## Regional Trials

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

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

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

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

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

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

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

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

[1] Total rainfall during cassava growing cycle.

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

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

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

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

| Site | Yield (t/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average of five cycles[1] | | | | 1979-80 cycle | | | | Average per site | | | |
| | Promising | | Local | | Promising | | Local | | Promising | | Local | |
| | FRW[2] | DM[2] | FRW | DM | FRW | DM | FRW | DM | FRW | DM | FRW | DM |
| Media Luna | 23.4 | 6.7 | 8.3 | 3.0 | 23.2 | 6.1 | 10.1 | 3.3 | 23.3 | 6.6 | 8.6 | 3.0 |
| Chigorodó | - | - | - | - | 59.8 | 16.4 | 28.9 | 8.6 | 59.8 | 16.4 | 28.9 | 8.6 |
| Carimagua | 20.4 | 6.7 | 13.3 | 4.2 | 15.8 | 4.9 | 4.5 | 1.3 | 19.6 | 6.4 | 11.8 | 3.7 |
| Río Negro | 33.2 | 9.9 | 14.9 | 4.6 | 24.0 | 5.6 | 13.6 | 3.1 | 31.6 | 9.2 | 14.7 | 4.3 |
| San Martín | - | - | - | - | 27.0 | 9.3 | 19.2 | 6.2 | 27.0 | 9.3 | 19.2 | 6.2 |
| Nataima | 33.3 | 10.0 | 18.0 | 5.1 | - | - | - | - | 33.3 | 10.0 | 18.0 | 5.1 |
| CIAT-Palmira | 36.8 | 13.0 | 22.3 | 7.7 | 49.6 | 18.7 | 25.5 | 8.2 | 38.9 | 13.9 | 22.8 | 7.7 |
| CIAT-Quilichao | 37.8 | 12.0 | 31.4 | 9.9 | 29.5 | 8.8 | 22.1 | 5.7 | 35.0 | 10.9 | 28.3 | 8.5 |
| Caicedonia | 41.9 | 14.9 | 29.2 | 9.9 | 47.4 | 17.8 | 27.7 | 10.1 | 42.8 | 15.3 | 28.9 | 9.9 |
| Average per cycle | 32.8 | 10.8 | 21.6 | 7.2 | 34.5 | 10.9 | 18.9 | 5.8 | 34.6 | 10.9 | 20.1 | 6.3 |

[1] See CIAT Cassava Prog. 1979 Ann. Rept., for details.

[2] FRW=fresh root yield; DM=dry root yield.

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

## Varietal Adaptation and Yield Stability

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

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

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

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

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

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

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

Table 4. (continued).

| Line or accession | Fresh root yield (t/ha) | | | | | | | | | | | Average | Dry Matter | Disease reactions[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Media Luna | Caribia | Chigorodó | Carimagua | Río Negro | San Martín | Nataima | CIAT-Palmira | CIAT-Quilichao | Caicedonia | Pereira | | (%) | CBB | Super-elongation |
| **Outstanding accessions** | | | | | | | | | | | | | | | |
| M Col 113 | | | | 3.4 ( 3) | | | | 20.2 ( 6) | | | *28.8 ( 2)* | *17.2 (11)* | 39 | S | S |
| M Col 1684 | 29.4 ( 3) | 36.2 ( 6) | 45.9 ( 1) | 20.1 ( 8) | 35.2 ( 3) | 24.5 ( 1) | 27.2 ( 3) | 29.1 ( 9) | 31.4 ( 3) | 50.5 ( 3) | | 30.8 (40) | 31 | MR | MR |
| M Col 22 | 19.6 ( 6) | 28.7 ( 6) | | 10.8 ( 8) | | | 26.0 ( 4) | 26.2 (11) | | 30.9 ( 3) | 8.8 ( 2) | 22.0 (40) | 34 | S | S |
| M Col 1468 (CMC 40) | 22.7 ( 5) | 25.5 ( 4) | 58.2 ( 1) | 17.6 ( 8) | 24.7 ( 5) | | 31.9 ( 5) | 37.6 ( 9) | | 36.9 ( 4) | 31.2 ( 4) | 29.1 (45) | 30 | MR | MR |
| M Ven 218 | 14.7 ( 3) | 29.3 ( 2) | | 9.5 ( 4) | | | 24.2 ( 3) | 36.1 ( 8) | | 32.4 ( 3) | | 26.1 (23) | 33 | S | R |
| M Col 1505 (CMC 76) | | | 34.5 ( 1) | | 26.2 ( 3) | | | 33.1 ( 3) | | | 28.7 ( 3) | 29.8 (10) | 35 | S | S |
| M Col 1513 (CMC 84) | 13.1 ( 5) | | | 17.0 ( 5) | 29.9 ( 5) | | 26.9 ( 2) | 35.0 ( 4) | | 31.5 ( 3) | 24.2 ( 2) | 24.5 (26) | 34 | S | S |
| M Mex 59 | 23.1 ( 5) | | | 17.7 ( 4) | 33.1 ( 5) | 30.1 ( 1) | 29.6 ( 5) | 24.8 ( 3) | | 32.7 ( 5) | 16.4 ( 3) | 24.6 (31) | 32 | S | R |
| M Col 1529 (CMC 99) | | | | | 31.6 ( 3) | | | | | | | 31.6 ( 3) | 30 | MR | S |
| M Ven 155 | 15.6 ( 3) | | | | *25.2 ( 3)* | | | 28.5 ( 3) | | | | 23.1 ( 9) | 34 | S | S |
| M Ven 77 | | | | 16.9 ( 5) | 27.7 ( 3) | | | | | | | 21.0 ( 8) | 28 | R | R |
| M Col 673 | | | | 9.3 ( 2) | 29.0 ( 3) | | | | | | | 21.1 ( 5) | 36 | S | MR |
| M Col 677 | | | | | 24.0 ( 3) | | | 22.5 ( 2) | | 28.7 ( 8) | | 25.4 ( 8) | 37 | S | MR |
| M Col 1686 | | | | | | | 32.3 ( 2) | | | | | 32.3 ( 2) | 28 | - | - |
| M Pan 70 | | | | | | | 23.5 ( 3) | 28.5 ( 3) | | 34.3 ( 3) | | 28.8 ( 9) | 33 | S | R |
| Ptr 26 | | | | | | | 28.1 ( 3) | 28.4 ( 3) | | | | 28.3 ( 6) | 33 | S | R |
| M Mex 17 | | | | | | | 24.8 ( 3) | 25.7 ( 3) | | | | 25.3 ( 6) | 34 | S | S |
| M Mex 23 | | | | 12.1 ( 2) | | | | 27.2 ( 3) | | 31.4 ( 3) | | 25.0 ( 8) | 37 | S | MR |
| M Col 1292 | | | | | | | | | | 33.9 ( 3) | | 33.9 ( 3) | 38 | S | S |
| M Col 1488 (CMC 59) | | | | | | | | | | | 41.3 ( 3) | 41.3 ( 3) | 40 | - | - |
| Chiroza | | | | *17.9 ( 4)* | | *19.2 ( 1)* | | | | | | 18.2 ( 5) | 32 | S | S |
| Weighted average | 19.8 (30) | 30.6 (18) | 46.2 ( 3) | 14.9 (53) | 28.8 (36) | 24.6 ( 3) | 27.7 (33) | 29.6 (70) | 31.4 ( 3) | 34.3 (33) | 26.7 (19) | 26.3 (301) | | | |
| Weighted average of control cultivars | 8.7 ( 6) | 11.7 ( 9) | 28.9 ( 1) | 12.5 (11) | 14.7 ( 6) | 13.4 ( 2) | 14.2 ( 4) | 23.7 (12) | 28.3 ( 3) | 29.1 ( 6) | 35.6 ( 4) | 18.5 (64) | | | |

[1] Reactions: S = Susceptible; MR = Moderately resistant; R = Resistant

[2] Figures in parentheses indicate number of cropping cycles.

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

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

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

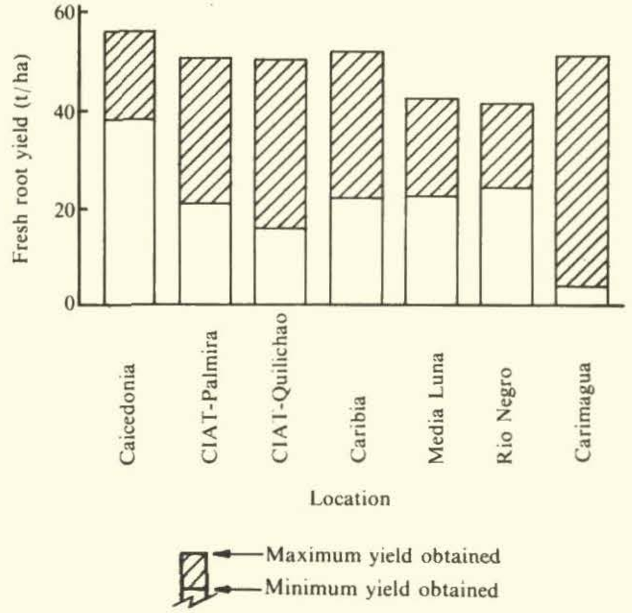

Figure 1. *Yield variation of variety M Col 1684 within and across seven locations. (Maximum yield at Carimagua from Soils and Plant Nutrition section, CIAT Cassava Prog. 1979 Ann. Rept).*

Yield variations at CIAT-Palmira, Caribia and Carimagua were analyzed for three germplasm accessions—Llanera, M Col 22 and M Col 1684 (Fig. 2). While M Col 1684 had the highest average yield at all locations, its yields were also the most unstable. Yields of Llanera and M Col 22 were similar at CIAT-Palmira although Llanera yields were stable. At Caribia, Llanera yielded poorly and unstably, and M Col 22 produced relatively high, stable yields. At Carimagua, yields of all three cultivars were unstable. These data suggest that wide adaptation and yielding ability are both independent of yield stability within a location. Since stable yield in one site does not guarantee stability in other locations, stable-yield must be sought in each location.

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

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

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

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

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

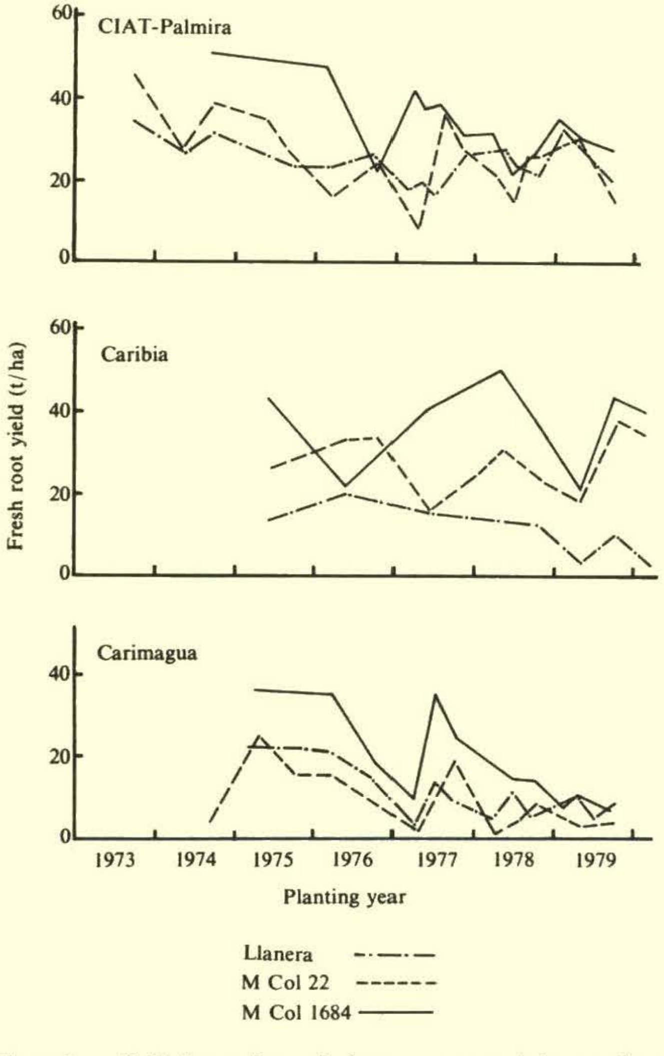

Figure 2. *Yield fluctuations of three cassava varieties at three locations.*

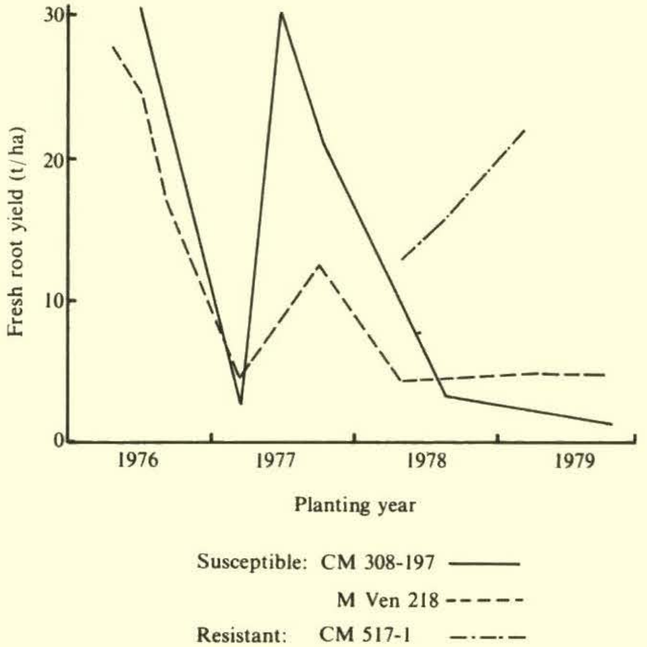

Figure 3. *Yield fluctuation of cassava lines having different resistance to cassava bacterial blight (CBB) at Carimagua.*

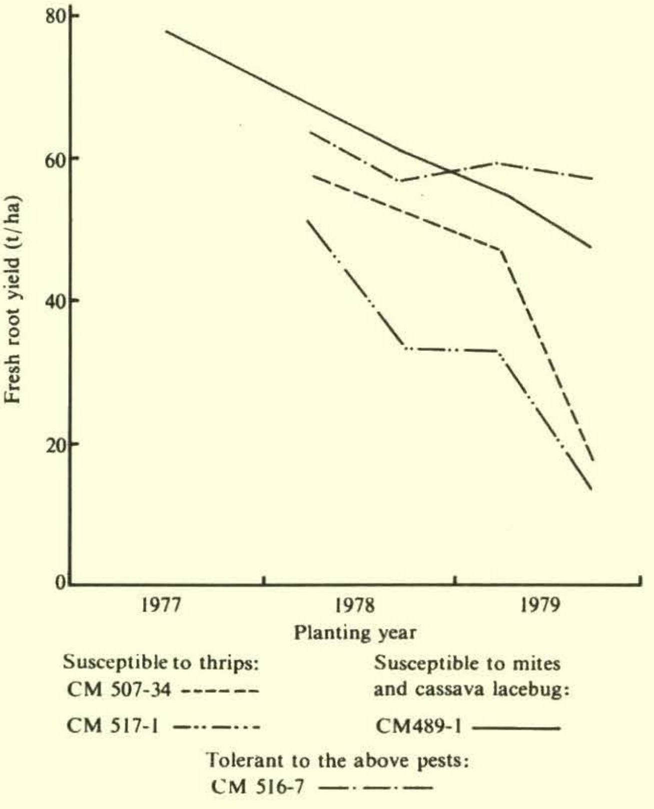

Figure 4. *Yield fluctuations of cassava lines having different resistances to insects, at CIAT-Palmira.*

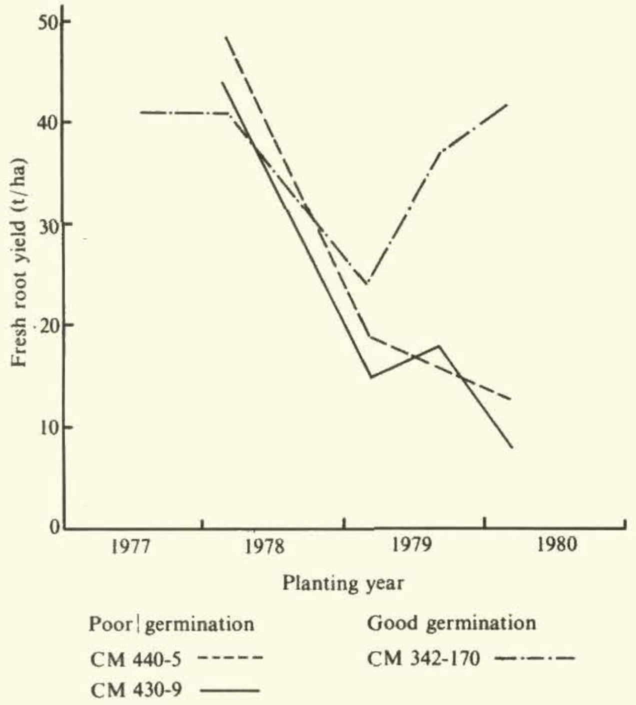

Figure 5. *Yield fluctuations of cassava lines having different germination habits, at Caribia.*

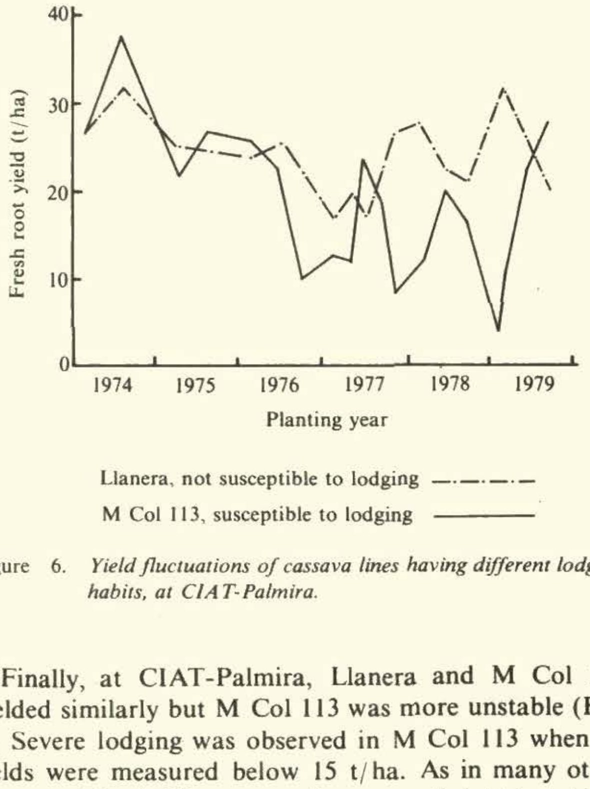

Figure 6. *Yield fluctuations of cassava lines having different lodging habits, at CIAT-Palmira.*

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

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

## International Yield Trials

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

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

## Cassava Propagation from Leaf-Bud Cuttings

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

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

## Cultural Practices

### Weed Control

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

#### Preemergent herbicide mixtures

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

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

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

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

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

[1] DAA = days after application.

[2] Chemical injury rating based on 0-10 scale where 0 is no injury and 10 is very severe injury leading to death of plants.

[3] No observations made due to absence of this weed.

[4] No commercial price could be obtained for fluridone.

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

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

### Weed control in mixed cropping systems

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

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

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

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

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

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

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

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

Five conclusions are evident from results in the two experiments:

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

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

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

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

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

### Purple nutsedge control

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

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

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

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

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

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

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

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

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

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

[1] Evaluated nine months after planting.

[2] Percentage based on a mean tuber number of 2300/m² representing the pretreatment infestation of plots.

## Multiple Cropping

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

### Legume agronomy in cassava-legume intercrops

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

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

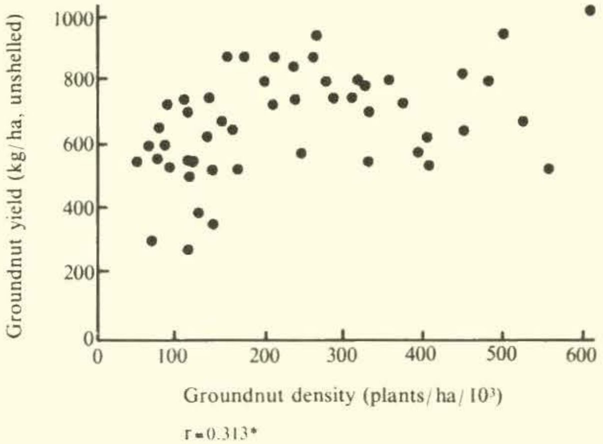

Figure 8. *Yield response of groundnut to planting density when intercropped with cassava cultivar CMC 84, at CIAT-Quilichao.*

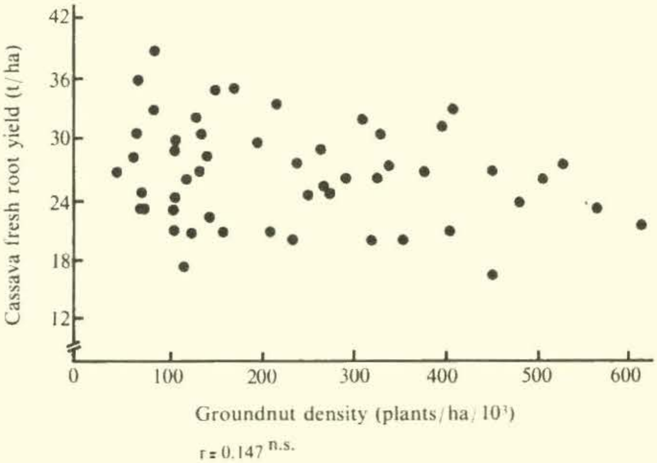

Figure 9. *Influence of groundnut planting density on cassava root yield in a groundnut-cassava intercropping system, at CIAT-Quilichao.*

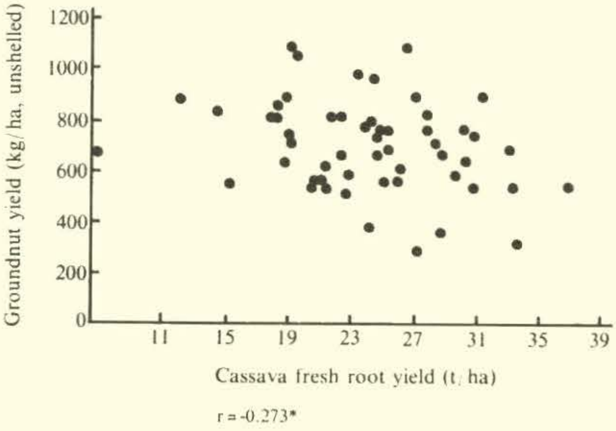

Figure 10. *Relationship between yields of groundnuts and cassava grown in an intercropping system, at CIAT-Quilichao.*

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

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

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

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

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

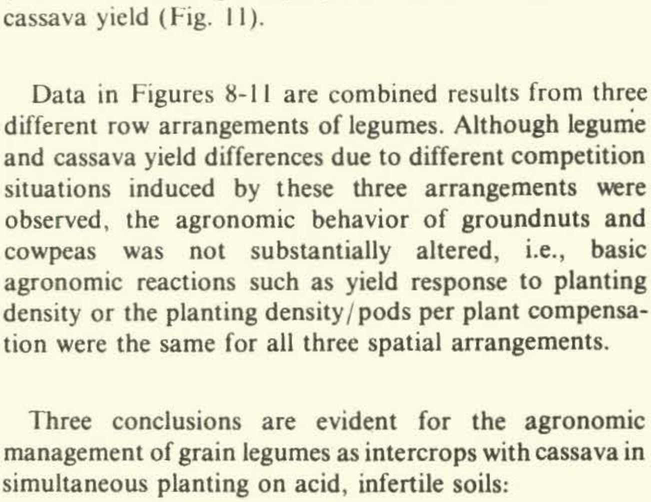

Figure 11. *Effect of cowpea planting density on yield of cassava cultivar M Ven 218 grown in an intercropping system, CIAT-Quilichao.*

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

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

### Nutrient responses of cowpea-cassava intercrops

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

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

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

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

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

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

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

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

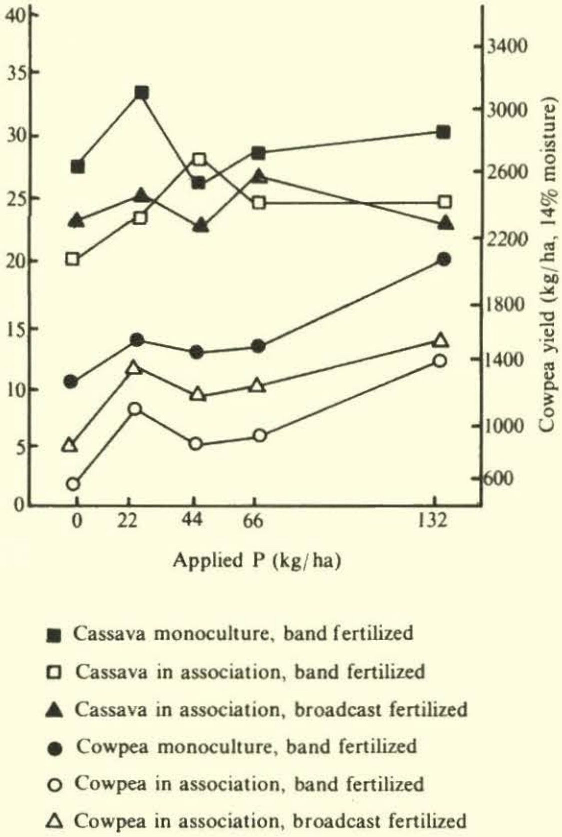

Figure 12. *Effects of rates and application methods of P on yields of cassava and cowpeas in association and monoculture, at CIAT-Quilichao, 1980.*

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

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

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

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

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

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

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

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

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

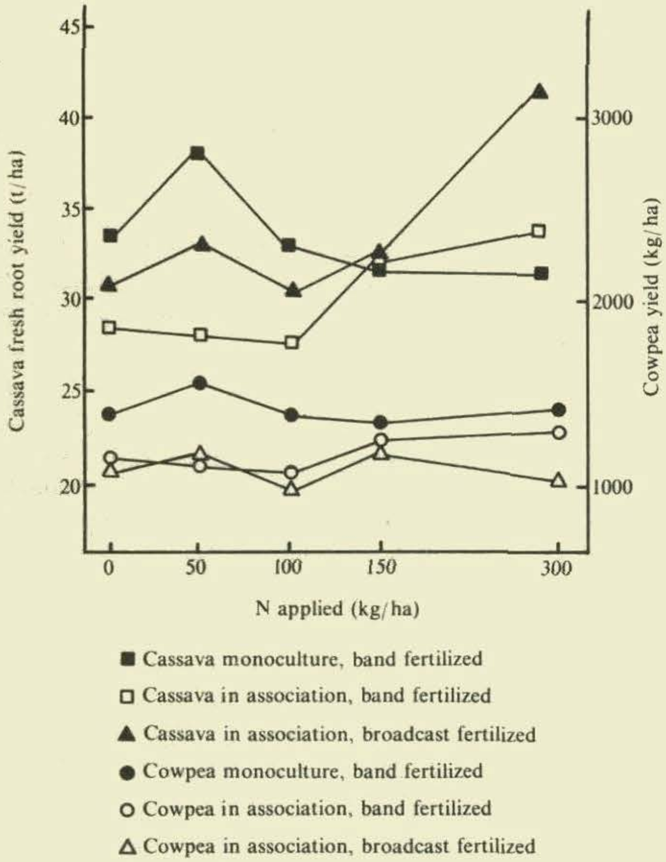

Figure 13. *Effects of rates and application methods of N on yields of cassava and cowpeas in association and monoculture, at Caribia, 1980.*

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

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

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

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

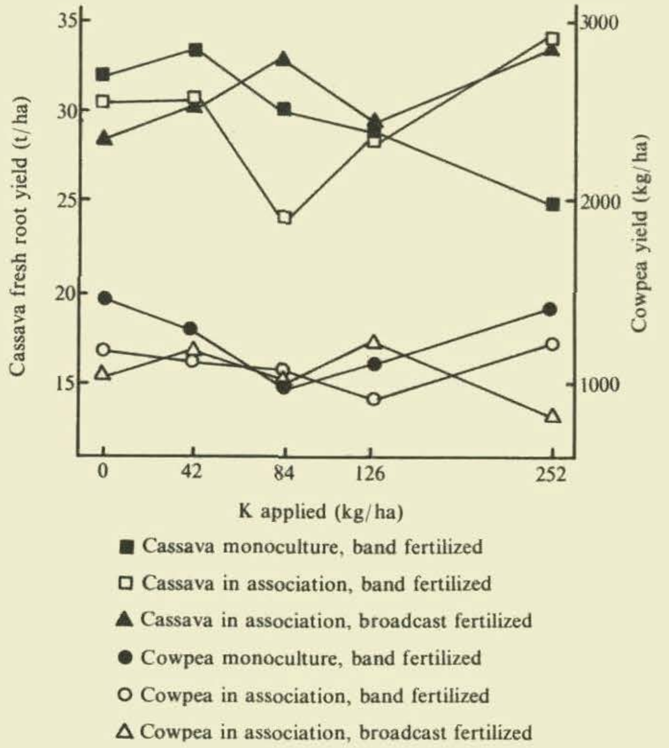

Figure 14. *Effects of rates and application methods of K on yields of cassava and cowpeas in association and monoculture, at Caribia, 1980.*

## Storage of Planting Material

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

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

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

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

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

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

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

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

| Storage duration (days) | Sprouting rate (plants day/plot) | Final sprouting, 31 DAP [2] (%) | Plant height, 45 DAP (cm) | Mean number stems/plant, 60 DAP | Mean leaf size, 60 DAP (cm²) | Light interception, 76 DAP (%) |
|---|---|---|---|---|---|---|
| 0 | 1.73 a[3] | 100 a | 26 a | 2.66 a | 278 ab | 77 a |
| 60 | 1.83 a | 100 a | 27 a | 2.73 a | 282 ab | 78 a |
| 120 | 1.59 ab | 100 a | 23 b | 2.36 b | 253 b | 72 a |
| 180 | 1.40 b | 98 b | 25 ab | 2.23 b | 296 a | 75 a |

[1] Variety CMC 40; treated with BCM and captan (3000 ppm each) before storage; means of two storage sites and two chemical treatments (with and without sodium alginate).

[2] DAP = days after planting

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

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

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

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

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

[1] DAP = days after planting.

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

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

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

These results indicate that:

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

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

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

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

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

# Errata

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