# INTERCROPPING GRAIN LEGUMES WITH CASSAVA ON ACID INFERTILE SOILS



Post Doctoral Report

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1/ This report was revised and edited by Dr. Dietrich E. Leihner, Cultural Practices Specialist, CIAT, Cassava Program. Apartado Aéreo 6713, Cali, Colombia.

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# LIST OF GENETIC MATERIALS USED IN THE EXPERIMENTS

| | | |
|---|---|---|
| 1. | CASSAVA | *Manihot esculenta* Crantz<br>Cultivars: CMC 40<br>CMC 84<br>MVen 218 |
| 2. | COWPEA | *Vigna unguiculata* |
| 3. | MUNGBEANS | *Vigna radiata* |
| 4. | WINGEDBEANS | *Psophocarpus tetragonolobus* |
| 5. | VELVET BEANS | *Stizolobium derringianum* |
| 6. | LIMA BEANS | *Phaseolus lunatus* |
| 7. | SOYBEANS | *Glycine max* |
| 8. | PIGEON PEA | *Cajanus cajan* |
| 9. | JACK BEAN | *Canavalia ensiformis* |
| 10. | SWORDBEAN | *Canavalia gladiata* |
| 11. | GROUNDNUT | *Arachis hypogea* |
| 12. | FLATPOD PEAVINE | *Lathyrus cicera* |

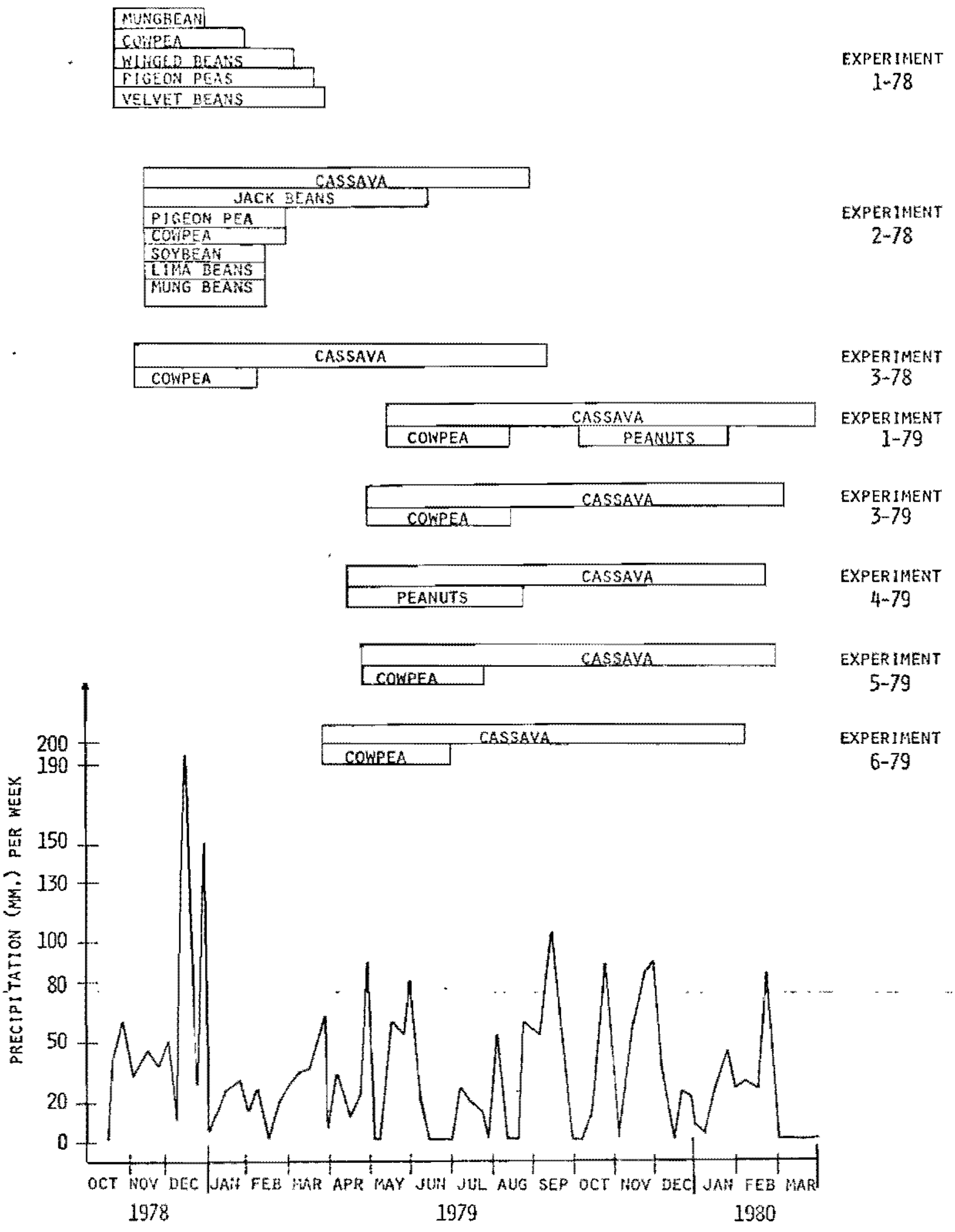


FIGURE 1. CHRONOGRAPH OF EXPERIMENTS PLANTED DURING 1978-1979 AND WEEKLY PRECIPITATION DURING THE GROWTH CYCLES. CIAT-QUILICHAO 1978-80.

# 1. INTRODUCTION

After the good results obtained in the last years with multiple cropping of cassava and common beans (Phaseolus vulgaris), research at CIAT was directed towards other tropical legumes, especially cowpea (Vigna unguiculata), in order to elaborate cassava intercropping systems for climatic and soil conditions, under which beans do not grow well. This is the case on soils with low pH, low fertility and high Al and Mn content, which are widely distributed in the tropics (Isbell, 1978). An example of these edaphic conditions is represented by the soil of the Experimental Station CIAT-Quilichao (see soil conditions in Chapter 2). On this soil common beans are only growing with a high input of lime and fertilizer. On the other hand, other legumes with tolerance of high levels of Al and Mn, and adaptation to low pH and low fertility show vigorous growth and high yield even at very low levels of purchased inputs. Although being lower in nutritive value as compared to common beans, their protein content is high enough to be a valuable complement to the high calorie producer cassava (Coursey & Haynes, 1970). The combination of cassava with grain legumes other than beans has with few exceptions not received a great deal of attention from researchers. A few experiments have been conducted by Mohan Kumar 1978 (cassava with groundnuts, mungbeans and soybeans) Gonzáles, 1976 (Cassava with cowpea) and Thamburaj and Muthukrishnan 1976 (Cassava with groundnut, cowpea and mungbeans).

Nevertheless it can be expected that for the combination of cassava with tropical grain legumes other than common beans the same principles should be valid as for the combination of cassava with common beans.

A relatively non-aggressive, erect growing legume with a rapidly growing root system should be found that matures in less than 100 days so that the legumes can reach pod filling stage before cassava starts to close rows and shading gets serious. A rapid top-growth of legumes to cover the ground is desirable in order to give protection against erosion and water losses through run off. Vigorous root growth is also very important in order to give protection against water erosion and enhance cassava growth through N fixation and Ca + P unlocking. Besides the search for a suitable high yielding legume with the above mentioned desirable characteristics, investigations were also started to determine optimum agronomic practices, such as legume planting density, spatial arrangements and fertilization.

## 2. EXPERIMENTAL CONDITIONS

The field experiments reported here were planted at CIAT-Quilichao on an Ultisol (Palehumult, high in manganese, and aluminium and with low water holding capacity).

| pH | Organic matter % | P Bray II ppm | Al | Ca | Mg | K | Mn ppm |
|---|---|---|---|---|---|---|---|
| | | | meq/100 g soil | | | | |
| 4.01 | 7.43 | 10.1 | 3.39 | 1.92 | 0.32 | 0.30 | 54.8 |

The climatic conditions can be summarized as follows: Altitude 990m, Yearly mean temperature, 23.1°C (mean-max 29.5, mean minimum 18.3) yearly rainfall with two not very intense dry seasons 1850 mm., average relative humidity 77,1% (Fig. 1). All experiments were irrigated when needed, especially after planting. Cassava and legumes were always planted simultaneously and cassava in all experiments was harvested after ten months.

## 3. SCREENING OF GRAIN LEGUME COLLECTIONS

### a. Monoculture

In this experiment, collections of grain legumes were tested: Mungbeans (*Vigna radiata*, 66 cultivars), Cowpea (*Vigna unguiculata*, 61 cultivars), *Pigeon pea* (*Cajanus cajan*, 14 cultivars), Jack bean (*Canavalia ensiformis*, 1 cultivar), Flat pod peavine (*Lathyrus cicera*, 1 cultivar) as non-climbing and Winged beans (*Psophocarpus tetragonolobus*, 9 cultivars), Velvet bean (*Stizolobium derringianum*, 2 cultivares) and Swordbean (*Canavalia gladiata*, 1 cultivar) as climbing species. Principal selection criteria were tolerance of low pH and high aluminium content of the soil, growth habit, growth duration and yield. A plot consisted of a double row 3.75 m in length, with a distance between rows of 0.6 m, distance between plants within a row was 0.15 m. (Fertilization see Table 10). Most species showed little tolerance of the soil conditions, best adaptation being shown by cowpeas (Table 1). The plants were mostly growing well, the germination was high and flowering and pod set were good. Average yield of the 61 cowpea cultivars was 1178 kg/ha (14% moisture). Three cultivars were yielding more than 2000 kg/ha (Table 2), 15 lines produced more than 1500 kg/ha and 19 were yielding more than 1000 kg/ha. In conclusion, the yielding ability of 37 lines of this collection was acceptable considering the prevailing soil conditions. Good yields were also obtained from Velvet beans, one species was yielding 1440 kg/ha and the other 490 kg/ha. Pigeon peas and the two Canavalia species were growing and flowering well without showing reaction to soil conditions but there was no pod-or seed set.

The winged beans were growing poorly with the typical symptom of Al-toxicity, but they were flowering (24 flowers /plot or 0.28 per plant) over a period of two months. A small yield of both fresh pods and grain was recorded. The yield of roots was very low.

Mungbeans had a mean germination of 47% after 7 days, but the young plants showed very low vigor and many of them died so that after 14 days live plants were only 31%

TABLE 1 YIELD OF LEGUME SPECIES SCREENED IN MONOCULTURE AND INTERCROPPED WITH CASSAVA (CMC-40) AT CIAT QUILICHAO, 1978

| | NUMBER OF CULTIVARS | GERMINATION AFTER 14 DAYS (%) | No. OF PODS (WITH GRAIN) /M² | PODS KG DM/HA | GRAIN YIELD KG/HA 14% $H_2O$ |
|---|---|---|---|---|---|
| MONOCULTURE | | | | | |
| COWPEA | 61 | 82 | 110.7 | 397.7 | 1,178.6 |
| VELVET BEANS | 2 | 63 | 68.3 | 297.2 | 948.0 |
| MUNG BEANS | 66 | 31 | 11.2 | 12.1 | 30.7 |
| WINGED BEAN | 9 | 61 | 2.9 | 29.4 | 11.1 |
| CANAVALIA ENSIFORMIS | 1 | 80 | 0.0 | 0.0 | 0.0 |
| PIGEON PEA | 14 | 68 | 0.0 | 0.0 | 0.0 |
| LATHYRUS CICERA | 1 | 9 | 0.0 | 0.0 | 0.0 |
| CANAVALIA GLADIATA | 1 | 23 | 0.0 | 0.0 | 0.0 |
| INTERCROPPED | | | | | |
| COWPEA | 61 | 71 | 38.5 | 108.3 | 499.1 |
| LIMA BEANS | 3 | 76 | 0.8 | 3.3 | 5.0 |
| MUNG BEANS | 66 | 34 | 3.0 | 2.7 | 6.0 |
| SOYBEAN | 8 | 17 | 7.9 | 16.2 | 24.1 |
| CANAVALIA ENSIFORMIS | 1 | 93 | 9.6 | 79.1 | 76.9 |
| PIGEON PEA | 24 | 71 | 0.4 | 0.8 | 0.2 |
| LATHYRUS CICERA | 1 | 42 | 0.0 | 0.0 | 0.0 |
| CANAVALIA GLADIATA | 1 | 31 | 0.0 | 0.0 | 0.0 |

TABLE 2 GRAIN LEGUME COLLECTION TRIALS 1/78 AND 2/78. DATA OF BEST COWPEA CULTIVARS IN MONOCULTURE AND ASSOCIATION WITH CASSAVA CV. CMC 84. CIAT-QUILICHAO, 1978.

| | YIELD (14% MOISTURE) KG/HA | | | NO. OF PODS /M2 | | WEIGHT OF 1000 SEEDS G. | | DAYS TO MATURITY | GRAIN COLOUR |
|---|---|---|---|---|---|---|---|---|---|
| | MONO | ASSOC. | IN % OF MONO | MONO | ASSOC. | MONO | ASSOC. | | |
| TVX-1193-059D | 2124 | 374 | 17.6 | 156.7 | 36.8 | 128.6 | 130.6 | 82 | PURPLE RED |
| TVN-1977-0D | 2048 | 644 | 31.5 | 146.9 | 64.5 | 92.6 | 91.4 | 84 | WHITE |
| TVX-1836-9E | 2009 | 429 | 21.3 | 179.2 | 56.6 | 114.5 | 107.5 | 80 | WHITE |
| TVN-3629 | 1816 | 275 | 15.1 | 143.1 | 35.0 | 163.9 | 136.3 | 80 | WHITE |
| TVN-2616-P-01D | 1777 | 270 | 15.2 | 137.8 | 34.6 | 131.0 | 128.9 | 79 | BEIGE |
| P-18 | 1743 | 573 | 32.9 | 120.8 | 34.2 | 136.4 | 136.6 | 81 | BROWN |
| TVX-1193-9F | 1722 | 164 | 9.5 | 165.0 | 22.8 | --- | 95.5 | 74 | PURPLE |
| TVX-1193-7D | 1710 | 344 | 20.1 | 143.3 | 40.1 | 114.2 | 102.8 | 80 | BROWN YELLOWISH |
| TVX-289-4G | 1688 | 516 | 30.6 | 117.2 | 44.3 | 150.7 | 142.3 | 83 | BEIGE-ROSE |
| VITA 4 | 1672 | 612 | 36.6 | 147.5 | 51.2 | 100.9 | 92.8 | 83 | WHITE |
| TVX-1836-P19 G | 1553 | 768 | 49.5 | 158.3 | 77.8 | 130.7 | 129.4 | 81 | WHITE |
| TVX-830-01B | 1448 | 657 | 45.4 | 126.4 | 60.1 | 155.5 | 159.5 | 87 | DARK-BROWN-YELLOW |
| TVX-1836-19E | 1622 | 571 | 35.2 | 158.3 | 64.2 | 123.6 | 126.7 | 77 | WHITE |
| TVX-337-3F | 1652 | 555 | 33.6 | 146.9 | 46.5 | 95.8 | 84.9 | 83 | WHITE |
| CAUPI COSTA | 1077 | 525 | 48.7 | 91.1 | 46.9 | 97.0 | 142.9 | 87 | WHITE |
| SVS 3 | 1601 | 523 | 32.7 | 96.4 | 36.3 | 131.2 | 133.3 | 81 | BROWN |

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and after three weeks only ± 26% of the original planting density. At harvest this number was further reduced to 21%, maximum grain yields being only 91 kg/ha.

Lathyrus cicera germinated but all plants died within four weeks. An influence of the different legumes on the following cassava-groundnut experiment was not given. The groundnuts (in association with cassava) were yielding 687.8 kg/ha (shelled groundnuts with 14% moisture) after mungbeans, 687.9 kg/ha after cowpea. The average yield of the total experiment was 686.8 kg/ha. There was a negative correlation between grain yield and Al-concentration in leaves (at flowering) and grain of cowpea, i.e. higher yielding cultivars had lower Al-concentrations in these plant parts. Root concentrations of Al did not show the same tendency (Table 3). On the other hand, P concentration in the grain showed a positive correlation to yield (Fig.2), indicating that a cultivar's avoidance of high Al-levels and reaching high P-levels in plant tissue particularly in the grain, was related to its yielding ability. Similar tendencies were not observed with Mn, Ca and Mg concentrations.

b. Association

In this experiment the same grain legume collection[1] which was tested in monoculture, was planted in association with cassava, cv. CMC 84. Nine plants of cassava were planted in two replications with one row of legume

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[1] The climbers winged bean and velvet bean were not tested in association while soybean and non-climbing limabeans were added.

TABLE 3 GRAIN YIELD AND MINERAL ELEMENT CONCENTRATION IN A COWPEA COLLECTION GROWN ON ACID, INFERTILE SOIL WITH HIGH AL AND LOW P LEVELS. CIAT-QUILICHAO, 1978

| RANK/CULTIVAR | GRAIN YIELD KG/HA | AL - PPM GRAIN[1] | AL - PPM LEAVES[2] | AL - PPM ROOTS[1] | P - PPM GRAIN[1] | P - PPM LEAVES[2] | P - PPM ROOTS[1] |
|---|---|---|---|---|---|---|---|
| **TEN BEST CULTIVARS** | | | | | | | |
| 1. TVX-1193-059D | 2123.5 | 10 | 370 | 7200 | 0.40 | 0.06 | 0.12 |
| 2. TVU-1977-OD | 2047.6 | 50 | --- | --- | 0.06 | --- | --- |
| 3. TVX-1836-9E | 2008.9 | 20 | 460 | 3500 | 0.40 | 0.12 | 0.09 |
| 4. TVU-3629 | 1815.5 | 50 | 270 | 4200 | 0.45 | 0.08 | 0.10 |
| 5. TVU-2616-P-01D | 1776.9 | 29 | 270 | 2320 | 0.13 | 0.10 | 0.35 |
| 6. P-18 | 1742.8 | 90 | 170 | 2220 | 0.36 | 0.08 | 0.08 |
| 7. TVX-1193-9F | 1722.4 | 100 | 500 | 2500 | 0.42 | 0.11 | 0 12 |
| 8. TVX-1193-7F | 1709.5 | 220 | 470 | 3900 | 0.37 | 0.15 | 0.08 |
| 9. TVX-289-46 | 1688.2 | 180 | 660 | 5000 | 0.26 | 0.10 | 0.08 |
| 10. VITA 4 | 1672.2 | 100 | 220 | 5500 | 0.32 | 0.12 | 0.12 |
| **WHOLE COLLECTION** | | | | | | | |
| 1-10 | 1823.7 | 87 | 377 | 4036 | 0.32 | 0.10 | 0.13 |
| 11-20 | 1570.5 | 88 | 539 | 4644 | 0.39 | 0.10 | 0.10 |
| 21-30 | 1304.4 | 99 | 675 | 5700 | 0.35 | 0.15 | 0.10 |
| 31-40 | 1041.3 | 37 | 612 | 4655 | 0.41 | 0.15 | 0.10 |
| 41-50 | 871.4 | 130 | 531 | 4024 | 0.39 | 0.10 | 0.11 |
| 51-61 | 525.4 | 70 | 418 | 4345 | 0.34 | 0.12 | 0.14 |
| CORRELATION COEFFICIENT | | -0.89 | -0.76 | -0.46 | 0.94 | 0.72 | 0.41 |

1 AT PHYSIOLOGICAL MATURITY

2 AT FLOWERING

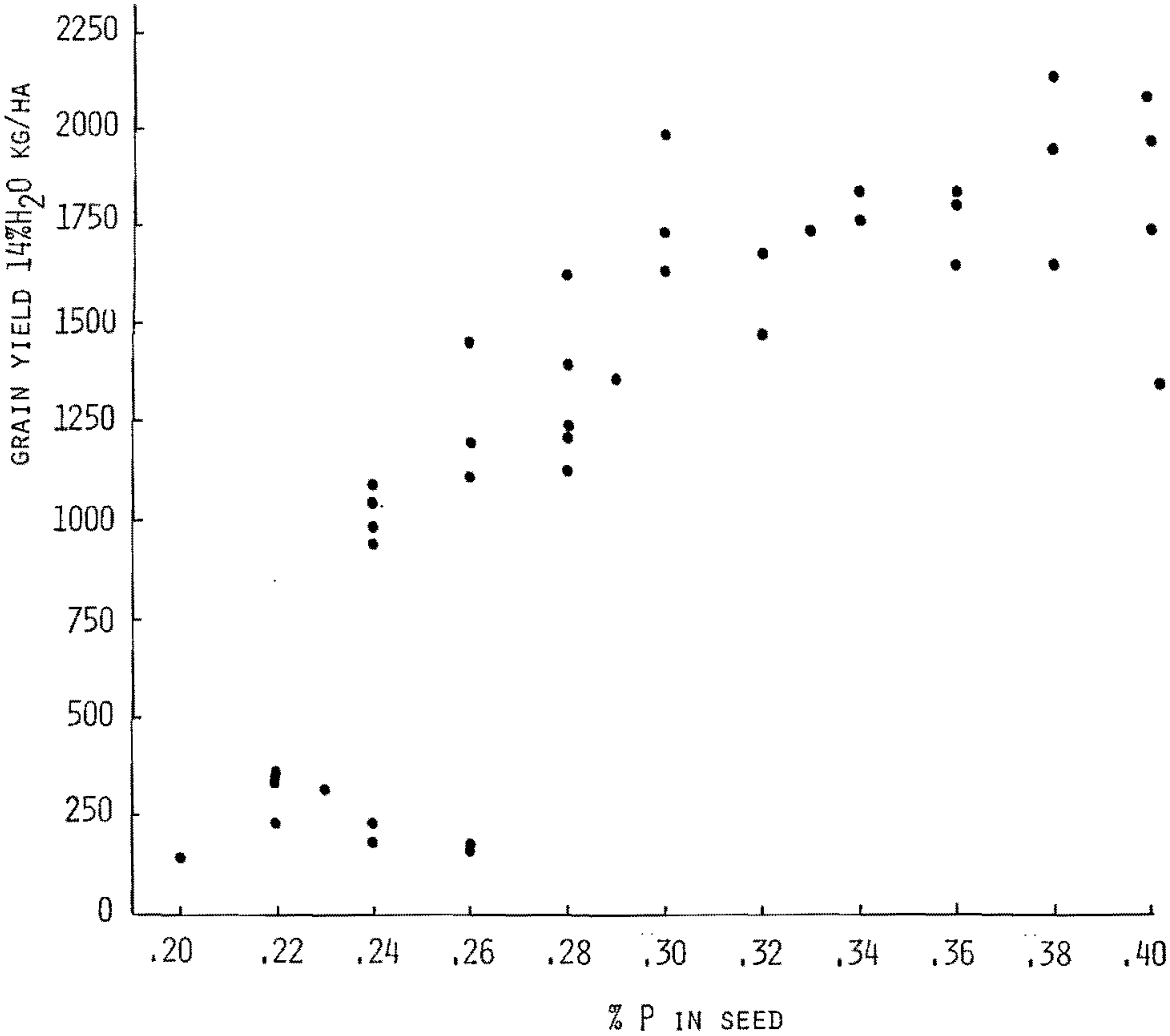


FIGURE 2 RELATIONSHIP BETWEEN PHOSPHORUS CONCENTRATION IN COWPEA SEED AND COWPEA YIELD, LEGUME MONOCULTURE SCREENING TRIAL 1/78, CIAT-QUILICHAO, 1978

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on both sides. The fertility level of the plots was extremely low, only 500 kg/ha of lime was applied, and the pH of the soil was even lower than in the monoculture screening experiment. As a result, legume grain yields in association suffered from double stress, both due to the soil conditions and competition from cassava. The vegetative growth of the legumes was reduced and grain yield reductions were strong: mungbeans yielded 20% and cowpea 39% of the monoculture yield. On the other hand, the cassava yield was also reduced through the competition with legumes, especially with cowpea and canavalia. Cultivar CMC 84 and also CMC 40 which was used in Experiment 3/78 suffered serious insect infestations, most severe damage being caused by thrips. Insecticides were not applied so that root yield was low in all cases, both due to insect damage and low soil fertility (Fig.3).

As this figure shows the relatively high cowpea yield was associated with a strong reduction in cassava yield. Mungbeans grew poorly (similar to monoculture) without affecting the cassava yield. The very poorly growing soybeans, limebeans and Lathyrus had a positive influence on cassava yield ($\bar{x}$ 106.8% of monoculture yield) as well as on the starch yield (107-114 % of monoculture), but since the number of cultivars in these species was low (12 data for soybean, 2 for canavalia, 2 for Lathyrus) these differences could not be secured statistically.

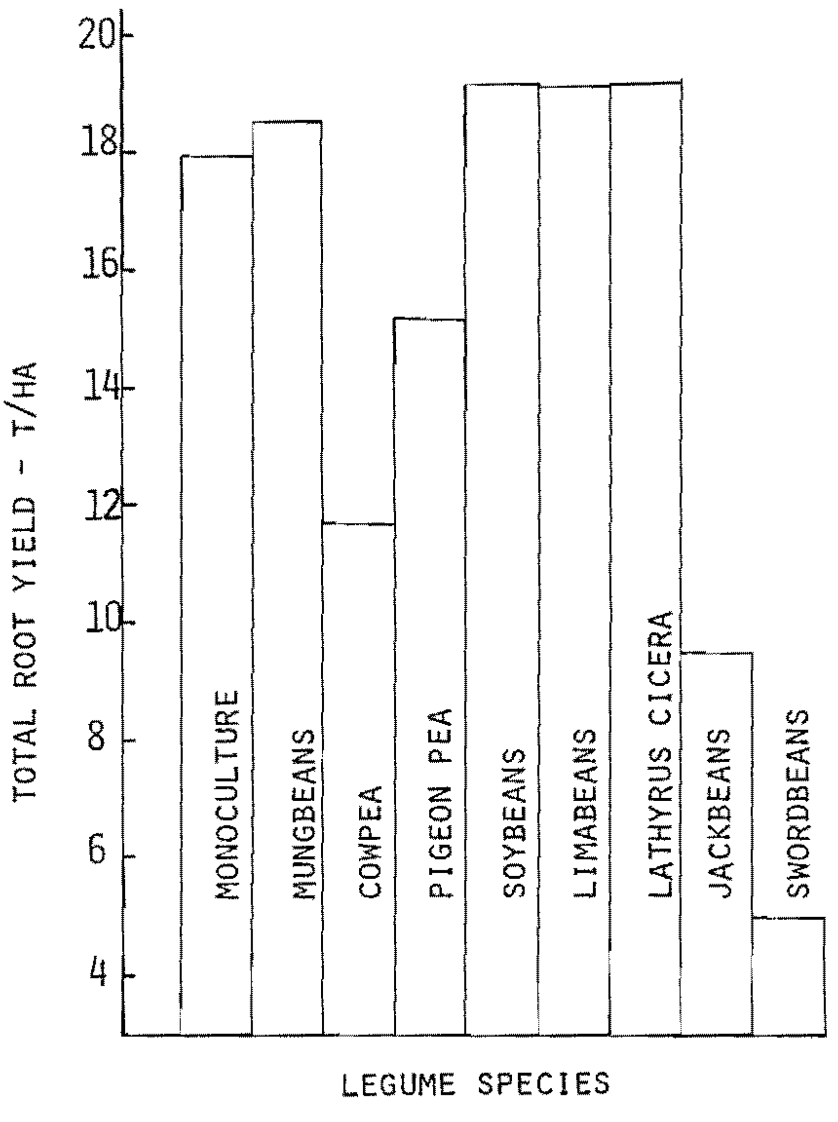


FIGURE 3 CASSAVA ROOT YIELD AS INFLUENCED BY ASSOCIATION WITH DIFFERENT LEGUME SPECIES. EXPERIMENT 2/78, CIAT-QUILICHAO, 1978.

c. Crop interaction

We found that the legume's growth habit and adaptation influenced the performance of both the legumes and cassava. Although distance between legumes and cassava was always the same at planting, legumes with a stronger vegetative development (root + top) due to both greater tolerance to acid, infertile soil conditions and genotypically determined growth habit - such as cowpeas and canavalia - may have left less distance or space between them and cassava, making competition for space (light, $CO_2$, water, nutrients), more serious than those species with a less vigorous vegetative development. For this reason, mungbeans, soybeans, limabeans and Latyrus did not reduce cassava yield whereas cowpeas, pigeon pea and canavalia reduced root yield of associated cassava markedly both due to vigorous growth (cowpea & canavalia) and inadequate growth habit (pigeon pea, too tall).

However, cowpea cultivars which showed less vegetative development due to an early and intense flowering habit left more "free space" between the associated crops and were therefore less aggressively competing with cassava.

d. Monoculture - association relationships

Besides the screening for tolerance against the soil conditions it was also important to examine how observations made with legumes in monoculture would correlate with those made with legumes and cassava in association. A significant correlation between traits in monoculture and association would allow to screen collections in monoculture only and avoid the more complicated and timekaking screening in association. General yield correlations were high between the cowpeas in both experiments (Table 4) but would nevertheless not allow to say which high yielding cultivar (in monoculture) would be high yielding and least competitive when planted in association.

There was a relatively high correlation (see Table 4) between the cowpea yield in monoculture and in association. This would indicate that high yielding cowpeas planted in monoculture would also be high yielders in association, and viceversa. There was also a lower, but constant correlation between number of flowers per hectare in monoculture and yield in association, but not between the number of flowers per plant and the yield in monoculture.

No correlation was found between cowpea yield in monoculture and the cassava yield in association. Also, the yield of tops (without grain) or roots of cowpea was without influence on the cassava root yield. However, a general negative relationship between number of flowers, number of pods per unit area and cassava root yield appeared to exist, pointing to the fact that cowpeas with a higher level of development at flowering and pod formation would impose stronger competition on cassava then cowpea cultivars with less development at this stage.

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TABLE 4 COREELATION COEFFICIENTS (r) BETWEEN COWPEA FLOWER NUMBER AND GRAIN YIELD IN MONOCULTURE AND COWPEA YIELD IN ASSOCIATION WITH CASSAVA. EXPERIMENT 2/78. CIAT-QUILICHAO, 1978.

| | | FLOWERS/HA | | | | COWPEA GRAIN YIELD MONOCULTURE |
|---|---|---|---|---|---|---|
| | | DEC 6 | DEC 11 | DEC 13 | DEC 16 | |
| COWPEA GRAIN YIELD ASSOCIATION | r = | 0.41 | 0.43 | 0.52 | 0.53 | 0.55 |
| | PROBABILITY | 0.0240 | 0.0160 | 0.0031 | 0.0029 | 0.0001 |

As a practical conclusion, it may be said that in selecting grain legumes for adaptation and high yield in association with cassava, it is relatively safe to do this selection in legume-monoculture screening trials as a first step to eliminate materials with low potential. Particularly on acid, infertile soils the overriding factor will be that of adaptation to adverse soil conditions; growth will be somewhat reduced and growth habit will therefore not vary so drastically as to cause large differences in association suitability and competition with cassava. Even though legumes with intense early flowering (and maturity) appear to be the most suitable, since early flowering reduces excessive vegetative development unfavourable for cassava yield formation and early pod filling enables the legume to escape serious shading by cassava. On the other hand, the possibility to screen cassava for intercropping with legumes independent of its companion crop appears not to exist i.e. screening cassava cultivars for association suitability in monoculture, since with cassava not only yield potential per se is important but growth habit (especially branching habit) has been shown to be of outstanding importance for the performance of associated legumes, this being decisive for the overall productivity of the system (Thung & Cock, 1978).

## 4. PLANTING DENSITY AND SPATIAL ARRANGEMENT OF COWPEA

### a. Experiment 3/78

The cassava-common bean research at CIAT showed that by simultaneously planting with normal monocrop densities of both crops in association, highest land equivalent ratios and greatest total yields are obtained. In order to examine this practice with cowpeas and groundnuts under acid, infertile soil conditions, trials were established using legume densities of 111.000, 222.000 and 555.000 plants/ha in different row arrangements between cassava (Fig.4). Cassava density was kept constant at 9.259 pl/ha in a 1.8 x 0.6 m arrangement. Yield results of intercropped cowpeas (Fig.5) showed that greatest yields were obtained with 110.000 pl/ha, a density which is currently also used for cowpea monoculture plantings (Erskine & Khan 1976). Cassava yield data from this trial showed that 110.000 pl/ha of cowpea imposed the least competition on cassava which produced the greatest fresh root yield at this cowpea density (Fig.6). However, both cowpea and cassava yields were less influenced by cowpea density than by spatial arrangement. Cowpea yields were lowest in the 70/2 system, possibly due to an increased intraspecific competition in this arrangement, whereas the 60/3 system produced greatest cowpea yields. On the other hand, cassava yields were greatest with the 70/2 arrangement since this system minimizes interspecific competition, and

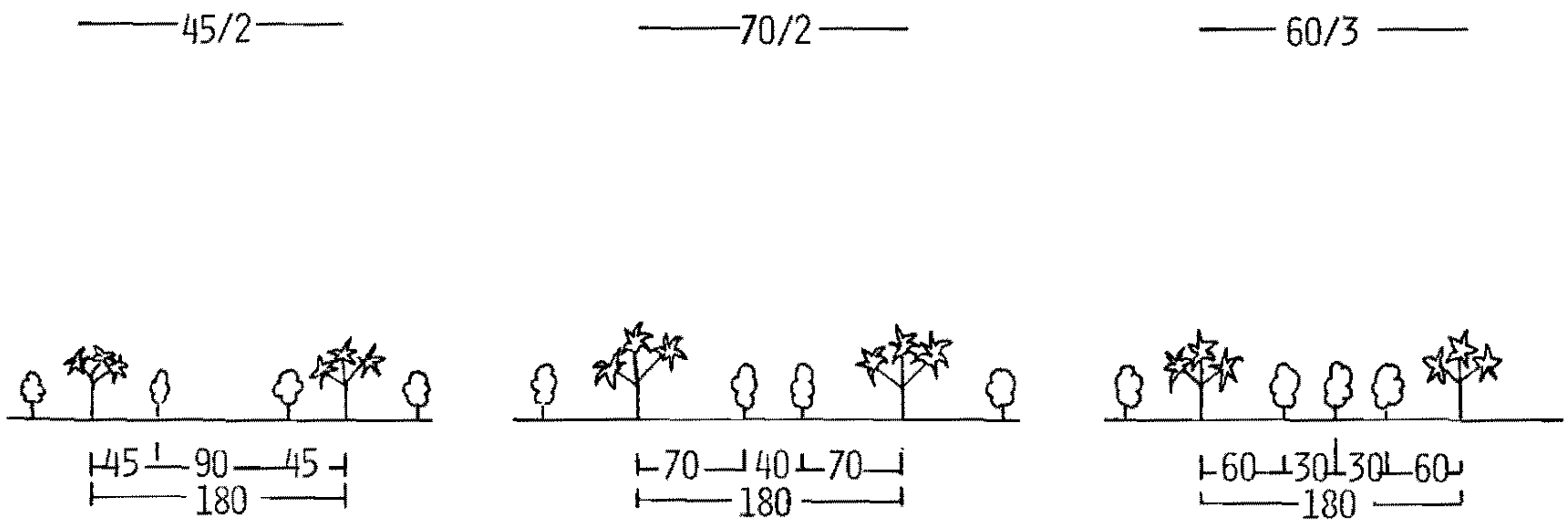


FIGURE 4 ROW ARRANGEMENTS USED FOR LEGUME PLANTING IN ASSOCIATION WITH CASSAVA. CIAT-QUILICHAO, 1978-1980.

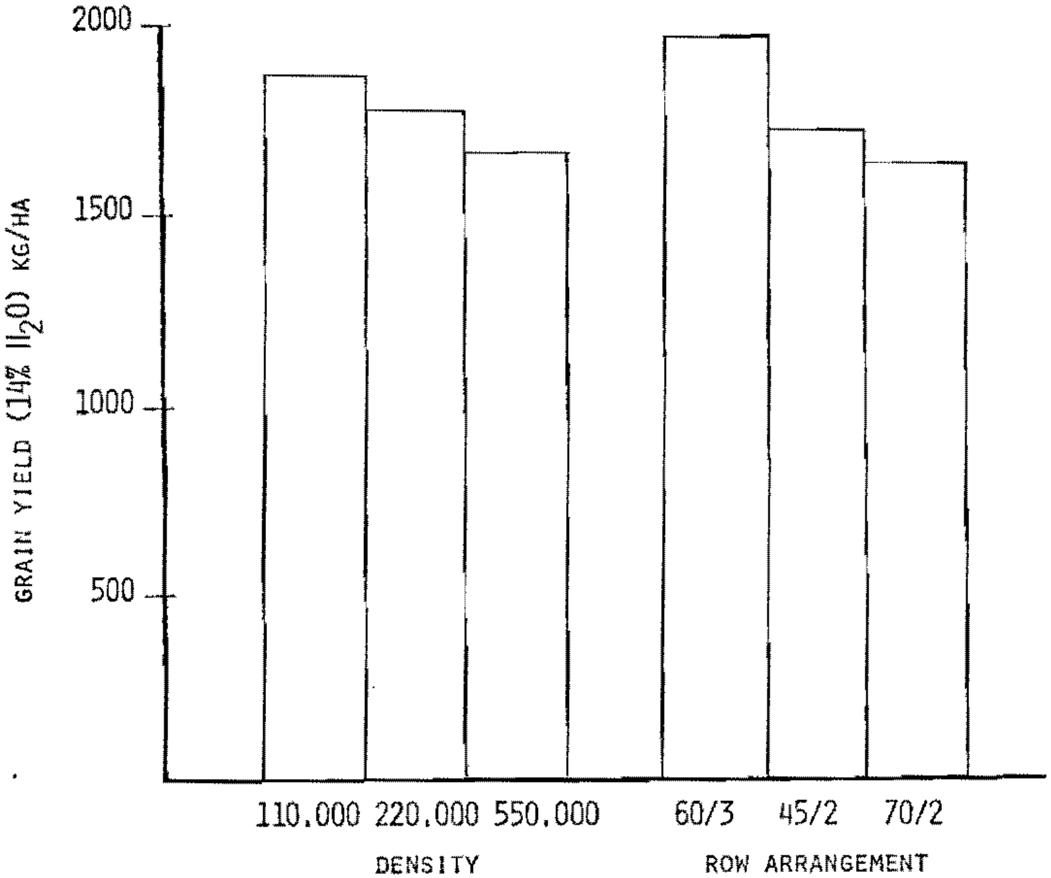


FIGURE 5 GRAIN YIELD (14% $H_2O$) OF COWPEA, CV. TVU 354-1B IN ASSOCIATION WITH CASSAVA CMC 40, AS INFLUENCED BY COWPEA PLANTING DENSITY AND SPATIAL ARRANGEMENT. CIAT-QUILICHAO, 1978

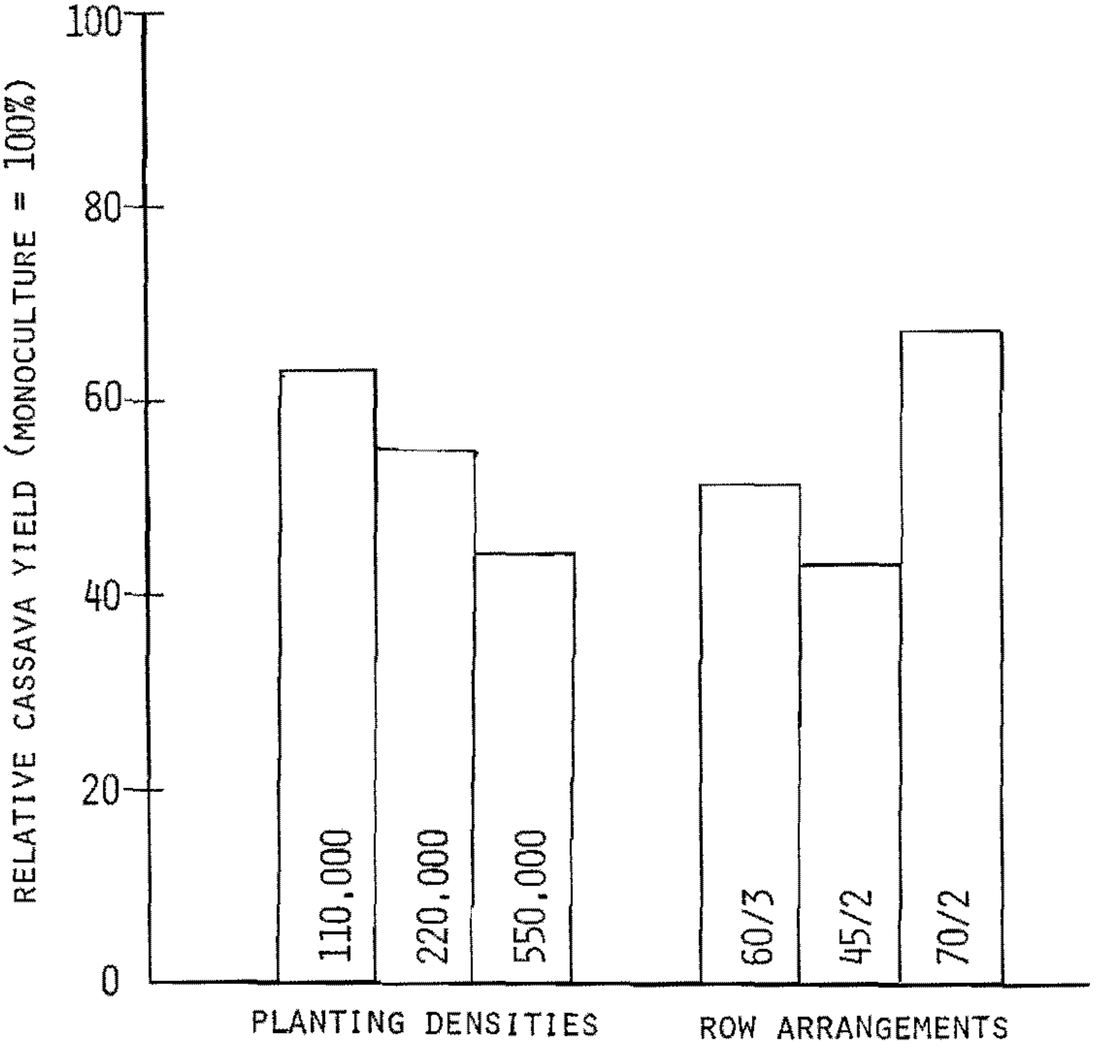


FIGURE 6 EFFECT OF COWPEA PLANTING DENSITY AND ROW ARRANGEMENT ON RELATIVE FRESH ROOT YIELD OF CASSAVA CV. CMC 40. CIAT-QUILICHAO, 1979.

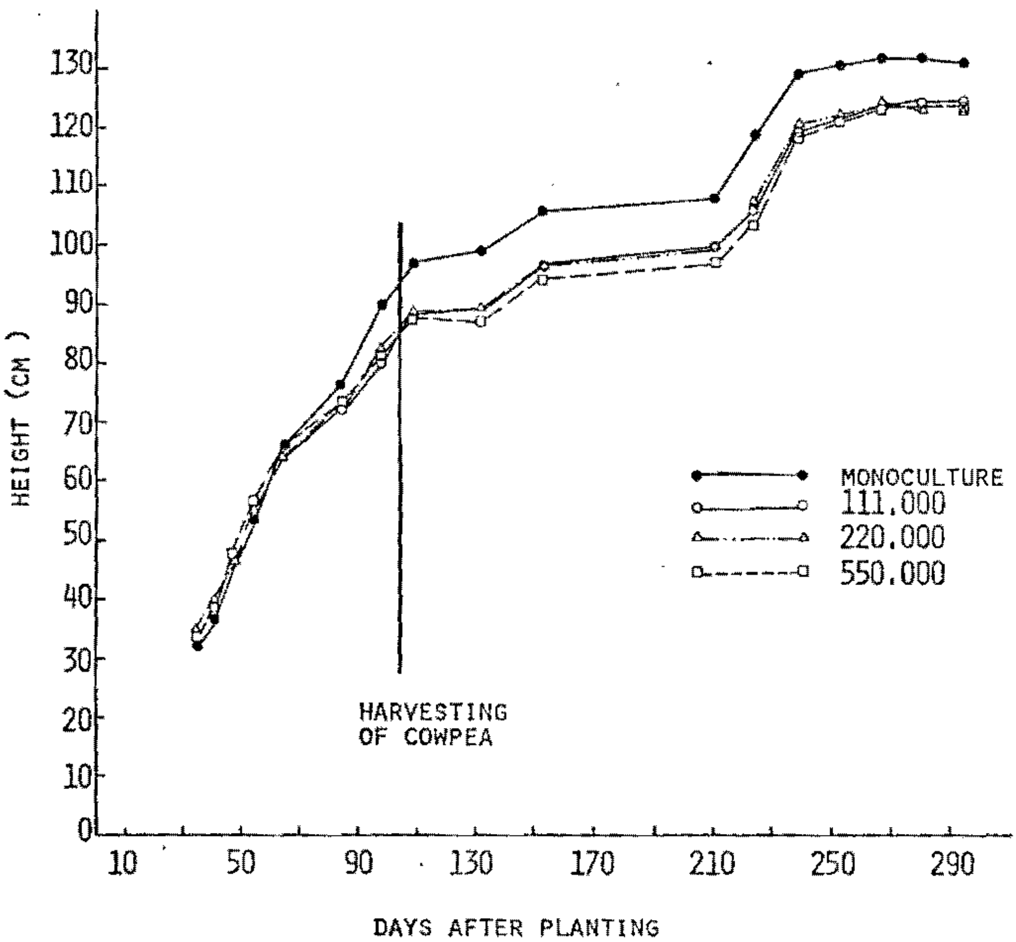


FIGURE 7 CASSAVA PLANT HEIGHT AS INFLUENCED BY COWPEA PLANTING DENSITY

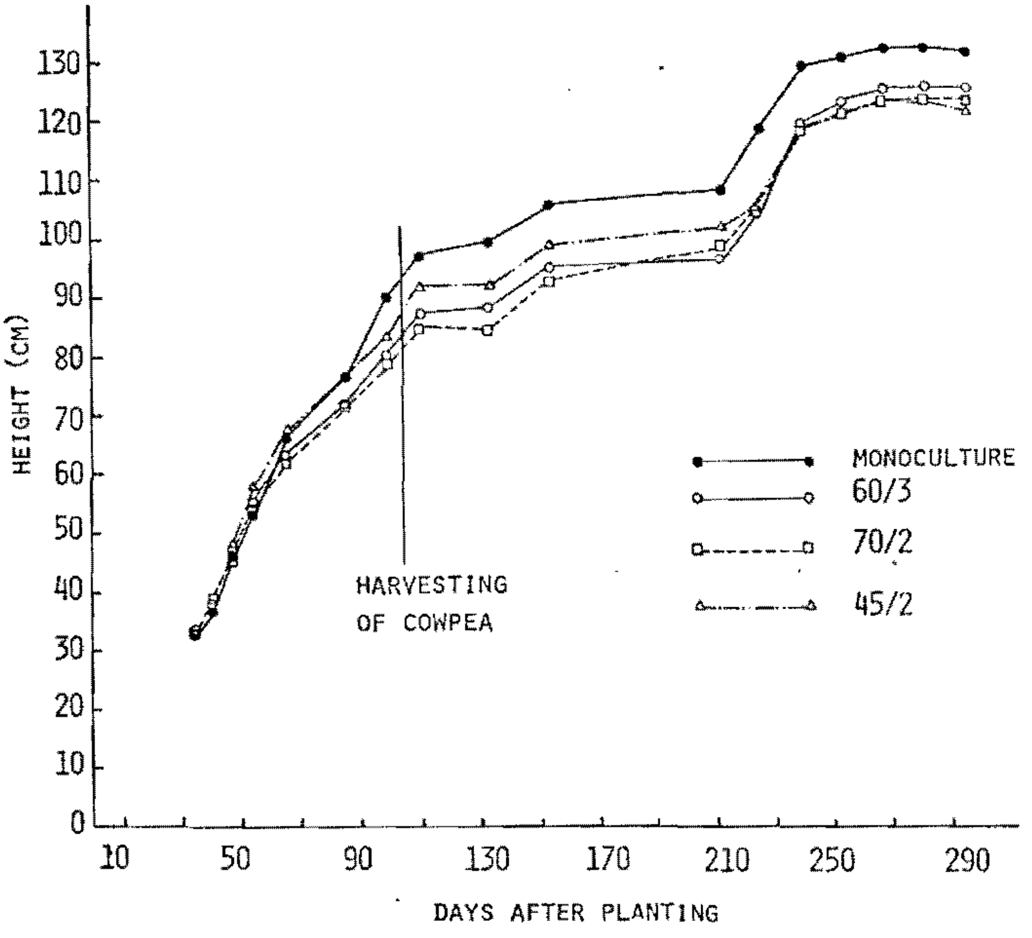


FIGURE 8 CASSAVA PLANT HEIGHT AS INFLUENCED BY COWPEA SPATIAL ARRANGEMENT

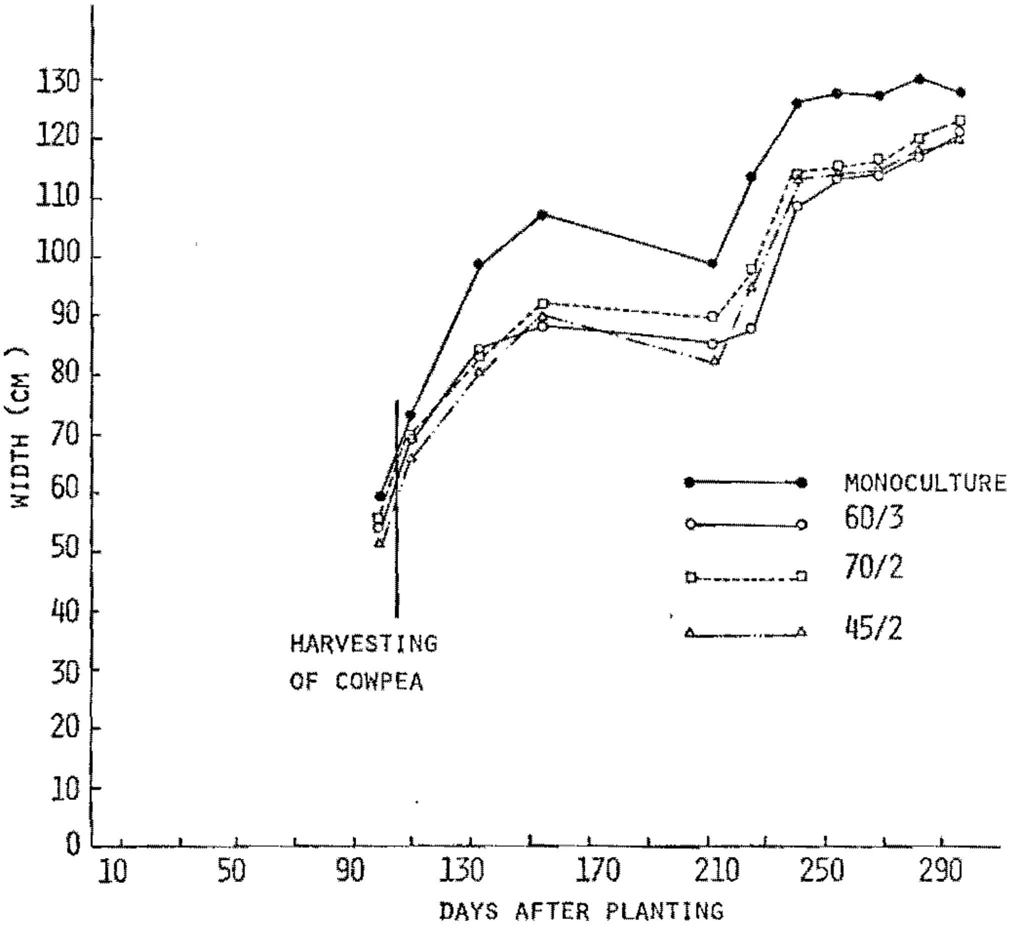


FIGURE 9 CASSAVA PLANT WIDTH AS INFLUENCED BY COWPEA SPATIAL ARRANGEMENT

lowest with the 45/2 system where the two species were planted at the closest distance. As a result, the 60/3 arrangement appears to be a reasonable compromise combining an intermediate cassava yield with highest cowpea yields. However, if emphasis is on cassava production, the 70/2 arrangement would be preferable.

Regarding the early vegetative development of cassava, especially plant height and plant width, the influence of cowpea while growing along with cassava was minimal with no differences between density or spatial arrangement treatments and only a slight difference between intercropped and monoculture cassava. Only after harvest of the legume, effects of cropping systems (monoculture-intercropped) on cassava growth could be observed, the influences of densities and arrangements remaining small throughout the rest of the cassava growth cycle (Figs. 7,8,9).

b. Experiment 5/79

In this experiment the results obtained in 1978 were to be verified using a narrower range of planting densities, 70.000, 100.000, and 150.000 plants per ha. Two spatial arrangements were the same as in 1978, the 45/2 and and the 60/3 systems. In addition, a 45/3 and a 60/2 arrangement was introduced.

Cowpea grain yield results from this experiment show a much stronger density - arrangement interaction than in the previous trial, however, in principle there was good agreement between results of this and the 1978 trial, spatial arrangements again having a greater influence on cowpea yield than planting densities. The data were rather variable since this trial was planted on a partly disturbed soil, but on the average, low planting densities again were giving highest grain yield, with no difference between 100.000 and 70.000 pl/ha. Only the 150.000 pl/ha treatment yielded somewhat lower (Fig.10).

Among the spatial arrangements tested, the 60/3 system again proved to be superior to any other arrangement, the second best being the 45/2 system. No particular advantage was noted from either of the newly introduced systems, 60/2 and 45/3 (Fig.11).

Cassava yields were rather variable due to soil variability masking to some extent the effect of cowpea planting density on root yield, but root number showed a clear response being most depressed by high cowpea planting density. The 60/3 spatial arrangement was in this trial the system which caused the least yield reduction to cassava, possibly through minimizing interference of one crop with the other allowing ample space between cassava and cowpea and providing the most even plant distribution of cowpea in the space available between cassava rows (Table 5). The 60/2 and the 45/3 arrangements caused slightly more yield reduction in cassava, the difference of these two treatments and the 60/3 arrangement being about 1000 kg/ha. Only the 45/2 system was notably inferior,

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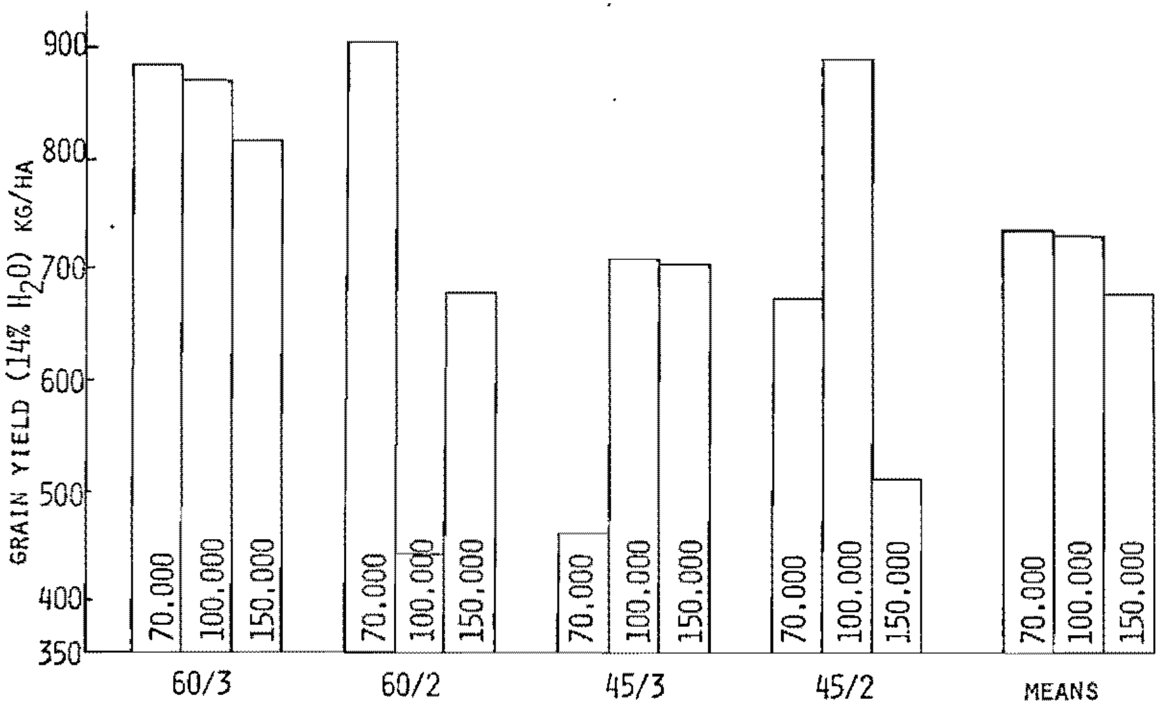


FIGURE 10 COWPEA YIELD IN ASSOCIATION WITH CASSAVA AS INFLUENCED BY DENSITY IN FOUR SPATIAL ARRANGEMENTS, EXPERIMENT 5/79. CIAT-QUILICHAO 1979.

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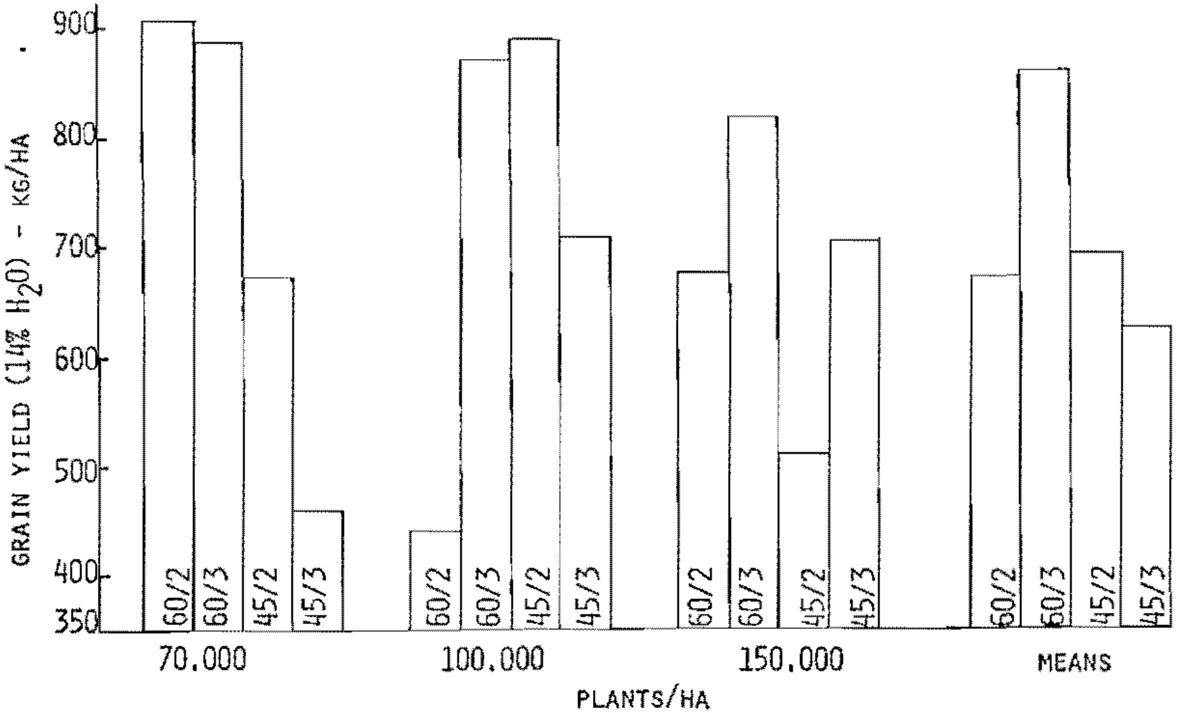


FIGURE 11. COWPEA YIELD IN ASSOCIATION WITH CASSAVA AS INFLUENCED BY SPATIAL ARRANGEMENT THREE PLANTING DENSITIES, EXPERIMENT 5/79. CIAT-QUILICHAO, 1979.

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TABLE 5 YIELD OF CASSAVA CV. M VEN 218 IN ASSOCIATION WITH COWPEA TVU 354-1B AS INFLUENCED BY COWPEA DENSITY AND SPACIAL ARRANGEMENT. CIAT-QUILICHAO, 1979.

| | ROOTS TOTAL KG/HA | NO. OF ROOTS KG/HA | STARCH KG/HA | COWPEA YIELD KG/HA |
|---|---|---|---|---|
| 70.000 | 25.676 | 89.236 | 8183 | 734.1 |
| 100.000 | 22.374 | 80.633 | 6989 | 730.1 |
| 150.000 | 24.251 | 79.552 | 7700 | 678.6 |
| 60/2 | 24.319 | 86.368 | 7767 | 676.0 |
| 60/3 | 25.332 | 87.500 | 8220 | 860.0 |
| 45/2 | 22.491 | 81.533 | 7025 | 693.6 |
| 45/3 | 24.261 | 77.160 | 7485 | 627.5 |

reducing cassava yield 3 t/ha more than the 60/3 system. (Table 5).

In terms of plant height and plant width, the cassava monoculture was always the best growing treatment. This result, being obtained in practically all experiments reported here is in contrast to Gonzales (1976) who found a positive influence of cowpea on cassava plant heigh and a negative influence of leaf area. Although cowpea and cassava yield results are not statistically different in this trial due to large soil differences within the plot area cassava shows the same trends as in the previous experiment. A density around 100.000 pl/ha of cowpea is optimal for both cowpea and cassava and a greater distance between cowpea and cassava rows gives rise to less interspecific competition. The arrangement of two or three legume rows between two cassava rows shows no clear advantage for either of these options in terms of cassava yield, but legume yield is always greater when a 3-row distribution is chosen.

## 5. PLANTING DENSITY AND SPATIAL ARRANGEMENT OF GROUNDNUT (Experiment 4/79)

A planting density-spatial arrangement experiment similar to trial 3/78 was carried out with groundnuts in 1979. In this experiment the spatial arrangement of 60/3 was the best for legue yield with no difference between the 45/2 and the 70/2 systems (Fig.12). In contrast to cowpea, the groundnut yield responded

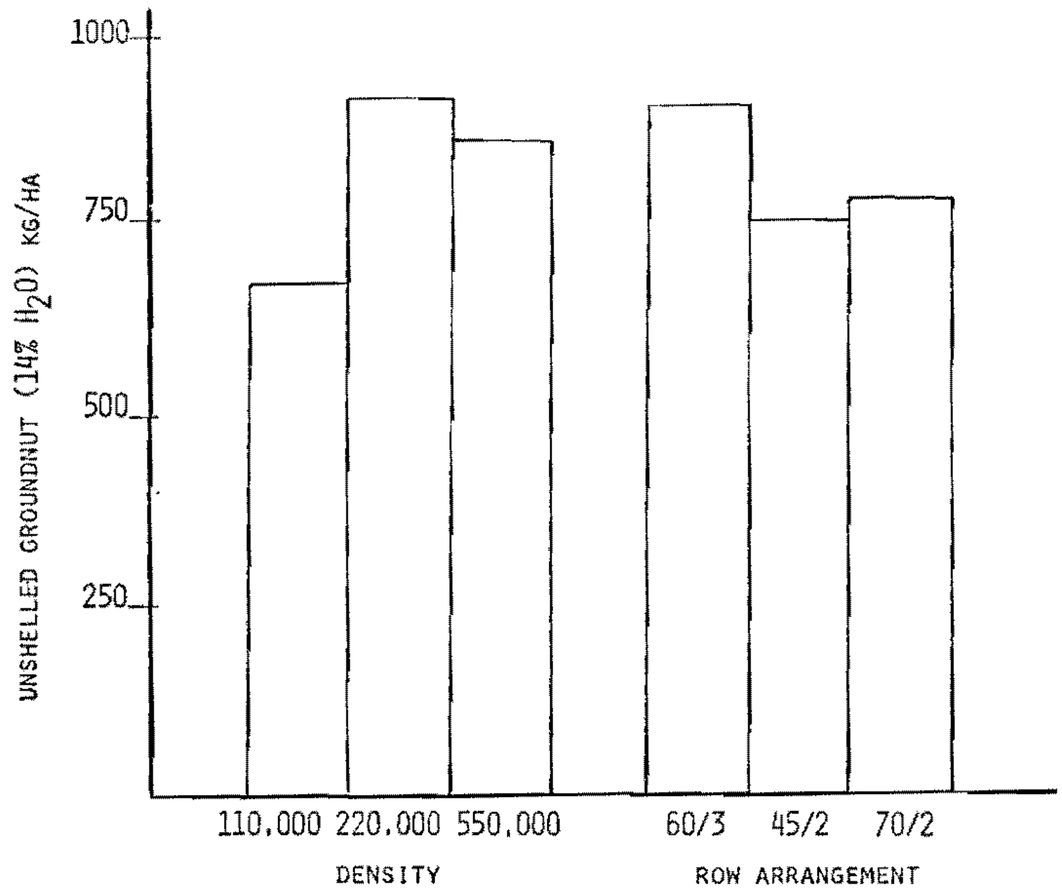


FIGURE 12. EFFECT OF PLANTING DENSITIES AND ROW ARRANGEMENTS ON YIELD OF UNSHELLED GROUNDNUTS (14% $H_2O$). CIAT QUILICHAO, 1979

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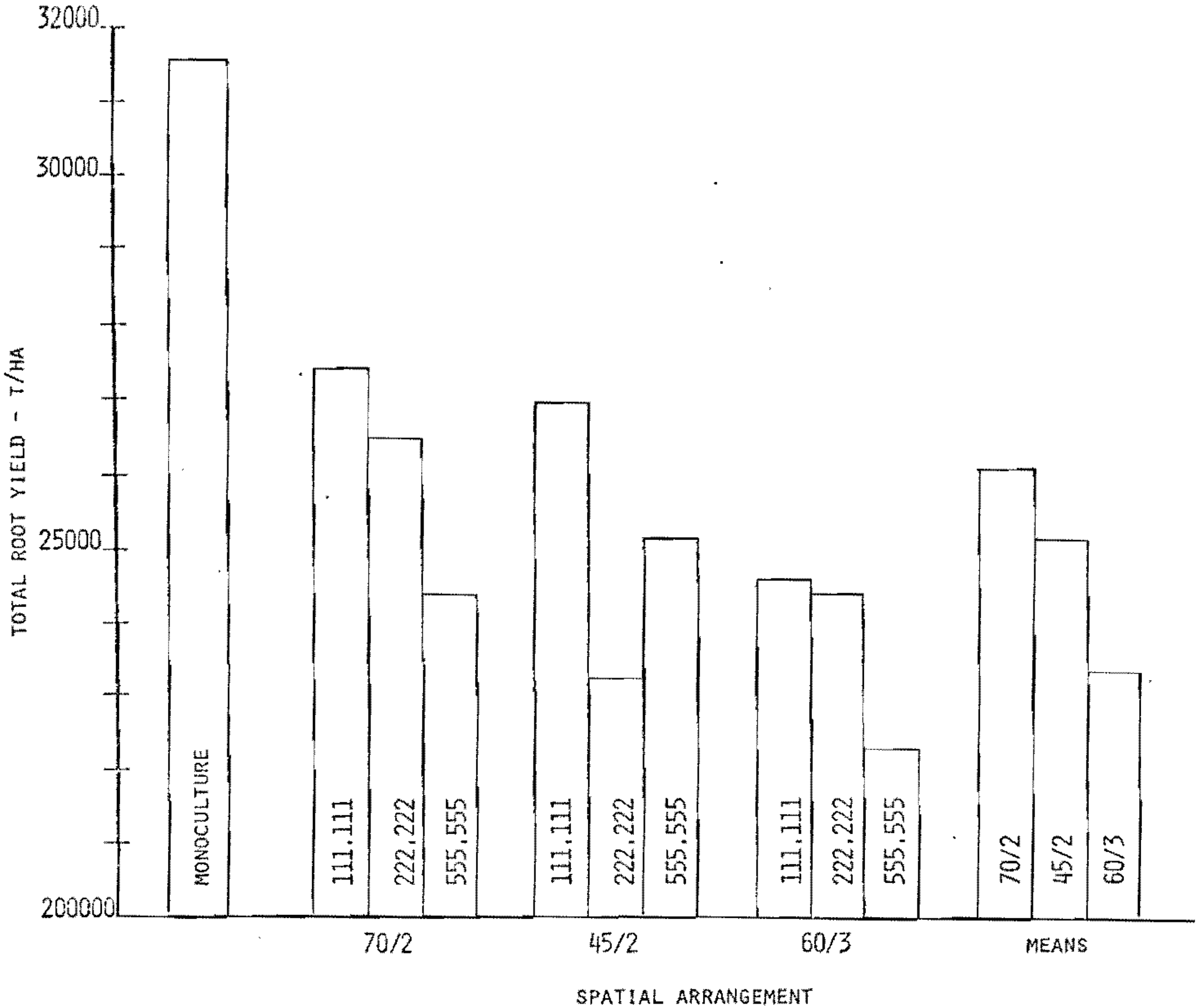


FIGURE 13 FRESH ROOT YIELD OF CASSAVA CV. CMC 84 AS INFLUENCED BY GROUNDNUT PLANTING DENSITY AND SPATIAL ARRANGEMENT. CIAT-QUILICHAO, 1979

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positively to higher planting densities up to 220.000 pl/ha. Cassava yield was following the same tendency as with cowpea, higher planting densities causing greater yield reductions in cassava than the low densities, and the 70/2 arrangement being less aggressive on cassava than the other arrangements (Fig.13). In this experiment the low groundnut yields are the result of the good conditions for cassava which was growing well and building up its canopy quickly so that shading became serious for the groundnuts before maturity. In consequence the number of flowers (mean of 859.000/ha) and the number of pods (mean of 830.000/ha) were very low. In contrast groundnuts in experiment 1/79 sown at a standard density of 220.000 pl/ha had 3'900.000 flowers/ha and 1'700.000 pods /ha resulting in a yield twice as high as that observed in this experiment.

## 6. CASSAVA - COWPEA YIELDING EXPERIMENT

After testing the cowpea collection both in monoculture and association the following cultivars were selected:

| | |
|---|---|
| TVX-1193-059D | (high yield in monoculture) |
| TVN-1977-OD | " |
| TVX-1836-9E | " |
| TVN-3629 | " |
| TVN-2616-P-01D | " |
| TVX-1836-P-196 | (high yield in association) |
| TVX-930-01B | " |
| TVN-1977-OD | " |
| Vita 4, and | " |
| P-18 | " |

These lines were planted in association with cassava, CMC 84 at a density of 110.000 pl/ha, using the 60/3 arrangement. Cassava was planted using the standard pattern of 1.8 x 0.6 m (9259 pl /ha). One line, TVN-1977-OD was selected both in monoculture and association, therefore, data of only nine lines are represented in Table 6. On the better soil of this field and with 1 t/ha of dolomitic lime instead of only 0.5 t/ha yields were higher than those measured before. The cowpea lines selected in the association with cassava were on the average higher yielding than the lines selected in monoculture, the former having higher number of plants/ha and more pods per plant and the latter a higher hundred-seed-weight. The best yielding line was P.18 with more than 1.500 kg/ha in association with cassava but the plants had a tendency to climb under the somewhat more favourable soil conditions of this experiment so that yield reduction of cassava was very high. The cassava yield shows no difference between planting with cowpea selected in monoculture (mean cassava yield 15.7 t/ha) and with cowpea selected in association (mean cassava yield 15.8 t/ha). In this experiment the cassava yields in association showed a depression of only 4.3-35% below monoculture yield. The highest yield of cassava was found with the low yielding cowpea TVN-1193-059, the lowest with the high yielding cowpea P.18 and TVN-1197-OD which produced a high yield (1.194 kg/ha) while affecting cassava yield very little (89.64% of the cassava monoculture yield were harvested). This line in 1978 occupied the second rank in the legume monoculture screening trial and the third rank when planted in association (Experiments 78/1 and 78/2), so that this line appears to have good potential and adaptation to both monoculture and multiple cropping in this edaphic environment.

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TABLE 6 COWPEA YIELD DATA OF YIELDING EXPERIMENT 1979 IN ASSOCIATION WITH CASSAVA (CMC 84).

| | CULTIVAR DESIGNATION | GRAIN YIELD KG/HA | PLANTS /HA | PODS /M2 | PODS/ PLANT | HUNDRED SEED WEIGHT | CASSAVA YIELD T/HA |
|---|---|---|---|---|---|---|---|
| O | TVX-1193-059 D | 878 | 96.320 | 58.8 | 5.95 | 15.1 | 17.7 |
| OX | TVN-1977-0D | 1.194 | 94.792 | 96.8 | 9.56 | 9.3 | 16.6 |
| O | TVX-1836-9E | 781 | 86.042 | 64.5 | 7.37 | 11.7 | 16.2 |
| O | TVN-3629 | 1.147 | 91.806 | 82.8 | 9.15 | 14.0 | 12.1 |
| O | TVN-2616-P-01D | 1.047 | 96.042 | 71.2 | 7.30 | 14.5 | 15.7 |
| X | TVX-1836-P-196 | 982 | 100.694 | 86.0 | 8.43 | 12.9 | 16.5 |
| X | TVX-930-01B | 973 | 99.583 | 77.5 | 7.52 | 13.9 | 16.4 |
| X | VITA 4 | 1.177 | 101.736 | 99.4 | 9.52 | 9.4 | 15.6 |
| X | P-18 | 1.555 | 84.375 | 77.7 | 9.14 | 15.2 | 13.8 |
| MEAN OF LINES SELECTED IN MONOCULTURE | | 1.010 | 93.016 | 74.8 | 7.87 | 12.9 | 15.7 |
| MEAN OF LINES SELECTED IN ASSOCIATION | | 1.176 | 96.236 | 87.5 | 8.83 | 12.2 | 15.8 |
| CASSAVA MONOCULTURE | | --- | --- | --- | --- | --- | 18.5 |

O LINES SELECTED IN MONOCULTURE
X LINES SELECTED IN ASSOCIATION

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## 7. MONOCULTURE - ASSOCIATION - ROTATION

This experiment was designed to test the influence of three cropping systems - cassava monoculture, cassava/grain legume intercropping and a one cycle cassava two cycles legume rotation - on soil fertility parameters and yield following a fertilized and an unfertilized system. Cassava root yield response to fertilization (500 kg/ha dolomitic lime, 60, 100, 75, 10, 1 kg/ha of N, $P_2O_5$, $K_2O$, Zn and B, respectively) was small in monoculture, possibly due to the high amount of organic matter being mineralized during the vegetation period. However, with a greater demand for nutrients in the cassava-cowpea association, there was a marked response to fertilization. In other terms, addition of nutrients proved to prevent a strong yield reduction of intercropped cassava, which suffered quite a strong reduction due to competition with cowpea when no fertilizer was added (reduction due to intercropping 23% without v.s. 11% with fertilizer). With cowpea, on the other hand, yield differences between monoculture (in the rotational scheme) and association were small without fertilizer showing that when nutrients are limiting, cowpea succeeds in appropriating a greater share for itself, leaving cassava with much less. When fertilizer was added, however, yield response was much greater in monoculture than with intercropped cowpea showing that with nutrients added, cowpea not only competes but also suffers from competition by cassava. Groundnuts being grown as the second legume component in the rotational scheme, yielded much better than in other groundnut trials, showing high yields without and with fertilizer. The yield response to added nutrients was only 18% (Table 7).

As a consequence of putting formerly virgin grassland under cultivation, and as a result of the diverse cropping systems, large differences in soil parameters were observed already after completing the first crop cycle. Major changes were the decrease of organic matter, P, Ca and K. On the other hand, Al which fell markedly during the first part of the vegetation period, rose to almost its initial level at the end of the first growth whilst Mn steadily declined and pH increased above its initial value(Table 8). At the end of the first cycle the plots with fertilizer had higher P and Mn, a higher pH and a lower Al but also lower Mg and K concentration. The organic matter and Ca were not different from the unfertilized plots. Comparing the three production systems, cassava monoculture, cassava cowpea association, and cowpea-groundnut-cassava rotation, cassava monoculture plots showed the highest O.M. and Al and the lowest Ca and K concentrations. The association was most effective in raising the pH whilst cassava monoculture consistently had the lowest(Table 9). The somewhat higher pH in association went along with lower Al and Mn, but also a lower P concentration was observed indicating a strong demand of the system for this element. The rotation[1] had the highest P, Ca, K and Mn and the lowest O.M., Mg concentration in the soil. In conclusion it can be said that the rotation (so far cowpea monoculture ) did not provide the expected positive influence

[1] at this stage equivalent to cowpea monoculture

TABLE 7 CROP YIELDS OF CASSAVA, COWPEA AND PEANUT OBTAINED IN A MONOCULTURE-ASSOCIATION-ROTATION TRIAL. EXPERIMENT 1/79. CIAT-QUILICHAO 1979-80.

| CROP SYSTEM | CASSAVA TOTAL ROOT - T/HA | COWPEA GRAIN YIELD -14% $H_2O$ KG/HA | GROUNDNUT SHELLED-14% $H_2O$ KG/HA |
|---|---|---|---|
| A. WITHOUT FERTILIZER | | | |
| CASSAVA MONOCULTURE | 36.2 | | |
| CASSAVA-COWPEA ASSOCIATION | 28.0 | 840.3 | |
| ROTATION (1ST YEAR) | | | |
| 1. COWPEA MONOCULTURE | | 888.7 | |
| 2. GROUNDNUT MONOCULTURE | | | 1137.3 |
| B. WITH FERTILIZER | | | |
| CASSAVA MONOCULTURE | 37.7 | | |
| CASSAVA-COWPEA ASSOCIATION | 33.6 | 1112.3 | |
| ROTATION (1ST YEAR) | | | |
| 1. COWPEA MONOCULTURE | | 1551.8 | |
| 2. GROUNDNUT MONOCULTURE | | | 1379.6 |

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TABLE 8 CHANGE IN SOIL PARAMETERS (5-20 CM) DURING THE FIRST CROP CYCLE OF MONOCULTURE-ASSOCIATION ROTATION TRIAL WITH CASSAVA, COWPEA AND PEANUT. OBSERVATIONS AFTER MAY 21 REPRESENT MEANS OF TREATMENTS, WITH FERTILIZER. CIAT-QUILICHAO, 1979-1980.

| TIME | DATE | O.M % | pH | P PPM | CA (MEQ) | MG (MEQ) | K (MEQ) | AL (MEQ) | MN PPM |
|---|---|---|---|---|---|---|---|---|---|
| BEFORE LAND PREPARATION | MARCH 10 | 8.4 | 3.7 | 3.4 | 1.15 | 0.37 | 0.39 | 3.9 | 81 |
| AFTER PREPARATION, BEFORE PLANTING | MAY 21 | 7.9 | 4.0 | 2.2 | 1.56 | 0.46 | 0.29 | 2.8 | --- |
| SHORTLY AFTER PLANTING AND FERTILIZATION | MAY 30 | 9.2 | 3.8 | 3.4 | 1.99 | 0.58 | 0.52 | 2.9 | 102 |
| AFTER COWPEA HARVEST | AUG 20 | 7.0 | 4.3 | 7.8 | 1.64 | 0.45 | 0.22 | 2.7 | 54 |
| AFTER GROUNDNUT HARVEST | FEB 5 | 6.0 | 4.2 | 2.0 | 0.53 | 0.20 | 0.13 | 3.6 | 24 |
| AFTER CASSAVA HARVEST | MARCH 18 | 7.3 | 4.2 | 2.5 | 1.37 | 0.31 | 0.16 | 3.4 | 45 |

TABLE 9 SOIL pH IN A MONOCULTURE-ASSOCIATION-ROTATION CROPPING SYSTEMS TRIAL AFTER COMPLETING THE FIRST HALF-CYCLE (COWPEA HARVEST) CIAT-QUILICHAO, 1979-80.

| SAMPLING DEPTH-CM | CASSAVA MONOCULTURE | CROPPING SYSTEM LEGUME-CASSAVA-ROTATION (ONLY 1 COWPEA CYCLE) | CASSAVA COWPEA ASSOCIATION |
|---|---|---|---|
| A. WITH FERTILIZER | | | |
| 5-20 CM | 4.25 | 4.30 | 4.40 |
| 21-40 CM | 4.13 | 4.15 | 4.33 |
| B. WITHOUT FERTILIZER | | | |
| 5-20 CM | 4.15 | 4.18 | 4.35 |
| 21-40 CM | 4.10 | 4.13 | 4.19 |

on soil conditions (pH, M.O., Al, Mn) but it was efficiently using the nutrients. The association (cassava-with cowpea) seemed to have a positive influence on soil conditions and was using nutrients in a moderate way. Cassava monoculture also seems to drain the nutrient reserves agressively while at the same time worsening soil conditions by lowering the pH. All together the association proved to be most advantageous for the soil and it also gave a good total yield. However, further crop cycles must be completed before a definite evaluation of these cropping systems is possible.

## 8. NUTRIENT REQUIREMENTS OF INTERCROP VERSUS MONOCROP SYSTEMS

This experiment was designed to throw light on the plant nutrition aspect of cassava intercropping. While individually nutrient requirements for both cassava and legumes in monoculture are relatively well established, there is little knowledge about how this requirement should be assessed for a crop association. One way is to grow the crops both in monoculture and association together in one trial where nutrients are increased stepwise from 0 to a high level, and compare the yield response curves obtained in each system in order to establish the optimum level for the intercrop and monocultures alike. Since at CIAT-Quilichao, the most limiting plant nutrient is P, we conducted such an experiment with cassava and cowpea, using $P_2O_5$-levels of 0, 50, 100, 150 and 300 kg/ha. Basal dressing was

500 kg/ha dolomitic lime and 100 N, 75 $K_2O$, 10 Zn and 1 kg/ha of Boron. Cassava was planted at a 1.8 x 0.6 m arrangement (9.259 pl/ha) with cowpea in monocutlure at 0.6 x 0.15 and as intercrop in a 60/3 arrangement, preserving 110.000 pl/ha in all treatments. Fertilizer was banded at planting. In cassava/cowpea association, an all-fertilizer-broadcast-treatment was added.

Cowpea grain yield response to increased P-levels showed two peaks, one at 50, the other at 300 kg/ha (Fig.14). Besides uield, this double peak was also observed with other parameters such as percent plant survival, No.of pods/$m^2$, No. of pods/plant and plant height. In association, broadcasting fertilizer gave consistently higher yields at all P-levels than banding. The pronounced sigmoidal yield response curve was not expected on this highly P-deficient soil where a more linear response would have been more likely. While different levels of mycorrhizal activities at different soil P levels might have given at least a partial explanation (Yost & Fox, 1979) we are not able to report on this since no mycorrhizal observations were made. Another explanation of the non-linear response of cowpea to applied P may lie in the variability of soil P levels which was rather high and mostly not in accordance with applied P levels (Fig.15). Furthermore, the better performance of cowpea in broadcast than in banded fertilizer plots was although observed by other workers (Foud, Zaki, Amerhorn and Abdallah, 1979). not very likely to occur on a low P soil with high P-fixing capacity. We have no ready explanation for this extraordinary behavior but it can be hypothesized than on a droughty soil like that of

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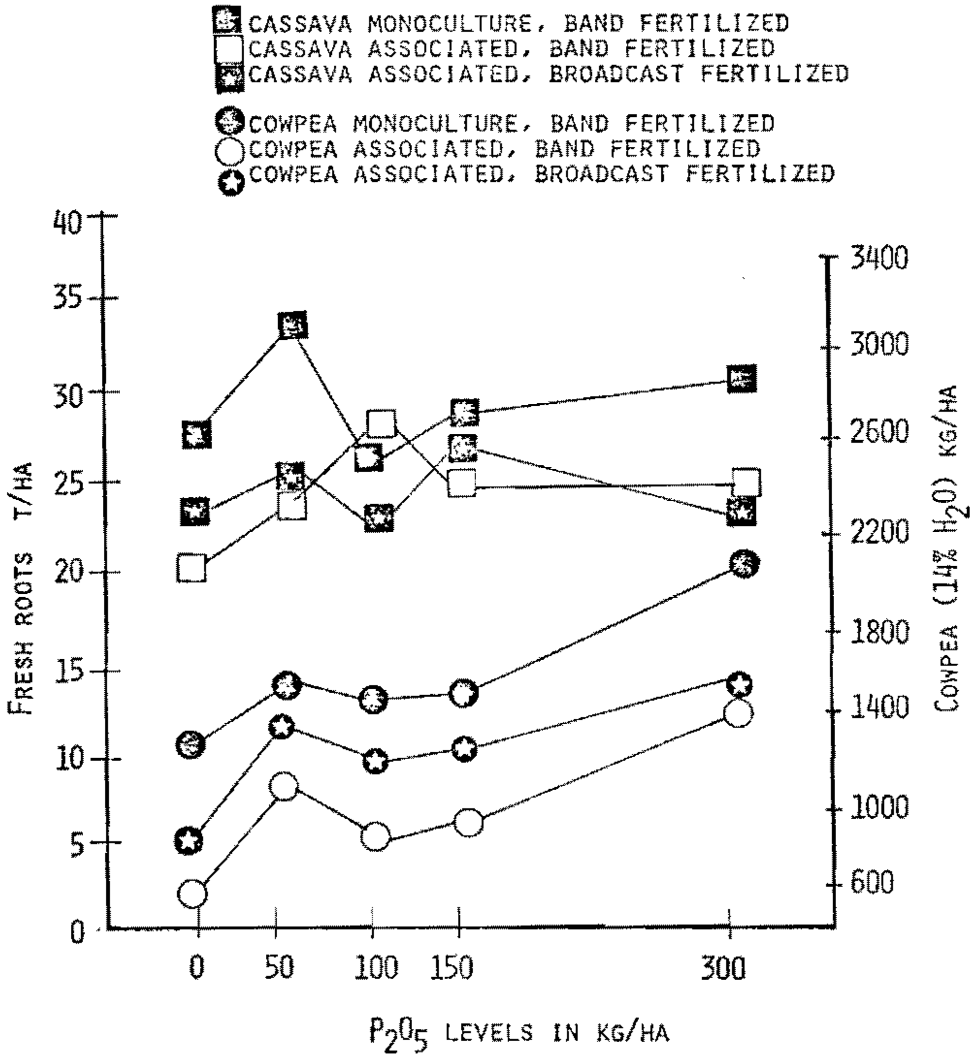


FIGURE 14.

: EFFECT OF FOSFORUS LEVELS, MODE OF APPLICATION (BANDED, BROADCAST) ON CASSAVA AND COWPEA YIELDS IN ASSOCIATION AND MONOCULTURE. CIAT-QUILICHAO. 1980.

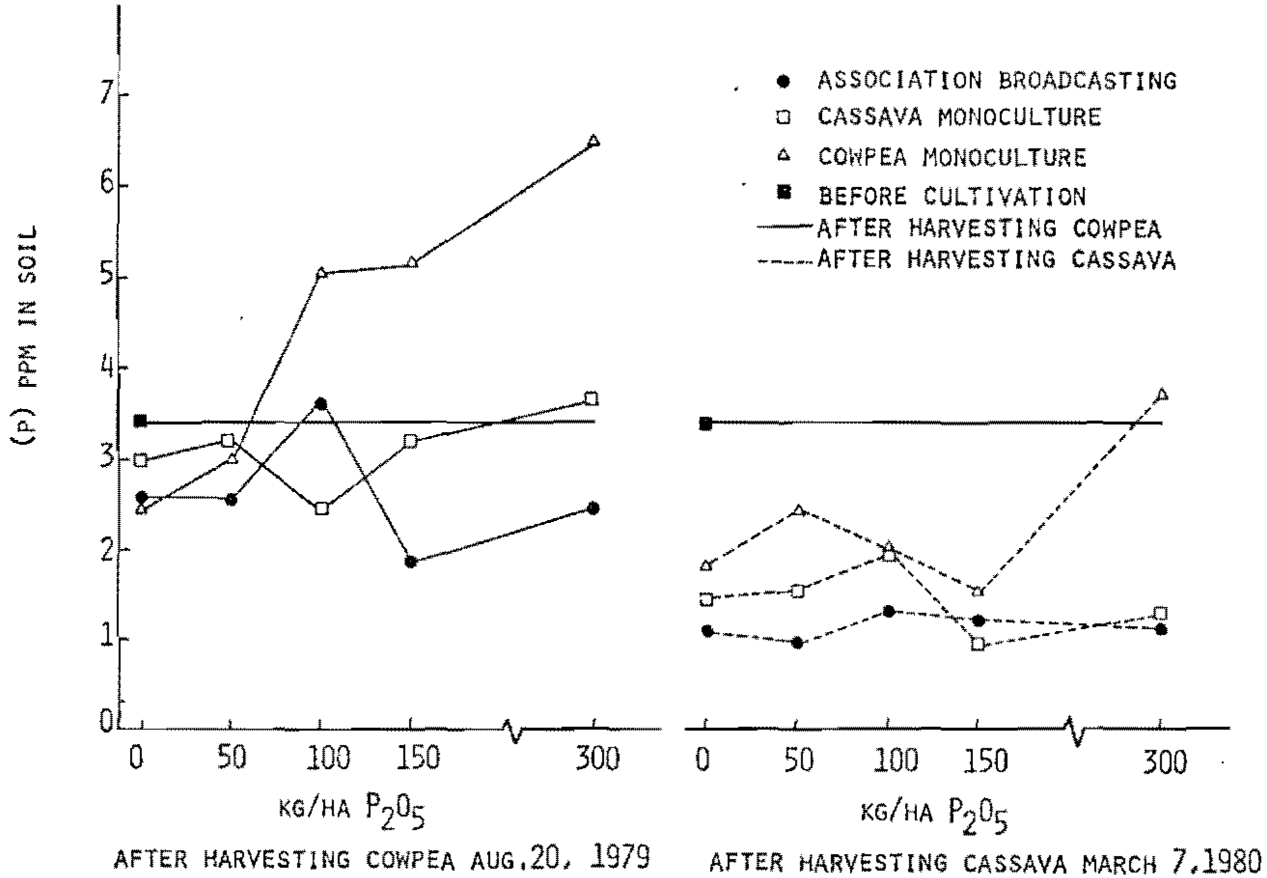


FIGURE 15 SOIL PHOSPHORUS LEVELS AS INFLUENCED BY P-APPLICATIONS, THREE AND TEN MONTHS AFTER PLANTING. EXPERIMENT 3/79. CIAT-QUILICHAO 1979-80

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CIAT-Quilichao root expansion was enhanced by the broadcast application and thus plants growing under these conditions were better able to absorb water and withstand the drought spells ocurring during the growth cycle. In the second cycle of this experiment which was replanted on the same plots, the advantage of broadcast fertilization is not going to be repeated. Cowpea in this second planting showed consistently better growth with band application of fertilizer as compared to the broadcast treatment. A sigmoidal response of growth parameters to increase P-levels was also observed with cassava which, however, did not exhibit this characteristic behavior in root yield. In monoculture, maximum root yield was reached with only 50 $P_2O_5$ whereas in the cassava cowpea association with banded fertilizer, maximum root yield was achieved with 100 $P_2O_5$, and in the broadcast application, 150 $P_2O_5$ were needed to produce maximum root yield (Fig.14). It appears logical that with greater demand for nutrients, in particular P, in association, the peak yield should have been produced at a higher P level than in monoculture. Also, with strong competition for P in the association, banding proved to be more efficient, producing 0.7 t/ha more roots with 50 $P_2O_5$ less. In no case was highest root yield obtained with the highest P level confirming that although cassava has a high external requirement of P for maximum growth in culture solution, maximum root production is achieved at much lower P levels in the field.

Under the soil conditions prevailing in this trial and other experiments conducted at CIAT-Quilichao, both cassava and cowpeas have been yielding reasonably well with levels as low as 50 kg/ha of $P_2O_5$. When intercropping the two species, indications are strong that P requirement rises to at least 100 $P_2O_5$ to maintain a reasonable yield level of both crops. The issue of banding v.s. broadcasting could not be fully clarified since results were contradictory, however, results from cassava would point at a higher efficiency of banding which ap= pears to be the more logical way of fertilizer application on this type of soil.

## 9. COWPEA GROWTH AND YIELD DEPENDING ON SOIL CONDITIONS

With cowpea, similar to dry beans (Phaseolus vulgaris), growth and yield depression due to adverse soil conditions (low pH, low Mg + Ca, high Al and Mn) can be observed but in the case of cowpea this reaction starts at a lower/higher level of these parameters. As can be seen in Table 10, no single soil parameter can be made responsable for high or low yields in a given trial or cropping system, rather the soil factors as a group or complex are acting together resulting in the growth and yield performance observed. Matching soil parameters with the corresponding cowpea yields, it is seen that their influence is very strong, this was demonstrated for example, by the mean cowpea yield of experiment 2/78 (cowpea with cassava, average of 61 cultivars) and experiment 3/78 (selected average of 27 plots with different cowpea densities and spatial arrangements). These drastic differences show that by working with

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a minimum fertilization and a minimum of lime (0.5 - 1 t/ha), soil conditions often remained on the borderline for cowpea growth and planting on land with even lower fertility brought about a yield depression of several hundred percent (Table 11) or a total loss of one replication. Often soil quality was also influenced by the topography of the field, when going down to the valley the soil quality and in consequence the cowpea yield was depressed.

Since the reaction of cowpea to the soil was not expressed only in a yield depression but also in poor growth there was not only loss of data but also no competition for cassava, so that the cassava data from these plots or replications had to be excluded either.

## 10. CASSAVA GROWTH AND YIELD DEPENDING ON SOIL CONDITIONS

Cassava suffered less from adverse soil conditions, but response to fertilization was limited, particularly when cassava was grown in monoculture. In experiment 3/78 for instance, where the maximum yield of cowpea was 75 times whe minimum yield, the difference between minimum and maximum yield of cassava was only five times. By planting in association, unfavourable soil conditions were frequently nearly compensated by lower competition from poorly growing cowpea. In terms of vegetative growth, the most depreseed growth was never below 70% of the best growing cassava. The difference between plant height in the plots with best and worst soil conditions become important only after

120 days (Fig.16). This same observation was reported comparing monoculture and intercropped cassava, and when transition from dry to wet periods was observed.

TABLE 10 SOIL CONDITIONS IN EXPERIMENTS WITH COWPEA

| EXPERIM. CODE | M.O. % | pH | Al | Ca | Mg | K | Mn | AVERAGE YIELD KG/HA MONO | AVERAGE YIELD KG/HA ASOCIATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | M.E. | | | | | | |
| 1-78 | 6.82 | 4.09 | 4.09 | 0.60 | 0.12 | 0.15 | 17.76 | 1179 | --- |
| 2-78 | 6.67 | 3.90 | 4.05 | 0.71 | 0.05 | 0.11 | --- | --- | 459 |
| 3-78 | 6.97 | 4.27 | 2.17 | 2.78 | 0.16 | 0.10 | --- | --- | 1711 |
| 1-79 | 9.19 | 3.91 | 2.54 | 2.37 | 0.64 | 0.60 | 115.13 | 1220 | 976 |
| 3-79 | 8.57 | 3.88 | 3.65 | 1.62 | 0.48 | 0.39 | 25.21 | 1553 | 1094 |
| 5-79 | 7.04 | 3.94 | 4.56 | 0.56 | 0.14 | 0.15 | 38.40 | --- | 714 |
| 6-79 | 8.98 | 3.82 | 2.61 | 2.29 | 0.57 | 0.63 | 116.10 | --- | 1069 |
| | 7.74 | 3.97 | 3.38 | 1.56 | 0.31 | 0.30 | 62.52 | 1317 | 1004 |

TABLE 11 YIELDS OF COWPEA IN THE EXPERIMENTS 1978-79 (KG/HA GRAIN YIELD WITH 14% MOISTURE)

| TITLE OF EXPERIMENT | EXPER. CODE | AVERAGE YIELD | MAXIMUM | MINIMUM | FERTILIZATION $N-P_2O_5-K_2O$ KG/HA | DOLOMIT LIME KG/HA |
|---|---|---|---|---|---|---|
| MONOCULTURE | | | | | | |
| 1. LEGUME COLLECTION IN MONOCULTURE | 1-78 | 1178.6 | 2123.5 | 76.1 | 50-100-75- 10 | 500 |
| 2. MONOCULTURE-ASSOCIATION-ROTATION | 1-79 | 1220.3 | 1855.2 | 528.0 | 60-100-75+100 | 500 |
| 3 PHOSPHORUS LEVELS | 3-79 | 1553.4 | 2638.1 | 318.6 | 100- -75- 10 | 500 |
| ASSOCIATION | | | | | | |
| 4. LEGUME COLLECTION IN ASSOCIATION WITH CASSAVA | 2-78 | 459.1 | 768.4 | 41.9 | NO | 500 |
| 5. COWPEA DENSITY AND SPACIAL ARRANGEMENT (RANGE 110.000 - 550.000 PL/HA) | 3-78 | 1211.9 | 2128.1 | 28.5 | NO | NO |
| 6. MONOCULTURE - ASSOCIATION - ROTATION | 1-79 | 976.3 | 1451.6 | 703.6 | 60-100-75-110 | 500 |
| 7. PHOSPHORUS LEVELS | 3-79 | 1094.0 | 1897.1 | 127.8 | 100- -75- 10 | 500 |
| 8. COWPEA DENSITY AND SPACIAL ARRANGEMENT (RANGE 70.000 - 100.000 - 150.000 PL/HA) | 5-79 | 714.3 | 1879.5 | 107.1 | 100-150-75-110 | 500 |
| 9. THE BEST SELECTED COWPEA CULTIVARS IN ASSOCIATION | 6-79 | 1081.7 | 1948.1 | 311.8 | 100-150-75- 10 | 1000 |

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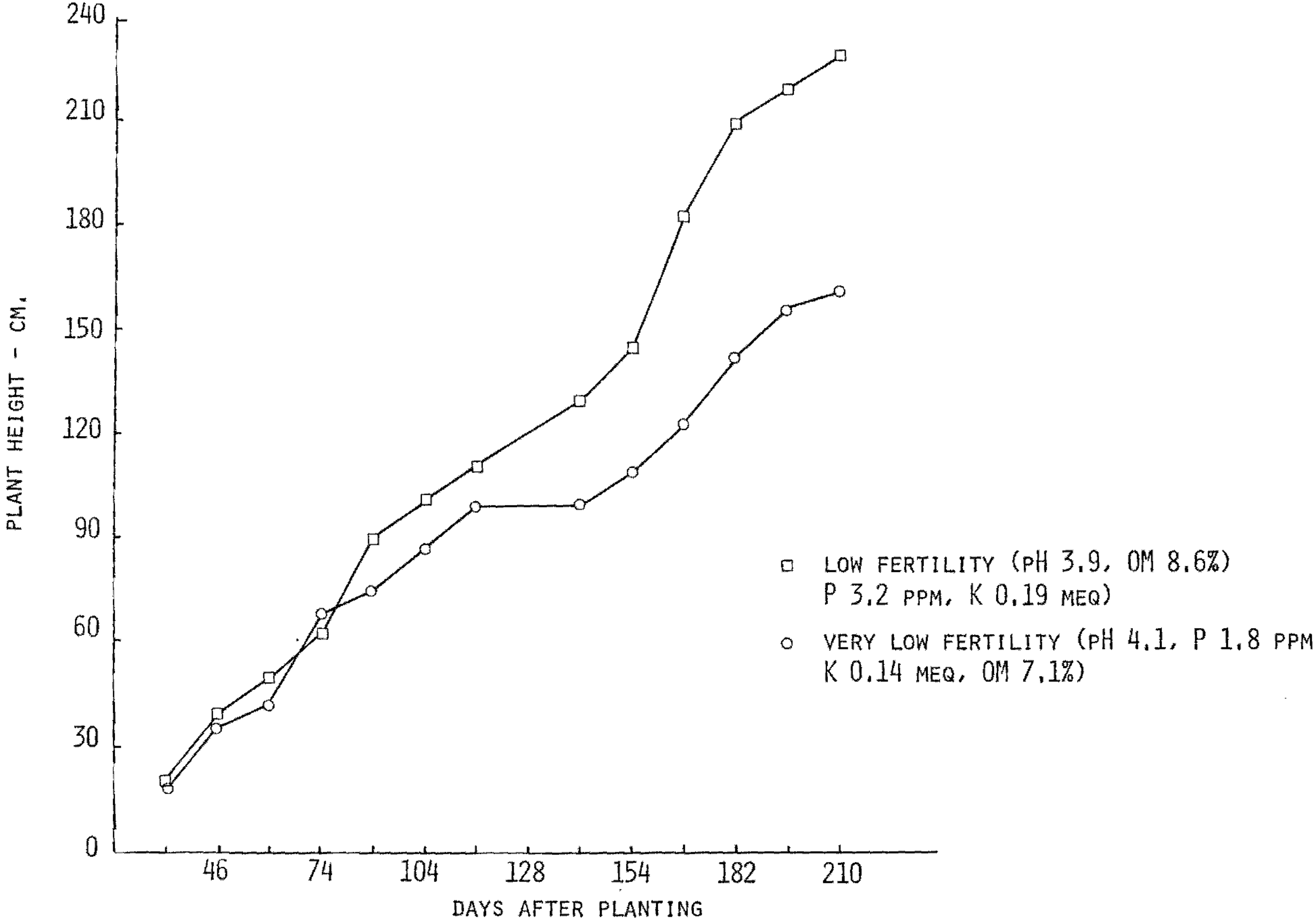


FIGURE 16 INFLUENCE OF SOIL CONDITIONS ON CASSAVA PLANT HEIGHT IN MONOCULTURE DURING SEVEN MONTHS OF GROWTH.

## 11. CONCLUSIONS AND COMMENT (By D. Leihner)

The experiments reported here were conducted in order to start the development of an intercropping technology for cassava with grain legumes on acid, infertile soils, where cassava cannot be successfully intercropped with dry beans (*Phaseolus vulgaris*). Investigation was focussed on three aspects:

1. Identification of suitable genetic materials
2. Clarification of agronomic management of these materials in association with cassava
3. Establishment of nutritional requirements of the crop association

Among the 10 grain legume species screened for adaptation to low soil fertility, acidity, growth habit and yield, two species - cowpea and groundnut - showed the greatest potential as an intercrop with cassava in simultaneous planting. A third species, velvet beans, also showed good adaptation to acid, infertile soil conditions. However, its climbing habit makes it unsuitable for simultaneous planting with cassava. We suggest that further investigation elaborates the management practices for intercropping this specie at the end of the cassava growth cycle using grown-up cassava as support. Cowpea, although its tolerance to low pH and P is not unlimited and somewhat less than cassava, was definitely the most promising legume, producing an average yield in association with cassav of more than one ton of dry grain (mean of 6 experiments, see Table 10). It also proved to be a rustic crop in phytosanitary terms, usually conditions. Without applying a minimal basal dressing of 0.5 t/ha of lime (normal limestone or better dolomitic lime), growth of all crops was poor and yields low. While organic matter and potassium were sufficiently high at least in newly cultivated soil which had been under pasture before, to provide N and K to the first crop, these elements and particularly P showed extremely low levels on land which had been cultivated for several crop cycles. We therefore tried to establish

a. the long-term effect of different cultivation systems on soil fertility and yield of cassava/legumes.

b. the P requirement of intercropped cassava with legumes as opposed to the respective monoculture requirements.

While with repect to a) we arrived only at very preliminary conclusions - intercropping generally having a more beneficial influence on the soil than either cassava or legume monocultures -we are able to make a more conclusive statement on P requiremnnts of cassava/cowpea associations. Our data led us to conclude that in order to produce acceptable yields, both cassava and cowpea require a minimal application of 50 (to 100) kg/ha $P_2O_5$ in monoculture and this quantity has to be increased to 100 (to 150) kg/ha if the two are grown in association. Cowpea does respond to higher P levels, but it may be uneconomical to apply them. Band applications produced lower cowpea yields than broadcast applied P, but for cassava,banded P was more efficient in terms of kg root yield produced per kg of applied P. The banding-broadcasting issue needs further clarification.

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requiring no or at most one insecticide spray while no fungicidal or other applications were necessary. Groundnuts, a food grain and highly valued specially crop at a time, proved to have great potential with low input levels, as well. However, we are more at the beginning with this crop since at time of planting these trails, no varietal collection was available, confining our work to one single cultivar, ICA-Tatui 76. We suggest that future efforts should be directed at obtaining and screening a greater variety of genotypes of this crop, identifying even superior materials.

With suitable genetic materials available, our next concern was agronomic management. We focussed on determining planting densities and spatial arrangements for the legumes in association with cassava, expecting that these should be different to those optimal for cassava/bush bean associations due to the largely different growth habit of cowpeas and groundnuts. From our data it can be concluded that under the acid, infertile soil conditions of Quilichao, cowpeas gave maximum yields at around 100.000 pl/ha whereas groundnuts had an optimum density of above 200.000 pl/ha. The spatial arrangement influenced both inter- and intraspecific competition, both being minimal in a 60-30-30-60 cm triple row arrangement of the legumes between cassava,a planting pattern which appears particularly suitable when planting is done on the flat. For cassava, we used the standard planting density and arrangement which had been tested already with cassava-dry bean associations.

Plant nutrition proved to be critical under the given soil

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In this two-year project, we stressed the legume-side of our intercropping research, partly because ideal genotypic characteristics and management practices for cassava in intercropping systems were already defined at an earlier stage; however, the process of selecting well adapted, high yielding cassava genotypes for acid infertile soil conditions has not come to an end, and as superior cassava selections or hybrids emerge, we shall be able to select those which, under the given edaphic conditions show sufficient early vigor, erect growth, late branching and high yield to make them ideal partners for cassava legume associations on acid infertile soils.