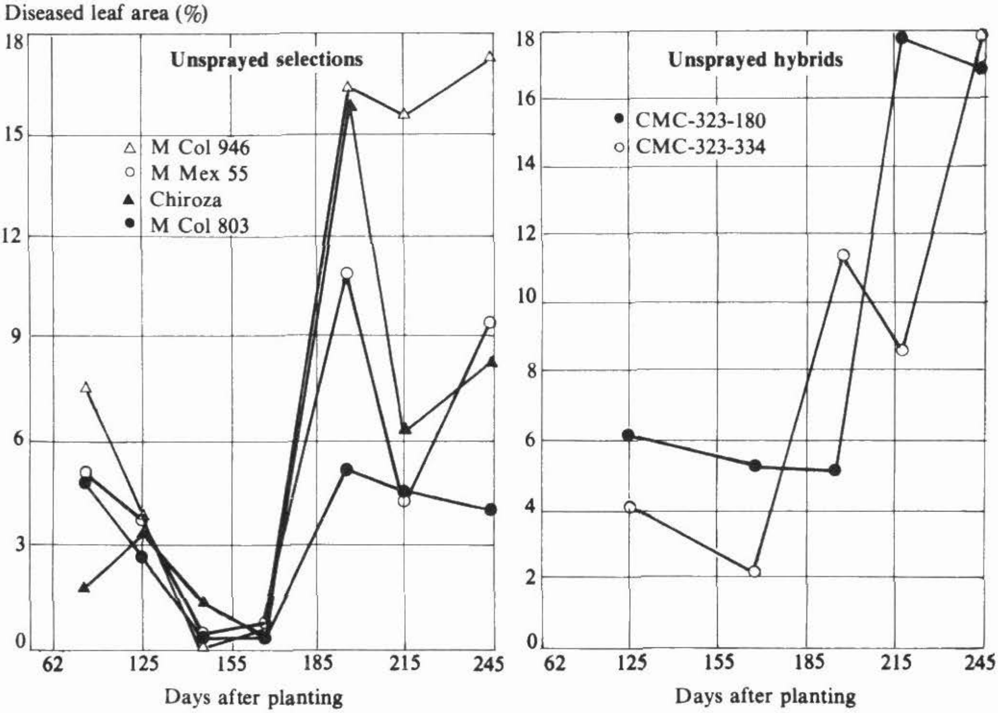

Figure 22. **Percentage of diseased leaf area in unsprayed cassava selections and hybrids infected with** ***Cercospora*** **leaf blight.**

Table 10. **Fresh root yield of cassava genotypes infected with leaf blight** *(Cercospora vicosae).*

Genotype	Reaction[1]	Yield (t/ha) Sprayed[2]	Unsprayed	Increase	Percentage increase
Varieties					
M Mex 55	S	23.36	19.74	3.62	15.50
M Col 946	S	16.24	14.21	2.03	12.50
M Col 803	S	20.83	14.86	5.97	28.66
M Mex 59	R	24.90	24.28	0.62	2.55
Chiroza	T	15.13	14.80	0.33	2.18
Hybrids					
CMC 323-180	S	35.40	24.65	10.75	30.36
CMC-323-334	S	34.40	25.43	8.95	26.08
CMC-323-483	R	27.30	27.14	0.16	0.59
CMC-323-497	R	28.20	28.90	-0.70	-2.48

1 S = susceptible, T = tolerant, R = resistant

2 Sprays were applied weekly; benomyl at 150 ppm a.i./100 liters was the fungicide

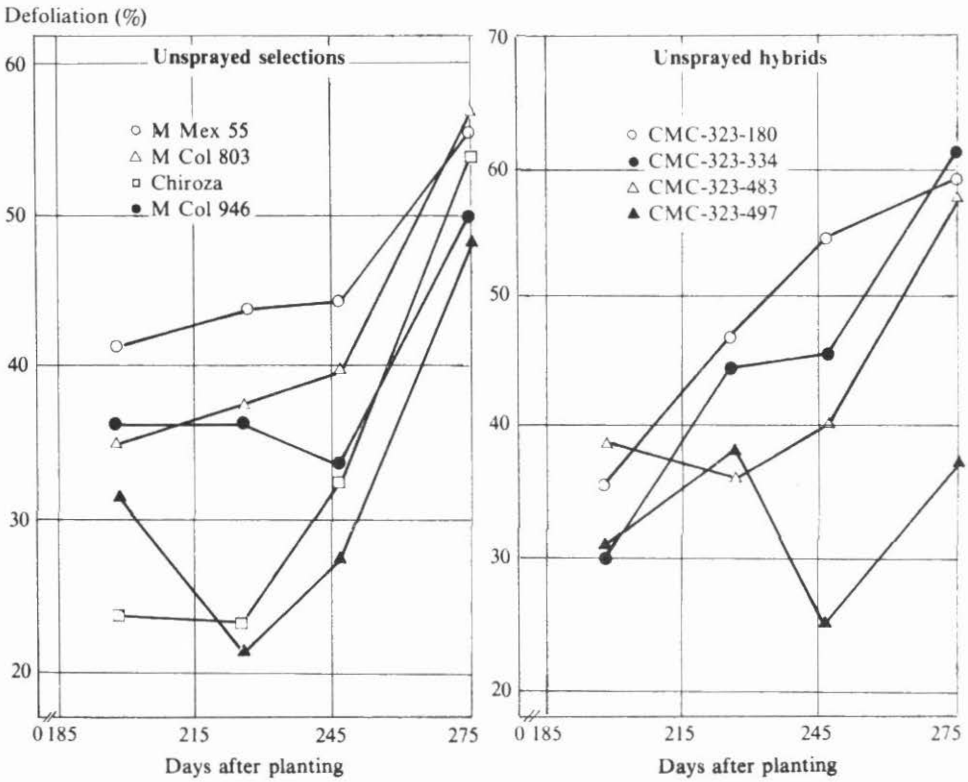

Figure 23. **Relative defoliation in resistant and susceptible cassava varieties and hybrids infected with** *Cercospora* **leaf blight.**

Relative importance of Cercospora diseases. Given the losses induced by these two *Cercospora* diseases and their occurrence in most cassava-growing areas, they are both economically important. Leaf blight may cause greater yield losses than brown leaf spot, but losses induced by both in areas where they occur simultaneaously may be higher than in areas where only one disease is present. Control methods that combine varietal resistance, with planting dates and spacing must be developed.

Table 11. **Percentage root starch content in cassava varieties infected with leaf blight** ***(Cercospora vicosae)*** **(sprayed/unsprayed plots).**

Variety	Reaction[1]	Root starch content decrease (%)
M Mex 55	S	3.6
M Col 803	S	8.2
M Mex 59	R	1.7
Chiroza	T	1.0

S = susceptible, T = tolerant, R = resistant

OTHER DISEASES OF CASSAVA

Frog Skin Disease

Investigations on transmission have shown that in addition to dissemination in cuttings (CIAT Annual Report, 1976), the disease is also transmitted by grafting (100%) and by using infested knives (about 5%). Furthermore, 90 percent of shoots taken from infected cuttings and rooted in sterile water produced diseased plants. New assessments of disease losses in the field were done in cooperation with the Secretaría de Agricultura of the Departamento of Cauca. These experiments showed that when diseased cuttings were used, complete loss of commercial root production was completely lost. But when healthy planting material of the same variety was used, yield was 22 t/ha.

Anthracnose

This year, it was found that this disease develops only in a high humidity environment. Following artificial spray inoculation, disease damage was severe (dieback on more than 50% of the plants) only on one-month-old seedlings when high humidity conditions were maintained for more than 24 hours. If the relative humidity dropped below 90 percent, plants tended to recover, producing new shoots. It appears that this disease is important only when cassava is planted during a heavy rainy period and when plants are attacked during the first two months. Nevertheless, disease damage to the stem can reduce the quality of the planting material. Germination of cuttings with heavy anthracnose damage (cankers) was reduced by about 15 percent, and about 20 percent of the germinated plants were weaker and smaller than controls.

TREATMENT AND STORAGE OF PLANTING MATERIAL

The effects of fungicidal treatment of cuttings on the variety M Mex 55 are shown in Table 12. Untreated control cuttings were attacked by insects and stem pathogens and were deliberately non-selected, to simulate what farmers normally do in the field. From the results, it is evident that unselected cuttings germinate poorly and plants have low yields. When these cuttings were treated with fungicide solutions, germination increased and plant yields were high. Results showed that captafol, which also controls superelongation in cuttings is a promising fungicide for cassava cutting treatments.

Table 12. Yield of M Mex 55, 12 months after planting unselected cuttings dip-treated for three minutes with different fungicide solutions.

Chemical	Germination (%)	Yield (kg/plant)
captafol	78[1]	4.1[1]
carbendizim + captan	75	3.5
carbendizim + captafol + PCNB	74	3.1
carbendizim	74	2.7
carbendizim + PCNB	74	2.3
carbendizim + maneb	66	2.3
maneb	62	1.9
Control	44	1.7

1 A significant difference (P = 0.01) existed between chemical treatments and the control.

To study the effect of fungicide treatments on storage of cuttings, long (70 cm) and short (20 cm) stem cuttings of M Col 946 (a good germinating variety) and M Col 803 (a poor germinating variety) were dip-treated for three minutes with BCM and captan (2000 ppm a.i. each) or chlorothalonil and maneb (4000 ppm a.i. each). Cuttings were stored in the shade in the field and weekly germination was tested by planting the cuttings at 50 plants/variety/treatment in a split plot design. Results (Figs. 24 and 25) indicated that: (1) there are varietal differences in germination over length of storage; (2) treatment of cuttings with fungicides prevents germination losses due to storage (BCM + captan appeared to be much better than other combinations); (3) germination losses are largely caused by pathogens and insects during storage (slight dehydration of cuttings does not seem to effect germination during the first month of storage); (4) short cuttings (20 cm) of a good germinating variety can be stored for a month without affecting germination if

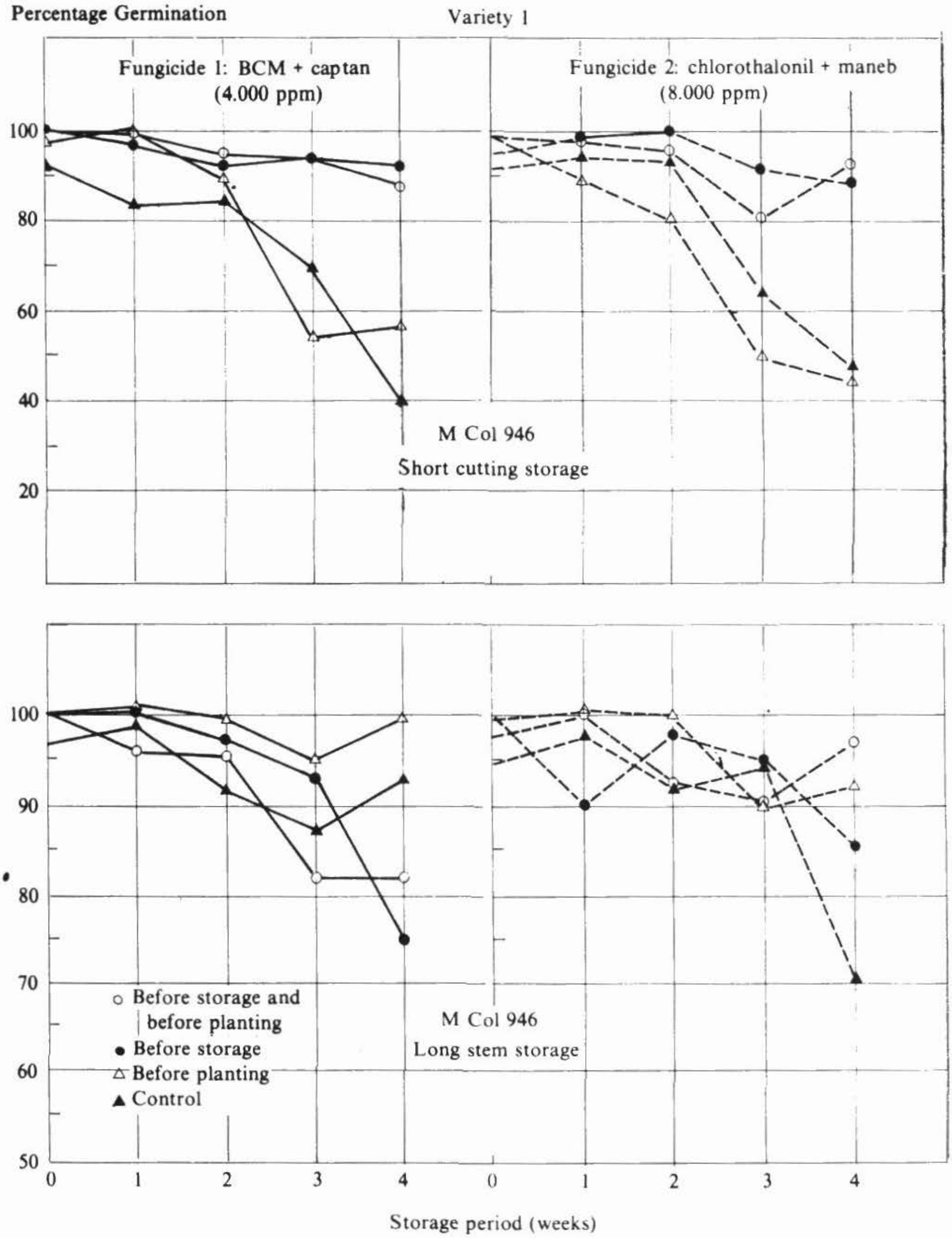

Figure 24. Effect on germination of cuttings after time of storage and treatment with two combinations of fungicides, field experiment.

they are treated with appropriate fungicide solutions: (5) for varieties with poor germinating ability, planting material should be stored in long (70 cm) stem pieces; and, (6) all planting material should be treated with appropriate fungicide solutions before storage. A second treatment before planting is recommended to

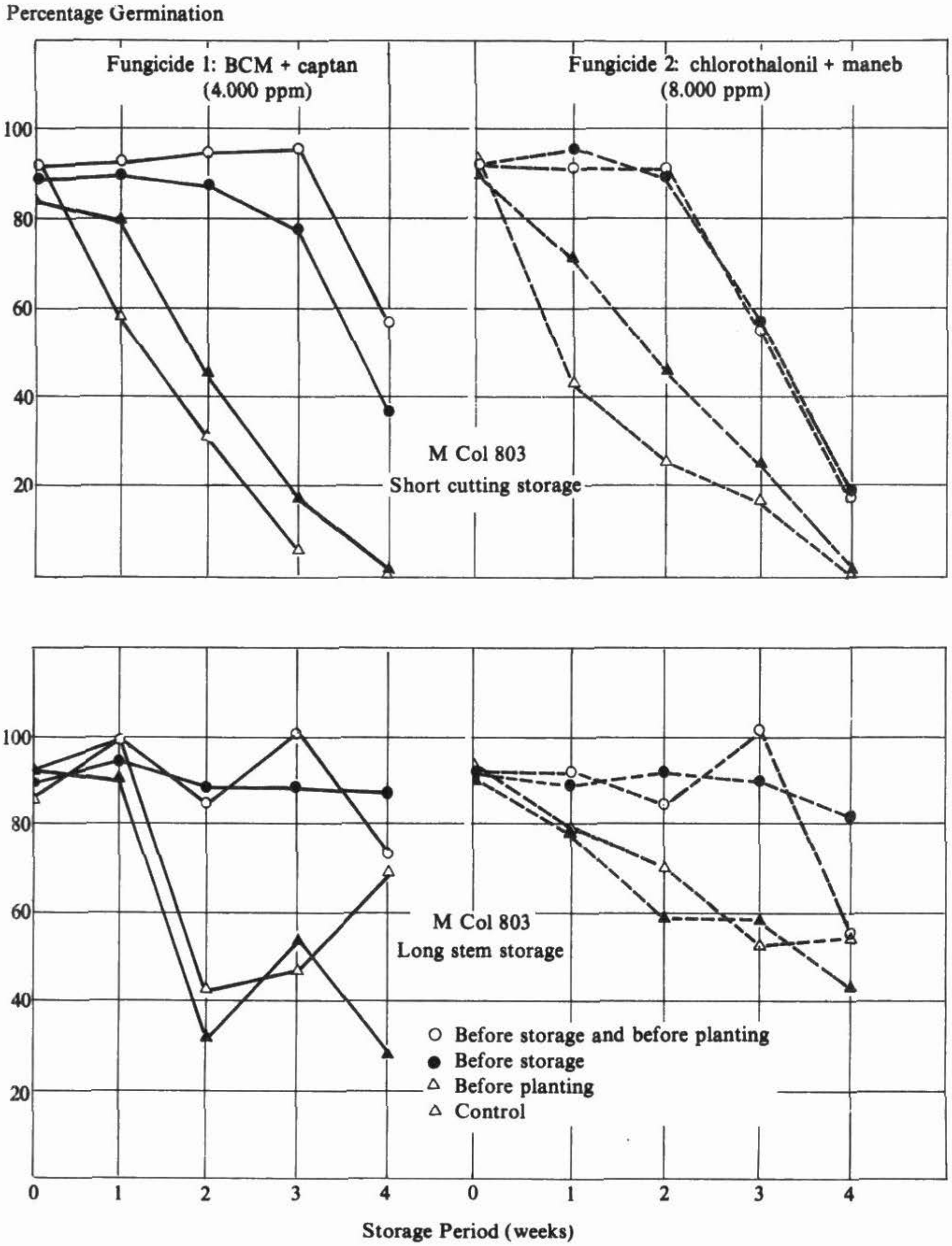

Figure 25. **Effect on germination of cuttings after time of storage and treatment with two combinations of fungicides, field experiment.**

protect cuttings of long stem pieces from microbial invasions through wounds made during shipping and preparation of cuttings.

Entomology

The main objective of the cassava pest management program is to suppress insect pests and maintain populations below their economic damage threshold avoiding the use of pesticides and other costly inputs when possible. Cassava entomology efforts emphasize the determination of yield losses, biology and ecology of pests, the use of insect-free planting material, and the development of control methods using host plant resistance, biological control, cultural practices and economic and discriminate use of pesticides.

CASSAVA HORNWORM

Economic Damage

The cassava hornworm *(Erinnyis ello)* has been described as a voracious feeder, defoliating extensive cassava hectarage and feeding on stem tissue and lateral buds. Yield losses have been estimated at 20-53 percent in damage simulation experiments (CIAT Annual Report, 1976). On a severely attacked commercial cassava farm where Chiroza, a vigorous, high-yielding variety was grown, four plots of 25 completely defoliated plants were maked near four plots of 25 undamaged plants. The plants were three months old when attacked and the crop was harvested at 12 months. Damaged plants had less foliage and were shorter than non-damaged plants. Average yield of undamaged plants was 4.58 kg/plant while defoliated plants yielded 3.75 kg/plant. This 18 percent yield loss equalled 6 t/ha on this farm.

Biological Control

Egg parasitism. Hornworm populations are cyclic and sharply increased oviposition during certain periods can disrupt natural predator equilibrium in many cassava plantations. However, natural egg parasitism by *Trichogramma* has been observed in many cassava fields and timing the liberation of *Trichogramma* parasites to coincide with increased oviposition could reduce subsequent hornworm populations (CIAT Annual Report, 1976).

This year two studies evaluated the effectiveness of liberating *Trichogramma* on the parasitism of hornworm eggs. During a period of high hornworm oviposition at CIAT, about 100,000 *Trichogramma* were released in a one-hectare field. A nearby field where no parasites were released was used as a control.

Natural egg parasitism before *Trichogramma* release in this experiment was 52.6 percent and 48.3 percent in the control and the treated field, respectively. Fifty plants/plot were sampled. Four days after parasite liberation percentage parasitism in the treated field increased by 24.8 percent but only 2.7 percent in the non-treated field— a difference of 22 percent increase in parasitism between the treatment and control.

In the second experiment, a field of cassava was sprayed with dichlorvos (a non-residual insecticide) to reduce natural hornworm egg parasitism. The field was then divided— the control portion having a 45 percent initial egg parasitism and the portion for *Trichogramma* release having 30.8 percent. *Trichogramma* were released at a rate of 100,000/ha and 150 plants/plot were sampled. After four days, the difference in percentage parasitism increase between the treatment and control was 23 percent (Table 13)— a rate similar to that recorded in the previous trial. One day later, parasitism of the control field increased to 74 percent and that of the release field reached 93 percent, demonstrating the effectiveness of release. These results indicate that *Trichogramma* release during periods of high hornworm

Table 13. Percentage of cassava hornworm *(Erinnyis ello)* eggs parasitized by *Trichogramma* sp. in release *vs.* Control fields.

	Release Field		Control		
Days after liberation	% of hornworm eggs parasitized[2]	% increase in parasitism	% of hornworm eggs parasitized	% increase in parasitism	% increase of liberated/non-liberated
1	30.8		45		
2	54.2	23.4	61	16	7.4
3	80	49.2	73.8	28.8	20.4
4	76	45.2	67	22	23.2
5	92.7	61.9	74.3	29.3	32.6

1 *Trichogramma* released 100,000/ha.

2 Sample of 150 plants/plot.

oviposition will significantly increase natural egg parasitism.

Larval parasitism. *Apanteles congregatus* and *A. americanus* are important larval parasites of the cassava hornworm in Colombia. These braconid wasps oviposit in hornworm larvae and the parasite larvae develop there. Mature larvae migrate from the host and pupate on the outer skin, forming a white cotton-like cocoon around the carcass of the hornworm larva.

Larval parasitism by *Apanteles* probably occurs during the first three hornworm instars. Observations indicate that during the later instars *Apanteles* usually emerge and pupate on the external surface of the hornworm larvae a few hours after emergence. The pupal cocoon encompassing the hornworm carcass averages 3.8 centimeters wide by 4.1 centimeters long. Each cocoon contains an average of 257 *Apanteles* pupae, about 80 percent of which emerge after 6-7 days.

Apanteles adults were liberated into hornworm-infested fields during 1977 to evaluated larval parasitism. In the first trial 11 cocoons were released in an isolated field and 408 cocoons collected after three weeks. At that time, 382 unparasitized hornworm larvae and 633 hornworm pupae were collected in the same field from which it was calculated that *Apanteles* produced about a 29 percent parasitism rate of hornworm larvae. A drawback to the use of *Apanteles* as a hornworm larval parasite is the high percentage of hyperparasitism observed. Seven different hyperparasites were collected from *Apanteles* at CIAT and a study of 112 *Apanteles* cocoons collected on three occasions showed an average of 56 percent hyperparasitism.

Bacillus Thuringiensis

Applications of *B. thuringiensis,* a commercial bacterial disease of hornworm larvae, were made when there were high populations of different larval instars. *B. thuringiensis* was effective against the first four instars (the fifth was not tested) but most effective against the first. In the treated fields four days after application first instar larval populations decreased 88 percent and second instar larvae, 46 percent. After six days third instar populations decreased 84 percent and after three days, a 70 percent decrease was observed for fourth instars. It should be noted that the untreated first instar hornworm population of the control was reduced 45 percent, probably due to natural parasitism in the field prior to the beginning of the experiment; the third instar hornworm population of the control was also reduced 53 percent due to extremely heavy rains.

HOST PLANT RESISTANCE

Mites

Screening in greenhouse and screenhouse. Screening of cassava varieties for resistance to *Mononychellus* and *Tetranychus* mites continued under controlled conditions in the screenhouse and greenhouse. Promising varieties selected during previous screenings (CIAT Annual Report, 1975, 1976) were re-evaluated in replicated trials to identify the most promising varieties, and 705 additional varieties were evaluated using the resistance scale (0-1 resistant; 2-3 intermediate resistance; 4-5 susceptible). Fifty-eight varieties were selected as promising for resistance to *M. tanajoa* and 31 as most resistant to *T. urticae*. Twenty varieties had resistance to both *M. tanajoa* and *T. urticae*, indicating a degree of cross resistance not previously suspected.

Field screening for M. tanajoa resistance. Almost 2200 cassava varieties were evaluated for *M. tanajoa* resistance during a natural outbreak at CIAT. One hundred and fifty-two varieties (6.9%) were scored resistant and 485 (38.5%) varieties showed intermediate resistance. Undoubtedly, a more severe mite attack would have resulted in fewer resistant varieties and some varieties selected as resistant may have been escapes. However, these results indicate considerable resistance to *M. tanajoa* under CIAT conditions which, because of the short dry seasons (2-3 months), do not allow large mite populations to build up.

Whiteflies

One hundred sixty-nine lines of cassava germplasm were evaluated for resistance to the whitefly *(Aleurotrachelus* sp.) When the plants were 2, 4 and 6-months-old, three separate ratings were made: one based on the level of whitefly infestation; one based on the number of whitefly pupae per leaf; and the third, on the degree of plant damage.

All 169 varieties were heavily infested by whitefly adults and pupae. However, the damage symptoms rating indicates that physical damage may be only moderate although the plant may be heavily infested. While yields of these varieties may not be directly affected by heavy whitefly infestations, these varieties may be susceptible to viruses transmitted by the whitefly.

Thrips

The CIAT cassava germplasm bank (2,247 accessions) was evaluated for resistance to the thrips, *Frankliniella williamsi*, during natural infestation in a three-month dry season. Results (Table 14) showed abundant sources of resistance to thrips in the cassava accessions. More than 58 percent were highly resistant (0-1 on a damage rating scale of 0-5) and only 20 percent were susceptible (3-5 on the damage rating scale). While more severe

Table 14. **Evaluation of 2,247 varieties of cassava for resistance to the thrips *Frankliniella williamsi* with natural infestations in the yield.**

Damage scale	No. of varieties	Percentage within grades
0	656	29.2
1	656	29.2
2	369	16.4
2.5	124	5.5
3	129	5.5
3.5	102	4.5
4	176	7.8
4.5	34	1.5
5	1	0.04

attacks of thrips could alter these ratings, these results indicate that resistance to thrips is the rule rather than the exception in cassava germplasm.

Scales

The adverse effect of scales on the germination of cassava cuttings during dry seasons has been previously reported (CIAT Annual Report, 1974). A study was designed to evaluate damage of the white scale *(Aonidomytilus albus)* to cassava cuttings of M Col 22 (a highly susceptible variety) treated with methamidophos and stored for one month before planting. Damage grades were also correlated to germination of the cuttings after planting in a randomized block of four plots with 25 cuttings per plot (Table 15). Germination was considerably reduced when scale-infected cuttings were stored for one month and insecticide treatment did not increase germination.

Treatment of planting material. Observations of cuttings of CMC 40 and M Col 113 (selected for tolerance and susceptibility, respectively, to scales) infested with only one or two scales around the bud showed that a severe scale attack can be produced when cuttings are planted vertically in the field under ideal environmental conditions (when the dry season begins shortly after planting). However, it was found that the insecticides—malathion, 4 percent at 1 g/liter; triazophos, 1 cc/liter; methamidophos, 1 cc/liter; and Triona + malathion, 2 cc + 1g/liter— all prevented a rapid increase of scale populations after planting. The treatments were more effective for CMC 40 than for M Col 113, indicating a varietal response to scale attack.

Table 15. **The effect of the white scale (*Aonidomytilus albus*) on the germination of cassava cuttings (var. M Col 22) treated with methamidophos and stored for one month prior to planting**

Damage rating scale[1]	% germination			
	Stored		Unstored	
	Treated	Untreated	Treated	Untreated
0	84	72	95	95
1	33	40	88	91
2	17	16	40	85
3	12	3	10	23
4	0	4	2	9

[1] Damage rating scale: 0 = no scales; 1 = few scales around buds; 2 = about 50% of buds covered with scales; 3 = scales covering buds and part of internodes; 4 = scales completely covering cuttings.

Yield losses. A field of M Col 22 was evaluated at harvest for scale damage using a damage rating scale of: 0 plants with considerable foliage and none or few scales on stems; 1 reduction in foliage and scales covering less than 50 percent of stem surface; and 2 severe defoliation, dead terminal buds and scales completely covering the stem surface. One hundred plants of each damage grade were harvested their weight recorded, and individual damage grades correlated with yield losses. Results showed a yield loss of 4 percent for those plants in damage grade 1 and a loss of 19 percent for damage grade 2; The latter damage represents a loss of 3 t/ha.

Biology of Aonidomitylus albus. The biology of the white scale, *Aonidomitylus albus* Cockerell, was studied in the laboratory (temp. 26°-28°C, RH 75-85%) on excised cassava stems (M Col 22 and M Col 113). Male scales passed through two nymphal instars averaging 10 and 6.5 days, respectively, and a prepupal and pupal stage totaling 4.5 days. Adults lived 1-3 days and the male life cycle was about 23 days. In a sample of 30 females, three nymphal instars were observed averaging 10, 5 and 9 days, respectively. The third nymphal instar is the adult stage. Eggs are oviposited under the scale and nymphs emerge during a seven-day period. Peak emergence occurred from day 3-5 and each female produced an average of 43 nymphs. Nymphs, or "crawlers" are mobile for up to three days, at which time they become stationary and feeding initiates. Males have wings and can fly while the female is wingless and stationary. Differentiation between the male and female occurs during the second instar. Copulation occurs when the female reaches the third instar.

Fruit Flies

Cassava fruit flies *(Anastrepha pickeli* and *A. manihoti)* damage planting material by tunneling in stems of growing plants and providing an entrance for the bacterial pathogen *Erwinia caratovora* var. *caratovora* which causes severe rotting of stem tissue.

The effects of fruit fly damage and subsequent attack by *E. caratovora,* on cassava (Var. Chiroza) in farmers' fields in Caicedonia, Colombia, were evaluated according to five damage grades which were correlated to yield losses (Table 16). Yield losses of the damaged cuttings ranged from 4.2 percent for grade 1 (least damage) to 33.1 percent for grade 3. Yield losses for grade 4 were less than in grade 3 for every trial. This may have been due to the possibility that while the grade 4 cuttings were more damaged, they may have come from a better part of the plant. In addition, this yield loss pattern observed on the three farms was not repeated in the trial at CIAT where a different variety, CMC 40, was used. Only three damage grades were used in the CIAT trial since damage was less severe. Results showed that cuttings with damage grade 3 yielded slightly higher than undamaged cuttings, possibly because they may have been taken from a better part of the plant as well.

Mealybugs

Outbreaks of the mealybug, *Phenacoccus gossypii,* caused severe defoliation and dessication of cassava stem tissue on the CIAT farm again this year but malathion effectively reduced populations.

The biology of the female mealybug was studied with 24 females placed on excised cassava stems (M Col 113) in the laboratory (temp. 26^0-28^0C, RH 75-85%). There were three nymphal instars with averages of 8.6, 5.7, and 6.3 days, respectively. Adult females survived up to 21 days. Oviposition was initiated between the fifth and seventh day and continued for

Table 16. **Effect of damage caused by the fruit fly *Anastrepha manihoti* and the bacterial pathogen *Erwinia caratovora* on germination of cassava cuttings.**

Damage scale[1]	Germination (%)	Yield (t/ha)[2] Farms 1	2	3	$\bar{X}$	% Yield reduction	Yield at CIAT (t/ha)[3]
0	90.3	38.9	41.0	41.7	40.2		23.9
1	85.7	32.9	38.1	44.5	38.5	4.2	21.9
2	83.7	26.3	39.2	38.4	34.6	13.9	22.1
3	82.7	19.9	26.5	34.2	26.9	33.1	26.2
4	74.0	29.3	31.6	37.7	32.9	18.3	

1 Damage scale: a brown discoloration in the pith area; 2= discoloration and some rotting at both ends of cuttings; 3 = severe rotting of pith; 4 = severe rotting of the tunnel and the pith area

2 Variety planted was Chiroza

3 Variety planted was CMC 40

five days. An average of 328 eggs per female were oviposited with the most eggs produced the first day and steadily decreasing thereafter. All eggs remain in an egg pouch on the posterior of the female's body until the nymphs hatch.

While nymphs in all instars are mobile they may feed in one area for several days. They prefer to feed on the undersides of leaves or on tender stems. The female is wingless, whereas males have wings and fly.

Several predators and parasites of mealybugs and scales were collected at CIAT (Table 17); not all the parasites have been completely identified.

Termites

Termites *(Coptotermes* spp.) attack cassava mainly in the tropical lowlands. They feed on propagation material, growing plants and roots. Principal damage appears to be loss of cuttings; during prolonged dry periods plant establishment can also be severely affected.

Since cassava propagation material is commonly stored for several months during dry periods before planting begins at the onset of the rainy season, a preliminary study was done to determine the effect of termites on stored planting material. One-hundred untreated cassava stems and 100 stems treated with a spray mixture of 10 percent aldrin and 10 percent parathion were stored for 80 days in the field. Insecticide applications were made every 20 days. All the untreated stems had termite damage while treated stems showed a 24 percent loss of planting material.

Two experiments were conducted to further study prevention of termite attack on stored propragation material and prevention of termite damage to cuttings after planting. In the first experiment, bundles of 15 cassava stems each were treated with an insecticide and stored in the field for 80 days. The most effective treatments (Table 18) were aldrin applied as a dust at 1 g/stem, (0% loss) Clorvel applied as a spray at 1 cc/liter of water (0% loss) and sevin in a dust application at 1 g/stem (6.6% loss) Meanwhile, 46 percent of the untreated stems were destroyed by termites.

Table 17. **Natural predators of *Aonidomytilus albus* Cockerell and *Phenacoccus gossypii* Townsend and Cockerell in cassava, at CIAT during 1977.**

Order	Family	Genus	Species	Predation
Coleoptera	Coccinellidae	*Cleotera*	*onerata*	Mealybug eggs and nymphs
		Cleotera	sp.	Mealybug eggs and nymphs
		Scymnus	spp.	Mealybug eggs and nymphs
		Coccidophilus	sp.	White scale all nymphal stage
Neuroptera	Chrysopidae	*Chrysopa*	*arioles*	Mealybug eggs and nymphs
	Hemerobiidae	*Sympherobious*	sp.	Mealybug eggs and nymphs
Dipteria	Syrphidae	*Ocyptamus*	*stenogaster* complex	Mealybug nymphs
Lepidoptera	Cosmopterigidae	*Pyroderces*	sp.	Mealybug and white scale eggs and nymphs

Table 18. **Effects of applying several pesticides on the prevention of termite damage on cassava propagating material stored 80 days in the field.**

Treatment	Application[1]	Loss (%)
Aldrin	dust	0
Clorvel	Spray	9
Sevin	dust	6.7
Chlordane	spray	8.3
Fenthion	spray	33.3
Control		46.7
Monocrotophos	spray	66.67
Aldrin (10%) + parathion (10%)	spray	73.3
Thiram	spray	86.7
Thiram	dip	86.7

Spray and dip applications applied at 1 cc/liter water and dust applications at 1 g/stem

In the second experiment cuttings were individually treated with an insecticide and planted in a randomized block with four plots of 25 cuttings/plot and evaluated 80 days after treatment. The most successful treatments were aldrin applied as a dust (3% loss) and a cutting dip with 10 percent aldrin and 10 percent parathion (6% loss). Termites destroyed 15 percent of the untreated cuttings.

INTERCROPPING POPULATIONS

A preliminary experiment was done on the protection potential of intercropping cassava/beans. The following insect populations— the hornworm *(Erinnyis ello)*, the cassava lace bug *(Vatiga manihoti)*, whiteflies *(Aleurotrachelus* sp.) and the shootfly *(Silba pendula)*—were monitored weekly for 2.5 months in monoculture cassava and intercropped cassava/beans. In addition, a comparison was made between insecticide and non-insecticide treatments in the intercropping system.

Table 19. **Insect population in cassava monoculture** *vs.* **intercropping (cassava/beans) with and without insecticide.**

Insect	Monoculture[1]		Intercropping[2]		% population reduction in intercropping/monoculture without insecticide
	With insecticide[3]	Without insecticide	With insecticide[3]	Without insecticide	
Lace bug: 3 leaves/plant	4.5	5.6	2.7	3.8	32.1
Whitefly: 3 leaves/plant	7.2	6.5	3.3	4.5	30.0
Shoot fly/plot	2.1	2.0	1.5	2.2	
Hornworms/plot	0.5	0.8	0.5	0.6	30.0
Hornworm eggs/parasitized/plot	50.7	52.4	51.2	45.5	

Cassava variety M Mex 11.
Bean variety Porrillo Sintetico with M Mex 11 cassava.
Endosulfan

Hornworm larval populations were lower in the intercropped cassava than in monoculture cassava but lowest when insecticides were applied to cassava monoculture or intercropping (Table 19). However, egg parasitism was lowest in the intercropped, non-sprayed plants and highest in the cassava monoculture. Lacebug and whitefly populations were also lower in the intercropping system than in cassava monoculture with or without pesticide application. However, the lowest insect populations were obtained when an insecticide was applied to the intercropping system.

Varietal Improvement

This year hybridization, evaluation and selection were intensified at CIAT and in outlying trials in Colombia. Data were also obtained on the first groups of hybrids from crosses among selected parental genotypes.

Two replicated yield trials were harvested at CIAT, Caribia and Carimagua. Each plot of all trials had 30 plants per genotype and each trial had two replications. Plant spacing was 1 x 1 meter at CIAT, 1 x 1.5 meters at Caribia, and 0.8 x 1 meter at Carimagua. After 12 months the central nine plants of each plot were harvested for data, leaving two border rows.

REPLICATED YIELD TRIALS

First Season Trial at CIAT

Total rainfall for the year was 655 millimeters and the experiment was not irrigated. No fertilizers, fungicides or insecticides were applied. Two-hundred hybrids and 25 germplasm selections and control cultivars were planted in July 1976 for evaluation. Results are in Table 20.

Yields were generally low (average of all genotypes was 26.2 t/ha, fresh weight). Nevertheless, many materials yielded more than 40 t/ha and some more than 50 t/ha fresh weight — outyielding the local cultivar by nearly 100 percent. The average fresh weight yield of the top ten cultivars, 48 t/ha/year, or 16 t/ha/year dry weight with less than 700 millimeters of rainfall is acceptable.

Second Season Trial at CIAT

This trial was planted in December 1976. During the trial total rainfall was 705 millimeters and was well distributed. The experiment was not irrigated and no fertilizer, fungicides or insecticides were applied. Results are in Table 21.

Yields were generally high (average of all genotypes was 35 t/ha, fresh weight). The average root dry matter yield of the top ten genotypes was 21 t/ha/year or 57 t/ha/year fresh weight. Twenty-one hybrid selections yielded more than 50 t/ha fresh weight, outyielding the local cultivar more than 100 percent.

First Season Trial at Caribia

This trial was planted in June 1976. Total rainfall was 1100 millimeters and the dry season (with less than 50 millimeters of rain) lasted four months. The experiment was not irrigated and no fertilizer, fungicides or insecticides were applied. Eighty-one hybrids and nine germplasm selections and control cultivars were evaluated. Results are in Table 22. The average fresh weight yield of the top ten hybrid selections (39 t/ha fresh weight) was double the yield of the local cultivar.

Table 20. **Selected results of the first season replicated yield trial at CIAT (harvested 15 April 977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selections				
CM 309-211	50.8	.353	17.9	.57
CM 308-197	50.3	.350	17.6	.66
CM 323-30	48.3	.344	16.6	.54
CM 317-16	48.1	.320	15.4	.49
CM 91-5	48.1	.288	13.9	.73
CM 321-170	47.8	.330	15.8	.64
CM 96-23	47.8	.280	13.4	.61
CM 309-281	46.9	.306	14.4	.68
CM 321-15	46.1	.344	15.9	.58
CM 323-69	46.1	.291	13.4	.61
CM 152-12	45.0	.327	14.7	.62
CM 181-14	44.4	.288	12.8	.75
CM 307-135	44.0	.349	15.4	.43
CM 152-30	43.9	.321	13.7	.58
CM 308-1	43.3	.376	16.3	.60
CM 309-32	43.3	.296	12.8	.69
CM 2-6	42.8	.332	14.2	.65
CM 309-11	42.2	.342	14.4	.57
CM 157-7	41.7	.296	12.3	.61
CM 307-133	41.1	.297	12.2	.52
CM 309-84	41.1	.375	15.4	.47
Germplasm selection				
M Col 1684	41.9	.321	13.4	.56
M Ven 218	41.7	.328	13.7	.62
M Mex 17	39.0	.334	13.0	.52
M Mex 59	37.6	.290	10.9	.48
M PTR 26	34.7	.305	10.6	.51
M Pan 70	33.6	.312	10.5	.54
M Col 1468	33.6	.307	10.3	.51
M Col 1292	28.6	.344	9.8	.41
M Ven 270	26.7	.348	9.3	.53
M Col 655A	26.1	.355	9.3	.38
Control cultivars				
M Col 113 (Local)	25.6	.327	9.4	.44
Llanera	24.7	.321	7.9	.50
M Col 22	19.7	.358	7.1	.51
Average of all genotypes	26.2	.324	8.5	.56

Table 21 Selected results of the second season replicated yield trial at CIAT (harvested 20 October 1977).

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 323-275	63.1	.365	23.0	.60
CM 321-188	60.6	.388	23.5	.69
CM 327-514	57.2	.346	19.8	.71
CM 326-407	56.7	.376	21.5	.67
CM 305-122	56.1	.401	22.5	.62
CM 327-135	55.3	.402	22.2	.62
CM 305-118	55.0	.372	20.5	.70
CM 344-27	54.7	.353	19.3	.65
CM 340-138	54.2	.329	17.8	.68
CM 344-17	54.2	.329	17.8	.59
CM 340-30	53.3	.328	17.5	.60
CM 323-142	52.2	.327	17.1	.55
SM1-150	51.7	.323	16.7	.65
CM 305-38	51.4	.376	19.3	.60
CM 344-71	51.4	.335	17.2	.55
CM 311-69	51.1	.364	18.6	.66
CM 314-12	50.8	.384	19.5	.57
CM 305-120	50.8	.332	16.9	.56
CM 345-68	50.6	.324	16.4	.64
CM 327-383	50.3	.346	17.4	.69
Germplasm selection				
M Pan 70	46.7	.367	17.1	.54
M PTR 26	44.4	.378	16.8	.55
M Mex 17	43.7	.367	16.0	.69
M Ven 270	42.8	.376	16.1	.51
M Ven 218	41.1	.371	15.2	.59
M Col 1468	33.3	.319	10.6	.61
M Ecu 47	32.5	.325	10.6	.54
M Col 638	30.6	.336	10.3	.47
M Col 1347	28.3	.245	6.9	.40
M Col 655A	27.2	.370	10.1	.33
M Col 1684	25.0	.307	7.7	.66
M Mex 59	22.5	.338	7.6	.32
Control				
Llanera	28.5	.323	9.2	.58
M Col 22	26.1	.370	9.6	.60
M Col 113 (Local)	22.2	.286	6.4	.30
Average of all genotypes	34.6	.350	12.1	.54

Table 22. **Selected results of the first season replicated yield trial at Caribia (harvested 29 April 1977. 11 months after planting).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 309-163	44.3	.288	12.8	.66
CM 320-2	42.0	.327	13.7	.51
CM 309-50	41.7	.328	13.7	.50
CM 309-32	38.0	.282	10.7	.63
CM 321-78	38.0	.290	11.0	.64
CM 323-75	37.8	.323	12.2	.62
CM 323-41	37.6	.324	12.2	.65
CM 322-20	36.7	.329	12.1	.56
CM 321-85	36.1	.320	11.6	.66
CM 309-128	34.8	.318	11.1	.60
CM 308-197	34.5	.332	11.4	.66
CM 309-227A	34.5	.302	10.4	.64
ICA, 72-8-07	33.7	.323	10.9	.58
ICA, 72-3-58	32.0	.290	9.3	.52
CM 308-75	31.3	.307	9.6	.48
CM 309-61	31.1	.325	10.1	.63
CM 321-58	30.9	.323	10.0	.53
CM 309-165	30.8	.330	10.2	.43
SM 92-73	29.9	.287	8.6	.47
CM 309-110	29.3	.279	8.2	.55
Germplasm selection				
M Mex 59	42.0	.327	13.8	.44
M Col 638	30.6	.321	9.8	.57
M Col 1684	25.2	.304	7.7	.61
M Col 1468 (CMC 40)	21.9	.240	5.5	.66
Control cultivars				
M Col 22	33.6	.341	11.4	.64
Llanera	20.7	.288	6.0	.47
Manteca (Local)	18.1	.279	5.0	.48
Montero (Local)	12.6	.342	4.3	.37

Second Season Trial in Caribia

This trial was planted in October 1976 and was irrigated twice during the dry season; no fertilizer, fungicides or insecticides were applied. Twenty-five hybrid selections and two control cultivars were evaluated. Results are in Table 23.

One of the hybrid selections yielded nearly 50 t/ha fresh weight, and the average yield of the top ten hybrid

Table 23. **Selected results of the second season replicated yield trial at Caribia (harvested 6 September 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 309-196	49.8	.295	14.7	.56
CM 323-403	47.6	.309	14.7	.71
CM 178-4	38.7	.308	11.9	.64
CM 309-163	37.1	.290	10.8	.58
CM 326-151	35.6	.294	10.5	.56
CM 310-140	35.2	.273	9.6	.54
CM 309-713	35.0	.291	10.2	.58
CM 314-2	34.8	.301	10.5	.60
CM 309-206	33.5	.294	9.8	.52
CM 309-146	32.5	.297	9.7	.46
CM 315-101	32.1	.299	9.6	.51
CM 309-303	31.4	.283	8.9	.58
CM 146-4	31.0	.302	9.4	.51
CM 309-239	29.8	.308	9.2	.46
CM 305-40	24.9	.307	7.6	.48
CM 305-17	24.7	.295	7.3	.62
CM 309-227	24.5	.277	6.8	.46
CM 314-20	24.5	.294	7.2	.59
CM 320-2	23.0	.309	7.1	.54
CM 309-93	22.3	.293	6.5	.42
Control cultivar				
M Col 22	35.0	.310	10.9	.66
Manteca (Local)	21.9	.313	6.9	.47
Average of all genotypes	29.8	.299	8.9	.53

selections (38 t/ha fresh weight) was nearly twice the yield of the local cultivar.

First Season Trial at Carimagua

The trial was planted in June 1976. The equivalent of 100 kg/ha of nitrogen, 200 kg/ha P_2O_5, 200 kg/ha K_2O, 500 kg/ha dolomitic limestone and 52 kg/ha of magnesium were applied. Fungicides were applied four times but failed to control superelongation. Cassava bacterial blight (CBB), the most devastating cassava disease in the area, was effectively controlled using disease-free planting material in an isolated field. Thirty-six hybrid selections and 14 germplasm selections and control cultivars were evaluated. Results are in Table 24.

Yields were generally low (average of all genotypes, 17 t/ha fresh weight) compared with those at the other two locations. However, the average of the top ten genotypes (29 t/ha fresh weight) was nearly 50 percent higher than the yield of the local cultivar and is acceptable for the poor soil conditions at Carimagua.

Table 24. **Selected results of the first season replicated yield trial in Carimagua (harvested May 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
CM 323-52	33.0	.303	10.0	.68
SM 92-73	33.0	.321	10.6	.71
CM 308-197	30.6	.324	9.9	.74
CM 323-142	26.0	.287	7.5	.62
CM 314-2	25.7	.328	8.4	.64
CM 323-99	24.3	.321	7.8	.55
CM 305-11	24.0	.288	6.9	.68
CM 323-41	24.0	.275	6.6	.58
CM 309-2	23.3	.322	7.5	.60
CM 321-88	21.5	.328	7.1	.62
Germplasm selection				
M Col 1684	32.3	.321	10.4	.74
M Mex 16	29.9	.318	9.5	.69
M Pan 114	29.9	.317	9.5	.64
M Ven 218	27.8	.317	8.8	.62
M Mex 59	25.7	.323	8.3	.53
M Col 638	25.3	.324	8.2	.60
M Ven 77	25.0	.323	8.1	.60
M Ecu 47	18.4	.281	5.2	.54
M Col 1292	17.4	.330	5.7	.46
M Mex 52	16.3	.290	4.7	.44
Control				
Llanera (Local)	21.5	.320	6.9	.63
M Col 22	19.4	.309	6.0	.64
M Col 113	10.4	.260	2.7	.47
Average of all genotypes	19.1	.313	5.9	.56

Second Season Trial at Carimagua

This trial was planted in November 1976; 25 hybrid selections and six germplasm selections and control cultivars were evaluated. Results are in Table 25.

The experiment was heavily attacked by superelongation disease and the hornworm, accounting for the low yield (average of all genotypes was 18 t/ha fresh weight). This is supported by the fact that the genotypes which showed some resistance to superelongation disease — such as CM 323-52, SM 92-73 and CM 308-197, in the first season trial, and SM 92-73, CM 321-15 and CM 181-13, in the second trial — produced the highest yields. Even under these conditions, the top hybrid selection out-yielded the local cultivar by more than 50 percent and the average yield of the top ten genotypes (30 t/ha fresh weight) was 35 percent higher than the yield of the local cultivar.

Table 25. **Selected results of the second replicated yield trial at Carimagua (harvested 19 September 1977).**

	Root fresh weight yield (t/ha/year)	Root dry matter content	Root dry weight yield (t/ha/year)	Harvest index
Hybrid selection				
SM 92-73	24.7	.320	7.9	.72
CM 321-15	24.3	.318	7.8	.76
CM 181-13	23.6	.328	7.7	.68
CM 309-56	21.5	.342	7.4	.68
CM 305-1	21.5	.283	6.1	.75
CM 309-37	21.2	.323	6.8	.72
CM 309-41	20.5	.333	6.8	.71
CM 180-4	20.5	.325	6.7	.73
CM 180-2	20.1	.316	6.4	.76
CM 315-101	20.1	.303	6.1	.71
CM 309-196	19.8	.314	6.2	.68
CM 309-165	18.4	.346	6.4	.65
CM 91-3	18.1	.327	5.9	.70
CM 305-15	17.4	.340	5.9	.83
CM 323-87	17.4	.335	5.8	.83
CM 91-1	16.7	.332	5.5	.75
CM 308-26	16.3	.300	4.9	.70
CM 304-160	16.0	.341	5.5	.56
CM 309-189	16.0	.335	5.4	.65
CM 328-10	16.0	.327	5.2	7.2
Control cultivar				
M Col 1684	21.5	.301	6.5	.77
M Col 1468	18.0	2.92	5.3	.72
Llanera (Local)	16.0	.330	5.3	.54
M Mex 59	15.6	.291	4.5	.64
M Ven 218	13.2	.314	4.1	.73
Average of all genotypes	18.0	.321	5.8	.70

PROMISING LINES

It has been shown that in the absence of CBB and superelongation disease, the top ten CIAT hybrid selections yielded at least 20 t/ha dry weight on fertile soils with less than 1000 millimeters of rainfall, and without fertilizer, fungicides, insecticides or irrigation, and 10 t/ha on extremely poor soils of the tropical savanna. These hybrids out-yielded local cultivars by 50-200 percent depending upon the soil and climate. The high yields of CM 308-197 in all three locations suggest that one genotype can cover a broad range of environments with temperature means above 24°C (see Physiology section).

Over the past three years, the initial harvest index average (0.42) of the original

Table 26. **Rankings of several promising cassava lines for 14 important characteristics.**

	Characteristics													
	Yield at CIAT	Yield at Caribia	Yield at Carimagua	Lodging resistance	Ease of harvest	Shape and color of root	Eating quality	Starch content	HCN content	Post-harvest root durability	CBB resistance	Superelongation resistance	Mite resistance	Thrips resistance
Hybrid selection														
CM 181-13	2[1]	2	4	4	2	4	4	2	2	1	3	2	1	1
CM 308-297	4	3	4	4	3	3	2	2	2	2	1	2	2	4
CM 309-41	3	2	3	3	1	2	4	3	2	1	3	1	1	3
CM 309-56	2	2	3	3	2	3	2	3	2	!	4	1	1	2
CM 309-163	3	4	2	3	3	3	2	2	2	1	1	1	1	3
CM 309-196	2	4	2	3	1	2	3	3	2	2	4	1	1	3
CM 321-15	3	2	4	4	4	3	2	2	2	2	1	1	1	1
CM 323-52	2	2	4	3	3	4	3	2	2	1	1	2	2	2
CM 323-142	4	2	3	1	1	2	2	2	2	2	1	1	1	3
SM 92-73	2	2	4	1	4	4	1	2	2	1	1	2	1	2
CM 305-38	4	[2]		2	3	2	4	3	2	1	1	1	2	4
CM 305-120	4			3	4	4	4	2	2	2	1	1	2	4
CM 305-122	4			3	3	4	4	4	2	1	2	1	2	3
CM 311-69	4			4	4	4	4	3	2	1	1	3	1	3
CM 321-188	4			3	4	4	3	4	2	1	1	1	1	3
CM 323-375	4			3	3	3	3	3	2	1	2	1	2	4
CM 326-407	4			4	2	2	3	3	2	1	1	2	1	3
CM 340-30	4			3	4	4	2	2	2	1	2	1	1	3
CM 344-27	4			3	2	2	3	3	2	1	1	3	1	3
CM 344-71	4			1	2	2	4	2	2	2	2	3	1	3
Germplasm selection														
M Col 1684	3	3	4	4	1	2	1	2	1	1	1	2	1	1
M Ven 218	4	2	3	2	1	3	4	3	2	1	1	2	1	3
M Ven 270	3	2	2	2	3	3	2	4	2	1	1	1	1	2
M Pan 70	4	2	3	2	1	3	4	3	2	1	1	2	2	3
M Mex 59	2	3	2	1	1	2	2	2	2	1	1	1	1	2
Control or local cultivar														
Llanera	2	1	2	3	1	3	3	2	2	1	2	3	1	2
M Col 22	2	3	2	4	4	3	4	4	2	1	1	2	1	3
M Col 113	2	1	1	1	1	2	2	2	2	2	1	1	2	4
M Col 638	2	1	3	2	3	2	1	2	2	1	4	3	1	3
M Col 1468	3	3	1	2	4	4	3	1	2	2	1	1	1	1

1. 4 = Very good; 3 = Good; 2 = Acceptable; 1 = Poor
2. Blanks indicate selections not tested at these locations.

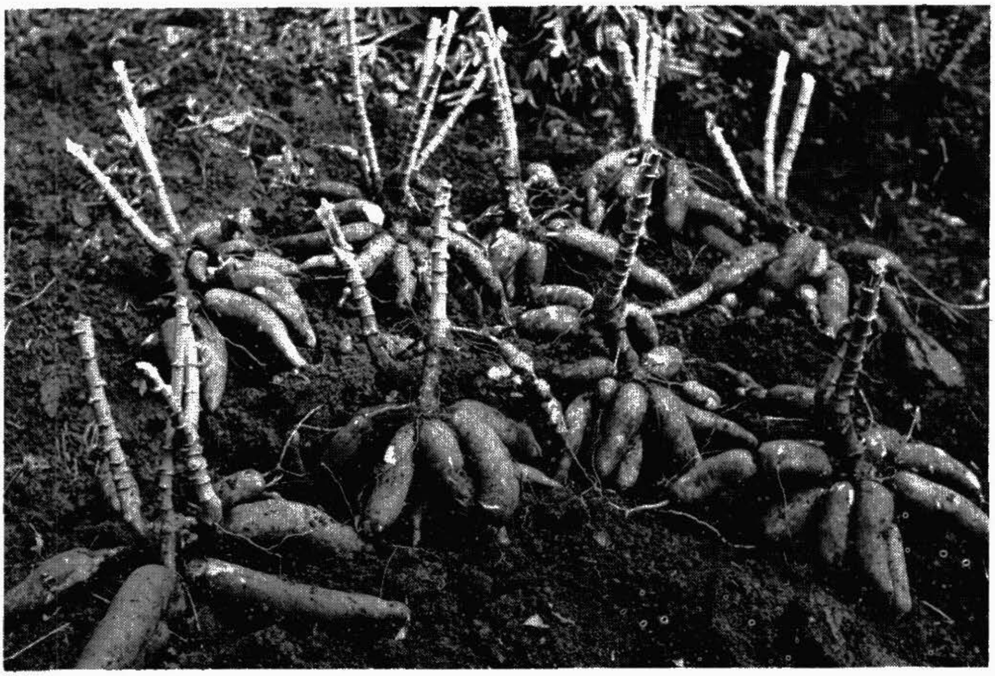

Figure 26. An excellent selection of roots from one of the promising CIAT-developed hybrid lines.

germplasm population has been increased to 0.55 in the latest populations. Table 26 shows the 14 breeding characteristics used for comparing promising hybrid selections with the best germplasm selections. These promising lines are the result of hybridizations in late 1973 and early 1974, and increasing numbers of new hybrids have been added each year. The outstanding hybrid materials were sent to the Agronomy section for rapid multiplication and further evaluation in regional trials. However, the emphasis in varietal improvement has now shifted to incorporating disease and insect resistance into high-yielding lines.

Agronomy

In 1977, the Agronomy section completed three years of regional trials with selected varieties and work has begun with testing the first generation of CIAT-produced hybrids regionally. Also, with the addition of two new agronomists to the team, research on cultural practices received major attention. Rapid propagation and testing of new promising lines from the Varietal Improvement section were also emphasized.

REGIONAL TRIALS IN COLOMBIA

Again this year in regional trials CIAT selections out-yielded local varieties in all locations except Popayan (Table 27). Table 28 shows the ecological and edaphic conditions for testing sites within and outside of Colombia.

The highest yield thus far in the regional trials of 1977 was produced by M Pan 70

Table 27. **Fresh root yield of ICA-CIAT promising cassava varieties at ten locations in Colombia.**

	Locations									
	Pereira	Rionegro	Media Luna	Carimagua	Caicedonia	CIAT	Nataima	El Tambo	Popayán	Florencia
	Days to harvest									
	416	369	387	355	370	352	363	357	460	393
Varieties	Fresh root yield (t/ha)									
CMC 40 (M Col 1468)	48.8[2]	32.4[3]	16.6[3]	22.1[2]		45.6[3]	27.8[3]	21.5		20.6
M Mex 59	25.3	45.0[3]	16.6[3]	26.3[2]	52.0[3]		7.2	24.3		21.2
CMC 84 (M Col 1513)		47.9[3]	7.9	23.2[2]		43.6[3]	—	24.4[2]		12.2
MPTR 26						34.1[1]	31.9[1]	12.2		
M Mex 17						38.6[1]	28.6[1]	13.6		
M Ven 218				22.4	45.8[1]		28.7[1]	20.9		
M Pan 70				21.0	54.3	33.9[1]	32.5[1]	17.6		
M Ven 156		33.0[1]	14.2[1]	21.6	41.4	37.3[1]	18.8	20.0		
M Col 1684						30.0	36.6[1]	32.3[1]		
CMC 57 (M Col 1486)		18.3	3.3	14.6	26.9	35.8		23.7		
CMC 59 (M Col 1488)	44.3	17.1	4.9	16.4	27.9	36.4	24.5	28.5		
CMC 76 (M Col 1505)	37.0	32.4[3]				33.7[3]				21.6[1]
CMC 99 (M Col 1529)		42.9	11.1	17.0	42.3	28.1	26.0	21.6		
M Col 1686						21.6	31.2[1]	15.0		
M Col 670		31.0	4.7	18.4	35.7	34.1[1]	16.6	17.7		
M Col 561		23.8	4.1	16.3	28.8	33.6[1]	27.3	23.1		
M Ven 77		38.5	11.4	20.1	45.9		28.0			
M Col 677		39.1[2]		12.5	37.2[2]	17.5		13.4	2.7	14.0
M Col 1292		24.2[2]	3.6	14.9	47.5[1]		8.9			
M Col 655		19.4	2.9	12.6	44.7	12.4	12.1	13.6		
M Ven 168						31.2	13.7	20.2		
M Col 22			18.1[3]			24.8	26.8[3]			8.8
M Ecu 159	38.3	15.7	3.4	13.2	42.8				4.3	15.3
M Col 673		41.8							1.7	9.9
M Mex 23					37.4	22.9				
M Ven 119	26.3								1.3	10.1
M Ven 119	28.1								3.4	12.2
M Col 113	36.8					—		—		10.5
Other varieties[4]	40.6(1) 32.5(6) 28.9(2)			22.1(7)					12.4(3) 9.9(4) 17.6(2)[2] 2.5(5)	11.5(5)
Regional varieties[5]	45.8(8)	16.1(9) 14.1(10)	5.7(11)	17.3(12)	41.2(8)	22.5(13)	8.0(16)	26.2(13)	14.3(14)	18.5(15)
Average including regional varieties	36.0	29.5	8.5	18.4	40.7	30.7	23.7	20.3	7.0	14.3
Average of best promising variety	48.8	47.9	18.1	26.3	54.3	45.6	36.6	32.3	17.6	21.6

[1] and [2] Respectively, varieties approved for second and third year evaluations at the same locations.
[3] Varieties that completed three years of evaluations in the same location.
[4] Other varieties: (1) CMC 39 (M Col 1467); (2) CMC 92 (M Col 1522); (3) CMC 102 (M Col 1530); (4) CMC 52 (M Col 1481); (5) M Mex 55; (6) CMC 71 (M Col 1500); and (7) Chiroza.
[5] Regional varieties: (8) Chiroza Gallinaza; (9) Colombiana, (10) Torrana Negrita, (11) Secundina; (12) CMC 9 (Llanera or M Col 1438); (13) M Col 113 (Valluna); (14) Regional (Popayan); (15) Caqueteña (Florencia); (16) CMC 84 (M Col 1513.

Table 28. **Main edaphic and climatological characteristics of the sites used in national and international yield trials with promising cassava materials during 1976-77 cycle.**

Sites	Latitude	Longitude	Altitude (masl)	Mean temperature (°C)	Rainfall (mm/year)[2]	Soil Texture	pH	Organic Matter (%)	P Bray II (ppm)	K (meq 100 gr)
Enmore (Guyana)[1]										
Anira Peat No. 20	6°25'N	52°30'W	0	27.0	2.928	Silty clay	3.7(VA)	52.0	37.5(M)	0.17(M)
Inky Clay No. 100	6°25'N	52°30'W	0	27.0	2.928	Clay	4.2(VA)	10.0	1.2(L)	0.30(M)
Xulha (Quintana-Roo, (Mexico)	18°24'N	88°38'W	10	26.0	1.608	Clay loam	7.8(AL)	5.3(H)	5.1(L)	2.18(H)
Medialuna (Magdalena, Col.)	10°33'N	74°30'W	10	27.2	1.326	Sandy	7.0(AL)	0.6(L)	7.3(L)	0.06(L)
Pichilingue (Quevedo-Ecuador)	1°06'S	79°29'W	100	25.0	1.483	Silt loam	6.5(N)	4.9(H)	45.8(H)	1.10(H)
Carimagua (Meta, Col.)	4°40'N	71°24'W	200	26.2	1.586	Clay loam	4.9(VA)	3.6(M)	1.0(L)	0.25(M)
Nataima (Tolima, Col.)	4°10'N	74°56'W	430	27.8	1.249	Sandy	5.8(A)	1.2(M)	51.0(H)	0.35(H)
Florencia (Caquetá, Col.)	1°31'N	75°14'W	450	25.0	3.186	Silty	4.7(VA)	3.9(M)	8.0(L)	0.38(H)
Rionegro (S. del Sur, Col.)	7°15'N	73°09'W	480	26.6	1.134	Clay loam	5.0(A)	2.3(M)	10.4(L)	0.15(M)
El Tambo (Cauca, Col)	2°19'N	76°54'W	900	26.0	1.797	Clay loam	4.9(VA)	5.1(H)	1.8(L)	0.16(M)
CIAT (Valle del Cauca, Col.)	3°31'N	76°21'W	1000	23.8	684	Clay	7.4(AL)	4.1(H)	81.5(H)	0.69(H)
Caicedonia (Valle del Cauca, Col.)	4°20'N	75°50'W	1100	22.2	1.684	Silt loam	5.6(A)	2.7(M)	13.8(L)	0.18(M)
Pereira (Risaralda)[1]	4°49'N	75°41'W	1480	19.0	3.171	Silty clay	5.3(A)	7.8(H)	20.0(M)	0.18(M)
Popayan (Cauca, Col.)[1]	2°27'N	76°34'W	1760	18.0	2.035	Clay loam	5.5(A)	7.4(H)	2.0(L)	0.04(L)

1 Pereira, Popayán and Guyana data respond to 1975-76 cycle.
2 Corresponds to actual rainfall during growing cycle.
3 Fertility codes: (N) Neutral; (AL) Alkaline; (A) Acid; (VA) Very acid; (L) Low; (M) Medium; (H) High.

(54 t/ha fresh weight) in Caicedonia, a major cassava-producing area of Colombia. A good local variety, **Chiroza, yielded** 41 t/ha in the trial there. Farmers of the region had not believed that there were better varieties than Chiroza. However, after results of the regional trial were presented this year, farmers took home planting material of the highest yielding varieties.

The lowest yield (1 t/ha) was produced by M Ven 119 at Popayan where the local variety yielded 14 t/ha. M Ven 119 suffered a serious attack of Phoma leaf spot while the local variety showed good resistance. This indicates that good selections for high altitude, cool locations are still lacking.

An examination of the performance of the three highest yielding varieties at each site over three years shows that not only was the mean yield of these varieties always superior to the best local variety, but yields were also more than three times the Colombian national average (estimated to be 8 t/ha) (Table 29). Mean yield of selected varieties in the third testing cycle was higher because better selections were included while the yield of local varieties was stable.

While the mean yield of the local varieties remained at 19.6 t/ha over the three-year period, this was more than double the national average. This indicates that with simple and inexpensive uniform technology used in these trials, Colombian cassava farmers can double their production with local varieties. However, the overall mean of the best three selections (28.8 t/ha) was 47 percent higher than the mean of the best local varieties, thus validating the CIAT selection procedures.

In 1977, the first generation of CIAT hybrids was planted in nine sites in Colombia. The varieties M Mex 59, CMC 40 (M Col 1468), CMC 84 (M Col 1513) and M Col 22 have shown high yield and stability across sites over the past three years and will serve as controls.

Cooperation also continued with the

Table 29. **Mean fresh root yield of the three best promising varieties of cassava in nine locations of Colombia, compared with the best local variety at each location during three years.**

	Fresh root yield (t/ha)							
	Crop cycle							
	1974-75		1975-76		1976-77		Mean yield/site	
Sites	Promising	Local	Promising	Local	Promising	Local	Promising	Local
Rionegro	29.7	15.7	21.9	11.7	45.2	16.1	32.2	14.5
Media Luna	26.7	17.7	17.6	4.0	17.1	5.7	20.4	9.1
Carimagua	6.2	3.8	25.6	22.9	23.9	17.3	18.5	14.6
CIAT	40.6	26.3	30.9	22.1	42.6	22.5	38.0	23.8
Caicedonia	37.3	32.3	25.0	15.8	51.2	41.2	37.8	29.7
Popayán	10.8	14.5	13.3	14.3	[1]	[1]	12.0	14.4
Pereira	19.8	16.9	44.5	45.8	[1]	[1]	32.1	31.3
El Tambo	—	—	22.4	22.3	28.4	26.2	25.4	24.2
Nataima	41.1	33.6	28.4	16.3	33.6	8.0	34.3	19.3
Mean yield/cycle	26.5	20.1	25.5	19.4	34.5	19.5	28.8	19.6

[1] Popayan and Pereira sites not yet harvested (30 October 1977).

Instituto Colombiano Agropecuario (ICA), the Federación Nacional de Cafeteros (FEDECAFE) and the various departmental Secretaries of Agriculture. This year, the ICA experimental station in Palmira sold 60,000 cuttings of promising varieties tested by ICA and CIAT to local farmers.

REGIONAL TRIALS OUTSIDE COLOMBIA

Regional trials were planted in Argentina, Costa Rica, Ecuador, Mexico and Venezuela. Similar trials were harvested in Ecuador, Guyana and Mexico; results of these trials are in Table 30.

In Ecuador, the best CIAT-selected variety, M Mex 59, out-yielded the best local variety, Yema de Huevo, by 6.7 t/ha fresh weight. Since the local variety is already the result of considerable selection by the Instituto de Investigaciones Agropecuarias (INIAP), these results indicate that CIAT-selected varieties, even before hybrids are released, can be of considerable use in that country.

CULTURAL PRACTICES

This year, research on cultural practices in cassava became a major part of the program with emphasis on: (1) identifying and resolving cassava production

Table 30. **Fresh root yield of promising cassava varieties in Guyana, Ecuador and Mexico.**

		Locations			
		Enmore, Guyana		Pichilingue, Ecuador	Kulha, Mexico
		Anira Peat 20	Inkv clay 100		
		Days to harvest			
		361	361	314	398
		Fresh root yields (t/ha)			
Varieties	Origin				
Tacana	Brazil	28.0	24.3		
Iracema	Brazil	27.6	23.3		
M Mex 23	CIAT	23.2	16.8		
Piracununga	Brazil	18.3	19.7		
CMC-40 (M Col 1468)	CIAT	17.9	18.1	24.6	7.2
M Mex-59	CIAT	17.3	16.1	28.3	13.0
Llanera CMC-9	CIAT	16.9	18.3	17.3	0.9
M Col-673	CIAT	14.2	12.3	7.3	0.9
Del País	Pto. Rico	13.0	11.5		
Badwoman	Guyana	11.6	10.0		
Twelve month	Guayana	8.6	5.5		
M Mex 55	CIAT	8.2	12.0		

Table 30. (Continued)

Varieties	Origin	Fresh root yields (t/ha)			
Four month	Guyana	6.7	5.0		
Chinese stick	Guyana	6.4	4.3		
M Col-22	CIAT	6.3	9.9	18.8	14.0
Uncle Mack	Guyana	5.3	8.0		
Brancha Butterstick	Guyana	4.6	6.4		
Bitterstick	Guyana	4.4			
R. Singh	Guyana	3.8	5.6		
L.H.Z.	Guyana	2.9	1.8		
CMC-844 (M Col 1513)	CIAT			25.6	9.3
Yema de Huevo	Ecuador			21.6	
Negrita	Ecuador			21.1	
Quintal	Ecuador			19.5	
CMC-76 (M Col 1505)	19.4	6.7			
M Ecu 159	CIAT			17.2	1.7
M Mex 52	CIAT			15.7	
M Col 113	CIAT			15.6	1.6
M Ven 156	CIAT			11.1	9.0
M Ven 119	CIAT			10.8	0.1
M Ven 218	CIAT				7.2
SMI 150	CIAT				8.6
M Col 677	CIAT				4.1
CMC-59 (M Col 1488)	CIAT				5.7
CMC-57 (M Col 1486)	CIAT				0.0

problems; (2) integrating the best cultural practices into a cassava production technology package; and, (3) developing simple, effective experimental designs to validate technology and adapt it to local conditions.

Long-term Fertility Trials

Although cassava is generally considered a soil-exhausting crop, there is little data on the effect on yield of interactions among fertilization, plant phenotypes and plant densities across a broad spectrum of soil fertilities.

Three phenotypes of cassava were each planted at populations of 5-, 10-, 15- and 20,000 plants/ha without fertilizer or with 50-100-100 kg/ha of split-applied N-P-K at CIAT (high fertility soil) Caribia (medium fertility) and Carimagua (low fertility). Preliminary, first-year results have been obtained from CIAT and Caribia.

Under CIAT conditions, fertilization did not affect root yield within varieties (Table 31) and no interaction was found for fertilization x plant density on total root yield. However, over all treatments, CMC 40 and M Col 22 produced

Table 31. **Effects of fertilization on fresh root yields of three cassava cultivars, means of four planting densities, CIAT, 1977.**

Fertilizer (kg/ha) $N\text{-}P_2O_5\text{-}K_2O$	Fresh weight yields (t/ha)		
	CMC 40	M Col 22	M Mex 52
CIAT			
None	50.5[1]	31.6[1]	19.2[1]
50-100-100	49.2[1]	33.8[1]	20.4[1]
Caribia			
None	25.9[2]	34.9[2]	18.4[2]
100-0-150 + 20 kg Zn	33.7[2]	38.3[2]	22.0[2]

1 F. test (P = 0.05) not significant within varieties.
2 LSD (5%) 7.4 within varieties.

significantly higher root yields with higher plant densities in contrast to M Mex 52 (Fig. 27). Commercial root production was only significantly affected (P = 0.05) by plant density with the cultivar CMC 40.

In Caribia, fresh root yield was significantly higher (P = 0.05) only for CMC 40 planted at 10,000 plants/ha, **although M Col 22 tended to increase its yield when planted at 15,000 plants/ha (Fig. 27). In Caribia, as in CIAT, the interaction of fertilization x planting density was not significant.**

The lack of response to first-year fertilization may be explained by the high- and medium-fertility conditions at the two locations, (pre- and post-harvest soil analyses at CIAT and Caribia (Table 32) did not show significant improvement of fertilities.) However, second cycle crops are already showing fertilizer effects on top growth of the more vigorous cultivars.

Spatial Arrangements

Good cultural practices require ridging in certain types of soils to improve surface drainage and to avoid root rotting. However, it was not known if plant spatial arrangements in ridges would affect yields. Three different phenotypes of cassava — CMC 40, M Col 22 and M Mex 52 — were planted at CIAT at 10,000 plants/ha in five different patterns (Fig. 28). Results showed that spatial arrangements did not significantly effect total and commercial root yields within varieties (Fig. 29). As expected, yields differed significantly among varieties.

Modification of Rapid Propagation

This year, it was proven that shoots for rapid propagation do not need to be placed in individual rooting flasks, as has been the custom. Forty young shoots can be rooted in a 500-cc beaker containing 200-cc of cool, previously boiled water. This new technique saves both time and effort.

Bud Quality and Planting Position

Planting position and bud quality of cassava cuttings were studied for their effects on the percentage and rate of germination, shoot production, callus formation and root initiation using the rapid propagation method.

Two hundred cuttings with two normal buds and 200 with one bruised and one normal bud were cut from mature (12-month-old) stems of CMC 40 variety (M Col 1468) and planted in a rapid propaga-

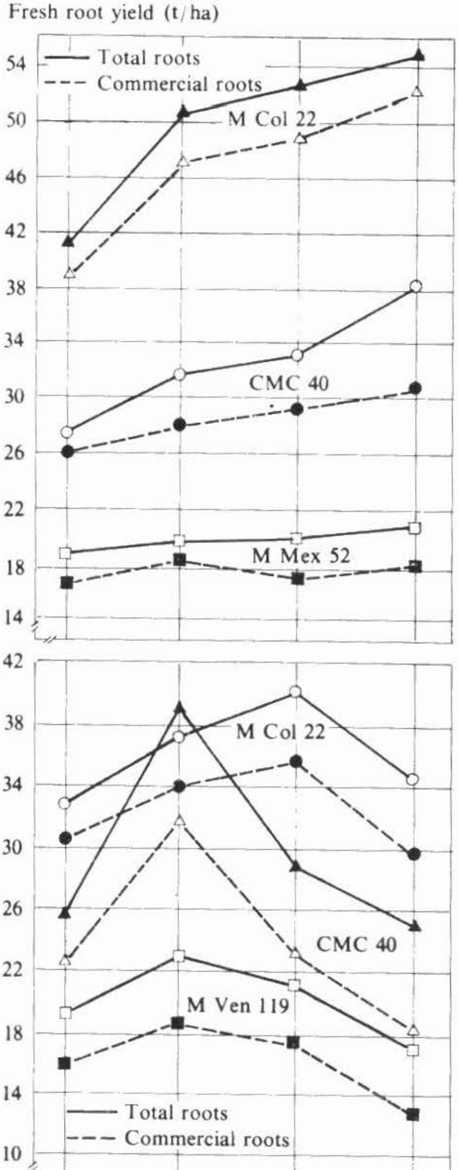

Figure 27. **Effects of plant density on root yields of cassava cultivars grown at CIAT (A) and Caribia (B), 1977.**

tion chamber in replicated blocks of 50 cuttings each. The cuttings were planted in four treatments: (1) 100 normal, two-node cuttings planted horizontally in the chamber; (2) 100 normal, two-node cuttings planted with one bud facing upward; (3) 100 two-node cuttings with one normal bud and one bruised bud, both oriented horizontally; and (4) 100 two-node cuttings with one bruised and one normal bud planted with the normal bud facing upward.

Germination of the cuttings in each treatment was recorded for 21 days after planting. The 5-centimeter shoots were excised and transferred to 500-cc beakers holding 200-cc of cool, boiled water to examine callus formation and root initiation.

Results (Table 33) showed the rate of germination increased rapidly beginning on the sixth day, reaching a maximum on day 12, after which germination continued to increase slowly until day 21. Treatment 1 had the greatest final germination.

The number of shoots produced monthly from the cuttings over a five-month period is shown in Table 34. Although differences among treatments were significant during the first three months, this was not so in the last two months. Treatment 1 produced the most shoots. However, in each treatment, the number of shoots produced was highest in the second month and then decreased slowly.

Callus formation was constant for all treatments. Eight days after shoots were placed in the flasks, calluses formed. Two days after callus formation, rooting began and at 18 days more than 95 percent of shoots in all treatments had rooted.

Interactions were evident between quality and planting position of cuttings and these factors affected germination and shoot production. The horizontal planting position favored only the normal two-bud cuttings but had no effect on the production capacity of cuttings with only one normal and one bruised bud (Table 34). A

Table 32. **Soil analyses of CIAT and Caribia plots before planting and after the first harvest of cassava.**

	Soil status		
	Organic matter (%)	P Bray II, (ppm)	K (meq/100 g)
CIAT			
Initital status	3.8	36	0.55
After harvest, no fertilizer	4.1	46	0.49
After harvest, with fertilizer[1]	4.2	51	0.54
Caribia			
Initital status	1.9	81	0.13
After harvest, no fertilizer	2.3	93	0.12
After harvest, with fertilizer[2]	2.4	96	0.13

1 50-100-100 kg/ha $N\text{-}P_2O_5\text{-}K_2O$
2 100-0-150-20 kg/ha $N\text{-}P_2O_5\text{-}K_2O\text{-}Zn$

comparison of Tables 33 and 34 shows that as the number of germinated buds increased, shoots produced increased, indicating that shoot production was closely correlated with the number of germinated buds.

Selection of Two-node Cuttings

The same two varieties of the previous experiment were used to evaluate the effect of selecting two-node cuttings from the apical, middle or basal part of the stem on the percentage and rate of germination, shoot production, callus formation and root initiation. Six-hundred cuttings each were taken from 12-month-old plants of the two varieties and planted for rapid propagation in a completely randomized block design.

The two-node cuttings taken from the basal, middle and apical parts of stems of CMC 40 and M Col 22 constituted Treatments 1, 2, 3, 4, 5 and 6, respectively. Two to three weeks after planting, ger-

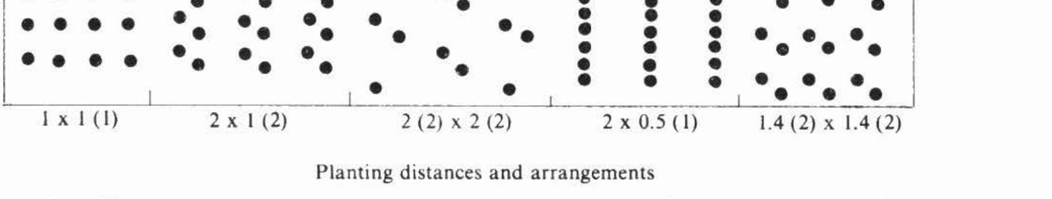

Figure 28. **Spatial arrangement of cassava planted at 10,000 plants/ha, at CIAT, 1977. First figures are distances (meters) between ridges, second figures are distances within ridges. Figures in parentheses are number of plants per site.**

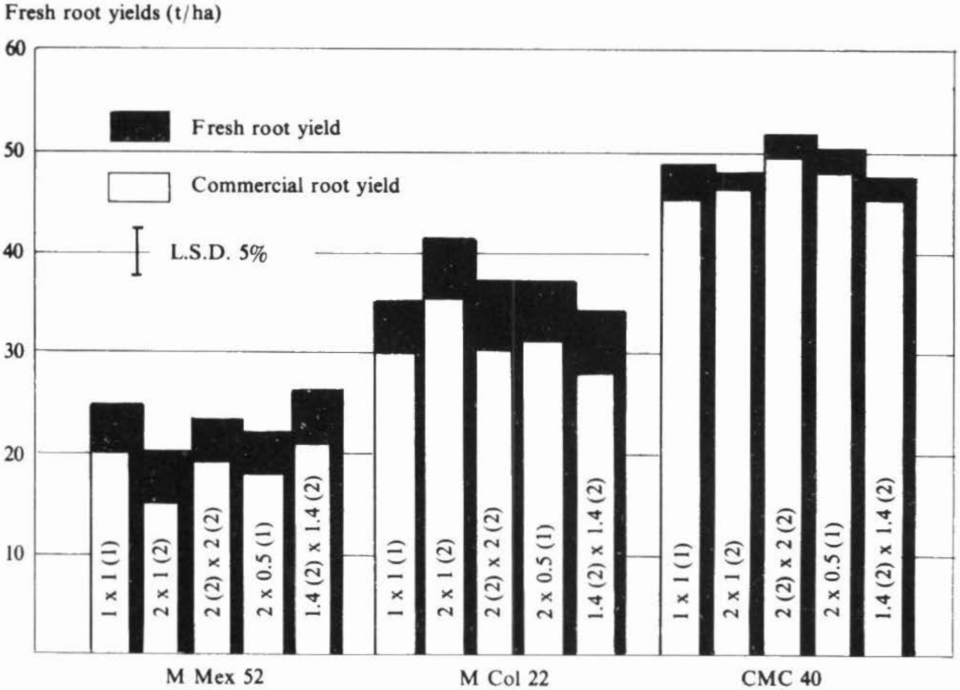

Figure 29. **Effects of planting patterns on total and commercial root yields of three cassava varieties at a standard density of 10,000 plants/ha, at CIAT, 1977. First figures in columns are distances (meters) between ridges, second figures are distances within ridges. Figures in parentheses are number of plants per site.**

mination of cuttings was recorded (Table 35). After shoots were excised from the cuttings, callus formation and root initiation were examined.

The shoot production capacity/node of the two-node cuttings is shown in Table 36. Cuttings taken from the middle of the stem of CMC 40 produced the highest

Table 33. **Cumulative percentage germination at times up to 21 days after planting of two-node cassava cuttings planted in two positions and with different bud qualities.**

	Days after planting					
Treatment[1]	6	9	12	15	18	21
1	9b[2]	52a	78a	80a	84a	87a
2	23a	48a	57b	60b	64b	72b
3	5b	32b	45b	47c	53c	58c
4	12b	34b	49b	54b	54bc	57c
C.V. (%)	21	3	9	6	5	4

[1] Treatments: 1 = cuttings planted horizontally in propagation chamber; 2 = cuttings planted with one bud facing upward; 3 = cuttings planted with one braised and one normal bud, both horizontal; 4 = cuttings planted with one bruised and one normal bud, the latter facing upward.

[2] Values followed by different letters are significantly different (P = 0.05) by Duncan's multiple range test.

Table 34. **Number of shoots produced each month over five months on 100 two-node cassava cuttings planted in two positions and having different bud quality.**

	Months after planting					
Treatment[1]	1	2	3	4	5	Total shoots
1	111a[2]	144a	115a	100a	82a	553a
2	85b	119b	100ab	87a	84a	476b
3	66c	107b	91b	82a	60a	416c
4	79bc	110b	90b	76a	65a	421c
C.V. (%)	7	3	5	9	8	2

[1] For description of treatments, see footnote 1, Table 33.
[2] Values followed by different letters are significantly different (P = 0.05) by Duncan's multiple range test.

germination while cuttings from the apical section of the stem of M Col 22 produced the lowest percentages. Overall germination of cuttings from the three different stem parts of CMC 40 was above 90 percent but it was less than 80 percent for M Col 22.

In both varieties, cuttings from the middle part of the stem produced the highest germination percentage. Germination rate for all treatments increased rapidly from the sixth day, peaking at 12 days and then continuing to increase slowly. The number of shoots produced was highest during the second month and then decreased slowly over the rest of the period for all treatments (Table 37). Treatment 2 gave the highest shoot production and Treatment 6, the lowest. Treatment 1 produced the highest average of shoots/node and Treatment 6, the lowest. Eight days after planting, callus formation occurred and rooting began two days later. At 18 days, root initiation was 90 percent in all treatments. At earlier

Table 35. **Germination percentage at different times during 21 days after planting of two-node cuttings taken from different stem parts of two cassava varieties.**

	Days after planting					
Treatment[1]	6	9	12	15	18	21
1	16a[2]	65abc	78a	84a[1]	88a	90ab
2	14a	82a	88a	91a	94a	96a
3	18a	73ab	86a	89a	90a	91ab
4	3a	44cd	62b	67b	70b	71c
5	2a	50bcd	65b	70b	71b	77bc
6	2a	33d	57b	65b	66b	68c
C.V. (%)	69	10	5	2	3	4

[1] Treatments: 1,2,3,4,5,6 are cuttings from basal, middle and apical parts of stems of CMC 40 and M Col 22, respectively.
[2] Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

Table 36. **Shoot capacity production after six months per node of two-node cuttings taken from different stem parts of two cassava varieties.**

Treatment[1]	No. of buds germinated	Total shoots produced	Shoots per node
1	190ab[2]	1453a	8a
2	192a	1481a	7ab
3	132ab	1209b	6c
4	143c	1018bc	7bc
5	154bc	817cd	5d
6	137c	656d	4d
C.V. (%)	4	5	3

[1] For description of treatments, see footnote 1, Table 35.
[2] Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

stages, percentage of root initiation was higher in CMC 40 than in M Col 22.

Results indicate that CMC 40 is more vigorous than M Col 22 for germination and shoot production. This could be due to the larger size of the cuttings — a varietal characteristic. Therefore, it is suggested that two-node cuttings from different varieties will give different germination and shoot production percentages. When cuttings are taken from different parts of the stems of the same variety, germination percentage is fairly constant. Cuttings from the basal part of the stems produced the most shoots/node (Table 36). Perhaps these cuttings are more vigorous. Nevertheless, when planting material is scarce, basal, middle or apical cuttings can all be used effectively (however, apical cuttings must be woody).

Table 37. **Number of shoots produced monthly for six months after planting by 100 two-node cuttings from different stem parts of two cassava varieties.**

	Months after planting						
Treatment[1]	1	2	3	4	5	6	Total shoots
1	241ab[2]	429a	315a	196a	147ab	125a	1453a
2	295a	418a	293a	191a	166a	117a	1481a
3	220ab	356a	247ab	154a	129abc	101a	1209b
4	134b	225b	213ab	164a	132abc	149a	1018bc
5	148b	173b	148b	132a	110bc	105a	917cd
6	107b	116b	141b	111b	85c	95a	656d
C.V. (%)	13	9	12	15	9	16	5

[1] For description of treatments, see footnote 1, Table 35.
[2] Values followed by different letters are significantly different (P = 0.01) by Duncan's multiple range test.

Soils and Plant Nutrition

Since cassava is generally tolerant of soil acidity it is frequently grown on acid and rather infertile soils. However, within the species different degrees of tolerance exist and varieties can be selected requiring minimum liming and fertilizer to produce good yields on poor soils. In 1977, a start was made to screen the germplasm collection for tolerance to soil acidity and low levels of phosphorus and potassium— the three most limiting factors on yield in the low fertility Oxisols and Ultisols of tropical Latin America and Africa. Work also continued on the nutritional requirements of the crop and the most economical application methods.

SCREENING FOR ALUMINUM TOLERANCE IN NUTRIENT SOLUTIONS

This year, a greenhouse technique was developed to screen for aluminum tolerance using cassava shoots, rooted by the rapid propagation method. Shoots were placed in nutrient solutions containing 3 and 30 ppm aluminum. In a preliminary trial, growth was better at 3 than at zero pp, aluminum, and therefore, this level was used as the optimum. Dry matter production of each variety was determined after three weeks in both solutions, and dry weight at 30 ppm over that at 3 ppm aluminum was used to indicate aluminum tolerance.

FIELD SCREENING FOR SOIL ACIDITY TOLERANCE

Fifty varieties from the germplasm bank, including some promising hybrids were planted in single rows with three replicates in Carimagua at four levels of lime: 0,0.5,2 and 6 t/ha MgO was incorporated with the lime at a calcium:magnesium equivalent ratio of 5:1. These lime applications increased the pH from 4.3 to 5.3 and decreased exchangeable aluminum from 2.0-0.3 meg/ 100 mg, essentially eliminating aluminum at the highest liming rate. Plots were fertilized as indicated in Table 38; in addition, zinc, copper, boron, molybdenum and manganese were applied

Table 38. **Fertilizer levels used in cassava experiments at Carimagua.**

Experiment	Lime	N	P_2O_5	K_2O	S	Zn
			(kg/ha)			
Lime screening 1976A	variable	100	100	200		15
Lime screening 1976B	variable	100	100	200		10
P screening 1976A	500	100	variable	200		stake streatment
P screening 1976B	1000	100	variable	200		10
K screening 1976A	500	100	150	variable	20	stake treatment
K fertilization	500	100	100	variable	20	stake treatment
Rock phosphate trial 1976B	500	100	variable	200		10
N x K interaction	500	variable	100	variable		10
Zn fertilization	6000	100	100	200		variable
Manure fertilization	500	variable	variable	variable		

to prevent lime-induced micronutrient deficiencies. Plants were harvested at 14.5 months.

Although plants were completely defoliated at eight months by a severe horriworm attack, yields were quite high. Several varieties were eliminated because of extreme superelongation disease. Without lime, plants were short (56 *vs.* 90 centimeters with 6 t lime/ha) and had yellow bottom leaves due to calcium and magnesium deficiencies.

Figure 30 shows the average response of the 42 cassava varieties compared with those of other crops screened for acid-soil tolerance in Carimagua. On the average, cassava and cowpea are much more acid soil tolerant than rice (dwarf varieties), corn, sorghum or beans. Overall cassava yields without lime were about 40 percent of those with lime. However, specific rice

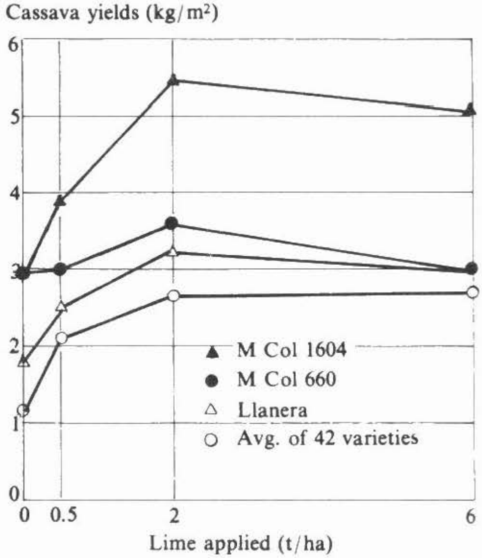

Figure 31. Single-row yields of three high-yielding cassava varieties selected from 42 varieties tested, as affected by lime applied at Carimagua.

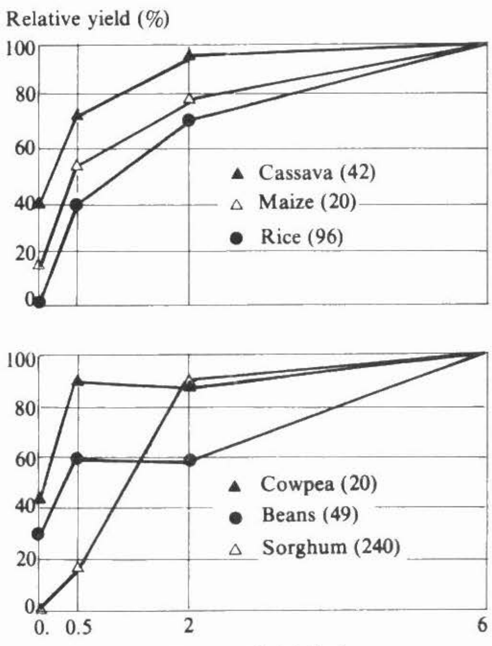

Figure 30. **Relative average yield of cassava and five other crops as affected by applications of various levels of lime, at Carimagua. F;gures in parentheses are numbers of varieties tested.**

varieties and cassava varieties may be tolerant of extremely acid soil as shown by the response of M Col 1604 in Figure 31. Without lime, this variety yielded 83 percent of maximum yield obtained with 2 t lime/ha. The control variety, Llanera, used in nearly all the fertility trials, was among the most acid soil tolerant, producing 55 percent of maximum yield without lime. Table 39 shows the yields and the tolerance index of the ten most tolerant varieties per trial, where the square of the yield at zero lime divided by that at 6 t/ha lime was used as the tolerance index.

Another group of 183 varieties were screened in early 1977 at lime levels of 0.5, 1, 2, and 6 t/ha. Although top growth was extremely vigorous, root yields were relatively low. The majority of varieties were affected to some degree by superelongation disease and a few by bacteriosis and by scales. Average yields were 13.9, 16.4, 16.0, and 17.1 t/ha for lime levels of 0.5, 1, 2, and 6 t/ha, respectively. Thus, with only 0.5 t lime/ha applied, cassava produced 81 percent of its max-

Table 39. **Root yields and tolerance to soil acidity of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)				Tolerance index
	Lime applied (t/ha)				
1976A	0	0.5	2	6	
M Col 660	29.3	39.2	54.7	50.9	16.9[1]
M Mex 59	24.0	35.9	55.8	48.2	11.9
CM 334-25	14.2	22.1	23.6	21.5	10.7
SM 1-133	18.9	26.7	31.7	33.3	10.7
Llanera	17.8	24.6	32.3	29.9	10.6
M Ven 168	19.4	37.7	55.2	42.5	8.8
M Pan 114	19.9	31.3	39.5	51.6	7.7
M Col 22	13.0	18.0	30.7	23.4	7.2
CM 308-23	19.0	37.3	38.6	50.9	7.1
M Ven 270	15.6	23.7	39.9	41.3	5.9
1976B	0.5	1	2	6	
Llanera	27.9	29.2	12.5	5.4	144.1[2]
M Col 88	26.2	20.0	7.9	9.6	71.5
M Col 1879	32.5	16.2	16.7	17.1	61.8
M Ven 33	38.3	23.2	30.4	27.9	52.6
M Col 565	26.7	33.3	14.6	15.8	45.1
M Ven 186	29.2	27.1	33.3	25.0	34.1
M Ven 183	35.8	21.2	25.8	39.2	32.7
M Col 1421	28.3	31.2	14.6	24.6	32.6
M Col 988	31.7	24.2	28.3	32.5	30.9
M Col 1468	38.3	19.6	52.9	55.0	26.7

[1] Tolerance index = $\frac{(\text{Yield 0 lime})^2}{(\text{Yield 6 t lime/ha})}$

[2] Tolerance index = $\frac{\text{Yield 0.5 t lime/ha})^2}{(\text{Yield 6 t lime/ha})}$

imum yield. Table 39 shows the yield of those ten varieties with the highest tolerance index. Llanera had the highest index, although yields at 2 and 6 t lime/ha were unusually low, possibly due to induced zinc deficiency.

FIELD SCREENING FOR LOW PHOSPHORUS TOLERANCE

One hundred varieties were planted in single rows with two replicates with levels of 0 and 150 kg P_2O_5/ha, band-applied as triple superhosphate (TSP) at planting. Plots were limed and fertilized as indicated in Table 38.

At 2.5 months, plants without phosphorus were short (47 *vs.* 68 centimeters with phosphorus) and lacked vigor. Many varieties showed yellowing or purpling of lower leaves which also were flaccid. Phosphorus contents of purple and yellow leaves were 0.09 and 0.11 percent, respectively, while the same varieties with applied phosphorus had 0.21 percent in their bottom leaves.

Table 40. **Root yields and tolerance to low soil phosphorus of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)		Tolerance index
	P_2O_5 applied (kg/ha)		
1976A	9	150	
M Col 1684	8.6	10.7	6.9[1]
M Col 660	13.6	30.1	5.1
M Pan 114	14.4	37.3	5.5
CM 213-9	9.2	17.2	4.9
CM 309-25	8.4	15.4	4.6
M Col 1686	9.0	19.3	4.2
M Ven 168	11.5	32.9	4.0
M Mex 59	11.3	31.8	4.0
CM 323-64	8.2	17.9	3.7
M Col 22	7.2	14.0	3.7
1976B	0	150	
M Mex 59	23.0	23.6	22.4[1]
M Pan 102	12.1	8.9	16.4
M Ven 246	12.1	10.5	13.9
M Col 1505	12.1	11.1	13.9
M Col 1524	13.4	15.0	12.0
M Ven 217	18.7	32.3	10.8
M Ven 156	14.0	19.1	10.3
M Ven 187	11.9	14.0	9.7
M Col 1513	8.2	7.2	9.3
M Mex 23	12.3	16.8	9.0

[1] Tolerance index = $\frac{(\text{Yield 0 P})^2}{\text{Yield (150 kg } P_2O_5\text{/ha)}}$

Table 40 shows the response of the most tolerant varieties and Figure 32 (part A) shows the response of some selected varieties. On the average, the absence of phosphorus reduced yields from 1.7 to 0.5 kg m^{2} or 29 percent of maximum in the first trial. M Col 1684 was the most phosphorus tolerant, but its yield was unusually low. Llanera had a low tolerance index of only 1.28.

In the second trial, another 160 varieties were screened for phosphorus tolerance in a different plot. Due to disease problems,

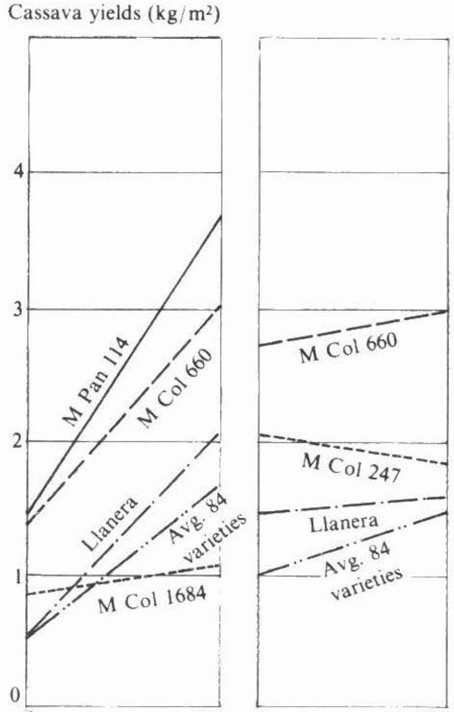

Figure 32. **Single row yields of several cassava varieties and the average yields of 85 varieties as affected by two levels of phosphorus and potassium.**

yields of the plot with 150 kg P_2O_5/ha were slightly lower, while some residual phosphorus in the soil raised the yields of the zero-phosphorus plot slightly higher than those of the first screening, resulting in a higher tolerance index as indicated in Table 40. M Mex 59 had the highest tolerance index.

Due to non-uniformaty of soil and climatic conditions, tolerance indices of varieties in different field screenings cannot be compared; screening in nutrient solution produces more uniform conditions. Moreover, differential susceptibility to diseases is seldom a complicating factor in nutrient solution screenings. Hence, in the future, nutrient solution screening will be emphasized.

FIELD SCREENING FOR LOW POTASSIUM TOLERANCE

The same 100 varieties used for the first phosphorus screening were also screened for low potassium tolerance by planting with two potassium levels— 0 and 200 kg K_2O/ha, applied as KCl, split applied at planting and at 60 days. The plots were limed and fertilized as indicated in Table 38.

Table 41. **Root yields and tolerance to low soil potassium of several cassava varieties (in single rows).**

Variety	Root yield (arbitrary units)		Tolerance index
	K_2O applied		
1976A	0	200	
CM 308-23	19.1	13.6	26.8[1]
M Col 660	27.1	29.7	24.7
M Col 247	20.7	18.5	23.2
M Ven 83	25.2	28.1	22.6
M Mex 23	11.5	6.4	20.7
CM 320-19	13.0	10.0	16.9
M Ven 168	21.6	27.7	16.8
M Ven 1823	17.5	22.0	13.9
M Col 783	10.9	8.6	13.8
Llanera	14.6	15.6	13.7

[1] Tolerance index $\frac{(\text{Yield 0 K})^2}{\text{Yield (200 kg } K_2O/\text{ha)}}$

Without applied potassium plant growth was only slightly reduced from 66 to 60 centimeters at 2.5 months. Potassium content of upper leaves decreased significantly from 1.70 to 0.98 percent, while contents of nitrogen, phosphorus and magnesium increased in the absence of potassium. The calcium content was not affected. Figure 32 (part B) and Table 41 give the response to potassium of the most tolerant varieties tested. On the average, lack of applied potassium reduced yields from 1.45 to 1.0 kg/m^2, that is, to 70 percent of maximum yield.

LEVEL AND TIME OF POTASSIUM APPLICATION

Under high rainfall conditions applied potassium can be lost partly through leaching. Therefore, split applications of potassium are generally recommended. To study this effect, the variety Llanera was planted, and levels of 0, 50, 100, 150, and 200 kg K_2O/ha were applied as KCl in a single or split application at various times after planting. The fertilization regimes are indicated in Table 38.

Application increased potassium contents of upper leaves at three months from 1.83 to 2.21 percent while calcium and magnesium contents were low but not significantly affected by potassium application. However, at nine months, plants in high-potassium treatments showed yellowing of lower leaves with magnesium contents of only 0.06 percent compared with 0.15 percent in plots without potassium. This suggests that high potassium applications induced magnesium deficiency, but calcium status of the plant was not affected. Figure 33 shows the yield response. Though yields

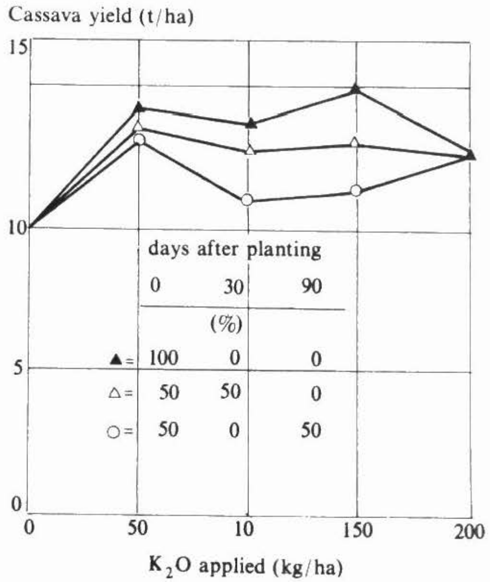

Figure 33. **Response of the cassava variety Llanera to several levels of potassium applied at various times after planting at Carimagua.**

were low, there was a significant response to potassium application, but no significant difference between levels of application; a single application at planting was superior to any split application or single application at 30 days. Thus, under the climatic and soil conditions of Carimagua a split application of potassium does not seem necessary. The application of 20 kg Mg/ha did not prevent magnesium deficiency induced by high potassium treatments.

RESIDUAL EFFECTS OF ROCK PHOSPHATES

The 1976 CIAT Annual Report showed the response of cassava to applications of various rock phosphates in Carimagua. This year, the trial was reseeded to measure the residual effect of the phosphate applications. One of the two sets of plots on which TSP had been applied was used to measure residual effect, while in the other set the same amount of TSP was reapplied as an optimum control. Nitrogen, potassium and zinc were uniformly reapplied to all plots. Plants were harvested at 11 months.

Yields of all plots were considerably lower in the second planting than in the first; the highest yield was 21.9 t/ha obtained with 400 kg P_2O_5/ha of reapplied TSP. Figure 34 shows the relative yields of both plantings. Application of basic slag produced the highest yields in the first planting, and had a better residual effect than any other source in the second planting. Of the rock phosphates, the residual effect of Gafsa rock was better than that of TSP and North Carolina rock. In the first planting, cassava only responded to 100 kg P_2O_5/ha, but in the second planting there was a significant response to 400 kg P_2O_5/ha, both for the residual and reapplied phosphates, indicating that 100 P_2O_5/ha was not sufficient for maximum yields.

POTASSIUM X NITROGEN INTERACTIONS

Results of a potassium x phosphorus systematic design trial with Llanera were reported in the 1976 CIAT Annual Report. A similar trial for potassium x nitrogen was planted in Carimagua using 14 levels of potassium combined with 14 levels of nitrogen, band-applied at seeding as K_2SO_4 and urea, respectively. Yields of Llanera varied between 17 t/ha at low nitrogen and potassium rates to 30 t/ha with the application of 130 kg N/ha and 160 K_2O/ha. No nitrogen response was observed in the absence of potassium nor a potassium response in the absence of nitrogen. Both elements were equally important in increasing yield but neither produced the large response obtained with phosphorus in the potassium x phosphorus trial.

Using values of $1, 500/t of cassava and $17,50/kg N, $18,50/kg K_2O, and $23.20/kg P_2O_5 (all in Colombian pesos), the value of the increased yield due to fertilization exceeded the cost of the fertilizers and transport.

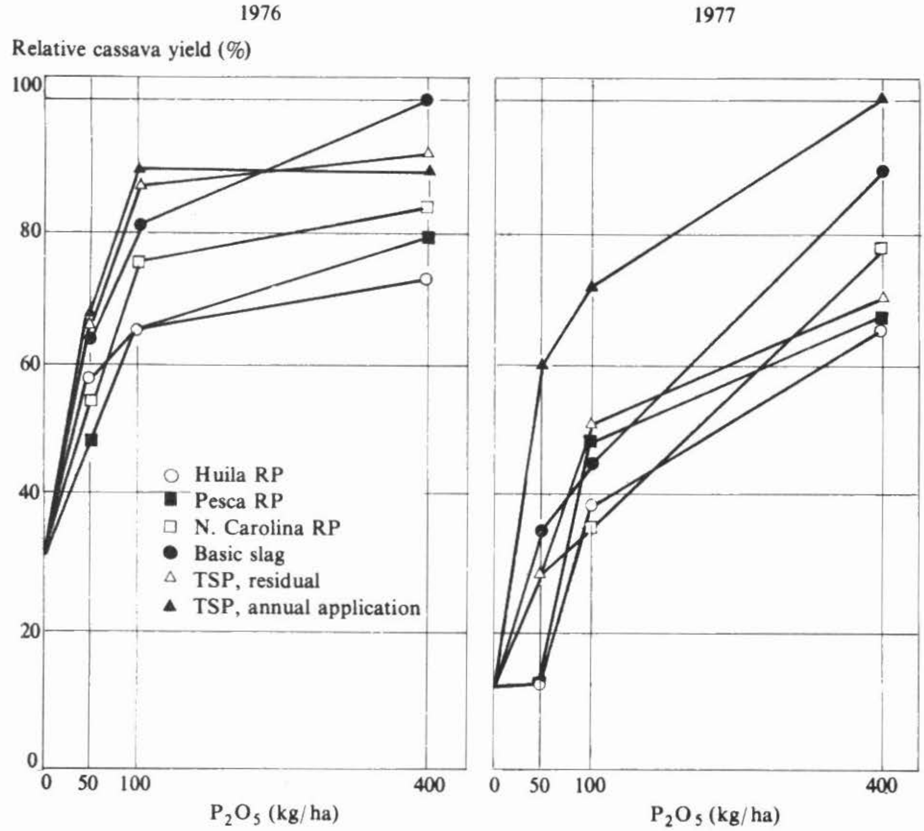

Figure 34. Initial (1976) and residual (1977) effects of various levels and sources of phosphorus on the relative yield of cassava variety Llanera in Carimagua.

Figure 35 shows the effect of nitrogen, phosphorus and potassium fertilization on the harvest index. Both nitrogen and potassium applications decreased the harvest index, indicating that the fertilizer stimulated top growth more than root growth. With phosphorus fertilization the harvest index increased up to 50 kilograms of applied P_2O_5/ha and then decreased. This initial increase in harvest index as phosphorus levels increased was also found in other phosphorus trials (CIAT Annual Report 1976) and indicates that phosphorus at low to intermediate levels is most efficient for root formation.

ZINC FERTILIZATION

Since zinc deficiency is very common in cassava on both acid and alkaline soils, a trial on sources, levels, and methods of application of zinc was conducted in Carimagua on acid soils and in CIAT on alkaline soils. Fertilization regimes at Carimagua are shown in Table 38; at CIAT, plants were only fertilized with zinc. The test varieties in Carimagua were M Mex 23 and M Mex 59, and in CIAT, Llanera. Plants were harvested at 12 months in Carimagua and at 15 months in CIAT.

Table 42 shows the responses to zinc application. Both varieties in Carimagua produced low yields due to a severe hornworm attack and infection with CBB. However, they responded significantly to soil application of 5 kg Zn/ha, but gave no

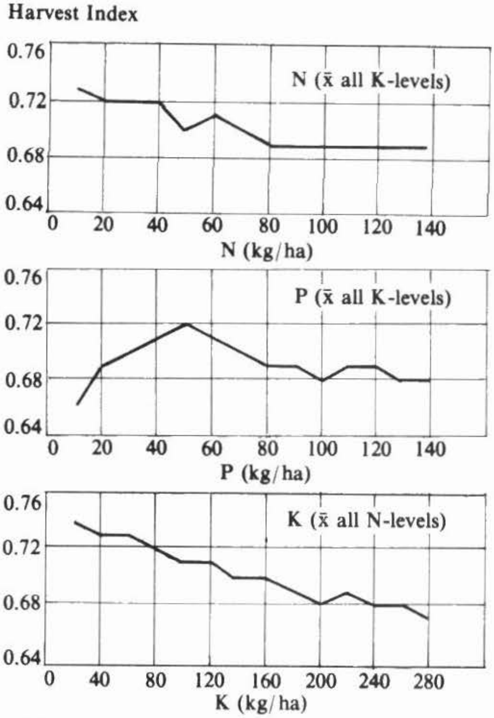

Figure 35. **Effects of various levels of nitrogen, phosphorus and potassium on the harvest index of cassava variety Llanera at Carimagua.**

additional response to higher levels; there was no significant difference between band-applied $ZnSO_4$ or broadcast ZnO. Foliar application or stake treatments were less effective than soil application. When yield was correlated to zinc contents of upper leaves at three months, a critical level for zinc deficiency of 37 ppm was determined for M Mex 59 and 51 ppm for M Mex 23.

In CIAT, Llanera responded very well initially to stake treatments of 2 and 4 percent $ZnSO_4$. However, most plants recuperated from zinc deficiency, while some suffered from soil salinity. Yields varied greatly because of soil variability (pH 6.7-8.0). Best yields were obtained with 15-minute stake dips in a suspension of 4 percent ZnO or a solution of 4 percent $ZnSO_4$ prior to planting. High yields were correlated with high zinc content (more than 45 ppm) of upper leaves but no critical level could be determined.

Thus in acid soils, soil application of ZnO or $ZnSO_4$ is effective, while under

Table 42. **Zinc content of upper leaves at three months and root yield as affected by various zinc treatments applied to two varieties of cassava in Carimagua and one variety in CIAT, Palmira.**

	Carimagua				CIAT	
	Yield (t/ha)		Zn in leaves (ppm)		Yield (t/ha)	Zn in leaves (ppm)
Treatment	M Mex 59	M Mex 23	M Mex 59	M Mex 23	Llanera	
Control	8.3	1.7	25	21	34.7	38.2
5 kg Zn/ha, $ZnSO_4$	12.7	8.4	35	34	33.2	37.2
10 kg Zn/ha, $ZnSO_4$	13.2	7.8	41	37	31.9	40.5
20 kg Zn/ha, $ZnSO_4$	14.1	7.4	60	52	40.0	42.2
5 kg Zn/ha, ZnO	15.1	6.0	45	32	39.1	42.2
10 kg Zn/ha, ZnO	12.5	10.2	50	34	27.8	35.0
20 kg Zn/ha, ZnO	13.0	10.7	50	45	38.8	39.5
1% $ZnSO_4$, foliar	10.9	4.2	—	—	38.4	44.7
2% $ZnSO_4$, foliar	11.2	6.2	—	—	32.3	43.0
4% $ZnSO_4$, foliar	13.2	4.4	—	—	37.4	45.0
1% $ZnSO_4$, stake	6.5	3.5	34	30	35.6	32.0
2% $ZnSO_4$, stake	10.7	5.5	26	27	34.3	37.5
4% $ZnSO_4$, stake	13.8	3.3	32	25	43.4	38.0
1% ZnO, stake	9.4	4.8	30	26	29.9	31.7
2% ZnO, stake	8.6	5.5	28	26	29.8	39.2
4% ZnO, stake	11.1	5.6	26	25	52.1	32.7

alkaline conditions stake treatments are recommended since soil-applied zinc is rapidly precipitated at a high pH.

FERTILIZATION WITH COW MANURE

Areas with acid infertile soils, presently used for beef production, are also areas of potential cassava production. The use of locally available cow manure to fertilize cassava is an obvious alternative to the use of imported chemical fertilizers. The effectiveness of various levels of cow manure was tested against manure combined with phosphorus or potassium applications, and against complete chemical fertilizers (10-20-20) applied in equivalent amounts of phosphorus as in the manure. Llanera was the cassava variety used. The manure was incorporated while chemical fertilizers were band-applied alongside the stakes.

Figure 36 shows that the application of 20 and 30 t/ha of manure doubled the yields, but that the addition of 80 kg P_2O_5/ha or 150 kg K_2O/ha significantly increased yields over those with manure alone. The application of equivalent phosphorus amounts of 10-20-20 fertilizers was generally superior to the use of manure alone, but not significantly different from the manure combined with phosphorus or potassium.

Using current prices (Colombian pesos) of $1,500/t for cassava and $8,400/t for 10-20-20 fertilizer (including transport), the use of manure on the average gave a higher net return only if the value of the manure, including cost of collection and application, were less than $200/ton. Generally, yield increases obtained by applying phosphorus or potassium to the manure did not compensate for the additional cost of these fertilizers.

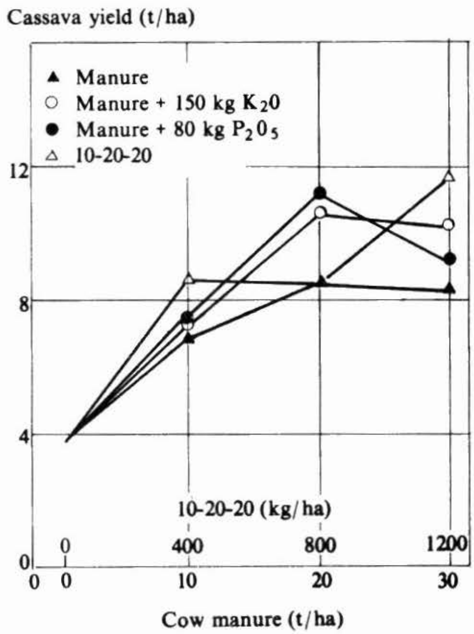

Figure 36. **Response of cassava variety Llanera to various levels of cow manure, applied either alone or combined with phosphorus or potassium, compared to equivalent amounts of applied 10-20-20 chemical fertilizers.**

Cassava Storage

Cassava roots deteriorate rapidly after harvest. Deterioration is either physiological or microbial, but the former generally occurs within 48 hours of harvesting. Physiological deterioration is characterized by a dry brown to dark necrosis, normally appearing as rings around the periphery of the cortex. This deterioration often appears on susceptible varieties within 48 hours of harvesting. Microbial deterioration commonly begins as vascular streaking, followed by soft rot, fermentation, and maceration of the root tissues. This type of deterioration, which does not occur in any special order, is normally noticeable five to eight days after harvesting (Fig. 37).

Figure 37. **Two forms of deterioration of cassava roots. (Left) Physiologic: dry brown-dark necrosis in the form of rings around the periphery of the cortex. (Right) Microbial: soft rotting, with fermentation and maceration of the root tissues.**

PRUNING

An experiment was done to evaluate the effect of pruning on cassava deterioration. Eight cassava varieties were selected with varying resistances to both physiological and microbial deterioration (see Cassava Storage, CIAT Annual Report, 1976). Plants of each variety were pruned to remove all green material (leaving only a 25-centimeter stem) and left in the ground for varying intervals before harvest. The results showed that the percentage of both physiological and microbial deterioration decreased with time from pruning to harvest for up to 14-21 days (Fig. 38).

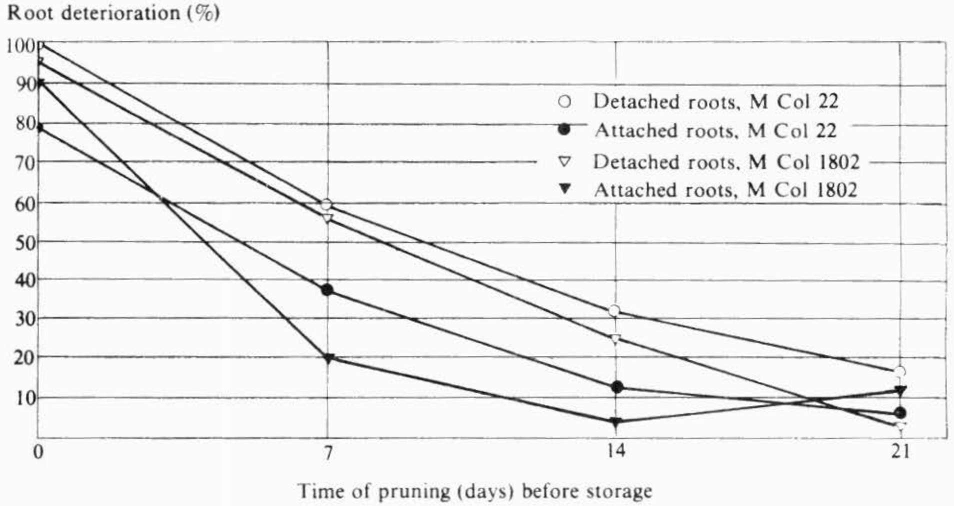

Figure 38. **Effect of stem on cassava root deterioration after 20 days of storage.**

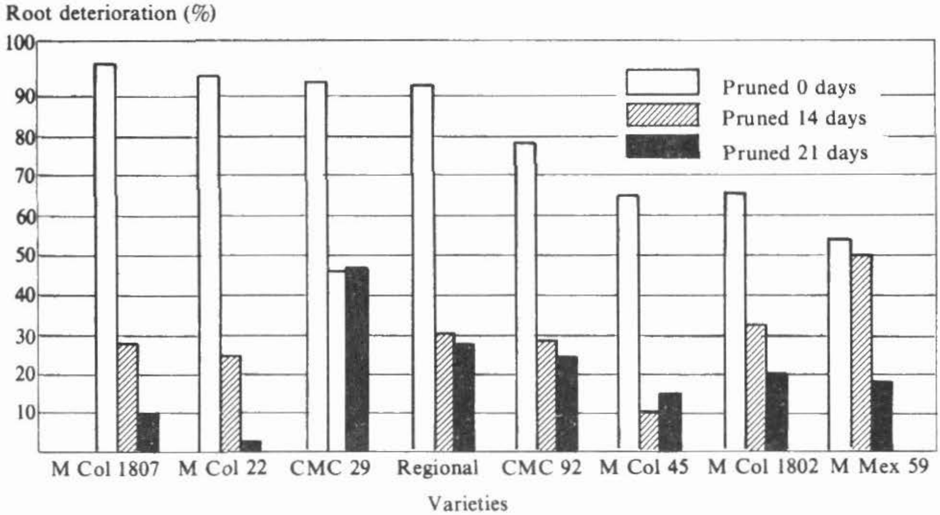

Figure 39. **Root deterioration of eight cassava varieties pruned 0, 14 and 21 days before harvesting and stored for 20 days.**

Roots left attached to the stem always deteriorated more slowly than those which had been detached. As indicated last year, susceptibility to deterioration is a varietal characteristc, for example, M Col 1807 and M Col 22 were more susceptible than M Col 1802 and M Mex 59 (Fig. 39). However, after 21 days, when these varieties were pruned, the first two varieties had deteriorated less than the latter two. Hence, varietal reaction to pruning varies and resistance without treatment is not related to resistance with treatment.

Normally, damaged roots deteriorate more rapidly than undamaged ones. However, after pruning, roots cut to

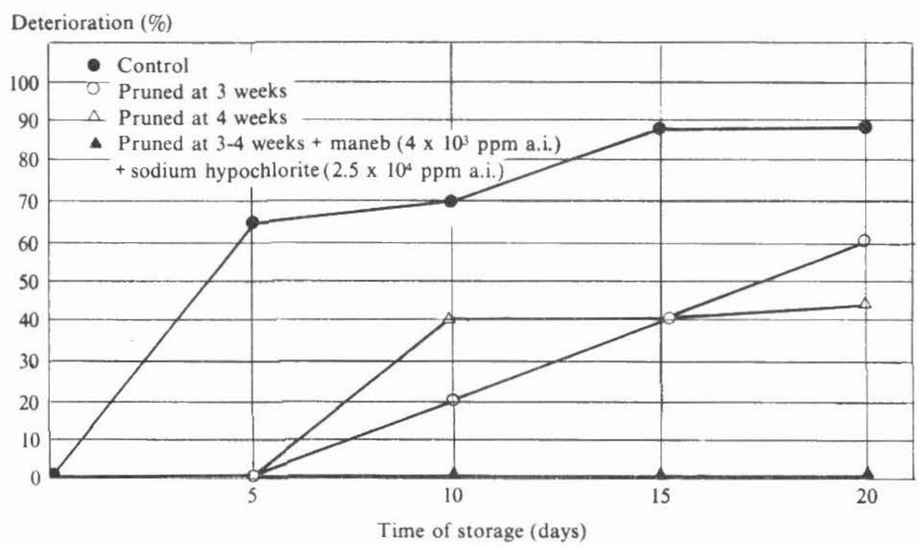

Figure 40. **Effect of plant pruning and chemical treatment on root deterioration of cassava variety M Col 113.**

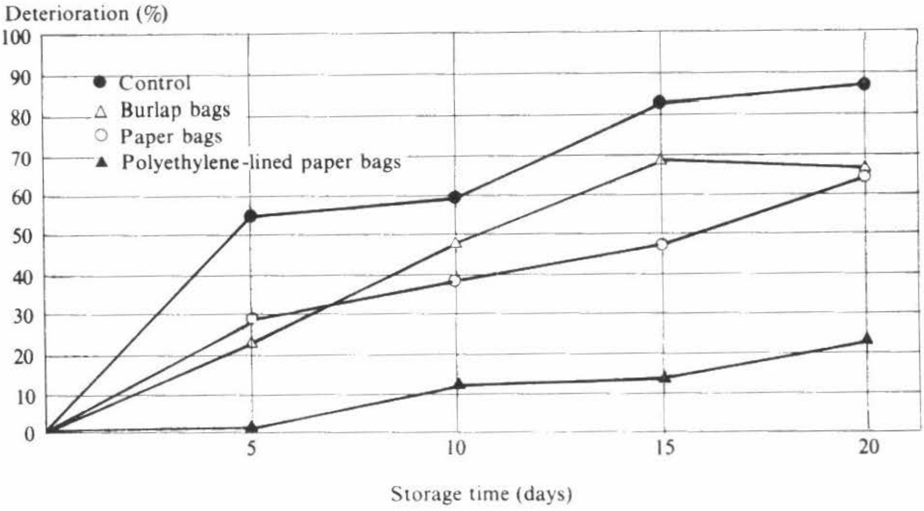

Figure 41. **Effect on deterioration of storing root of cassava variety M Col 113 in bags.**

simulate damage deteriorated at the same rate as treated, undamaged roots even when held at low humidity to prevent curing.

When roots with stems were stored after pruning, the physiological deterioration which normally occurs during the first two days was prevented. However, after ten days microbial rotting occurred but this was prevented by dipping roots in maneb and sodium hypochlorite (4×10^3 and 2.5×10^4 ppm a.i., respectively) (Fig. 40).

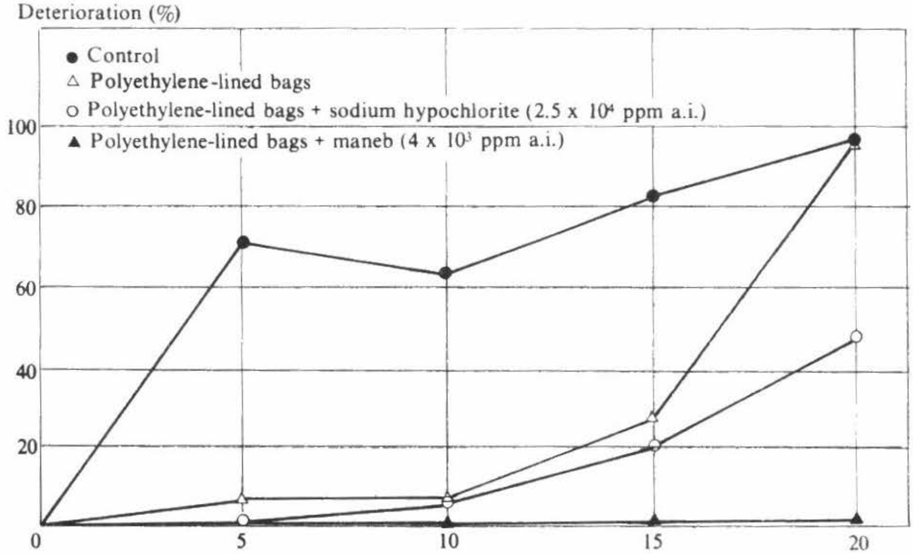

Figure 42. **Effects of polyethylene-lined paper bags and chemical treatments on deterioration of stored cassava roots.**

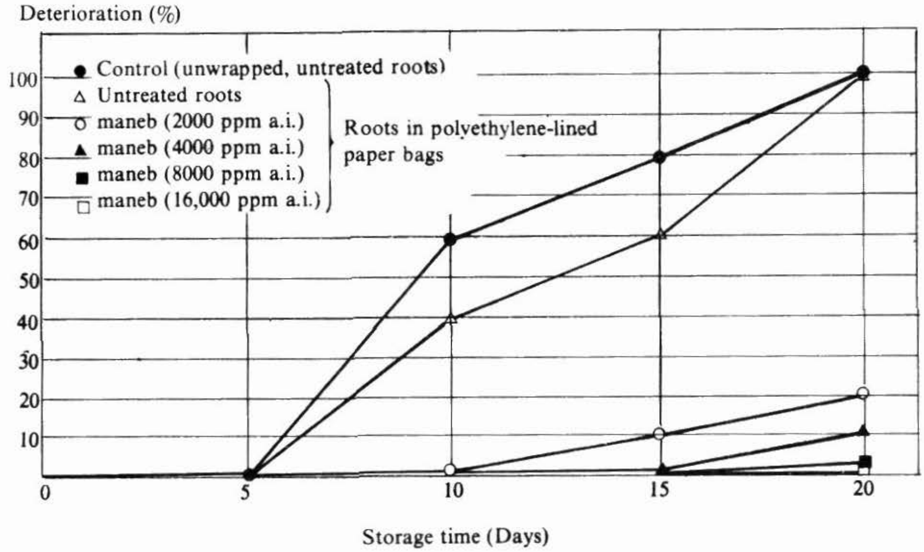

Figure 43. **Prevention of cassava root microbial deterioration with maneb treatments.**

STORAGE IN BAGS

Storage in burlap and paper bags increased the number of undeteriorated roots when compared with controls (Fig. 41), but treatments still gave a high percentage of both microbial and physiological deterioration. There was, however, a tendency for microbial deterioration to begin after about five days, similar to results for the pruning treatments. This was partially prevented by treating the roots with sodium hypochlorite (2.5 x 10^4 ppm a.i.) and completely prevented by a treatment of 4 x 10^4 ppm a.i. of maneb (Fig. 42). Further trials showed that at this concentration of maneb, some microbial rot occurred but that at concentrations of 8 x 10^4 ppm a.i., excellent control was obtained (Fig. 43).

International Cooperation

International cooperation activieties were markedly increased in the Cassava Program in January 1977 with the assignment of two staff positions— one based at CIAT, to coordinate Latin American activities and the other, posted at SEARCA, Philippines, to coordinate outreach activities in Asia. Both positions are funded by the International Development Research Centre (IDRC), of Canada.

However, outreach and international cooperation activities were initiated as early as 1972 when several Latin American countries were visited. CIAT, being an apolitical organization, can only influence what happens by demonstrating the usefulness of what it has to offer. The network of technical visits, training, and interpersonal and friendly communications, are the basis of this program. Throughout these years, these approaches have served as a means to: (a) help other countries to organize, with different degrees of success, their research on cassava; (b) to adapt, adopt and apply some of the minimal input technology developed at CIAT; (c) to field test CIAT-developed and other cultivars and hybrids; and (d) to cooperate in establishing an international network for exchange of information and germplasm, the latter through uniform regional trials using selected cassava cultivars. Two cassava scientists, upon special request, have worked with several sponsoring countries providing special assistance on specific problems.

The international cooperation philosophy is to *Inform* of what CIAT can offer, *Wait* until the national agency decides on what action it wishes to take, and then *Assist* the national agency in solving their problems. (The demand from the collaborating countries is mainly centered on germplasm exchange, technology, training, and assistance in program development).

Training plays a major role as a first step in international cooperation and it has changed from a rather opportunistic position of accepting random trainees to a very selective attitude that concentrates efforts in given countries at a given time, consequently providing training to several scientists in order to form teams for research in production in those countries.

The Cassava Program, as a result of its research and outreach activities, has decided that it is not only technology that needs to be transferred, but rather the ability to define the optimum technology that can be adapted to specific conditions by national agencies.

Experience has shown the effectiveness of the regional trials methodology as published in "The International Exchange and Testing of Cassava Germplasm", the result of a workshop in which country representatives presented their needs. Work is now concentrated on designing a series of standardized simple experiments to validate the technology generated at CIAT.

The development of international cooperation activities in Asia, being newer in its outreach than in Latin America, has as its major present responsibilities the multiplication and exchange of germplasm, including the establishment of regional trials; selection of candidates for training, and coordination of their work after training; and definition of the *status quo* of cassava production in Asia.

At this early stage, only five countries in Asia are involved in the Asian Outreach Program— India, Indonesia, Malaysia, the Philippines and Thailand. In the immediate future, other Asian countries, notably Sri Lanka, Burma and Vietnam, will be informed of the CIAT program and what it has to offer. Visits and program discussions had already been done with cassava scientists in the first five countries, and correspondence for possible cassava linkages with agricultural agencies for the other Asian countries has been initiated. In the field of manpower development for the countries, the response from developing national cassava programs to send participants to the January 1978 Intensive Cassava Course at CIAT has been encouraging. It is expected that some 25 Asians from India, Indonesia, Malaysia, the Philippines and Thailand will be selected for this course.

In the future then, the regional trials network will serve as an effective means of informing national agencies about their potential production capacity and the scope of the regional trials will be expanded so as to validate the low-cost cultural practices technology implementing the international collaboration activities in those countries wanting to commit their interest to increased cassava production. However, understanding that CIAT's clients are the national institutions and, that consequently, it does not have the responsibility nor the right to transfer technology directly to farmers, it cannot commit itself to cause any increase in yields in any region or country, unless the committment originates in the national institutions.

Achievements and projections in international cooperation activities can be summarized as follows:

Since the first visit to Brazil in 1972, and by special request of national research institutions and organizations of several countries, 124 scientists have been trained in cassava research and production at CIAT. Of these, 37 have come from Brazil, 12 from Mexico, 20 from Colombia, and 35 from other Latin American and Western countries; four have come from Malaysia, 11 from Thailand and five from Africa. Many of the professionals were trained in two intensive courses and two more intensive courses are programmed for 1978, one for participants from Asia, the other for Latin Americans. Twenty other agronomists have participated in longer training periods (3 to 12 months), and 14 have completed postgraduate research projects on cassava at CIAT.

As a result of this diversified training, some countries have taken longer steps in defining their cassava programs.

In Brazil, the National Cassava Center has been organized and CIAT, by special request of the Empresa Brasilerira do Pesquisa Agropecuaria (EMBRAPA), assisted in the planning and organization. CIAT's cassava agronomist has also spent over a month in the Brazilian Cassava Center, assisting in organizing a national network of regional trials, and in 1978, the cassava entomologist will help them in organizing the program in Brazil.

Consultations and visits to the Instituto Nacional de Investigación Agropecuaria (INIA) of Mexico, by the pathologist, agronomist and coordinator of CIAT's cassava program, resulted in the writing of a National Cassava Program for Mexico, which has been approved. A national center has been established.

Training in pathology by a Costa Rican agronomist at CIAT and visits of the CIAT cassava pathologist to that country, resulted in the eradication of bacteriosis from the experimental fields in Santa Clara and a program to eradicate cassava bacteria blight from major cassava growing areas in the country. Additional visits of the international cooperation specialist and other personal communications resulted in the establishment of an international regional trial with CIAT's best selections and later, in a formal agreement between the Ministry of Agriculture of Costa Rica and CIAT's Cassava Program, assistance in developing cassava research and production.

In the Dominican Republic, former trainees from CIAT will be assisted in organizing their cassava program and in establishing an international regional trial.

Ecuador, through its Instituto Nacional de Investigaciones Agropecuarias (INIAP), asked for specific assistance to define the *status quo* of cassava production in that country, with special emphasis on economic aspects. CIAT assisted, with the funding of IDRC, in the design and data processing of an agro-economic survey that showed yields were only of the order of 10 t/ha. This was low compared with what should be expected. Hence, an international regional trial was established in a major cassava growing area and has shown that yields of more than 20 t/ha, are easily obtainable.

In Colombia, the Federación Nacional de Cafeteros has adopted CIAT's technology for a specific program in the Caicedonia area, and, at least for those farmers who keep production records, showed increased yields from 25 to 45 t/ha over a five-year period. This is a clear example of how a national institution has assimilated CIAT's technology and transferred it to farmers. In both the Cauca Valley and the Atlantic Coast regions, ICA is multiplying new lines selected in the ICA/CIAT regional trials for later distribution to farmers.

In other countries complete success has not been achieved. IDRC has provided special funds for Peru, but the objectives proposed have not yet been accomplished. Others have been informed, and have not responded yet, while others have called for assistance.

The network of regional trials has produced yield data from 48 different sites, within and outside Colombia. Of these, in 47 cases, CIAT's selected cultivars have produced highest yields indicating an adaptability to a wide range of ecological conditions. It has also proved that the local varieties can yield 50 to 100 percent more, even with minimal inputs, if CIAT's technology is adopted.

The collaborating countries in this regional trial network have been Guyana and Ecuador (two cycles), Mexico (three trials), Venezuela (two trials), and Costa Rica, Argentina, and the U.S.A. (one trial). Selected varieties, hybrids and seeds from controlled crossings have been sent to more than 30 countries, and the first results and comments are being received.

The success achieved so far has proven the validity of the technology generated, and the many problems faced indicate that research has to continue.