CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out mainly at its Experimental Centers at Turipaná and Carimagua. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research. During the current year these donors are 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 Interamerican Development Bank (IBD), the United Nations Environment Programme, the Ministry of Overseas Development of the United Kingdom and the governments of Australia, Belgium, the Federal Republic of Germany, the Netherlands and Switzerland. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada. Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

# Cassava production systems

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Cables CINATROP

# PERSONNEL OF THE CASSAVA PRODUCTION SYSTEMS PROGRAM

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* Left during 1975
** Assignment divided between two programs

CONTENTS

## Climatic and edaphological data for locations where CIAT's Cassava Program has done research work in 1975

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

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

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

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

# Cassava production systems

## HIGHLIGHTS IN 1975

The cassava program's objective is to provide the technology for obtaining high cassava yields with low input levels. It has developed simple cultural and sanitary practices to be used with improved germplasm or varieties, which are the mainstay of this technology. This new germplasm will consist of efficient plants that are naturally resistant to diseases and pests, as well as to certain soil conditions such as acidity and low fertility.

An efficient plant is one that has a correct balance between the source of production—the leaves—and the product sought—the roots. It has been found that the correct balance for an efficient plant is best achieved by varieties that maintain a leaf area index (ratio of leaf surface to ground surface area) of 3 to 3.5. Model data suggest that the best varieties are those with a long leaf life and with branches that begin to form at four to six months. In the absence of restrictions (i.e., diseases and pests) and with a nearly perfect balance, yields of about 25 tons/ha/year of dry roots should be easily obtainable under CIAT conditions.

Although CIAT had previously developed technology for producing "seed" material free of cassava bacterial blight, there were doubts as to whether farmers would always accept it; therefore, varietal resistance was investigated. A rapid inoculation procedure was developed for use in screening, whereby plants are infected by clipping leaves with infested scissors. Good resistance was found in a very limited number of cultivars; however, it was found to be transmitted to the progeny from resistant lines crossed with susceptible lines, thereby making it possible to produce high-yielding lines. Similar results were obtained with superelongation disease and Phoma leaf spot (of local importance) and with the Cercospora leaf spots (of worldwide prevalence). However, a new bacterial disease, probably spread by insects, was discovered.

Work continued on the evaluation of insect-resistant lines and on control measures. Substantial losses occurred in lines susceptible to thrips even under the conditions of high fertility and fairly uniform rainfall found at CIAT. A large part of the germplasm bank was found to be thrips resistant. Studies on spider mites, common in drier cassava-growing areas, suggest that some cassava lines may be resistant. Although the use of insecticides does not constitute a major part of our technology, low levels of insecticides placed around the seed material are effectively used to control pests nonspecific to cassava that reduce germination and seedling establishment.

The breeding program is attempting to combine the components of efficient plants and resistance with other characters such as improved postharvest shelf life and increased starch content. The disconcerting lack of correlation between single-row yield and population yield was overcome by using harvest index as a selection criterion. It was also found that there was a high correlation of yield data between seedling and stake-planted generations as early as seven months after transplanting, which is very helpful for more rapid selection. Yields of 60 tons/ha were obtained at CIAT using varieties selected by these techniques.

Data collection was completed for the agro-economic survey of cassava production in Colombia. So far, analyses have been made for disease and insect incidence, soil characteristics, yield trends and the use of improved technology in five ecological zones. Average yields were below 8 tons/ha in four of these zones and only 12 tons/ha in the best zone.

Regional trials using minimum inputs but good cultural practices (weed control, clean seed, optimal plant populations) were carried out at nine sites in Colombia. Local varieties averaged 18 tons/ha in less than a year, which is much higher than those obtained by local farmers (3 to 12 tons/ha). Using selected CIAT/ICA lines, yields were further increased to an average of 30 tons/ha. Thus large yield increases can be obtained by simple improvement in technology and dramatic increases by combining these with improved varieties. The economic survey shows that the highest yields (up to 43 tons/ha) were obtained in the Caicedonia region, where the Federación Nacional de Cafeteros cooperates with CIAT in the introduction of new technology through two extension officers trained at CIAT. In the acid soils of the Llanos, representative of vast areas of the tropics that are presently very unproductive, yields of 25 tons/ha were obtained in 9 1/2 months by using improved technology and good fertilizer practices.

These techniques are being taught to trainees; during the past year there were students from Asia, Africa and the Americas. A workshop was also held at CIAT to standardize research methods for evaluating new material; and as a result, the basis for regional testing programs in 16 countries was established.

# ECONOMICS

## Agro-economic analysis

The data collection and certain parts of the analysis for the agro-economic survey of cassava production in Colombia were completed during 1975. Final results are presented for disease and insect incidence, soil characteristics, yields and use of modern technology in the production process, in addition to the principal results and conclusions from a comparative economic analysis of selected cassava cropping systems.

Table 1 shows the presence of diseases on sample farms for cassava crops four to eight months of age. The presence of some diseases was greatly influenced by crop age; data for crops of other ages may be obtained directly from CIAT. While considerable differences were found among zones, brown leaf spot *(Cercospora henningsii)*, white leaf spot *(Cercospora caribaea)* and Phoma leaf spot (**Phoma** sp.) were present in many of the cassava lots in all zones. Superelongation (**Sphaceloma**) was found on a large number of farms in Zone III, while cassava bacterial blight was important in Zones III, IV and V. Another potentially important disease, frog skin root disease, was identified in Zone I. Although this disease was found on a relatively small number of farms, yields were severely affected.

Thrips, gall midges (Cecidomyiidae) and whiteflies (**Bemisia** sp.) were found on a large proportion of sample farms in all zones (Table 2). Other insects of local importance include mites and fruit flies (**Anastrepha** sp.).

Results of soil tests taken on sample farms are summarized in Table 3. Considerable differences were found among zones; however, it appears that cassava is most frequently cultivated on relatively heavy, inorganic, low-fertility soils with a low pH, low organic matter content and low phosphorus and potassium contents. Zone II had the highest yields and also the highest potassium content in the soil. Until further

Table 1. **Disease incidence in cassava on sample farm in five zones* (Percentage of farms and area affected).**

| | I | | II | | III | | IV | | V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Farms | Area | Farms | Area | Farms | Area | Farms | Area | Farms | Area |
| Brown leaf spot | 28 | 6.1 | 31 | 6.5 | 75 | 9.9 | 71 | 29.4 | 80 | 42.7 |
| White leaf spot | 70 | 39.9 | 92 | 48.3 | 24 | 2.0 | 29 | 3.7 | 57 | 21.7 |
| Cercospora leaf blight | 57 | 26.5 | 31 | 7.3 | 69 | 28.5 | 49 | 7.6 | 55 | 25.1 |
| Cassava ash disease | 46 | 17.4 | 16 | 31.1 | 52 | 5.3 | 9 | 1.2 | 9 | 3.0 |
| Phoma leaf spot | 41 | 13.0 | 42 | 9.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Superelongation | 2 | 0.5 | 0 | 0 | 63 | 7.3 | 24 | 3.9 | 0 | 0 |
| Cassava bacterial blight | 2 | 0.4 | 0 | 0 | 14 | 2.3 | 25 | 11.0 | 30 | 8.6 |
| Root rot | 2 | 0.3 | 3 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Powdery mildew | 2 | 0.1 | 0 | 0 | 24 | 3.3 | 5 | 0.8 | 0 | 0 |
| Frog skin root disease** | 11 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

* I, Cauca; II, Valle and Quindío; III, Tolima; IV, Meta; V, Magdalena

** Incidence measured at time of harvest

analysis has been made, however, it would be premature to conclude that the higher potassium content is an important reason for the higher yields in other zones as in Zone II.

Although the use of modern technology differs among zones, regional differences are less marked for cassava than for certain other crops such as beans. The most advanced cassava production, from a technological point of view, is found in Zone II; the most traditional systems are found in Zones I, III and V (Table 4). Many cassava producers in all zones use insecticides, but the use of chemical fertilizers, fungicides and herbicides is low. Machinery is used only for land preparation; its use is determined primarily by topography and farm size.

Table 2. **Insect incidence in cassava on sample farms in five zones (Percentage of farms and area affected).**

| | I | | II | | III | | IV | | V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Farms | Area | Farms | Area | Farms | Area | Farms | Area | Farms | Area |
| Thrips | 59 | 14.2 | 88 | 36.6 | 100 | 63.9 | 95 | 62.9 | 86 | 29.2 |
| Gall midges | 25 | 3.1 | 44 | 8.3 | 69 | 8.9 | 65 | 8.6 | 84 | 15.3 |
| Whiteflies (**Bemisia** sp.) | 70 | 34.3 | 14 | 1.7 | 37 | 16.7 | 25 | 13.2 | 70 | 15.5 |
| Whiteflies spp. | 48 | 14.4 | 5 | 0.3 | 12 | 3.8 | 0 | 0 | 5 | 0.9 |
| Leaf-cutter ants | 10 | 2.5 | 5 | 0.3 | 24 | 2.5 | 0 | 0 | 2 | 2.6 |
| Shoot flies | 8 | 1.3 | 30 | 8.1 | 3 | 0.7 | 24 | 8.6 | 0 | 0 |
| Fruit flies (in stems) | 7 | 2.0 | 75 | 25.6 | 14 | 6.3 | 5 | 0.6 | 9 | 10.2 |
| Leafhoppers | 2 | 0.2 | 2 | 0.8 | 0 | 0 | 0 | 0 | 18 | 1.6 |
| Hornworms | 0 | 0 | 2 | 0.6 | 0 | 0 | 0 | 0 | 11 | 2.3 |
| Chrysomelids (leaf beetles) | 5 | 0.3 | 6 | 1.9 | 0 | 0 | 0 | 0 | 5 | 0.6 |
| Tingids (lace bugs) | 16 | 2.6 | 3 | 0.4 | 7 | 0.5 | 7 | 1.6 | 0 | 0 |
| Mites | 7 | 1.6 | 8 | 1.0 | 41 | 11.4 | 9 | 2.7 | 43 | 34.3 |

Table 3. **Selected soil characteristics on sample farms (average by zone).**

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| Organic matter (%) | 5.22 | 3.69 | 5.33 | 3.53 | 1.93 |
| Less than 4%* | 26.20 | 75.00 | 32.20 | 60.00 | 97.70 |
| Phosphorus (ppm) | 1.78 | 32.89 | 2.62 | 21.36 | 69.66 |
| Less than 15 ppm* | 100.00 | 35.90 | 100.00 | 72.70 | 31.80 |
| Potassium (meq/100 g) | 0.21 | 0.45 | 0.26 | 0.12 | 0.22 |
| Less than 0.30 meq/100 g* | 80.30 | 37.50 | 76.30 | 94.60 | 81.80 |
| Aluminum (meq/100g) | 4.37 | 0.06 | 0.84 | 2.84 | 0.06 |
| pH | 4.69 | 5.73 | 5.21 | 4.75 | 6.59 |
| Less than 5.5* | 100.00 | 12.50 | 83.10 | 89.10 | 6.80 |
| Sodium saturation (%) | 1.46 | 0.46 | 0.18 | 0.48 | 5.16 |
| Calcium/magnesium | 1.66 | 5.42 | 2.67 | 2.65 | 4.37 |
| Exchange capacity (meq/100 g) | 20.33 | 15.26 | 24.08 | 11.80 | 9.75 |

* Percentage of farms

Cassava yields were extremely low in Zones I, III and V. Quantitative analysis is presently being carried out to identify the principal factors determining yields. This analysis has been completed for an extended sample of farms in Zone II, where yields ranged from 0.5 to 43.3 tons/ha, with an average yield of 12.6 tons/ha.

Independent of cropping system, rainfall and soil potassium content were identified as the most important factors affecting yield in Zone II. Rainfall pattern and quantity during the crop cycle were classified for each farm as normal, excessive or deficient, according to the farmer's perception. Sixty percent of the

Table 4. **Farm size, yields and selected technology characteristics of cassava production on sample farms (average by zone).**

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| Average farm size (ha) | 7.2 | 37.5 | 16.5 | 61.3 | 18.0 |
| Cassava acreage (ha) | 2.9 | 6.4 | 2.0 | 9.4 | 5.3 |
| Input use (% of farms) | | | | | |
| Fertilizers | 18.0 | 35.9 | 8.5 | 21.8 | 13.5 |
| Insecticides | 96.7 | 60.9 | 79.7 | 85.5 | 36.4 |
| Fungicides | 0 | 3.1 | 0 | 1.8 | 0 |
| Herbicides | 0 | 10.9 | 0 | 3.6 | 0 |
| Purchased seed | 41.0 | 23.4 | 0 | 12.7 | 27.3 |
| Credit | 29.5 | 12.5 | 10.2 | 23.6 | 20.5 |
| Technical assistance | 8.2 | 6.3 | 27.1 | 1.8 | 9.1 |
| Mechanical land preparation (% of farms) | 0 | 81.3 | 3.4 | 80.0 | 52.3 |
| Monocropping (% of farms) | 77.1 | 48.4 | 71.2 | 74.6 | 36.4 |
| Cassava yields (tons/ha) | 4.2 | 12.6 | 3.0 | 6.2 | 3.7 |

farmers reported excessive rainfall while the rest said rainfall had been normal. A simple comparison of yields under these two different conditions showed a highly significant difference of about 12,000 kg/ha. Average yields on excess rainfall lots were 8,238 kg/ha, as compared with 20,509 kg/ha on lots with normal rainfall.

On the basis of soil tests made on the sample farms, lots were classified into two groups according to their potassium content; the level of 30 meq/100 g was used as the minimum acceptable level. About 45 percent of the lots contained less than this level. Average yields on these lots were estimated at 7,388 kg/ha and 19,812 kg/ha for excessive and normal rainfall, respectively. Yields on lots with 30 meq/100 g or above were 9,259 kg/ha and 20,857 kg/ha for each of the rainfall conditions, respectively. Hence a simple yield comparison indicated that low potassium content reduced yields by 1 to 2 tons/ha.

A more complete analysis of the impact of rainfall and potassium content on yields, using a production function approach, showed that the impact of rainfall was 11,800 kg/ha and that of potassium, 1,700 kg/ha, supporting the results of the simple comparisons.

Analyses aimed at identifying the principal factors causing low yields in the other zones are yet to be carried out; but it appears that in addition to the aforementioned factors, frog skin root disease in Zone I, superelongation in Zone III and cassava bacterial blight in Zones III, IV and V may also be causes of the low yields.

### Economic analysis of selected cropping systems

In approximately 30 percent of the area dedicated to cassava in Colombia, some 40 percent of the growers mix cassava with other crops (1974 Annual Report, p.106). Because of the importance of mixed cropping in cassava production and because of the lack of information on the relative economic behavior of such systems, an economic analysis of selected cropping systems was carried out in Zone II. The objectives were (1) to estimate relative yields, labor use, costs and net returns for each of the systems and (2) to identify factors—other than relative net returns—influencing the farmer's choice of cropping system for cassava in Colombia: cassava alone, cassava and maize, and cassava and beans.

Zone II (Valle and Quindío) was chosen for the analysis because of its importance in cassava production and because of the large number of farmers with each of the three cropping systems within a small region. Slightly more than one half of the cassava producers in the region grew cassava alone. Cassava mixed with maize or beans was found on 34 percent (17 percent each) of the farms while the rest of the farmers grew cassava mixed with other crops.

Farm size, area planted to cassava and use of modern technology on sample farms by cropping system are shown in Table 5. There is a very strong correlation between the level of technology and cropping system. The highest level of technology was found among farmers growing cassava alone; monocropping was basically found on the larger, more progressive farms while the small farmer tended to use mixed cropping. The larger producer's preference for monocropping is based partly on the expressed belief that net returns per unit of land are higher, which in turn appears to be based more on the influence of the extension agent than actual experience and partly on the fact that credit is easier to obtain for monocropping. Hence, institutions providing credit and technical assistance seem to play an important part in promoting monocropping among the more progressive farmers; i.e., those that need credit and receive technical assistance.

Table 5. **Farm size and use of modern technology by cropping system in Zone II.**

| | Cassava alone | Cassava and beans | Cassava and maize |
|---|---|---|---|
| Farm size (ha) | 65.0 | 34.9 | 18.7 |
| Cassava acreage (ha) | 13.3 | 4.9 | 4.0 |
| Percentage of farmers using | | | |
| Chemical fertilizers | 52.2 | 28.6 | 16.7 |
| Insecticides | 67.4 | 38.1 | 41.7 |
| Fungicides | 4.3 | 0.0 | 0.0 |
| Herbicides | 17.4 | 4.8 | 0.0 |
| Machinery | 82.6 | 81.0 | 58.3 |
| Credit | 45.7 | 23.8 | 8.3 |
| Technical assistance | 50.0 | 19.0 | 0.0 |

The main reasons for maintaining a mixed cropping system, as expressed by the producers, were (1) to maintain a supply of beans and/or maize, as well as cassava, for home consumption, (2) to provide for cash incomes during the cassava growing cycle, and (3) to obtain a higher net return per unit of land. Many farmers felt that cassava yields would not be greatly affected by the presence of maize and/or beans, hence the land would be more efficiently exploited by intercropping. The present economic analysis does not disprove the validity of this; however, it should be noted that bean and maize yields are extremely low. Furthermore, cassava yields are far below those obtained by the best farmers in the region.

Survey farmers seemed quite willing to change from one system to another. From 1972 to 1974, more than half of them (53.2 percent) changed from one system to another. The primary reasons for changing from mixed to monocropping were that (1) the previous crop had failed and the farmer was experimenting to identify a better system, (2) the farmer was told that monocropping was better, and (3) no bean and/or maize seed—or funds to pay for it—were available at planting time. On the other hand, farmers changing from mono to mixed cropping did so because they wanted to grow maize and/or beans for home consumption.

A slightly tendency toward increased monocropping was found among the survey farmers during this three-year period. This trend was not represented by an increase in the number of farmers using monocropping exclusively, but rather by an increase in the number of farmers having both cassava alone and intercropped simultaneously and the resulting reduction in the number of farmers having only a mixed cropping system. The primary reason for this tendency seems to be the desire to try monocropping initially on a limited scale while maintaining the more traditional mixed cropping systems.

Estimated labor and production costs by cropping system are shown in Tables 6 and 7. A considerable difference in labor requirements was found. The higher total labor requirements for mixed cropping systems are a result of higher requirements for planting, vigilance and harvesting. The differences in labor needs for land preparation and input application can be attributed to the differences in the level of

Table 6. **Labor use by production activity and cropping system (man-days/growing season) in Zone II.**

| | Cassava alone | Cassava and beans | Cassava and maize |
|---|---|---|---|
| Land preparation | 7.4 | 8.6 | 14.7 |
| Planting | 9.9 | 17.3 | 11.9 |
| Replanting | 0.7 | 0.6 | 0.5 |
| Input application | 5.6 | 3.8 | 1.7 |
| Weed control | 62.1 | 77.3 | 60.8 |
| Vigilance | 10.4 | 14.7 | 26.8 |
| Harvesting | 14.3 | 20.2 | 31.4 |
| Seed collection | 2.7 | 3.3 | 3.2 |
| Other activities | 1.4 | 1.2 | 1.1 |
| Total | 114.5 | 147.0 | 152.1 |

technology (mechanized land preparation) mentioned earlier and not to the cropping system per se.

Although total variable costs differ among systems, these differences were not statistically significant, basically because the variation was great among farms within each system. Principal cost differences were found in (1) seed—because of the high cost of bean seed; (2) fertilizers, insecticides and fungicides—because of the difference in use; and (3) harvesting—because of the higher costs of harvesting beans and maize.

Cassava yields were equal when cassava was grown alone or with beans (Table 8). When grown with maize, yields were lower. Although the yield difference was about 2,000 kg/ha, it was not statistically significant, primarily because of a high

Table 7. **Variable costs (US$/ha)* by production activity and cropping system in Zone II.**

| | Cassava alone | Cassava and beans | Cassava and maize |
|---|---|---|---|
| Land preparation | 44.66 | 46.71 | 41.44 |
| Seed, planting and replanting | 24.53 | 56.97 | 26.15 |
| Fertilizers, insecticides, fungicides and application | 32.22 | 21.29 | 6.38 |
| Weed control | 84.73 | 103.07 | 81.07 |
| Harvesting | 7.46 | 10.70 | 14.48 |
| Other variable costs | 8.93 | 4.51 | 2.49 |
| Total variable costs | 202.53 | 243.25 | 172.01 |

* Exchange rate used: Col $30 = US$1

Table 8. **Yields, value of production and margin for fixed costs and net returns by cropping system in Zone II.**

| | Cassava alone | Cassava and beans | Cassava and maize |
|---|---|---|---|
| Yields (tons/ha): Cassava | 12.9 | 13.2 | 11.0 |
| Beans | - | 0.16 | - |
| Maize | - | - | - |
| Value of production (US$/ha)* | 869 | 984 | 815 |
| Total variable costs (US$/ha) | 203 | 243.25 | 172 |
| Margin for fixed costs and net returns | 667 | 742 | 643 |

* Average prices received on sample farms: cassava, US$67.33/ton; beans, US$612.70/ton; maize, US$107.73/ton

variation in yields within the cropping system. Furthermore, a production function analysis did not reveal any significant difference among cassava yields for the different systems. The data provide strong evidence that the presence of beans and maize intercropped with cassava did not reduce cassava yields on the sample farms. Since no significant difference was found among total variable costs, it may be concluded that net returns per unit of land from cassava alone are below those obtained from cassava mixed with maize or beans unless yields or prices of the latter crops are zero. Relative net returns from the mixed cropping systems depend on the relative prices of maize and beans. At the current price ratio of $\frac{P\ (Maize)}{P\ (Beans)} = 0.18$, cassava and beans provide the highest net returns. Net returns from the two systems would be equal at a price ratio of 0.23.

On the basis of the findings from this study, it appears that net returns from the cropping systems are slightly above those from cassava monocropping among the sample farms. In addition to relative net returns, it appears that farmers favor mixed cropping because they want to produce maize and beans for home consumption and they need cash income during the cassava crop cycle. On the other hand, certain institutional pressures favor monocropping. The survey farmers seemed quite willing to experiment with cropping systems other than the one they were currently using so they would probably shift rapidly toward whichever system offered relatively higher yield potentials.

## PHYSIOLOGY

Efforts to define a plant ideotype for cassava have continued. Last year the importance of having a leaf area index (LAI) of about 3 during the root bulking period, coupled with a long leaf life, was stressed mainly through a study based on a hypothetical model. This year the experimental data confirmed this hypothesis more directly.

M Colombia 113 was planted in a systematic density design to give different leaf area indices. Two harvests were taken at a six-week interval, during which time all fallen leaves were collected. Leaf life was quite short at about seven weeks (Fig. 1). Crop growth rate increased with LAI to about 110 g $m^{-2}wk^{-1}$ at LAI 4; above this level it declined rapidly (Fig. 2). The reason for this decline is not apparent but may be due to high respiration rates at higher plant populations or the large proportion of very

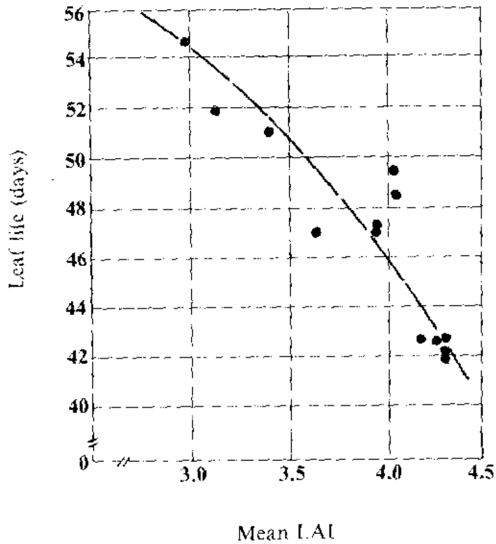


Figure 1. **Leaf life as a function of mean LAI during the six weeks after leaf formation in M Colombia 113.**

young leaves at high populations. In many crops photosynthesis increases with leaf age and then declines slowly; at high populations with a leaf life of only 42 days, it is probable that average photosynthesis is quite low. Root growth rate showed a marked decline from 45 g $m^{-2}wk^{-1}$ at a LAI of 3 to 3.5 to less than 20 g $m^{-2}wk^{-1}$ at a LAI of 4.2 (Fig. 3). These data confirm the hypothesis that the optimum LAI for root growth in cassava is 3 to 3.5 during the bulking period.

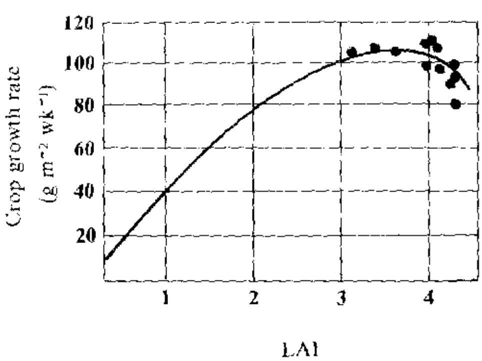


Figure 2. **Crop growth rate of M Colombia 113 as a function of LAI.**

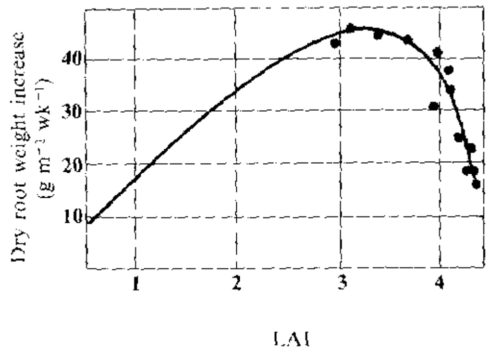


Figure 3. **Root weight increase as a function of LAI in M Colombia 113.**

M Colombia 113 and M Colombia 22 were grown at 1 x 1 m spacing. In the treated plots, half the young leaves were removed as they formed at different growth stages. In M Colombia 22 yields decreased markedly when LAI was reduced at all stages (Fig. 4). As maximum LAI was always less than 2, this result was consistent with the idea of an optimum LAI of 3 to 3.5. In M Colombia 113 the control plots had LAI's below the optimum at 100 and 300 days but above the optimum at 200 days; plots with leaves removed at 100 to 200 days had LAI's similar to the control at 100 and 300 days but below the optimum at 2.1 at 200 days. The treated plants yielded 97 percent as much as the controls; thus it appears that the control plots exceeded the optimum whereas treated plots were below, once again placing the optimum between 3 to 4 (Fig. 4). In plots clipped at 0 to 100 days and at 200 to 300 days, LAI's were considerably lower for long periods and yields were substantially reduced (Fig. 4).

Leaf area index is a function of individual leaf size, rate of leaf formation per apex, branching habit and leaf life. In CMC-84 plots planted and harvested at different times, there was an increase in leaf size up to three to four months after planting, after which time, it decreased (Fig. 5). Similar data were found for CMC-9 grown in entomology plots (Fig. 6). Both varieties branch (CMC-9 profusely and

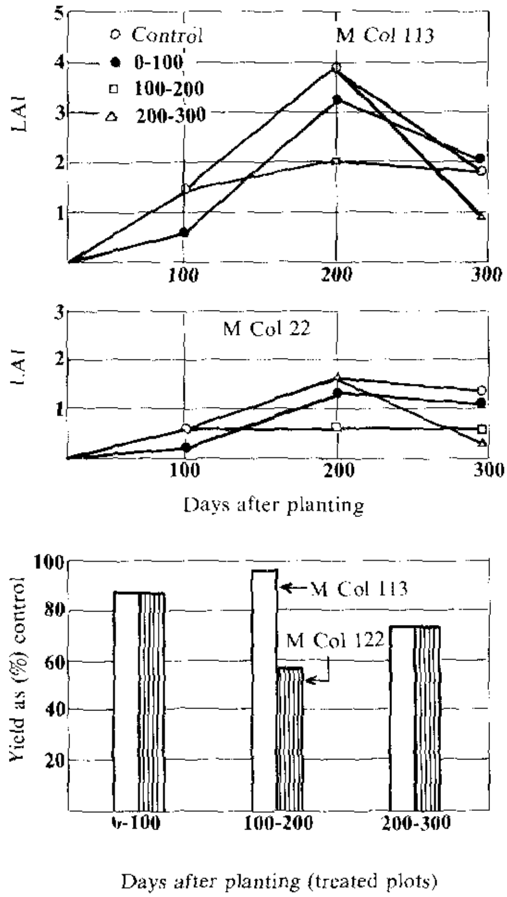


Figure 4. **Effects of removing 50% of the leaves as they form at different growth stages on yield and LAI of M Colombia 113 and 22.**

CMC-84 less profusely), and it was thought that this decrease in leaf size might be related to changes in branch number. However, the same trend was noted in M Colombia 1120, a nonbranching variety (Fig. 6); thus leaf size tends to decline with time after about four months although great variability exists among varieties.

The number of leaves formed per continuous branch was measured on spaced plants. The cumulative number formed per apex increased with time from 10 to 40 weeks after planting; however, the rate of increase declined (Fig. 7). There was little difference among varieties; i.e., about

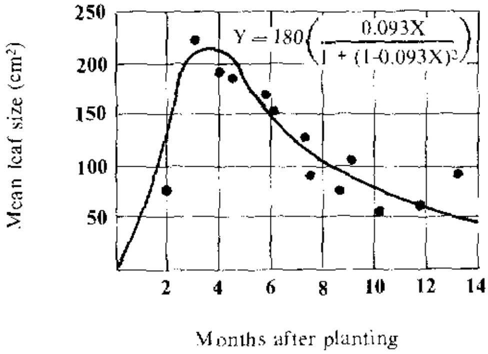


Figure 5. **Leaf size of CMC-84 at different times after planting.**

10 percent. M Colombia 22 and M Colombia 113 were grown at 1 x 1 m spacing. Once again little difference between the two varieties was found; furthermore the increase from 10 to 40 weeks was similar to that found in the other trial. The number of leaves formed per branch could be very precisely described by the equation $Y = 2.85 \tan^{-1} (0.0296t)$ in the case of M Colombia 113 (Fig. 8). From these data it is concluded that little varietal difference exists in the number of leaves formed per apex.

Shading was found previously to reduce leaf life. M Colombia 113 was planted in a

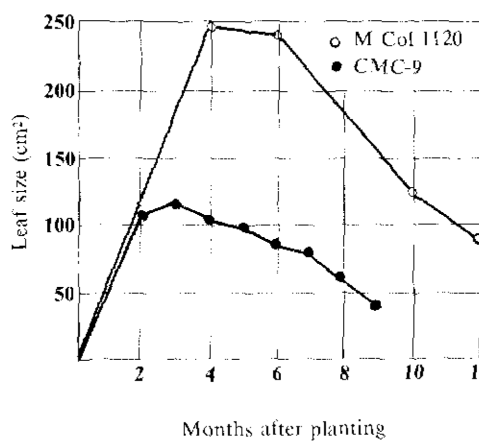


Figure 6. **Leaf area per leaf of CMC-9, a highly branched variety, and M Colombia 1120, a nonbranching type.**

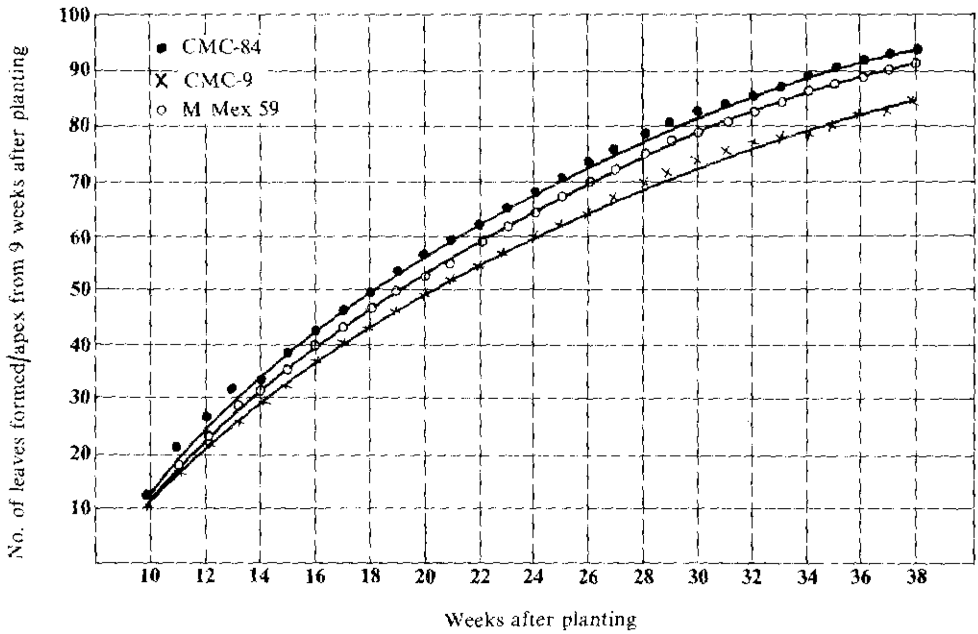


Figure 7. **Total number of leaves produced per apex from nine weeks after planting (spaced plants).**

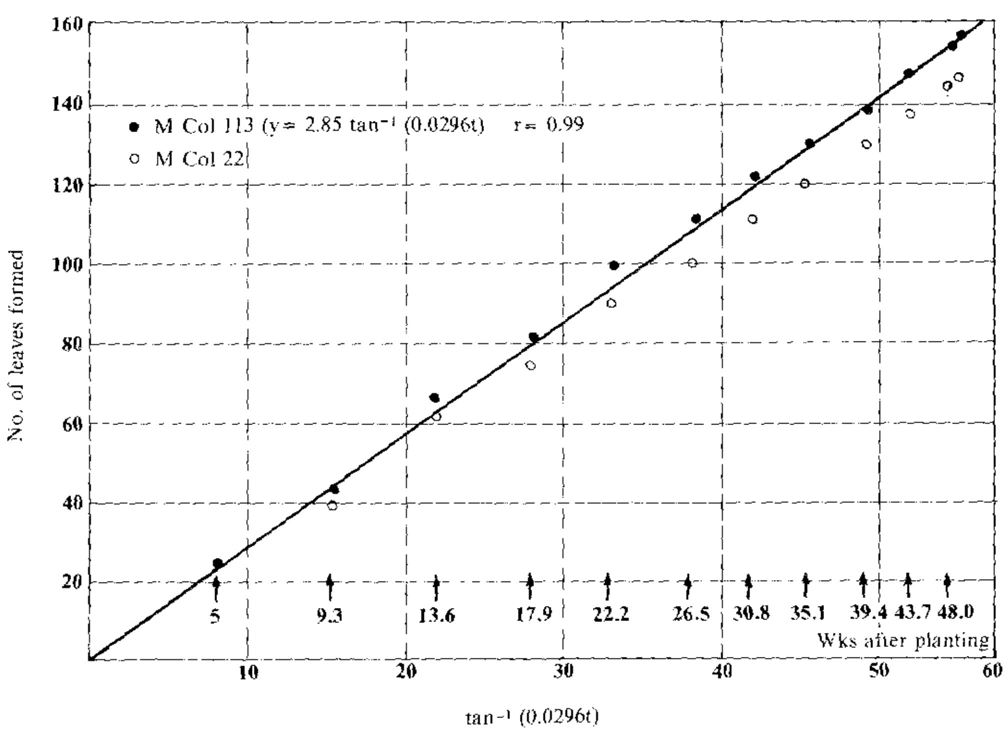


Figure 8. **Number of leaves produced per apex in M Colombia 113 and M Colombia 22.**

systematic density trial and leaf life was measured. Leaf life decreased in proportion to the LAI at the time the leaves formed (Fig. 1). These data suggest that it will be difficult to obtain LAI's above 4 as leaf life drops very rapidly above this level. The low efficiency of maintaining high LAI's for root growth (Fig. 3) is not only explained by mutual shading and reduced crop growth rate but also by the extra energy used for producing a large number of short-lived leaves whose efficiency is low in terms of energy produced per unit of energy expended in formation.

Leaf life of spaced plants was measured for leaves formed 10 to 23 weeks after planting. Leaf life did not apparently change with plant age (Fig. 9). Consistent varietal differences were found: The variety CMC-9 (Llanera) had a consistently long leaf life (94-114 days) in comparison to the other four varieties (66-98 days). This difference is not likely due to shading because the plants were widely spaced (2,500 plants|ha) and CMC-84 (with a short leaf life) is of about the same vigor as CMC-9. It is therefore concluded that large and useful differences in leaf life exist among varieties.

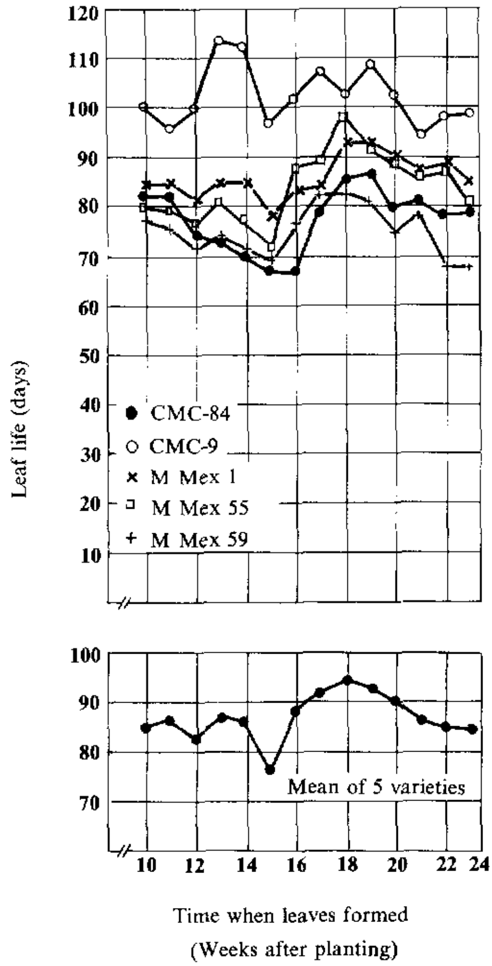


Figure 9. **Leaf life of five varieties as a function of time after planting (spaced plants).**

These data suggest that the key to high root yields in cassava is to maintain LAI at the optimum level for as long as possible during the root bulking phase. There appears to be little genetic variation in rate of leaf formation per apex and the tendency for leaf size to decrease after four months; hence manipulation of these characters to maintain optimum LAI does not appear possible. On the other hand, variation does exist for leaf life and branching habit so these can be manipulated to maintain the optimum LAI. At present the interaction between these characters and the environment is not known.

The model to describe the existence of an optimum LAI and the overall growth of cassava was based on the fact that top growth takes precedence over root growth and that roots accept the excess carbohydrate produced by the tops. Shading five-month-old plants of M Colombia 22 reduced the number of new leaves formed per apex by 15 percent, increased leaf size by 6 percent and reduced stem weight changes by 8 percent. Therefore, the effects of reduced carbohydrate supply on top growth are minimal at a level of 50 percent shading. On the other hand, shading reduced root dry weight increase by 35 percent, confirming that top growth has preference (not complete) over root growth.

Many varieties of cassava flower and fruit readily; however, little is known of the effects of flowers and fruit production on root yield. Five varieties were grown as spaced plants and flowers were removed as they formed. This was quite easy to do up to about seven months after planting, when it became difficult without damaging plants and several flowers could not be removed. Ten months after planting, the roots and tops were harvested. There was no relationship between yield and number of fruits per plant; therefore, it was concluded that flowering, at least at moderate levels, had no adverse effect on root yield.

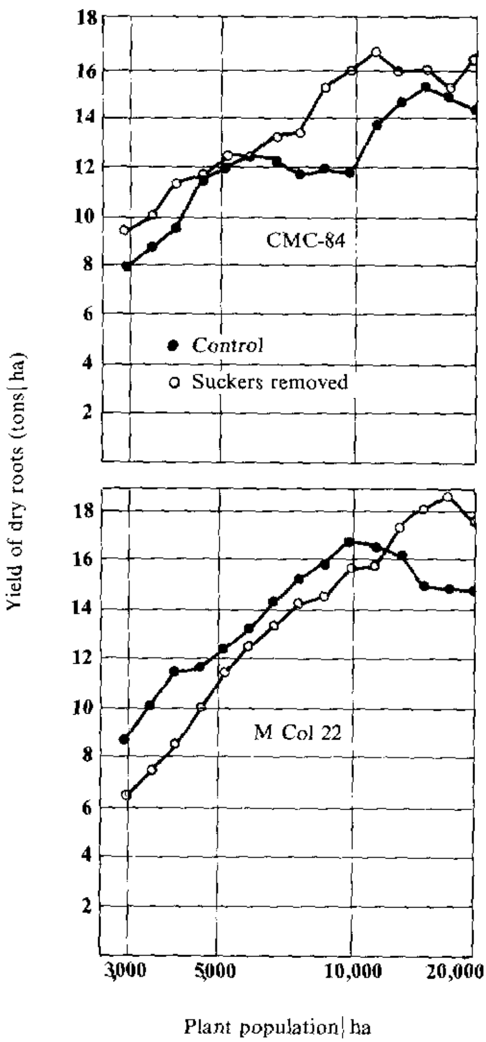


Figure 10. **Yield of two cassava varieties at different plant densities with removal of suckers.**

Many farmers in Colombia remove side or sucker branches. At CIAT it was found that these suckers generally have long internodes and very small leaves. This suggests that leaf production per unit of stem weight is small and that these suckers would be rather inefficient in producing excess carbohydrate to meet their own needs. M Colombia 22 and CMC-84, a low- and a medium-vigor variety, were planted in a systematic density design. On treated plants the suckers were removed every month. In CMC-84, treated plants yielded slightly more at all plant populations; the mean increase was approximately 1.5 tons|ha of dry roots (Fig. 10). The less vigorous M Colombia 22 yielded about 2 tons|ha less when suckers were removed at low plant populations but about 3 tons|ha more at high plant populations. Maximum yields were about 16.5 tons|ha with suckers and about 18 tons|ha without suckers. It appears that suckers are useful only at low populations with low vigor types; otherwise they are inefficient and reduce yields.

## PROPAGATION

In the 1973 Annual Report a propagation method was described. Small green shoots were rooted in peat pots filled with sterilized soil and placed in a propagation frame; after rooting they were transplanted in the field. This system was costly because of the need to sterilize soil and purchase peat pots.

Recently it was found that young green shoots rooted in sterile water satisfactorily. Green shoots (8 cm tall) are placed in small flasks containing boiled water (Fig. 11).

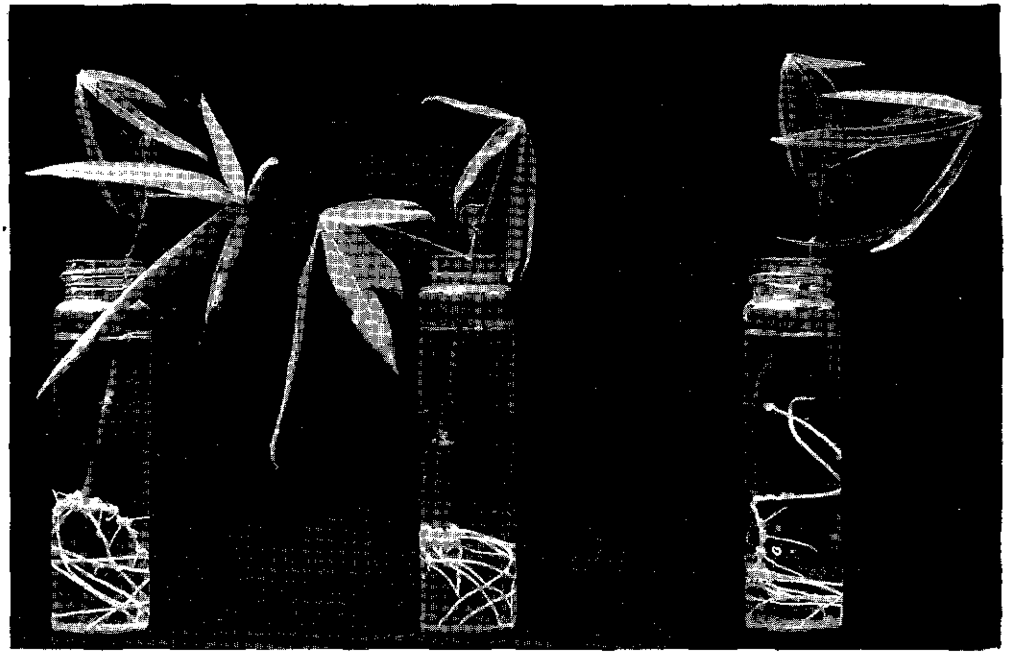

Figure 11. **Shoots rooted in water. These plants have passed the stage when they should be planted.**

After about one week, a callus forms on the base of the shoots and very shortly afterwards small roots appear. When these roots appear, the plantlets can be transplanted directly to the field if it is well prepared. The plantlets must be planted deep enough (up to the lowest leaf) so they do not dry out.

## PATHOLOGY

During 1975 emphasis was placed on the identification of cultivars and the testing of $F_1$ lines for resistance to the major diseases of cassava in America: cassava bacterial blight (CBB), Cercospora leaf spots (*Cercospora henningsii* and *C. vicosae*), Phoma leaf spot and the superelongation disease. Several etiological aspects of the causal agent of the superelongation disease and of an unknown bacterial disease of cassava (bacterial stem rot) were investigated, as well as methods for screening for resistance to the major cassava diseases. The survival of CBB in plant tissues and exudates is being investigated under controlled environmental conditions. Assessments for disease losses (some of which are still under way) were established by planting in localities where the severity of each particular disease was great.

### Cassava bacterial blight

#### Screening for resistance

Although screening for resistance under field conditions has given consistent results, final evaluations are possible only after a rainy season, thus requiring extensive time after inoculation to obtain results. A simple method for rapid screening under greenhouse conditions was developed. Six to ten cuttings per hybrid or cultivar are grown in pots inside a greenhouse with about 83 percent relative humidity (maximum, 99 percent; minimum, 65 percent) and a temperature of 24°C (maximum, 34°C; minimum,

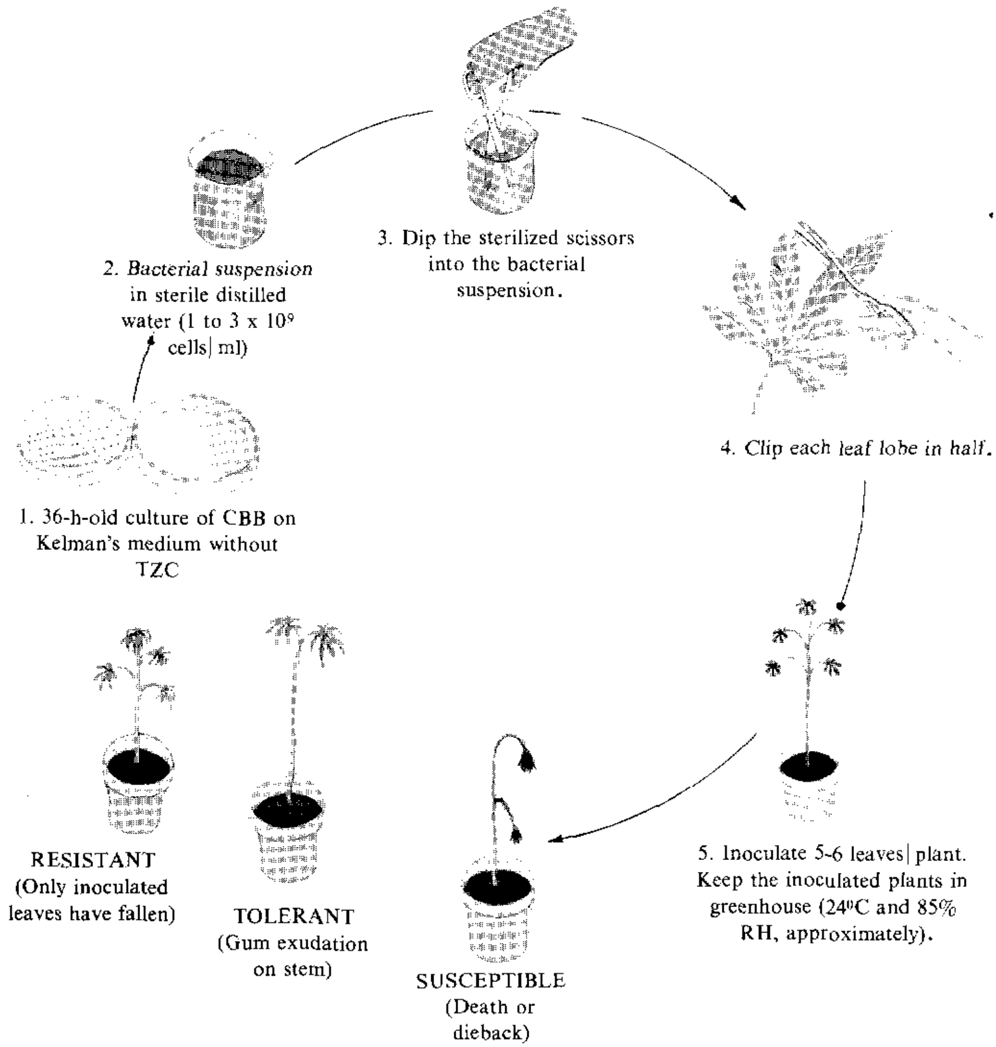


Figure 12. **Clipping method for screening for resistance to CBB.**

19°C). When plants are 30 to 35 days old, five to seven leaves are clipped with scissors infested by dipping into a bacterial suspension of 1.5 to 3.0 x $10^9$ cells| ml. The first leaf symptoms occur seven days after inoculation; 19 to 24 days later, gum exudation is observed along the stem on the susceptible genotypes. Resistance is evaluated 40 to 45 days after inoculation. (Fig. 12).

Interactions between bacterial concentrations, serial inoculations, plant and inoculum ages were also investigated. Best results were obtained when one-month-old plants were clip inoculated with 36-hour-old cultures at a concentration of 1 to 3 x $10^9$ cells| ml. A high relative humidity (more than 80 percent and a moderate temperature (around 24°C) gave best results.

### Disease evaluation for resistance

An evaluation of 870 $F_1$ lines obtained from different crosses was made for resistance to CBB under greenhouse conditions by inoculating six to ten plants| line (Table 9). A higher percentage of resistant lines appeared when CBB-resistant cultivars, which had been identified after screening the entire germplasm collection, were used for controlled hybridizations. This stresses the importance of using CBB-resistant sources and controlled pollinations for a high breeding efficiency for resistance to CBB.

Simultaneous to the screening of hybrids, several well-known cultivars such as Llanera, M Colombia 22, M Colombia 113 and M Colombia 647, were also tested by using the clip inoculation method for CBB reaction. Results were in complete accordance with those obtained in repeated field trials. Cultivars like M Colombia 22 and M Colombia 113 were very susceptible, both in the field and by using the new inoculation method under greenhouse conditions. M Colombia 647, which had always shown resistance to CBB under field conditions, showed high resistance with clip inoculation. These results confirm the efficiency of the clip inoculation technique; moreover, a considerably larger amount of material can be tested in a short time with this method.

### Disease losses

Data taken by the cassava soil group at Carimagua show that CBB could reduce yields of the tolerant cultivar Llanera from 50 to 90 percent when the disease appeared during the first four months of growth. This obviously suggests that CBB seriously affects yield in cassava plantations in areas where there are prolonged periods of rainfall, such as in the Llanos Orientales of Colombia. When infection occurred immediately after germination, yield was more severely reduced than when it appeared four months after planting. N (as urea) or K (as KCl) applications did not correlate with CBB severity, but Mg applications (as MgO) increase its severity and reduced yield.

### CBB survival

The survival of CBB in soil was studied during 1974. During 1975, CBB survival in exudates and plant tissues was investigated. Results up to October, 1975 showed that CBB may survive for more than four months and at high concentrations (1 x $10^7$ cells| ml) in plant exudates stored at room temperature (around 24°C and 70% RH) or in a controlled dry environment by using $CaCl_2$ (24°C and 20% RH). CBB also appears to survive for the same period in plant tissues but at lower concentrations than in

Table 9. Evaluation of resistance to CBB of $F_1$ crosses among cultivars with different degrees of resistance.

| Cross type | Total no. of $F_1$ crosses | Disease rating * 1 | 2 | 3 |
|---|---|---|---|---|
| Open pollinated lines | 59 | 1 (1.6%)** | 9 (15.3%) | 49 (83.1%) |
| Control pollinated lines (Susceptible x Susceptible) | 267 | 3 (1.1%) | 64 (23.9%) | 200 (75.0%) |
| Control pollinated lines (Susceptible x Resistant) | 544 | 30 (5.5%) | 178 (32.7%) | 336 (61.8%) |

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

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

exudates. CBB survival in necrosed stem tissue is longer than in necrosed petiole and leaf tissues. These results stress the importance of our previous suggestions for a careful elimination of all cassava debris and volunteer plants by burning in order to eradicate CBB from infected plantations.

### Cercospora leaf spots

Work on Cercospora leaf spots was concentrated on *C. henningsii* (brown leaf spot) and *C. vicosae* (blight leaf spot), the most serious and widespread pathogens in cassava plantations located below 1200 m.

#### Screening methods

*Cercospora henningsii* and *C. vicosae* are prevalent and endemic at CIAT, possibly because of the continuous planting of cassava and the favorable environmental conditions for disease development. Field evaluation was possible throughout the year, giving consistent results when readings were taken on seven- to eight-month-old plants spaced 1 x 1 m apart. Disease rating was evaluated on hybrids and cultivars by calculating the percentage of infection of the leaves for each pathogen. Resistant hybrids or cultivars were those which showed narrower leaf lesions and less than 10 percent of the total leaves infected.

Checking 454 and 449 leaves of two susceptible cultivars (M Ecuador 150 and M Panama 64) from their emergence to leaf drop, it was found that only 13 and 11 percent, respectively, of their leaves remained healthy. Of 325 leaves of CMC-84, a cultivar resistant to *C. henningsii* but susceptible to *C. vicosae*, 27 percent were healthy. In contrast, 90 percent of the leaves of M Mexico 59, a cultivar resistant to both **Cercospora** spp., remained healthy. It was also found that healthy leaves of the susceptible cultivars (M Ecuador 150 and M Panama 64) fell about 17 percent later than the diseased ones.

It appears that the environmental conditions at CIAT are good for the occurrence of these two diseases; therefore, field evaluation for *C. henningsii* and *C. vicosae* resistance could be successfully done in areas located at around 1000 m altitude with steady rainfall distribution throughout the year. Evaluation must be taken seven months after planting. It appears that high plant density per area increases disease severity and therefore the efficiency of screening.

#### Evaluation for resistance

The evaluation of resistance to *C. henningsii* and *C. vicosae* in CIAT's cassava germplasm is presented in Table 10. Resistance to *C. henningsii* (58 percent) was higher than to *C. vicosae* (11 percent). This suggests that resistance to *C. henningsii* is more commonly found and easier to incorporate.

Table 10. **Field evaluation of resistance to *Cercospora henningsii* and *C. vicosae* in CIAT's cassava germplasm collection (2,061 cultivars).**

| | Disease rating * | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| *C. henningsii* | 1,192 (58%)** | 555 (27%) | 314 (15%) |
| *C. vicosae* | 221 (11%) | 1,134 (55%) | 706 (34%) |
| Evaluation for both pathogens | 175 ( 8%) | 1,157 (56%) | 729 (36%) |

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

** Percentage related to the total number of evaluated cultivars

Many of the cultivars resistant to *C. vicosae* were also resistant to *C. henningsii*, but the resistance to these two pathogens does not appear to be linked in any way because there were cultivars with resistance to either one. A relatively satisfactory percentage (8 percent) of resistance to both pathogens exists in CIAT's cassava germplasm.

The evaluation of resistance to *C. henningsii* and *C. vicosae* of $F_1$ hybrids among cultivars with different degrees of resistance is presented in Tables 11, 12 and 13. As was found in the evaluation of the germplasm (Table 10), resistance to *C. henningsii* among $F_1$ hybrids was much more frequent than resistance to *C. vicosae* (Tables 11 and 12).

For both *C. henningsii* and *C. vicosae*, higher percentages of resistant lines were obtained when resistant cultivars were used as the cross parents (Table 13). There seems to be no apparent barrier to incorporating resistance to the two **Cercospora** spp. into one genotype; hence the resistance to Cercospora can be incorporated into any favorable genotype by using resistant parents in hybridization programs.

## The superelongation disease

### Etiological studies

The identification of the causal agent of the superelongation disease of cassava was confirmed as a species of the fungal genus **Sphaceloma**; the pathogen may well be *Sphaceloma manihoticola,* which was previously reported causing a somewhat similar disease on *Manihot esculenta* and *M. glaziovii* in Brazil in 1950. A host range study of the superelongation pathogen was made, using a number of available **Manihot** and related species including *M. esculenta, M. glaziovii, M. carthagenensis, M. faetida, M. silvestre, Ricinus communis, Jatropha gossypifolia* and *Euphorbia pulcherrima* (poinsettia). Only *M. esculenta* and *M. glaziovii* were

Table 11. **Field evaluation of resistance to *Cercospora henningsii* (brown leaf spot) of $F_1$ crosses among cultivars with different degrees of resistance.**

| Pollination system | Total no. of $F_1$ crosses | Disease rating * | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | |
| Self-pollinated | | | | | | | |
| Resistant | 30 | 12 | (40%)** | 8 | (27%) | 10 | (33%) |
| Tolerant | 52 | 15 | (29%) | 23 | (44%) | 14 | (27%) |
| Susceptible | 7 | 2 | (29%) | 5 | (71%) | 0 | ( 0%) |
| Controlled pollination | | | | | | | |
| Resistant x Resistant | 259 | 160 | (62%) | 69 | (27%) | 30 | (11%) |
| Resistant x Tolerant | 78 | 27 | (35%) | 42 | (54%) | 9 | (11%) |
| Resistant x Susceptible | 235 | 40 | (17%) | 92 | (39%) | 103 | (44%) |
| Tolerant x Tolerant | 1,240 | 159 | (13%) | 337 | (27%) | 744 | (60%) |
| Tolerant x Susceptible | 1,331 | 269 | (20%) | 265 | (20%) | 804 | (60%) |
| Tolerant x Resistant | 3,967 | 2,192 | (55%) | 664 | (17%) | 1,111 | (28%) |
| Susceptible x Tolerant | 46 | 9 | (21%) | 16 | (37%) | 18 | (42%) |
| Susceptible x Resistant | 76 | 30 | (39%) | 25 | (33%) | 21 | (28%) |
| Total | 7,321 | | | | | | |

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

** Percentage related to the total number of $F_1$ lines evaluated, cross type

Table 12. **Field evaluation of resistance to *Cercospora vicosae* (blight leaf spot) of $F_1$ crosses among cultivars with different degrees of resistance.**

| Pollination system | Total no. of $F_1$ crosses | Disease rating * | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Self-pollinated Tolerant | 89 | 15 (17%)** | 25 (28%) | 49 (55%) |
| Controlled pollination | | | | |
| Resistant x Tolerant | 44 | 23 (52%) | 14 (32%) | 7 (16%) |
| Tolerant x Tolerant | 2,233 | 275 (12%) | 555 (24%) | 1,403 (64%) |
| Tolerant x Susceptible | 3,797 | 212 ( 6%) | 836 (22%) | 2,749 (72%) |
| Tolerant x Resistant | 911 | 359 (39%) | 253 (28%) | 299 (33%) |
| Susceptible x Susceptible | 178 | 5 ( 3%) | 70 (39%) | 103 (58%) |
| Susceptible x Tolerant | 60 | 5 ( 8%) | 25 (42%) | 30 (50%) |
| Susceptible x Resistant | 6 | 0 ( 0%)? | 0 ( 0%)? | 6 (100%) |
| Total | 7,318 | | | |

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

** Percentage related to the total number of $F_1$ lines evaluated|cross type

infected by the pathogen, and the pathogen was isolated from naturally infected plants belonging to these two species. However, a **Sphaceloma** sp. previously reported as *S. poinsettiae,* isolated from infected poinsettia plants, induced symptoms on cassava similar to those induced by **Sphaceloma** sp. on cassava. Until further evidence can prove otherwise, it is suggested that the superelongation pathogen may be the same fungus as reported by Bitancourt and Jenkins as *Sphaceloma manihoticola*.

The conidia of the superelongation causal agent are produced on phialides and are small (averaging 5.3 x 2.7 µ), oblong to oblong-elliptical. The conidia swell greatly prior to germination. The effects of temperature, moisture, light, spore concentration and age of colony upon conidial germination were tested. Free moisture was shown to be essential for germination, and optimum germination occurred at approximately 28.5°C. Light and spore concentration had little or no effect upon germination, but the percentage of germination decreased with increased colony age.

The aforementioned data were necessary to establish a successful system for

Table 13. **Field evaluation of resistance to both *Cercospora henningsii* and *C. vicosae* of $F_1$ crosses among cultivars with different degrees of resistance.**

| Pollination system | Parental reaction | Resistant lines\| No. of lines evaluated | % of resistance |
|---|---|---|---|
| Self-pollinated | Tolerant | 11\|82 | 13.4 |
| Self-pollinated | Susceptible | 0\|8 | 0.0 |
| Control pollinated | Resistant x Susceptible* | 225\|976 | 23.6 |
| Control pollinated | Tolerant x Susceptible* | 238\|6,075 | 3.9 |
| Control pollinated | Susceptible x Susceptible* | 2\|198 | 1.0 |
| Total | | 476\|7,318 | 6.5 |

* Including some reciprocal combinations

Table 14. **Yields of two resistant (R) and one susceptible (S) cassava clone when the superelongation disease occurred five months after planting.**

| Replicate | Yield (tons/ha) | | |
|---|---|---|---|
| | Llanera (R) | M Col 22 (R) | M Col 113 (S) |
| 1 | 29.13 | 25.57 | 33.27 |
| 2 | 23.23 | 31.06 | 27.87 |
| 3 | 32.90 | 37.67 | 35.53 |
| Average* | 28.42 | 31.43 | 32.22 |

* The difference between means of the above three yields was not significant at the 1% level (F test).

artificially inoculating young cassava plants. A minimum of approximately eight hours of free moisture was necessary for infection to occur. Increased disease incidence and severity occurred as the number of hours under free moisture increased. No conclusive evidence of pathogenic races of the fungus has been observed yet. Histological studies of inoculated leaves showed that the fungus directly penetrates the host.

## Disease losses

Yields can be greatly reduced in heavily infected fields. Two resistant cultivars, Llanera and M Colombia 22, and the susceptible cultivar M Colombia 113 were inoculated one month after planting; in a second trial, inoculation was made five months after planting. Where infection occurred early, yield losses were approximately 80 percent. After the fifth month after planting, no significant loss was recorded (Tables 14 and 15 and Fig. 13).

## Dissemination

Disease dissemination and reduction in plant establishment by the use of infected planting material was studied with the susceptible cultivar M Colombia 113. Cuttings (144) taken from healthy and diseased plantations were planted in an isolated locality. After 25 days germination

Table 15. **Yields of two resistant (R) and one susceptible (S) cassava clone when the superelongation disease occurred one month after planting.**

| Replicate | Yield (tons/ha) | | |
|---|---|---|---|
| | Llanera (R) | M Col 22 (R) | M Col 113 (S) |
| 1 | 19.08 | 18.05 | 3.75 |
| 2 | 17.32 | 15.45 | 3.75 |
| 3 | 19.17 | 17.43 | 3.25 |
| Average | 18.52* | 16.98 | 3.58 |

* LSD between mean yields at the 1% level is 3.04.

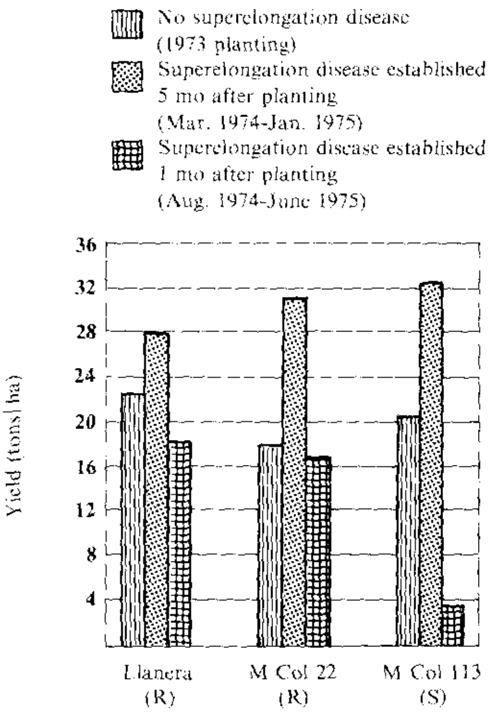


Figure 13. **Mean yield of two resistant (R) and one susceptible (S) cassava clone under three different superelongation disease situations.**

was reduced about 3 percent; 26 percent of the plants obtained from diseased cuttings were infected and the weight of leaves and stems was reduced by about 41 percent.

## Phoma leaf spot

The correlation between disease reaction and yield of more than 348 cultivars was determined 15 months after planting. A group of 113 cultivars was harvested at the end of the rainy season, and another group of 235 cultivars was harvested immediately after the dry season. The cultivars were planted in rows (1 m apart) of 11 plants|cultivar (0.50 m apart) with two replications.

Fresh root yields in the area (Popayán) average 6 tons|ha. When cultivars were harvested at the end of the rainy season, 100 percent of the very susceptible and 84 percent of the susceptible cultivars yielded less than the regional average. In contrast, 70 and 100 percent of the tolerant and resistant cultivars, respectively, produced more than the regional average. When harvested at the end of the dry season, 93 and 68 percent of the very susceptible and susceptible cultivars, respectively, yielded less than 6 tons|ha; but 92 and 100 percent of the tolerant and resistant cultivars yielded more. To increase yields in areas above 1300 m, where Phoma leaf spot disease is more severe and endemic, it is necessary to incorporate resistance to this disease into high-yielding cultivars.

By grouping cultivars in accordance with their disease rating (Figs. 14 and 15), it can be seen that yields increase when resistance to Phoma leaf spot increases. Some of the resistant cultivars yielded only as much as the tolerant ones (Fig. 15), which could be related to genetic yield ability per se.

To verify the resistance shown by cultivars previously evaluated in the

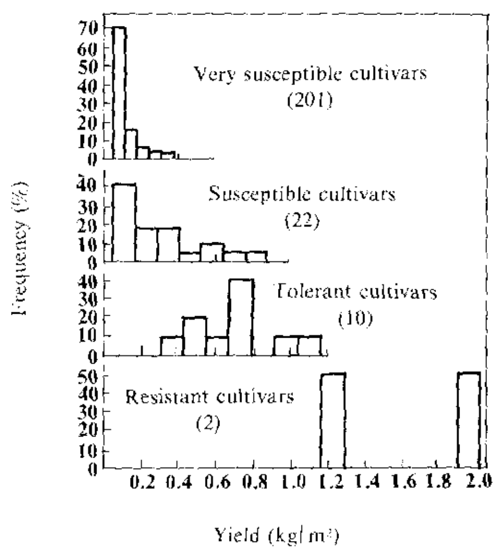


Figure 14. **Yield of 235 cultivars grouped according to their reaction to Phoma leaf spot. Cultivars were harvested 15 months after planting and at the end of the rainy season.**

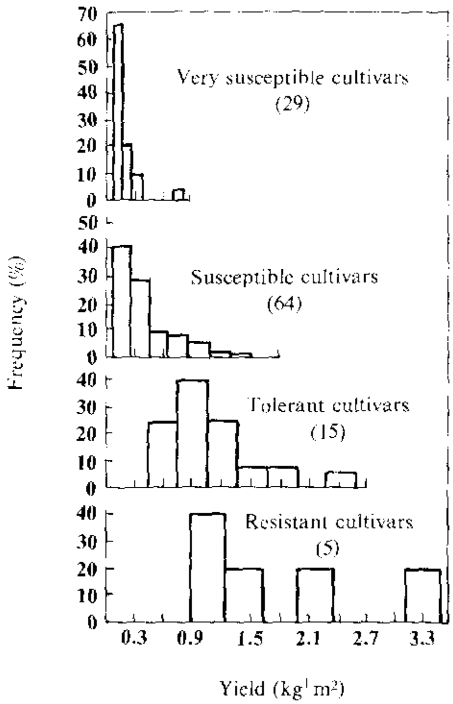


Figure 15. **Yield of 113 cultivars grouped according to their reaction to Phoma leaf spot. Cultivars were harvested 15 months after planting and at the end of the dry season.**

Popayán area, nine highly resistant cultivars were planted in El Darién (1430 m), where the disease occurs with greater severity. In both localities, the susceptible cultivars showed complete defoliation, dieback and, in many cases, death; consequently, total plant weight was considerably reduced. The resistant cultivars grew normally, producing a high total weight of fresh matter according to the intrinsic vigor of each cultivar (Table 16). It was concluded that these highly resistant cultivars could be used successfully in any breeding program for resistance to this disease.

## Bacterial stem rot

A bacterial species pathogenic to cassava was isolated from rotted stem samples taken from three different cassava-growing areas. Preliminary cultural, morphological, physiological and biochemical tests, as well as disease symptomatology, showed that this bacterial species and the disease it induces are far different from the cassava blight bacterium.

Tests suggest that the species belongs to the genus **Erwinia.** It is a Gram-negative, rod-shaped peritrichous organism that grows well on several sugar media, producing round, white and entire colonies. It produces gelatinase; causes soft rot in potatoes, carrots and cassava slides; liquefies pectate gel and does not use sorbitol.

Bacterial penetration and establishment occur through wounds, which in nature may be caused by insects. Infected plants were always damaged by **Anastrepha** sp. (fruit flies), but not all Anastrepha-infected plants showed bacterial infection. The relationship between insects and this bacterium to pathogenesis is still

Table 16. **Total plant weight of cultivars resistant (R), tolerant (T) and susceptible (S) to Phoma leaf spot, 12 months after planting in El Darién.**

| Cultivar collection no. | Disease reaction | % of defoliation | Total weight* (tons/ha) |
|---|---|---|---|
| CMC-92 | R | 20 | 54.4 |
| M Col 340 | R | 25 | 14.3 |
| M Col 230 | R | 22 | 19.1 |
| M Col 276 | R | 18 | 29.4 |
| M Col 80 | R | 24 | 25.7 |
| M Col 235 | R | 22 | 23.3 |
| M Col 291 | R | 21 | 15.9 |
| M Col 2 | R | 17 | 15.1 |
| M Col 307 | T | 53 | 13.0 |
| CMC-39 | T | 58 | 12.4 |
| Valluna | S | 98 | 3.6 |
| M Col 22 | S | 100 | 0.17 |

* Total plant weight was calculated from three randomized plots of 9 plants; plot borders were eliminated.

unknown; the insect damage is further discussed in the entomology section.

Pathogenic tests showed that the organism is restricted to stem tissues. Infected plants show blackish necrosis, then wilting and finally dieback. Buds located along infected stem portions are first invaded and necrosed; thus the infected stem parts may be lost for planting purposes. Even though its effect on cassava production is unknown, it appears that the most important factor is related to the damage to buds, which could be reflected in germination and crop establishment when planting material is taken from infected plants.

### Cassava rust

Cassava rust was first reported in 1887. Six different species belonging to the Uredinal order are reported, but neither their taxonomic status nor their geographic distribution had been defined. A cooperative study between the Instituto Colombiano Agropecuario/Universidad Nacional and CIAT was initiated this year.

The characteristic taxonomic features for each pathogenic species were determined. Keys for their taxonomic identification are being produced with descriptions and illustrative diagrams based on samples obtained from different herbaria.

## ENTOMOLOGY

An extensive program to evaluate the cassava germplasm bank for resistance to several mite species was initiated this year. A procedure was developed to evaluate resistance to mites. Continued emphasis was placed on determining yield losses associated with thrips, mites, fruit flies and shoot flies. Studies were undertaken on the biology, ecology and importance of whiteflies and fruit flies. Control practices were investigated for insects attacking planting material and germinating plants.

### Insect and mite population fluctuations

A two-year study of the factors influencing insect populations in cassava was completed at CIAT during 1975. This insect complex includes mites, thrips, the cassava hornworm, the shoot fly (*Silba pendula*) and the cassava lace bug (*Vatiga manihoti*). Three cuttings in two replications of 90 cassava varieties were planted on May 1, August 1 and November 1, 1973. Fifty varieties were planted on February 1 and May 1, 1974. Monthly evaluations were made of the aforementioned insects.

Mite populations were measured by sampling the central part of the plant and counting the number of mites found in a 20-$cm^2$ leaf area. Thrips populations were determined by evaluating the damage using a visual scale of 0 to 5 (0 = no damage, 5 = apical and lateral buds dead). The number of parasitized and nonparasitized cassava hornworm eggs were sampled weekly and larvae were counted on 75 randomly chosen plants. In addition a monthly evaluation by variety was made. Shoot fly populations were measured by monthly counts of the total number of growing tips per plant and the number of attacked tips. The percentage of infestation per variety and per planting was thereby determined. Populations of the cassava lace bug (nymphs and adults) were sampled by inspecting three leaves from each of the upper, central and lower parts of the plant.

During the first three months after planting, attack by thrips, shoot flies, hornworms and the cassava lace bug were the most severe. The mite populations, however, increased with the age of the plant (Fig. 16). The dry period was especially favorable for higher populations of thrips (Fig. 17), mites, lace bugs, shoot flies and oviposition by the hornworm.

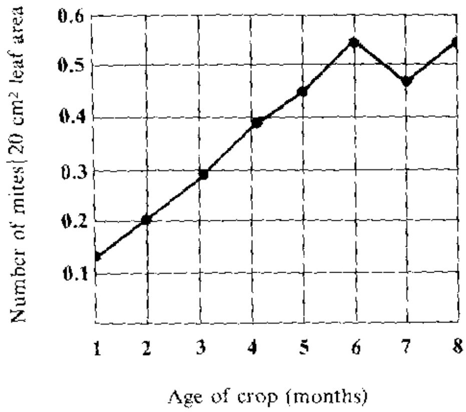


Figure 16. **Monthly evaluations of *Mononychellus mcgregori, Tetranychus urticae* and *Oligonychus peruvianus* mite populations measured on several cassava varieties.**

## Mites

Four species of mites have been identified as attacking cassava in Colombia. All belong to the family Tetranychidae and include *Mononychellus tanajoa, M. mcgregori, Tetranychus urticae* and *Oligonychus peruvianus. M. tanajoa* and *T. urticae* appear to be the most important species on a global basis. *O. peruvianus* is of limited importance while *M. mcgregori* has been reported in limited regions of Colombia and Venezuela.

The **Mononychellus** mite is usually found around the growing points of the plant on buds, young leaves and stems; lower leaves are less affected. The leaves emerge from the bud marked with yellow spots, lose their normal green color and become deformed. The attacked shoots lose their green color, turning rough and brown. The stems and leaves die progressively from top to bottom (Fig. 18).

Damage from the **Tetranychus** mite first appears on the lower leaves of the plant. Damage first shows as yellow dots along

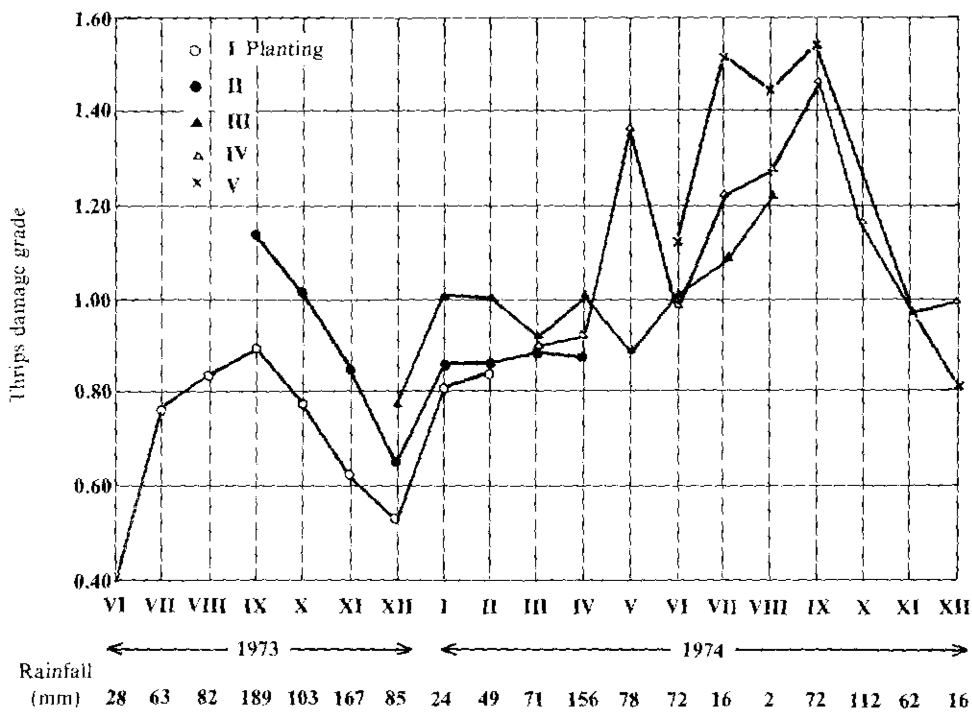


Figure 17. **Monthly evaluation of thrips damage for five plantings on several cassava varieties.**

Figure 18. **Typical damage caused by** Mononychellus **sp. on the growing points of the cassava plant.**

Figure 19. **Severe leaf damage and webbing caused by** *Tetranychus urticae* **under controlled environmental conditions.**

the main leaf vein and eventually spreads over the whole leaf, which turns reddish brown or rusty in color. Beginning with the basal leaves, severely infested leaves dry and drop; under severe attack plants may die (Fig. 19).

Presence of the **Oligonychus** mite is characterized by a small whitish web that the female spreads on the undersides of the leaves, commonly along the center and lateral leaf veins. Yellow to brown dots form on the leaf's upper surface. Damage is more pronounced on the lower leaves.

A procedure was developed to evaluate the cassava germplasm bank for resistance to the **Tetranychus** and **Mononychellus** mites under screenhouse conditions since natural infestations in Colombia are neither high enough nor sufficiently uniform for field screening. Cassava varieties are planted in floor beds or pots in a screenhouse and are surrounded with plastic to raise the temperature to 34°C. Leaves infested with mites are placed on one-month-old plants to inoculate them. Resistance is evaluated at weekly intervals from two to six weeks after inoculation; second and third inoculations are made if the initial one was not successful.

Screening for **Oligonychus** resistance was done on 1,884 varieties in the germplasm bank during a natural outbreak on the CIAT farm.

Preliminary results indicate that there are only low levels of resistance to the **Tetranychus** mite but intermediate resistance to both the **Mononychellus** and **Oligonychus** mites. Of the 427 varieties screened for resistance to the **Tetranychus** mite, only one variety (M Colombia 114) was selected as having a moderate level of resistance. Several varieties, however, have

Table 17. **Resistance of cassava varieties to three species of mites.**

| Mite | No. of varieties evaluated | Resistance evaluation scale*** | No. of varieties in each resistance class | | |
|---|---|---|---|---|---|
| *Tetranychus urticae* | 427* | 0 - 5 | 5.0 = 370 var. | | |
| | | | 4.5 = 46 var. | | |
| | | | 4.0 = 10 var. | | |
| | | | 3.5 = 1 var. | | |
| *Mononychellus mcgregori* | 45* | 0 - 5 | 5.0 = 4 var. | | |
| | | | 4.5 = 12 var. | | |
| | | | 4.0 = 44 var. | | |
| | | | 3.5 = 9 var. | | |
| | | | 3.0 = 8 var. | | |
| | | | 2.0 = 2 var. | | |
| *Oligonychus peruvianus* | 1,884** | No. of mite colonies/leaf | 0 - 10 | 72 | 3.82% |
| | | | 10 - 50 | 591 | 31.36% |
| | | | 50 - 100 | 454 | 24.09% |
| | | | 100 - 200 | 421 | 22.34% |
| | | | 200 - 500 | 319 | 16.93% |
| | | | 500 - 1000 | 27 | 1.43% |

* Artificial infestation in screenhouse

** Natural infestation in the field

*** Damage rating: 0-1 = resistant; 2-3 = intermediate resistance; 4-5 = susceptible been selected as promising for future testing. Only 45 varieties have been evaluated for resistance to the **Mononychellus** mite, but several lines appear to have good intermediate resistance. On the varieties screened for resistance to **Oligonychus,** 0.5 to 1,205 webs per leaf were found. Seventy-two varieties had less than 10 webs per leaf (Table 17) and 16 varieties less than 5.

## Thrips

Five species of thrips have been identified as attacking cassava: *Corynothrips stenopterus, Scirtothrips manihoti, Euthrips manihoti, Frankliniella williamsi* and **Frankliniella** sp.

Yield reductions induced by thrips attack were studied in two trials on the CIAT farm. In the first trial thrips attack was heavy during the dry season, and losses were up to 15.4 percent in susceptible cultivars and 11 percent for intermediate resistant cultivars (Table 18). Yield reduction in thrips-susceptible cultivars was attributed to all insects attacking cassava; in resistant cultivars it was

Table 18. **Cassava yields of thrips-susceptible (S), intermediate resistant (I) and resistant (R) cultivars, ten months after planting, with and without insecticidal application.**

| Cultivar | Thrips resistance evaluation | Yield (tons/ha) Without insecticides | Yield (tons/ha) With insecticides* | % yield reduction |
|---|---|---|---|---|
| **Trial 1** | | | | |
| M Col 890 | R | 17.3 | 18.0 | 3.9 |
| M Col 113 | R | 23.9 | 25.8 | 7.4 |
| M Col 65 | R | 25.5 | 27.9 | 8.6 |
| Average | | 22.2 | 23.9 | 6.6 |
| M Col 22 | I | 28.1 | 33.1 | 15.1 |
| M Col 1438 | I | 34.0 | 42.5 | 20.0 |
| Average | | 31.0 | 37.8 | 17.6 |
| M Col 1703 | S | 21.5 | 25.7 | 16.3 |
| M Mex 34 | S | 14.3 | 18.9 | 24.3 |
| M Col 248 | S | 18.0 | 24.1 | 25.3 |
| Average | | 17.9 | 22.9 | 22.0 |
| **Trial 2** | | | | |
| M Col 1696 | S | 20.2 | 21.4 | 5.6 |
| M Col 1745 | S | 21.9 | 24.0 | 8.8 |
| M Col 1670 | S | 20.2 | 22.4 | 9.8 |
| M Col 1765 | S | 20.8 | 24.3 | 14.4 |
| M Col 1703 | S | 21.5 | 27.1 | 20.7 |
| M Col 1777 | S | 19.5 | 25.3 | 22.9 |
| M Col 1701 | S | 16.8 | 22.5 | 25.3 |
| M Col 1767 | S | 16.9 | 23.6 | 28.4 |
| Average | | 19.7 | 23.8 | 17.2 |

* Dimethoate applied every month at 0.75 liters a.i./ha

attributed to all insects except thrips. Assuming that insects other than thrips attack cultivars equally, the greater yield reduction in susceptible cultivars can be attributed to thrips damage.

In the second trial, yield reduction due to thrips was estimated by the reduction in yields of plots without insecticidal protection as compared to protected plots. Yield reduction ranged from 5.6 percent for M. Colombia 1696 to 28.4 percent for M. Colombia 1767, with an average reduction for all varieties of 4.1 tons/ha or 17.2 percent (Table 18).

### White grubs

White grubs, the larval stage of a beetle (Scarabaeidae) feed on the roots of young plants, causing considerable damage. Grubs feed on the bark and buds of recently planted cuttings, reducing germination. Attacks are more severe in fields that were in pasture prior to the planting of cassava.

Two control methods of insecticidal application were studied: Soil applications of a granular or dust insecticide were made at the time of planting, or cuttings were submerged in an insecticidal solution for 20 minutes before planting. Two varieties (CMC-59 and 57) were treated with eight insecticides and one herbicide; stake germination was recorded 15, 25 and 35 days after planting. In another experiment using the insecticides carbofuran and disulfoton, three methods of application were studied: incorporation in the soil, placed below the cutting or around the cutting.

Results in the first experiment show that white grubs can reduce germination markedly unless controlled. Of 160 cuttings planted in the four control replicates, 153 (95.6 percent) did not germinate due to white grub damage (Table 19). Aldrin and carbofuran (granulated form only) gave the best control with 80.6 and 73.1 percent germination, respectively. Disulfoton (50.6

Table 19. **Effects of the application of several insecticides on the germination of cassava cuttings in the presence of white grubs (Scarabaeidae).**

| Insecticide treatment | Dosage | No. germinated* | % germination** |
|---|---|---|---|
| toxaphene—DDT | 1.2 liters/100 liters $H_2O$ | 34.0 | 21.3 |
| carbofuran (granulated) | 3 g/m² | 117.0 | 73.1 |
| carbofuran (dip) | 100 cc/100 liters $H_2O$ | 17.0 | 10.6 |
| Herbicide (alachlor + diuron) | 2 liters + 2 kg/ha | 17.0 | 10.6 |
| methamidophos | 100 cc/100 liters $H_2O$ | 15.0 | 9.4 |
| fenthion | 75 cc/100 liters $H_2O$ | 48.0 | 30.0 |
| disulfoton | 3 g/plant | 81.0 | 50.6 |
| aldrin | 60 kg/ha | 129.0 | 80.6 |
| diazinon | 70 cc/100 liters $H_2O$ | 14.0 | 12.5 |
| Control | | 7.0 | 4.4 |

* Randomized block of 4 plots of 40 cuttings per plot

** Significant at 1 percent level

Table 20. **The effectiveness of the distribution of the placement of the granulated insecticides carbofuran and disulfoton for the control of white grubs (Scarabaeidae).**

| Insecticide | Method of soil application | No. germinated* | % germinated |
|---|---|---|---|
| carbofuran | Incorporated in 20 m² | 65 | 81.3 |
| carbofuran | Below the cutting | 74 | 92.5 |
| carbofuran | Around cutting | 66 | 82.5 |
| disulfoton | Incorporated in 20 m² | 62 | 77.5 |
| disulfoton | Below cutting | 66 | 82.5 |
| disulfoton | Around cutting | 57 | 71.3 |
| Control | ——— | 58 | 72.5 |

* Randomized block of plots of 20 cuttings per plot

percent germination) gave moderate control, but the remainder of the insecticides gave little or no grub control. The dip method of application was not effective.

In the second experiment, carbofuran (granular) applied below the cutting gave the best results (Table 20). This resulted in only a 7.5 percent reduction in germination as compared to a 27.5 percent reduction in the control.

**Cassava fruit flies**

Cassava fruit flies have become one of the most serious pests of cassava in the coffee-growing region of Colombia. Originally believed to be only a pest of the cassava fruit, two species of fruit flies, *Anastrepha pickeli* and *A.manihoti* (Tephritidae) have now been identified as also attacking the stem. The female prefers to oviposit in the fruit but frequently oviposits in the soft tissue of the stem of the young cassava plant about 10 to 20 cm below the growing point. The young larva hatches and bores its way into the pith region of the stem and tunnels downward. This tunneling is a point of entry for a bacterial pathogen that can cause extensive rotting of the stem (See pathology section).

During their initial stages, the larvae are white, turning yellow later. The presence of the larvae within the stem can often be noted by the white liquid exudate that flows from the larval wound down the stem. This extensive rotting often causes death of the growing point of young plants (Fig. 20). On one field 84 percent of the plants were observed with this damage, while in another field about 75 percent of the plants had collapsed 20 to 30 cm below the growing point.

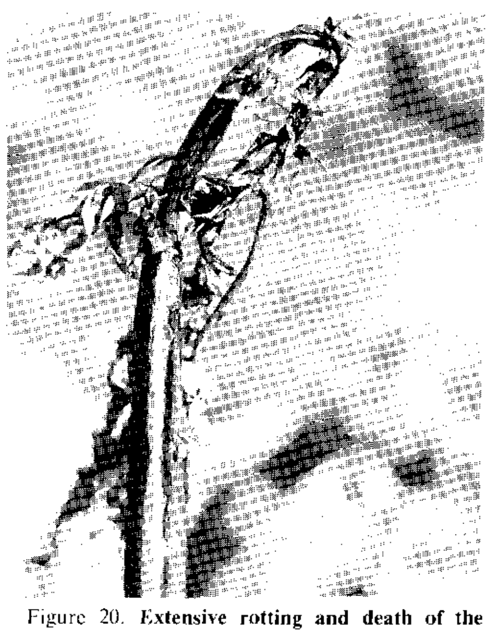

Figure 20. **Extensive rotting and death of the growing point caused by a bacterial pathogen in association with the larvae of the cassava fruit fly** (Anastrepha **sp.).**

Table 21. **Fecundity, egg viability and longevity of the whitefly *Trialeurodes variabilis* under caged conditions in the field (based on 10 pairs of adults).**

| Developmental stage | Minimum | Maximum | Average | Standard deviation |
|---|---|---|---|---|
| No. of eggs per female | 134 | 178 | 161.1 | ± 14.50 |
| Eggs hatched (%) | 89.9 | 100 | 95.2 | ± 3.59 |
| Pupae formed (%) | 59.3 | 96.1 | 79.7 | ± 11.64 |
| Adults emerged (%) | 86.2 | 98.4 | 95.3 | ± 3.28 |
| Survival egg to adult (%) | 55.1 | 90.3 | 72.4 | ± 10.50 |
| Longevity of female (days) | 14 | 22 | 19.2 | ± 2.31 |
| Longevity of male (days) | 5 | 15 | 8.8 | ± 3.12 |

## Whiteflies

Whiteflies (Aleyrodidae) are distributed over many of the cassava-growing areas of the world. Several species have been identified as attacking cassava; these include *Trialeurodes variabilis, Bemisia tabaci, B. tuberculata,* **Aleurotrachelus** sp. and **Aleurothrixus** sp. Although indications are that whiteflies may not cause direct damage due to feeding, they are of particular importance because of their ability to transmit mosaic disease in Africa. In addition a sooty mold growing on their excretions may have an adverse effect on plant photosynthesis.

The biology of the whitefly *I. variabilis*, commonly found in Colombia, was studied under field conditions in screened cages (Table 21).

An evaluation for resistance to the whitefly **Aleurotrachelus** sp. was made on 189 cassava cultivars during a heavy field infestation. The oblong pupal stage of this whitefly is black with a white waxy excretion around the outer edge, making it easy to detect on the leaf undersurface. Several varieties were identified with very low levels of infestation (Table 22), indicating that resistance to **Aleurotrachelus** sp. is available in the cassava germplasm bank. Infestation was uniform, but only one evaluation was made and therefore needs to be repeated.

## Cassava hornworm

A system for biological control of the cassava hornworm *(Erinnyis ello)* was described in the 1974 Annual Report. The combination of egg parasitism by *Trichogramma fasciatum* and larval predation by the paper wasp *Polistes erytrocephalus* supressed the hornworm population at CIAT throughout the year. There has been no outbreak at the CIAT farm since these biological control agents were introduced in 1973.

Hornworm outbreaks were studied on two nearby farms. In both cases an insecticide had been applied to the cassava crop for insect (thrips and fruit fly) control

Table 22. **Evaluation of 189 cassava cultivars for resistance to the whitefly** Aleurotrachelus **sp.**

| Total no. of cultivars | Damage rating* | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| 189 | 2 | 36 | 42 | 72 | 33 | 4 |

* 0 = no whitefly infestation; 1 = less than 20% of leaves infested; 2 = 20 to 40% of leaves infested; 3 = 40 to 60% of leaves infested; 4 = 60 to 80% of leaves infested; and 5 = 80 to 100% of leaves infested

prior to the outbreak. Egg parasitism by **Trichogramma** was between 50 and 60 percent. The **Polistes** wasp was introduced into both fields. In the first field there has been no further outbreak for six months; the second field is still being studied.

## VARIETAL IMPROVEMENT

During the past three years a substantial amount of basic data on germplasm and genetic behavior and selection efficiency of the cassava plant was accumulated. Evaluation of more than 2,000 entries in the germplasm collection was completed. Hybridization and seedling selection techniques were established. Selection based on harvest index of the plant proved to be efficient, both genetically and physiologically.

During the year, approximately 230 cultivars, 3,000 hybrid lines and 8,000 hybrid plants were evaluated and harvested in a replicated yield trial, an observational yield trial and a hybrid selection field, respectively. About 160 hybrids lines, 1,200 hybrid lines and 25,000 hybrid seeds were planted in the replicated yield trial, the observational yield trial and the selection field, respectively. Approximately 30,000 hybrid seeds were produced from about 250 cross combinations. A major part of these seeds are sown at CIAT within six months of harvest; some are sent to breeders in many countries of America, Asia and Africa.

A yield of more than 60 tons|ha|year was obtained in a replicated yield trial. The highest yielding cultivars at CIAT are outperforming the local cultivars not only at CIAT but also outside CIAT; thus yield improvement through modifying the cultivars seems a forthcoming reality.

### Germplasm collection

The present status of the CIAT germplasm collection is presented in Table 23. Useful genotypes have been identified for all the major diseases and insect problems.

Table 23. **Present status of the CIAT cassava germplasm collection.**

| Country of origin | No. of cultivars maintained at present | No. of cultivars evaluated |
|---|---|---|
| Colombia | 1,676 | 1,646 |
| Venezuela | 269 | 255 |
| Ecuador | 134 | 134 |
| Mexico | 68 | 65 |
| Brazil | 22 | 5 |
| Panama | 20 | 20 |
| Puerto Rico | 16 | 15 |
| Costa Rica | 16 | 0 |
| Dominican Republic | 5 | 0 |
| Peru | 2 | 2 |
| Paraguay | 2 | 2 |
| Total | 2230 | 2,142 |

### Yield trials

Selected mainly on the basis of harvest index and root yield when grown in single rows, 232 cultivars were harvested in replicated yield trials at CIAT. The experiments had two replications and all harvested plants had two border rows. The nine central plants were harvested 12 months after planting in each replicate. No fertilizer, fungicide or insecticide was applied to the experiment.

Data on the best-yielding cultivars are presented in Table 24. One cultivar yielded more than 60 tons|ha, eleven cultivars yielded more than 50, and three gave a dry matter yield of more than 20 tons|ha. Llanera, a local cultivar, yielded 26.7 tons|ha of fresh root or 8.7 tons of root dry matter. These results suggest the possibility

Table 24. **Twenty best yielding cultivars.**

| | Root yield (tons\|ha\|year) | Dry matter content of roots | Root dry matter yield (tons. ha\|year) | Total plant weight (tons\|ha\|year) | Harvest index |
|---|---|---|---|---|---|
| M Ven 218 | 60.6 | .359 | 21.7 | 96.7 | .626 |
| M Mex 17 | 54.2 | .368 | 19.9 | 83.9 | .646 |
| M Col 946 | 53.6 | .394 | 21.1 | 106.1 | .505 |
| M Pan 70 | 52.8 | .376 | 19.8 | 79.4 | .664 |
| M Col 1686 | 52.5 | .306 | 16.1 | 99.2 | .529 |
| M Col 1292 | 52.2 | .387 | 20.2 | 118.6 | .440 |
| M PTR 26 | 52.2 | .368 | 19.2 | 79.4 | .657 |
| M Col 803 | 51.4 | .365 | 18.8 | 106.7 | .482 |
| M Col 1684 | 50.8 | .331 | 16.8 | 78.3 | .649 |
| M Mex 59 | 50.6 | .358 | 18.1 | 100.3 | .504 |
| M Ven 77 | 50.0 | .334 | 16.7 | 88.6 | .564 |
| M Ven 168 | 49.4 | .369 | 18.2 | 86.9 | .550 |
| M Mex 16 | 49.2 | .353 | 17.4 | 83.9 | .590 |
| M Pan 114 | 49.2 | .375 | 18.4 | 76.2 | .645 |
| M Col 638 | 48.6 | .351 | 17.1 | 106.9 | .454 |
| M Col 655A | 46.7 | .385 | 18.0 | 105.6 | .442 |
| M Col 1468 | 46.1 | .327 | 15.1 | 94.7 | .487 |
| M Ecu 47 | 46.1 | .371 | 17.1 | 93.1 | .495 |
| M Ven 270 | 45.8 | .395 | 17.9 | 108.9 | .421 |
| M Mex 52 | 44.1 | .390 | 17.4 | 107.6 | .416 |
| Llanera (Local cultivar) | 26.7 | .325 | 8.7 | 53.1 | .503 |
| M Col 22 (Control) | 26.7 | .398 | 10.6 | 41.4 | .644 |
| M Col 113 (Control) | 38.1 | .354 | 13.5 | 85.3 | .446 |

of immediate yield increase by varietal selection. Considering that the eleven cultivars that yielded more than 50 tons|ha compose the upper 0.5 percent selection from the original collection, it is obviously important to start a selection program with a very broad variability of germplasm.

High total plant weight and harvest index are very important in obtaining high yields (Figs. 21 and 22). There seems no way of obtaining high yields when the harvest index is less than 0.40. Harvest index was negatively correlated with leaf and stem weight (Fig. 23), thus confirming that the top and roots are competing sinks. The types with too vigorous top growth have a very low harvest index; and the types with a very high harvest index cannot maintain a reasonable level of top growth and hence leaves, resulting in a low total dry matter accumulation.

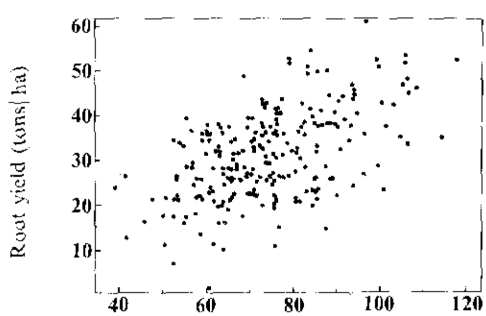


Figure 21. **Relationship between total plant weight and root yield (fresh weight).**

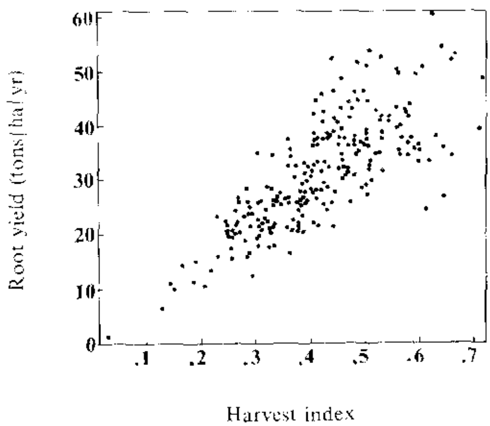


Figure 22. **Relationship between harvest index and root yield in population trial.**

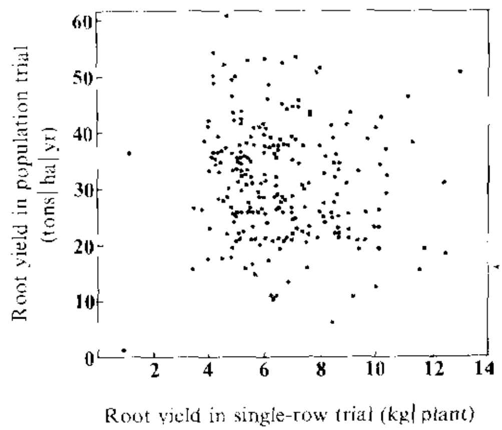


Figure 24. **Relationship between root yield data in single-row and population trials.**

The correlation between yield data in the single-row and population trials was surprisingly low (Fig. 24), probably because of intensive intergenotypic competition. The correlation between harvest index in the single-row and population trials (Fig. 25) was high. As a result, the harvest index in the single-row trial was highly correlated with the yield in the population trial (Fig. 26); this indicates that harvest index as a selection trait is even better than yield itself when genotypes are tested at the observational yield trial level.

A remarkable varietal variation was observed in initial vegetative vigor. Initial vigor was highly correlated with leaf and stem weight at harvest and negatively correlated with harvest index; however, it was not significantly related to yield (Table 25). Under CIAT conditions, which are regarded as nearly ideal for obtaining high yields, the yield of more than 50 tons|ha was obtained with a rather wide range of initial vigor. However, when considering less favorable conditions for cassava growth that are more representative of vast cassava-growing areas in the tropics, the

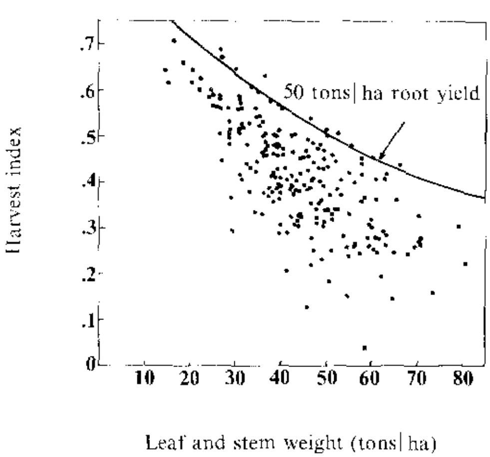


Figure 23. **Relationship between top growth and harvest index in population trial.**

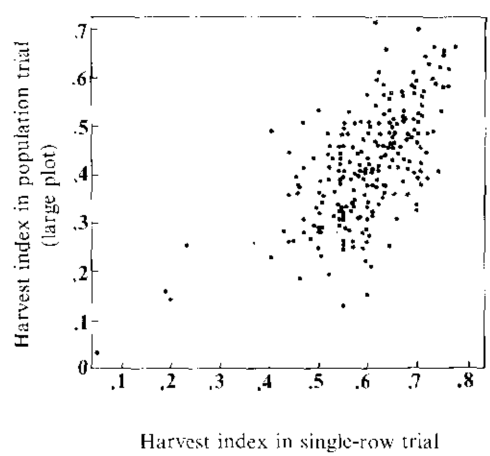


Figure 25. **Relationship between harvest indexes in single-row and population trials.**

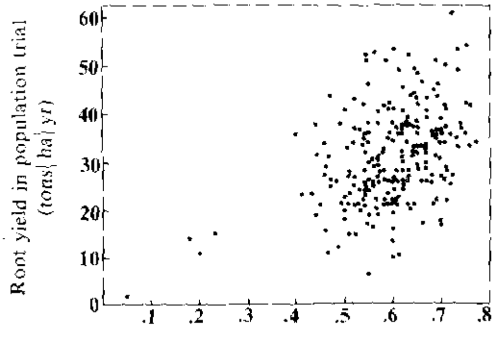


Figure 26. **Relationship between harvest index in single-row trial and root yield in population trial.**

Table 26. **Effect of lodging on yield and harvest index.**

| Lodging* | Number of plots | Root yield (tons\|ha) | Harvest index |
|---|---|---|---|
| 0 | 177 | 37.6 | .499 |
| 1 | 88 | 31.2 | .434 |
| 2 | 55 | 28.8 | .378 |
| 3 | 52 | 30.0 | .357 |
| 4 | 43 | 28.0 | .317 |
| 5 | 39 | 18.7 | .238 |

* Evaluated at ten months after planting: 0 = no lodging; 5 = complete lodging

types with high initial vigor may be given more importance than those with a high harvest index and low vigor.

Yields decreased parallel to the degree of lodging index (Table 26). Like almost any other crop, lodging is fatal to cassava yields and should be avoided at all cost.

### Trials outside CIAT

A number of selected cultivars and hybrid lines were planted in Carimagua (Llanos Orientales), Caribia (Northern Coast) and Popayán (mountain zone). In Caribia, the center of cassava production in Colombia, M Mexico 59, M Colombia 638, M Colombia 1468 (CMC-40, ICA selection) and M Colombia 1684 were among 15 best yielders in 300 lines evaluated. This suggests that there are high-yield selections adapted at least to the altitude range from 0 m in Caribia to 1,000 m at CIAT.

### Selection

From a total of approximately 8,000 $F_1$ hybrid plants, about 1,200 were selected on the basis of harvest index and root yield (Table 27). These materials were forwarded to the observational yield trials, and some are also being observed in Carimagua and Caribia.

The high correlation of yield data—i.e., harvest index, root yield and total plant weight—between the seedling and the stake-planted generations has been

Table 25. **Effect of initial vigor on yield characters.**

| Initial vigor* | Number of cultivars | Root yield (tons\|ha) | Harvest index | Total plant wt (tons\|ha) | Leaf and stem wt (tons\|ha) |
|---|---|---|---|---|---|
| 1 | 4 | 27.5 | .523 | 53.2 | 25.7 |
| 2 | 49 | 32.0 | .473 | 67.8 | 35.8 |
| 3 | 90 | 32.5 | .439 | 74.1 | 41.6 |
| 4 | 80 | 29.0 | .363 | 79.2 | 50.2 |
| 5 | 7 | 32.9 | .338 | 96.0 | 63.2 |

* Evaluated at two months after planting: 1 = very low vigor; 5 = very high vigor

Table 27. **Data on selection of $F_1$ hybrids.**

| Cross | Parents | Total no. of hybrids | No. hybrids selected | Average yield of all hybrids* | Average yield of selected hybrids (kg/plant) | Average harvest index of all hybrids | Average harvest index of selected hybrids |
|---|---|---|---|---|---|---|---|
| CM 305 | M Col 113 x M Col 22 | 150 | 40 | 5.9 | 7.1 | .69 | .69 |
| CM 307 | M COL 22 x M Col 340 | 254 | 13 | 5.0 | 7.7 | .58 | .64 |
| CM 309 | M Col 22 x M Col 647 | 737 | 193 | 5.2 | 7.1 | .62 | .65 |
| CM 310 | M Col 22 x M Col 667 | 310 | 17 | 3.7 | 7.6 | .55 | .61 |
| CM 314 | M Col 22 x M Col 1292 | 74 | 12 | 5.2 | 8.2 | .66 | .67 |
| CM 321 | M Col 22 x M Ven 270 | 423 | 69 | 4.4 | 7.0 | .64 | .69 |
| CM 323 | M Col 22 x M Mex 59 | 680 | 140 | 4.6 | 8.1 | .62 | .64 |
| CM 334 | M Mex 55 x M Col 647 | 35 | 10 | 5.2 | 10.3 | .61 | .66 |
| CM 342 | M Col 22 x M Col 1468 | 178 | 17 | - | 7.6 | - | .64 |
| CM 345 | M Col 113 x M Mex 59 | 100 | 8 | - | 10.6 | - | .59 |
| CM 356 | M Col 647 x M Mex 55 | 35 | 11 | - | 8.2 | - | .61 |

* Planted at 1 x 2 m spacing and harvested ten months after transplanting

confirmed. This high correlation or high efficiency of selection with seedling plants exists as early as seven months after transplanting them (Fig. 27). Even if the seedling plants are kept until 15 months, these correlations do not improve (Fig. 28).

Since only a few planting stakes can be obtained with seedling plants less than seven months old, it is unlikely that the breeder will practice selection with seedling plants before the plants reach this age. The results do, however, suggest that very efficient seedling selection is guaranteed whenever the planting stakes can be cut from the seedling plants as long as they are widely spaced to avoid intergenetypic competition in a reasonably uniform field.

**Hybridization**

Results of the yield trial were significant, not only because quite a few cultivars yielded well but also because many of these high-yielding cultivars had been actively utilized in our hybridization program for two years. Of 20 of the best yielders, eight had been used quite actively in hybridization and several hundred selections from these hybridizations are already being evaluated in observational trials in and outside CIAT. There is a good chance of perfecting such cultivars as M Mexico 59 and M Colombia 1468, which easily outyield local cultivars in and outside CIAT, by selecting from the hybrid lines which exist in the order of tens of thousands if the problem is high yield potential and wide adaptability. Thus, the emphasis in our hybridization program has shifted to disease resistance and some other characteristics such as long root durability after harvest or high starch content.

Additions to the hybridization program are given in Table 28. M Colombia 638 is of particular interest because it seems to combine yielding ability with high resistance to cassava bacterial blight. As a result of one initial cycle of hybridization and selection, several hybrid lines with a high harvest index and resistance to CBB

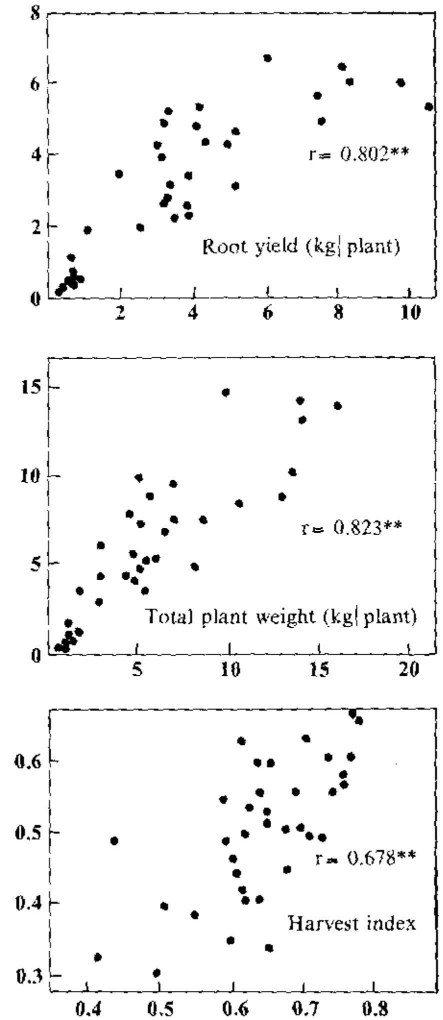


Figure 27. **Correlation of data for seedling plants (horizontal axis) harvested at seven months compared to that of the stake-planted plants (vertical axis) of the same genotype.**

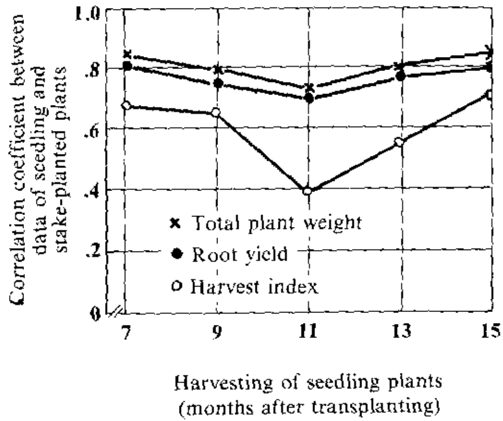


Figure 28. **Harvesting time of seedling plants and the efficiency of selection.**

were identified; thus hybrids such as CM 309-41, CM 309-56 and CM 309-206 are actively used in hybridization.

Using the data with seedling plants, a highly significant regression of parental average on $F_1$ hybrids average in harvest index had already been shown. The same type of analysis was made with both the parents and the $F_1$ hybrids, using the data of stake-planted plants. By nature, this type of analysis is more accurate and practical than the former. A highly significant regression was obtained not only in harvest index but also total plant weight. The regression in root yield itself was not as high as in harvest index and total plant weight; nevertheless, it was also significant (Figs. 29, 30 and 31). This encourages breeders to believe that almost any character with practical meaning can be inherited, thereby justifying the fact that a large part of our hybridizations are by controlled pollinizations.

## Disease resistance

The pathology group has shown that there are at least five major diseases to be taken into account when breeding for resistance. Highly resistant genotypes for cassava bacterial blight and Cercospora leaf spots were identified (See pathology section and Table 28). The data suggest that this resistance can be readily incorporated into agronomically desirable types. Highly resistant genotypes for Phoma leaf spot, a disease prevailing in temperate climates, were also identified; but it is not yet known whether this is easily incorporated into high-yielding types at low temperatures. Several moderately resistant types for superelongation disease

Table 28. **Characteristics of cultivars or hybrid lines frequently used in hybridization programs.**

| | | | | | | | | Resistance to | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harvest index | Vigor | Leaf area retention | Early maturity | Easy to harvest | Root durability | Starch content | CBB | Super-elongation disease | *Cercospora* spp. | *Phoma* sp. |
| Llanera | + | | | | | | | + | + | | |
| M Col 22 | ++ | | | ++ | ++ | | ++ | | | | |
| M Col 113 | | | ++ | | | | | | | | |
| M Col 197 | | | | | | | | ++ | | | |
| M Col 340 | | | | | | | | | | | ++ |
| M Col 638 | + | | | | | | | ++ | + | | |
| M Col 647 | | | | | | | | ++ | | | |
| M Col 655A | | ++ | | | | | + | | | | |
| M Col 667 | | | | | | | | ++ | | | |
| M Col 1292 | | ++ | | | | | + | | | | |
| M Col 1468 | + | | | | | | | | | | |
| M Col 1684 | ++ | | | | | | | | | | |
| M Mex 55 | + | | | | | | | | | | |
| M Mex 59 | + | ++ | | | | | | | | ++ | |
| M Ven 270 | | + | | | | | ++ | | | | |
| M Pan 114 | ++ | | | | | | | | | | |
| CM 309-41 | ++ | | | | | | | ++ | | | |
| CM 309-56 | ++ | | | | | | | ++ | | | |
| CM 309-206 | ++ | | | | | | | ++ | | | |
| CM 321-15 | ++ | | | | | + | | | | | |
| CM 327-12 | ++ | | | | | + | | | | | |

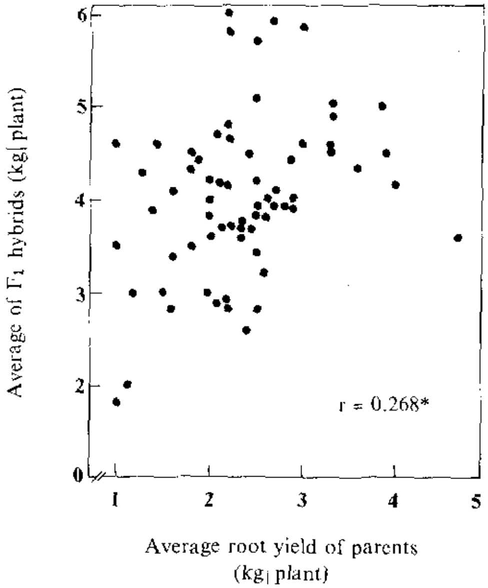


Figure 29. **Relationship between average root yields of parents and the respective $F_1$ hybrids.**

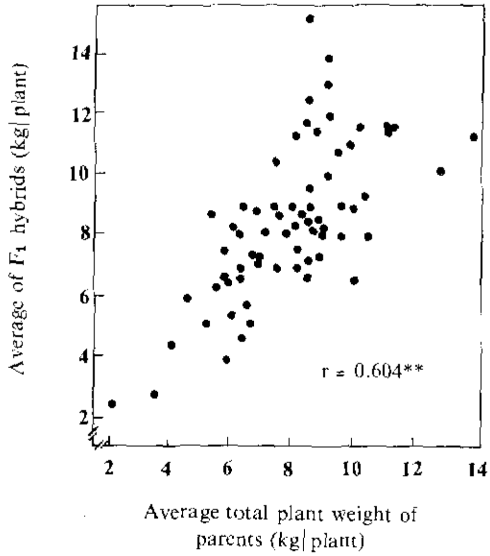


Figure 31. **Relationship between average total plant weight of parents and the respective $F_1$ hybrids.**

were identified; however, it is not known how effective the resistance of these types will be and how long the resistance will last. Needless to say, all resistant types are actively hybridized with high-yielding types and among themselves.

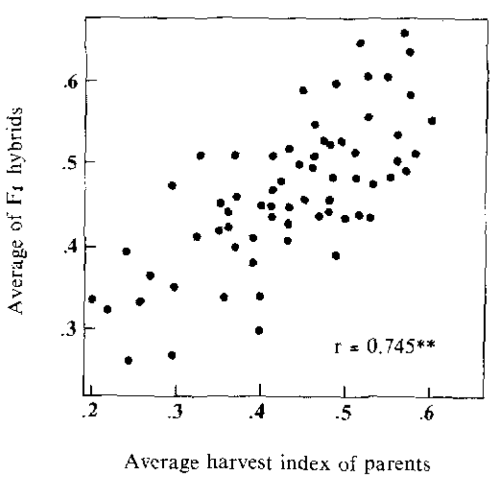


Figure 30. **Relationship between average harvest indexes of parents and the respective $F_1$ hybrids.**

The observational yield trial at Caribia was infected by CBB, and a clear varietal difference in the reaction to this disease was observed. The observational yield trial at CIAT was free from CBB. The varietal yields of the two locations were compared at each level of the CBB attack in Caribia (Table 29). The yield difference of about 3.5 kg between CIAT and Caribia with resistant and tolerant cultivars (CBB, grades 1 and 2) represents the general yield difference between the two trials. With highly susceptible cultivars (grade 5), the yield difference was 6.4 kg. Results indicate that even under a moderate level of CBB attack, resistant cultivars are highly desirable, moderately susceptible cultivars give a significant yield reduction, and susceptible cultivars will give disastrous results. Thus, the first cultivar to be recommended should possess at least a moderate level of CBB resistance, if not a high one, in addition to high yielding ability with wide adaptability.

The observational yield trial at Carimagua was heavily infected by CBB and superelongation disease. Practically

Table 29. **Comparison of root yields at Caribia and CIAT at different levels of varietal CBB reaction.**

| CBB attack in Caribia* | Number of cultivars | Yield at Caribia (kg/plant)** | Yield at CIAT (kg/plant)*** | Difference |
|---|---|---|---|---|
| 1 | 6 | 2.23 | 5.85 | 3.62 |
| 2 | 52 | 2.18 | 6.05 | 3.27 |
| 3 | 76 | 2.47 | 6.71 | 4.24 |
| 4 | 37 | 1.87 | 6.52 | 4.65 |
| 5 | 25 | 1.09 | 7.54 | 6.45 |

* 1 = no symptoms; 5 = heavy CBB infection

** Planted at 1 x 1 m spacing and harvested at nine months

*** Planted at 1 x 1.4 m spacing and harvested at ten months

all the plants were wiped out, and only M Colombia 638 gave roots of edible size. The results simply indicate that under extraordinarily heavy attacks of CBB and superelongation, an extremely high level of resistance to these diseases is required; and in the long run, this level of resistance should be incorporated into high-yielding types.

## Starch content and root durability

Since a significant portion of cassava production is expected to go for animal feeding and starch extraction in the future, yield should be expressed in terms of root dry matter or starch yield, as well as root fresh yield. Varietal variation in root dry matter content was great, even among the 20 cultivars selected on the basis of fresh weight yield (Table 24). This suggests that the yield ceiling level has not been reached as regards dry matter yield per area per time.

The correlations between root specific gravity and root dry matter content and between root specific gravity and root starch content were very high. Conversion diagrams from specific gravity to dry matter content and starch content in the peeled root are presented (Figs. 32 and 33). The proportion of root peel fresh weight to whole root fresh weight and the starch content of root peel varies according to cultivars. Assuming 20 percent as a rough average for both, conversion diagrams from root specific gravity to starch content of (1) the whole root and (2) of the peeled root over the whole root are also presented (Fig. 34).

One of the biggest shortcomings of cassava is its extremely rapid root decay after harvest. Some genetic difference in

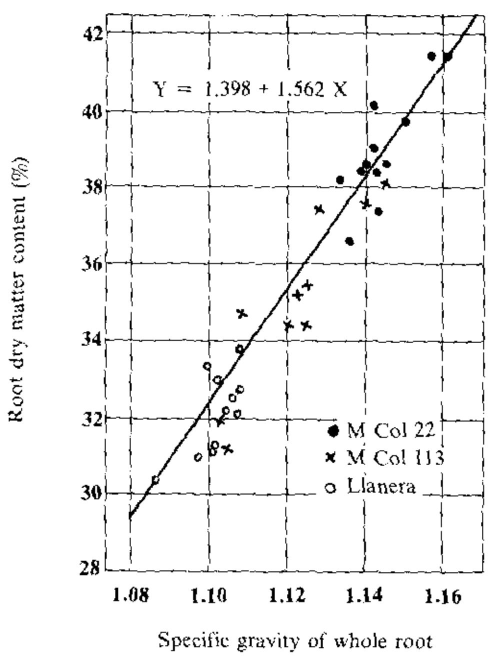


Figure 32. **Regression of root specific gravity on dry matter content (roots harvested at 11 months).**

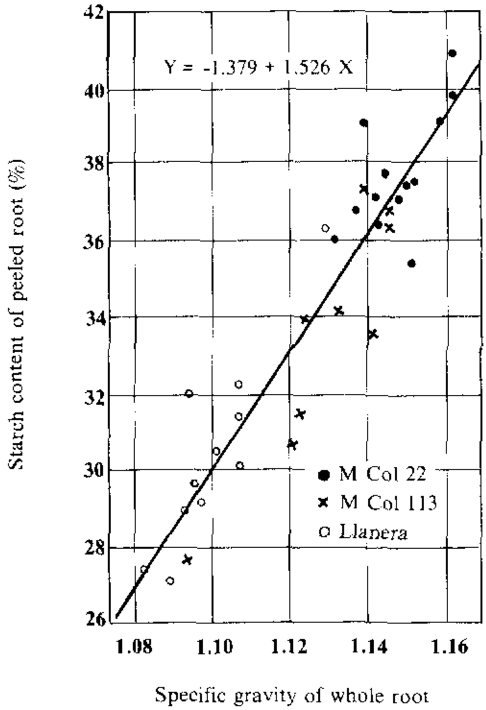


Figure 33. **Regression of root specific gravity on starch content of peeled root (roots harvested at 11 months).**

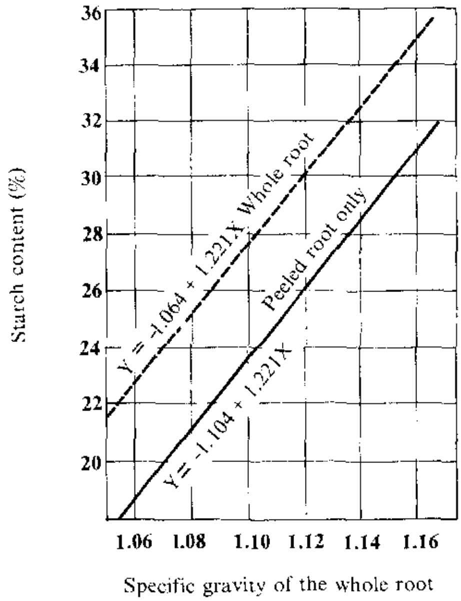


Figure 34. **Regression of the specific gravity of the whole root on the starch content of the whole root and the proportion of starch in the peeled root as compared to the whole fresh root.**

root durability after harvest has been observed. Two methods representing two extremes of conditions to which cassava is subjected before marketing or processing, were devised to evaluate this characteristic. In the field evaluation, 15 randomly selected roots were left in the field for two weeks and then evaluated by chopping them. In the laboratory evaluation, 15 randomly selected roots were kept inside a room at a normal temperature of about 24°C. After one week, all the roots were chopped and the degree of streaking on the root was evaluated. In this way, the fitness of stored roots for human consumption, animal feeds and starch extraction can be more objectively evaluated.

In the great majority of cultivars, roots simply decayed after three or four days whether they were kept in the field or in the laboratory. However, roots of some cultivars of hybrid lines were occasionally found edible even at two weeks after harvest. There is a large margin of error associated with the two methods. The correlation between the field and the laboratory evaluations was not high but acceptably useful. After eliminating all the cultivars or lines which showed unacceptable decay in any evaluation, there were still a certain number of cultivars and hybrid lines that survived all evaluations. There seems to be no association between root durability and yielding ability. The selected materials are being utilized in the hybridization program, and the genetic behavior of this character is being studied.

## AGRONOMY

During 1975, 90 percent of the work was done outside CIAT, principally in collaboration with farmers and national agencies such as the Instituto Colombiano Agropecuario (ICA), the Federación

Nacional de Cafeteros and regional departments (secretarías) of agriculture. Although work was done on cultural practices, major emphasis was placed on regional trials.

**Regional trials**

Cassava shows great variability. To select a variety based on marked differences in character is easy, but to select compatible genetic characteristics that react favorably to several environments and produce optimal yields under intensive growing conditions is difficult. For this reason, yield evaluations in the field must still be made.

From the 14 trials planted in different regions of Colombia (Table 30), nine have been harvested. Five trials were planted in cooperation with ICA, three with the Federación Nacional de Cafeteros and one with the Department of Agriculture in Santander del Sur.

**Multiplying promising varieties**

The rapid propagation method (see section on propagation) was used to multiply 22 promising varieties in sufficient number to plant 21 regional trials. Asexual "seeds" (cuttings) from these varieties were distributed to the Philippines, Australia, Guyana, Ecuador, Venezuela and Mexico.

**Objectives**

As Colombia is a relatively small country that offers a wide gamut of climatic and edaphic conditions, it is ideal for evaluating promising varieties for their productivity and adaptation. The trials have two main objectives: (1) to measure the components that have the most influence on yield under different environmental conditions in order to extrapolate results to other regions, both within and outside Colombia; and (2) to replace local varieties with improved varieties that not only give higher yields but that are also disease and insect resistant, tolerate poor soils, are easy to harvest and are of superior quality for human consumption and industrial uses.

**Technology and methodology used**

The same technology was applied to all trials; the use of modern, expensive inputs was avoided. Planting was done on ridges when the soil was heavy and on the flat when soils were very permeable or sandy. A randomized block design with four replications was used. The soil was analyzed in each replication, and a pluviometer was installed at each site. The regional variety or varieties were used as controls. The harvested area was always surrounded by at least two border rows, either of the same variety or at least one of the harvested variety and others of the neighboring line. Stakes (20 cm) were planted vertically at a population density of 10,000 plants/ha.

Cuttings were dipped in a 5 percent arazan solution for five minutes to prevent the rotting of cuttings and the death of seedlings at the time of germination. Toxaphene-DDT 40-20 was applied at a rate of 1 gal/ha to control soil insects that are not specific to cassava but that could hinder normal germination and good plant development during the initial stage.

A mixture of preemergence herbicides (diuron and alachlor) was applied immediately after planting in variable dosages according to soil texture (Table 31). Diuron was used to control broadleaf weeds and alachlor, grasses. Weedings were carried out in accordance with the rainfall pattern of each region. Carimagua was the only site where fertilizers were used. Insects attacking the aerial portion of the plant and diseases were not controlled in order to determine the true potential of the promising varieties under the conditions found on the majority of cassava-growing farms.

Table 30. **Sites where the first group of promising ICA/CIAT varieties were planted and the main soil and climatic characteristics.**

| | Altitude (m) | Mean Temperature (°C) | Rainfall (mm/yr) | RH (%) | Soil type | pH | Organic matter (%) | P (Bray II) (ppm) | K (meq/100 g) |
|---|---|---|---|---|---|---|---|---|---|
| Media Luna | 10 | 27.2 | 1,486 | 77.6 | Sandy | 6.28 (N) | 0.7 (L) | 8.2 (L) | 0.6 (L) |
| Carimagua | 200 | 26.1 | 2,031 | 75.2 | Clay loam | 4.7 (VA) | 0.6 (L) | 1.0 (L) | 0.1 (L) |
| Nataima | 430 | 27.8 | 1,479 | 69.0 | Sandy | 6.2 (N) | 1.3 (M) | 24.7 (M) | 0.2 (M) |
| Villavicencio | 450 | 26.3 | 4,306 | 75.6 | Clay loam | 4.3 (VA) | 2.8 (M) | 4.1 (L) | 0.1 (L) |
| Florencia | 450 | 25.0 | 3,475 | 85.0 | Sandy loam | 5.5 (A) | 2.3 (M) | 18.9 (M) | 0.2 (M) |
| El Nus | 847 | 23.7 | 1,875 | 63.6 | Loam | 5.0 (A) | 3.8 (M) | 4.3 (L) | 0.1 (L) |
| Rionegro | 480 | 26.6 | 1,594 | 79.5 | Silt loam | 5.1 (A) | 1.5 (M) | 3.9 (L) | 0.7 (M) |
| CIAT | 1,000 | 23.5 | 1,055 | 74.5 | Clay | 6.4 (N) | 3.6 (M) | 25.0 (M) | 0.4 (H) |
| Caicedonia | 1,100 | 22.2 | 1,900 | 80.7 | Silt loam | 5.5 (A) | 5.3 (H) | 70.0 (H) | 0.7 (H) |
| La Zapata | 1,100 | 22.7 | 1,219 | 75.2 | Clay loam | 5.2 (A) | 6.8 (H) | 5.0 (L) | 0.1 (L) |
| Darién | 1,450 | 19.5 | 1,500 | 83.0 | Silt loam | 5.1 (A) | 15.0 (H) | 1.9 (L) | 0.1 (L) |
| Pereira | 1,480 | 19.0 | 2,000 | 80.0 | Silty clay | 5.1 (A) | 8.3 (H) | 8.3 (L) | 0.1 (L) |
| Popayán | 1,760 | 18.0 | 2,500 | 85.0 | Clay loam | 5.0 (A) | 7.6 (H) | 2.4 (L) | 0.4 (H) |
| La Unión | 1,800 | 17.0 | 1,844 | 70.0 | Clay loam | 5.7 (A) | 12.3 (H) | 6.1 (L) | 0.4 (H) |

N = Neutral, A = Acid, VA = Very acid, L = Low, M = Medium, H = High

Table 31. **Preemergence herbicide mixture recommended according to soil texture.**

| | | | |
|---|---|---|---|
| Clay | 2.0 kg diuron | + | 3.0 liters alachlor |
| Silt loam | 1.5 kg diuron | + | 2.5 liters alachlor |
| Clay loam | 1.5 kg diuron | + | 2.0 liters alachlor |
| Sandy | 1.0 kg diuron | + | 2.0 liters alachlor |

The recommendation of varieties in each country corresponds to the respective national agency; however, CIAT and the local agency conduct a field day at harvest time to inform farmers about the results and let them select the varieties that best suit their needs. They then receive seed to make their own evaluations. A register is kept of the farmers and the places where the varieties are to be planted. So far, the criteria for selecting varieties for the second or third year of trial have been flexible, depending mainly upon the zone and the behavior of the control. At Rionegro, for example, those varieties that outyielded the best regional one by 50 percent were selected. At Media Luna, the percentage was 25; at Caicedona, 20; and at CIAT, 34. Rejected varieties are replaced yearly with new ones being tested for the first time. This is a continuous, dynamic process in which excellence is the criterion for selection.

Each site was visited eight times to check the development of the trial, collect data and order the necessary weedings.

**Results**

As regards diseases, there was a severe outbreak of bacteriosis at Carimagua and a moderate outbreak at Media Luna, La Zapata and Nataima. Although clean material was taken to all sites, it is difficult to prevent contamination where the disease already exists.

Superelongation disease was also found at Carimagua. Phoma leaf spot decimated the majority of varieties at Darién, which explains the low yields obtained at this site (Table 32). All three types of Cercospora were found at all sites, but *C. vicosae* was

Table 32. **Principal characteristics of the promising cassava varieties planted at the 1974-1975 regional trials.**

| | | | Resistance to | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Plant height (m) | Easy to harvest | Thrips | Bacteriosis | Superelongation disease | **Phoma** sp. | *C. henningsii* | *C. vicosae* |
| M Col 22 | 1.50* | Easy | R** | S | R | S | R | T |
| M Col 113 | 1.98 | Difficult | R | S | S | S | T | S |
| M Col 673 | 2.00 | Moderate | T | S | - | S | R | S |
| M Mex 23 | 2.23 | Difficult | R | S | - | S | T | S |
| M Mex 55 | 1.70 | Easy | T | S | - | S | S | S |
| M Mex 59 | 1.85 | Moderate | S | S | - | S | R | R |
| CMC-9 (M Col 1438) | 2.00 | Moderate | S | T | R | S | S | S |
| CMC-40 (M Col 1468) | 2.35 | Easy | S | S | - | S | R | T |
| CMC-76 (M Col 1505) | 2.25 | Easy | S | -*** | - | S | R | T |
| CMC-84 (M Col 1513) | 2.35 | Easy | T | S | - | S | R | T |

* Plant height for ICA/CIAT promising varieties is given for conditions at CIAT.

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

*** Not evaluated

Table 33. **Fresh weight (tons/ha) and dry matter yield (kg/ha/ha) of cassava varieties at nine sites in Colombia, harvested at 11 months.**

| | Rio Negro | | Media Luna | | Darien | La Zapata | | Caicedonia | | Nataima | | El Nus | | CIAT | | Carimagua |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F.W. | D.M. | F.W. | D.M. | F.W. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. |
| **Trial varieties** | | | | | | | | | | | | | | | | |
| M Mex 59 | 34.7* | 20.5 | 28.7* | 22.0 | 2.4 | 29.2* | 30.5 | 40.0* | 49.0 | 43.6* | 44.0 | 14.6* | 16.9 | 33.1 | 35.6 | - |
| CMC-40** | 28.6* | 21.6 | 29.3* | 25.8 | 5.3* | 18.3 | 17.6 | 32.0 | 35.7 | 45.3* | 40.9 | 15.0* | 17.3 | 42.2* | 42.3 | - |
| CMC-84** | 26.0* | 26.1 | 17.8* | 15.6 | 4.0 | 26.6 | 29.3 | 27.1 | 31.9 | 33.6* | 36.3 | 26.0* | 33.2 | 40.3* | 44.7 | 7.3* |
| CMC-76** | 25.8* | 25.9 | 18.2 | 19.5 | 1.4 | 17.7 | 17.5 | 32.4 | 35.3 | 26.7 | 29.8 | 20.0* | 24.9 | 36.0* | 39.2 | - |
| M Col 113 | 22.9 | 16.4 | 13.4 | 10.8 | 2.5 | 38.9* | 43.9 | 31.2 | 35.2 | 23.8 | 18.5 | 15.6* | 18.0 | 26.8* | 29.0 | 1.6 |
| CMC-9** | 20.2 | 21.4 | 8.0 | 7.8 | 0.1 | 20.7 | 21.2 | 24.4 | 28.8 | 17.7 | 16.7 | 7.8* | 9.0 | 31.7 | 31.9 | - |
| M Col 22 | 19.8 | 17.4 | 22.3* | 24.0 | 0.0 | 20.0 | 22.2 | 27.7 | 35.8 | 34.5* | 34.4 | 13.6* | 18.2 | 39.4* | 46.2 | 4.1 |
| M Mex 23 | 14.5 | 12.0 | 11.8 | 12.6 | 1.0 | 35.6* | 41.5 | 39.6* | 43.6 | 24.5 | 24.8 | 4.5 | 5.6 | 34.3* | 36.3 | 5.8* |
| M Col 673 | 25.1* | 19.0 | 10.5 | 10.8 | - | 32.8* | 38.2 | - | - | - | - | - | - | 25.0 | 28.8 | 4.7 |
| M Mex 55 | 12.8 | 8.1 | 18.8 | 20.1 | - | - | - | - | - | - | - | - | - | 28.8 | 32.4 | - |
| **Regional varieties** | | | | | | | | | | | | | | | | |
| Colombiana | 15.7 | 12.0 | | | | | | | | | | | | | | |
| Torrana Negrita | 11.9 | 8.4 | | | | | | | | | | | | | | |

* Varieties approved for a second-year trial

** Promising ICA varieties

Table 33. (Continuation)

| | Rio Negro | | Media Luna | | Darien | La Zapata | | Caicedonia | | Nataima | | El Nus | | CIAT | | Carimagua |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F.W. | D.M. | F.W | D.M. | F.W. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. | D.M. | F.W. |
| Blanca Mona | | | 17.7 | 21.2 | | | | | | | | | | | | |
| Secundina | | | 11.0 | 12.8 | | | | | | | | | | | | |
| Nativa | | | | | 6.3 | | | | | | | | | | | |
| Tolima | | | | | | 28.1 | 32.3 | | | | | | | 19.5 | 20.0 | |
| Chiroza Gallinaza | | | | | | | | 32.3 | 33.0 | | | | | | | |
| Varasanta | | | | | | | | | | 22.3 | 21.6 | | | | | |
| Aguabajo | | | | | | | | | | 18.3 | 19.3 | | | | | |
| Palmireña | | | | | | | | | | | | 7.7 | 9.6 | | | |
| M Col 113 | | | | | | | | | | | | | | 26.8 | 29.0 | |
| Chiroza Acacías | | | | | | | | | | | | | | | | 3.8 |
| Average including regional varieties | 21.5 | 17.4 | 17.3 | 16.9 | 2.5 | 26.7 | 29.4 | 31.8 | 41.9 | 29.0 | 28.6 | 13.9 | 17.0 | 32.5 | 35.1 | 4.3 |
| Average without regional varieties | 23.0 | 18.7 | 17.9 | 16.8 | 2.0 | 26.6 | 29.1 | 31.8 | 43.0 | 31.2 | 30.7 | 14.7 | 17.9 | 33.0 | 35.7 | 4.4 |
| Best regional average | 15.7 | 12.0 | 17.7 | 21.2 | 6.3 | 28.1 | 32.3 | 32.3 | 33.0 | 22.3 | 21.6 | 7.7 | 9.6 | 26.8 | 29.0 | 3.8 |

most frequent at Rionegro and Media Luna.

As for insects, La Zapata was severely attacked by thrips, which were also reported at Caicedonia, although in smaller numbers.

In relation to dry matter, there was a great deal of variation, as can be seen in Table 33. Taking into account only the four most outstanding varieties, it can be seen that as fertility increases so does dry matter content (Table 34). It was interesting to find that in areas of low soil fertility such as Media Luna, there were varieties so efficient as CMC-84 (13 percent more dry matter than M Mexico 59). These data are especially important for the starch and pelletizing industries and should be taken into account in the final evaluation of varieties.

The principal characteristics of the outstanding promising varieties are given in Table 32. Data on fresh weight and dry matter content are given in Table 33. The general average yield for the best regional varieties at the nine sites in Colombia was 17.8 tons|ha. In comparison to the estimated national average (8 tons|ha), there is a difference of 9.8 tons|ha. Results from the agro-economic survey carried out on 300 Colombian cassava farms suggest that this difference is even greater. Therefore, the national average was surpassed 122 percent through such simple agronomic practices as planting clean, treated seed; incorporating insecticides in the soil at planting; and keeping the crop weed free. The best CIAT|ICA line in each region gave an average yield of about 30 tons|ha, suggesting the enormous yield potential through using not only improved, low-input technology but also improved varieties.

## Cultural practices

### Planting systems

A trial to determine the effect of planting system (on ridges or on the flat) on yield was carried out in collaboration with cassava growers from the region of Caicedonia, where the majority of farmers plant cassava on ridges, even on the slopes. The farmers do this to reduce root rot, which occurs when the soil is very moist. Since some farmers had found that this system produced fewer roots in comparison to planting on the flat, a trial was designed to determine whether this was true. The local variety Chiroza was used with a fixed population of 10,000 plants|ha. Weed control was practiced; it was not necessary to apply either fertilizers or insecticides.

Table 34. **Variation in dry matter content (percentage) of four outstanding varieties, according to site and soil fertility.**

| | M Mex 59 | CMC-40 (M Col 1468) | CMC-84 (M Col 1513) | M Col 22 |
|---|---|---|---|---|
| Media Luna | | | | |
| Low NPK levels | 19.5 | 24.9 | 33.0 | 29.0 |
| Nataima | | | | |
| Medium NPK levels | 33.0 | 29.8 | 35.7 | 32.9 |
| Caicedonia | | | | |
| High NPK levels | 40.4 | 36.8 | 38.9 | 42.7 |
| La Zapata | | | | |
| High N, low P and K levels | 34.5 | 31.8 | 36.3 | 36.6 |

Table 35: **Yields, harvest index, percentage of commercial roots and weight of commercial roots for the different plant populations of the variety Chiroza, taken at 340 days.**

| Plants/ ha | Fresh weight yield total roots (tons/ha) | Harvest index* | Commercial roots (%) | Fresh weight commercial roots (tons/ha) |
|---|---|---|---|---|
| 4,000 | 20.5 | 0.50 | 100 | 20.5 |
| 7,000 | 30.9 | 0.51 | 100 | 30.9 |
| 11,000 | 31.4 | 0.49 | 91 | 28.5 |
| 14,000 | 27.8 | 0.46 | 91 | 25.2 |
| 17,000 | 35.7 | 0.49 | 84 | 29.9 |

* Data taken from 20 plants selected at random

Harvesting was done at 341 days. Average yield on ridges was 28.4 tons/ha whereas on the flat it was 32.2 tons. Nevertheless, planting cassava on the flat is not advisable in all cases; soil texture must be taken into account. On sandy soil, planting should be done on the flat; and on heavy soils, ridges should be used to avoid

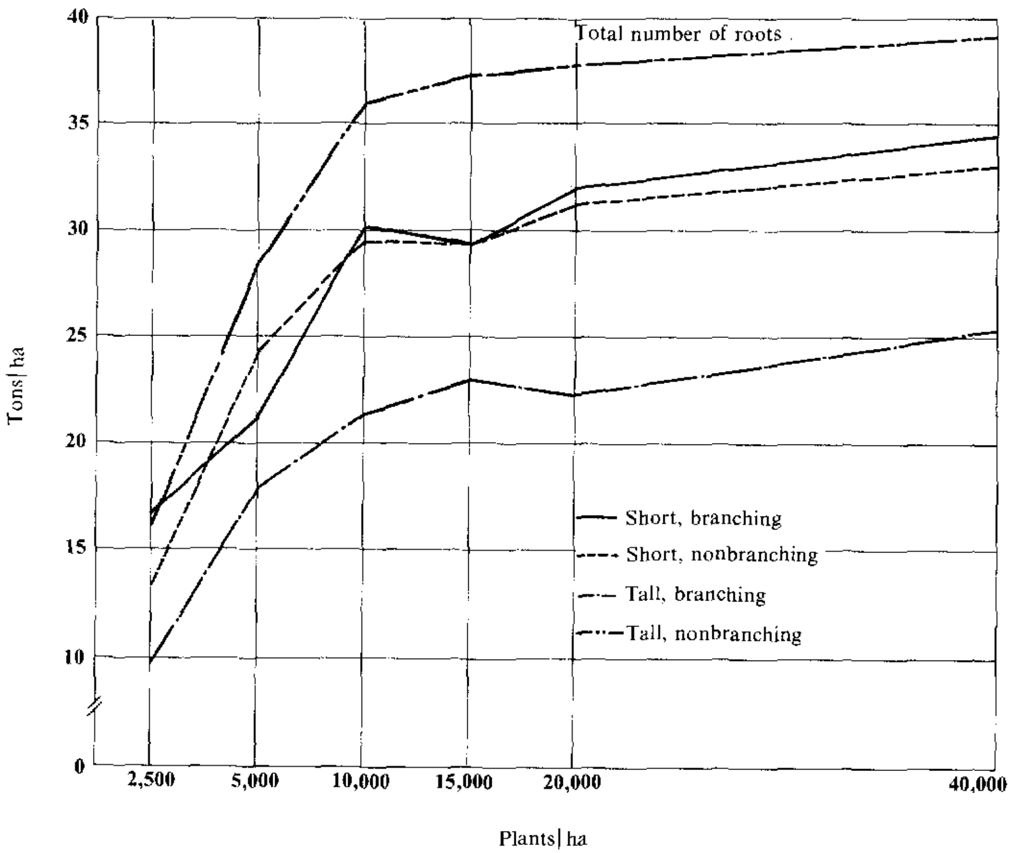


Figure 35. **Effect of plant population on fresh weight yield of total number of roots from four different plant types.**

the danger of rotting. Although yields are lower when cassava is planted on ridges, harvesting is easier. This is not evident in the case of Caicedonia because of the special soil conditions of this region. When planting on ridges, an average of 1,070 kg|man was harvested during a seven-hour day, as compared to 896 kg for the other system. In a similar trial at CIAT, it was found that planting on ridges required 12.6 tractor hrs|ha, whereas planting on the flat required only 8.4; therefore, the latter system is recommended on soils where rotting is not a serious risk.

**Optimal plant populations on ridges**

In order to determine the optimal plant population for the medium-height variety Chiroza, a trial was designed using low and high populations in contrast to the 7,000 plants|ha commonly used in the region. Populations ranging from 4,000 to 17,000 plants|ha were used.

Between the 7,000 and 17,000 plant population, there was a difference of 4,790 kg|ha, significant at 5 percent with the Duncan test (Table 35). Nevertheless, this higher weight is not profitable because as the population increases, the percentage of commercial roots decreases. Consequently, a population of 7,000 plants|ha is adequate for the conditions in Caicedonia, where the roots are destined for fresh consumption.

**Plant type versus population**

In cassava, optimal plant population depends upon the height of the variety. The fan-shaped trials have provided a great deal of information, but further study is needed in relation to the different plant types.

Two short and two tall varieties with different branching habits were selected. Populations ranging from 2,500 to 40,000

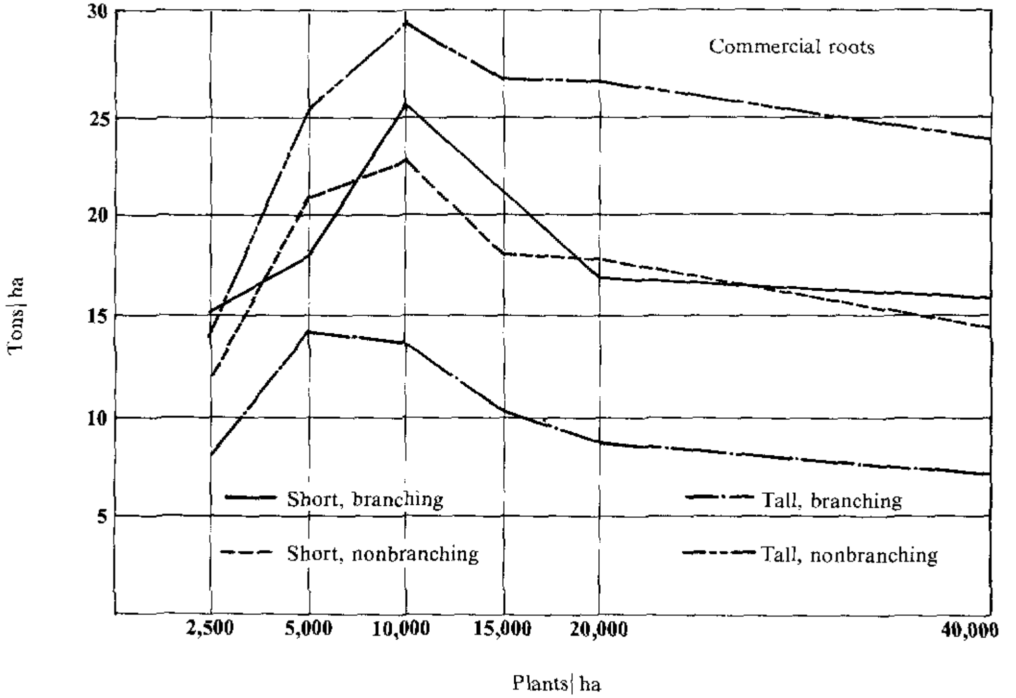


Figure 36. **Effect of plant population on fresh weight yield of commercial roots from four different plant types.**

plants/ha were used. The trial was harvested at 367 days.

Figure 35 shows the trend for total root production; that is, as plant population increases, cassava production increases. This would be the ideal case for countries like Brazil and Thailand, where cassava is processed before being marketed. In the 1974 Annual Report (physiology section), population curves tended to descend at 40,000 plants/ha. In this case, however, these curves do not descend at this level because weeding was done only three times and weed populations were lower at higher densities, whereas in the physiology trials, weeding was done throughout the trial.

In areas where cassava is consumed fresh, it is necessary to find an optimal plant population for commercial root production (roots longer than 25 cm and more than 5 cm in diameter). For the short varieties and the tall, nonbranching varieties, this was 10,000 plants/ha; whereas for the tall, branching variety, the optimal population was 5,000 (Fig. 36). Each variety must be analyzed separately and cannot be compared, as each has a different genetic nature that determines its potential yield. It was also found that as plant populations increase, the number of weeds decreases. Branching varieties let less light through than nonbranching ones, thus exercising better weed control.

## SOILS

At the beginning of 1974 various experiments were planted in the acid soils in Carimagua (Llanos Orientales) to study the response of cassava to fertilization and to determine the best agronomic practices for this type of soil. A severe attack of CBB eliminated several experiments and affected plant growth to a lesser extent in others. In October, 1974 several experiments were repeated in Tranquero, a few kilometers from Carimagua; and these remained free of CBB until harvest. The results of the Tranquero and the least affected Carimagua experiments are reported below. Except for the element(s) under study, the trials received a uniform fertilizer application of 1/2 ton lime/ha with a Ca/Mg ratio of 10:1;100 kg N/ha as urea; 100 kg $P_2O_5$/ha as triple superphosphate; 200 kg $K_2O$/ha, half as KCl and half as $K_2SO_4$; and 10 kg Zn/ha as zinc sulfate. The variety Llanera was used; all experiments were harvested at 9 1/2 or 10 months of age.

### Fertilization

#### Potassium*

In last year's report it was indicated that K is the element that most limits cassava yields in many soils. The importance of K was again demonstrated in Carimagua and Tranquero, as well as in Jamundí, on an acid, but relatively high base-status soil (1974 Annual Report, Table 26, p.91). Studying the effect of three sources of K(KCl, KCl + S and $K_2SO_4$) in Tranquero, it was found that plants with the KCl treatments had severe yellowing of bottom leaves, indicative of S deficiency, at three months of age while those with KCl + S and $K_2SO_4$ applications remained green and showed better plant growth. Sulfur content of leaves, averaged over three levels of application, was 0.29, 0.30 and 0.37 percent for KCl, KCl + S and $K_2SO_4$ treatments, respectively. The S contents were above the 0.2-0.25 percent level, given as the criticals content for most crops; but cassava may have an unusually high S requirement as it was the only crop showing clear S-deficiency symptoms in Carimagua.

Figure 37 shows the yield response to K applications in Jamundi and Tranquero. In Jamundí there was a significant response to the application of 120 kg $K_2O$/ha, but no significant differences were observed between KCl and $K_2SO_4$. In

* This and the next two experiments were part of a PhD thesis project.

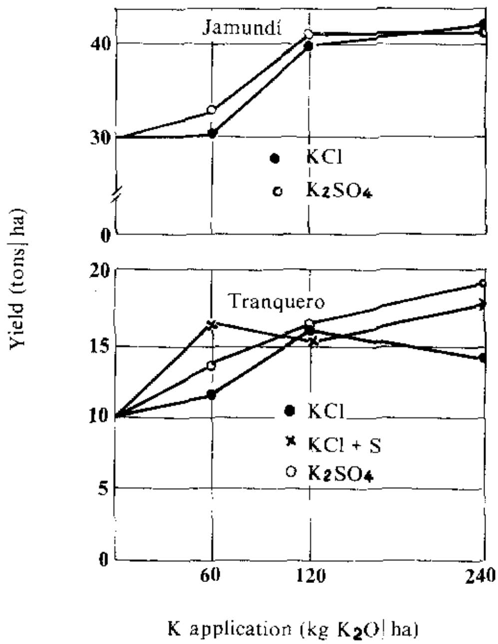


Figure 37. **Response of cassava to the application of several levels and sources of K in Jamundí and Tranquero; harvest at 10 and 9 1|2 months, respectively.**

Tranquero cassava showed a large response to applications of 120 kg $K_2O$|ha as KCl and 240 kg $K_2O$|ha as KCl + S or $K_2SO_4$. The negative response to high KCl applications could be due to a high leaf N|S ratio of 17.2, as compared to 15.1 and 14.8 for comparable KCl + S and $K_2SO_4$ treatments. In other crops N|S ratios over 15 are generally indicative of S deficiency. Also, the high chloride application reduced the uptake of sulfate by anion competition, intensifying the S deficiency even more. A direct toxicity of the chloride anion (as observed in potatoes) is also a possible explanation since the high KCl treatment had a chloride content of 0.11 percent in the roots as compared to 0.09 percent for KCl + S and 0.06 percent for $K_2SO_4$ treatments. The lack of significant differences between K sources in Jamundí was mainly due to a lack of S response, which is due to the higher S status of these volcanic-ash influenced soils (7.8 ppm available sulfate S) compared with the Llanos soils (4.0-4.5 ppm). Yields in both trials were high, particularly for the Llanos, where a yield of just under 20 tons|ha was obtained.

**NxK interaction**

A complete factorial trial of three levels of N by three levels of K was established in Tranquero to study the interaction of these important plant nutrients. There was no response to N in the absence of K, but there was a strong positive response to K in the absence of N (Fig. 38). Cassava yields with no N and 300 $K_2O$ were nearly double those obtained with no K and 200 N. In the presence of K there was a positive response to the application of 100 kg N|ha but a subsequent negative response to 200 kg. In the presence of N there was a strong positive response to the application of 150 kg $K_2O$|ha (as KCl), but there was no additional yield increase with 300 kg $K_2O$|ha.

It appears that K is the main element limiting yields, but once the K requirement is satisfied, plants respond to a moderate

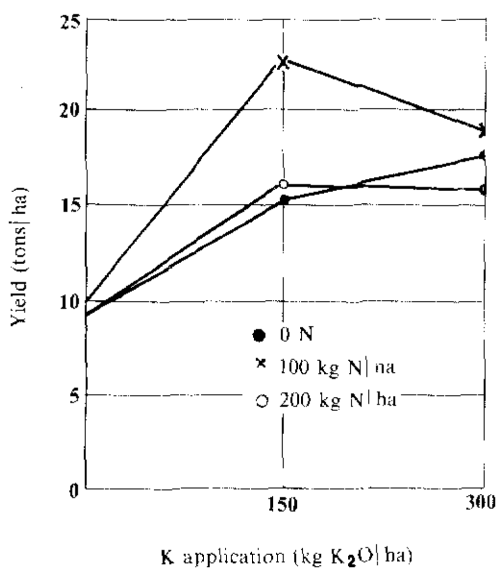


Figure 38. **Response of cassava to the application of several levels of K and N in Tranquero; harvest at 9 1|2 months.**

but not too high application of N. Information in literature indicating that high N applications increase leaf growth but decrease root growth was not corroborated in this experiment since leaf area as well as yield were depressed by high N applications in the presence of K. Root dry matter production was highly correlated (r = 0.97) with total dry matter production.

Although yields increased, K fertilization reduced the N content and thus the protein content of roots significantly; nevertheless, protein yield|ha was increased. The application of K reduced the Mg content of leaf blades and petioles, possibly inducing Mg deficiency, resulting in a yield reduction with the high K treatments.

### Magnesium

Since cassava plants grown in Carimagua generally have a very low Mg content in the leaves, a trial was established to determine the significance of Mg fertilization, using two sources and five levels of Mg. Figure 39 shows that cassava yields can be increased by 10 tons|ha, applying 50 kg|ha of Mg as $MgSO_4$. Higher levels of $MgSO_4$ were detrimental, possibly due to induced Ca deficiency. Ca levels in petioles at 3 1|2 months decreased

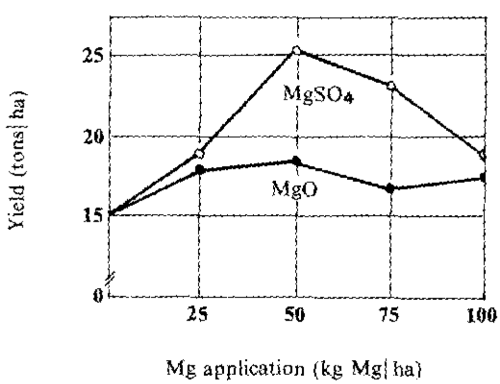


Figure 39. **Response of cassava to several levels of applied magnesium using two different Mg sources in Tranquero; harvest at 9 1|2 months.**

from 2.95 to 1.38 percent by high $MgSO_4$ applications. $MgSO_4$ was a more effective source than MgO because of its higher solubility and the presence of sulfate, which apparently is essential for optimum cassava production in these soils. The yield of 25 tons|ha, the highest obtained to date in the Llanos, is very promising in view of the fact that it was achieved after 9 1|2 months.

### Lime x minor element interactions

During a previous evaluation it was observed that most cassava cultivars produced highest yields with applications of 1|2 or 2 tons|ha of lime but showed a strong negative response to higher lime applications. At the 6 tons|ha lime level, many varieties showed severe chlorosis and deformation of the growing points, which was attributed to a possible deficiency of minor elements. Although the problem was thought to be due mainly to Zn deficiency, an experiment was planted to study the interaction of lime with all minor elements except Fe, which is abundant in these soils. Within main plots with applications of 0, 1|2, 2 and 6 tons|ha of lime, subplots of minor elements (added individually and in complete combination) were established.

The effect of liming on pH and Al has been reported before (1973 Annual Report, p.211). The Chirosa variety used was intermediately affected by CBB; the attack was less severe at high levels of lime application. During the entire growth cycle, plants did not show deficiency symptoms, and there appeared to be a positive response to the application of 2 and 6 tons|ha of lime.

Foliar analyses at two months (Fig. 40) indicated that without Zn applications the Zn content decreased from 72 to 38 ppm with the application of 6 tons lime|ha. With applications of 20 kg Zn|ha, the Zn content decreased from 212 to 71 ppm. As compared to other varieties, Chirosa had a

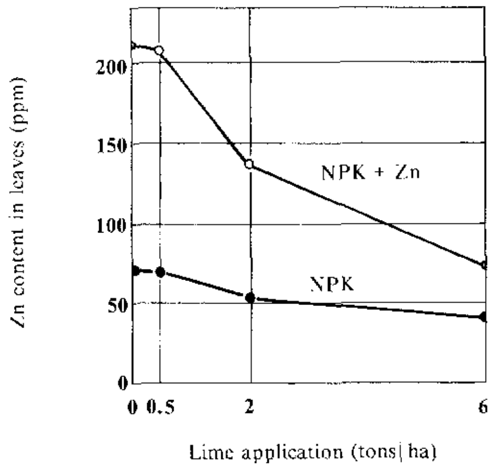


Figure 40. **The effect of lime application on the zinc content of cassava leaves with and without soil-applied zinc.**

high Zn content; but without Zn applications its Zn content (38 ppm) was deficient although it was not low enough to produce deficiency symptoms, which generally appear below 20 ppm.

Figure 41 shows yield responses to lime applications with and without added Zn. It is clear that without Zn there is a negative response to the high lime application whereas with Zn the variety responded

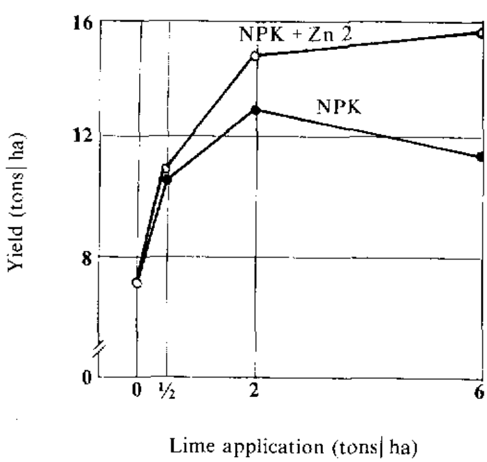


Figure 41. **Response of cassava to lime applications with and without soil-applied zinc in Carimagua; harvest at ten months.**

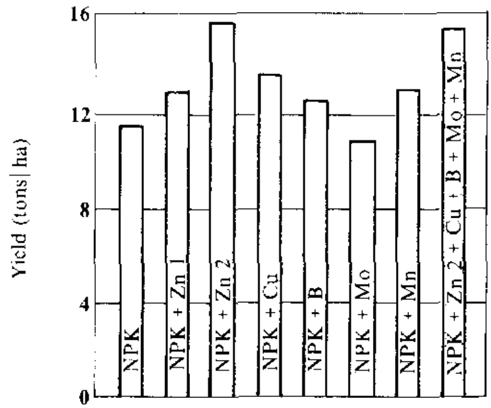


Figure 42. **Response of cassava to minor element applications at a lime level of 6 tons| ha in Carimagua; harvest at ten months.**

positively up to 6 tons lime| ha. This was the only minor element treatment without a yield reduction at the high lime level. Thus, the negative response of cassava to even moderate lime applications, not observed in any other crop studied, is due to induced Zn deficiency, to which cassava is apparently very susceptible. Figure 42 shows the yield response to all minor elements at the 6 tons| ha lime level, indicating the relative importance of Zn and, to a lesser extent, Cu and Mn. At the lower lime levels, the response to minor elements was smaller.

## Nutrient content of plant parts

Table 36 shows the nutrient contents of leaf blades, petioles and roots at various times during the growth cycle. These nutrient contents correspond to near maximum yields in Carimagua; they give an indication of what may be considered to be "normal" nutrient contents although these may vary to some degree according to soils, varieties, climatic conditions and fertilization.

N, P and S contents were higher in the leaf blades than in the petioles while levels of K, Ca and Mg were much higher in the petioles. The petioles also showed a wider

Table 36 **Nutrient content of leaf blades and petioles in upper canopy and roots at various times during the growth cycle of cassava plants grown in Carimagua.**

| | Leaf blades | | | Petioles | | | Roots |
|---|---|---|---|---|---|---|---|
| Months | 2 | 4 | 6 | 2 | 4 | 6 | 10 |
| N(%) | 5.60 | 4.90 | 5.00 | 1.60 | 1.50 | 1.40 | 0.50 |
| P(%) | 0.27 | 0.25 | 0.25 | 0.13 | 0.12 | 0.12 | 0.05 |
| K (%) | 1.80 | 1.60 | 1.50 | 3.30 | 2.80 | 2.20 | 0.80 |
| Ca (%) | 0.60 | 0.60 | 0.70 | 1.20 | 1.50 | 1.50 | 0.04 |
| Mg(%) | 0.23 | 0.23 | 0.22 | 0.37 | 0.30 | 0.41 | 0.05 |
| S (%) | — | 0.37 | 0.34 | – | 0.14 | 0.13 | 0.05 |
| Zn (ppm) | 60 | 60 | – | — | — | — | — |

range for the latter group of elements and thus were more indicative of their nutrient status. Roots had a much lower nutrient content than either leaf blades or petioles. Most elemental contents decreased slightly during the growth cycle with the exception of Ca. Ca and Mg contents in Carimagua were low compared to those on many other soils and may have resulted in relatively high K contents.

**Economics of fertilization**

Without fertilizer application, cassava yields in the Llanos soils are extremely low (5-10 tons|ha). An adequate level of fertilization would be the application of 500 kg|ha of dolomitic lime; 100 kg N|ha as urea, band applied at seeding and 60 days; 100 kg $P_2O_5$|ha, band applied as basic slag at seeding; 200 kg $K_2O$, band applied as KCl; 25 kg|ha of elemental sulfur; and two foliar applications of Zn as 2 percent zinc sulfate.

At current fertilizer and transport costs, this amounts to about $4,500 in fertilizer and $1,500 in transport costs or a total of $6,000|ha. At current prices for cassava ($3|kg), the cost of fertilization can be paid for by producing an extra 2 tons of cassava|ha. With a potential yield increase (due to fertilization) of at least 15 to 20 tons|ha, the application of fertilizers seems economically justified.

**Agronomic practices**

**Methods of fertilization**

Comparing various methods of application of a complete fertilizer (broadcoast, band, circle and spot placed), it was found that broadcast applications were entirely ineffective in supplying nutrients to recently planted cassava, inducing excessive weed growth only. Among the localized placement methods, spot placement either in the stake hole or 15 cm from the stake, as well as the single- or double-interrupted band placement, looked most promising at the early growth stage. At two months of age, plants had heights of 31 to 36 cm with localized fertilization, as compared with 19 and 20 cm for the broadcast and check plots, respectively.

**Time and method of seeding**

In areas with a pronounced dry season, it is important to determine the best time of seeding in relation to the dry season. Monthly seedings were carried out between October and June, when the trial had to be terminated because of CBB. In

Table 37. **Yields of cassava planted in Carimagua at monthly intervals on ridges or on the flat; harvest at ten months.**

| Month of planting | Yield (tons/ha) | |
|---|---|---|
| | Ridge | Flat |
| October | 17.1 | 18.1 |
| November | 8.6** | 17.5 |
| December | 12.0 | 12.3 |
| January* | 17.7 | 14.4 |
| February* | 18.9 | 20.2 |
| March* | 14.5 | 12.8 |
| April | 9.0 | 5.3 |
| May | 10.5 | 9.1 |
| June | 12.8 | 11.7 |

* One initial irrigation at seeding

** Low yield due to damage by pigs

Carimagua the dry season extends from December to March, with highest precipitation in June and July. The January, February and March seedings received one irrigation at time of seeding since soils moisture was entirely inadequate for germination.

Best yields were obtained by seeding one to three months before the onset of the dry season or during the dry season when irrigation was possible. Lowest yields were obtained seeding two to three months before the wettest months when high rainfall coincides with a period of high plant susceptibility to diseases and root formation coincides with a period of soil moisture stress. Seeding on ridges was better during the wet season plantings whereas seeding on the flat was better during the dry season plantings (Table 37).

## WEED CONTROL

In the agro-economic survey conducted last year, bracken fern (*Pteridium aquilinum*) was found to be an important weed in several cassava-growing regions. None of the herbicides recommended for cassava give effective control of this rhizomatous weed. As a postemergence herbicide, asulam is reported to control bracken fern; a trial was conducted to determine its selectivity in two cassava varieties. Applications of 2 and 4 kg/ha were made over the top of 45-day-old cassava or to the lower half of the plants.

The over-the-top application caused severe initial injury to both varieties at the high rate but only to M Colombia 137 at the low rate (Table 38). There was partial recovery from the initial effects when the entire plant was treated. Spraying the

Table 38. **Tolerance of two cassava varieties to postemergence applications of asulam.**

| Asulam rate | Part of plant treated | Injury rating* | | | |
|---|---|---|---|---|---|
| | | M Col 137 | | M Pan 64 | |
| | | 30 DAA** | 60 DAA | 30 DAA | 60 DAA |
| 2 | Lower half | 1.0 | 1.2 | 0.8 | 1.3 |
| 2 | Entire | 5.2 | 3.5 | 3.3 | 3.0 |
| 4 | Lower half | 2.3 | 1.6 | 1.3 | 1.0 |
| 4 | Entire | 7.3 | 6.6 | 7.0 | 6.6 |
| Check | – | 0 | 0 | 0 | 0 |

* Visual scale where 0 = no injury; 10 = crop killed

** DAA = days after application

Table 39. **Summary of three years' research on selective herbicides in cassava.**[1]

| Highly selective[2] | Marginally selective[3] | Nonselective[4] |
|---|---|---|
| alachlor | butylate | ametryn |
| benthiocarb | chlorbromuron | amitrole (post)[5] |
| bifenox | CIPC + naptalam | atrazine |
| butachlor | diuron | bentazon (post) |
| chloramben | fluometuron | bromacil |
| cyanazine | linuron | dalapon (post) |
| dinitramine | methabenzithiazuron | DNBP (post) |
| DNBP | metribuzin | DPX-1108 (post) |
| DPX-6774 | oxadiazon | DPX-3674 |
| fluorodifen | | EPTC |
| FMC-25213 | | glyphosate (post) |
| H-22234 | | karbutilate |
| IT-5914 | | MSMA (post) |
| methazole | | paraquat (post) |
| napropamide | | prometryn |
| nitralin | | tebuthiuron |
| nitrofen | | terbutryn |
| norea | | 2, 4-D (post) |
| perfluidone | | vernolate |
| pronamide | | |
| prinachlor | | |
| S-2846 | | |
| trifluralin | | |

1 All herbicides applied as preplant incorporated or preemergence treatments unless otherwise noted

2 No injury to cassava even at four times the normal rate

3 No injury at the normal rate but serious injury at double and quadruple rates

4 Serious injury even at the recommended rates

5 Postemergence treatments were applied over the top of young cassava plants.

lower half caused only slight injury at either rate. Therefore, where bracken fern is a serious problem, directed applications of asulam should be tested as a possible control measure.

As a conclusion to the intensive herbicide screening activities in cassava which began in 1972, a large selectivity trial was carried out. The recommended rate and four times this rate were applied preemergence in a medium-textured soil to the variety M Colombia 113. Injury observations were taken during the first three months, and foliage and root yields were taken ten months after planting. Based on these and all previous trials, a summary of the relative selectivity of herbicides in cassava is presented in Table 39.

Twenty-three compounds were found to be highly selective. These products applied singly or in combination would provide effective treatments for nearly all weed species commonly found in cassava-growing regions. In addition, the marginally selective compounds could also be recommended under most conditions if applied correctly.

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* This list includes only journal articles published outside CIAT's series.