PRODUCTION POTENTIAL OF CASSAVA-BASED CROPPING SYSTEMS

By

ASHOKAN, P. K.

THESIS

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DECLARATION

I hereby declare that this thesis entitled "PRODUCTION POTENTIAL OF CASSAVA-BASED CROPPING SYSTEMS" is a bonafide record of research work done by me during the course of the research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
Date: 07.04.1986

(ASHOKAN, P.K.)
Ad. No. 81.21.01

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(Dr. C. SREEDHARAN)
Chairman,
Advisory Committee,
Professor and Head,
Department of Agronomy,
College of Horticulture,
vellanikkara

Vellanikkara
Date: 07 .04.1986

CERTIFICATE

We the undersigned, members of the Advisory committee of Mr. P.K. ASHOKAN (81.21.01) a candidate for the degree of Doctor of Philosophy in Agronomy, agree that the thesis entitled "PRODUCTION POTENTIAL OF CASSAVA-BASED CROPPING SYSTEMS" may be submitted in partial fulfilment of the requirement for the degree.

(C. SREEDHARAN)
Chairman

(R. VIKRAMAN NAIR)
Member

(V.K. SASIDHAR)
Member

(P.A. WAHID)
Member

(K.C. GEORGE)
Member

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(P.K. ASHOKAN)

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Introduction

INTRODUCTION

Believed to be a native of North-East Brazil, cassava (Manihot esculenta, Crantz) is a cheap source of calorie food throughout the tropics and warm sub-tropics. In India, the State of Kerala accounts for about 80 per cent of the annual production and it forms a subsidiary food for the poor millions. Of late, cassava production in the State suffered a serious set back because of the wide fluctuation in prices. Adopting scientific farming practices aimed at increasing the productivity is the only way for stabilising the returns of the farmers. One of the methods suggested for improving the productivity of cassava based cropping systems is to adopt multiple cropping practices like intercropping/mixed cropping, the advantages of which are discussed in detail by Andrews and Kassam (1976). A wide variety of crops like cereals, legumes, vegetables, medicinal plants, oil seeds etc., are reported to be in use as intercrops in cassava. Interaction between component crops both complementary and competitive are also reported in many of these intercropping systems (Hart, 1974; Kang and Wilson, 1980 ; CIAT, 1982 and Ashokan et al., 1984b). However, a critical analysis of the interspecific interactions existing in such intercropping systems has not been attempted so far.

Paired row planting of cassava has been suggested both under sole and intercropped situations, with yield advantage in some cases (Ezumah and Okigbo, 1980 and Souza et al., 1981). By modified geometries of planting, the light infiltration and interspace availability will be improved considerably. So there is scope for accommodating longer duration intercrops in the cropping system.

Another possibility of increasing the production potential of cassava based cropping systems is sequential intercropping. The concept, though found unsuccessful under normal planting of cassava (AICPITC, 1978 and CTCRI, 1978) has not been tested under paired row planting wherein we expect free interspace for prolonged periods of time. There is also the possibility of saving some fertilizer for the individual crops in a cropping system. Sharing of nutrients by the component crops has also been reported (Eaglesham, et al. 1981). The response of the intercrops for the applied nutrients and the saving in fertilizer on account of the interactions between the component crops has not been investigated in detail. Hence a series of investigations were undertaken with the following objectives:

i. To study the influence of different geometries of planting of cassava in intercropping systems.

ii. To study the scope of growing longer duration intercrops like colocasia, elephant foot yam and banana in cassava.

iii. To assess the performance of cowpea, groundnut and elephant foot yam as floor crops in cassava+banana intercropping.

iv. To study the possibility of growing sequential intercrops in paired row cassava.

v. To study the rhizosphere and canopy level interactions between cassava and the associated crops.

vi. To arrive at the optimum doses of fertilizers for the intercrop cowpea and groundnut grown in paired row cassava.

Review of Literature

REVIEW OF LITERATURE

The productivity of cassava based cropping systems can be improved considerably by scientific cropping practices. Of late considerable research efforts have been directed towards maximising the productivity of cassava based cropping systems. Consequently a lot of information has been documented in literature on the crop compatibility, planting geometry and cultural and manurial practices which are reviewed in this section.

Multiple cropping methods like sequential cropping, mixed or intercropping, relay cropping etc. have been in practice throughout the tropics and warm sub-tropics (Andrews and Kassam, 1976). Descriptions of such multiple cropping practices are available in literature in plenty (Aiyer, 1949; Kanwar, 1970; Mahapatra et al., 1973; Nelliat et al., 1974; Swaminathan, 1970; IRRI, 1974; Andrews, 1972; Finlay, 1974; Willey and Osiru, 1972 and Francis et al., 1976).and CTCRI, 1981).

Intercropping cassava with other short duration crops has been in practice since the beginning of this century (Marcus, 1935). However, a scientific approach towards organising such cropping systems began only during the later half of the century largely due to the success obtained in intercropping systems with other field crops.

2.1 Intercropping practices of cassava in India

Several short duration and short statured intercrops have been grown successfully with cassava. Groundnut is one of the most acclaimed intercrops for cassava in Kerala. (Singh and

Mandal,1968; Mohankumar, 1975; Thomas and Nair, 1979; KAU, 1983; Sheela, 1981). The feasibility of crops like horsegram, sesamum, coleus, bhindi, groundnut and cowpea as intercrops in cassava was examined by Singh and Mandal (1970). Mohankumar (1975) studied the possibility of growing maize, greengram, groundnut, soybean and sunflower. It was seen that groundnut gave the most satisfactory performance. Trials under the All India Co-ordinated Project for the Improvement of Tuber Crops (other than potato) conducted at Nileswar and Trichur showed that cowpea can be successfully grown as intercrop with cassava in high rainfall tracts (KAU, 1977 and 1983).

Prabhakar et al. (1979) tried intercrops like groundnut, cowpea, maize, fodder maize, horsegram, greengram, blackgram, redgram, french bean, amaranthus, cucumber, bhindi etc. in different trials and found french bean as the most economical intercrop for cassava. They also indicated the possibility of growing medicinal plants like *Vinca rosea* and legumes like red gram as intercrops in cassava.

2.2 Intercropping practices in other countries

The practice of growing sorghum, maize, rice, groundnut, cowpea, mung bean, chickpea, sweet potato, cotton, sisal etc. along with cassava has been reported from many countries.

Deeratikasikorn and Wickham (1977) from Thailand reported a cassava-townsville stylo intercropping system. In Nigeria, mixed cropping cassava and maize and cassava and cowpea were found to be more productive than sequential pure stands of maize followed by cowpea (Wilson and Adeniran, 1976). Lizarraga (1976) studied the effect of planting sweet potato between rows of cassava and maize at densities of 50 , 40 and 20 thousand plants per hectare. It was found that interception of solar radiation was more in maize-sweet potato association than in cassava-sweet potato association. Kanchanahut (1976) studied the row spacing and time of intercropping cassava with beans and reported that planting two rows of beans at a spacing of 30 x 20 cm in between two rows of cassava (1 x 1 m) on the same day of planting of cassava was the best practice. Experiments at Costa Rica showed that a polyculture system involving cassava, maize and beans was more efficient in yield and biomass production than the sole crop (Lacharme, 1976). Colombian farmers have been reported to adopt many crop combinations in cassava cultivation; important ones being cassava-maize, cassava-plantain, cassava-beans, cassava-maize-beans, cassava- maize-plantain, cassava-maize-coffee, cassava-plantain-coffee etc. (Diaz and Pintrup-Andersen, 1977). De and Frazao (1980) concluded from their studies that for maximum crop returns the best system was maize-cassava intercropping followed by maize-cowpea. Wilson and Lawson (1982) also reported the success of cassava-maize and cassava-cowpea combinations in Tanzania.

From the above review it is evident that very many crop species are suitable for intercropping in cassava; the crop can be a legume, tuber crop, vegetable, cereal, medicinal plant etc.

2.3 Crop interactions - complementary

Complementary and competitive interactions between cassava and associated crops have been reported from various countries.

Singh and Mandal (1968) observed that cassava yield was not significantly reduced by the intercrop of groundnut. Mohankumar (1973) also noted that cassava yield was not adversely affected by intercrops of groundnut or maize. Results of a trial conducted in Costa Rica indicated that higher economic return could be obtained by growing cassava, bean and maize in a polyculture system (Hart, 1974). He also studied the dynamics of interspecific competitions in a polyculture by computer simulation of an energy flow model. The level of interspecific competition within a polyculture was inversely related to risk. In polyculture, with high interspecific competition, a decline in yield of one species resulted in increase in yield of the other. Total polyculture yield was maximum at some point between zero interspecific competition and a point at which interspecific competition was equal to intraspecific competition.

Intercropping experiments of cassava with maize, melon and vegetables were carried out at the International Institute of Tropical Agriculture, Nigeria, and the results indicated that an intercrop of maize and melon increased the cassava yield as compared to the sole crop of cassava (IITA, 1975).

Field trials conducted in North Kerala showed that intercropping cassava with blackgram, greengram and cowpea did not reduce the yield of cassava and in some cases the yield was even increased in intercropped plots (KAU, 1977). Patanothi et al.

(1977) reported that there was no significant reduction in yield of cassava when intercropped with groundnut, soybean, mung bean, maize or modan rice. Report from Philippines showed that cassava yield was not affected by growing the intercrops like ground nut, cowpea and maize (IRRI,1978). Bhat (1978) observed that the tuber and shoot weight of cassava were not significantly affected by growing groundnut, cowpea, blackgram and greengram as intercrops. Nitis (1978) obtained marginal increase in cassava yield consequent to intercropping with stylo. However, the yield was reduced substantially when intercropped with native grasses. Sinthuprama et al.(1973) compared the performance of four populations of intercrops under normal square planting of cassava and observed that an intercrop population of 30 to 280 thousand plants per hectare did not affect the yield of cassava. Trials conducted at Tamil Nadu Agricultural University, Coimbatore indicated that growing onion as intercrop in cassava did not show significant influence on the yield of cassava (Muthukrishnan and Thamburaj, 1979).

Escalda and Javier (1979) obtained maximum quantity of marketable cassava tubers when it was intercropped with bush beans. It was also noted that the yield of legumes grown in association with cassava was low as compared to that of sole legumes. The effect of maize plant population on maize-cassava intercropping was investigated by Kang and Wilson (1980). It was also found that increasing maize population from 10 to 30 thousand plants per hectare increased the maize yield significantly without reducing cassava yield. Further increase in the population had no effect on grain yield of maize but was found to reduce the yield of cassava.

According to Burgos (1980) reduced soil nutrient losses and maintenance of good physical condition of soil were the reasons for the increased yield in simultaneous intercropping. Sheela (1981) reported that the growth of cassava was suppressed by legume intercropping in the early stages, but later cassava recouped its vigour and growth and by the time of harvest no difference was perceptible.

Trials conducted in command areas of various irrigation projects in Kerala indicated the suitability of cowpea varieties like V-37 and Kanakamani, groundnut varieties like JL-24, Pollachi-1, Pollachi-2, FSB-7-2 and TMV-2 as intercrops in cassava (KAU, 1984). Kawano and Thung (1982) studied the intergenotypic competition in cassava - bean intercropping systems. They reported that beans planted in association with cassava yielded as much as its sole crop, whereas the yield of soybean was considerably reduced. The yield of beans and soybean were negatively correlated with the vegetative vigour of the associated cassava genotype, but were not correlated with yield or competitive ability of the cassava genotypes. They were of the opinion that cassava could be planted in association with short duration crops without sacrificing much the yield of either crop; high yielding cassava genotypes with low vegetative vigour would bring about high combined yields of cassava and the associated crops.

In Tanzania, Wilson and Lawson (1982) studied the cassava maize association and reported that presence of cassava did not adversely affect the maize yield and vice versa, when 30 to 40 thousand plants were intercropped with 10,000 cassava. They have also seen that cassava suppressed by maize in early growth recovers rapidly once the maize has been harvested; the long post-competition growth period allows for high yield because tuberisation occurs mainly during this competition free period.

2.4 Crop interactions- competitive

In intercropping experiments with cassava, harmful interactions between cassava and associated crops were also observed.

Experiments conducted at Central Tuber Crops Research Institute(CTCRI), Trivandrum, invariably showed that the yield of cassava was reduced by growing intercrops such as horsegram, sesamum, coleus, bhindi, greengram, blackgram, groundnut, cowpea, redgram, maize etc. (Singh and Mandal, 1970; Mohankumar, 1975; Prabhakar et al., 1979). However, they did not compare the relative performance of the intercrops with the sole crops.

Studies conducted at Columbia indicated that cowpea planted in cassava grew very vigorously and competed for light during the early growth phase of cassava and cassava never recovered from this early set back; kudzu and velvet bean climbed over cassava and reduced its growth considerably; stylo reduced cassava yield because of its strong competition for water during dry periods (CIAT, 1981).

Prabhakar et al. (1979) reported that the reduction in the yield of cassava consequent to intercropping was due to the interspecies competition and the resultant reduction in tuber number and weight.

Intercropping studies with plantain, maize, cassava and colocasia showed that bunch weight of plantain was not decreased when intercropped with colocasia, cassava and maize; the performance of cassava was poor in such intercropping systems (Devos and Wilson, 1979).

Prabhakar and Náir (1979) observed that pigeonpea can be successfully grown as an intercrop with cassava but it reduced the cassava yield by about 28 per cent. Nevertheless the crop combination was profitable because the yield of pigeonpea more than compensated for the reduction in yield of cassava. Gerodetti (1979) reported that the cassava-maize association reduced the productivity of cassava by 40 per cent, but highest biomass production was recorded for cassava-maize association.

In cassava-maize association, maize is reported to prevail over cassava, depending on the maize population. The cassava yield varied from 75 per cent with 10,000 maize plants per hectare to 46 per cent with 50,000 maize plants per hectare (Meneses and Moreno, 1979).

Mohankumar (1980) noticed significant reduction in cassava yield consequent to intercropping with greengram, groundnut, maize, soybean and sunflower. Because of competition, reduction in cassava yield to the extent of fifty per cent was reported (Howler, 1980). Evaluation of cowpea and groundnut varieties as intercrops in cassava revealed that all varieties except H 42-1 of cowpea reduced cassava growth and yield (CIAT, 1981).

Intercropping experiments with cowpea, groundnut, greengram, red gram, winged bean, velvet bean, sword bean and jack bean were conducted at CIAT, Columbia. The results indicated a reduction in cassava root yield to the order of 1 to 68 per cent and legume seed yield to the order of 10 to 81 per cent due to intercropping. The sword bean and jack bean caused the greatest reduction in cassava yield (CIAT, 1982).

The literature available shows that complementary or competitive interactions between cassava and the intercrops are reported from different parts of the world. Conflicting results are obtained with the same intercrop raised in cassava in different places; may be due to the difference in soil, agro-climate and the plant types. However, it may be noted that in none of the studies reported, the exact reasons for the increase or decrease in yield of cassava or the associated crops in such cropping systems were made clear. In some of the studies, eventhough the argument of competition was put forward, the nature of such competition was neither emphasised nor substantiated with material data.

2.5 Intercropping at the later phase of cassava growth

At Columbia, CIAT made extensive studies on intercropping in cassava at early and later phases of growth. They succesfully raised bush bean in the early phase and climbing bean in the later phase of growth of cassava (CIAT, 1978).They have also reported that cassava reaches maximum leaf area at approximately 4-6 months after planting, when light interception under good growing condition is 95 per cent or more. There after leaf area decreased as older leaves fell and fewer new leaves were formed; the light interception decreased; bush beans and climbing beans could be sown by 7, 8 and 9 months after planting cassava. The relative amount of light passing through the cassava canopy started to increase at about 7 months after cassava planting and stabilised two months later at light transmission values between 30 and 40 per cent. The relative yield of beans was higher in those planted at 9 months age of cassava. Cassava yields were not affected when either bush beans or climbing beans were intercropped at this late stage of cassava development (CIAT, 1981). It is evident that at the late stage of cassava growth the light regime in the interspace of cassava is favourable for the growth of intercrops because of the drastic decrease in leaf area of cassava. But in places like Kerala where the crop is grown rainfed, the moisture regime in the soil will not be favourable for the growth and development of a second intercrop during the later stages.

2.6 Sequential intercropping in cassava

Studies were conducted on the feasibility of growing two short duration legume intercrops in cassava one after another during the early 6-7 months period. The results showed that the second intercrop was not economical as cassava closed in its canopy by about 3-4 months stage under the normal method of planting and the light infiltration through the cassava canopy will not be sufficient to support the second intercrop (Prabhakar et al., 1979). Experiments at Nileswar, Kerala, also showed similar results (AICPITC, 1978). In these experiments the reason for the failure of the second intercrop was found to be the low light available in the interspace of cassava after four to six months growth, the period when the second intercrop was grown. So the concept of a second intercrop in cassava may become successful under modified geometries of planting where the interspace and the light infiltration to the interspace are improved.

2.7 Planting geometry of cassava and intercrops

Altering orientation of the planting rows keeping the total population constant had been suggested as a viable method for increasing the yield of cassava and accommodating more of intercrops (De et al., 1978). Such planting methods will augment the utilization of available space, time, nutrients and light to boost the production per unit of natural and applied inputs (Singh, 1979). As in the case of many field crops, paired row system of planting cassava was reported from many countries. Experimental results from Brazil indicated that paired row planting did not reduce the yield of cassava and hence more area could be made available for intercrops (Porto et al., 1978).

Mattos et al. (1980) opined that paired row system of planting in cassava offers the advantage of allowing other crops to be planted between the double rows and produce more yields than conventional cassava cropping systems. They also pointed out the following advantages of paired row planting system. The system permits easy use of mechanical equipment, reduces labour cost, allows continuous use of the same area by alternating rows, easy for multiple cropping, facilitates crop inspection, increases productivity due to border effect, application of pesticides becomes easier, allows easy mulching of interspaces with organic materials for enriching the soil, reduces the fertilizer use, reduces soil preparation only to the planting areas and makes better use of the land. They have suggested an orientation with 2 m between the paired rows and 0.6 x 0.6 m within the rows for highest productivity and maximum return.

Prabhakar and Nair (1982) observed that there was no significant difference among cassava yields obtained under paired row (1.35 - 0.65 x 1 m), wide row (2 x 0.5 m) and square (1 x 1 m) method of planting. The geometry of planting plays a very vital role in the success of intercropping. Mohankumar (1976) evaluated the performance of intercropped cassava under normal and paired row methods of planting. He observed that the yield of cassava was reduced by the influence of intercrops like greengram, groundnut, maize, soybean and sunflower; but the tuber yield was not significantly different for normal and paired row methods of planting.

Kanchanahut (1976) reported that planting two rows of beans at a spacing of 30 x 20 cm between two rows of cassava was superior to monoculture, planting on the cassava rows or planting three rows of mungbean. Patanothi et al.(1977) from Thailand compared single and double row methods of planting in cassava-legume intercropping systems. They could not find significant difference in the yield of cassava or intercrops due to the modified geometry of planting. Among the various planting patterns, cassava intercropped with two rows of groundnut (30 x 20 cm) between cassava rows, 35 cm apart from the cassava row was found to be more profitable than the cassava monocrop and cassava intercropped with three rows of peanuts between its rows (Ekmahachai et al., 1978).

Ezumah and Okigbo (1980) reported favourable effects of double row planting of cassava on groundnut productivity, especially at high populations. Hagewald (1980) evaluated cowpea and groundnut as intercrop in cassava and observed that planting geometry influenced the inter and intra specific competitions. Both are at minimum in a 60 -30 -60 cm triple row arrangement of legumes with cassava. Rego (1981) evaluated different spatial arrangements for cassava and intercrops. He observed that cassava monoculture exhibited a slow initial growth; at two months stage cassava had 33 per cent soil cover while in association with cowpea the coverage was 75 per cent. Souza et al.(1981) reported that double row planting of cassava with intercropping and minimum tillage is a profitable method of cropping. Ternes (1981) observed that the root yield increased when cassava was planted in single rows. However, marketable tuber yield was 13 per cent more when planted in double rows. According to him the best agronomic and economic cropping system was cassava in double rows intercropped with maize.

The effect of double row planting of cassava alone or in combination with different populations of mungbean was evaluated by Villamayor and Destriza (1982). They obtained a root yield of 2.25 kg per square metre with double row planting and 2.04 kg per square metre in single row planting. The results of the experiments conducted at Mannuthy, Kerala indicated that high yields from groundnut and cassava could be obtained when one row of groundnut was raised at a spacing of 30 cm in cassava grown at a spacing of 75 x 75 cm (KAU, 1984).

Majority of the results showed that cassava yield was not reduced by paired row method of planting; instead more light and space could be made available to intercrops by this method. The relative light transmission pattern in this modified method of planting has not been investigated so far. Similarly sequential or double intercropping is not seen attempted in paired row planting of cassava.

2.8 Fertilizer application to intercropping systems

Experiments to standardise the fertilizer management of the cassava based intercropping systems are comparatively rare. Deeratikasikorn and Wickham (1977) studied the response of cassava to inorganic fertilizer application when sown with townsville stylo as intercrop. In fertilized plots, yield from the stylo was higher. Oversowing stylo resulted in decrease in cassava yield in both fertilized and unfertilized plots. Experimental results at CTCRI, Trivandrum, showed that application of fertilizers to cassava and intercrops like greengram, groundnut, soybean and sunflower produced more root yield and was significantly superior to the application of fertilizers to cassava alone (Mohankumar,1976).

Ekpete (1976) recommended the application of fertilizers to cassava only in an intercropping system involving cassava, maize and bhindi. Lacharme (1976) studied the nutrient absorption pattern in a bean, maize and cassava production agro-system. He observed that the greatest need for soil nutrients was between 25 to 75 days of growth. The requirement decreased in the order cassava, maize, beans. Cassava and maize were great biomass producers and soil nutrient extractors. Fertilizer efficiency was in the order K, N, P, S.

Contrary to this, Patanothi et al. (1977) failed to observe any response in cassava to fertilizer application when it was intercropped with groundnut, soybean and mung bean.

As a companion crop, stylo was reported to supplement 20 kg urea equivalent per hectare to cassava. With sufficient P and K application, the N supply by stylo reached an amount equivalent of 160 kg urea (Nitis, 1977). He also observed that shoot and root weight of cassava were considerably increased by the influence of the associated stylo crop. From a trial conducted at College of Agriculture, Vellayani, Bhat (1978) concluded that intercrops should be fertilized separately in addition to the fertilizers applied to the main crop of cassava. He also found improvement in the fertility status of the soil due to intercropping cassava with legumes.

The fertilizer requirement of cassava-cowpea and cassava-groundnut intercropping systems was assessed by Sheela (1981). She compared the combined doses of N, P and K fertilizers to cassava and the intercrops considering the requirements of both the crops and arrived at a combined dose of 50: 62.5 : 62.5 and 93.75 : 75 : 93.75 of N, P_2O_5 and K_2O kg per hectare respectively for cassava-cowpea and cassava-groundnut intercropping systems. She also found an improvement in the fertility status of the soil due to intercropping cassava with legumes.

Palada and Harwood (1977) from Philippines reported that when cassava, maize and rice were planted together on the same date, maize and cassava had a better competitive ability than rice. Growth balance between the three crops was best at low nitrogen level (60 kg/ha) but total productivity was lower. Highest total productivity was obtained at 180 kg nitrogen per hectare with a land equivalent ratio of 1.9 for the three crop combination. Pinto and Cepeda (1978) indicated that the nutritional requirements were different for each crop in a maize-cassava yam association; this should be considered while formulating the fertilizer recommendations in intercropping systems. Fertilizer dose in a cassava based intercropping system is found to exhibit a highly significant effect on number and weight of marketable roots (Meneses and Moreno, 1979). Porto et al. (1978) obtained high cassava yields when single super phosphate, potassium chloride and ammonium sulphate were applied at 300, 100 and 150 kg/ha respectively to an association of cassava with beans, soybean, rice, peanut, sorghum or maize. Reports from CIAT indicated that some of the leguminous crops grown with cassava failed to exhibit the beneficial effect of nitrogen fixation. Cassava yield was reduced when competition from the cover crop increased (CIAT, 1978). Anilkumar (1983) recorded that growth and yield attributing characters were not influenced by inter-cropping or nitrogen level in a cassava-stylo intercropping system. The root and shoot weights of cassava were not significantly affected by stylo. In field trials in Turrialba, Latin America, maize was sown at densities upto 5 plants per square metre in association with cassava at one plant per square metre and given 90 to 120 kg N, 200 kg $P_{2}0_{5}$ and 75 to 120 kg K20 per hectare. Maximum economic return was obtained at the lower levels of N, P and K application; but higher rates were beneficial when cassava was grown alone or with maize at the lowest density.

The literature available on fertilizer response of cassava and the intercrops show that the response to applied fertilizer vary widely. Fertilizer response of the intercrop legumes in cassava as compared to its sole crop, especially in paired row planting of cassava, needs further investigation.

The productivity of cassava based intercropping systems can be improved only by a thorough understanding of the resource utilisation pattern of each component in the system. A critical review of the available literature shows the following gaps in information on the cassava based intercropping systems. The intraspecific competition in the modified methods of planting of cassava has not been examined so far.

Apart from paired row method, other geometries of planting like square cluster, triangular cluster etc. may also be possible in cassava. However, such methods have not been tried so far in any of the studies reported. It is also possible that the productivity of some of the cassava based intercropping systems can be improved by such modified geometries of planting cassava. Investigations are required to develop cropping systems which utilize the extra interspace resulting from such modified methods of planting in cassava. It is also necessary to standardise the management practices for such intensive cropping and to study the long term impact of these cropping systems on continued soil productivity.

2.9 Use of P-32 for studying the root interactions in mixed cropping systems

Conventional methods of root studies had been to a large extent replaced by radioisotopic methods ever since Lott et al.(1950) and Hall et al.(1953) had studied the plant root system in the field using P-32. Since then P-32 and many other radioisotopes were utilised for studying the root activity pattern and distribution of roots of many crops. The review of those results are not of much relevance in this context since we are interested in the use of radioisotopes for studying the plant interactions in intercropping systems. Unfortunately such studies are rare and the present investigation was fomulated based on the few studies reported.

Among the different crops proposed in the study, the root activity of banana was studied by using P-32 (IAEA, 1975). They found that the maximum root activity of banana was near the surface of the soil at a distance of 40 cm from the plant. Lawton et al.(1954) studied the uptake of P-32 by brome grass and alfalfa grown in mixed stand. They have concluded that more efficient use of P was from the surface in the case of brome-grass and from a depth of 3 to 6 inches in the case of the legume.

The root competition for the radiophosphorus by species grown in intercropping systems including corn - field bean, corn -sesame, corn - castor bean, castor bean - sesame were studied by Lai and Lawton (1962). They have observed that corn was the most effective feeder of fertilizer P. Its roots penetrated the less extensive root system of beans and sesame to obtain P banded close to the other component crops and in contrast there was little cross feeding between adjacent rows of beans or sesame. The vertical and lateral growth of alfalfa, birdsfoot trefoil and orchard grasses were reduced when grown as a companion crop with barley. Barley was able to compete with forage seedlings for moisture and nutrients early in the established period due to rapid root growth (Cooper and Ferguson, 1964).

The search of the literature showed that most of the root studies using P-32 were made in monocrop situations. Attempts to study the radio-phosphorus absorption by component crops in intercropping systems are comparatively rare.

Materials and Methods

MATERIALS AND METHODS

The production potential of cassava based intercropping systems in relation to planting geometry was evaluated in a series of field experiments conducted at the College of Horticulture, Vellanikkara and the Banana Research Station, Kannara for two consecutive cropping seasons of 1983-84 and 1984-85. Three field trials and two microplot trials were conducted to achieve the objectives.

Trial I. Influence of planting geometry on cassava + colocasia/ elephant foot yam / banana intercropping systems.

Trial II. Effect of planting geometry on cassava + banana cropping system with different floor crops.

Trial III. Evaluation of sequential intercropping in paired row cassava with legumes and the response of intercrops to fertilizers.

Micro plot trial I. Competition for applied P-32 in a cassava + banana + elephant foot yam intercropping system.

Micro plot trial II. Competition for applied P-32 in a cassava + groundnut intercropping system.

3.1 Experimental site

The first trial was conducted at the Instructional Farm, Vellanikkara. The second and third trials and the micro plot studies with P-32 were conducted at the Banana Research Station, Kannara. Both locations are in Trichur district and enjoy a typical tropical climate. The weather data for the cropping periods are given in Appendix II.

The soil at these locations is laterite of sandy clay loam texture. The physical and chemical characteristics of the soils are given in Appendix I.

3.2 Season

The crops were grown under rainfed conditions. The cassava was grown from May to February. The intercrops were planted at the same time along with cassava, except in the case of banana in the second year, where the ratoon of the first year banana was used.

3.3 Cropping history

The experimental area was lying fallow during the previous year. Before that, the land used for trial I was under sweet potato and that used for trials II and III was under bulk banana.

3.4 Treatment details

3.4.1 Trial I

The treatments included two planting geometries of cassava and four intercropping practices, in factorial combination and a control plot of normal planted cassava (Fig. 1&2).

3.4.1a Planting geometry of cassava

i. Paired row planting: Cassava was planted at 50 x 90 cm spacing with the paired rows spaced at 130 cm.

ii. Square cluster planting of cassava: Cassava was planted at four corners of squares of sides 50 cm each with a

TRIAL-III

GN GN M_2	CP GN M_0	GN GN M_1	CP GN M_1	CP GN M_2	CP CP M_1	P	GN CP M_2	GN GN M_0	GN CP M_1	CP CP M_1	CP CP M_2	GN CP M_0	N	N CP	N GN	GN + RG	R-I
GN GN M_1	GN GN M_2	CP CP M_1	P	GN CP M_0	CP CP M_2	GN CP M_2	N CP	CP GN M_1	CP CP M_0	N	GN GN M_0	N GN	GN CP M_1	CP GN M_2	CP GN M_0	GN + RG	R-II
N	CP CP M_0	GN CP M_1	CP GN M_0	GN CP M_0	P	GN CP M_2	GN GN M_1	N CP	CP GN M_2	CP GN M_1	N GN	GN GN M_1	GN GN M_2	CP CP M_2	CP CP M_1	GN + RG	R-III

TRIAL-II

SC GN	TC GN	TC	P CP	SC	TC CP	TC EFY	P EFY	P GN	P	SC EFY	SC CP	R-I
TC EFY	TC CP	P GN	P CP	SC	TC GN	SC CP	P EFY	SC EFY	P	SC GN	TC	R-II
SC	TC CP	SC EFY	SC GN	TC EFY	P	P EFY	P CP	TC GN	TC	P GN	SC CP	R-III

TRIAL-I

P EFY	P Col.	SC Col.	N	SC EFY	P	SC B	P B	SC	R-I
SC Col.	P EFY	P B	SC	P Col.	SC B	N	P	SC EFY	R-II
SC	N	P EFY	P Col.	SC B	SC Col.	P B	P	SC EFY	R-III

FIG. 1. LAY-OUT PLAN
RANDOMISED BLOCK DESIGN

1. PLANTING GEOMETRY OF CASSAVA.

P- PAIRED ROW PLANTING
SC- SQUARE CLUSTER PLANTING
TC- TRIANGULAR CLUSTER PLANTING
N- NORMAL METHOD OF PLANTING

2. INTERCROPS

Col.- COLOCASIA
B.- BANANA
EFY- ELEPHANT FOOT YAM
GN- GROUNDNUT
CP- COWPEA
RG- RED GRAM

3. FERTILIZER LEVELS FOR THE INTERCROPS

M_0 - 0 % OF THE SOLE CROP RECOMMENDATION
M_1 - 50% — — —
M_2 - 100% — — —

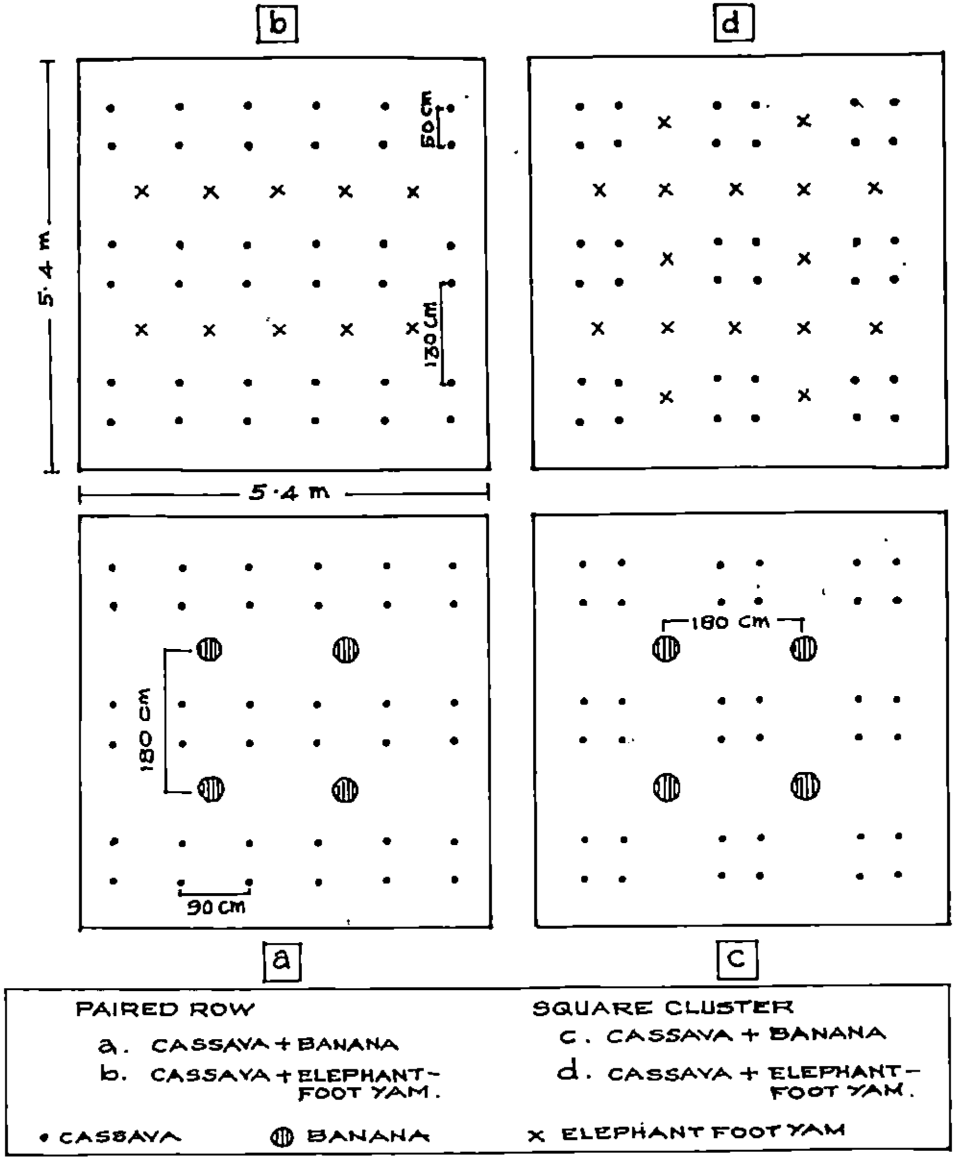


FIG. 2. PLANTING PATTERN IN INTER CROPPING SYSTEMS. (TRIAL I).

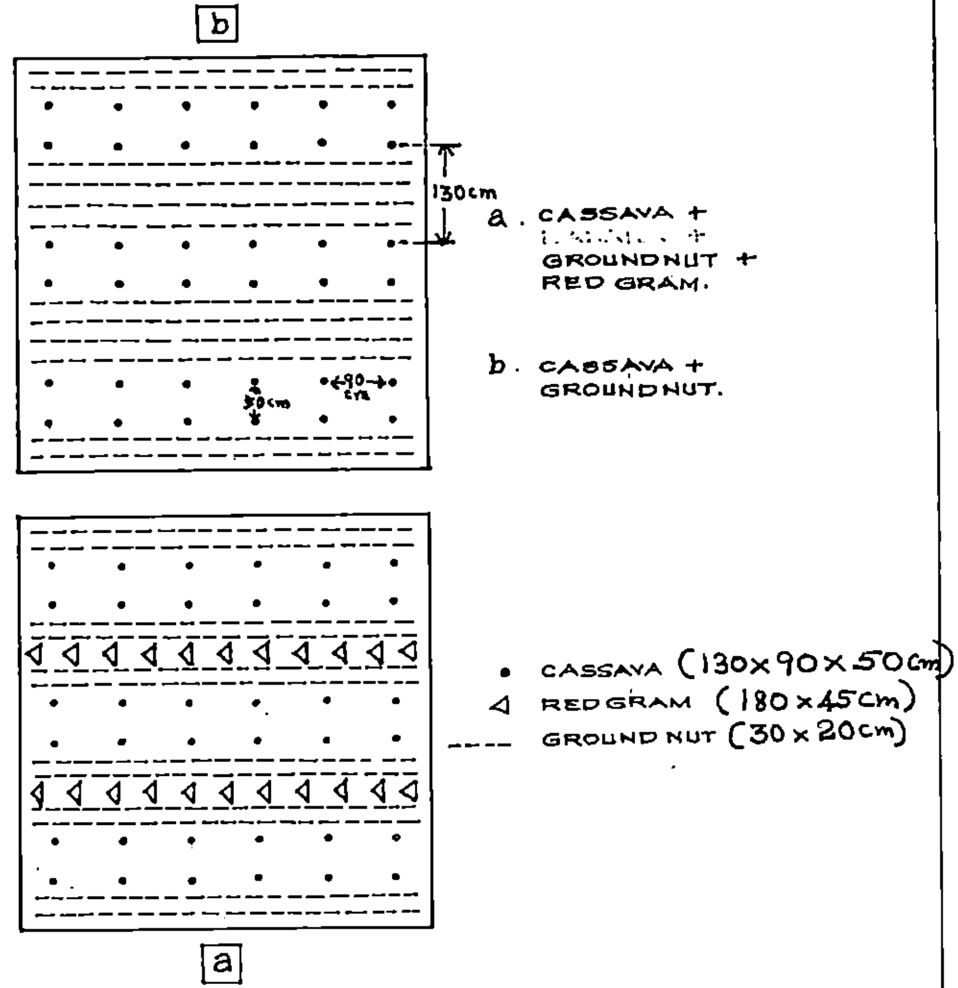


FIG. 3. PLANTING PATTERN IN INTER CROPPING SYSTEMS. (TRIAL III)

POPULATION OF CASSAVA AND INTERCROPS IN DIFFERENT TREATMENTS

	Trial I	Trial II	Trial III
Cassava			
Paired row	12300	10580	12300
Square cluster	12300	9070	--
Triangular cluster	--	6800	--
Banana	1370	1008	--
Elephant foot yam			
Paired row	4800	4280	--
Square cluster	7890	5790	--
Triangular cluster	--	5790	--
Colocasia			
Paired row	18500	--	--
Square cluster	33900	--	--
Cowpea			
Paired row	--	1.03 lakhs	1.11 lakhs
Square cluster	--	1.68 "	--
Triangular cluster	--	1.68 "	--
Groundnut			
Paired row	--	1.72 "	1.11 lakhs
Square cluster	--	2.8 "	--
Triangular cluster	--	2.8 "	--
Red gram	--	--	12300
Sole crop			
Cassava	12300	12300	12300
Banana	2250	2250	--
Elephant foot yam	12300	12300	--
Colocasia	55500	--	--
Cowpea	--	2.67 lakhs	1.67 lakhs
Groundnut	--	4.44 "	1.67 "
Red gram	--	--	49400

square to square distance of 130 cm.

3.4.1b Intercrops

i. Elephant foot yam

Single row of elephant foot yam was planted with a spacing of 90 cm between plants in the interpair or intercluter spaces of cassava.

ii. Banana

Single row banana was planted with 180 cm between plants in the interpair or intercluster spaces of cassava.

iii. Colocasia

Single row of colocasia was planted at a spacing of 30 cm between plants in the interpair/ intercluster spaces of cassava.

3.4.1c Control

Cassava was planted at the normal recommended spacing of 90 x 90 cm.

Single plots of pure crop banana, elephant foot yam and colocasia at normal spacing were also raised for comparison with the respective intercrop.

3.4.1d Lay out

Treatment combinations- 9

Design - Randomised Block Design

Replications - 3

Plot size - 5.4 x 5.4 m gross and 3.6 x 3.6 m net.

3.4.2 Trial II

The treatments compared in this trial were factorial combinations of three planting geometries of cassava in cassava + banana intercropping and four types of floor cropping (Fig.1&4).

3.4.2a Planting geometry of cassava

i. Cassava was planted in paired row system with a spacing of 50 x 90 cm between plants within the pair, the pairs being spaced at 160 cm.

ii. Square clustering of cassava with a plant to plant distance of 50 cm within the cluster and 160 cm between the clusters

iii. Triangular clustering of cassava with plant to plant distance of 50 x 56 x 56 cm and a cluster to cluster distance of 160 cm.

In all the above three cases banana was planted in the interpair/intercluster spaces at a distance of 210 cm.

Banana was planted uniformly over the entire experimental area in a square cluster arrangement obtained by skipping alternate rows of banana in either direction. The ultimate spacing of banana was 210 x 210 cm in the four-plant-cluster and 420 cm between clusters. Then the experimental plots were demarcated (6.3 X 6.3 m) and cassava planted as per the methods mentioned above.

3.4.2b Intercrops

i. Elephant foot yam - planted at a distance of 90 cm

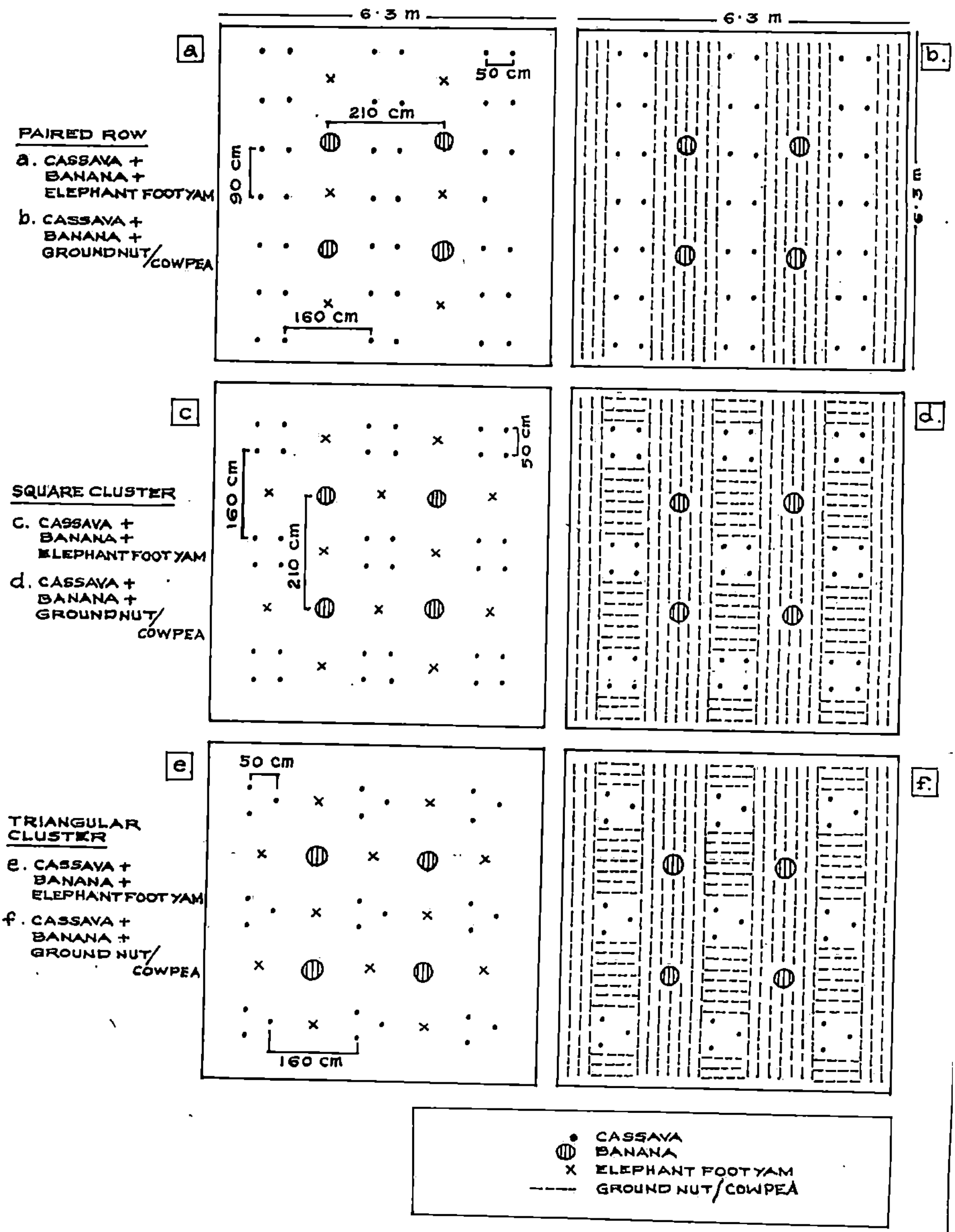


FIG. 4. PLANTING PATTERN IN INTER CROPPING SYSTEM. (TRIAL II).

between plants in the interpair/intercluster spaces.

ii. Cowpea - planted at a distance of 25 x 15 cm in the interpair/intercluster spaces.

iii. Groundnut - planted at a distance of 15 x 15 cm in the interpair/intercluster spaces.

iv. No floor crop

Unreplicated plots of sole cassava in the three geometries of planting were also grown as a check, these plots were not included in the lay out of the experiment. Similar to this, sole banana plots, both under normal and square cluster methods and sole crops of elephant foot yam, cowpea and groundnut were also raised.

3.4.2c Lay out

Number of treatments - 12

Design - Randomised Block Design

Number of replications - 3 (1 replication was used for root studies and destructive sampling).

Plot size - 6.3 x 6.3 m gross and 4.5 x 4.5 m net

A border row of banana was put around the experimental area.

3.4.3 <u>Trial III</u>

The treatments consisted of factorial combinations of intercropping systems and fertilizer levels (Fig. 1&3).

3.4.3a Intercropping systems

i. Cassava + cowpea (kharif) - cowpea (rabi)

ii. Cassava + cowpea (kharif) - groundnut (rabi)

iii. Cassava + groundnut (kharif) - groundnut (rabi)

iv. Cassava + groundnut (kharif) - cowpea (rabi)

3.4.3b. Fertilizer levels (kg/ha)

		Cowpea			Groundnut		
		N	P205	K20	N	P205	K20
i.	M0	0	0	0	0	0	0
ii.	M1	3.5	10	10	3.5	25	25
	(50 per cent of the sole crop recommendation)						
iii.	M2	7	20	20	7	50	50
	(100 per cent of the sole crop recommendation)						

Cassava was given an uniform dose of fertilizer at the rate of 50:50:50 kg/ha nitrogen, phosphate and potash respectively.

3.4.3c Control

i. Cassava in normal planting (90 x 90 cm) + groundnut.

ii. Cassava in normal planting + cowpea

iii. Paired row planting of sole cassava at a spacing of 50 x 90 cm within the pair and 130 cm between pairs.

iv. Sole crop of cassava in normal planting.

Additional treatment included during 1984-85:

v. Cassava in paired row planting + groundnut (kharif) + red gram (kharif)

3.4.3d Lay out

Total number of treatments - 16 (During 1984-85 there were 17 treatments)

Design - Randomised Block Design

Replications - 3

Plot size - 5.4 x 5.4 m gross and 3.6 x 3.6 m net.

3.5 Details of varieties

The description of the different crop varieties used in this investigation are given below.

Crop	Name of variety	Description
Cassava	M4	Non-branching, tall, 9-10 months duration
Groundnut	TMV2	Bunch type, 105-120 days duration
Cowpea	C.152	Bunch type, 80-100 days duration
Elephant foot-yam	Local	7-8 months duration
Colocasia	Local	6 months duration
Banana	Palayankodan	12-16 months duration
Red gram	Prabhat	8 months duration

3.6 Planting materials

The stems of cassava, corm of elephant foot yam and colocasia were obtained locally. The groundnut and cowpea seeds were supplied by the Agricultural Research Station, Mannuthy. The banana suckers were obtained from the Banana Research Station, Kannara. Care was taken to collect banana suckers of uniform age and quality to the extent possible.

3.7 Manures and fertilizers

The farm yard manure used for the trial was found to contain 0.44 per cent nitrogen, 0.23 per cent phosphate and 0.25 per cent potash. Fertilizers with the following grades were used for the experiment.

Urea - 46 per cent nitrogen

Super Phosphate - 16 per cent phosphate

Muriate of Potash - 60 per cent potash

Quicklime (CaO) - Neutralising value 162

In trials I and II, each component crop was manured separately around individual plants, as recommended in the Package of Practices Recommendations (KAU, 1982). In the third trial, cassava was manured uniformly on ridges with the recommended doses (Farm yard manure @ 12 t/ha; nitrogen, phosphate and potash @ 50 : 50: 50 kg/ha respectively).

3.7.1 Methods of manuring

3.7.1a. Cassava

Dried and powdered farm yard manure was mixed with the soil at the time of first digging. Half of the nitrogen and potash and full dose of phosphate were incorporated to the ridges or mounds before planting the cassava setts. The remaining quantities of nitrogen and potash were also incorporated to the ridges or mounds 60 days after planting in trial I and after the harvest of groundnut or cowpea in trials II and III. In trial II where elephant foot yam was grown, the second fertilizer dose was given at 60 days stage.

3.7.1b Banana

Farm yard manure was incorporated to each pit at the rate of 10 kg at the time of planting. A fertilizer dose of 100: 200: 200 g/plant of nitrogen, phosphate and potash respectively was given to banana. Half of the nitrogen, full phosphate and half of the potash were applied within an area of 30 cm radius and to a depth of 20 cm, at 60 days stage. The balance of nitrogen and potash were applied 120 days after planting.

3.7.1c Elephant foot yam

Farm yard manure was applied to each pit at the rate of 2kg after mixing with top soil, before planting the corms. First dose of fertilizer - 40 : 60 : 50 kg/ha of nitrogen, phosphate and potash respectively - was incorporated to the soil around the plant at 20 cm distance and 20 cm depth. The second dose of fertilizer - 40 : 50 kg/ha of nitrogen and potash respectively- was applied one month after the first dose.

3.7.1d Colocasia

Powdered farm yard manure was incorporated into the soil before forming the ridges. The first dose of fertilizer - 40 : 50 : 50 kg/ha of nitrogen, phosphate and potash respectively -

was applied on either side of the plant and incorporated to the soil. This was done within a week of sprouting of the corm. Colocasia was top dressed after one month with 40 kg nitrogen and 50 kg potash per hectare.

3.7.1e Groundnut

Groundnut in trial II was given the full dose of fertilizer recommended for the intercropped groundnut (10 : 20 : 20 kg/ha of nitrogen, phosphate and potash respectively). In trial III fertilizers were applied as per the treatments. Groundnut was manured twice - half N + full P + full K as basal dose and the remaining quantity 30 days after planting.

3.7.1f Cowpea

In trial II, cowpea was given a manurial dose of 10 : 20 : 20 kg/ha nitrogen, phosphate and potash respectively. In trial III, fertilizer application was done as per the treatments.

3.8 Application of lime

Lime at the rate of 1000 kg per hectare was applied uniformly to all plots before the final digging. In addition to this, lime at the rate of 500 kg per hectare was applied to groundnut at the time of flowering and the soil was raked.

3.9 After cultivation

Unsprouted cassava setts were replaced 15 days after planting. Groundnut and cowpea were gap filled or thinned one week after sowing. Gap filling was not necessitated in the intercrop of elephant foot yam and colocasia. Unhealthy banana suckers were also replaced with healthier ones to get a uniform stand.

Excess sprouts on cassava were removed, retaining only two vigorous shoots. The plots were weeded and earthed up 30 and 60 days after planting. In cowpea and groundnut intercropped plots earthing up was done after the harvest of intercrops.

3.10 Plant protection

Ekalux (0.1%) was sprayed to groundnut and cowpea 15 days after planting. Banana was sprayed with Bordeaux mixture (1%) in September and April. Elephant foot yam was drenched with 0.3% Delchlor. Rodent control measures, both chemical and mechanical were followed periodically.

3.11 Harvest

The cassava and the intercrops were harvested according to maturity stages. In cowpea, three pickings (80, 90 and 100 days after planting) were required. The haulm of groundnut and cowpea were incorporated in the soil. Banana was harvested on maturity of the bunches; the first crop of banana took about 16 months to mature and harvesting continued upto 18 months. The ratoon crop took 14-16 months. Colocasia was harvested 6 months and elephant foot yam 8 months after planting. Cassava was harvested 9 months after planting.

3.12 Observations

Three plants each of cassava and the intercrops were selected at random and tagged for recording monthly/ bimonthly observations of growth characters and yield attributes.

3.12.1 Cassava

3.12.1a Height

The height of cassava was measured from the base of the sprouts to the tip of the terminal buds at monthly intervals in the trials II & III and at bimonthly intervals in trial I.

3.12.1b Leaf area

The leaf area was estimated from linear measurements of the leaf lobes, following the method of Ramanujam and Indira (1978).

3.12.1c Root distribution

The root distribution of cassava was studied by carefully excavating the plants, using a fork with minimumm possible damage to the roots. An ordinary knapsack hand compression sprayer was used for washing off the forked soil and tracing the roots.

During the second year of the study the root interactions between the component crops in some promising intercropping systems were studied by using 32P. The details are given in the section 3.18.

3.12.1d Number of tubers per plant

The total number of tubers from the three observation plants were recorded at the time of harvest and the mean values were used for statistical analyses.

3.12.1e Tuber yield

At the time of harvest, the plants in net plots were pulled out, the tubers separated, cleaned and weighed. The yield per hectare was computed from this data.

3.12.1f Shoot weight

The total fresh weight of the shoot of the plants from net plots was taken at the time of harvest. From this the mean weight per plant was worked out.

3.12.1g Dry matter production

The dry matter production of cassava was worked out from the dry weight of tuber and shoot recorded from the observation plants.

3.12.1h Harvest index

This is the ratio of the dry weight of tuber to the weight of the whole plant on dry basis.

3.12.2 Intercrops

3.12.2a Height

The height of the intercrops was measured from the base to the growing tip of the plants in their vertical position.

3.12.2b Leaf area index

In the case of groundnut, cowpea and red gram the gravimetric method (Ruck and Bolas, 1956) was used for estimating leaf area. In the case of elephant foot yam, a regression equation was developed by measuring the actual leaf area by gravimetric method and working out its regression with the canopy size of the plants. The equation is given below.

$$LA = -7594.94 + 259.36x \quad (R^2 = 0.973)$$

Where LA = Leaf area per plant in cm2

x = Average size of the main branch.

The average size of the main branch was obtained by measuring the length of the three branches from the point of forking of the pseudostem and calculating the mean value.

The leaf area of colocasia was found out by the regression method of Venkateswarlu and Biradar (1980).

3.12.2c Root distribution

The vertical and lateral spread of the roots of the intercrops were studied by excavation of the plants as described earlier.

3.12.2d Yield

Colocasia and elephant foot yam were harvested when the pseudostem of the plants had dried completely (6 and 8 months after planting respectively). The tubers were cleaned and the fresh weight recorded.

The banana bunches were harvested as and when they matured. The harvested cowpea pods were dried and threshed under feet. The grains were further dried in the sun and weights recorded. Moisture correction was made before summing up the yields obtained in different harvests. The per hectare yield was computed from this value.

Groundnut was harvested at full maturity. The pods were separated from the shoot and dried in the sun for recording their weights. The per hectare yield was then worked out.

3.12.2e Haulm weight

The fresh haulm weight of groundnut, cowpea, redgram and banana were recorded immediately after harvest. For finding out the haulm weight of banana, elephant foot yam and colocasia, the fresh weight of leaf and pseudostem were recorded separately when the plants showed the symptoms of maturity. Sub samples were drawn from these and oven dried at 70oC for getting their dry weights from which total dry mass was worked out for each crop using the dry matter percentage and the fresh weights recorded.

3.12.2f Dry matter production

The dry matter production in each intercrop was obtained by summing up the dry weight of all the plant parts.

3.13 Harvest index

The harvest index was worked out from the dry weight of the whole plants and the economic produce.

3.14 Total biomass

The productive efficiency of each cropping system was studied by comparing the total biomass production which was obtained by totalling the dry matter production of the component species in each cropping system.

3.15 Land equivalent ratio

The land equivalent ratio was worked out by following the method suggested by Willey (1979).

3.16 Light infiltration

The light measurements in each plot were made at ten randomly selected points at 8 AM, 12 Noon and 4 PM, by using an Aplab luxmeter. This observation was made at 30 days interval. The lux readings in the experimental plots were expressed as a percentage of the lux readings in the open condition.

3.17 Nutrient uptake

Total uptake of N, P, K, Ca, Mg and S by cassava and the associated crops was estimated in all the three field trials. The content of these elements in each plant part, viz.,leaf, petiole, stem, tuber, pod and bunches was estimated and the total nutrient uptake was worked out.

Nitrogen in plant samples was estimated colorimetrically in sulphuric acid- hydrogen peroxide digest (Wolf, 1982).

1:1 nitric-perchloric acid mixture was used for digestion of plant samples for the estimation of all other elements (Johnson and Ulrich, 1959).

Phosphorus in plant digests was estimated by the vanado-molybdo-phosphoric yellow colour method, K by flame photometry, Ca & Mg by atomic absorption spectro-photometry and S by turbidimetry (Jackson, 1967).

3.18 Nutrient balance in intercropping systems

A balance sheet for the major nutrients in the intercropping systems were proposed based on the pre and post crop soil test value, manures and fertiliser application, nutrients recycled through the haulm of intercrops and cassava leaf fall and N fixation.

The pre-experiment soil samples, collected block-wise from each experimental site and the post-experiment soil samples collected plot-wise were analysed for organic C, total N, available P, exchangeable K, Ca and Mg after each crop of cassava. The available micronutrients of the soils were estimated before and after the experiments.

The organic carbon was estimated by Walkley- Black method, total nitrogen by modified micro-kjeldahl method, available phosphorus extracted by Bray-I and estimated colorimetrically by the chloro-stannous reduced blue colour method and available K extracted by neutral normal ammonium acetate and estimated by flame photometry (Jackson, 1967).

Calcium and magnesium were extracted in neutral N ammonium acetate (Jackson, 1967) and the micronutrients in a dilute HCl-H_2SO_4 extract (Perkins, 1970). The estimation of Ca, Mg, Fe, Mn, Zn and Cu was done by the atomic absorption spectrophotometer. The sulphate content of the soils were estimated by the turbidimetric method (Jackson, 1967).

3.19 Microplot Trials

3.19.1 Trial I. Competition for applied P-32 in a cassava + banana + elephant foot yam intercropping system

After reviewing the results of the first year trial, the rhizosphere interactions of selected cropping systems were studied during the second year by deducing the root activity of the component crops by using P-32.

The cassava + banana + elephant foot yam polyculture with cassava in square cluster was selected for one of the root interaction studies. For this purpose, one replication of the trial II was modified during the second year. The plant crop of banana was in peak vegetative phase in these plots when the trial was laid out.

The following crop combinations (Fig. 24) were included in this trial.

a. Cassava + banana + elephant foot yam

b. Cassava + banana

c. Cassava + elephant foot yam

d. Banana

e. Elephant foot yam

f. Cassava

Sufficient number of microplots were marked out for application of P-32. In each type of polyculture systems and the sole crops mentioned above, the following treatments were adopted for P-32 application.

i. To cassava in cassava + banana + elephant foot yam

ii. To banana in cassava + banana + elephant foot yam

iii. To elephant foot yam in cassava+banana+elephant foot yam

iv. To cassava in cassava + banana

v. To banana in cassava + banana

vi. To cassava in cassava + elephant foot yam

vii. To elephant foot yam in cassava + elephant foot yam

viii. To banana in banana + elephant foot yam

ix. To elephant foot yam in banana + elephant foot yam

x. To cassava sole crop

xi. To banana sole crop

xii. To elephant foot yam sole crop

The trial was laid out in completely randomised design with three replications.

3.19.2 Trial II. Competition for applied P-32 in cassava + groundnut intercropping system

For studying the rhizosphere interaction in cassava + groundnut intercropping system, a microplot experiment was conducted during 1984-85. Phosphorus-32 absorption by cassava and groundnut in the intercropping systems were studied.

The cassava was planted in three methods.

a. Paired row-ridge

b. Mound

c. Flat bed

The study compared the following treatments of applying P-32.

i. To cassava in mound planted cassava + groundnut

ii. To groundnut in mound planted cassava + groundnut

iii. To cassava in paired row planted cassava + groundnut

iv. To groundnut in paired row planted cassava + groundnut

v. To cassava in flat bed planted cassava + groundnut

vi. To groundnut in flat bed planted cassava + groundnut

vii. To mound planted sole cassava

viii. In the bare interspace of mound planted cassava

ix. To sole cassava in paired row

x. To the bare interspace of sole cassava in paired row

xi. To sole groundnut.

The trial was laid out in completely randomised design with three replications.

3.19.3 Application of P-32

The radioactive solution was applied along the fertilizing zone in the rhizosphere. For different crops, the following specifications were fixed for application, based on the root data collected.

a. Banana - 30 cm radius and 20 cm depth

b. Cassava- 20 cm radius and 20 cm depth

c. Elephant foot yam - 20 cm radius and 20 cm depth

d. Groundnut - 5 cm radius and 5 cm depth

The Phosphorus-32 solution was injected to the desired soil depth through PVC access tubes of 3/4" diameter. The soil injection of P-32 solution was done using a device designed for the purpose at the Radiotracer Laboratory, Kerala Agricultural University, Trichur (Sankar, 1985).

The reservoir bottle of the dispenser was washed with distilled water before use. Then the stock P-32 solution in the vial was transferred into the reservoir bottle through a funnel. The vial was washed five to six times with 1000 ppm carrier P solution (KH PO) and the washings were added to the bottle. Finally the required volume of the carrier solution was added to the bottle to give 23 uCi of P-32 per ml. A "Lumac Dispensette" was then fitted to the reservoir bottle. The calibrated dispenser was set to deliver 3 ml with every stroke of the plunger. Equally spaced 6 holes to the required depth were made along the circumference of the fertilizer application area (radius as indicated earlier) around the plant. The holes were dug a day in advance of the application using a soil auger of 2 cm diameter. The PVC access tubes were inserted in the hole and the opening at the top of the tube were closed with polythene covers and secured with rubber bands to prevent filling up of the holes during rains.

The delivery tube of the dispenser was introduced into the access tube during application of P-32 solution. The access tube was raised to give a clearance of 1 cm at the bottom of the hole and 3 ml of the radioactive solution was dispensed into each hole. The radioactivity remaining on the sides of the access tube was washed down with a jet of about 5 ml distilled water using a wash bottle. The total activity applied per plant was 0.414 mCi. Soon after the application, the PVC tubes were taken out and the holes were filled with the soil removed from them.

3.19.4 Plant sampling for radioassay

Leaves from the plants in the intercropping system were sampled at 15, 30 and 45 days after application of P-32. The treated and the surrounding plants were sampled separately.

In cassava the fifth leaf from the terminal bud, which was found to give stable values of P-32 count, was taken for radioassay. The third leaf from the top was considered as the reflect for nutrient analysis in banana (Hewitt, 1955) and this leaf was taken for radioassay. Since there was only one pseudo-stem in elephant foot yam, leaflets were collected from throughout the pseudostem at random. In groundnut, the leaves were collected from all the shoots of the plant from tip to bottom at random and the leaves were pooled and sub sampled.

3.19.5 Determination of total P-32 uptake

The treated plants were cut at ground level 45 days after application of P-32. Cassava was sampled as leaves, petiole and stem. Banana and elephant foot yam were sampled as leaf and pseudostem. In the case of flowered plants in banana, the bunch samples were also taken. The total fresh weight of each plant was recorded and dry weight worked out from the dry matter percentage of each plant part.

3.19.6 Radioassay of plant samples

The oven dried plant samples were cut into small pieces and one gram samples were weighed out and digested with 15ml 1:1 HNO_3 : $HClO_4$ diacid mixture, until the digest is clear and reduced to 2 to 3 ml. Then the digest was transferred to scintillation vials. The flask was washed two to three times with about 5ml of distilled water and the washings transferred to the vial and made up the volume to 20 ml with reference to the 20 ml mark of water kept in another scintillation vial. It was kept for four hours and the radioactivity was determined by Cerenkov technique in a liquid scintillation system (Wahid et al., 1985).

3.20 Statistical analysis

The data recorded during each year was analysed separately. Pooled analyses were not done since the error of the two years were heterogenous in most of the characters analysed and only two years data were available (Gomez and Gomez, 1984).

The analysis of variance for P-32 counts were obtained after log transformation.

Results and Discussion

RESULTS AND DISCUSSION

The results of the trials conducted to evaluate the production potential of a few cassava-based cropping systems are presented in this chapter. The results of the three field experiments and the two microplot trials are presented in this section. The main effects of the treatments alone are presented in cases where significant and consistent interactions were not obtained.

4A. Trial I: Influence of Planting Geometry on Cassava + Colocasia/ Elephant foot yam/ Banana Intercropping Systems

4A.1 Cassava

4A.1.1 Growth characters

4A.1.1.1 Height

Intercropping with colocasia, elephant foot yam and banana increased the height of cassava significantly (Table 1). This trend was observed at all stages of growth during both the years. Intercropping with elephant foot yam recorded maximum height at all stages except at 270 days.

The geometry of planting had no influence on the height of cassava plants upto 120 days. At 180 days stage, cassava in square cluster planting was taller than that in paired row and normal method of planting. The normal mound planting resulted in comparatively shorter plants eventhough at some stages the differences were not statistically significant.

Table 1. Effect of geometries of planting and the intercrops on the height of cassava at different stages of growth

Cropping systems	(1983-84) Days after planting (DAP)				(1984-85) Days after planting (DAP)			
	60	120	180	270	60	120	180	270
	(Height in cm)							
C + Col.	72	121	156	245	76	126	165	231
C + EFY	96	136	176	249	76	131	177	236
C + B	91	133	171	278	71	170	205	259
C	62	114	141	216	69	126	167	207
C.D.(0.05)	12	13	15	19	NS	17	17	22
SEM +/-	4	4	5	6	4	6	6	8
Geometry of planting								
P	82	128	155	239	70	133	172	231
SC	78	124	167	255	76	143	185	235
C.D.(0.05)	NS	NS	11	13	NS	NS	12	NS
SEM +/-	3	3	4	4	2	4	4	5
Control								
C(N)	69	111	127	248	69	135	160	209
C.D.(0.05)	NS	19	22	NS	NS	NS	24	32
SEM +/-	6	6	7	9	4	8	8	11

C-cassava Col.-colocasia EFY-elephant foot yam B-banana P-paired row SC-square cluster (N)-normal method of planting

The increase in height obtained in intercropped cassava could be due to the competition offered by the intercrops. Colocasia and elephant foot yam, by their inherent morphological nature, cannot grow beyond certain heights and the canopies were well below cassava for most of the growth period (Plates I&II). But at the initial stages, the colocasia and elephant foot yam canopies were slightly taller than cassava and this would have induced the growth of cassava in intercropped plots and resulted in taller plants. Of the two intercrops, elephant foot yam induced maximum height of cassava probably because elephant foot yam at the initial stages was much taller and its canopy was much wider. In the second year trial, cassava in the cassava + banana cropping system (Plate III) was subjected to intense shade of banana for a prolonged period starting from its sprouting and this resulted in very tall cassava plants.

The increase in height of cassava plant observed in square cluster planting may be due to the intraspecific competition as the plant to plant distance in each cluster was only 50 cm compared to 90 cm in the normal method. The difference in height was not significant up to 120 days since the crop growth was slow during the initial stages and a spacing of 50 x 50 cm was sufficient to avoid intraspecific competition. By 120 days the cassava plants had grown much with the result that the canopies of the plants in the cluster overlapped leading to severe intraspecific competition. In the normal method of planting, as the cassava plants were widely spaced, the competition within the species was less and therefore the plants were shorter. Increase in height of cassava consequent to shading was reported by Ramanujam et al. (1984). Increase in cassava height when intercropped with legumes was reported by Bhat (1978); Sheela (1981) and Anilkumar (1984).

4A.1.1.2 Leaf area

The intercropping in general increased the leaf area of cassava especially during the second year (Table 2). However,the geometry of planting and control vs. rest comparisons were not significant.

The increased leaf area of intercropped cassava may be due to the stimulatory effect of the intercrops by way of their rhizosphere interactions. Another reason for the observed increase in leaf area may be the shade caused by the intercrops on cassava especially by banana in the second year. Increase in leaf area of cassava consequent to shading was reported by Ramanujam et al. (1984). In shade grown cocoa, Hardy (1958) observed thin and broader leaves leading to higher leaf area of the plant.

From the two years results, it was observed that geometry of planting of cassava did not produce any definite response.

4A.1.2 <u>Yield attributes</u>

4A.1.2.1 Tuber length

There was no significant difference in the length of tuber (Table 3) due to the effect of intercrops and planting geometry

Table 2. Effect of geometries of planting and the intercrops on the leaf area of cassava at different stages of growth

Cropping systems	(1983-84) Days after planting 60	120	180	270	(1984-85) Days after planting 60	120	180	270
	(Leaf area in m^2/plant)							
C + Col.	0.693	1.030	1.340	0.158	0.672	1.653	1.843	0.191
C + EFY	0.688	1.270	1.548	0.178	0.728	1.803	1.993	0.176
C + B	0.756	1.264	1.428	0.234	0.843	1.700	2.129	0.264
C	0.715	1.096	1.438	0.177	0.533	1.607	1.757	0.172
C.D.(0.05)	NS	0.167	0.147	0.035	0.209	NS	0.218	NS
SEM +/-	0.047	0.055	0.049	0.012	0.070	0.082	0.073	0.026
Geometry of planting								
P	0.705	1.142	1.488	0.173	0.674	1.634	1.930	0.197
SC	0.721	1.051	1.439	0.200	0.714	1.747	1.958	0.204
C.D.(0.05)	NS	NS	NS	0.025	NS	NS	NS	NS
SEM +/-	0.033	0.040	0.035	0.008	0.049	0.058	0.051	0.019
Control C(N)	0.724	1.114	1.462	0.209	0.637	1.887	1.982	0.192
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	0.070	0.077	0.069	0.060	0.099	0.116	0.130	0.037

C-cassava Col.-colocasia EFY-elephant foot yam B-banana P-paired row SC-square cluster (N)-normal method of planting cassava

of cassava. The difference between normal planting of sole cassava and the rest of the treatments was also not significant.

4A.1.2.2 Tuber girth

The girth of tuber (Table 3 and Fig. 5) was significantly influenced by the intercrops elephant foot yam and banana, but not by colocasia. During the second year trial, the girth of tuber was maximum in the plots intercropped with elephant foot yam. Geometry of planting was not found to influence this tuber characteristic.

It is evident from these results that there is a favourable effect of the intercrops on tuber girth. The larger leaf area (Table 2) recorded in intercropped plots might have increased the photosynthate production of the plant. Another probable reason may be the additional plant nutrients derived by cassava by rhizosphere interaction with elephant foot yam. An increase in tuber girth of cassava consequent to intercropping was also reported by Bhat (1978) and Anilkumar (1984).

4A.1.2.3 Tuber number

The number of tubers per plant was significantly influenced by the intercrops (Table 3 and Fig. 5). Among these, elephant foot yam and banana induced more tuber production during the first year. However, in the second year, the tuber production in banana-intercropped plots was the lowest. The number of tubers produced in the colocasia and elephant foot yam intercropped plots were more or less the same. The geometry of planting did

Table 3. Effect of geometries of planting and the intercrops on the length, girth and number of tubers and harvest index of cassava

Cropping systems	(1983-84)				(1984-85)			
	Length (cm)	Girth (cm)	No.of tubers	Harvest index (%)	Length (cm)	Girth (cm)	No.of tubers	Harvest index (%)
C + Col.	33.6	12.7	8.0	53.3	39.7	13.4	10.1	50.7
C + EFY	28.0	13.1	9.5	56.3	42.0	13.8	9.3	49.9
C + B	25.3	13.1	9.1	54.3	32.5	13.3	5.5	41.2
C	25.2	12.0	6.7	61.0	31.2	12.6	8.1	48.5
C.D.(0.05)	NS	1.0	1.0	NS	NS	0.8	0.8	4.7
SEM +/-	4.0	0.3	0.3	2.1	4.2	0.3	0.3	1.6
Geometry of planting								
P	24.0	12.7	8.4	57.2	32.8	13.4	8.2	50.0
SC	32.0	12.8	8.1	55.3	39.8	13.1	8.3	50.0
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	2.9	0.2	0.2	1.5	3.0	0.2	0.2	1.1
Control C(N)	29.7	11.5	9.3	60.7	41.0	13.2	10.0	52.6
C.D.(0.05)	NS	NS	NS	NS	NS	NS	1.1	6.6
SEM +/-	5.7	0.4	0.4	3.0	5.9	0.4	0.4	2.2

C-cassava Col.-colocasia EFY-elephant foot yam B-banana P-paired row SC-square cluster (N)-normal method of planting cassava

not influence the number of tubers produced per plant during both the years.

The effect of intercrops on tuber production in cassava was conspicuous in the first year with elephant foot yam or banana as the intercrop. The increase in tuber number in these intercropped plots could be due to the complementary rhizosphere interaction existing from the initial growth stage itself. The tuber initiation generally starts by about 30 days after planting and the tuber production will be complete within two to three months thereafter (Keating, et al., 1982). In the second year trial, where cassava was planted with banana, the situation was much different as it was planted with fully grown banana. Therefore, the shade cast by banana during the initial two to three months of cassava growth would have adversely affected the tuber production in these plants.

4A.1.2.4 Tuber yield

The yield of tuber (Table 4 and Fig. 5) in intercropped plots was significantly higher. From an overall review of the results, it was seen that cassava + elephant foot yam had given the highest yields during both years. Eventhough the cassava + banana combination had also produced high yields in the first year, the yield from this trial was the lowest in the second year.

Tuber yield was not found to be influenced by geometry of planting in the two trials. However, the interactions were significant in the second year. It was observed that the tuber

Table 4. Effect of geometries of planting and intercrops on the tuber yield of cassava

Cropping systems	(1983-84) P	SC	Mean	(1984-85) P	SC	Mean
	(Tuber yield in t/ha)					
C + Col.	14.43	14.60	14.51	19.68	20.37	19.78
C + EFY	16.73	16.77	16.75	20.80	23.53	22.15
C + B	15.99	16.89	16.45	12.79	12.37	12.58
C	14.11	14.35	14.23	17.44	18.99	18.20
Mean	15.31	15.66		17.55	18.82	
Control C(N)			14.35			18.11

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal planting

	C.D.(0.05)	SEM +/-	C.D. (0.05)	SEM +/-
1.Cropping systems	1.81	0.6	3.28	1.1
2.Geometry of planting	NS	0.43	NS	0.78
3.Combinations	NS	0.85	4.65	1.55
4.Control vs. rest	NS	0.85	4.65	1.55

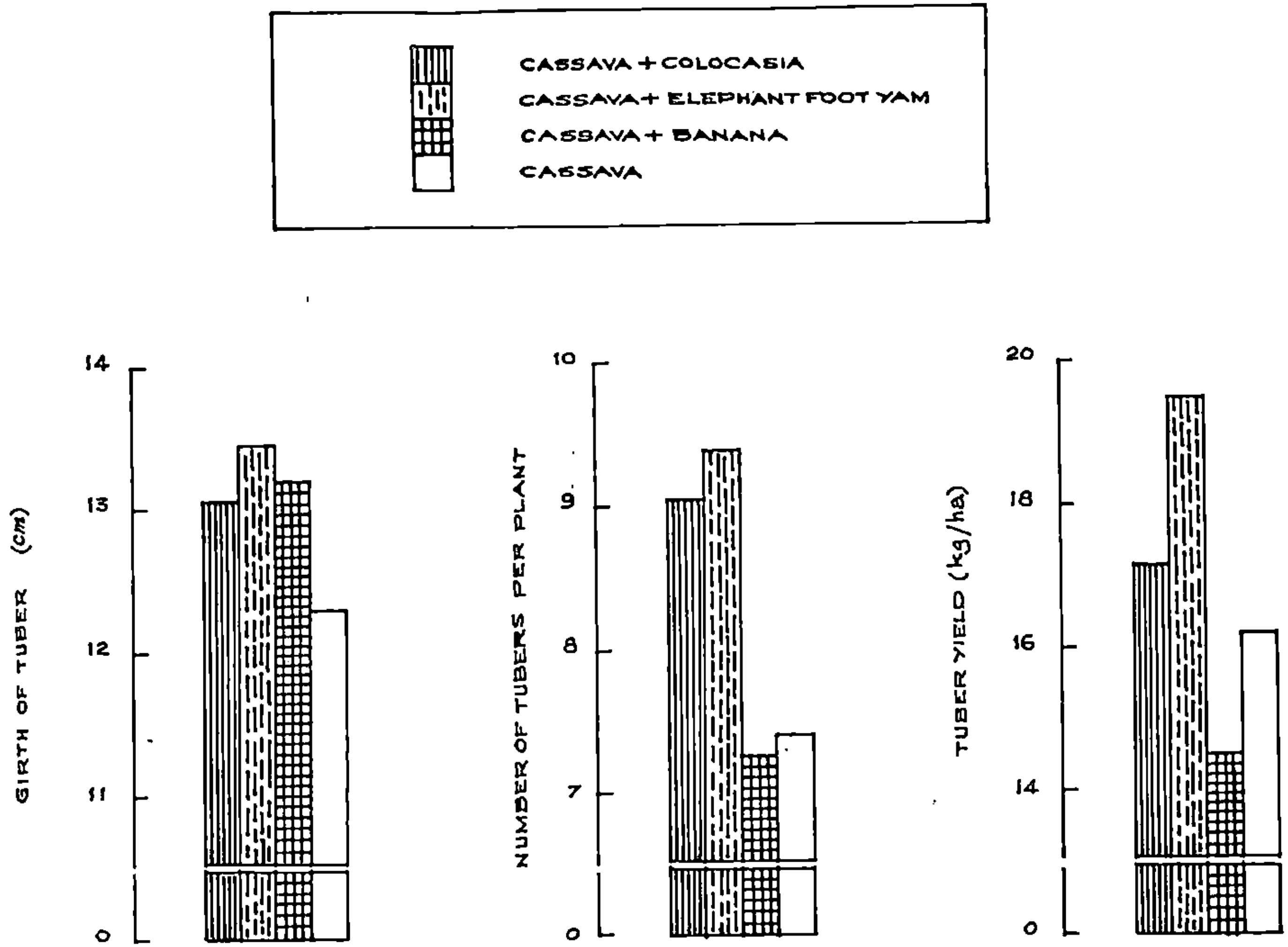


FIG. 5. GIRTH, NUMBER AND YIELD OF CASSAVA TUBER IN CASSAVA + COLOCASIA/BANANA/ ELEPHANT FOOT YAM INTERCROPPING.

yields were increased when cassava was planted in square cluster in association with elephant foot yam. The differences between control and rest of the treatments were significant only during second year, where square clustered cassava intercropped with elephant foot yam recorded higher yield than sole cassava in normal method of planting.

The improvement in the yield of intercropped cassava could be due to the complementary effect of the associated species. It can be seen that, in general, the presence of intercrops stimulated the growth and development of cassava plants notably in height (Table 1), leaf area (Table 2) and shoot weight (Table 5). The enhanced photosynthesis resulting from the increased leaf area may be another reason for the higher yield of cassava in the intercropped plots. It is important to note that in the first year the interspecific competition between cassava and banana in the intercropped plots would have occurred only during the later phase of cassava growth, because, in the initial stages, the growth and leaf area development of banana were too insufficient to affect the growth of cassava. During the later phase also cassava planted under paired rows and in square clusters did not exhibit much canopy overlapping (Plate III). This is expected because cassava canopy is cylindrical and its full development is attained in about six months. Thereafter it remains constant for some time and then decreases (Ashokan et al., 1986). Eventhough the intercrop banana outgrew cassava in height by 120 days, the leaf area development in banana was not as fast (Table 7). Hence cassava plants were not shaded seriously. This is indicated by the data on the relative light transmission in plots cropped with cassava + banana (Fig. 9).

On the contrary in the second year, cassava was planted amidst the standing crop of banana at a time when the banana canopy was tall and dense. Consequently, the cassava was shaded severely in the initial stages of growth which resulted in its poor tuber initiation and tuber production. Ramanujam et al. (1984) observed poor tuberisation and yield in cassava under the shaded situation prevailing in coconut gardens.

After flowering there was a gradual reduction in leaf area of banana with the result the relative light transmission onto the cassava plants improved gradually. Nevertheless some shade was still caused by the suckers of banana retained for the ratoon crop. With the harvest of the plant crop banana, the light received on cassava canopy was considerably improved. However, by this time the main tuberisation period in cassava was over and the damage already caused by shading was irreparable. Nevertheless the already initiated tubers developed well. It may also be noted that the tuber size was not much reduced in banana intercropped plots compared to other treatments (Fig. 5).

The situation in cassava + elephant foot yam intercropping system was entirely different. Elephant foot yam, because of its characteristic growth pattern, does not further increase in height or canopy spread once the sprout comes out and fully opens (Plates II&V). The size of pseudostem is mainly decided by the size of the planting material and not by the environmental factors (Ashokan et al., 1984a). Therefore, there is only limited scope for the environmental factors to cause canopy expansion though they do influence the heliotropic movement of the canopy in relation to the intensity and direction of light received. The cassava plant in such situations is competing with a "stationary canopy"of elephant foot yam for light, but the extent of competition from the intercrop will be negligible throughout the growth period of cassava. Another reason for the higher tuber yield in cassava + elephant foot yam system may be the favourable soil microclimate prevailing in these plots. Brown (1985) reported that the lower soil temperature in sugarcane plots favoured the tuber production in potato intercropped in it.

The best performance recorded in square clustered cassava intercropped with elephant foot yam may in part be attributed to the spatial advantage also. In square cluster planting, sufficient interspace is available for the uninhibited growth of both cassava and elephant foot yam (Plate IV). Besides it is also possible that such a planting system would have facilitated better reception of light by the cassava plants in each cluster from all the four sides.

In the intercropping system involving cassava and colocasia (Plate I), the canopy development pattern was much similar to that in cassava + elephant foot yam system. Initially there was a tendency for the colocasia plants to grow taller due to the shade received from the nearby cassava plants. However, in about three to four months, cassava outgrew colocasia with no more competition from the latter for light.

The rooting patterns of cassava (Fig. 6) and the intercrops (Fig. 7) studied by excavation method showed that, eventhough about 75 per cent of the cassava roots were distributed within a radius of 25 to 30 cm and depth of 30 to 40 cm, some of the cassava roots could invade the rhizosphere of the intercrops. This is expected because the cassava was planted on soil mounds and the intercrops in the intermound spaces. The extension of intercrop roots to the cassava rhizosphere was rarely observed. The colocasia and elephant foot yam roots at its peak vegetative growth stages were distributed to a radius and depth of about 20 to 25 cm only whereas banana roots were distributed upto 30 to 35 cm radius and 25 to 30 cm depth. The invasion of the rhizosphere of intercrops by cassava roots would have been responsible for the higher uptake of N, P, K, Ca, Mg and S by cassava. The cassava + elephant foot yam cropping system which gave the highest yield removed the largest quantities of N, P, K, Ca, Mg and S from soil during both the years (Fig. 11).

4A.1.2.5 Shoot weight

Intercropping resulted in significantly more shoot weight during the first year (Table 5). In the second year, intercropping with elephant foot yam resulted in the highest shoot weight of cassava while intercropping with banana recorded the lowest value. The planting geometry however did not influence the shoot weight.

Significant interaction effects were observed in the first year and it was found that the square cluster planted cassava

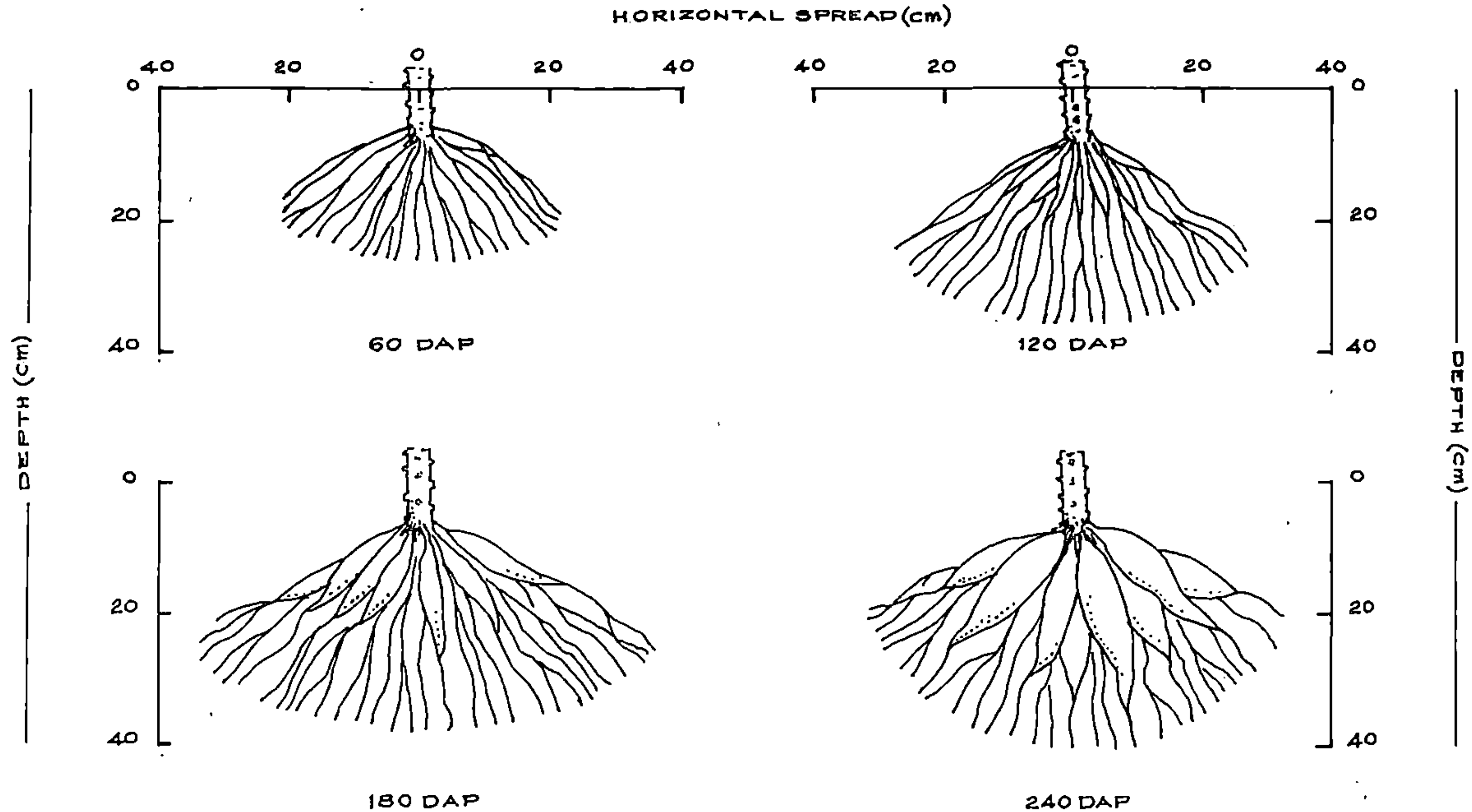


FIG. 6. ROOT DISTRIBUTION PATTERN OF CASSAVA AT 60, 120, 180 AND 240 DAYS AFTER PLANTING (DAP).

Table 5. Effect of geometries of planting and intercrops on the fresh weight of shoot of cassava

Cropping systems	(1983-84) P	SC	Mean	(1984-85) P	SC	Mean
	(Fresh weight of shoot in g/plant)					
C + Col.	933	600	767	1100	967	1033
C + EFY	733	1034	883	1533	1933	1733
C + B	867	867	867	967	967	967
C	600	533	567	1100	967	1033
Mean	753	758		1175	1208	
Control C(N)			567			1233

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal planting

	C.D.(0.05)	SEM +/-	C.D.(0.05)	SEM +/-
1. Cropping systems	148	49	213	71
2. Geometry of planting	NS	34	NS	50
3. Combinations	209	70	NS	101
4. Control vs. rest	209	70	NS	101

intercropped with elephant foot yam gave the highest shoot weight. The shoot weight in control plot was comparatively low.

The increase in cassava shoot weight consequent to intercropping could be due to complementary effects already discussed under the section on tuber yield.

4A.1.2.6 Dry matter production

Dry matter production in cassava was high in elephant foot yam and banana intercropped situations during the first year. Intercropping with colocasia was on par with sole cassava (Table 6). During the second year also the same trend was seen in elephant foot yam intercropped plots. However, intercropping with banana resulted in lowest dry matter production.

In this case also planting geometry failed to show any significant influence.

4A.1.2.7 Harvest index

The harvest index of cassava (Table 3) was not significantly influenced by any of the intercrops during first year. However, during the second year, the banana intercropped cassava had recorded lowest harvest index among the three cropping systems.

Planting geometry had no significant influence on the harvest index of cassava. Similarly control vs. rest comparisons were also not significant.

The lower harvest index registered in cassava + banana treatment during the second year may be due to the shading of

Table 6. Effect of geometries of planting and the intercrops on the dry matter production of cassava

Cropping systems	(1983-84) P	(1983-84) SC	(1983-84) Mean	(1984-85) P	(1984-85) SC	(1984-85) Mean
	(Dry matter of cassava in t/ha)					
C + Col.	10.04	8.95	9.50	11.71	11.66	11.69
C + EFY	10.16	10.99	10.58	14.19	16.80	15.50
C + B	10.14	10.13	10.13	9.00	8.68	8.84
C	7.74	8.42	8.08	10.11	11.53	10.80
Mean	9.52	9.62		11.30	12.17	
Control C(N)			7.61			11.40

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal planting

	C.D.(0.05)	SEM +/-	C.D.(0.05)	SEM +/-
1. Cropping systems	0.95	0.32	3.30	1.10
2. Geometry of planting	NS	0.22	NS	0.78
3. Combinations	1.34	0.45	NS	1.56
4. Control vs. rest	1.34	0.45	NS	1.56

cassava by banana. The shade must have caused more shoot growth at the expense of tuber growth.

4A.2 Intercrops

Since the interspecific comparison of the intercrops was not relevant and the observations recorded for each intercrop were only from six plots, statistical analysis was not carried out for these data. A comparison of the different growth characters and yield based on the mean values is given in this section.

4A.2.1 Colocasia

4A.2.1.1 Growth characters

The height of colocasia (Table 7a) recorded at different stages indicated that colocasia intercropped in the different geometries of cassava planting was taller than the sole crop colocasia during both the years. In general, there was no perceptible difference in the height of intercrop colocasia due to the geometry of planting of cassava. The taller plants of colocasia observed in intercropped plots may be due to the competition for light offered by cassava.

The leaf area of intercrop colocasia (Table 7a) was low as compared to the sole crop at 60 and 120 days after planting during both the years. Colocasia intercropped in paired row cassava produced more leaf area as compared to square clustered cassava. The leaf area decrease observed in intercrop colocasia

Table 7a. Effect of geometries of planting cassava on the height and leaf area of intercrop colocasia

Geometry of planting cassava	(1983-84) Days after planting 60	120	180	(1984-85) Days after planting 60	120	180
			(Height in cm)			
P	31	42	50	54	65	68
SC	31	38	49	62	67	68
Sole crop	28	30	46	57	58	59
			(Leaf area m2 /plant)			
P	0.483	0.645	0.188	0.572	0.725	0.086
SC	0.472	0.539	0.100	0.356	0.489	0.037
Sole crop	0.606	0.788	0.081	0.720	0.732	0.064

Table 7b. Effect of geometries of planting cassava on the yield, dry matter production and harvest index of intercrop colocasia

Geometry of planting cassava	(1983-84)				(1984-85)			
	Yield		Dry matter	Harvest index	Yield		Dry matter	Harvest index
	kg/ha	g/pl.	g/pl.	%	kg/ha	g/pl.	g/pl.	%
P	4035	218	89	62	4015	217	91	65
SC	7173	212	79	64	6713	198	78	68
Sole	16227	293	123	68	12188	224	133	68

P-paired row SC-square cluster pl.-plant

may be due to the competition offered by cassava both for nutrients and light.

4A.2.1.2 Yield

During both the years the yield per plant of intercrop colocasia (Table 7b) was lower than that of sole crop. Between the geometries of planting of cassava there was not much difference as far as colocasia yield was concerned.

The total dry matter production by colocasia (Table 7b) was highest in sole planting. In intercrop colocasia, the dry matter production was more in paired row planting of cassava. As far as harvest index was concerned, no definite trend could be obtained in colocasia. The yield reduction observed in intercrop colocasia may be due to the competition for light offered by the main crop cassava. Colocasia was very much at a disadvantage as far as light utilization was concerned because of its shorter canopy. Moreover when the intercrop colocasia was in its active vegetative phase, cassava also was in full flush and the relative light transmission to the colocasia canopy was considerably lower. The influence of the low light received on intercrop colocasia was reflected in total dry matter production, but not on harvest index. This indicates that the reduced light received on colocasia decreased the plant photosynthate production in total, but not its partitioning. Lalithabai and Nair (1984) classified colocasia as a shade tolerant crop from their studies under artificially shaded conditions. But they have also recorded yield reduction in colocasia even when the shade was only 25 per cent, but the reduction was not as drastic as other shade susceptible crops. In this study also the yield reduction observed in intercrop colocasia was not serious. It may also be remembered that unlike in an artificially shaded situation here the rhizosphere competition for nutrients also might have affected colocasia yield. Karikari (1981) from his experiments in Ghana reported that colocasia can be grown as an intercrop in cassava, but there will be considerable reduction in yield of both the crops. However, he has not attempted a disciplined plant arrangement for cassava so as to accommodate and accomplish uninterrupted growth of cassava and intercrop colocasia.

4A.2.2 Elephant foot yam

4A.2.2.1 Growth characters

In general, elephant foot yam was taller in intercropped situations (Table 8a). With regard to leaf area, a decreasing trend was observed in the intercropped situations. Eventhough these two morphological characters were largely decided by the size of the planting materials (Ashokan et al., 1984a), here the environment played some role in modifying these characters.

The increase in height observed in intercrop elephant foot yam may be attributed to the competition for light and the decrease in leaf area may be due to the competition for light and nutrients.

Table 8a. Effect of geometries of planting cassava on the height and leaf area of intercrop elephant foot yam

Geometry of planting cassava	(1983-84) Days after planting 60	120	180	(1984-85) Days after planting 60	120	180
	(Height in cm)					
P	62	65	65	55	60	62
SC	56	63	60	52	54	66
Sole crop	52	58	68	44	60	60
	(Leaf area m2/plant)					
P	0.326	0.327	0.334	0.356	0.489	0.484
SC	0.321	0.330	0.334	0.360	0.434	0.431
Sole crop	0.323	0.333	0.340	0.435	0.494	0.510

Table 8b. Effect of geometries of planting cassava on the yield, dry matter production and harvest index of intercrop elephant foot yam

Geometry of planting cassava	(1983-84) Yield kg/ha	Yield g/pl.	Dry matter g/pl.	Harvest index %	(1984-85) Yield kg/ha	Yield g/pl.	Dry matter g/pl.	Harvest index %
P	5596	1360	426	81	4527	1100	354	79
SC	10493	1530	434	84	9601	1400	428	85
Sole	23124	1880	535	87	20910	1700	499	85

P-paired row SC-square cluster pl.-plant

4A.2.2.2 Yield

Sole planting of elephant foot yam resulted in maximum yield per plant (Table 8b). The yield was lower in intercrop elephant foot yam in paired row planted cassava. Similar trend was noticed in dry matter production also. The difference in intercrop and sole elephant foot yam was not perceptible as far as harvest index is concerned.

The logical explanation for the low yield and dry matter recorded in intercrop elephant foot yam may be the shade cast by the main crop of cassava. The morphological character of elephant foot yam is similar to that of colocasia as far as light utilization in the intercropping system is considered. Rhizosphere interaction and competition for nutrients is probable, as is evidenced from the root excavation study. Eventhough the root system of cassava and elephant foot yam (Fig. 6&7) were confined to 25 to 40 cm radius and depth, some of the roots were found to intermingle. Since the harvest index was not markedly different in intercrop and sole elephant foot yam, it may be concluded that the partitioning and translocation of photosynthates in elephant foot yam was not markedly influenced by the shade of cassava. The harvest index of 80 per cent observed in elephant foot yam was very high considering the other intercrops studied. The elephant foot yam is peculiar in its morphological behaviour that the canopy is having only a single layer of leaves and the canopy does not expand once it is fully formed (Plate V); so there is no chance of mutual shading. The full formation of the canopy takes only about 30 days from planting. After this period for about 210 days the major portion of the assimilates is used for the corm formation and development only. According to Loomis and Williams (1963) a single horizontal canopy can utilise only about 25 per cent of the total photosynthetically active radiation received and the rest go unutilised. Hence solar energy may be under - utilised in places where this crop is grown in sole stand.

4A.2.3 Banana

4A.2.3.1 Growth characters

The height of banana (Table 9a) did not show much difference in intercropped situations under different geometries of planting of cassava. However, during the second year, sole crop banana recorded a consistently lesser height of the plant.

There was a definite trend in the leaf area (Table 9a) developed by intercrop banana. The leaf area was lower in intercrop banana as compared to sole crop. This was conspicuous at 120 and 180 days after planting during the first year.

Since banana canopy occupied the uppermost layer during most of the period, the crop underneath could not influence the height of banana. The marginal increase in the height of banana recorded during the second year could be due to the competition between cassava and banana. The lower leaf area observed in the intercrop banana could be due to the competition for nutrients offered by cassava. Considerable number of cassava roots were seen in the rhizosphere of banana and the uptake of nutrients by intercrop banana was lesser than that of sole banana.

Table 9a. Effect of geometries of planting cassava on height and leaf area of intercrop banana

Geometry of planting cassava	(1983-84) Days after planting 60	120	180	270	300	360	(1984-85) Days after planting 60	120	180	270	300	360
						(Height in cm)						
P	96	140	189	212	218	242	256	256	190	198	229	272
SC	96	135	187	217	222	245	272	273	195	204	252	280
sole banana	92	145	192	215	220	249	255	255	191	200	216	278
						(Leaf area m2/plant)						
P	0.82	1.64	4.03	6.02	6.51	9.67	12.67	8.23	12.56	8.16	9.88	12.56
SC	0.97	1.74	3.84	5.98	6.01	10.78	13.98	8.20	14.60	7.91	9.78	14.60
sole banana	0.88	2.82	5.68	7.74	7.71	10.39	14.07	8.97	14.80	8.25	9.99	14.80

Table 9b. Effect of geometries of planting cassava on the yield, dry matter production and harvest index of intercrop banana

Geometry of planting cassava	(1983-84) Yield kg/ha	g/pl.	Dry matter g/pl.	Harvest index %	(1984-85) Yield kg/ha	g/pl.	Dry matter g/pl.	Harvest index %
P	10016	7300	3262	45	8644	6300	3082	41
SC	11895	8670	3264	48	9192	6700	3023	43
Sole crop	16770	7800	3006	47	12902	6000	2785	43

P-paired row SC-square cluster pl.-plant

4A.2.3.2 Yield

The bunch weight of banana (Table 9b) showed a different trend as compared to colocasia and elephant foot yam. It was not markedly influenced by cassava. The intercrop banana grown in square clustered cassava gave the highest yield followed by sole banana and intercrop banana in paired row planted cassava. But the dry matter production was higher in sole banana compared to intercrop banana in both the geometries of planting of cassava. The harvest index of intercrop banana in paired row planted cassava was lower than in square clustered cassava and sole banana, the difference between the latter two treatments being not significant.

The intercrop banana, because of its tall canopy was in an advantageous position as far as light utilization in the cropping systems were considered. During most of its growth period banana intercepted almost 100 per cent of light received (Fig. 9). So the yield of intercrop banana was not reduced considerably as in colocasia and elephant foot yam.

The intercrop banana in square clustered cassava had more uninterrupted rhizosphere and canopy area resulting in less competition for nutrients and light (Fig. 8). This may be the probable reason for the higher yield observed in intercrop banana in square clustered cassava. In sole banana, the land space available per plant was lesser than in intercrop banana and the resultant intraspecies competition may be the reason for the low yield of sole banana. In a cassava+banana intercropping study in Nigeria, the yields of both banana and cassava were

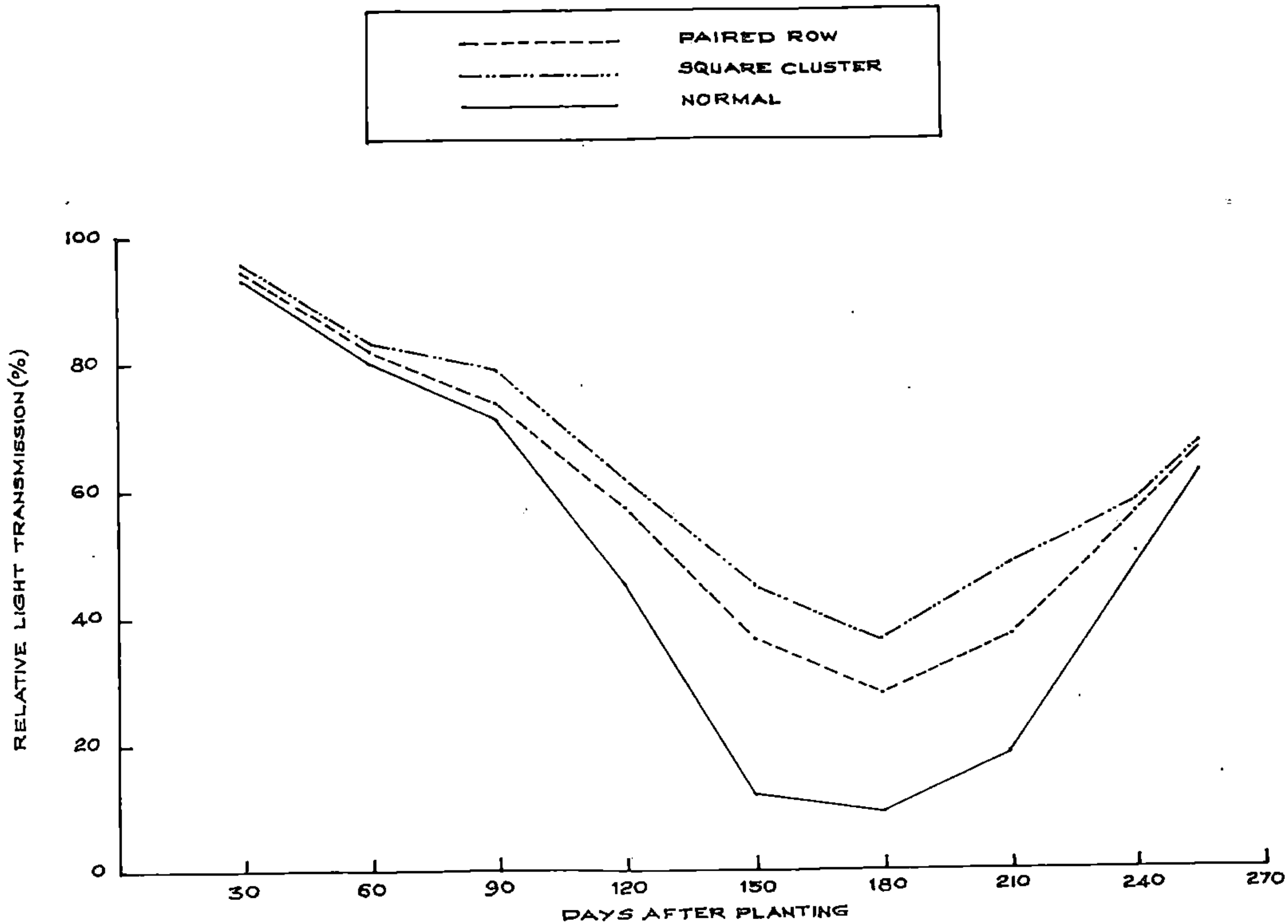


FIG.8. RELATIVE LIGHT TRANSMISSION THROUGH CASSAVA CANOPIES UNDER DIFFERENT GEOMETRIES OF PLANTING.

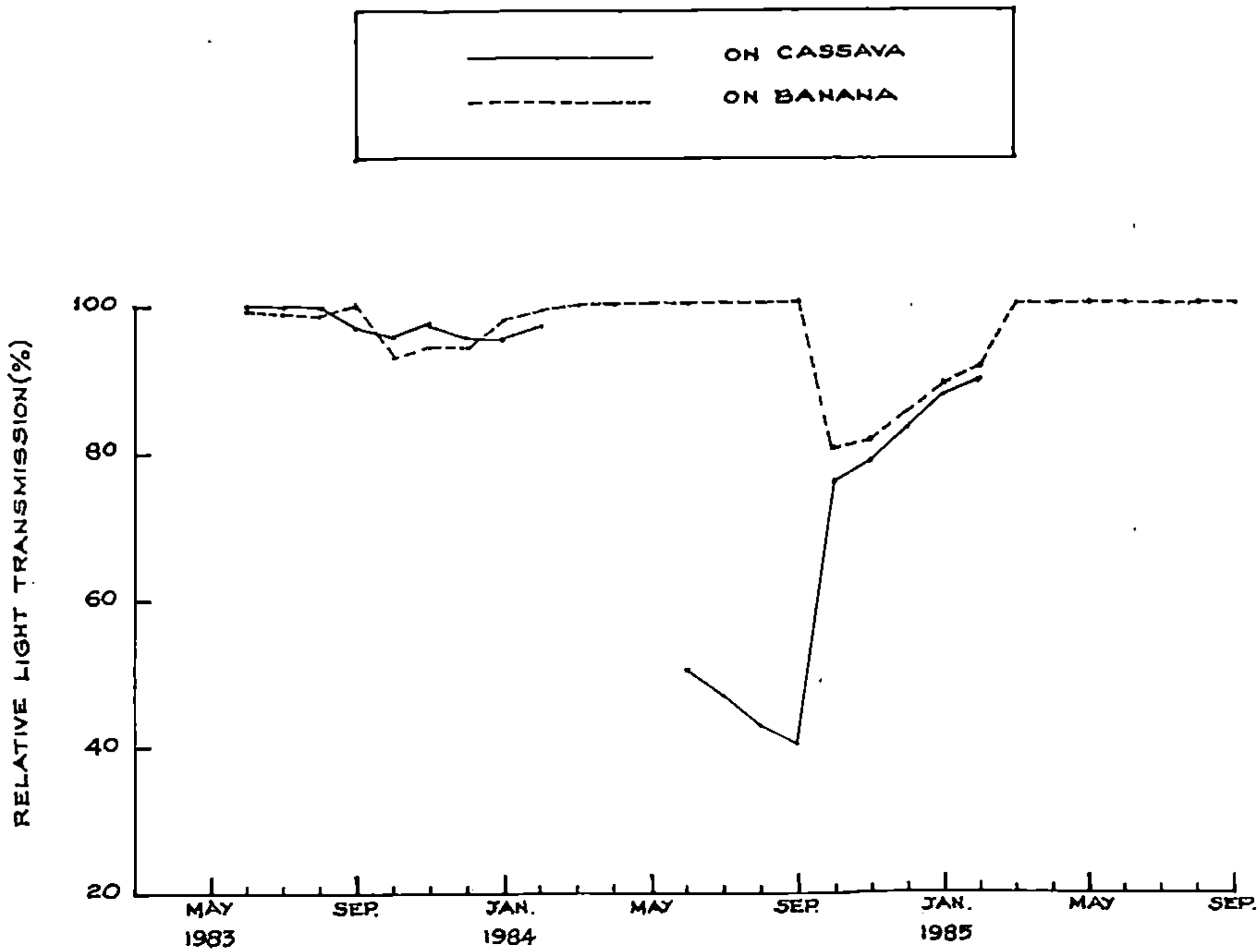


FIG. 9. RELATIVE LIGHT TRANSMISSION ON TO CASSAVA AND BANANA IN INTERCROPPING SYSTEM.

reduced (Obiefuna and Ndubizu, 1983). But in their study, spatial arrangement of cassava to accommodate the intercrops was not considered.

It may be further seen that the ratoon banana was inferior to the plant crop. This may be attributed to the rhizosphere competition of the ratoon banana and cassava, the feeding zones of which overlapped. The uptake studies also showed that (Fig.11) it was less in ratoon banana than the plant crop. Another probable reason may be the competition between cassava and banana at the canopy level during the peak vegetative development period of ratoon banana. The banana yield is very much influenced by the assimilate accumulation during its early vegetative phase (Simmonds, 1966).

The lower harvest index observed in intercrop banana may be the result of the competition between cassava and banana and the utilization of more photosynthates for its vegetative growth.

4A.3 Total biomass production

The total biomass production was significantly high in cassava + elephant foot yam and cassava + banana during the first year as compared to cassava + colocasia and sole cassava (Table 10). Cassava + colocasia was superior to sole cassava. During second year the maximum biomass was recorded in cassava+ elephant foot yam followed by cassava + colocasia. The cropping system cassava + banana was on par with sole cassava. The higher biomass recorded in these intercropping systems may be due to the higher interception of incident solar energy because

Table 10. Effect of geometries of planting and the intercrops on total biomass (cassava + intercrop) in different cropping systems

Cropping system	(1983-84)			(1984-85)		
	P	SC	Mean	P	SC	Mean
	(Total biomass in t/ha)					
C + Col.	10.9	9.4	10.1	12.8	13.2	13.0
C + EFY	11.8	14.0	12.9	15.6	19.8	17.7
C + B	12.4	13.0	12.7	10.9	11.5	11.2
C	7.8	8.4	8.1	11.1	11.5	11.3
Mean	10.7	11.2		12.6	14.0	
Control C(N)			7.6			11.4

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal planting

	C.D.(0.05)	SEM +/-	C.D.(0.05)	SEM +/-
1. Cropping systems	1.0	0.3	1.5	0.5
2. Geometry of planting	NS	0.2	1.1	0.4
3. Combinations	1.4	0.5	2.1	0.7
4. Control vs. rest	1.4	0.5	2.1	0.7

Table 11. Land Equivalent Ratio of cassava and intercrops in different cropping systems

Cropping systems	(1983-84) Land equivalent ratio			(1984-85) Land equivalent ratio		
	La	Lb	Total	La	Lb	Total
C + Col.	1.01	0.35	1.36	1.09	0.44	1.53
C + EFY	1.17	0.36	1.53	1.22	0.34	1.56
C + B	1.15	0.66	1.81	0.69	0.69	1.38
C	0.99	-	0.99	1.01	-	1.01
C.D. (0.05)	NS	-	0.19	0.26	-	0.27
SEM +/-	0.07	-	0.06	0.09	-	0.09

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
La- LER of cassava Lb- LER of intercrops

of the higher leaf area index maintained throughout the cropping season.

4A.4 Land equivalent ratio

The land equivalent ratios of cassava (La) in intercropped and sole cropped plots were on par (Table 11) during the first year. Cassava in elephant foot yam intercropped plots showed a higher value during both the years.

During the second year significant difference was observed and the land equivalent ratio of cassava in banana intercropped plots were significantly lower. The difference in land equivalent ratio of cassava under different geometries of planting were not significant.

Among the three intercrops, the land equivalent ratio of banana(Lb) was high during both the years. Intercrop elephant foot yam and colocasia were not remarkably different in this index. The land equivalent ratio of all the intercrops were high in square cluster planting of cassava (data not presented).

The total land equivalent ratio (LER) was significantly superior in all the intercropped plots compared to sole cassava during both the years (Fig. 10). During the first year, the maximum value (1.81) was recorded for cassava+banana and it was significantly superior to cassava + elephant foot yam and cassava + colocasia. During the second year cassava + colocasia, cassava + elephant foot yam and cassava + banana were on par as far as LER was concerned. It is also evident that the production

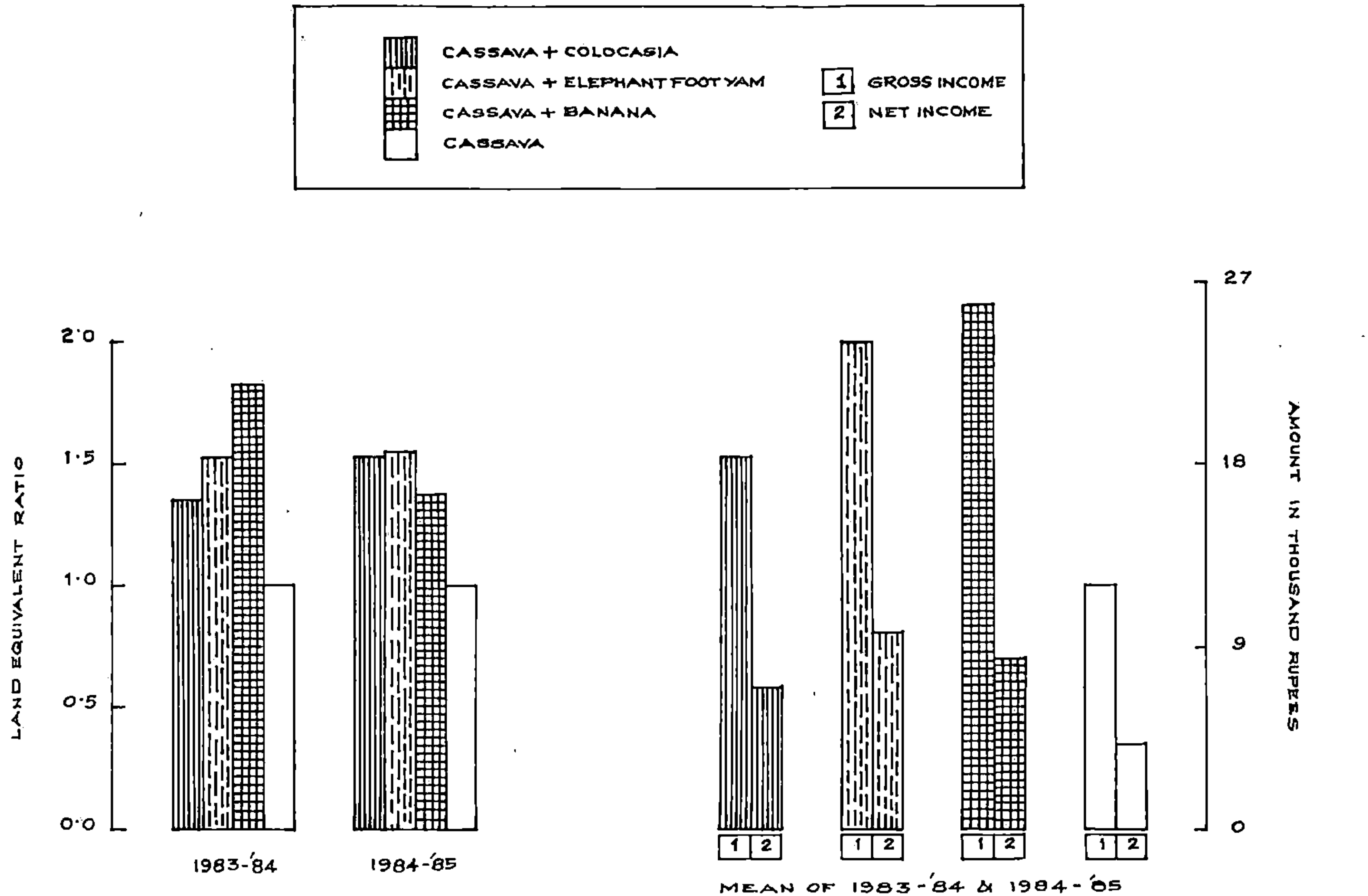


FIG. 10. LAND EQUIVALENT RATIO AND ECONOMICS OF CASSAVA + COLOCASIA / ELEPHANT FOOT YAM/BANANA INTERCROPPING SYSTEM.

efficiency of cassava was not significantly influenced by the geometry of planting.

The land equivalent ratio of the intercrop banana was higher because of its advantageous position as far as solar energy utilization in the intercropping system is considered due to its tall competitive growth. Colocasia and elephant foot yam occupied the lower canopy during the major part of the cropping period and hence recorded a low land equivalent ratio. Considering the total land equivalent ratio recorded during both the years, intercropping with colocasia or elephant foot yam or banana seems to increase the productivity of the system as a whole. During second year eventhough the cassava yield was drastically reduced by banana, the LER was on par in different intercropping systems because of the higher land equivalent ratio registered in intercrop banana compared to elephant foot yam and colocasia.

4A.5 Economics

The economics (Fig. 10) of different intercropping systems showed that much higher gross income could be obtained by intercropping cassava as compared to sole crop. Maximum net return was derived from cassava + banana intercropping followed by cassava + elephant foot yam and cassava + colocasia in the first year. During the second year maximum gross and net return was obtained when elephant foot yam was intercropped in cassava. It was least in cassava + banana combination during this year. The per day return showed that the maximum value was obtained in elephant foot yam intercropping followed by colocasia and banana. This was lowest in sole cassava.

In the first year, all the intercropping systems gave higher benefit:cost ratio as compared to sole cassava (Appendix III). The difference in benefit:cost ratio among the intercropping systems was more pronounced in the second year . It was maximum in colocasia intercropping followed by elephant foot yam. As in the case of net return banana intercropping resulted in lowest benefit:cost ratio during second year.

The results of the first year wherein banana intercropping resulted in maximum net profit is attributed to the higher yield of plant crop banana as compared to the ratoon. In the second year maximum net return was bagged by cassava + elephant footyam intercropping. This was inspite of the high cost of cultivation of elephant foot yam. When the benefit:cost ratio was considered the elephant foot yam intercropping was shifted to second place on account of the high cost of cultivation as already mentioned.

4A.6 Nutrient uptake in intercropping systems

4A.6.1 Cassava

The uptake of N, P, K, Ca, Mg and S (Table 12) in general showed the same trend as that of dry matter production. The uptake of nitrogen by intercropped cassava was significantly higher than the sole cassava. During the second year higher N uptake was observed only when elephant foot yam was the intercrop. Cassava in banana intercropped situations recorded

Table 12. Effect of geometries of planting and intercrops on the nutrient removal by cassava

Cropping systems	(1983-84) N	P	K	Ca	Mg	S	(1984-85) N	P	K	Ca	Mg	S
	(Nutrient removal in kg/ha)											
C + Col.	126	8.2	87	28.1	8.7	3.3	102	10.0	78	31.5	10.3	8.5
C + EFY	144	10.1	104	38.8	13.6	4.0	151	13.1	95	47.0	14.4	13.5
C + B	147	9.3	103	39.7	11.9	3.6	91	7.5	57	30.5	9.2	7.7
C	101	7.4	65	23.9	8.0	2.7	99	9.7	77	30.9	10.8	8.7
C.D.(0.05)	22	1.1	13	8.9	3.8	0.6	21	1.2	15	5.9	1.5	1.7
SEM +/-	7	0.4	4	3.0	1.3	0.2	7	0.4	5	2.0	0.5	0.6
Geometry of planting												
P	124	8.8	88	32.5	11.1	3.3	101	9.8	71	35.1	11.0	9.5
SC	130	8.7	92	32.7	10.0	3.4	120	10.4	82	34.8	11.4	9.7
C.D.(0.05)	NS	NS	NS	NS	NS	NS	15	NS	NS	NS	NS	NS
SEM +/-	5	0.3	3	2.1	0.9	0.2	7	0.3	4	1.4	0.4	0.4
Control												
C(N)	96	7.0	67	27.4	7.1	2.3	119	11.5	79	35.1	11.4	10.2
C.D.(0.05)	32	1.6	18	13.0	NS	0.9	NS	1.7	NS	NS	NS	NS
SEM +/-	11	0.5	6	4.0	1.8	0.3	10	0.6	7.3	2.8	0.7	0.8

C-cassava Col.-colocasia EFY-elephant foot yam B-banana P-paired row SC-square cluster (N)-normal method of planting cassava

lowest nitrogen uptake. The uptake of P was also influenced by the intercrops and the results were similar to N. During the first year all the intercropped plots recorded a higher value of K uptake, but in the following year this trend was observed only in elephant foot yam intercropped situations. The uptake of K in cassava + banana plots was lowest in this year.

The effects of planting geometries were not significant.

The uptake of Ca, Mg and S were also increased by intercropping (Table 12). During the second year, elephant foot yam intercropped cassava showed significantly higher uptake. The other treatments were on par, except in the case of Mg where banana intercropped plots showed significantly lower uptake.

In general, a lower uptake value was recorded in control plots for all the six nutrients.

A complementary rhizosphere interaction between cassava and the intercrops is evident in the removal of N, P, K, Ca, Mg and S by cassava. The higher removal of these nutrients in intercropping systems indicate that cassava derived some quantity of these nutrients from the root zones of the intercrops. During the second year a reverse trend was observed in banana intercropped cassava, probably because of the poor growth of cassava on account of shading from banana.

4A.6.2 Intercrops

The nutrient uptake in general was more in sole colocasia during both the years (Table 13). In elephant foot yam also similar result was observed. In general, intercrop colocasia in

Table 13. Effect of geometries of planting on the nutrient removal by the intercrops

Geometry of planting	(1983-84) N	P	K	Ca	Mg	S	(1984-85) N	P	K	Ca	Mg	S
	(Nutrient removal in kg/ha)											
Colocasia												
P	18.7 (1011)	1.2 (65)	18.7 (1011)	8.0 (432)	1.9 (103)	1.1 (59)	19.7 (1065)	1.1 (59)	22.0 (1189)	12.3 (665)	1.8 (97)	1.5 (81)
SC	27.7 (816)	2.4 (71)	27.4 (807)	13.3 (392)	3.0 (88)	1.5 (44)	29.7 (875)	3.0 (88)	30.7 (904)	28.3 (834)	2.7 (80)	2.8 (82)
Sole	58.1 (1046)	4.2 (76)	56.2 (1012)	25.3 (455)	5.9 (106)	3.7 (67)	65.3 (1175)	3.9 (70)	70.0 (1260)	35.5 (639)	5.5 (99)	4.7 (85)
Elephant foot yam												
P	39.3 (8188)	3.9 (813)	32.0 (6667)	9.7 (2021)	4.6 (958)	1.9 (396)	38.7 (8063)	3.8 (792)	28.7 (5979)	11.3 (2354)	5.6 (1167)	1.9 (396)
SC	68.0 (8619)	7.3 (925)	58.0 (7351)	16.0 (2028)	8.4 (1065)	3.5 (444)	69.3 (8783)	3.7 (769)	50.7 (6426)	24.3 (3080)	9.1 (1153)	3.4 (431)
Sole	108 (8808)	11.8 (960)	109 (8837)	33.8 (2748)	17.4 (1415)	6.6 (536)	111 (8992)	11.2 (912)	85 (6914)	50 (3818)	15.3 (1240)	6.8 (552)
Banana												
P	109 (80)	5.1 (3.7)	153 (112)	23.7 (17)	3.3 (2.4)	4.1 (3.0)	106 (77)	5.3 (3.9)	98 (72)	34.3 (25)	5.6 (4.1)	4.3 (3.1)
SC	93 (68)	6.0 (4.4)	184 (134)	27.7 (20)	4.3 (3.1)	4.6 (3.4)	124 (91)	6.8 (5.0)	185 (135)	52.7 (38)	8.3 (6.1)	8.2 (6.0)
Sole	178 (79)	9.4 (4.2)	244 (108)	39.5 (18)	6.5 (2.9)	5.9 (2.6)	175 (78)	8.7 (3.9)	182 (81)	53.1 (24)	7.5 (3.3)	5.6 (2.5)

The figures in parentheses are uptake in mg/plant for colocasia and elephant foot yam; g/plant for banana.
P-paired row SC-square cluster

paired row cassava resulted in more uptake while in the case of elephant foot yam, intercropping among the square clustered cassava resulted in more uptake. In intercrop banana the highest uptake value was recorded in situation where cassava was planted in square cluster. Sole banana recorded an uptake value lower than this.

A perusal of the data on dry matter production showed that it was more in sole colocasia and elephant foot yam as compared to the intercrop. Similarly intercrop colocasia in paired row cassava showed more dry matter production while the elephant foot yam planted in square clustered cassava recorded the highest dry matter production. The pattern of nutrient uptake was similar to dry matter production in the respective treatments.

The uptake values on per hectare basis were maximum in sole crop followed by that in square cluster and paired row cassava because the population of the intercrops decreased in that order.

4A.6.3 Total nutrient uptake

The total nutrient uptake (Table 14 and Fig. 11) was considerably higher in intercropping systems as compared to sole crops. This is evident from the uptake data for all the nutrients. Since the intercropping system produced more biomass, it removed more of plant nutrients from the soil. The total nutrient uptake in intercropping systems was more in the square cluster planting of cassava.

Table 14. Effect of geometries of planting and intercrops on the total nutrient removal in different cropping systems

Cropping systems	(1983-84)						(1984-85)					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
	(Nutrient removal in kg/ha)											
C + Col.	150	10.0	110	39.2	11.2	5.1	126	12.1	104	51.8	12.5	10.7
C + EFY	198	15.7	149	51.8	20.1	6.7	205	16.9	139	64.8	21.8	16.2
C + B	248	14.9	272	65.7	15.8	7.9	206	13.5	199	74.0	16.1	13.9
C	101	7.4	65	24.0	8.0	2.7	99	9.7	100	32.5	10.8	8.7
C.D.(0.05)	33	1.3	16	9.0	4.0	0.7	30	1.4	60	11.0	1.7	1.6
SEM +/-	11	0.4	5	3.0	1.3	0.3	8	0.5	20	3.7	0.6	0.5
Geometry of planting												
P	170	11.4	139	43.1	13.6	5.1	143	12.3	120	49.4	14.3	11.5
SC	183	12.6	159	47.3	13.9	6.1	175	13.7	151	62.2	16.4	13.3
C.D.(0.05)	NS	0.9	11	NS	NS	0.5	18	1.0	NS	7.8	1.2	1.2
SEM +/-	8	0.3	4	2.1	0.9	0.2	6	0.3	14	2.6	0.4	0.4
Control												
C(N)	96	6.9	67	17.3	7.1	2.3	119	11.5	89	35.3	11.4	10.2
C.D.(0.05)	46	1.8	23	13.0	5.6	1.0	35	1.5	NS	15.6	2.4	2.3
SEM +/-	15	0.6	8	4.3	1.9	0.4	12	0.7	28	5.2	0.8	0.8

C-cassava Col.-colocasia EFY-elephant foot yam B-banana P-paired row SC-square cluster (N)-normal method of planting cassava

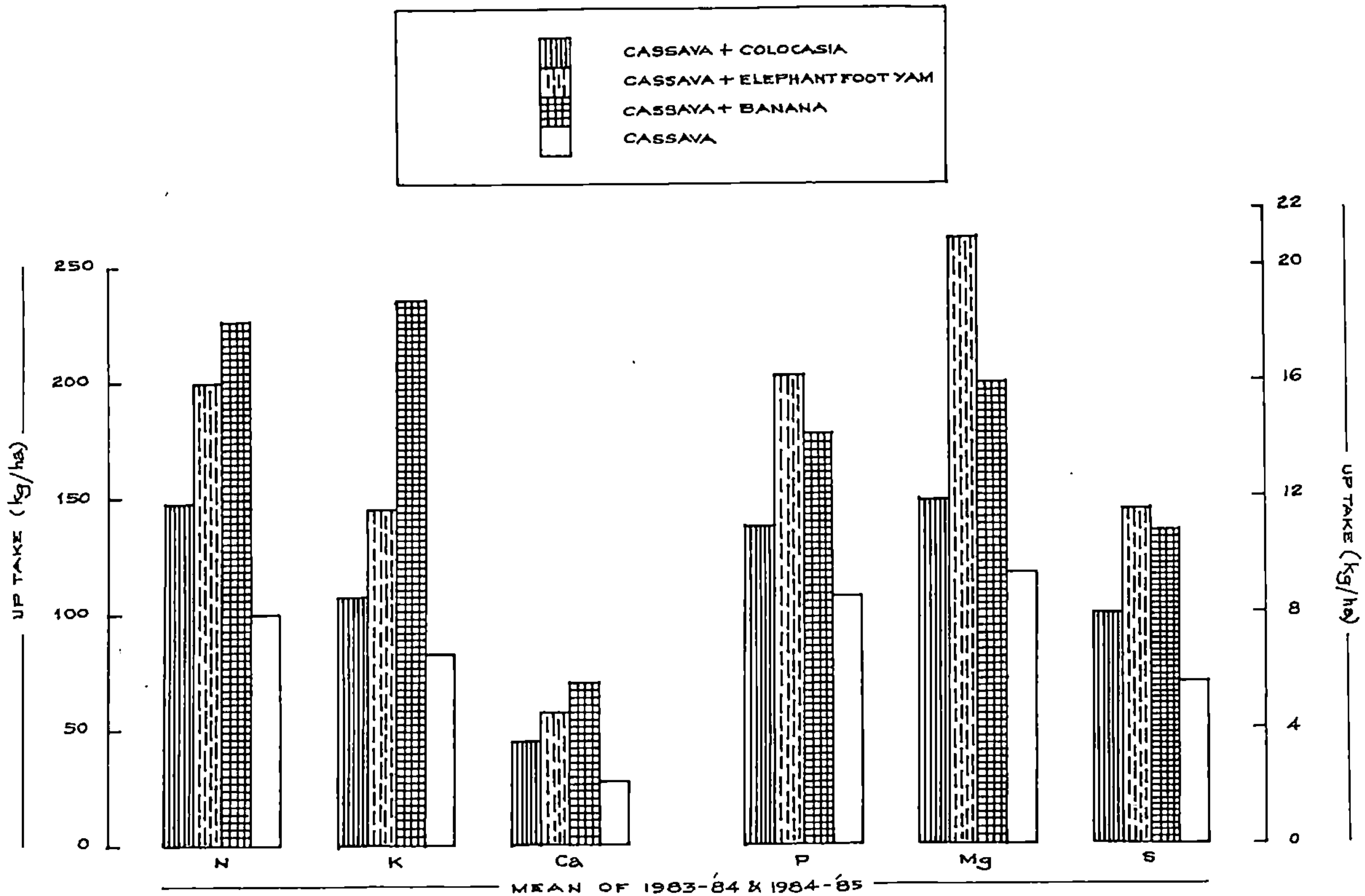


FIG. 11. TOTAL NUTRIENT UPTAKE IN CASSAVA + COLOCASIA / ELEPHANT FOOT YAM / BANANA INTERCROPPING.

4A.7 Post crop soil nutrient status

The post crop soil analysis data on total N, available P and K, exchangeable Ca, Mg and SO_4 (Table 15 a&b) indicated that except total N recorded during the first year, other nutrient contents did not vary significantly. The total N recorded in cassava + banana plot was low compared to other intercropping systems. The same trend was observed during the second year also. Banana being a crop which requires more N, a decreased post harvest value was observed in this crop combination. Inter-cropping with colocasia and elephant foot yam has recorded a higher N content during both the years. These tuber crops require only less quantities of N (Table 13) as compared to banana. Moreover the N applied by way of farmyard manure might not have been utilised by the plant in full, leading to an increase in residual soil N content. Incidentally it may be stated that the organic carbon content was also higher in these two treatments. In available P and K there was no definite trend noticed when different intercropping systems were compared. It may be further observed that there was an overall decrease in the organic carbon, available P and K contents of soil when compared to the pre-crop soil analysis data (Appendix I).

The exchangeable Ca, Mg and SO_4 also were depleted from the soil consequent to the two season cropping. The micronutrients, extractable Cu and Mn were decreased due to the continuous two season cropping; but Zn and Fe status of soil were not remarkably influenced except in cassava+banana and sole cassava where the Zn status was comparatively low.

Table 15a. Effect of geometries of planting and the intercrops on the post crop soil nutrient status

Cropping systems	(1983-84)				(1984-85)			
	Organic C (%)	Total N(%)	Available P (ppm)	Available K (ppm)	Organic C (%)	Total N (%)	Available P (ppm)	Available K (ppm)
C + Col.	1.289	0.198	21	62	1.295	0.196	22	65
C + EFY	1.276	0.219	19	63	1.310	0.222	20	68
C + B	1.270	0.147	20	64	1.287	0.207	21	64
C	1.116	0.166	18	62	1.220	0.188	19	65
C.D.(0.05)	NS	0.051	NS	NS	NS	NS	NS	NS
SEM +/-	0.115	0.017	4	4	0.061	0.026	1	3
Geometry of planting								
P	1.165	0.178	18	64	1.252	0.205	19	65
SC	1.310	0.187	18	62	1.303	0.201	20	66
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	0.081	0.012	3	3	0.041	0.019	1	2
Control C(N)	1.260	0.140	20	62	1.301	0.181	20	65
Pre-crop values	1.608	0.175	14	68				

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal method of planting cassava

Table 15b. Effect of geometries of planting and the intercrops on the post crop soil nutrient status

Cropping systems	(1983-84)			(1984-85)						
	Exchangeable			Exchangeable			Acid extractable			
	Ca	Mg (ppm)	SO_4	Ca	Mg (ppm)	S04	Cu	Zn (ppm)	Fe	Mn
C + Col.	87	9.3	23	61	12.3	27	2.9	4.6	20	37
C + EFY	116	9.7	27	72	11.6	27	2.8	4.5	21	48
C + B	158	24.2	25	104	12.4	29	2.4	3.2	18	45
C	128	24.2	19	56	9.2	22	2.6	3.5	19	28
C.D.(0.05)	14	2.7	3	NS	NS	2	NS	1.1	NS	12
SEM +/-	5	0.9	1	15	1.1	1	0.2	0.4	2	4
Geometry of planting										
P	122	13.1	23	68	11.9	22	2.6	4.0	20	42
SC	122	20.6	24	78	10.9	21	2.7	3.9	19	37
C.D.(0.05)	NS	1.9	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	3.4	0.6	0.7	11	0.8	0.5	0.1	0.8	1.2	2.8
Control										
C(N)	64	6.7	22	56	10.0	20	2.6	3.2	18	26
Pre-crop values	254	20	32	-	-	-	3.6	4.5	19	79

C-cassava Col.-colocasia EFY-elephant foot yam B-banana
P-paired row SC-square cluster (N)-normal planting of cassava

The salient findings of this experiment are as follows.

Intercropping cassava without reducing the sole crop population is possible with colocasia, elephant foot yam and banana by adjusting the planting geometry. The overall performance showed that cassava + elephant foot yam is the best intercropping treatment. The yields of cassava obtained in normal method, paired row and square clustered planting were not significantly different when the same population was maintained in different geometries of planting. The cassava+banana cropping system was profitable during the first year. Ratoon crop is inferior to plant crop in the case of banana cv. Palayankodan when intercropped in cassava under rainfed conditions. The per day productivity and return were maximum in cassava + elephant foot yam intercropping. The benefit:cost ratio was maximum in cassava + colocasia intercropping.

4B. Trial II. Effect of Planting Geometry on Cassava + Banana Cropping System with Different Floor Crops.

The objective of this trial was to study the possibility of growing three crops simultaneously in the same unit of land. Cassava + banana (Plate VI) was taken as a base cropping system and three floor crops viz., cowpea, groundnut and elephant foot yam were tried as the component crops. As shown in figure four the cassava plants were widely spaced and arranged in paired rows (10,600 plants per hectare), square clusters (9070 plants per hectare) and triangular clusters (6900 plants per hectare). The floor crop population was lower in the paired row planting than in square and triangular clusters; the population of floor crop being same in the latter two geometries of planting. Banana was planted uniformly in all the treatments in the square cluster method consisting of 1070 plants per hectare.

The salient interactions between geometry of planting and the intercrops are discussed below.

4B.1 Cassava

4B.1.1 Growth characters

4B.1.1.1 Height

The height of cassava (Table 16) was significantly influenced by the associated crops at all the stages except at 60 days after planting during first year and 60 and 270 days after planting during the second year. The height was maximum in the

Table 16. Effect of different floor crops and the geometries of planting on the height of cassava at different stages of growth in a cassava + banana intercropping system

Cropping systems	(1983-84) Days after planting				(1984-85) Days after planting			
	60	120	180	270	60	120	180	270
	(Height in cm)							
C+B+CP	45.5	112	227	258	54.5	207	251	296
C+B+EFY	48.3	135	244	265	61.5	243	256	298
C+B+GN	43.7	100	185	221	56.7	194	230	330
C+B	46.0	135	241	263	55.2	218	264	305
C.D.(0.05)	NS	24	25	23	NS	28	24	NS
SEM +/-	3.1	8	8	8	3.2	9	8	11
Sole cassava								
P	44.0	135	213	218	55.0	182	228	239
SC	41.0	132	218	216	46.5	203	222	236
TC	39.5	124	200	218	42.5	191	202	219
N	44.0	149	203	219	59.5	201	204	225

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut P-paired row SC-square cluster TC-triangular cluster N-normal planting

crop combination cassava + banana + elephant foot yam. This trend was observed during both the years. The height was lowest when groundnut was the intercrop. Sole cassava plant was shorter as compared to the intercropped plots during later stages.

As in trial I, here also intercropping has increased the height of cassava and the probable reason for such a behaviour has already been discussed.

4B.1.1.2 Leaf area

In general the leaf area of cassava was substantially influenced by the floor crops (Table 17). Among the floor crops elephant foot yam (Plate VIII) induced higher leaf area of cassava except in the early stages. In the case of cowpea intercropping the leaf area was lesser. The sole cassava, however produced more leaf area than the intercropped ones at 120 days after planting.

The leaf area in cowpea intercropped plots was lowest probably because of the smothering effect of cowpea (Plate VII). In cassava + banana + groundnut intercropping system (Plate IX), groundnut always occupied the lowest canopy and did not show any significant influence on cassava leaf area. The suppressing effect of intercrop cowpea on cassava leaf area was observed by Anilkumar (1984). He also observed that the competition between cassava and groundnut was less and did not influence the leaf area of cassava

Table 17. Effect of different floor crops and geometries of planting on the leaf area of cassava at different stages of growth in a cassava+banana intercropping system

Cropping systems	(1983-84) Days after planting (m2/plant)					
	30	60	90	120	180	270
C+B+CP	0.189	0.575	0.867	1.277	2.533	2.525
C+B+EFY	0.175	0.600	1.100	1.826	2.851	1.540
C+B+GN	0.180	0.587	0.879	1.538	2.668	1.365
C+B	0.192	0.596	0.998	1.970	2.547	1.499
C.D.(0.05)	0.030	NS	0.170	0.343	NS	NS
SEM +/-	0.010	0.026	0.060	0.114	0.116	0.099
Sole cassava						
P	0.200	0.675	0.956	1.959	2.789	1.373
SC	0.195	0.653	0.942	2.143	2.623	1.461
TC	0.210	0.707	0.991	2.156	2.991	1.552
N	0.185	0.697	0.909	2.311	2.619	1.507
	(1984-85)					
C+B+CP	0.158	0.419	0.751	1.090	3.403	1.143
C+B+EFY	0.195	0.537	0.960	1.524	3.503	1.049
C+B+GN	0.171	0.473	0.703	1.092	3.386	1.285
C+B	0.166	0.556	0.778	1.014	3.655	1.004
C.D.(0.05)	NS	NS	0.110	0.321	NS	0.159
SEM +/-	0.030	0.050	0.040	0.107	0.069	0.053
Sole cassava						
P	0.210	0.629	0.906	1.711	3.407	1.162
SC	0.195	0.617	0.991	1.651	3.590	0.993
TC	0.205	0.588	0.900	1.689	3.526	1.099
N	0.198	0.619	0.899	1.352	3.895	1.069

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut P-paired row SC-square cluster TC-triangular cluster N-normal planting

4B.1.2 Yield attributes

4B.1.2.1 Number of tubers

The number of tubers (Table 18) per plant recorded during the first year cropping was on par in all the cropping systems. But in the second year, sole cassava produced more number of tubers than that in intercropped situation. The number of tubers per plant in intercropped plots was relatively low during the second year as compared to the first year whereas in sole cassava this year to year difference was not perceptible.

The tuber differentiation in cassava is completed by about 3 months from planting (Hunt, et al.,1977). Probably none of the intercrops involved in the present study offered any serious competition to cassava during its early phase of growth in first year. During the second year the cassava was planted in the standing crop of intercrop banana which was at its peak vegetative phase. Hence there was considerable shading on cassava from its sprouting stage itself (Plate X). This adversely affected the tuber initiation in cassava and resulted in lower number of tubers per plant. Ramanujam et al. (1984) reported that the number of tubers per plant of cassava variety M4 was considerably reduced under the shaded situation in a coconut garden. Bhat (1978), Sheela (1981) and Anilkumar (1984) observed an increase in tuber number when cassava was intercropped with short statured, short duration legumes. In a trial conducted at Trichur, Ashokan et al.(1984b) observed no significant effect of intercrop cowpea, groundnut, blackgram and green gram on tuber number of cassava. In all the above cases the intercrops were

Table 18. Effect of different floor crops and the geometries of planting on the number, length and girth of tubers of cassava in a cassava+banana intercropping system

Cropping systems	(1983-84) No. of tubers	(1983-84) Length of tuber (cm)	(1983-84) Girth of tuber (cm)	(1984-85) No. of tubers	(1984-85) Length of tuber (cm)	(1984-85) Girth of tuber (cm)
C+B+CP	8.2	40.0	16.2	6.4	28.9	11.7
C+B+EFY	7.8	42.7	17.4	6.5	29.6	12.5
C+B+GN	7.2	39.1	15.8	6.6	27.6	12.0
C+B	8.5	40.8	17.3	6.6	26.8	12.0
C.D.(0.05)	NS	NS	1.0	NS	NS	NS
SEM +/-	0.6	0.5	0.3	0.2	0.7	0.5
Sole cassava						
P	8.5	41.3	17.6	8.9	42.8	17.5
SC	7.5	44.8	17.0	9.4	38.5	16.6
TC	8.5	47.9	16.7	9.8	39.6	16.9
N	8.6	47.3	17.6	8.8	40.5	17.2

Table 19. Effect of different floor crops and the geometries of planting on the tuber yield of cassava in a cassava + banana intercropping system.

Cropping systems	(1983-84) P	SC	TC	Mean	(1984-85) P	SC	TC	Mean
	(Tuber yield t/ha)							
C+B+CP	10.28	9.95	8.52	9.57	9.22	8.14	7.16	7.33
C+B+EFY	10.00	13.45	11.01	11.49	8.06	7.84	7.11	7.69
C+B+GN	10.00	9.68	9.12	9.60	8.14	7.11	6.70	7.31
C+B	10.25	10.88	9.37	10.18	8.21	6.37	7.18	7.26
Mean	10.13	11.01	9.50		8.42	7.36	7.03	
C	10.94	11.37	9.87	10.73	11.72	11.34	9.78	10.95
C(N)				15.20				15.85

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut P-paired row SC-square cluster TC-triangular cluster N-normal planting

	(1983-84) C.D.(0.05)	SEM+/-	(1984-85) C.D.(0.05)	SEM+/-
1. Cropping systems	1.26	0.42	NS	0.77
2. Combinations	2.22	0.73	NS	1.33

of short duration and dwarf that it did not shade cassava during its initial stages as done by banana in the second year in this trial.

4B.1.2.2 Length of tuber

The length of tuber of cassava (Table 18) was not significantly influenced by the cropping system. The only perceptible difference was that the tubers were shorter in the second year crop of cassava. This is apparently due to the competition from the already established banana as explained above.

4B.1.2.3 Girth of tuber

The girth of tuber (Table 18) showed significant variation in different cropping systems in the first year. The crop combination cassava + banana + elephant foot yam recorded the highest tuber girth which was significantly superior during the first year. In general the girth of cassava tuber was low in the second year. The reasons for this differential performance are given in the section on tuber yield (4B.1.2.4).

4B.1.2.4 Tuber yield

The cropping systems significantly influenced the tuber yield of cassava (Table 19) only during the first year. The crop combination cassava + banana + elephant foot yam recorded the highest yield. The other cropping systems cassava + banana + cowpea, cassava + banana + groundnut and cassava + banana were on par. There was also not much difference between sole cassava and the above three cropping systems.

In the second year there was no significant difference between the various crop combinations. However, there was remarkable yield decrease in the intercropping systems as compared to the sole cassava.

The superiority of cassava + banana + elephant foot yam combination is evident from the tuber yield of cassava. It may be recalled that the leaf area (Table 17) and the girth of tuber were more in cassava + banana + elephant foot yam combination. So the yield increase obtained in this treatment may be due to the increased photosynthetic activity resulting from the higher leaf area and the consequent better tuber development. Another possible reason for the increase in tuber yield of cassava may be the favourable micro-climate during the four to eight months period after planting when the tuber bulking rate in cassava is maximum. The soil temperature recorded during this period was less than that of the other cropping systems (data not presented). Since the cowpea and groundnut were harvested by this period the benefit of the cool environment could not be utilized by cassava in those treatments resulting in lower girth of tuber as compared to that in elephant foot yam intercropped plots (Table 18). There is little information available regarding the influence of micro-climate on the tuber development in cassava. However, in potato a similar study of intercropping in sugarcane resulted a higher tuber yield on account of the cooler environment created by the sugarcane crop (Brown, 1985). Another probable reason for the higher yield recorded in elephant foot yam intercropped situations is the beneficial rhizosphere interaction between cassava and elephant foot yam. This is indicated by ^{32}P count recorded in cassava when the elephant foot yam root zone was treated (Table 49 & Fig 24). Probably cassava might have derived nutrients from that applied to elephant foot yam and produced more tubers.

In the cropping system cassava+banana where the competition effect of cowpea and groundnut was not present, the tuber yield was on par with the cropping systems cassava + banana + cowpea and cassava + banana + groundnut. This indicates that cowpea and groundnut did not have any remarkable effect on cassava yield because of the short stature and short duration of these two floor crops.

During the second year the tall and dense banana canopy present in the field (Plate XI & XII) at the time of planting of cassava suppressed cassava growth and tuber development. Here the dominance of banana overshadowed the other treatment effects and the tuber yields in all the cropping systems were on par. This is evident from the fact that the sole crop yield of cassava was superior to the yield recorded in intercropping systems.

The interactions were statistically significant only during the first year when the highest yield was recorded by cassava + banana + elephant foot yam with cassava in square clustered planting. All the other treatment combinations were on par but inferior to cassava + banana + elephant foot yam with cassava in square cluster. The superior yield recorded here may be due to the better light utilization by cassava in square clustered planting since cassava is exposed to light from all the four sides apart from the environmental and rhizosphere effects resulting from elephant foot yam intercropping as already explained. During the second year these influences were not evident because of the dominating effect of banana and the considerable amount of shade cast by it on cassava and the floor crops. In an experiment in Ghana, Karikari (1981) observed considerable reduction in yield of cassava when plantain and colocasia were grown mixed with cassava. Nevertheless, the planting geometry of cassava was not adjusted to facilitate uninterrupted growth of the component crops therein.

The sole planting of cassava gave comparable yields as in intercropped situations during the first year. During the second year the yields were considerably higher in sole cassava as compared to intercropped cassava.

4B.1.2.5 Shoot weight

During the first year of the trial the fresh shoot weight of cassava (Table 20) was significantly different in the intercropping treatments. The cassava in cassava + banana + elephant foot yam cropping system recorded significantly higher weight of shoot which was on par with cassava + banana. The cropping system cassava + banana + cowpea recorded the lowest shoot weight.

In the second year, the shoot weight of cassava in different intercropping treatments were on par. However, the cassava +

Table 20. Effect of different floor crops and geometries of planting on the shoot weight, dry matter production and harvest index of cassava in a cassava + banana intercropping system

Cropping systems	(1983-84)			(1984-85)		
	Shoot weight g/plant	Dry matter kg/ha.	Harvest index %	Shoot weight g/plant	Dry matter kg/ha.	Harvest index %
C+B+CP	1733	9073	44	2150	8765	31
C+B+EFY	2033	9530	49	2517	10421	28
C+B+GN	1767	8710	45	2467	10143	25
C+B	2017	1005	43	2333	9561	27
C.D.(0.05)	275	NS	NS	NS	1192	NS
SEM +/-	91	454	2	105	395	3
Sole cassava						
P	1850	14800	45	1900	1426	28
SC	1100	10165	43	1900	11050	25
TC	1750	9931	48	2000	10560	30
N	1950	8565	45	2750	9330	43

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut P-paired row SC-square cluster TC-triangular cluster N-normal planting

banana + elephant foot yam combination gave the highest and cassava + banana + cowpea combination the lowest values.

The beneficial effect of elephant foot yam on cassava growth has already been discussed. The suppressing effect of cowpea because of its luxuriant and twining vegetative character resulted in lower shoot weight of cassava. During the second year the treatment effects were not significant.

In general the shoot weight of cassava was higher in all the intercropped plots during second year. The higher shoot weight recorded in intercropped situation is due to the competitive growth of cassava under the influence of the associated species. Cassava in its effort to harness more sunlight might have produced more shoot growth. Ramanujam et al. (1984) observed higher shoot weight in cassava planted in the shade of coconut garden.

4B.1.2.6 Dry matter production

During both the years the elephant foot yam intercropping has recorded maximum dry matter production of cassava and it was significant in the second year (Table 20). This was followed by groundnut intercropping. The lowest dry matter production was recorded in the cowpea intercropped plots.

During the second year the total dry matter production of cassava in intercropped situation was considerably less than that of the first year because of the shading effect of banana.

The dry matter production of cassava was maximum in cassava+ banana + elephant foot yam intercropping system because of higher shoot and root weight. It was lowest in cassava + banana + cowpea intercropped situation probably due to the combined suppressing effect of banana and cowpea. Cowpea under the shade of banana grew profusely and twined over cassava depressing its growth and production considerably.

4B.1.2.7 Harvest index

The harvest index value (Table 20) was not significantly influenced by the intercropping systems or their interactions during both the years. In the second year the harvest index of intercropped cassava was reduced by about 50 per cent as compared to the sole crop. The conspicuous reduction in harvest index noticed in the second year cassava may be due to the preferential shoot growth observed, because of the limited sink activity resulting from the intense shade caused by banana. Similar observation under shaded situation was also made by Ramanujam et al. (1984).

4B.2 <u>Intercrops</u>

4B.2.1 <u>Banana</u>

4B.2.1.1 Height

The height of plant and ratoon banana (Table 21) at the different stages was not significantly influenced by the different cropping systems. The intercrop and sole banana did not show much variation in the height of the plants. Since banana was occupying the upper canopy in the cropping system its height was not influenced by the crop growing below it.

Table 21. Effect of different floor crops and the geometries of planting on height of banana at different stages in a cassava + banana intercropping system

Cropping systems	(1983-84) Days after planting						(1984-85) Days after planting					
	60	120	180	270	300	360	60	120	180	270	300	360
	(Height in cm)											
C+B+CP	113	129	161	211	213	233	246	246	166	242	248	263
C+B+EFY	105	142	167	204	215	238	259	259	168	241	244	268
C+B+GN	100	134	164	210	212	235	251	251	159	241	249	259
C+B	104	138	154	216	208	230	252	252	159	247	253	263
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	7	7	5	4	3	3	6	7	3	11	3	7
Sole Banana												
SC	115	152	167	218	219	242	243	243	171	269	247	267
N	114	161	157	215	218	239	242	228	174	198	248	268

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut
SC-square cluster N-normal method

4B.2.1.2 Leaf area

The leaf area of banana in general (Table 22) was not significantly influenced by the associated crops during both the years. The leaf area of sole banana was not remarkably different from that of intercrop in both the plant and ratoon crops.

4B.2.1.2 Number of hands and fingers per bunch

The number of hands and fingers per bunch of banana (Table 23) in the different cropping systems were on par. This result was obtained both in plant and ratoon crops. The sole banana planted in square cluster produced the highest number of hands and fingers per bunch which was remarkably more than that of the intercrop banana and normal planted sole banana.

In banana the number of hands and fingers per bunch is mainly decided by the dry matter accumulation by the plant during its early vegetative phase (Simmonds, 1966).In this trial the intercrop banana was not subjected to much competition because banana was occupying the upper canopy most of the time and its dry matter accumulation during the early growth phase was not affected by the intercrops.

The square clustered sole banana gave the maximum value because of the benefit of the 'border effect'. In intercropped situation it was lower because the cassava was growing adjacent to banana almost upto seven months after planting and the 'border effect' was not much.

Table 22. Effect of different floor crops and the geometries of planting on leaf area of banana at different stages in a cassava + banana intercropping system

Cropping systems	30	60	90	120	180	270	300	360
			Days after planting (Leaf area in m2/plant)					
			(1983-84)					
C+B+CP	0.916	1.216	1.847	1.914	4.034	4.097	5.210	11.80
C+B+EFY	0.995	1.384	1.927	1.981	4.263	4.587	4.620	11.30
C+B+GN	1.106	1.543	2.083	2.118	3.626	4.476	5.250	11.50
C+B	1.156	1.345	1.837	2.166	3.055	4.445	5.190	11.10
C.D.(0.05)	NS	NS	0.939	NS	NS	NS	NS	NS
SEM +/-	0.085	0.150	0.172	0.085	0.312	0.224	0.274	0.444
Sole banana								
SC	0.992	1.160	2.112	2.221	4.107	4.317	5.900	12.90
N	0.962	1.210	1.966	2.072	3.868	4.533	5.420	12.03
			(1984-85)					
C+B+CP	11.40	10.817	3.265	6.082	6.519	5.262	4.970	10.95
C+B+EFY	11.50	11.621	3.664	5.467	9.788	6.261	4.520	11.10
C+B+GN	11.70	10.811	4.005	5.364	7.974	5.881	4.730	10.95
C+B	11.50	10.448	2.974	5.615	8.379	5.448	4.850	10.78
C.D.(0.05)	NS	NS	NS	NS	1.014	NS	NS	NS
SEM +/-	0.65	0.702	0.354	0.203	0.338	0.300	0.178	0.26
Sole banana								
SC	11.5	11.305	3.849	6.037	7.610	5.860	4.900	13.00
N	11.2	11.180	3.250	5.752	7.680	5.460	4.850	11.90

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut
SC-square cluster N-normal method

4B.2.1.4 Yield

The yield of banana (Table 23) was not significantly influenced by any of the treatment effects both in plant and ratoon crops. The sole banana planted in square cluster resulted in the maximum yield and was more than the intercrop and normal planted sole banana.

The per plant yield of sole banana in normal planting was comparable to the intercropped banana yields. However, on per hectare basis the normal planted sole banana resulted in maximum yield, due to higher population possible under this situation.

The different floor crops showed no significant influence on banana because the floor crops were short statured and were never above the banana canopy and offered no competition for light. The chances for nutrient competition were also less since the floor crops root systems were relatively small and exclusive and the component crops were separately manured.

4B.2.1.5 Dry matter production

The dry matter yield of banana (Table 23) in different intercropping systems was on par. The result obtained in this case was similar to that of the bunch weight and hence not further discussed.

4B.2.1.6 Harvest index

The harvest index of banana was not significantly influenced by the intercropping systems (Table 23). The feasibility of growing a floor crop like cowpea, groundnut and elephant foot

Table 23. Effect of different floor crops and geometries of planting on the number of fingers and hands per bunch, bunch weight, dry matter production and harvest index of banana in a cassava + banana intercropping system

Cropping systems	(1983-84)					(1984-85)				
	No.of fingers	No.of hands	Bunch weight (kg)	Dry matter (g/pl.)	Harvest index (%)	No.of fingers	No.of hands	Bunch weight (kg)	Dry matter (g/pl.)	Harvest index (%)
C+B+CP	136	9.1	9.8	4415	38	127	8.2	7.1	3097	40
C+B+EFY	147	9.8	10.0	4508	38	126	8.2	7.3	3099	40
C+B+GN	146	9.6	9.3	4362	37	124	8.7	7.3	3085	40
C+B	141	9.6	9.2	4432	36	118	8.3	6.9	2911	39
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	6.1	0.3	0.5	95	1	5	0.3	0.3	77	0.8
Sole banana										
SC	147	10.9	12.2	5198	41	190	11.5	11.2	4890	45
N	142	9.2	9.7	4616	37	170	10.5	9.0	4454	39

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut
N-normal planting of banana SC-square clustered planting of banana
pl.-plant

yam in cassava + banana is evident from the harvest index of banana also. Slightly higher value of harvest index recorded in square clustered banana indicates the favourable partitioning of assimilates which may be due to better light utilisation.

4B.3 Floor crops

4B.3.1 Cowpea

The floor crop cowpea was taller (Fig. 12) than its sole crop. During the first year this trend was pronounced at 60 days stage onwards whereas in the second year this was seen from 30 days stage itself.

In the first year the partial shade and mild competition for light offered by cassava and banana resulted in taller plants of cowpea in intercropped situations. At 30 days stage banana and cassava were too small to cause any remarkable shade on cowpea and the height difference was not evident.

The increase in height obtained in floor crop cowpea was more pronounced during the second year because of severe shade caused by banana from the initial stage itself. It can also be seen that the height in the second year was almost double that of the first year. This is also attributed to the thickly shaded conditions existing even from the seedling stage of cowpea. An increase in height of cowpea under shaded situation was observed by George (1982).

During the first year the leaf area per plant at 30 days stage was similar in sole and intercropped situations (Fig. 12). But by 60 days after planting the mean leaf area of floor crop

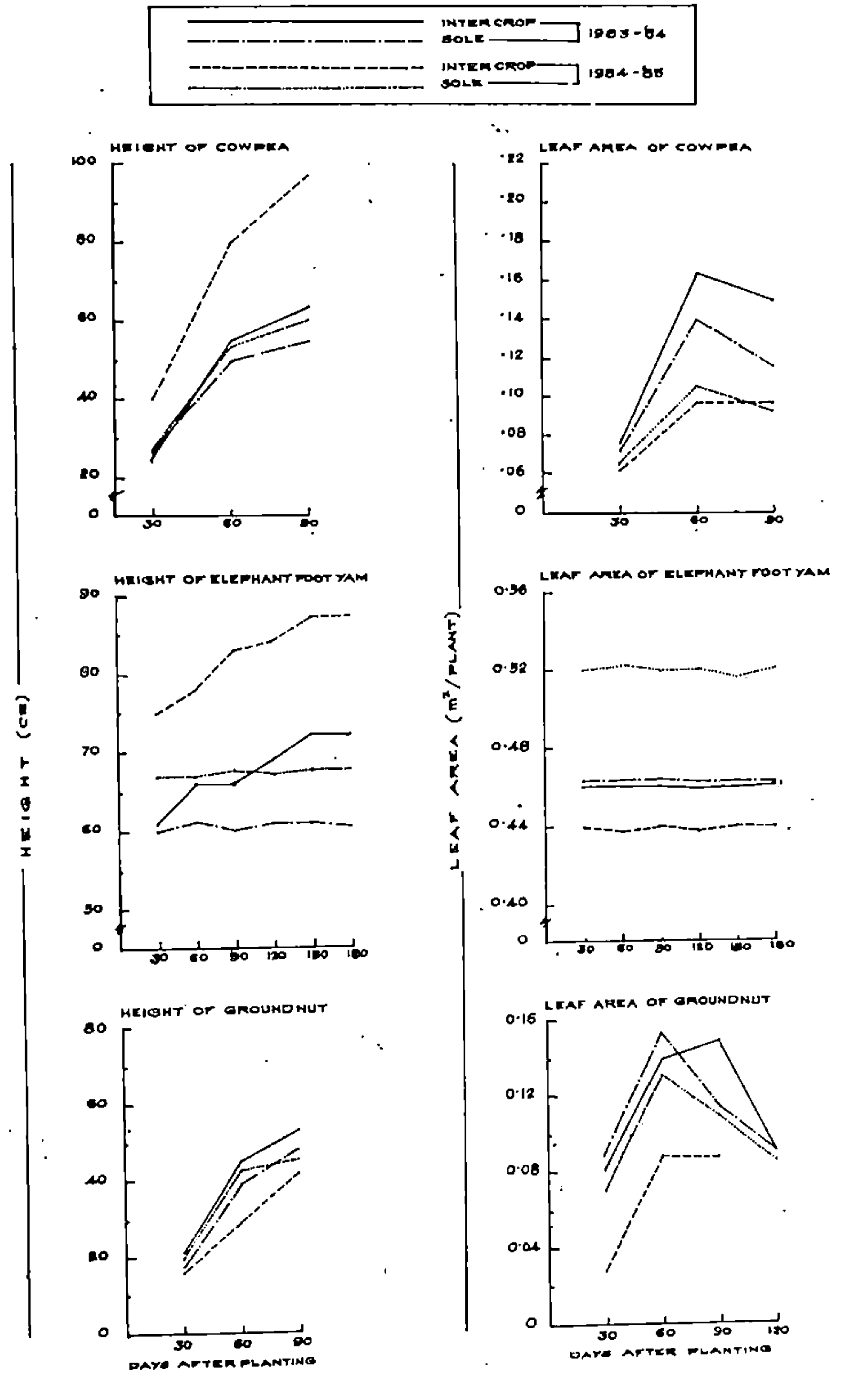


FIG. 12. HEIGHT AND LEAF AREA OF COWPEA, ELEPHANT FOOT YAM AND GROUND NUT IN CASSAVA + BANANA + COWPEA / ELEPHANT FOOT YAM / GROUND NUT INTERCROPPING - SYSTEMS.

cowpea was higher than the sole crop. This trend continued upto 120 days after planting. During the second year there was no marked difference between floor crop and sole cowpea except at the last stage wherein floor crop cowpea showed slightly higher leaf area. During the second year the leaf area of floor crop cowpea was much less than that of first year. As in the case of height, increase in leaf area of cowpea in intercropped situations was conspicuous only from 60 days stage.

When the per plant yield of cowpea was compared (Table 24) it was almost equal in the floor crop and sole cowpea during the first year. However, in the second year the floor crop cowpea yield was considerably low as compared to sole crop irrespective of the geometry of planting of cassava.

The same trend was observed in haulm weight as well as dry matter production of cowpea during both the years (Table 24).

In the first year the harvest index of cowpea (Table 24) was not much influenced by intercropping treatments or geometries of planting of cassava. But in the second year the harvest index of floor crop cowpea was considerably low as compared to the sole crop.

The performance of floor crop cowpea was markedly inferior during the second year with respect to all the growth and yield characters.

During the first year, the shade level of cassava + banana intercropping during the early three to four months did not offer any serious competition for light as far as floor crop cowpea is concerned. Though the height and leaf area increased

Table 24. Effect of different geometries of planting of cassava on the yield, haulm weight, dry matter production and harvest index of the floor crops - cowpea, elephant foot yam and groundnut in a cassava + banana intercropping system

Cropping systems	1983-84				1984-85			
	Yield (g/pl.)	Haulm weight (g/pl.)	Dry matter (g/pl.)	Harvest index (%)	Yield (g/pl.)	Haulm weight (g/pl.)	Dry matter (g/pl.)	Harvest index (%)
				COWPEA				
P	5.3 (554)	55.4	20.2 (1774)	28	1.6 (108)	28.6	11.0 (1018)	8
SC	5.7 (835)	54.2	21.3 (3092)	26	1.5 (136)	28.9	11.5 (1683)	8
TC	5.4 (839)	58.1	22.1 (3396)	23	1.6 (155)	30.0	11.8 (1763)	9
Sole	5.9 (1337)	50.6	22.5 (4094)	29	5.2 (1260)	48.4	20.3 (4082)	28
				ELEPHANT FOOT YAM				
P	1350 (5264)	1017	389 (1580)	74	1610 (6780)	892	423 (1725)	74
SC	14407 (7967)	1320	455 (2516)	78	2150 (12052)	1027	495 (2771)	74
TC	13753 (7723)	1300	458 (2484)	81	2215 (12556)	1025	520 (2930)	75
Sole	2060 (24600)	1365	564 (6686)	87	2750 (32340)	1100	775 (9311)	86
				GROUNDNUT				
P	6.2 (1002)	35.8	15.7 (2170)	40	1.1 (115)	11.5	4.5 (463)	17
SC	6.6 (1563)	35.0	13.2 (3305)	41	1.3 (161)	12.6	4.6 (798)	19
TC	6.8 (1588)	35.4	15.5 (3550)	39	1.0 (172)	12.6	4.5 (827)	18
Sole	7.0 (2017)	33.6	16.8 (4912)	39	7.0 (1815)	30.1	15.2 (4094)	36

P-paired row   SC-square cluster   TC-triangular cluster   pl.-plant
Figures in parantheses indicate yield in kg/ha

in floor crop cowpea, the per plant yield of cowpea was almost similar in intercropped and sole cropped situations during first year. So the indications are that during the first year even though the mild shade caused by cassava + banana has slightly increased the height and leaf area of cowpea, it may not be serious enough to inhibit its photosynthetic process and grain yield. During the second year, the situation was altogether different. The highly shaded habitat, because of banana resulted in very low grain yield in cowpea. George (1982) reported that cowpea was highly sensitive to shade and even under a shade of 25 per cent the yield was markedly reduced.

The higher per hectare yield of cowpea recorded in square clustered and triangular clustered planting of cassava compared to paired row planting may be attributed to the population difference in the respective situations. It may be noted that the per plant yield was almost the same in all situations because there was not much difference in the light received by floor crop and sole crop cowpea during the first year. In the second year the per plant yield was much lower in intercrop cowpea as compared to sole crop because of the thick shade caused by banana.

The difference in yield response observed between the sole and intercropped plots in both the years may be attributed to the difference in population between these two systems.

The marked decrease in the harvest index in floor crop cowpea during second year is attributed to the high haulm yield and very low grain yield.

4B.3.2 Elephant foot yam

The height of the floor crop elephant foot yam was not much different from the sole crop at 30 days stage during the first year (Fig. 12). But at subsequent stages floor crop elephant foot yam showed slight increase in height whereas in sole crop it remained almost the same. In the second year, the floor crop elephant foot yam was much taller than the sole crop from the initial stage itself. As in the first year, the height of plant remained more or less same throughout its growth.

The leaf area of floor crop elephant foot yam (Fig. 12) was not markedly different from that of the sole crop during the first year. But during the second year, the floor crop recorded a low leaf area as compared to the sole crop. The leaf area of both floor crop and sole crop elephant foot yam remained more or less the same throughout its growth during both the years.

At the time of germination of elephant foot yam the interspaces were comparatively free as cassava and banana were slow growing and had been planted in arranged geometry to leave sufficient interspace for floor crops. So as far as the floor crop elephant foot yam was concerned in the initial stages, the light situation was similar to sole crop and hence height of floor crop elephant foot yam was not considerably different. As the pseudostem of elephant foot yam cannot grow once fully formed, the height increase was due to the heliotropic movement of the shoot. The leaf area in elephant foot yam also cannot increase once it is formed, excepting in cases where additional pseudostem are produced. The conditions in the intercropped plots were similar to sole crop at the time of the formation of the pseudostem and hence the leaf area was not much different from that of sole crop during first year.

During the second year, the shade of banana which was dominant during the initial stage itself increased the height and reduced the leaf area of floor crop elephant foot yam.

The corm yield of floor crop elephant foot yam was perceptibly low during both the years (Table 24) as compared to the sole crop. Among the geometries of planting of cassava, square and triangular cluster planting resulted in higher yield of elephant foot yam than the paired row. In the second year, the performance of elephant foot yam was superior in both sole and intercropped situations.

The haulm weight of elephant foot yam (Table 24) was less in intercropped plots during both the years of planting. Paired row planting of cassava resulted in lowest shoot weight of elephant foot yam as compared to square cluster and triangular cluster.

The difference in corm yield observed between floor crop and sole elephant foot yam could arise from the difference in photosynthetic efficiency of the canopy during first year since the leaf area was not different. Evidently in floor crop elephant foot yam the canopy was less efficient photosynthetically because of the shade caused by cassava and banana towards the latter part of its growth (Fig. 15), eventhough the light regime on the floor crops was improved considerably after the harvest of the plant crop banana (Plate XIII).

In the second year since the elephant foot yam was planted in the full grown banana, the shade effect was conspicuous from the beginning itself. The shade situations in the field may be sensed by the plant from the sprouting stage itself and hence produced a taller canopy with less leaf area. During second year also yield depression in floor crop elephant foot yam was noticed but the percentage decrease was not as great as that of cowpea or groundnut. This shows that elephant foot yam can tolerate considerable shade and produce appreciable yield. Experiments on intercropping coconut gardens with various crops revealed that elephant foot yam can tolerate shade and produce reasonable yield (Nelliat and Krishnaji, 1976).

It may also be noticed that the general performance of both floor crop and sole elephant foot yam was better in the second year probably due to the favourable climatic conditions.

The dry matter production by floorcrop elephant foot yam (Table 24) was less than that of the sole crop. The intercropped elephant foot yam has recorded lesser harvest index (Table 24) than sole crop; however this reduction was much more drastic in the second year. This may be due to the greater shade caused by the banana in the second year.

The higher harvest index of floor crop elephant foot yam recorded in triangular clustered planting of cassava may be due to the better light availability to floor crop elephant foot yam. The lowest harvest index recorded in paired row may be due to the higher cassava population and the consequent shade caused from both the sides. There was not much difference in the harvest index of floor crop elephant foot yam in different geometries of planting of cassava during the second year.

4B.3.3 Groundnut

The growth and yield performance of groundnut was similar to cowpea. The first year data indicated that floor crop groundnut was taller than sole crop (Fig. 12). But in the second year the floor crop groundnut did not grow well and the height was much less than that in sole crop. The leaf area of floor crop groundnut (Fig.12) recorded slightly higher value as compared to the sole crop during the first year. In the second year, the trend was reversed and there was considerable reduction of leaf area of floor crop groundnut.

The behaviour of groundnut grown as a floor crop in cassava + banana cropping system was similar to that of cowpea. However, during second year, groundnut growth was poorer than cowpea as reflected by height and leaf area.

The first year results showed that on per plant basis the groundnut pod yield (Table 24) was not much different in the floor crop and sole crop situations. During the second year the pod yield of floor crop groundnut was drastically reduced as compared to the sole crop. The haulm weight of floor crop groundnut (Table 24) was not considerably different during first year, but during the second year it was only about one-third of that of sole groundnut.

The total dry matter production by groundnut (Table 24) showed similar trend as that of pod yield.

The harvest index of sole groundnut (Table 24) showed no difference as compared to floor crop groundnut during the first year. However, during the second year it was remarkably low in floor crop groundnut.

The yield performance of the floor crop groundnut was similar to the floor crop cowpea. But during second year the yield of groundnut was much lower than in floor crop cowpea. Probably groundnut is less tolerant to shade than cowpea. In cowpea the shading resulted in high vegetative growth, prolonged vegetative phase and low yield. In groundnut the growth of the plant from the beginning itself was weak and lanky, leaf area developed was low and the canopy was sparse finally resulting in a very low pod yield, haulm weight and dry matter production.

The light infiltration to the floor crop groundnut was similar to the sole crop during the first year and hence the harvest index was not much different. But during the second year the harvest index was only about half of that of sole groundnut due to the severe shade caused by banana which induced proportionately more vegetative growth and less pod yield.

A comparison of the harvest indices of the different floor crops shows that elephant foot yam has recorded a very high harvest index both under sole crop and floor crop situations. In fact, this is much higher than that of most of the tuber crops like cassava, yam, colocasia etc. This being a crop of fixed canopy size, the vegetative growth after the full formation of the canopy is negligible. So most of the photosynthates from the source are utilised for the development of the sink (corm). Even under shaded conditions there is not much reduction in the harvest index value indicating the higher solar energy conversion efficiency. So it can be presumed that elephant foot yam is more suitable as an intercrop even under comparatively dense shade situations. The performance of cowpea in shade was better than groundnut. Even though the harvest index of cowpea was lower than groundnut under shaded situations, total dry matter production was more in cowpea. In the case of groundnut both pod and haulm yield were poor under shaded conditions thereby indicating the poor adaptability of this crop for such situations.

4B.4 Total biomass

The total biomass (Fig. 13) production in intercropping systems was much higher than the sole crops. The total biomass production was superior when any one of the floor crops viz. cowpea, elephant foot yam, groundnut was grown in a cassava + banana cropping system. This tendency was observed irrespective of the geometry of planting of cassava. It may be noted that the leaf area index in these cropping systems were higher than that of any of the sole crops (Fig 14 a&b). The higher leaf area index and the consequent increased photosynthesis for most of the growing season may be the reason for the higher biomass

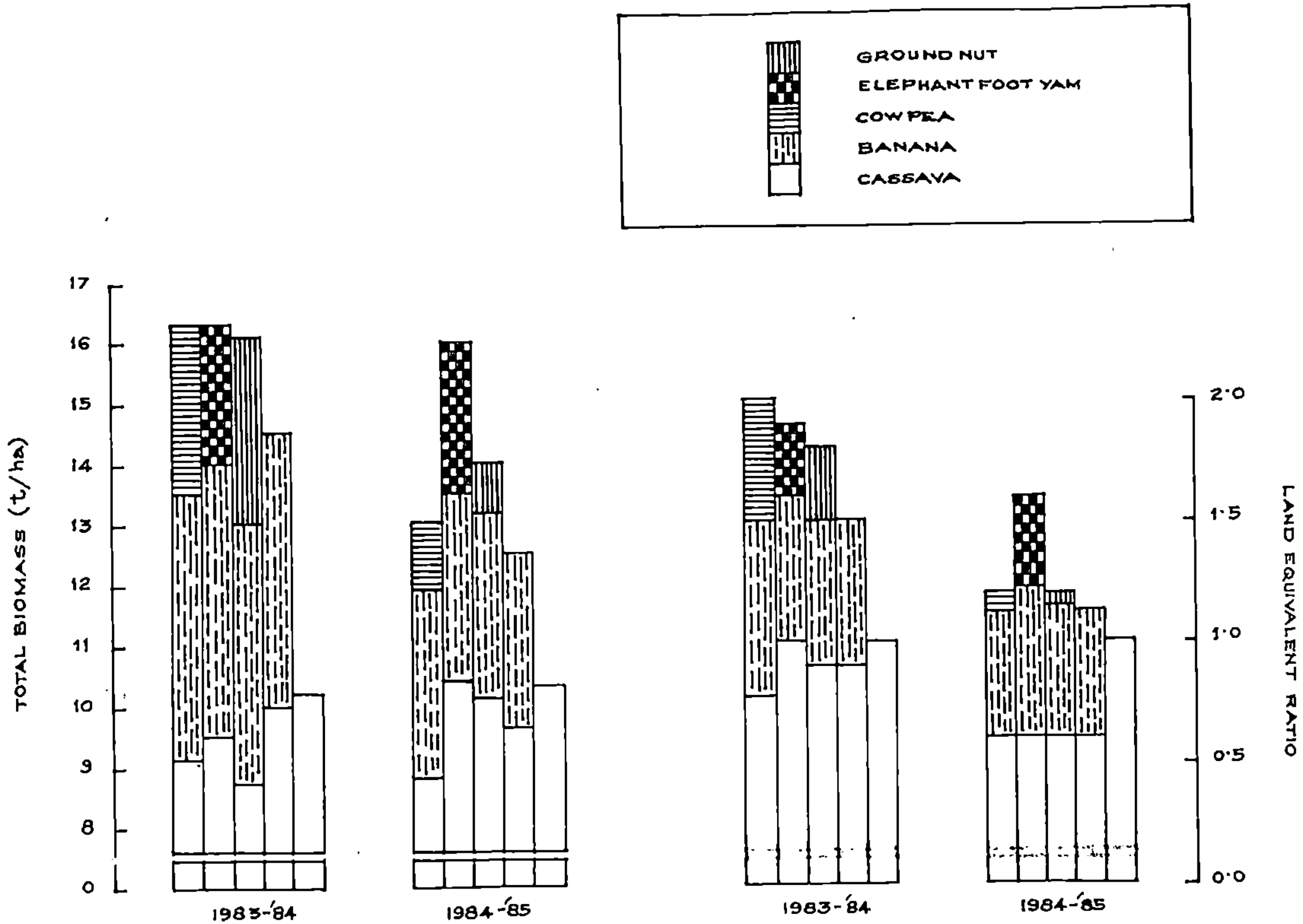


FIG. 13. TOTAL BIOMASS AND LAND EQUIVALENT RATIO IN A CASSAVA-BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR CROPS.

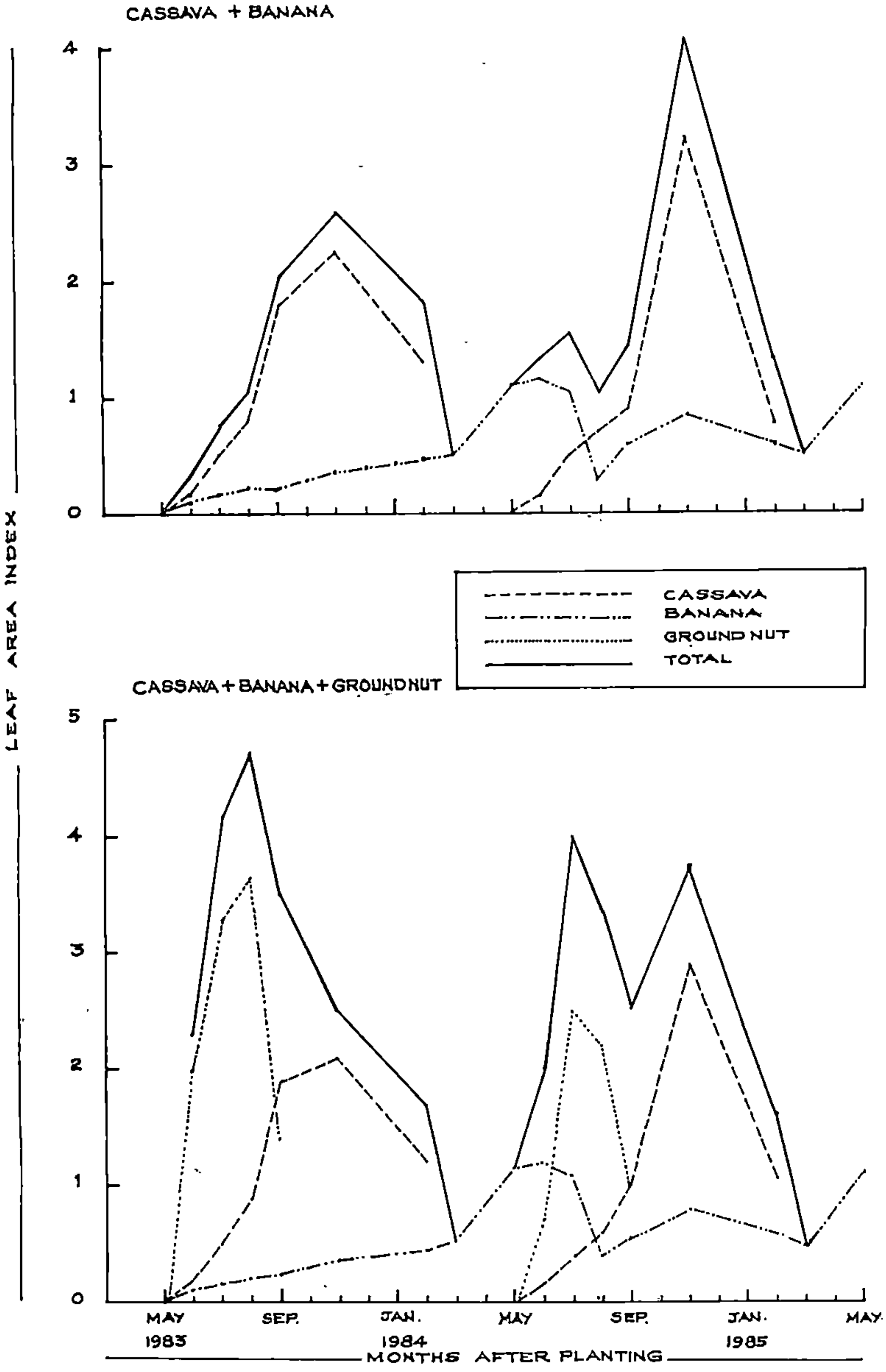


FIG. 14a. LEAF AREA INDEX IN CASSAVA-BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR-CROPS.

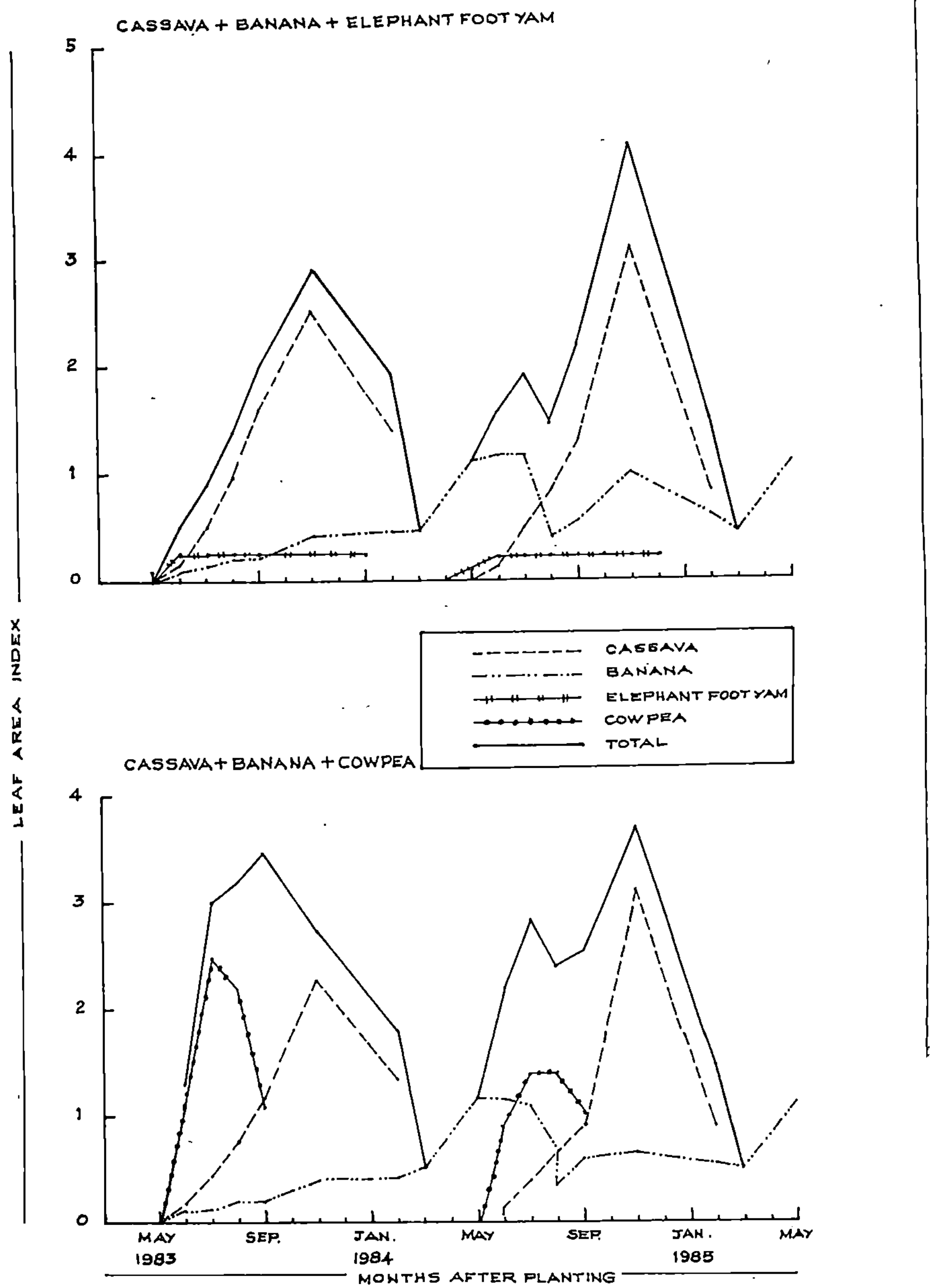


FIG. 14b. LEAF AREA INDEX IN CASSAVA-BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR CROPS.

recorded when a floor crop was introduced in a cassava + banana cropping system.

It can be seen that cowpea and groundnut are better dry matter producers than elephant foot yam (Fig. 13). This may be because they were able to develop very high leaf area index within a short period. This is in spite of the shorter duration of cowpea and groundnut compared to elephant foot yam.

Since cowpea and groundnut were not successful during the second year for the intense shade cast by banana (Fig. 15), the total biomass production was also low. The combinations involving elephant foot yam has given almost the same quantity of biomass as in the first year because of the reasons already explained.

4B.5 Land Equivalent Ratio

In the first year trial the total land equivalent ratio (LER) was maximum in cassava + banana + cowpea followed by cassava + banana + elephant foot yam and cassava + banana + groundnut (Fig. 13). The lowest value was in cassava + banana. During the second year the maximum value of 1.58 was recorded in cassava + banana + elephant foot yam. The values in other treatments were almost equal.

The maximum LER value of cassava was recorded in elephant foot yam intercropped plots during both the years. The LER value of banana was not influenced by different intercrops.

With respect to the floor crops, the maximum LER of 0.56 was recorded by floor crop cowpea during first year. But during

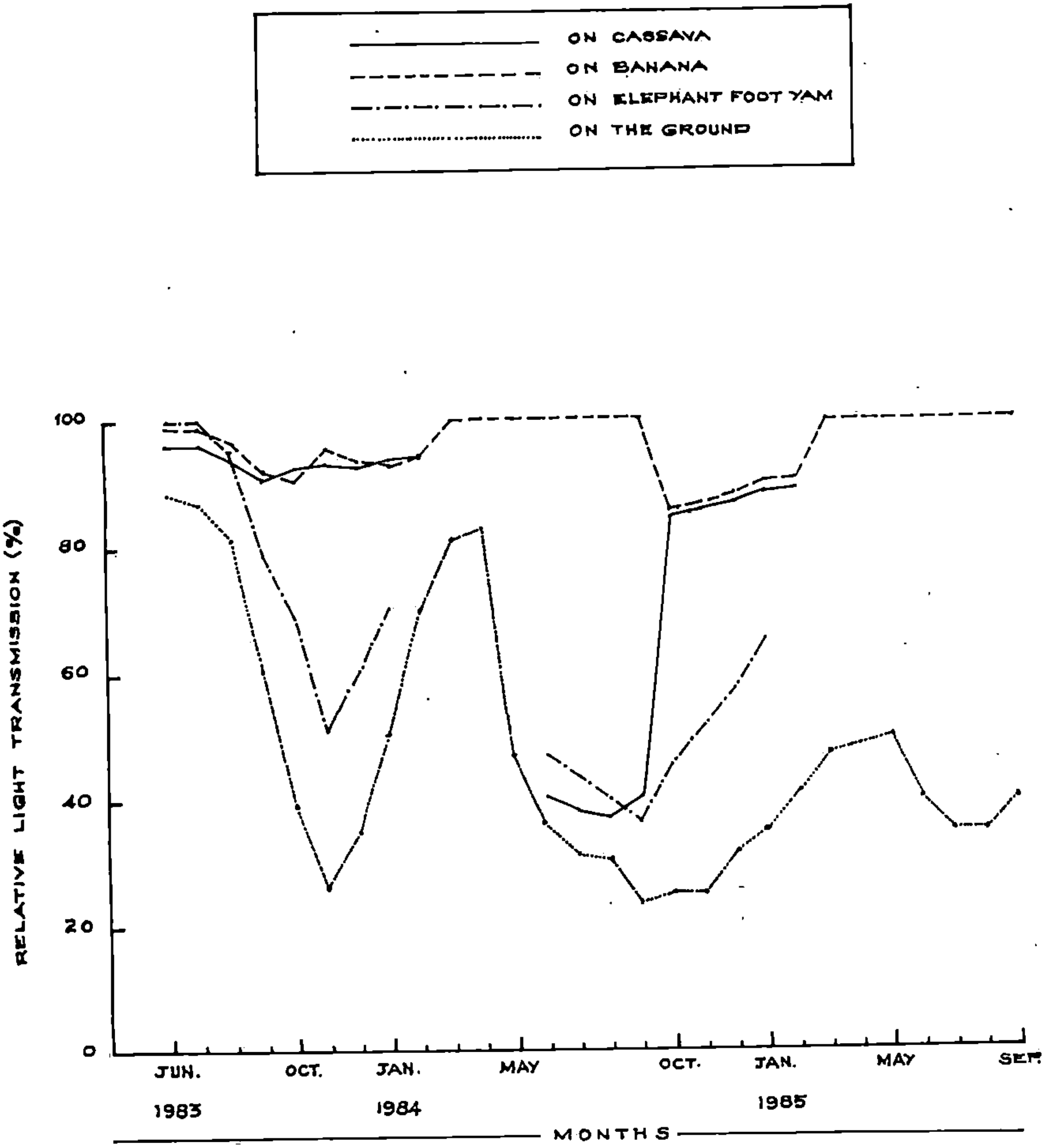


FIG. 15. RELATIVE LIGHT TRANSMISSION ON TO DIFFERENT CROPS IN CASSAVA + BANANA + ELEPHANT FOOT YAM INTERCROPPING.

the second year, cowpea and groundnut recorded very low LER values and the highest value was recorded by elephant foot yam. The square clustered and triangular clustered cassava planting resulted in a higher LER of floor crop elephant foot yam during both the years. The LER of cowpea and groundnut during the first year cropping was better than elephant foot yam due to the following reasons. The cowpea and groundnut were not much exposed to shade during the first year(Plate VII&IX) and their per plant yield was not affected whereas elephant foot yam was subjected to considerable shade of cassava and banana after about four months growth. Since elephant foot yam takes about eight months for maturity, for half of its life period it was grown in shade with only about 50 to 70 per cent of the normal sunlight (Fig. 15). As a result the per plant yield in floor crop elephant foot yam was lower. Another reason was that the floor crop cowpea and groundnut were grown at about 50 per cent of the sole crop population whereas that of elephant foot yam was only about 40 per cent .

During the second year the light received on the elephant foot yam growing below banana was very low (Plate XII). Because of the shade tolerating ability of elephant foot yam the LER recorded was higher as compared to cowpea and groundnut which are very much susceptible to shade. In cassava also the LER during the second year was low because of the dominating effect of banana. This is evident from the light regime on the cassava canopy depicted in Fig. 15.

Eventhough the total LER during the first year was highest in the intercropping system, cassava + banana + cowpea, conside-ring the two years performance, cassava + banana + elephant foot yam seems to be the best.

4B.6 Economics

The gross income and the net income (Fig. 16) were maximum in cassava + banana + elephant foot yam during both the years. The results of the first year trial showed that the cassava + banana + elephant foot yam with the cassava in square clustered planting recorded the maximum gross and net incomes. The next year also the result was similar but the triangular planting of cassava gave the maximum value; the difference between square clustered and triangular clustered planting was not appreciable.

In the first year result, the returns from cassava + banana + cowpea and cassava + banana + groundnut cropping systems did not remarkably vary. During second year, cowpea and groundnut were totally unsuitable as floor crops in the cassava + banana cropping system, as is evident from the net return.

Considering the benefit-cost ratio also, cassava + banana + elephant foot yam was the best during both the years (Fig. 17). The superior performance of elephant foot yam in this cropping system when cassava was planted in square cluster or triangular cluster is reflected in the benefit-cost ratio. Hence cassava + banana + elephant foot yam cropping system with cassava planted in square cluster or triangular cluster is viable economically.

The cropping system cassava + banana and sole cassava were inferior when the net returns were considered. During the

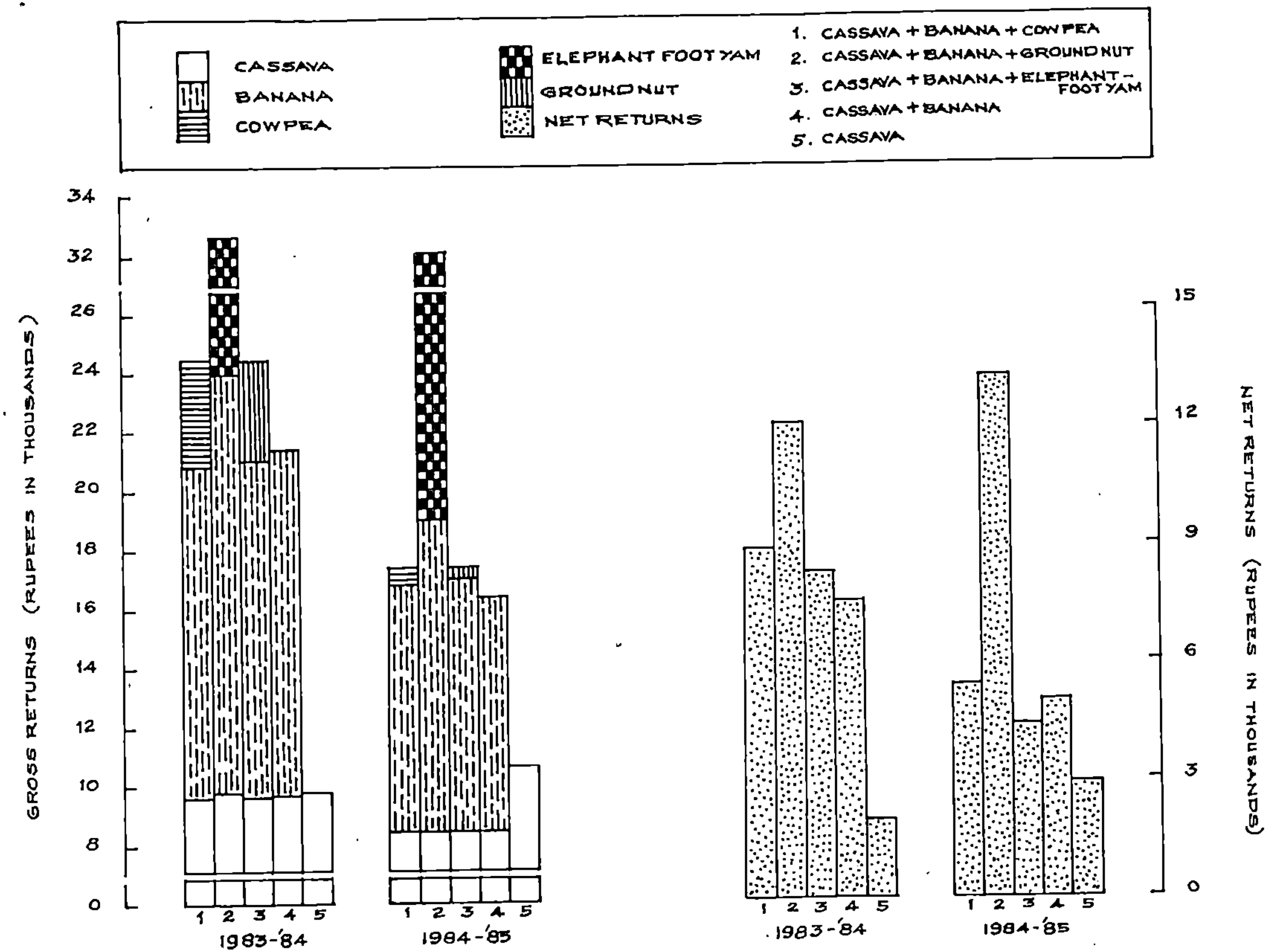


FIG.16. GROSS AND NET RETURNS IN A CASSAVA-BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR CROPS.

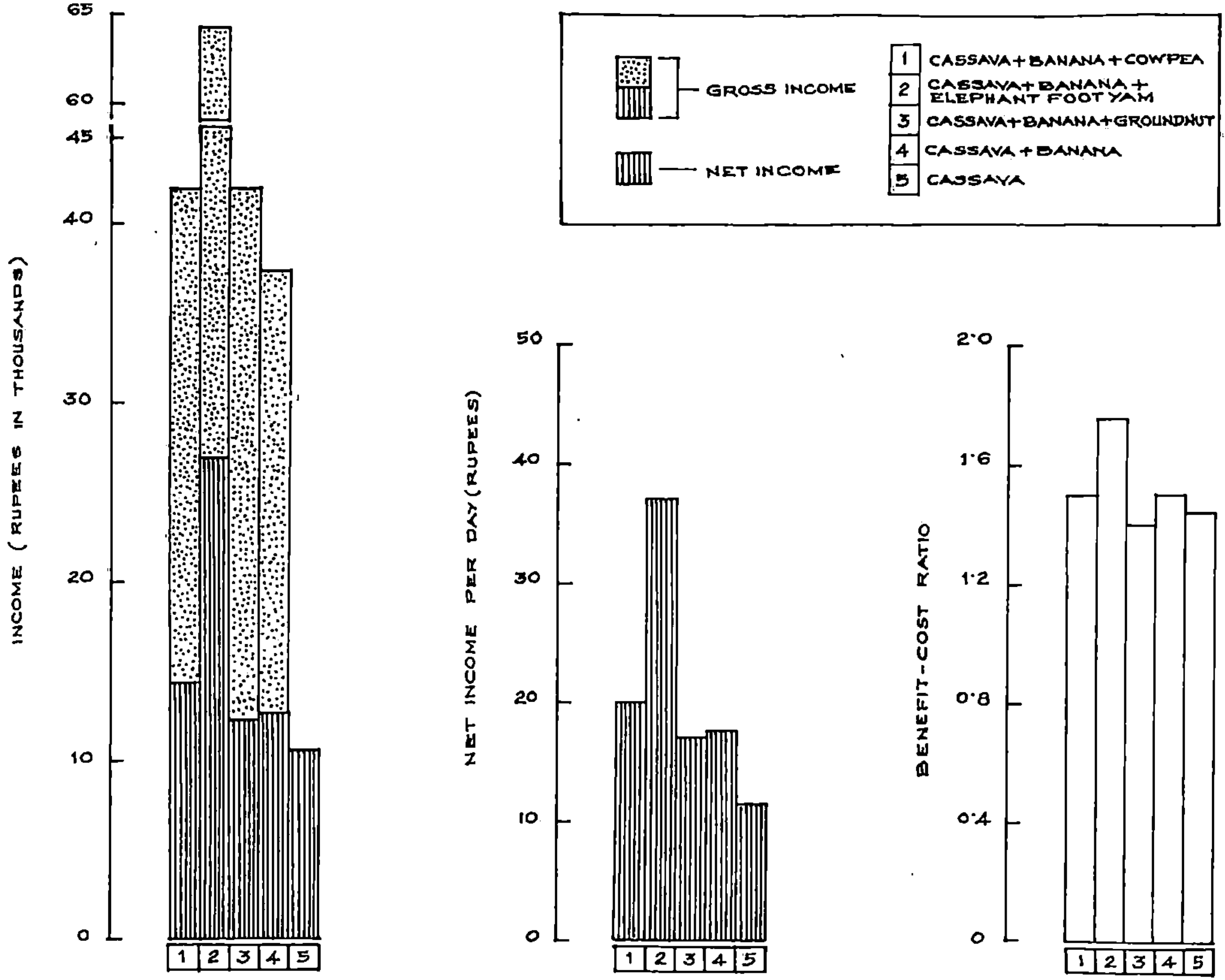


FIG.17. ECONOMICS OF CASSAVA-BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR CROPS.

second year, growing cowpea or groundnut in cassava + banana reduced the profitability of the system and the benefit-cost ratios were lower than that of cassava + banana or cassava sole.

It can be seen that among the cropping systems cassava + banana + elephant foot yam has given the maximum net income. This is followed by cowpea floorcropping. Among the floor crops, groundnut has given the lowest net income. Net income per day and benefit-cost ratio also followed the same trend. This shows that elephant foot yam is the most profitable floor crop in a cassava + banana intercropping system.

4B.7 Nutrient uptake in different cropping systems

The N, P, K, Ca, Mg and S content of cassava leaves, stem, petiole and tuber were estimated at the time of harvest and were found to be not significantly different in the various cropping systems in most of the cases. In some cases though the results were significant no definite trend could be observed. Hence the total nutrient removal by the component crops in the intercropping systems were worked out for studying the soil depletion by different cropping systems.

The cassava in different cropping systems were on par as far as the uptake of these nutrients was concerned (Fig 18). On an average cassava removed 103, 12, 122, 103, 21 and 16 kg per hectare of N, P, K, Ca, Mg and S respectively during the first year. The respective values during the second year were 127, 12, 137, 147, 31 and 20 kg per hectare. There was not much difference in the uptake by sole crop compared to intercropped

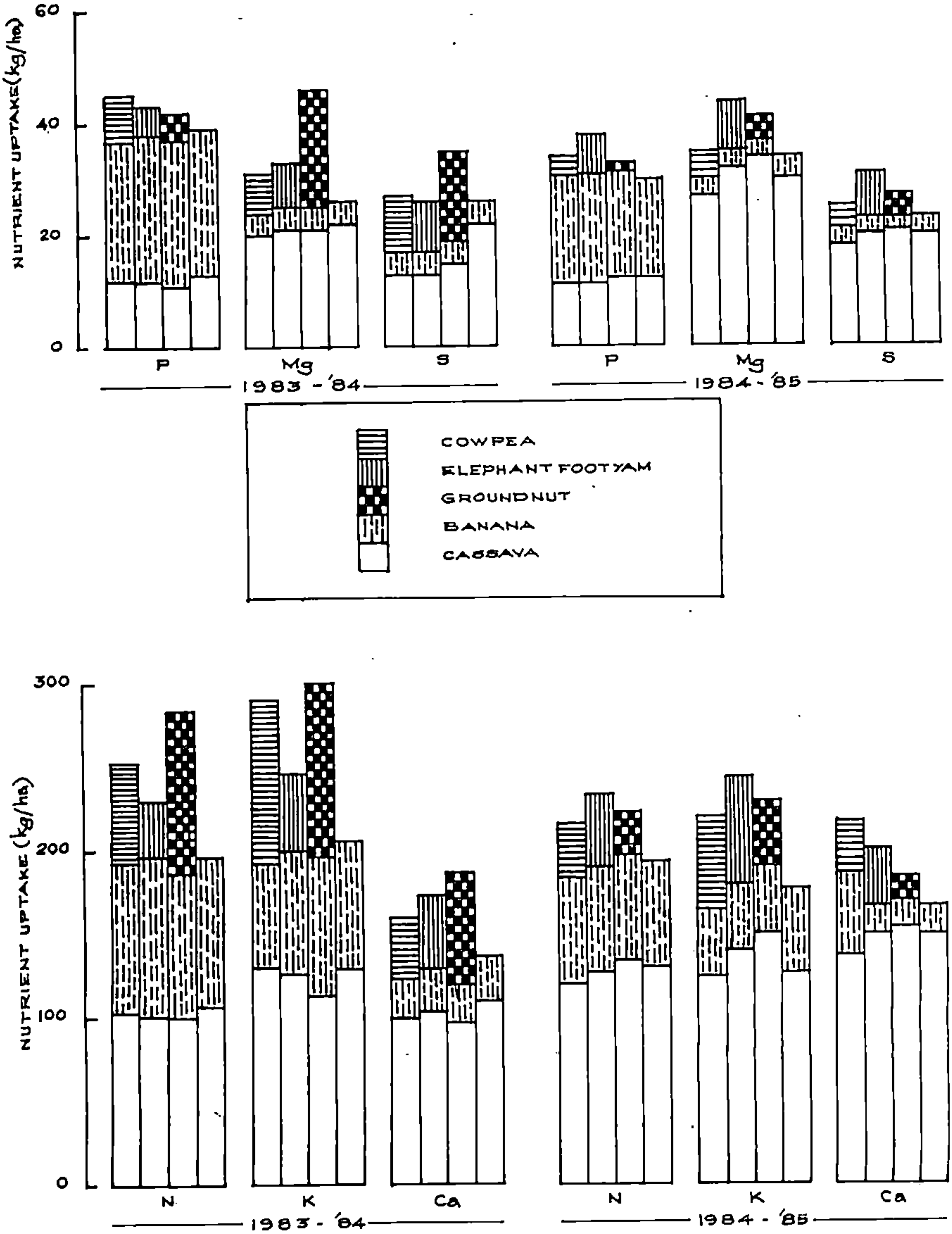


FIG.18. NUTRIENT UPTAKE IN CASSAVA - BANANA CROPPING SYSTEM WITH DIFFERENT FLOOR CROPS.

cassava and hence these are not separately represented in the figure. Irizarry and Rivera (1983) reported nutrient removal to the extent of 204, 12, 222, 86 and 33 kg per hectare of N, P, K, Ca and S respectively for a cassava crop of 10 months duration in an intercropping system. The comparatively higher nutrient removal may be due to the higher tuber yield they had obtained (37.5 t/ha) compared to the present study.

The nutrient status of the different plant parts were not significantly different in intercrop and sole crop banana. The uptake values worked out for banana in intercropping systems are 89, 26, 75, 25, 4 and 4 kg per hectare of N, P, K, Ca, Mg and S for the plant crop and 63, 20, 54, 16, 3 and 2 kg per hectare for the ratoon crop of banana. The N, P, K, Ca, Mg and S uptake by irrigated banana crop (c.v. Palayankodan) were reported to be 246, 16, 343, 100, 50 and 10 kg per hectare respectively (Rajeevan,1985). However, in this experiment the banana was rainfed and its population was only half of that of the sole crop and hence a lower uptake value was recorded.

The floor crop cowpea on an average removed N, P, K, Ca, Mg and S at the rate of 64, 7, 96, 37, 7 and 10 kg per hectare respectively during the first year and 34, 3, 38, 21, 5 and 4 kg per hectare respectively during the second year.

In the floor crop elephant foot yam the corresponding nutrient uptake values were 36, 5, 47, 42, 8 and 7 kg per hectare during first year and 43, 7.3, 46, 36, 8 and 9 kg per hectare during second year.

The nutrient removal by floor crop groundnut was 97, 5, 102, 66, 21 and 16 kg per hectare of N, P, K, Ca, Mg and S respectively during first year and 24, 2, 26, 15, 4 and 4 kg per hectare during second year cropping.

The total nutrient removal (Fig 18) was higher in all the polycultures consisting of three component crops. During the first year the total removal of N, P, K, Ca, Mg and S was maximum in cassava + banana + groundnut cropping system. This is mainly due to the uptake of these nutrients by groundnut since the cassava + banana was a common factor in all the cropping systems compared. During the second year the maximum removal of all the nutrients except Ca was from cassava + banana + elephant foot yam. It may be recalled that during this year, elephant foot yam gave a satisfactory performance while cowpea and groundnut were practically a failure. This indicates that in polyculture the successful component species should be manured separately and adequately to prevent soil deterioration in the long run.

4B.8 <u>Soil nutrient status after the cropping</u>

The data on organic C, total N, available P, K, Ca, Mg and S and extractable Fe, Mn, Zn and Cu in soil after the two year cropping are given in Tables 25, 26 and 27. The post crop organic C, total N and available K status of the soil were not significantly different during both the seasons. But there was noticeable difference with respect to S. The extractable SO_4 of the soil after the cropping was higher in all the three crop

Table 25. Effect of different floor crops on the soil nutrient status after the first year cropping in a cassava + banana intercropping system

Cropping systems	Organic carbon (%)	Total N (%)	Available P (ppm)	Available K (ppm)	Exchangeable Ca (ppm)	Exchangeable Mg (ppm)	Exchangeable SO4 (ppm)
C+B+CP	1.214	0.116	49	206	367	52	41
C+B+EFY	1.208	0.109	37	213	426	64	40
C+B+GN	1.348	0.111	81	318	390	51	39
C+B	1.155	0.102	55	192	308	46	23
C.D.(0.05)	NS	NS	23	NS	NS	NS	12
SEM +/-	0.046	0.004	8	46	27	4	4
Sole Cassava	1.076	0.099	57	200	425	45	28

Table 26. Effect of different floor crops on the soil nutrient status after the second year cropping in a cassava + banana intercropping system

Cropping systems	Organic Carbon (%)	Total N (%)	Available P (ppm)	Available K (ppm)	Exchangeable Ca (ppm)	Exchangeable Mg (ppm)	Exchangeable SO4 (ppm)
C+B+CP	0.718	0.131	99	217	316	39	41
C+B+EFY	0.855	0.107	133	251	360	35	40
C+B+GN	0.798	0.128	112	217	443	34	40
C+B	0.745	0.107	98	202	288	32	23
C.D.(0.05)	NS	NS	NS	NS	NS	NS	15
SEM +/-	0.034	0.017	20	22	96	3	5
Sole Cassava	0.750	0.098	72	219	283	36	23

Table 27. Effect of different floor crops on the micronutrient status of soil after the two years cropping in a cassava + banana intercropping system

Cropping systems	Acid extractable Zn (ppm)	Acid extractable Cu (ppm)	Acid extractable Mn (ppm)	Acid extractable Fe (ppm)
C+B+CP	3.7	2.3	42	21
C+B+EFY	3.9	2.3	44	21
C+B+GN	4.3	2.4	43	20
C+B	3.4	2.3	41	21
C.D. (0.05)	NS	NS	NS	NS
SEM +/-	0.3	0.2	4.5	4.5
Sole Cassava	3.1	2.8	45	21

C-cassava B-banana CP-cowpea EFY-elephant foot yam GN-groundnut polycultures during both the years as compared to cassava + banana.

It is evident from the results that in spite of the intensive cropping practice, the nutrient status of the soil was not appreciably affected. This is evident from the lack of significant differences between sole cassava, cassava + banana and other cropping systems. This could be due to the fact that component crops in the cropping systems were separately manured and plant residues were recycled. The higher extractable SO_4 status observed in cowpea and groundnut intercropped plots could be due to the incorporation of legume haulm to the soil in these treatments. It can be seen that maximum uptake of S was seen in floor crop groundnut followed by cowpea. In the case of elephant foot yam, farm yard manure was applied to each pit at the rate of 2 kg and this could be the source of high extractable SO_4 noticed in elephant foot yam intercropped plots.

The acid extractable Zn, Fe, Cu and Mn status of the soil were also not significantly influenced by the cropping systems. This shows that there is no appreciable depletion of any of the nutrients by the cropping systems practised with respect to these micronutrients. It may be seen that considerable quantity of haulm of the intercropped plants were incorporated in the case of groundnut and cowpea (Table 24). In the case of elephant foot yam there was higher rate of farm yard manure applied. Apart from this, considerable quantity of nutrients may be recycled by the leaf fall of cassava and intercrops.

The salient findings from this trial are that in cassava + banana cropping system, the tuber yield of cassava planted in different geometries was not reduced due to the introduction of a floor crop of cowpea or groundnut or elephant foot yam. The intercropping systems produced more biomass than any of the sole crops. The cassava + banana + elephant foot yam cropping system gave the highest biomass, LER, net return and benefit: cost ratio during both the years. The crop association cassava+ banana + cowpea and cassava + banana + groundnut were economically viable during the first year. But during the second year, the intercrops cowpea and groundnut failed as they were sown under the thick shade of standing banana crop. Among the floor crops, only elephant foot yam was able to perform well during both the years because it was able to tolerate the shade to a great extent. The cowpea and groundnut are shade sensitive and hence not recommended for thickly shaded situations. Elephant foot yam is noted for its very high harvest index even under shaded situations. From the data on nutrient uptake it is suggested that the component species in a cropping system should be manured separately and adequately.

Trial III. Evaluation of Sequential Intercropping in Paired Row Cassava with Legumes and the Response of Intercrops to Fertilizers

4C.1 Cassava

4C.1.1 Growth characters

4C.1.1.1 Height

The height of cassava in paired row (Plate XIV) in general was not influenced by the cropping systems or the fertilizer levels applied to the intercrops during both the years (Table 28 a&b). Eventhough the control vs. rest comparisons were significant at some of the stages of growth, no specific trend could be noticed.

In the cropping system cassava + groundnut + red gram the cassava plants were taller at later stages of growth.

The intercrops cowpea and groundnut (Plate XV&XVI) were short statured and of short duration. They were harvested by the time the cassava canopy was fully developed. Hence cowpea and groundnut did not show much influence on cassava height. In the case of cassava + groundnut + red gram cropping system (Plate XVII) the red gram also was competitively elongating (Table 38) along with cassava during the later stages. Probably to avoid competition cassava tried to outgrow red gram resulting in taller plants in that treatment.

Table 28a. Effect of sequential intercropping with legumes and fertilizer levels to the intercrops on the height of cassava in paired row at different stages of growth (1983-84)

Cropping systems	30	60	90	120	150	210	270
			Days after planting (Height in cm)				
C+CP-CP	32	55	84	110	162	188	203
C+CP-GN	34	56	96	111	172	195	205
C+GN-CP	33	55	82	102	154	180	193
C+GN-GN	33	58	83	109	157	186	202
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS
SEM +/-	1.4	1.1	2.8	4.0	3.5	4.4	5.0
Fertilizer levels							
MO	32	54	83	103	163	188	204
M1	33	57	90	112	158	182	202
M2	34	58	85	109	163	186	196
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS
SEM +/-	1.2	1.0	2.4	3.5	3.0	3.8	4.3
Controls							
C(N)+GN	31	53	67	118	173	195	218
C(N)+CP	29	60	68	122	170	190	216
C(P)	34	57	73	121	176	193	208
C(N)	31	53	74	117	171	182	207
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS
SEM +/-	2.4	1.1	4.8	6.9	6.0	7.6	8.6

C-cassava CP-cowpea GN-groundnut. MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. P-paired row N-normal planting

Table 28b. Effect of sequential intercropping with legumes and fertilizer levels to the intercrops on the height of cassava in paired row at different stages of growth (1984-85)

Cropping systems	Days after planting (Height in cm) 30	60	90	120	150	210	270
C+CP-CP	22	37	58	89	137	196	230
C+CP-GN	20	35	58	88	134	194	243
C+GN-CP	20	36	61	92	139	200	246
C+GN-GN	19	35	61	91	140	201	246
C.D. (0.05)	0.9	NS	NS	NS	5.0	5.0	NS
SEM +/-	0.4	1.2	1.8	1.8	1.8	2.0	2.0
Fertilizer levels							
MO	20	35	59	89	130	192	239
M1	20	35	61	92	138	198	243
M2	22	37	59	90	144	202	243
C.D. (0.05)	NS	NS	NS	NS	5.0	NS	NS
SEM +/-	0.3	1.1	1.6	1.6	1.6	1.8	1.8
Controls							
C(N)+GN	19	36	61	91	140	189	214
C(N)+CP	19	37	60	101	145	186	216
C(P)+GN+RG	20	36	61	92	140	201	245
C(P)	20	34	55	88	130	178	203
C(N)	19	37	65	94	133	177	201
C.D. (0.05)	NS	NS	NS	9.1	9.0	10.0	NS
SEM +/-	0.7	1.2	3.2	3.2	3.2	3.5	3.1

C-cassava CP-cowpea GN-groundnut. MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. P-paired row N-normal planting

4C.1.1.2 Leaf area

The leaf area of cassava (Table 29 a&b), in general, was not significantly influenced by the cropping system. At some stages though it was significant no definite trend could be obtained.

The levels of fertilizers applied to the intercrops increased the leaf area of cassava in general and was significant at 60, 150, 210 and 270 days after planting during the first year and 30, 120, 150, 210 and 270 days after planting during the second year. In all these cases significantly higher leaf area was observed when the intercrops were fertilized at the highest dose (M2). The results indicated that cassava derived nutrients from the fertilizers applied to the intercrops. It can be seen from the microplot experiment using radiophosphorus that the root activity of cassava planted on ridges was extended into the interspaces also (Table 50, Fig. 25).

The influence of fertilizers applied to the intercrops was conspicuous on leaf area from 150 days after planting during both the years. This is probably due to the basal dose of fertilizer applied to the second season intercrop which failed to come up. This might have resulted in considerable residual effect of the fertilizer applied to the intercrop which probably was utilised by cassava. In a wheat-moong-maize cropping system, Subbiah and Sachdev (1982) observed considerable residual effect of the fertilizer applied to wheat on the succeeding moong and that 25 per cent of the N fertilizer applied to the wheat was utilized by the moong crop following it.

Table 29a. Effect of sequential intercropping with legumes and fertilizer levels to the intercrops on the leaf area of cassava in paired row at different stages of growth (1983-84)

Cropping systems	30	60	90	120	150	210	270
	Days after planting (Leaf area in m2/plant)						
C+CP-CP	0.299	0.441	0.894	1.652	2.011	1.354	0.817
C+CP-GN	0.284	0.570	0.986	1.624	2.180	1.529	0.923
C+GN-CP	0.284	0.499	0.958	1.674	2.405	1.435	0.980
C+GN-GN	0.263	0.524	0.978	1.718	2.584	1.531	1.135
C.D. (0.05)	NS	0.029	NS	NS	NS	NS	NS
SEM +/-	0.019	0.012	0.036	0.048	0.040	0.094	0.033
Fertilizer levels							
MO	0.276	0.470	0.941	1.691	2.251	1.291	0.910
M1	0.265	0.498	0.983	1.662	2.299	1.415	0.973
M2	0.306	0.560	0.937	1.650	2.335	1.556	1.010
C.D. (0.05)	NS	0.034	NS	NS	0.115	0.242	0.095
SEM +/-	0.019	0.010	0.031	0.041	0.035	0.081	0.029
Controls							
C(N)+GN	0.273	0.481	0.981	1.518	2.181	1.166	0.933
C(N)+CP	0.234	0.406	0.987	1.507	2.137	1.163	0.981
C(P)	0.296	0.507	0.924	1.434	2.241	1.212	0.956
C(N)	0.282	0.498	1.024	1.411	2.162	1.158	0.939
C.D. (0.05)	NS	0.058	NS	0.240	NS	NS	NS
SEM +/-	0.030	0.020	0.063	0.080	0.070	0.163	0.057

C-cassava CP-cowpea GN-groundnut. MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. P-paired row N-normal planting

Table 29b. Effect of sequential intercropping with legumes and fertilizer levels to the intercrops on the leaf area of cassava in paired row at different stages of growth (1984-85)

Cropping systems	30	60	90	120	150	210	270
	Days after planting (Leaf area in m2/plant)						
C+CP-CP	0.285	0.725	1.010	1.689	2.463	1.506	1.144
C+CP-GN	0.301	0.793	1.064	1.760	2.592	1.513	1.146
C+GN-CP	0.308	0.790	1.142	1.909	2.547	1.502	1.143
C+GN-GN	0.279	0.731	1.108	1.900	2.797	1.501	1.170
C.D. (0.05)	NS	NS	NS	0.090	NS	NS	0.017
SEM +/-	0.015	0.028	0.024	0.036	0.053	0.015	0.007
Fertilizer levels							
MO	0.272	0.689	1.050	1.611	2.570	1.418	1.140
M1	0.290	0.802	1.074	1.811	2.623	1.539	1.152
M2	0.320	0.823	1.120	1.904	2.607	1.560	1.160
C.D. (0.05)	NS	NS	0.068	0.103	0.155	0.042	0.019
SEM +/-	0.013	0.025	0.020	0.031	0.046	0.013	0.006
Controls							
C(N)+GN	0.290	0.898	1.185	1.821	2.250	1.410	1.151
C(N)+CP	0.310	0.829	1.163	1.814	2.224	1.401	1.144
C(P)+GN+RG	0.300	0.750	1.119	1.800	2.821	1.550	1.160
C(P)	0.250	0.751	1.201	1.786	2.236	1.405	1.142
C(N)	0.280	0.938	1.286	1.892	2.341	1.392	1.145
C.D. (0.05)	NS	NS	NS	NS	NS	0.268	0.073
SEM +/-	0.033	0.030	0.049	0.041	0.062	0.093	0.025

C-cassava CP-cowpea GN-groundnut. MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. P-paired row N-normal planting

Comparison between the control and other treatments were not significant.

4C.1.2 Yield attributes

4C 1.2.1 Number, length and girth of tuber

The number of tubers per plant (Table 30) was not significantly influenced by cropping systems or the fertilizer levels given to the intercrops. The control vs. rest of the treatments were on par.

The length of tuber also showed similar results.

The cropping systems had no significant effect on girth of tuber (Table 30). However, it increased with higher levels of fertilizers applied to the intercrops. The M2 level of fertilizer was significantly superior to M0 level during both the years.

The tuber number is decided during the early stage itself (Hunt et al., 1977); it takes some time for the cassava plants on the ridges to send out roots into the rhizosphere of the intercrops. Hence the fertilizers applied to the intercrops were not available to cassava during the early stage resulting in more or less uniform number of tubers in all the plots.

The girth of the tubers was influenced by the fertilizer applied to the intercrops since tuber bulking continued upto the harvest of the crop. It may also be seen that the leaf area of cassava was increased due to the effect of higher levels of fertilizers applied to the intercrops (Table 29 a&b). This might have resulted in higher carbohydrate synthesis and its

Table 30. Effect of sequential intercropping with legumes and the fertilizer levels to the intercrops on number, length, girth and yield of tuber of cassava in paired row

Cropping systems	(1983-84) No.of tubers	Tuber length (cm)	Tuber girth (cm)	Tuber Yield (t/ha)	(1984-85) No.of tubers	Tuber length (cm)	Tuber girth (cm)	Tuber yield (t/ha)
C+CP-CP	6.6	38.2	16.5	15.78	8.7	39.0	17.2	19.10
C+CP-GN	7.4	38.5	16.3	17.42	9.7	38.5	17.5	18.25
C+GN-CP	6.6	36.8	16.7	17.50	9.6	37.8	18.0	19.81
C+GN-GN	7.9	37.5	16.2	15.97	8.9	39.2	17.2	18.21
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	0.5	0.7	0.2	0.99	0.4	0.6	0.3	0.90
Fertilizer levels								
MO	7.0	37.5	16.0	14.39	9.2	38.0	16.5	18.18
M1	6.9	38.0	16.6	16.86	9.0	38.5	17.5	18.10
M2	7.4	38.0	16.8	19.02	9.4	39.3	18.1	20.20
C.D.(0.05)	NS	NS	0.6	2.48	NS	NS	0.9	NS
SEM +/-	0.4	0.7	0.2	0.86	0.4	0.6	0.3	0.78
Controls								
C+GN+RG	-	-	-	-	9.5	38.4	17.3	19.51
C(N)+GN	7.3	37.5	16.0	18.52	10.0	38.8	17.4	19.62
C(N)+CP	7.3	38.4	16.5	18.11	9.7	38.2	17.5	19.75
C	7.7	38.6	16.2	17.35	8.0	39.2	17.5	20.20
C(N)	7.7	38.0	16.3	16.88	10.0	38.5	17.7	20.51

C-cassava in paired row C(N)-cassava in normal planting
CP-cowpea GN-groundnut RG-red gram. MO, M1 and M2 are 0, 50 and 100 % of the recommended sole crop fertilizer dose.

accumulation in the tubers. Bhat (1978) also observed an increase in tuber girth of intercropped cassava due to the effect of fertilizers applied to the intercrops.

40.1.2.2 Yield of tuber

The tuber yield (Table 30) was not significantly influenced by the cropping systems. The intercrops of cowpea and groundnut were having a smaller root system confined to a radius of about 5 cm and depth of 5 to 10 cm (Fig. 19). In cassava + groundnut + red gram, the root systems of the three component species were more or less exclusive. However, some of the cassava roots were found in the interspaces at 110 days stage which may offer competition to the intercrops for nutrients and water (Fig. 20). Experiments conducted at College of Agriculture, Vellayani also showed that cassava yield was not affected by growing groundnut as intercrop in cassava (Sheela, 1981). Contrary to this, Anilkumar (1984) from the same station recorded a lower yield of cassava both in paired and normal methods of planting when intercropped with cowpea or groundnut. He ~~had~~ found that the yield depression was more with cowpea as intercrop. One of the reasons for the varying results obtained in the present study may be that the cowpea cv. C. 152 used here is comparatively nonspreading as compared to the cv. Kanakamani used by Anilkumar (1984). Bridgit (1985) observed an increase in tuber yield of cassava when intercropped with groundnut.

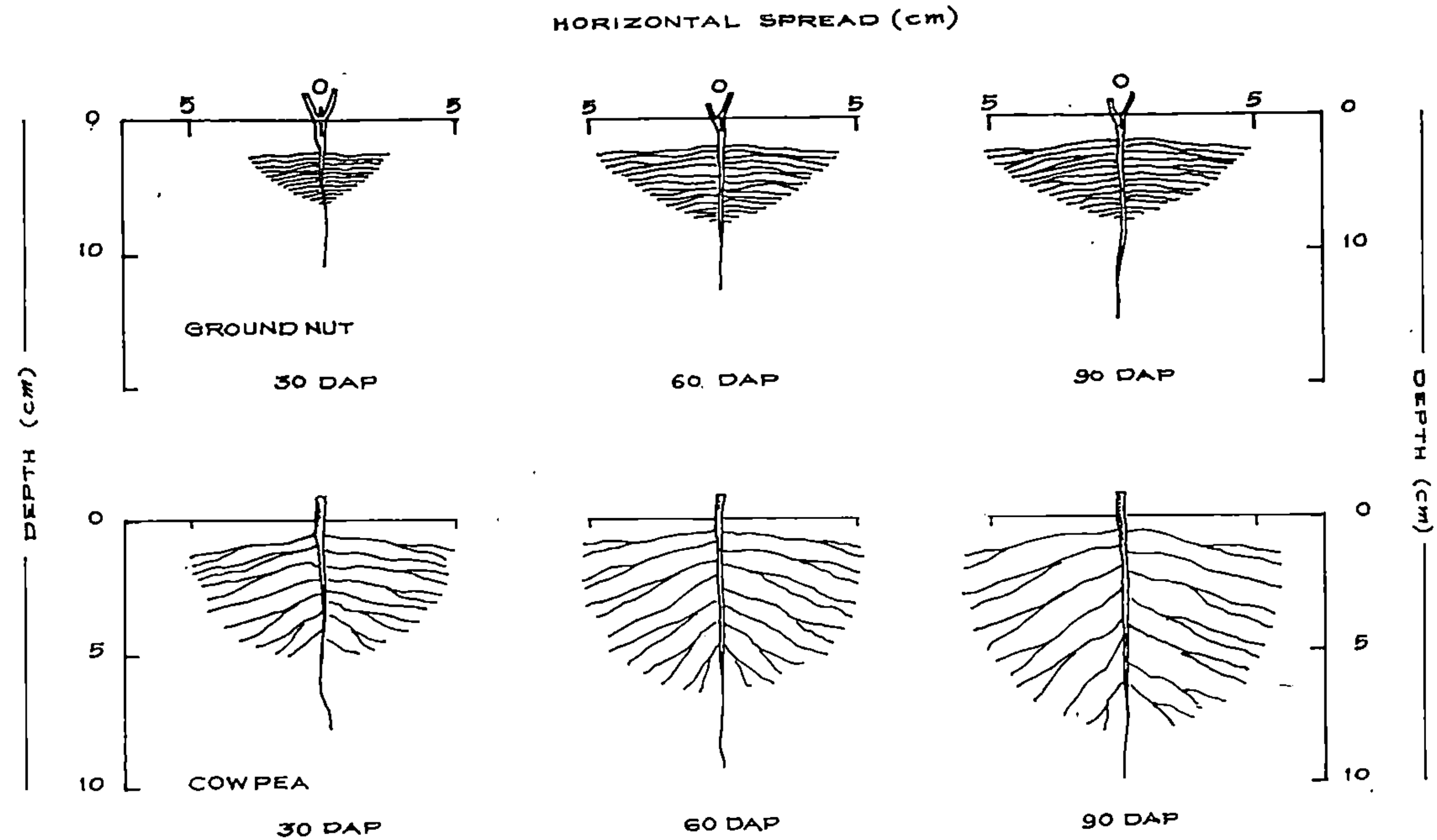


FIG. 19. ROOT DISTRIBUTION PATTERN OF GROUND NUT AND COW PEA AT 30, 60 AND 90 DAYS AFTER PLANTING (DAP).

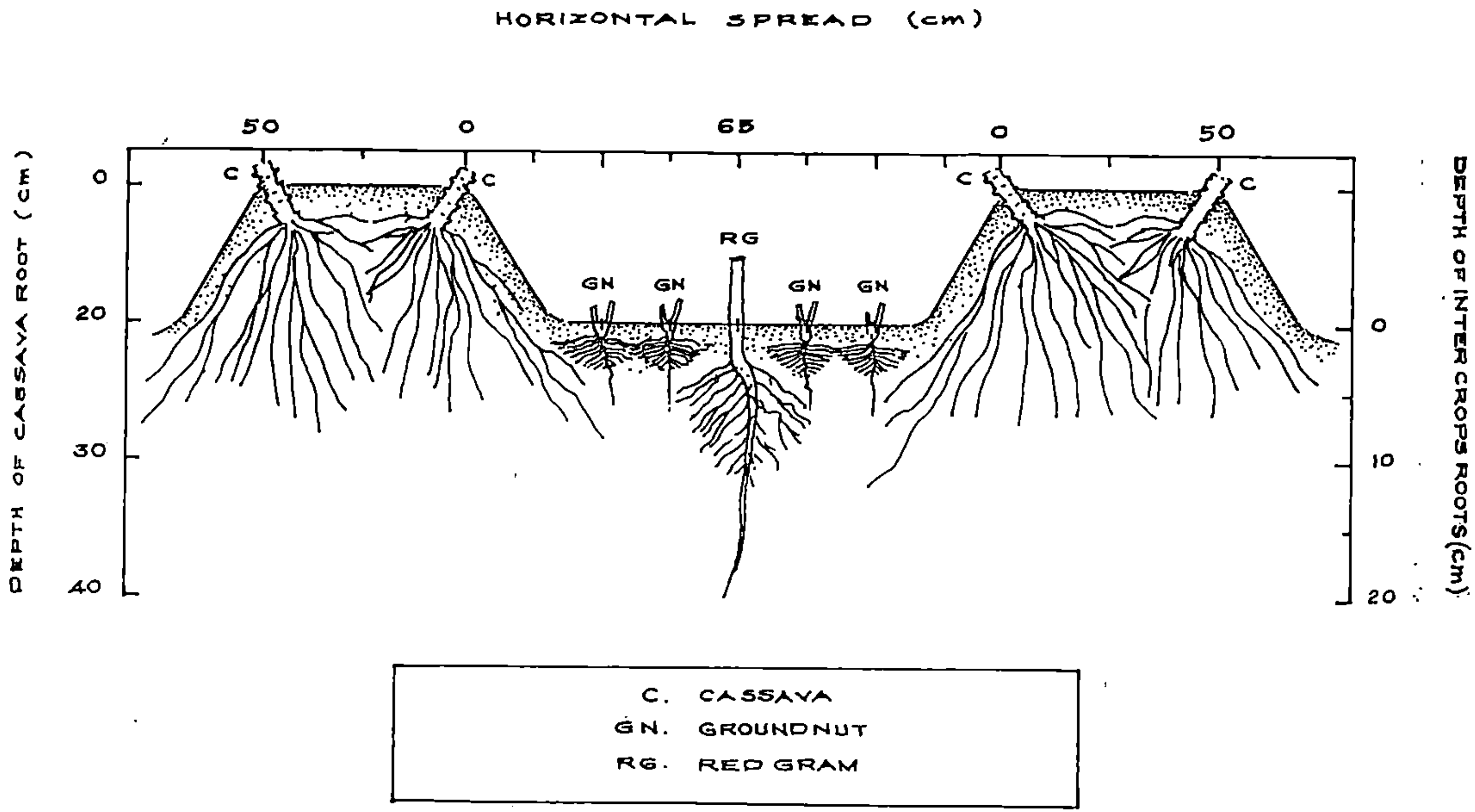


FIG. 20. ROOT DISTRIBUTION PATTERN OF DIFFERENT CROPS IN INTER CROPPING OF PAIRED ROW CASSAVA (110 DAP).

The higher levels of fertilizer applied to the intercrops resulted in higher yield of cassava tuber during both the years and it was significantly higher in the first year.

The yield increase obtained in this case may be due to the better tuber development resulting from the beneficial/complementary effect of fertilizers applied to the intercrops. The data on tuber girth provides ample testimony to this argument. The possibility of root level interaction between cassava and the intercrops is indicated by the results obtained from the studies using radiophosphorus (Table 50). Bhat (1978) also observed an increase in cassava yield due to the effect of fertilizers applied to the intercrops.

The tuber yield in control plots were on par with other treatments. Cassava yield in the cropping system cassava + groundnut + red gram was also on par with the sole cassava.

These results show that either in the paired row or in the normal method of planting cassava, legume intercrops do not in any way reduce the yield of cassava. This is very much apparent in cassava + groundnut + red gram where in spite of the simultaneous presence of two intercrops the tuber yield remained on par with the sole cassava. Since cassava was planted in paired row, the interspaces available were more. The initial growth rate of red gram was low and so its canopy was always below that of cassava during the early phases. This low pace of growth continued till the groundnut crop was harvested. After this there was a sharp increase in the growth rate of red gram and it increased in height and leaf area substantially (Table 38). By the time of harvest of cassava, the red gram plants were almost as tall as cassava. Still it did not offer much competition to cassava since cassava had a less vigorous rate of growth during the later stages on account of then prevailing dry season. It may also be noted that both the intercrops were legumes. The root system of these legumes were confined to a smaller soil volume. Hence the competition for plant nutrients will be mild and one can expect the benefit of N fixation also. Hence it was possible to obtain full yield of cassava even after growing two intercrops viz. groundnut and red gram, the former being of short duration and short stature and the latter being of long duration and tall growth. Mattos et al.(1980) reported that in paired row planting of cassava, there is not much scope for competition from the intercrops grown in the interrow spaces.

4C.1.2.3 Shoot weight

The cropping systems showed no significant influence on the shoot weight of cassava (Table 31) during both the years. The fertilizer levels applied to the intercrops also showed no significant effect during both the years.

4C.1.2.4 Dry matter production

The dry matter production of cassava (Table 31) was on par in the different cropping systems. The cropping system cassava + groundnut + red gram also was on par with the rest of the treatments. Higher levels of fertilizers applied to the intercrops increased dry matter production. The trend of the results was

Table 31. Effect of sequential intercropping with legumes and the fertilizer levels to the intercrops on the shoot weight, dry matter yield and harvest index of cassava in paired row

Cropping systems	(1983-84) Shoot weight (g/pl.)	Dry matter (g/pl.)	Harvest index (%)	(1984-85) Shoot weight (g/pl.)	Dry matter (g/pl.)	Harvest index (%)
C+CP-CP	1018	1284	58	992	1019	56
C+CP-GN	1122	1249	57	987	994	56
C+GN-CP	997	1178	58	998	990	55
C+GN-GN	1130	1288	60	995	1089	55
C.D.(0.05)	NS	NS	NS	NS	NS	NS
SEM +/-	53	54	1.6	52	45	0.9
Fertilizer levels						
MO	1034	1104	60	953	960	55
M1	1147	1276	59	1036	1009	55
M2	1020	1370	56	974	1099	56
C.D.(0.05)	NS	140	NS	NS	113	NS
SEM +/-	47	47	1.4	46	39	0.8
Controls						
C+GN+RG	-	-	-	1016	1206	53
C(N)+GN	1104	1293	60	994	1087	55
C(N)+CP	1098	1217	56	982	1130	52
C	1092	1099	53	986	1040	57
C(N)	1110	1017	59	988	1068	60

C-cassava in paired row C(N)-cassava in normal planting
CP-cowpea GN-groundnut RG-red gram. MO, M1 and M2 are 0, 50 and 100 % of the recommended sole crop fertilizer dose. Pl.-plant

the same during both the years. The dry matter production of sole cassava planted under paired row and normal methods was on par with the different intercropping systems.

The general trend of dry matter production of cassava was the same as that of tuber yield and hence not further discussed.

4C.1.2.5 Harvest index

The harvest index of cassava (Table 31) was not significantly influenced by the cropping systems or the fertilizer levels applied to the intercrops. This indicates that the different treatments had not significantly influenced the partitioning of photosynthates thereby retaining almost the same harvest index.

4C.2 Intercrops

The second season (Rabi) intercrop of cowpea or groundnut raised in sequence to the first season (Kharif) cowpea or groundnut was unsuccessful in cassava since the interspaces were completely shaded by the tall growing cassava (Plate XVIII). Another probable limiting factor is the soil moisture at the time of sowing of the second season intercrops. Hence the data on the second season intercrops are not presented and discussed.

4C.2.1 Cowpea

4C.2.1.1 Height

Intercrop cowpea was taller than the sole crop (Table 32).

Table 32. Effect of fertilizer levels on the height of intercrop cowpea at different stages of growth

Fertilizer levels	(1983-84) Days after planting 30	60	90	(1984-85) Days after planting 30	60	90
	(Height in cm)					
MO	23.8	38.9	71.3	16.5	37.3	50.5
M1	26.4	41.5	70.8	18.8	43.8	55.7
M2	28.6	45.2	75.3	22.2	54.3	64.2
C.D.(0.05)	3.9	3.4	8.1	1.9	4.3	5.7
SEM +/-	1.3	1.1	2.7	0.6	1.4	1.9
Controls						
C(N)+CP	26.7	43.3	70.3	17.7	39.0	53.7
Sole CP	25.5	37.5	54.3	15.3	34.0	44.0
C.D.(0.05)	NS	4.5	11.4	2.4	6.0	8.1
SEM +/-	1.8	1.5	3.8	0.8	2.0	2.7

Table 33. Effect of fertilizer levels on the leaf area of intercrop cowpea at different stages of growth

Fertilizer levels	(1983-84) Days after planting 30	60	90	(1984-85) Days after planting 30	60	90
	(Leaf area in m2/plant)					
MO	0.054	0.122	0.171	0.029	0.077	0.171
M1	0.071	0.145	0.190	0.085	0.110	0.184
M2	0.071	0.148	0.214	0.041	0.117	0.200
C.D.(0.05)	0.015	0.012	0.033	0.005	0.022	NS
SEM +/-	0.005	0.004	0.010	0.002	0.007	0.011
Controls						
C(N)+CP	0.063	0.134	0.194	0.036	0.106	0.141
Sole CP	0.067	0.134	0.192	0.040	0.112	0.152
C.D.(0.05)	NS	0.018	NS	0.006	0.030	NS
SEM +/-	0.007	0.006	0.015	0.002	0.010	0.016

MO, M2 and M3 are 0, 50 and 100% of the recommended sole crop fertilizer dose. C(N)-cassava in normal planting CP-cowpea

Higher levels of fertilizer increased the height of cowpea significantly at all stages of growth. The height increase is a general response to applied fertilizers. Similar observation was recorded by Bhat (1978). The taller cowpea observed in intercropped plots could be due to the partial shade caused by cassava on cowpea. The trend of the results were similar during both the years.

4C.2.1.2 Leaf area

No consistent trend could be observed when leaf areas of intercrop and sole cowpea were compared (Table 33). Higher levels of fertilizer increased the leaf area of cowpea. It was significant at all the stages except at 90 days after planting during the second year. A consistently significant increase in leaf area was obtained only with the M2 level of fertilizers.

4C.2.1.3 Yield

The yield of cowpea (Table 34) increased with higher levels of fertilizers applied. The M1 and M2 levels of fertilizers were significantly superior to MO level; the former two being on par. This response was observed during both the years. Bhat (1978) also observed similar yield response in cowpea intercropped in normal spaced cassava.

The results indicate that intercrop cowpea needed only about 90 per cent of the sole crop recommendation. The following quadratic response function was found to be in good fit to the data on cowpea yield.

Table 34. Effect of fertilizer levels on the grain yield, haulm weight, dry matter production and harvest index of intercrop cowpea.

Fertilizer levels	(1983-84) Grain yield kg/ha	Grain yield g/pl.	Haulm weight g/pl.	Dry matter g/pl.	Harvest index %	(1984-85) Grain yield kg/ha	Grain yield g/pl.	Haulm weight g/pl.	Dry matter g/pl.	Harvest index %
MO	580	5.2	52.8	22.1	22	586	5.3	51.1	19.9	25
M1	672	6.0	69.8	28.5	22	684	6.2	67.9	28.7	21
M2	695	6.3	86.7	34.3	20	713	6.4	81.9	31.4	20
C.D.(0.05)	69	1.0	7.0	1.1	1	61	0.9	11.1	7.0	2
SEM +/-	22	0.3	2.4	0.4	0.3	20	0.3	3.9	2.4	0.7
Controls										
C(N)+CP	634	6.2	89.5	34.7	18	664	6.0	79.8	32.2	17
Sole CP	1067	6.4	70.6	35.8	22	1078	6.4	71.8	33.0	21
C.D.(0.05)	96	1.4	9.2	1.7	1.4	86	1.3	14.5	2.0	3.0
SEM +/-	32	0.5	3.0	0.5	0.5	29	0.4	4.8	0.7	1.0

CP-cowpea C(N)-normal planting of cassava. MO, M1 and M2 are 0, 50 and 100 % of the recommended sole crop fertilizer dose. Pl.-plant

$$y = -34.5[(x-0.5)^2]/0.5 + 60.5(x-0.5) + 478$$

where x = 0, 0.5 and 1.0 representing 0, 50 and 100 per cent of the sole crop recommendation respectively.

From the response fuctions it was seen that 6 kg N, 18 kg P205 and 18 kg K_2O were the optimum doses for a hectare of intercrop cowpea.

The intercrop cowpea in paired row and normal planted cassava gave almost similar yields.

The sole cowpea produced higher yield during both the years on per hectare basis and not on per plant basis indicating that the yield of cowpea was not reduced on account of the competition from cassava. The yield reduction observed in intercrop cowpea on per hectare basis is mainly due to the population difference in sole and intercropped situations. The sole crop had a population of 1.67 lakhs whereas the intercrop had only 1.11 lakhs per hectare.

4C.2.1.4 Haulm weight

The fresh weight of haulm per plant (Table 34) showed a significant increase in the intercropped situation as compared to the sole crop. This may be the result of the increased height of intercrop cowpea. Similar increase in vegetative growth of cowpea when grown as intercrop or put under shade was reported by Sheela (1981), George (1982) and Anilkumar (1984).

The haulm weight also increased with increasing levels of fertilizers during both the years. It may be recalled that the height and leaf area of the plants also had increased due to the effect of fertilizers. This was reflected in haulm weight also.

4C.2.1.5 Dry matter

The dry matter per plant (Table 34) showed significant response to the levels of fertilizer added to intercrop cowpea; the highest was observed at the maximum level of fertilization (M2). This is attributed to an increase in haulm weight and pod yield on account of fertilizer dressing.

There was no significant difference between the sole and the intercropped cowpea in dry matter production. As already explained, under shaded conditions the partitioning of assimilates was shifted in favour of vegetative growth at the expense of grain production. The data on haulm weight per plant showed that it was less in the sole cropped situation. Thus, when there was an increase in the vegetative growth under the intercropped situation, grain yield was increased under sole cropped situation. This has resulted in the production of almost the same quantity of dry matter in both intercrop and sole cowpea.

4C.2.2 Groundnut

4C.2.2.1 Height

The sole crop of groundnut was shorter than the intercrop groundnut (Table 35). The fertilizer levels had no significant effect on the height of intercrop groundnut. The shorter plants observed under sole cropped situation indicate that cassava partially shaded the intercrop groundnut and induced elongation.

Table 35. Effect of fertilizer levels on the height of intercrop groundnut at different stages of growth

Fertilizer levels	(1983-84) Days after planting 30	60	90	120	(1984-85) Days after planting 30	60	90	120
	(Height in cm)							
MO	17.7	33.7	58.5	29.8	14.8	31.5	41.0	27.8
M1	18.6	34.6	59.5	31.0	15.5	34.2	43.3	27.2
M2	16.8	37.6	59.8	28.7	16.5	34.8	43.3	28.3
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	1.7	1.2	2.2	1.1	0.5	1.1	1.1	1.6
Controls								
C(N)+GN	19.3	40.6	53.3	27.7	13.0	28.3	38.3	24.0
C+GN+RG	—	—	—	—	13.5	29.7	35.1	27.4
Sole GN	21.4	31.8	44.0	25.0	13.7	30.0	34.0	28.3
C.D.(0.05)	NS	5.2	9.3	4.7	2.3	4.6	4.5	NS
SEM +/-	2.5	1.7	3.1	1.6	0.7	1.5	1.5	2.2

Table 36. Effect of fertilizer levels on the leaf area of intercrop groundnut at different stages of growth

Fertilizer levels	(1983-84) Days after planting 30	60	90	120	(1984-85) Days after planting 30	60	90	120
	(Leaf area in m2/plant)							
MO	0.070	0.123	0.168	0.065	0.044	0.111	0.202	0.062
M1	0.078	0.136	0.168	0.063	0.051	0.134	0.251	0.063
M2	0.086	0.164	0.216	0.178	0.056	0.135	0.304	0.073
C.D.(0.05)	NS	0.016	0.036	0.010	NS	0.012	0.025	0.009
SEM +/-	0.006	0.005	0.010	0.013	0.002	0.004	0.008	0.003
Controls								
C(N)+GN	0.080	0.137	0.198	0.064	0.049	0.132	0.299	0.062
C+GN+RG	—	—	—	—	0.040	0.145	0.270	0.057
Sole GN	0.083	0.137	0.196	0.053	0.048	0.147	0.289	0.062
C.D.(0.05)	NS	0.022	NS	0.014	NS	NS	NS	NS
SEM +/-	0.009	0.008	0.017	0.105	0.003	0.006	0.012	0.004

MO, M2 and M3 are 0, 50 and 100% of the sole crop fertilizer dose. C(N)-cassava in normal planting C-cassava in paired row. GN-groundnut RG-red gram

Anilkumar (1984) observed that intercrop groundnut in normal planted cassava was taller than that in paired row cassava. But such a response was not observed in this study.

Intercropping cassava with either groundnut alone or groundnut + red gram did not significantly influence the height of groundnut.

Eventhough the situation here also was as in cowpea intercropped plots where there was partial shade caused by cassava, the height increase as was observed in intercrop cowpea was not seen in intercrop groundnut. Groundnut did not show any definite response to higher levels of fertilizer also. This is mainly due to the fact that after a certain height the groundnut plant showed a tendency to lodge and creep over the soil. This behaviour of the plant resulted in vitiating the observation on height of groundnut. So much so, much significance is not given to this result.

4C.2.2.2 Leaf area

The leaf area of intercrop groundnut was on par with that of the sole crop during both the years (Table 36). The leaf area at later stages was significantly influenced by the fertilizer levels. Maximum leaf area was recorded with the M2 level of fertilizer applied to groundnut. The results of this trial also indicate that leaf area of groundnut was not much influenced by the partial shade of cassava.

The leaf area of groundnut in the cropping system cassava + groundnut + red gram was also on par with other treatments.

In one of the earlier experiments also, the leaf area of groundnut recorded in paired row and normal planted cassava was similar (Anilkumar, 1984). But he has not compared the intercrop groundnut with sole groundnut. The conspicuous increase in leaf area observed in intercrop groundnut in the present study is attributed to the increased uptake of nutrients (Table 43).

4C.2.2.3 Yield

The sole groundnut gave higher yield than the intercrop (Table 37) on per hectare basis but on per plant basis it was on par. The groundnut pod yields in cassava + groundnut + red gram and cassava + groundnut cropping systems were on par.

The fertilizer levels significantly influenced the yield of groundnut during both the years. The M0 level of fertilizer resulted in the lowest yield of intercrop groundnut. The M1 level has recorded the highest yield during both the years. The yield at M2 level showed a decrease and this was significant in the second year.

The following quadratic response function was found to be in good fit to the data on the yield.

$$y = -204.5[(x-0.5)^2]/0.5 + 75.75(x-0.5) + 1324.5$$

where x = 0, 0.5 and 1.0 representing 0, 50 and 100 per cent of the sole crop recommendation respectively.

From the response function the optimum doses of N, P_2O_5 and K_2O worked out were 4, 30 and 30 kg per hectare respectively.

The increased yield of intercrop groundnut recorded with higher levels of fertilizers could be due to the enhanced leaf

Table 37. Effect of fertilizer levels on the grain yield, haulm weight, dry matter production and harvest index of intercrop groundnut

Fertilizer levels	(1983-84)					(1984-85)				
	Grain yield		Haulm weight	Dry matter	Harvest index	Grain yield		Haulm weight	Dry matter	Harvest index
	kg/ha	g/pl.	g/pl.	g/pl.	%	kg/ha	g/pl.	g/pl.	g/pl.	%
MO	1067	9.6	58	26	33	1022	9.2	57	25	32
M1	1395	12.6	69	30	37	1254	11.3	67	28	35
M2	1260	11.4	83	33	30	1132	10.2	78	31	29
C.D.(0.05)	259	2.3	10	3	5	79	0.7	7	2	3
SEM +/-	86	0.8	3.2	1	1.7	26	0.2	2	0.6	1
Controls										
C(N)+GN	1106	10.0	84	32	28	1157	10.4	72	30	29
C+GN+RG	–	–	–	–	–	1233	11.1	75	31	32
Sole GN	1980	11.9	46	36	30	1988	11.9	65	32	31
C.D.(0.05)	367	3.3	14	5	NS	112	1.0	9	4	4
SEM +/-	121	1.1	4.5	1.5	2.4	37	0.3	3.0	1.2	1.3

MO, M1 and M2 are 0, 50 and 100 % of the recommended sole crop fertilizer dose. GN-groundnut RG-red gram. Pl.-plant
C(N)-normal planting of cassava. C-paired row cassava

area and the resultant increase in photosynthate production. At the M2 level of fertilization, the vegetative growth was more at the expense of pod yield as could be seen in Table 37. So the result of this investigation shows that in intercropped situation, the full sole crop fertilizer recommendation is not required for the intercrops. There would have been some leaching down of the fertilizers applied to the ridges of cassava and sharing of nutrients between cassava and the intercrop.Thus there is a possibility of saving some fertilizer required for the groundnut intercropped in cassava. Further work is needed to elucidate this aspect in detail.

The higher per hectare yield worked out for sole groundnut is mainly due to the population effect. This is evident from the per plant yield which does not vary remarkably in sole and intercrop groundnut. The yields of groundnut intercropped in normal and paired row planted cassava were on par. Such observation was made by Anilkumar (1984) also.

4C.2.2.4 Haulm weight

The fresh haulm weight of groundnut (Table 37) was lower in the sole crop as compared to that in intercrop. In cassava + groundnut + red gram intercropping also groundnut haulm weight was higher than that in sole crop.

The haulm weight progressively increased with higher levels of fertilizers applied to the intercrop groundnut during both the years and the maximum was obtained in the M2 level of fertilization.

The enhanced leaf area recorded in intercrop groundnut with higher levels of fertilizers will explain the higher haulm weight observed in these treatments. The balance between the source and sink in intercrop groundnut was probably shifted in favour of the source at the highest level of fertilization which has recorded lower sink values. In the case of sole groundnut sunlight was in plenty and there was more photosynthesis which was more efficiently utilized for pod formation rather than for vegetative growth.

4C.2.2.5 Dry matter production

The dry matter production by intercrop groundnut (Table 37) was lower than the sole crop. In intercrop groundnut dry matter production increased with increasing levels of fertilizers; it being the lowest in MO level and highest in M2 level. Dry matter production in general showed the same trend as that of haulm weight. This shows that in this case the contribution towards total dry matter production was more from haulm of groundnut than from the pod yield under intercropped situations.

4C.2.3 Red gram

The treatment combination cassava + groundnut + red gram was introduced during the second year as a midcourse correction. The sequential intercrop of both cowpea and groundnut failed to establish under the canopy of 4 months old cassava because of shade (Plate XVIII) during the first year. This observation was taken into account while including the new treatment. Red gram was introduced so that this will grow alongwith cassava thereby harvesting sunlight at almost the same height. Since the treatment had to be fitted in the existing lay out, only three replications were possible. Hence mean values are presented without statistical analysis. So the results are only of preliminary nature.

4C.2.3.1 Height

The height of intercrop red gram (Table 38) was remarkably more from 60 days stage onwards as compared to the sole red gram. This trend continued upto the harvest. The leaf area per plant also showed a similar trend. Cassava canopy caused partial shade on red gram inducing increase in height. By the time of harvest the intercrop red gram was much taller than the sole red gram.

It may also be noted that the maximum increase in height was observed during the period from 120 days after planting to 180 days after planting. This is the stage when groundnut was harvested and red gram was relatively free from competition.

4C.2.3.2 Leaf area

From 180 days after planting the leaf area was markedly higher in intercrop red gram (Table 38). It may be noted that since the groundnut crop was harvested and the haulm incorporated before this stage the extra nitrogen derived from groundnut haulm would have produced the increased leaf area of red gram.

Table 38. Effect of mixed row intercropping cassava with groundnut and red gram on the height and leaf area of red gram

Cropping system	Days after planting							
	30	60	90	120	150	180	210	240
	(Height in cm)							
C+GN+RG	22	45	75	105	152	192	201	210
Sole RG	21	38	59	85	110	137	141	149
	(Leaf area in m2/plant)							
C+GN+RG	0.099	0.185	0.335	1.053	1.645	1.805	1.676	1.607
Sole RG	0.095	0.183	0.265	0.962	1.496	1.622	1.482	1.376

Table 39. Effect of mixed row intercropping cassava with groundnut and red gram on the grain yield, haulm weight, dry matter production and harvest index of red gram.

Cropping systems	Grain yield (kg/ha)	Haulm-fresh weight (g/plant)	Dry matter (g/plant)	Harvest index (%)
C+GN+RG	222 (24)	295	79	30
Sole RG	1056 (38)	262	88	43

C-paired row cassava GN-groundnut RG-red gram
Figures in parentheses are yield in g/plant

4C.2.3.3 Grain yield

The red gram yield (Table 39) was low in the intercropped plots compared to the sole crop. This was true when yield per plant or yield per hectare was compared. The yield per plant was reduced by 37 per cent and on per hectare basis the reduction was 80 per cent.The reduction in per plant yield may be due to the competition for aerial space between cassava and red gram. From a shade tolerance study, George (1982) observed that red gram was shade sensitive and under extremely shaded situations even pod formation was retarded. The large reduction of grain yield observed in the intercrop red gram on per hectare basis is attributed to the reduced plant population in this situation. The population of intercrop red gram was only about 25 per cent of the sole crop.

4C.2.3.4 Haulm weight

The haulm weight (Table 39) showed a reverse trend as compared to grain yield. It was more in intercrop redgram on per plant basis. The taller growth and higher leaf area of intercrop redgram resulted in more haulm weight. The increased haulm weight on per hectare basis observed in sole red gram is only the effect of higher population.

4C.2.3.5 Dry matter production

The dry matter production (Table 39) was lower in intercrop red gram. It may be recalled that the per plant grain yield also showed a similar trend, while the haulm yield showed a reverse trend. This shows that the intercrop red gram uses more of photosynthates for shoot growth rather than for grain production. Intercropping red gram with pearl millet resulted in 50 per cent reduction in the yield of red gram (Patel et al., 1985). Ali and Raut (1985) observed that the dry matter production in the intercrop red gram was only 45 per cent of that in sole crop.

4C.2.3.6 Harvest index

The harvest index (Table 39) was less in intercrop red gram. This is due to the preferential growth of vegetative parts as is evidenced from the taller growth, higher leaf area and haulm weight in intercrop red gram.

Thus from the overall performance of the intercrop red gram it is surmised that growing red gram in preference to second crop groundnut or cowpea is a viable proposition and can be advantageously exploited. However, the encouraging results obtained are to be confirmed by further trials.

4C.3 **Total biomass**

The total biomass production is presented in Fig. 21. There was significant difference in biomass production between the sole and intercropped cassava. Maximum production was recorded by the cropping system cassava + groundnut + red gram (Plate XVII). This was followed by cassava + groundnut (Plate XVI) and cassava + cowpea (Plate XV). Normal planted sole cassava was almost equal to paired row cassava when the total biomass production was considered.

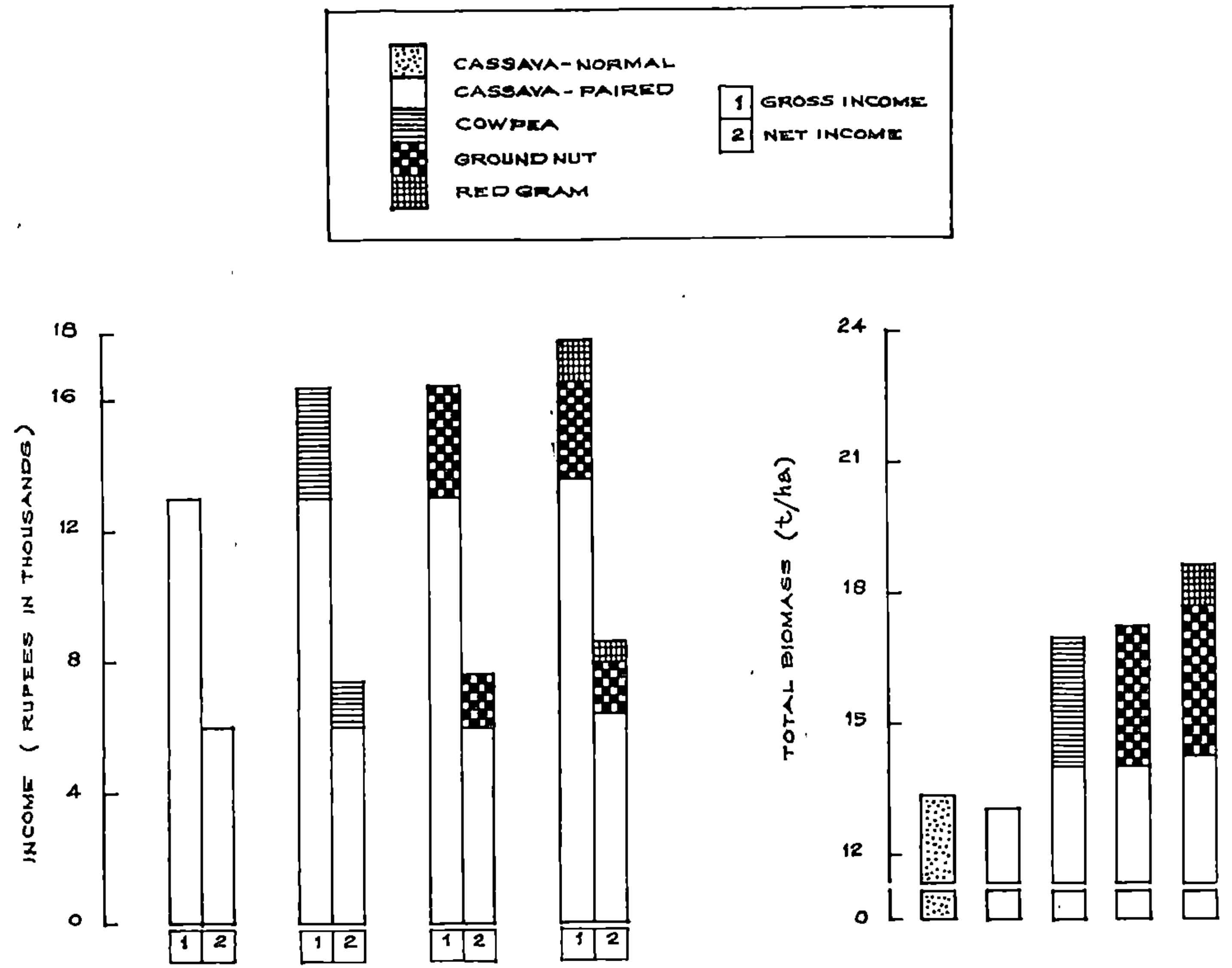


FIG. 21. TOTAL BIOMASS PRODUCTION AND ECONOMICS OF INTER CROPPING PAIRED ROW - CASSAVA WITH LEGUMES.

The increased biomass observed in the intercropping systems can be directly related to the total leaf area index (Fig.22). The cassava + groundnut + red gram combination has recorded the maximum leaf area index at all the stages of observation. This was followed by cassava + groundnut, cassava + cowpea and sole cassava. It may be seen that the leaf area index of cassava was less than the optimum of three, suggested for an ideal plant (Cock et al., 1979) during most of its growth stages. The system can be made more productive by increasing the leaf area index and leaf area duration which can be achieved by the introduction of one or two intercrops in cassava. The total leaf area index for all the cropping systems compared in this study was less than five and cannot be considered excessive. This enabled the intercrops to utilise the solar energy more efficiently and there was no wastage of the sunlight falling in the interspaces of the sole cassava.

4C.4 Land equivalent ratio

The land equivalent ratio (LER) of cassava (Table 40) was not significantly influenced when it was intercropped with cowpea or groundnut.

The total LER values in all the intercropping systems were superior to sole cropping. The maximum value was recorded by cassava + groundnut + red gram followed by cassava + groundnut and cassava + cowpea intercropping systems.

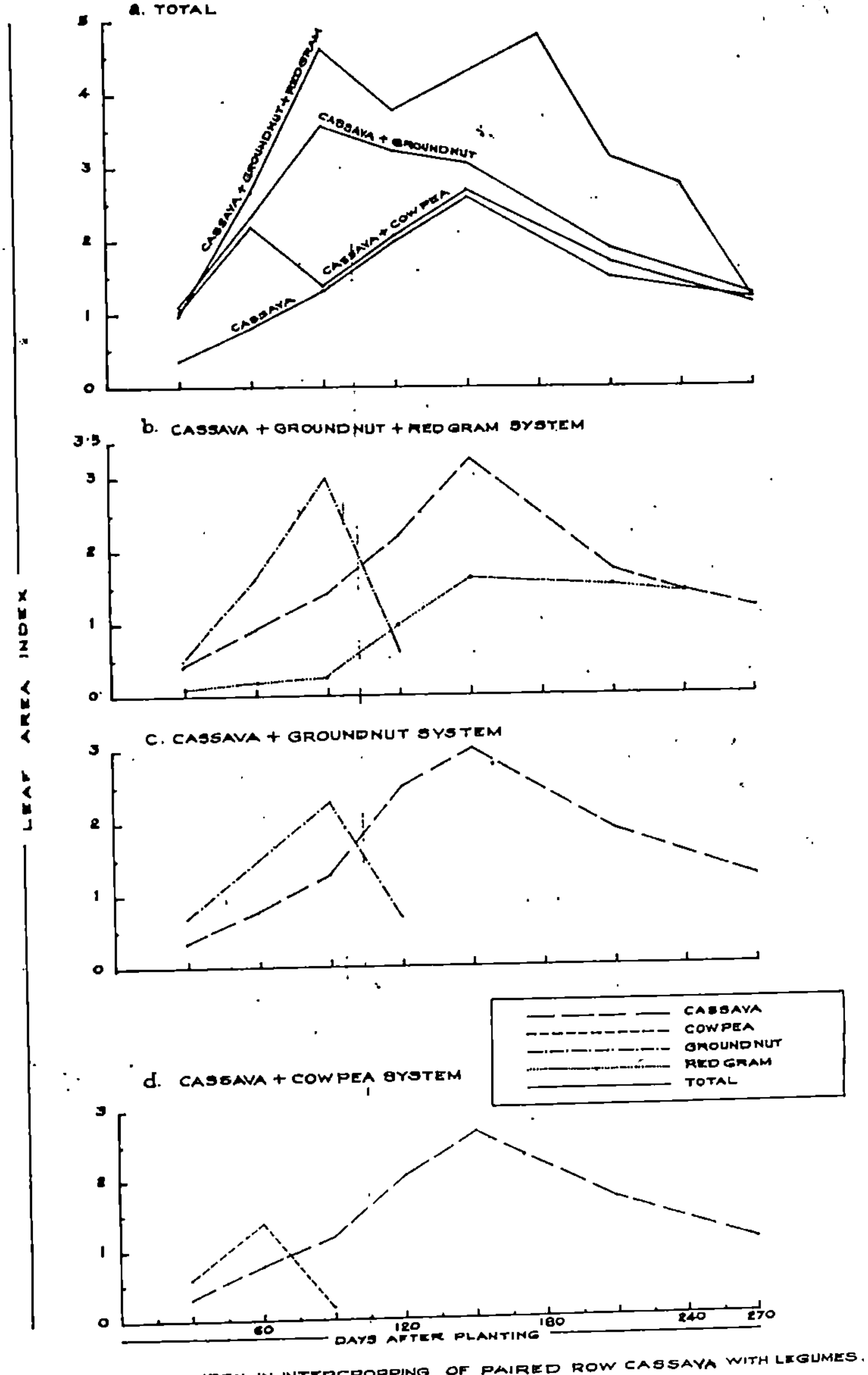


FIG. 22. LEAF AREA INDEX IN INTERCROPPING OF PAIRED ROW CASSAVA WITH LEGUMES.

Table 40. Effect of sequential intercropping with legumes on the land equivalent ratio of cassava and intercrops

Cropping systems	(1983-84) (Land equivalent ratio)			(1984-85) (Land equivalent ratio)		
	Cassava	Intercrops	Total	Cassava	Intercrops	Total
C+CP-CP	0.99	0.53	1.52	0.96	0.60	1.56
C+CP-GN	1.10	0.59	1.69	0.92	0.55	1.47
C+GN-CP	0.99	0.72	1.71	0.92	0.66	1.58
C+GN-GN	1.10	0.65	1.74	0.99	0.59	1.59
C.D.(0.05)	NS	--	NS	NS	--	NS
SEM +/-	0.09	--	0.09	0.04	--	0.05
Controls						
C(N)+GN	1.13	0.56	1.69	1.00	0.55	1.74
C(N)+CP	1.15	0.90	2.05	0.98	0.70	1.68
C+GN+RG	--	--	--	1.01	0.58 (0.30)	1.89
C	1.23	--	1.23	1.00	--	1.00
C(N)	1.00	--	1.00	1.00	--	1.00
C.D.(0.05)	NS	--	0.46	NS	--	0.22
SEM +/-	0.15	--	0.16	0.08	--	0.08

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. C-paired row cassava C(N)-cassava in normal planting. CP-cowpea GN-groundnut RG-redgram
Figure in parenthesis is LER of red gram

The LER value of the intercrop red gram was the lowest. It was partly due to the low plant population of intercrop red gram and its shade susceptible nature. It may be seen that on per plant basis also the intercrop red gram yield was considerably lower (Table 39).

4C.5 Economics

The abstract of data on the economics of the different intercropping systems showed that the gross and net income were higher by the inclusion of intercrops in cassava (Fig. 21). The income was highest in cassava + groundnut + red gram followed by cassava + groundnut and cassava + cowpea, eventhough there was not much difference between the latter two. Sole cassava recorded the lowest return. The LER values (Table 40) also indicated similar pattern of results. There was a progressive increase in returns with corresponding increase in LER. This shows that the cropping systems adopted are viable and scientific. The canopy architecture of the crops selected as intercrop must have played an important role in establishing the relationship between the LER and the net income.

The benefit:cost ratio worked out showed that the maximum (1.94) was in the case of cassava + groundnut + red gram. There was not much difference in the benefit:cost ratio of the other cropping systems which recorded a value of 1.86 for cassava + groundnut, 1.81 for cassava + cowpea and 1.83 for sole cassava.

So it can be concluded that cassava + groundnut is the best intercropping system whether cassava is planted in paired row or normal method. Cassava + groundnut + red gram is possibly a still superior cropping system, but this requires further study to confirm the results already obtained.

4C.6 Nutrient uptake in the intercropping systems

4C.6.1 Cassava

The cropping systems had no significant influence on N, P, K, Ca, Mg and S uptake by cassava (Tables 41 to 44) during both the years.

The fertilizer levels given to the intercrop showed significant effect on N, P, K and S uptake by cassava during both the years. The N uptake of cassava was highest in M2 level and lowest in MO level. Similar trend was observed in the case of P, K, Ca, Mg and S uptake during both the years. The Ca uptake was significant only during the second year and Mg uptake only during the first year. However, in general the trend of the results was similar during both the years.

The higher uptake noticed in cassava under the influence of fertilizer levels applied to the intercrops may be due to the vigorous growth and better tuber yield of cassava (Table 30).

4C.6.2 Cowpea

The uptake of N, P, K, Ca, Mg and S (Table 42) increased with higher levels of fertilizers applied to cowpea. The trend of the results was the same during both the years. However, the differences were not significant during the second year with respect to N and P. Higher uptake of these nutrients recorded

Table 41. Effect of fertilizer levels to the intercrops on the uptake of N, P, K, Ca, Mg and S by cassava

	N	P	K	Ca	Mg	S
			(1983-84) (Uptake in kg/ha)			
Fertilizer levels						
MO	109	16	125	85	23	8.7
M1	124	19	130	93	25	9.3
M2	133	22	143	93	29	10.2
C.D. (0.05)	14	2	14	NS	2.7	1.0
SEM +/-	5	0.7	5	3	0.9	0.3
			(1984-85)			
Fertilizer levels						
MO	104	15	97	94	28	8.1
M1	108	16	102	100	29	8.5
M2	123	18	111	109	32	9.4
C.D. (0.05)	10	1.8	11	11	NS	1.0
SEM +/-	4	0.6	4	4	1.1	0.3

Table 42. Effect of fertilizer levels on the uptake of N, P, K, Ca, Mg and S by intercrop cowpea

	N	P	K	Ca	Mg	S
			(1983-84) (Uptake in kg/ha)			
Fertilizer levels						
MO	39	3.7	32	30	8	3.9
M1	53	4.7	41	43	12	5.3
M2	62	5.7	53	48	13	6.2
C.D. (0.05)	4	0.6	4	3.4	1.1	0.5
SEM +/-	1.3	0.2	1.4	1.1	0.4	0.2
			(1984-85)			
Fertilizer levels						
MO	48	3.4	27	35	8	4.1
M1	46	3.8	33	48	9	5.4
M2	54	4.4	42	47	9	6.2
C.D. (0.05)	NS	NS	2.6	3.1	0.6	0.5
C.D. (0.05)	NS	NS	2.6	3.1	0.6	0.5
SEM +/-	3.3	0.3	0.9	1.0	0.2	0.2

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose.

Table 43. Effect of fertilizer levels on the uptake of N, P, K, Ca, Mg and S by intercrop groundnut

	N	P	K	Ca	Mg	S
			(1983-84) (Uptake in kg/ha)			
Fertilizer levels						
MO	58	3.4	45	33	14	6.1
M1	74	4.9	68	44	18	7.3
M2	85	5.3	85	49	21	8.8
C.D. (0.05)	11	1.0	10	6	2	1.0
SEM +/-	3.7	0.3	3.2	1.9	0.8	0.3
			(1984-85)			
Fertilizer levels						
MO	59	3.5	46	30	12	6.2
M1	78	3.9	49	40	13	7.3
M2	72	3.9	63	50	13	8.5
C.D. (0.05)	16	NS	10	5	NS	0.7
SEM +/-	5.3	0.2	3.4	1.7	0.5	0.2

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose.

Table 44 Effect of mixed row intercropping cassava with groundnut and red gram on the nutrient uptake by red gram

Cropping systems	N	P	K	Ca	Mg	S
			(1984-85) (Uptake in kg/ha)			
C+GN+RG	29	2.4	24	25	5.4	3.6
Sole RG	107	9.0	99	89	21.0	15.0

C-cassava in paired row GN-groundnut RG-red gram with higher levels of fertilizers may be due to the improved growth and dry matter production by these plants.

4C.6.3 Groundnut

The uptake of N, P, K, Ca, Mg and S by intercrop groundnut (Table 43) increased with increasing levels of fertilizers as in the case of cowpea. However, P and Mg uptake during the second year were not significantly different. The higher uptake observed with higher levels of fertilizer applied to intercrop groundnut is a reflection of the higher dry matter production.

4C.6.4 Red gram

The uptake of N, P, K, Ca, Mg and S (Table 44) was less in intercrop red gram. The lower uptake of nutrients is the reflection of the lesser dry matter production in intercrop redgram as already discussed.

4C.6.5 Total nutrient uptake

The cumulative total of the nutrient uptake by different components of the intercropping systems are given in Fig. 23. The total uptake of N, P, K, Ca, Mg and S by the intercropping systems was considerably higher as compared to sole cassava.

4C.7 Post crop soil nutrient status

The post crop soil analyses data on organic C, total N, available P and K, exchangeable Ca, Mg, S04 and acid extractable Cu, Zn, Mn and Fe are given in Tables 45, 46 and 47. It can be

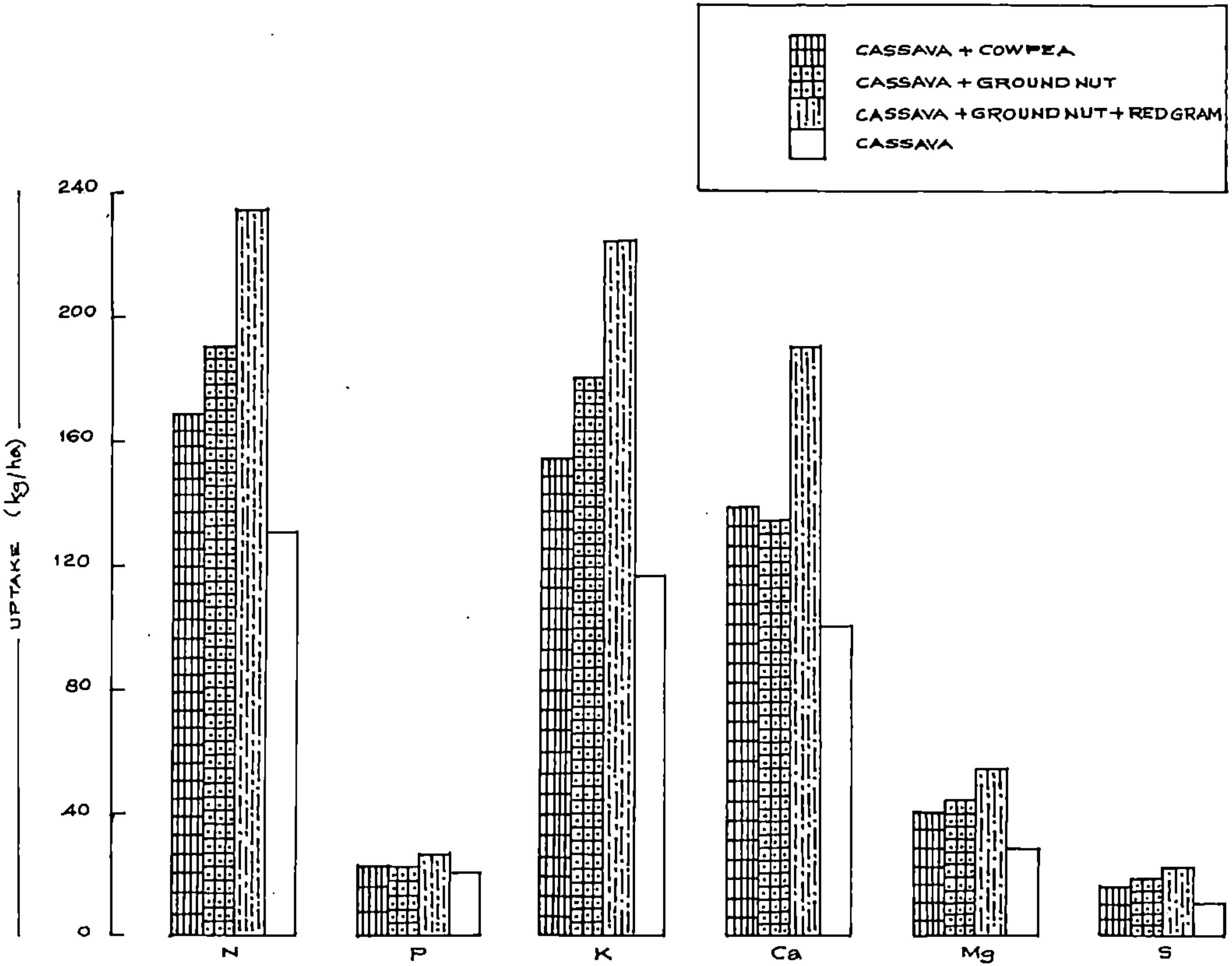


FIG. 23 TOTAL NUTRIENT UPTAKE IN INTERCROPPING OF PAIRED ROW CASSAVA WITH LEGUMES.

Table 45. Effect of sequential intercropping with legumes and the fertilizer levels given to the intercrops on the post crop soil nutrient status (C, N, P and K)

Cropping systems	(1983-84)				(1984-85)			
	Organic C (%)	N (%)	P (ppm)	K (ppm)	Organic C (%)	N (%)	P (ppm)	K (ppm)
C+CP-CP	1.321	0.161	29	133	0.825	0.112	11	196
C+CP-GN	1.335	0.173	27	108	0.836	0.110	11	191
C+GN-CP	1.267	0.142	29	119	0.871	0.103	12	180
C+GN-GN	1.344	0.152	28	137	0.820	0.103	11	195
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM +/-	0.048	0.012	1.6	10	0.028	0.005	1.4	23
Fertilizer levels								
MO	1.222	0.142	21	107	0.776	0.105	11	195
M1	1.357	0.158	29	137	0.871	0.107	10	178
M2	1.370	0.172	34	128	0.867	0.109	13	198
C.D.(0.05)	0.126	NS	4	25	0.072	NS	NS	NS
SEM +/-	0.042	0.010	1.4	8	0.024	0.004	1.6	20
Controls								
C(N)+GN	1.448	0.168	29	125	0.839	0.105	11	131
C(N)+CP	1.335	0.189	35	143	0.794	0.098	10	135
C+GN+RG	-	-	-	-	0.845	0.098	10	136
C	1.051	0.154	13	114	0.854	0.091	11	183
C(N)	1.074	0.136	15	76	0.795	0.091	11	183
C.D.(0.05)	0.253	NS	8	NS	NS	NS	NS	NS
SEM +/-	0.084	0.021	3	16	0.048	0.008	3	40

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. C-paired row cassava C(N)-cassava in normal planting CP-cowpea GN-groundnut RG-red gram

Table 46. Effect of sequential intercropping with legumes and the fertilizer levels given to the intercrops on the post crop soil nutrient status (Ca, Mg and SO_4)

Cropping systems	(1983-84)			(1984-85)		
	Exchangeable			Exchangeable		
	Ca (ppm)	Mg (ppm)	SO_4 (ppm)	Ca (ppm)	Mg (ppm)	SO4 (ppm)
C+CP-CP	256	35	63	197	30	63
C+CP-GN	252	37	63	213	35	62
C+GN-CP	299	42	59	300	29	64
C+GN-GN	302	51	61	270	32	51
C.D.(0.05)	35	NS	NS	51	NS	NS
SEM +/-	12	5	6	17	4	12
MO	230	37	62	215	31	55
M1	317	46	60	252	33	62
M2	284	39	61	267	30	63
C.D.(0.05)	30	NS	NS	NS	NS	NS
SEM +/-	10	4	5	15	4	11
Controls						
C(N)+GN	303	31	76	240	46	72
C(N)+CP	289	33	75	223	31	74
C+GN+RG	-	-	-	236	35	70
C	245	42	58	193	28	63
C(N)	210	30	60	231	44	52
C.D.(0.05)	60	NS	NS	NS	NS	NS
SEM +/-	20	8	10	29	7	22

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. C-paired row cassava C(N)-cassava in normal planting. CP-cowpea GN-groundnut RG-red gram

Table 47. Effect of sequential intercropping with legumes and the fertilizer levels given to the intercrops on the post crop soil micronutrient status -1984-85

Cropping systems	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
C+CP-CP	4.4	2.1	48	25
C+CP-GN	4.4	2.4	53	27
C+GN-CP	4.0	2.2	46	25
C+GN-GN	3.8	2.1	44	26
C.D.(0.05)	NS	NS	NS	NS
SEM +/-	0.2	0.1	3	2
Fertilizer levels				
MO	3.8	2.1	52	26
M1	4.4	2.2	45	25
M2	4.3	2.3	46	26
C.D.(0.05)	0.5	NS	NS	NS
SEM +/-	0.2	0.11	3	2
Controls				
C(N)+GN	3.9	2.1	42	24
C(N)+CP	4.2	2.1	50	25
C+GN+RG	4.0	2.0	48	27
C	4.0	2.2	48	28
C(N)	3.8	1.9	37	27
C.D.(0.05)	NS	NS	NS	NS
SEM +/-	0.3	0.2	5	3

MO, M1 and M2 are 0, 50 and 100% of the recommended sole crop fertilizer dose. C-paired row cassava C(N)-cassava in normal planting. CP-cowpea GN-groundnut RG-red gram seen that the nutrient status was not influenced by different intercropping practices except in the case of exchangeable Ca.

The organic C in soil after the cropping (Table 45) varied significantly during both the years. Higher fertilizer levels applied to the intercrops resulted in higher residual organic C in the soil. During the second year the difference was not as conspicuous as during the first year. It may be noted that the haulm yield of cowpea and groundnut incorporated to the soil was higher with higher levels of fertilizer applied to them. This might have resulted in higher organic C in those plots.

The total N percentage of soil (Table 45) was not significantly influenced by any of the treatments. But the pattern of result was similiar to that of organic C.

The available P and K content of the soil (Table 45) also showed higher values when the fertilizer dose was increased. The values recorded in sole cropped plots were low as compared to the intercropped plots. This difference was not perceptible during the second year.

The exchangeable Ca (Table 46) was more in groundnut intercropped situations. Lime was applied to groundnut at the rate of 500 kg per hectare at flowering and this might have contributed to the high exchangeable Ca. The higher levels of fertilizer also increased the exchangeable Ca content in the soil. The super phosphate used for giving different levels of fertilizers may be the source of the difference obtained here.

The exchangeable Mg and S04 content of the soil (Table 46) was not significantly influenced by any of the treatments.

The extractable Zn, Fe, Mn and Cu status of the soil (Table 47) estimated at the end of the two year cropping indicated that it did not vary significantly either with the different cropping systems or the fertilizer levels given to the intercrops, except in the case of Zn. The Zn content was more in plots where higher doses of fertilizers were applied to the intercrops.

4C.8 Nutrient balance in the intercropping systems

An estimate of the nutrient balance in the cassava + cowpea and cassava + groundnut intercropping systems as against the sole cassava was arrived at by considering the pre-crop and post-crop soil analyses data, plant removal of nutrients, the manures and fertilizers applied and the nutrients recycled through leaf fall of cassava and incorporation of legume haulm (Table 48).

It may be noted that the actual balance of total N recorded in the soil after the first year cropping was only about half of that expected. This was true both in intercropped and sole cropped situations inspite of the substantial quantity of N added to the soil by way of legume N fixation and haulm incorporation. The only plausible explanation for this discrepancy is the probable wash off of soil and nutrients due to the heavy rainfall (Appendix II) prevalent in the locality. The same trend of results was obtained when the nitrogen balance after the second year cropping was considered. It may also be seen that the N balance was better in the intercropped plots during both the years, compared to that in sole cassava. This may be due to the nitrogen fixed and the nutrients recycled

Table 48. Nutrient balance sheet for cassava-legume intercropping systems

Particulars	Total N			Available P			Available K		
	C+CP	C+GN	C	C+CP	C+GN	C	C+CP	C+GN	C
	(Quantity of nutrients in kg/ha)								
Nutrient input									
a. Initial soil status (1983)	560	560	560	38	38	38	122	122	122
b. Fertilizer+FYM	102	102	92	89	112	74	89	112	74
c. Cassava leaf fall	77	82	70	13	16	12	68	70	64
d. Legume haulm	29	44	—	3	3	—	24	32	—
e. N-Legume fixed	50*	50	—	—	—	—	—	—	—
Total	818	838	722	143	169	124	303	336	260
Nutrient removal									
a. Plant uptake	175	198	130	24	24	21	171	201	124
b. Nutrient losses	?	?	?	?	?	?	?	?	?
Balance									
a. Expected	643	640	592	119	145	103	132	135	136
b. Actual	334	394	308	56	58	26	241	256	228
Nutrient input									
a. Initial soil status (1984)	334	394	308	56	58	26	241	256	228
b. Fertilizer+FYM	102	97	92	89	112	74	89	112	74
c. Cassava leaf fall	79	87	75	12	14	12	58	60	55
d. Legume haulm	31	46	—	3	3	—	22	26	—
e. N-Legume Fixed	50	50**	—	—	—	—	—	—	—
Total	596	674	475	160	187	112	410	454	357
Nutrient removal									
a. Plant uptake	159	181	122	21	23	17	136	158	105
b. Nutrient losses	?	?	?	?	?	?	?	?	?
Balance									
a. Expected	437	493	353	139	164	95	274	296	252
b. Actual	222	206	182	22	24	22	388	376	366

C-cassava CP-cowpea GN-groundnut.
* Eaglesham (1981) ** Nambiar et al. (1983)

by the legume intercrops. Apart from this, the presence of intercrops can reduce the beating action of the rainfall and reduce the soil loss and nutrient leaching. This is evident from the work of Viswambharan (1981).

In the case of available P balance also, almost same type of result was obtained. But by the end of the second season cropping, the available P balance was only about 25 per cent of that expected. Such drastic changes in the available P may be the result of the fixation of P in soil, apart from the probable loss by wash off of soil, resulting from the reduction in soil pH consequent to the two season cropping. The soil pH was decreased from 6.1 to 5.0 by the end of the two year cropping. Decrease in soil pH to the extent of 1 to 1.2 units was noticed in acid red loam soils of Bangalore under continuous cropping with the application of recommended level of N (Nambiar and Ghosh, 1984).

A different picture was obtained when the K balance in the soil was considered. Unlike in the case of N and P, the exchangeable K balance of the soil gave far higher value than anticipated. This was true with respect to the results obtained at the end of two year cropping. Breland et al. (1950) observed that under intensive cropping, the plants removed more K from the non exchangeable soil source. They also failed to get any relationship between the K removed by the crops and the K present in the soil initially or after cropping. Tandon et al.(1981) reported that in intensive cropping when the soil test data on soils were considered, some component for contribution from non-exchangeable K also should be included. Nambiar and Ghosh (1984) also reported that a lot of mining of soil K was noticed even when K fertilizer was applied in substantial quantities. The higher available K recorded in this experiment also may be the result of mobilisation of non-exchangeable K by the cropping effect. It is also possible that some of the soil K in the deeper layers may be brought to the surface soil by way of plant nutrient cycling. However, the dynamics of soil K in the intensive cropping systems needs much more understanding.

The salient findings from this trial are summarised below.

Cassava planted in paired rows can be intercropped with cowpea or groundnut without reduction in yield of either cassava or the intercrop. It is not feasible to grow cowpea or groundnut as intercrop in cassava for two seasons in sequence (Kharif and Rabi). The second season (Rabi) intercrop, whether cowpea or groundnut, was a failure even under paired row planted cassava. The mixed row intercropping of cassava + groundnut + red gram is found as an improvement over cassava + groundnut and cassava + cowpea intercropping system. The intercrops cowpea and groundnut recorded yields which were almost equal to the respective sole crop yields. But the intercrop red gram yield was considerably less than its sole crop. The intercrop red gram did not interfere with cassava or groundnut yield. But red gram, because of its long duration, was shaded by cassava during part of its growth period and resulted in low yield. The intercrop cowpea and groundnut responded to graded doses of fertilizers.

N, P and K doses equal to 60 to 90 per cent of those recommended for the sole crop were sufficient for the intercrop cowpea and groundnut. The optimum doses of N, P and K were worked out using a quadratic response function. The optimum doses for intercrop cowpea were 6, 18 and 18 kg per hectare of N, P and K. For the intercrop groundnut, the respective N, P and K levels were 4, 30 and 30 kg per hectare.

4D Interspecific Competition for Applied P-32 in a Cassava, Banana and Elephant Foot Yam Intercropping System

Interspecific root interaction in a cassava + banana + elephant foot yam intercropping system was studied by using the P-32 absorption by the component species as an index of its root activity. Absorption of applied P-32 in a three crop intercropping system was evaluated by quantifying the radioactivity absorbed during 45 days after application (135 days after planting cassava and elephant foot yam) by the crop to which the radiophosphorus was applied, as well as by the component species. The cropping system consisted of cassava and elephant foot yam interplanted with a standing crop of banana which was at its peak vegetative growth. The cassava was planted in square cluster. All possible two crop combinations viz., cassava + banana, cassava + elephant foot yam as well as banana + elephant foot yam were also evaluated similarly.

The use of leaf assay data for evaluating the absorption of applied label among different plant species and also among plants within the same species can at best give only an approximate comparison. The accuracy of such comparisons was however confirmed by resorting to statistical methods. The suitability of counts per minute (cpm) values of leaf sample for camparison of relative uptake of the applied P-32 by plants within species was adjudged by the degree of correspondence of the leaf cpm values with total radioactivity absorbed. For obtaining the total radioactivity absorbed by the plants, they were destructively sampled at the end of the experiment and the total counts in each plant was separately worked out by summing up the radioactivity accumulated in each part of the plant. From these figures the cpm per gram dry matter for each plant was worked out. The leaf cpm values for each plant within the species were then compared with cpm per gram dry matter by paired "t" test. It was found that the two values were related as evidenced from the non significance of the "t" value. Therefore, for comparison of the absorption by different plants within the species, leaf cpm values can be used. However, for the interspecific comparison of the absorption of applied P-32, the use of leaf cpm values alone is not sufficient as the values are likely to be affected by the differences in growth among the plant species, especially that in dry matter. Applied P-32 has been reported to be readily absorbed from the soil and translocated in plants (IAEA, 1975). Assuming that uniform distribution of the absorbed P-32 has taken place in different plant species rapidly, an estimate of total P-32 absorbed by the plants can be obtained if due weightage is given to the dry matter production. Based on this reasoning, the recovery data presented above were obtained by multiplying the leaf cpm values with the corresponding total dry matter content.

4D.1 Competition in three crop intercropping system

When all the three crops were present and P-32 was applied to the root zone of one of the plants in the system, it was found that the applied label was absorbed not only by the plant which received the treatment but also by the neighbouring plants of the same species as well as that of other species. This was observed at 15, 30 and 45 days after application (Table 49). Thus when P-32 was applied to one of the cassava plants surrounded by three other cassava, two elephant foot yam and one banana (Fig. 24) 31 per cent of the total recovery in the three crop system was accounted for by the cassava which received the treatment, 15 per cent each by the neighbouring three cassava plants, 4 per cent each by the two elephant foot yam plants and 16 per cent by the banana at 45 days after application.

In the same system when the radioactivity was soil injected into the root zone of banana, activity was detected not only in the treated plants but also in the surrounding four elephant foot yam and four cassava plants. The extent of absorption by the treated banana plant (36 %) was comparatively much higher than either a cassava plant (7%) or an elephant foot yam (9%). However, when all the neighbouring plants around the treated banana were considered, the percentage absorption by the four cassava plants was 28, and by the four elephant foot yam plants, 36 per cent.

When the third component crop of the system, elephant foot yam was treated with radiophosphorus, the treated plants absorbed only 28 per cent of the total activity recovered in the whole system at 45 days after application. The surrounding four cassava plants together accounted for 44 per cent of the total recovery while the two banana plants on either side of the treated yam accounted for 28 percent of the total P-32 recovered.

Table 49. Absorption of 32P by the component species in cassava - banana-elephant foot yam intercropping system (cpm/g).

Cropping systems	Sampled plants	Surrounding plants: Days after application 15	30	45	Treated plants: Days after application 15	30	45
C+B+**EFY**	EFY	-	-	-	1939 (3.288)	3107 (3.492)	3859 (3.587)
	B	188 (2.275)	378 (2.577)	375 (2.574)	-	-	-
	C	637 (2.804)	2721 (3.435)	2014 (3.304)	-	-	-
C+**B**+EFY	B	-	-	-	136 (2.133)	331 (2.520)	182 (2.261)
	C	142 (2.153)	359 (2.555)	226 (2.355)	-	-	-
	EFY	12 (1.074)	197 (2.294)	243 (2.385)	-	-	-
C+B+EFY	C	-	-	-	3271 (3.515)	5688 (3.755)	4425 (3.646)
	EFY	46 (1.664)	161 (2.208)	463 (2.665)	-	-	-
	B	64 (1.809)	201 (2.303)	337 (2.528)	-	-	-
C+B	C	-	-	-	1723 (3.236)	2157 (3.334)	1971 (3.295)
	B	58 (1.762)	181 (2.259)	361 (2.558)	-	-	-
C+**B**	B	-	-	-	55 (1.740)	1055 (3.055)	356 (2.552)
	C	5 (0.693)	164 (2.214)	426 (2.630)	-	-	-
C+EFY	C	-	-	-	2781 (3.444)	3833 (3.584)	4671 (3.669)
	EFY	228 (2.359)	495 (2.694)	837 (2.923)	-	-	-
C+**EFY**	EFY	-	-	-	633 (2.801)	1161 (3.065)	1644 (3.216)
	C	525 (2.720)	458 (2.661)	1350 (2.130)	-	-	-
EFY+**B**	B	-	-	-	191 (2.281)	490 (2.691)	683 (2.834)
	EFY	27 (1.425)	137 (2.136)	410 (2.613)	-	-	-
EFY+B	EFY	-	-	-	6594 (3.819)	12041 (4.081)	14376 (4.158)
	B	213 (2.328)	775 (2.889)	1738 (3.240)	-	-	-
C	C	-	-	-	558 (2.747)	3369 (3.528)	2664 (3.425)
B	B	-	-	-	168 (2.226)	373 (2.572)	323 (2.509)
EFY	EFY	-	-	-	17343 (4.239)	25262 (4.402)	27899 (4.446)
C.D.(0.05)		(0.614)	(0.717)	(0.689)	(0.535)	(0.353)	(0.374)
SEM +/-		(0.210)	(0.244)	(0.239)	(0.183)	(0.121)	(0.128)

Figures in parentheses are log. transformed values. Underscore indicate treated plants. C-cassava B-banana EFY-elephant foot yam

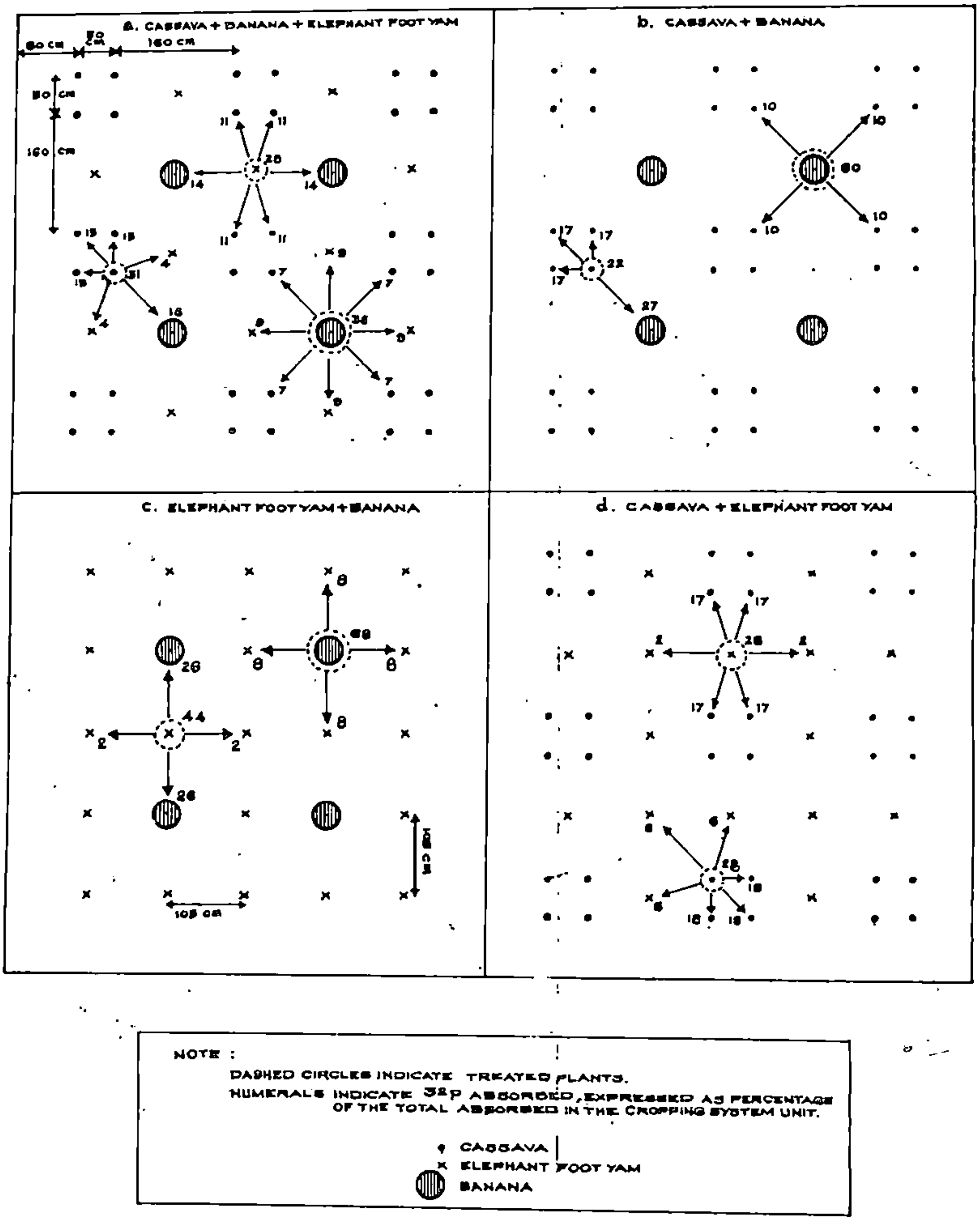


FIG. 24. ABSORPTION OF ^{32}P BY CASSAVA, BANANA AND ELEPHANT FOOT YAM IN INTERCROPPING SYSTEMS.

4D.2 Two species intercropping system

In a two crop intercropping system involving cassava and banana, the application of P-32 to the banana plants resulted in the accumulation of 60 per cent of the total radioactivity recovered in the whole system in banana alone (Fig. 24b). The remaining 40 per cent was accounted for by the four cassava plants surrounding the treated banana. On the other hand, when P-32 was applied to cassava plant, only 27 per cent of the total absorbed radioactivity in the system was contributed by banana, while the treated cassava plant absorbed 22 per cent and the three nearby cassava plants on the same mound accounted for 17 per cent each.

In cassava + elephant foot yam intercropping system, the absorption of P-32 was studied when applied to either of the crops in the system (Fig. 24d). Application of P-32 to elephant foot yam resulted in 28 per cent of the total recovery in the applied plant itself, two per cent each in the two elephant foot yam plants on either side of the treated plant and 17 per cent each in the four cassava plants on either side of the treated elephant foot yam.

When P-32 was applied to cassava, 28 per cent of the total radioactivity absorbed in the system was recovered in the treated plants and 18 per cent in each of the neighbouring cassava plants in the same cluster. The recovery of the applied label was comparatively less in the elephant foot yam near the treated plant, each contributing to only six per cent.

In the banana + elephant foot yam combination, the treated banana accounted for 68 per cent of the total radioactivity recovered, while each of the four elephant foot yam plants spaced equally from the treated banana absorbed only eight per cent of the activity recovered (Fig. 24c). When elephant foot yam was treated with P-32, 44 per cent of the total absorbed activity in the system was recovered in the treated plant itself; the two elephant foot yam plants on either side of the treated plant accounted for two per cent each and the remaining 52 per cent by the two banana plants on either side of the treated elephant foot yam.

The data on the relative uptake of applied P-32 by the treated and the other plants surrounding it indicate the availability of the applied label not only to the plant to which it is applied, but also to the neighbouring plants. Absorption of applied P-32 by plants around the treated ones points to the possibility of intraspecific as well as interspecific competition in nutrient absorption in the intercropping systems studied. In the case of two crop mixed systems, more than half of the radioactivity recovered in the whole system was due to the absorption by the surrounding plants rather than by the treated plants, except when the treated plant was banana. This could probably be due to the differences in the extent and density of active roots among the component crops. In rainfed banana, maximum percentage of active roots (32 %) were observed in a soil zone of 40 cm radius and 30 cm depth (Sobhana, 1985). Studies on the root activity of ridge planted cassava indicated that 61 per cent of the active roots were confined to 20 cm radius and 20 cm depth during 75 to 150 days growth period of the crop (Data not presented). Similarly it was found from root excavation that distribution of roots of elephant foot yam is mainly confined to a radial distance of 25 cm from the plant and to a depth of 20 cm. Based on these results it is more or less obvious that the absorption of P-32 applied to banana could be much higher by the treated plant than by the surrounding cassava or elephant foot yam plants since the roots of cassava and elephant foot yam are concentrated outside the root zone of banana. For the same reason in situations where it is a neighbouring plant, relatively higher uptake of P-32 by banana as compared to other neighbouring plant species may also be expected. It is interesting to note that eventhough the cassava plants treated with P-32 were on the mounds, it was possible for the neighbouring banana planted in the inter-mound spaces to absorb the applied label. This indicates that banana roots could reach into the soil mounds and absorb P-32. It could also be due to the run off of soil containing P-32 from the mounds during rain as well as transfer of P-32 between the cassava and banana through intertwined roots below the soil surface (Halm et al., 1972). This reasoning is further strengthened by the negligible absorption of P-32 by the elephant foot yam planted in the inter-mound spaces, eventhough these are closer to cassava, probably because their root system is not well spread out as that of banana. Cassava plants were also found to be able to absorb P-32 from the soil basins of banana indicating the probable extension of cassava roots to the P-32 treated area around the banana. However the absorption was not much considering the quantity absorbed by the treated banana. Almost similar trend was seen in the absorption of P-32 by elephant foot yam from the soil basin of banana. In other words, the absorption of P-32 by banana from its own soil basin does not seem affected by the presence of other plant species surrounding it in the two crop system.

As in the case of cassava + banana cropping system, the probable intrusion of banana roots to the P-32 applied area around the elephant foot yam has resulted in the recovery of considerable amount of radioactivity in the banana plants near to the treated elephant foot yam. At the same time, the radioactivity absorbed by the neighbouring elephant foot yam plants was practically insignificant.

In three crop mixed system also, banana was found to be dominating over other plant species in the absorption of applied label. Thus on single plant basis, the absorption by banana accounted for 16 and 14 per cent when the treated plants were cassava and elephant foot yam respectively. At the same time a cassava plant near the treated elephant foot yam contributed 11 per cent and an elephant foot yam near the treated cassava 4 per cent only of the total radioactivity recovered in the whole system. A similar comparison of the P-32 absorption by the neighbouring plants of a treated banana indicated that a cassava plant in the vicinity of the treated banana could contribute only 7 per cent and an elephant foot yam could contribute only 9 per cent of the total P-32 recovered in the whole system. The accumulation of a slightly higher amount of radioactivity in elephant foot yam in this system may be due to its nearness to the treated banana compared to cassava which is planted on the diagonally opposite mounds. Moreover cassava was on mounds and elephant foot yam and banana were below the mounds. The treated cassava, elephant foot yam and banana plants accumulated 31, 28 and 36 per cent of the total radioactivity recovered in the respective systems.

From the foregoing discussions the following conclusions can be drawn.

In two and three component intercropping systems banana was the most dominant species among the neighbouring plants when root activity was considered. It is apparent that the neighbouring banana and elephant foot yam plants around the mound planted cassava are able to derive nutrients applied on to the mounds. In this respect banana is a better competitor than elephant foot yam. The mound planted cassava plants were also found to absorb nutrients from the rhizosphere of banana and elephant foot yam planted in the inter-mound spaces.

4E Interspecific Competition for Applied P-32 in Cassava-Groundnut Intercropping Systems

Absorption of P-32 by cassava and groundnut in mixed stand, where cassava was planted on paired row ridge, mounds or flat beds and groundnut in the respective interspaces were studied. In addition to these, the absorption of radiophosphorus by sole cassava from ridges/mounds and interspaces was also monitored. The results of the previous study gave evidence of the absorption of applied P-32 by the mound planted cassava from the interspaces. In this context the two treatments viz., the application of P-32 either on the ridges/mounds or in the interspaces, in the absence of the intercrop were studied to confirm whether the P-32 applied to the interspaces is taken up by the ridge/mound planted cassava. It was found that considerable quantity of P-32 was absorbed by cassava planted on ridges/ mounds when the application of radiophosphorus was done in the interspaces. Surprisingly, the absorption from the interspaces surpassed that from the ridges/mounds by 105 days after planting (Table 50a&b, Fig. 25). The situation was not much different due to the presence of the intercrop. The ability of the intercrop groundnut to utilise the P-32 applied on the ridges is insignificant compared to the absorption of P-32 applied to the intercrop by the cassava. On an average, the cassava plants absorbed 52 per cent of the total radioactivity recovered in the system when the P-32 was applied to the interspaces, while the intercrop accounted for only 48 per cent. On the other hand when P-32 was

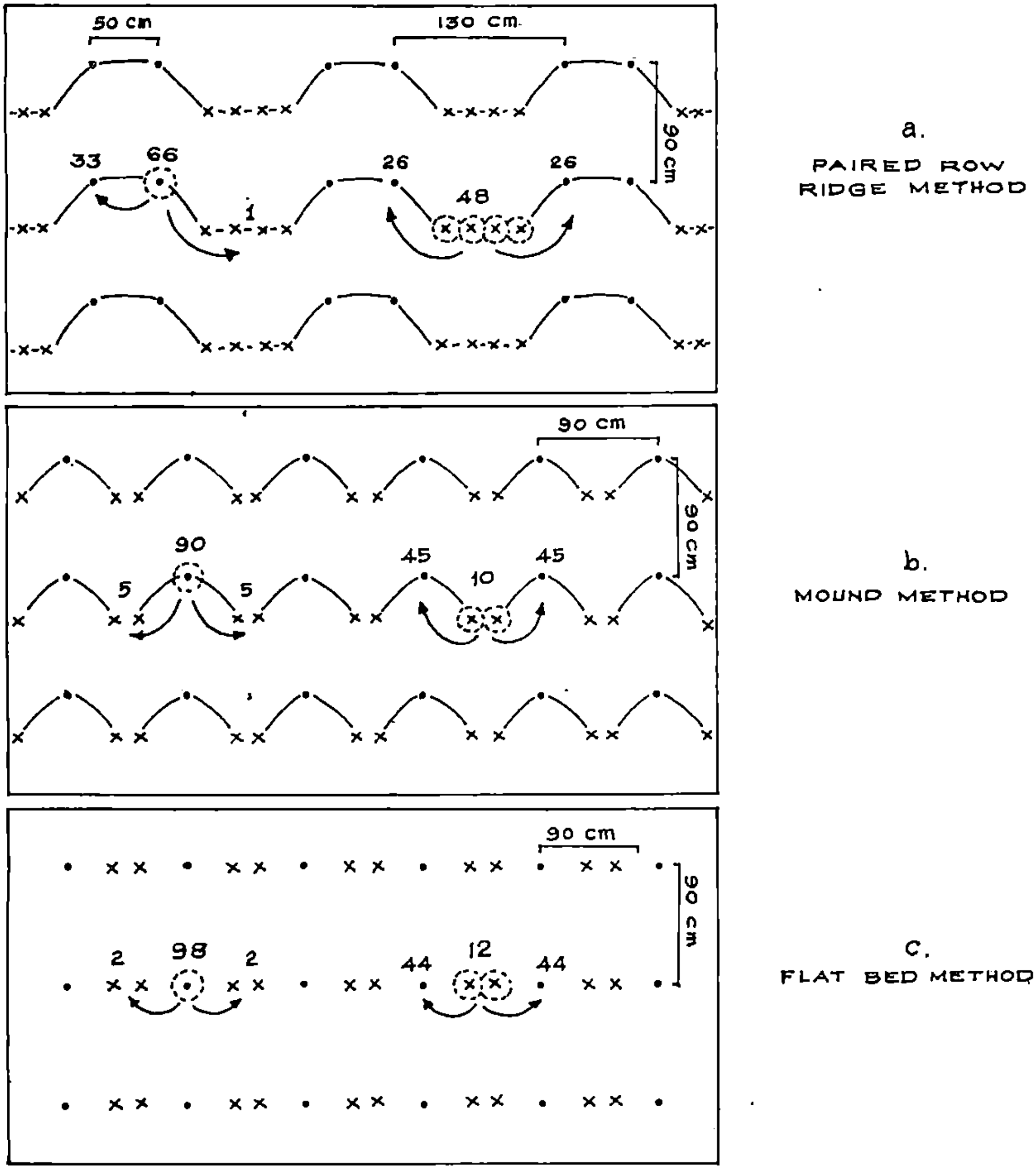
Table 50a. Absorption of 32P by the component species in cassava + groundnut intercropping systems.

Cropping systems	Days after application		
	15	30	45
	(Absorption by cassava in cpm/g)		
C+GN - mound	5741 (3.759)	12163 (4.085)	6666 (3.824)
C+GN - mound	8690 (3.939)	27994 (4.447)	25647 (4.409)
C+GN - flat bed	3404 (3.532)	5262 (3.721)	24338 (4.386)
C+GN - flat bed	5636 (3.751)	14675 (4.167)	17640 (4.247)
C+GN - paired row ridge	3733 (3.572)	8727 (3.941)	7508 (3.876)
C+GN "	4898 (3.690)	5775 (3.762)	5803 (3.764)
C - mound	8035 (3.905)	15679 (4.195)	13132 (4.118)
C - Interspace	1384 (3.141)	18146 (4.259)	41945 (4.623)
C - paired row ridge	5408 (3.733)	10969 (4.040)	7684 (3.886)
C - Interspace	925 (2.966)	13535 (4.131)	24848 (4.395)
C.D. (0.05)	(0.511)	(0.302)	(0.328)
SEM +/-	(0.174)	(0.103)	(0.111)

Table 50b. Absorption of 32P by the component species in cassava + groundnut intercropping systems.

Cropping systems	Days after application		
	15	30	45
	(Absorption by groundnut in cpm/g)		
C+GN - mound	1286 (3.109)	322 (2.508)	292 (2.465)
C+GN - mound	2083 (3.319)	4033 (3.606)	4892 (3.689)
C+GN - flat bed	231 (2.364)	394 (2.595)	364 (2.561)
C+GN - flat bed	3260 (3.513)	3951 (3.597)	4083 (3.611)
C+GN - paired row-ridge	88 (1.944)	155 (2.190)	210 (2.322)
C+GN - paired row-ridge	3140 (3.497)	4078 (3.610)	5015 (3.700)
GN	3400 (3.531)	7074 (3.850)	6944 (3.842)
C.D. (0.05)	(0.302)	(0.411)	(0.352)
SEM +/-	(0.100)	(0.141)	(0.121)

Figures in parentheses are log. transformed values. Underscore indicate treated plants or area. C-cassava GN-groundnut



NOTE:
DASHED CIRCLES INDICATE TREATED PLANTS.
NUMERALS INDICATE ^{32}P ABSORBED EXPRESSED AS PERCENTAGE OF THE TOTAL ABSORBED IN THE CROPPING SYSTEM UNIT

• CASSAVA   × GROUND NUT

FIG. 25. ABSORPTION OF ^{32}P BY CASSAVA AND GROUND NUT IN INTERCROPPING SYSTEM.

applied to the ridge, the treated plants absorbed 66 per cent of the total recovery; the other cassava plant in the paired row absorbed 33 per cent and only 1 per cent was accounted for by the intercrop planted in the interspaces.

In single row mound system, application of P-32 to the cassava resulted in the absorption of a major portion (about 90 per cent of the total recovery) of P-32 by the treated plant itself, while the groundnut plants on either side of the mound absorbed only about 5 per cent each of the total recovery.

When the application of P_32 was done to the intercrop in the interspaces, 45 per cent of the total P-32 recovery was accounted for by each cassava plant on the two mounds on either side of the applied area. Here again, inspite of the application made to the intercrop, the absorption by the intercrop was negligible as compared to the cassava.

The absorption pattern of P-32 by ridge/mound planted cassava, when the activity was applied either on the ridges/ mounds or in the interspaces in the absence of the intercrop gives further evidence to the considerable absorption of the applied label by cassava plants from the interspaces of the mounds.

In flat bed system also the P-32 absorption pattern by these two species was almost similar to ridge/mound system. Irrespective of whether the application was done to the cassava or to the intercrop, the utilization of applied P-32 was predominently by cassava. On the whole it may be deduced that interspecies competition for applied nutrients in cassava +

groundnut intercropping system will be severe and will always be in favour of cassava.

Though cassava-groundnut intercropping system is found to be successful in India and many other countries, the yield responses of cassava obtained in such intercropping systems are highly conflicting. The yield decrease in cassava noticed in some of the trials (Mohankumar, 1980; CIAT, 1981; Prabhakar and Nair, 1982) and the yield increase recorded in some other experiments (Mattos et al., 1980 and KAU, 1983) are not convincingly explained. The results of the present trial provide strong indications of plant interactions in cassava-groundnut intercropping systems.

Since groundnut is short statured and of short duration the chances for canopy overlapping and competition for light are limited. This is substantiated by the data on relative light transmission through the cassava canopy (Fig. 8).

The extent of root level competition existing in a cassava-groundnut intercropping system can be adjudged from the relative uptake of the radio-label by the component species. The absorption pattern of P-32 observed in the present study indicates that cassava roots are active in the interspaces and absorb nutrients by competing with groundnut. But the uptake of P-32 by the groundnut crop from the cassava root zone was negligible indicating that the groundnut roots are not so active in the cassava root zone and the chances for absorption of plant nutrients by groundnut in competition with cassava are practically nil. This is also evident from the root excavation studies

(Fig. 7) which revealed that groundnut root system was comparatively more confined and shallow.

The conclusions which can be arrived at from this study are that in cassava-groundnut intercropping, cassava roots are active in the interspaces. This is true irrespective of whether cassava was planted on ridge, mound or flat bed. In all these situations the intercrop roots are confined to the interspaces and do not offer serious competition for the fertilizers applied to cassava. In this cropping system, the only possibility of nutrient competition is that resulting from the root activity of cassava in the interspaces. In such cases the cassava will be in an advantageous position and may derive more nutrients than sole cassava; the intercrops may suffer. Experiments carried out at IITA, Nigeria showed that intercropping with maize and melon increased the cassava yield as compared to sole cassava (IITA, 1975). Experiments conducted in Kerala also showed that intercropping with groundnut and blackgram increased cassava yield. (KAU, 1983). However, in these trials the yields of the intercrops were not compared with that of sole crop and hence it cannot be confirmed whether the intercrop yield was less than its sole crop. The results of the groundnut-cassava intercropping discussed in section 4C of this investigation showed that neither the cassava nor the groundnut yield was influenced by intercropping. The groundnut yield obtained in intercropped situation was similar to that of the sole crop. Two reasons can be assigned to this. One is that the cassava roots may be active in groundnut root zone but since cassava and groundnut were fertilized separately and adequately the competition for nutrients may not be significant. Secondly, the cassava roots may be active in the interspaces only from 75 to 90 days after planting. Till this time their main zone of activity was away from the groundnut root zone. Since by 90 days the peak growth period of groundnut was completed, the competition from cassava was not manifested on groundnut yield.

Summary

SUMMARY

A series of investigations were conducted at the College of Horticulture, Kerala Agricultural University, Trichur, Kerala, India to evaluate some of the cassava based intercropping systems and to investigate the interspecific interactions, during the years 1983-84 and 1984-85. There were three field trials and two micro-plot trials. In field trial I, the effect of planting geometry of cassava and intercropping with colocasia, elephant foot yam and banana were studied. In trial II, the performance of three floor crops viz., cowpea, elephant foot yam and groundnut as influenced by the planting geometry of cassava in a cassava + banana mixed cropping system was studied. In trial III, the possibility of sequential intercropping with groundnut or cowpea in paired row planting of cassava and the fertilizer response of the intercrops were studied. All these trials were laid out in Randomised Block Design and replicated thrice.

In one of the micro plot trials conducted, the absorption of ^{32}P by the component species in a cassava + banana + elephant foot yam polyculture with cassava planted in square cluster was investigated. In the other micro plot trial, ^{32}P absorption by cassava and groundnut under the situations of cassava planted in paired row-ridge, mound and flat bed methods were studied. These two micro plot trials were laid out in Completely Randomised Design with three replications.

The results obtained from these trials are summarised below.

5.1 Trial I

Intercropping with colocasia, elephant foot yam and banana resulted in an increase in the height and leaf area of cassava. Paired row and square clustered planting of cassava also resulted in increased plant height as compared to the normal planting of cassava.

Among the different intercrops, elephant foot yam and banana increased the number of tubers per plant and the girth of tuber of cassava.

The tuber yield of cassava intercropped with elephant foot yam was found to be consistently better. Cassava intercropped with banana also produced higher yield than sole cassava. The best treatment combination was square clustered planting of cassava and intercropping with elephant foot yam, which gave a cassava tuber yield of 20.1 t/ha.

The different geometries of planting of cassava showed no significant influence on the tuber yield when compared with the normal method of planting.

The intercrops colocasia and elephant foot yam were slightly taller than their sole crops. But in banana, this difference was not perceptible. Leaf area was less in intercrops colocasia, elephant foot yam and banana compared to their sole crops.

The yield of intercrop colocasia was 211 g/plant and that of sole colocasia was 259 g/plant. The intercrop elephant foot yam gave an yield of 1.37 kg/plant whereas its sole crop gave an yield of 1.8 kg/plant. The yield of banana in intercropped and sole cropped situations were not different on per plant basis. The harvest index of intercrop colocasia, elephant foot yam and banana were not much different from their respective sole crops.

High biomass production was recorded by cassava + elephant foot yam combination and cassava + banana during the first year trial; the respective values being 12.9 and 12.7 t/ha. The total land equivalent ratio of intercropping treatment were significantly higher and the maximum was recorded by cassava + banana (1.81); during the second year, cassava + banana, cassava + elephant foot yam and cassava + colocasia were on par.

Intercropping cassava with colocasia, elephant foot yam and banana increased the nutrient uptake by cassava. Cassava + colocasia combination removed 133, 11, 107, 46, 12 and 8 kg/ha of N, P, K, Ca, Mg and S respectively. In the case of cassava + banana cropping system, the respective nutrient removal figures were 227, 14, 236, 70, 16 and 11 kg/ha and in cassava + elephant foot yam 202, 16, 144, 58, 21 and 12 kg/ha. The net income from cassava cultivation can be increased by the intercropping. Maximum net return was obtained from cassava + elephant foot yam cropping system during both the years.

5.2 Trial II

In a cassava + banana cropping system the cassava height and leaf area were increased when a floor crop of cowpea or elephant foot yam or groundnut was grown. In the first year cassava, the number of tubers was not influenced by the floor crops but in the second year, intercropping with banana resulted in the lowest number of tubers per plant.

Cassava recorded the maximum girth of tubers in the cassava + banana + elephant foot yam cropping system. The cassava yield in this cropping system was maximum when cassava was planted in square cluster (13.5 t/ha) or triangular cluster (11 t/ha).

The height, leaf area, number of hands and fingers, weight of bunch, dry matter production and harvest index of the banana intercrop were not affected by cassava or the floor crops.

The floor crops of cowpea, groundnut and elephant foot yam were taller than the respective sole crops. The leaf areas of the floor crops cowpea and groundnut in general were slightly higher than the sole crops.

The floor crop of elephant foot yam grown in cassava + banana mixed stand gave appreciable yield during both the years (5.3 to 8 t/ha during the first year and 6 to 12.6 t/ha in the second year). The floor crops cowpea and groundnut gave reasonable yield only during the first year, at 1 to 1.6 t/ha depending on the geometry of planting of cassava.

Considerable quantity of plant nutrients were recycled by the haulm of the floor crops especially with respect to the legumes.

The total biomass production in cassava + banana intercropping can be considerably increased by growing the floor crops of cowpea, elphant foot yam or groundnut. Cowpea and groundnut produced about 1.4 to 2.6t/ha of dry matter within a period of 90 to 120 days whereas elephant foot yam produced 1.7 to 2.7t/ha within 240 days. The land equivalent ratio was maximum in cassava + banana + elephant foot yam (1.7) followed by cassava + banana + cowpea (1.6).

The nutrient uptake by the component species in the polycultures was not significantly different. The cumulative uptake of N, P, K, Ca, Mg and S was considerably higher in all the three component polycultures.

The organic C, total N, available P and K, and exchangeable Ca, Mg and SO4 content of the soil were decreased due to the two year cropping. The intercropping practices did not influence the acid extractable Zn, Fe, Cu and Mn status of the soil.

5.3 Trial III

The intercropping of cassava with cowpea, groundnut and groundnut + red gram did not reduce the yield of cassava. In the sequential intercropping practices attempted in cassava under paired row planting, the second intercrop of cowpea or groundnut was unsuccessful. An alternate cropping system found successful in utilising the additional interspace made available by paired row planting of cassava is the simultaneous planting of two leguminous intercrops, one a short duration, short statured and the other of long duration and long statured, the typical example evaluated being cassava + groundnut + red gram. The groundnut and cassava yields in the cropping system were not reduced due to the presence of red gram. The maximum total land equivalent ratio of 1.8 was recorded by cassava + groundnut + red gram.

This was followed by cassava + groundnut and cassava + cowpea. Considering the net income and the benefit:cost ratio also the same rating can be made.

The uptake of N, P, K, Ca, Mg and S by cassava and the intercrops were worked out. The maximum uptake was from cassava + groundnut + red gram system and were 198, 24, 208, 166, 34 and 19 kg/ha respectively.

The higher levels of fertilizer applied to the intercrops increased the uptake by cassava and the intercrops. The fertilizer requirements of intercrop cowpea and groundnut were only about 60 to 90 per cent of the sole crop recommendation and the optimum doses of nitrogen, phosphate and potash were found to be 6, 18 and 18 kg/ha respectively for intercrop cowpea. The corresponding values for intercrop groundnut were 4, 30 and 30 kg/ha.

The soil organic carbon and total nitrogen in legume intercropped plots were more as compared to sole crop. The exchangeable Ca status of the soil was better in groundnut intercropped plots. The exchangeable Mg and sulphate in the soil were not influenced by the intercrops or the fertilizer level given to the intercrops. The extractable Zn, Fe, Mn and Cu contents of the soil were not significantly different in intercropped and sole cropped plots after two years of cropping. As compared to the pre-crop soil analyses data, the organic carbon and total N content was decreased by cropping whereas the other exchangeable nutrients were increased. The micronutrient status was not considerably changed due to two year cropping whether in intercropping or in sole cropping.

The nutrient balance sheet worked out based on input-output relationships for the two year cropping showed that the total N and available P contents of the soil were far less than the expected values indicating loss by leaching, erosion etc. In the case of available K, the balance observed was much more than that expected and the possibility of mobilisation of fixed K as a result of intensive cropping is indicated.

5.4 <u>Micro plot Trial I</u>

The radiophosphorus applied to the root zone of any of the components in the mixed cropping system involving cassava, banana and elephant foot yam was absorbed not only by the applied plants but also by the surrounding plants. Banana was the most dominating species in the cassava + banana + elephant foot yam mixed cropping system and accumulated the major share of the P-32 applied. Cassava planted on raised mounds absorbed P-32 from the root zones of elephant foot yam and banana which were planted in the interspaces. The reverse interaction of elephant foot yam and banana absorbing P-32 from mound planted cassava root zone also was observed, but only to a small extent in the case of elephant foot yam.

5.5 <u>Micro plot Trial II</u>

In a cassava + groundnut cropping system, cassava was the most dominant component, accumulating about 90 to 98 per cent of the P-32 applied to cassava on mounds and about 50 per cent of that applied to the intercrops in the interspaces. This was true

5.6 Conclusions and Future Line of Work

The results of these experiments lead to the following conclusions and future line of work.

There is immense scope for increasing the production potential of cassava based cropping systems by inter/mixed cropping practices. Apart from the short duration legumes like cowpea and groundnut, longer duration intercrops like colocasia, elephant foot yam and banana also can be successfully grown in cassava without yield loss of cassava. However, for the success of these cropping systems, interspace more than that available under normal planting of cassava is required, which can be accomplished by paired row, square cluster or triangular cluster planting of cassava. The banana variety 'Palayankodan' was successful as an intercrop under modified geometry of planting of cassava; however it took 16 to 18 months to harvest the bunches under rainfed conditions, where there is 4 to 6 months dry period. So the field was engaged by banana even when it was time to plant the second year cassava; the cassava planted in the standing banana was affected by the shade. In the first year there was complementary interaction between cassava and banana and as such, it is a viable cropping system. But to make it more productive we have to substitute the second year cassava crop with shade tolerant species which are to be identified.

The production potential of the cassava + banana cropping system can be further improved by reducing the population of cassava and banana and including a third component like cowpea or groundnut or elephant foot yam. The maximum production was observed in cassava + banana + elephant foot yam with cassava planted in square cluster or triangular cluster. This cropping system likewise can be made more productive by substituting the second year cassava with some shade tolerant species.

The sequential intercropping of cassava with cowpea and/or groundnut is not possible with paired row cassava. The second season intercrop will be a failure if it is short statured because of the shade from tall growing cassava. Under such situation tall growing legumes which can increase in height competitively with cassava will get sufficient light when grown in the interspaces. So the intercrop selected for the second season should be tall growing or shade tolerating. Instead of attempting sequential intercropping, simultaneous planting of groundnut + red gram in the interspaces of paired row planted cassava resulted in maximum utilization of sunlight and biomass production. Cropping systems of this type may be more productive and viable, but further studies are needed to establish the growth pattern of each component in the cropping system and the interspecific interactions.

In this study rows of cassava were arranged in North-South direction. The light regime in the interspaces might have been better for the intercrops if the rows were aligned East - West. But such alignment may adversely affect the cassava productivity by mutual shading. The success of sequential intercropping with cowpea or groundnut under East-West arrangement of cassava rows and the performance of cassava under such systems require detailed study.

Studies with radiophosphorus indicated that there can be considerable root interaction in intercropping systems which may be complementary or competitive. The most active interaction is possible when all the component crops are of long duration as in cassava + banana + elephant foot yam system. The influence of such interactions on the growth and development of each component crop requires further investigation. The root interactions in cassava-groundnut intercropping systems always favoured cassava because of the smaller root system of groundnut. The cassava roots were more active in the mound boundaries and interspaces after 2 to 4 months growth. This means that the top dressing of cassava may be more effective if it is done in the inter-mound area instead of the existing practice of applying on the mounds. This aspect also needs a detailed investigation.

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* Originals not seen

Appendices

Appendix.I Physical and chemical properties of the soil of the experimental sites.

	Trial I (Vellanikkara)	Trial II (Kannara)	Trial III (Kannara)
A. Physical properties			
Clay (%)	25.78	42.20	44.50
Silt (%)	14.06	5.25	5.30
Fine sand (%)	43.56	35.93	33.93
Coarse sand (%)	16.60	16.60	16.30
Textural class	sandy clay loam	sandy loam	sandy loam
B. Chemical properties			
Organic Carbon (%)	1.608	1.305	1.684
Total Nitrogen (%)	0.175	0.163	0.280
Available P (ppm)	14	54	19
Available K (ppm)	68	226	61
Exchangeable Ca (ppm)	254	356	226
Exchangeable Mg (ppm)	20	62	44
Exchangeable SO4 (ppm)	32	43	38
Exchangeable Fe (ppm)	19	20	17
Exchangeable Mn (ppm)	79	106	48
Exchangeable Cu (ppm)	3.6	2.0	2.4
Exchangeable Zn (ppm)	4.5	6.2	3.8
Soil pH	5.9	6.3	6.1

Appendix.II Meteorological data for the crop period of the experiments (recorded at Vellanikkara)

Month	Temperature Min. (oC)	Temperature Max. (oC)	Mean Relative Humidity (%)	Total rainfall (mm)	No.of rainy days	Total Evapo-ration (mm)	Total sunshine hours
Apr. 1983	25.8	36.2	66	Nil	Nil	220	271
May	25.5	35.1	69	37.4	3	183	241
Jun.	24.5	31.9	79	387.2	19	75	114
Jul.	23.7	29.7	87	580.6	21	-	90
Aug.	23.8	29.1	87	754.7	26	32	61
Sep.	23.4	29.5	84	494.6	24	104	108
Oct.	23.1	31.2	77	149.8	6	127	216
Nov.	22.3	31.8	71	60.2	3	138	245
Dec.	23.9	31.2	63	24.4	3	179	216
Jan. 1984	23.3	32.4	58	Nil	Nil	219	256
Feb.	24.2	34.3	56	27.0	3	211	237
Mar.	24.3	35.2	67	18.9	2	199	238
Apr.	24.9	34.8	73	109.2	9	160	220
May	25.8	34.5	71	40.6	6	215	247
Jun.	22.7	29.0	87	853.1	28	-	42
Jul.	22.9	28.6	87	730.0	24	90	78
Aug.	22.2	29.3	84	260.2	21	125	155
Sep.	23.2	30.4	80	158.6	7	138	195
Oct.	22.1	29.9	79	323.7	12	119	188
Nov.	23.1	32.1	67	7.8	1	160	219
Dec.	20.8	31.9	58	16.4	1	202	278
Jan. 1985	22.6	32.6	67	14.7	2	241	278
Feb.	22.8	34.7	58	Nil	Nil	179	248
Mar.	24.6	36.1	63	2.0	Nil	224	279

Appendix.III Economics of intercropping cassava in paired row and square cluster planting with colocasia, elephant foot yam and banana.

Cropping systems		Gross return: Cassava	Gross return: Inter-crops	Gross return: Total	Cost of cultivation: Inter-crops	Cost of cultivation: Total	Net return	Benefit-cost ratio
		(Rupees)						
(1983-84)								
C	P	10583	-	10583	-	7860	2723	1.4
	SC	10763	-	10763	-	7860	2903	1.4
	Mean	10673	-	10673	-	7860	2813	1.4
C+Col.	P	10823	4035	14858	2050	9910	4948	1.5
	SC	10950	7173	18123	3300	11160	6963	1.6
	Mean	10887	5604	16491	2675	10535	5956	1.6
C+EFY	P	12548	6955	19503	4800	12660	6843	1.5
	SC	12578	13116	25694	8000	15860	9834	1.6
	Mean	12563	10036	22599	6400	14260	8339	1.6
C+B	P	11993	15024	27017	10960	18820	8197	1.4
	SC	12668	17843	30511	10960	18820	11691	1.6
	Mean	12331	16434	28764	10960	18820	9944	1.5
(1984-85)								
C	P	13080	-	13080	-	7860	5220	1.7
	SC	14243	-	14243	-	7860	6383	1.8
	Mean	13662	-	13662	-	7860	5802	1.7
C+Col.	P	14760	4015	18775	2050	9910	8865	1.9
	SC	15278	6713	21991	3300	11160	10831	2.0
	Mean	15019	5364	20383	2675	10535	9848	1.9
C+EFY	P	15600	5659	21259	4800	12660	8599	1.7
	SC	17648	12001	29649	8000	15860	13789	1.9
	Mean	16624	8830	25454	6400	14260	11194	1.8
C+B	P	9593	12966	22559	8220	16080	6479	1.4
	SC	9278	13788	23066	8220	16080	6986	1.4
	Mean	9436	13377	22813	8220	16080	6733	1.4

C-cassava Col.-colocasia B-banana EFY = Elephant foot yam
P-paired row SC-Square cluster
Cassava @ Rs.750, Colocasia @ Rs.1000, EFY @ Rs.1250 and Banana @ Rs.1500 per tonne.

Appendix.IV Economics of floor-cropping cassava + banana cropping system with cowpea, elephant foot yam and groundnut.

Cropping systems		Gross return				Cost of cultivation		Net return	Benefit cost ratio
		Cassava	Banana	Floor crops	Total	Floor crops	Total		
		(Rupees)							
(1983-84)									
C (N)	Mean	9752	-	-	9752	-	7140	2612	1.4
C+B+CP	P	7710	14652	2878	25240	1425	16249	8991	1.6
	SC	7464	12537	4351	24352	2030	15894	8458	1.5
	TC	6387	13595	4369	24351	2030	15294	9057	1.6
	Mean	7187	13595	3866	24648	1828	15812	8836	1.6
C+B+EFY	P	7502	14501	6580	28583	5200	20024	8559	1.4
	SC	10092	15558	9959	35608	7050	20914	14694	1.7
	TC	8258	15407	9654	33319	7050	20314	13005	1.6
	Mean	8617	15155	8731	32503	6433	20417	12086	1.6
C+B+GN	P	7502	12084	2615	22201	1700	16524	5677	1.3
	SC	7256	13896	4082	25234	2450	16314	8920	1.6
	TC	6841	14652	4160	25653	2450	15714	9939	1.6
	Mean	7200	13544	3619	24363	2200	16184	8179	1.5
C+B	P	7691	13896	-	21587	-	14824	6763	1.5
	SC	8163	12840	-	21003	-	13864	7139	1.5
	TC	7030	15105	-	22135	-	13264	8871	1.7
	Mean	7628	13947	-	21295	-	13984	7591	1.5
(1984-85)									
C (N)	Mean	10660	-	-	10660	-	7140	3520	1.5
C+B+CP	P	6916	10272	540	17728	925	13057	4671	1.4
	SC	6104	11753	680	18567	1330	12593	5966	1.5
	TC	5366	11783	775	17974	1330	12058	5866	1.5
	Mean	6129	11279	665	17443	1195	12571	5501	1.5
C+B+EFY	P	6047	12537	8475	27059	4700	16832	10227	1.6
	SC	5877	13595	15065	34537	6550	17818	16719	1.9
	TC	5329	13595	15695	34619	6550	17278	17341	2.0
	Mean	5751	13242	13078	32072	5933	17309	14762	1.9
C+B+GN	P	6104	11330	288	17722	1300	13432	4290	1.3
	SC	5329	11783	403	17515	1850	13118	4397	1.3
	TC	5027	11330	430	16787	1850	12578	4209	1.3
	Mean	5487	11481	374	17341	1667	13043	4299	1.3
C+B	P	6161	10574	-	16735	-	12132	4603	1.4
	SC	4781	11027	-	15808	-	11268	4540	1.4
	TC	5386	11330	-	16716	-	10728	5988	1.6
	Mean	5443	10977	-	16420	-	11376	5044	1.4

Cost of cultivation of cassava (C) @ Rs.6760, 5800, 5200 per hectare respectively for paired row (P), square cluster (SC), triangular cluster (TC) cassava in the first year. The figures for second year- Rs.6084, 5220 and 4680 respectively.
Cost of cultivation of banana (B) @ Rs.8 per plant for plant crop (Rs.8064 per ha) and Rs.6 per plant for ratoon. (Rs.6048 per ha).
Price of produce per tonne- Rs.750 for C, Rs.1500 for B, Rs.2500 for Groundnut (GN), Rs.5000 for cowpea (CP) & Rs.1250 for Elephant foot yam (EFY).

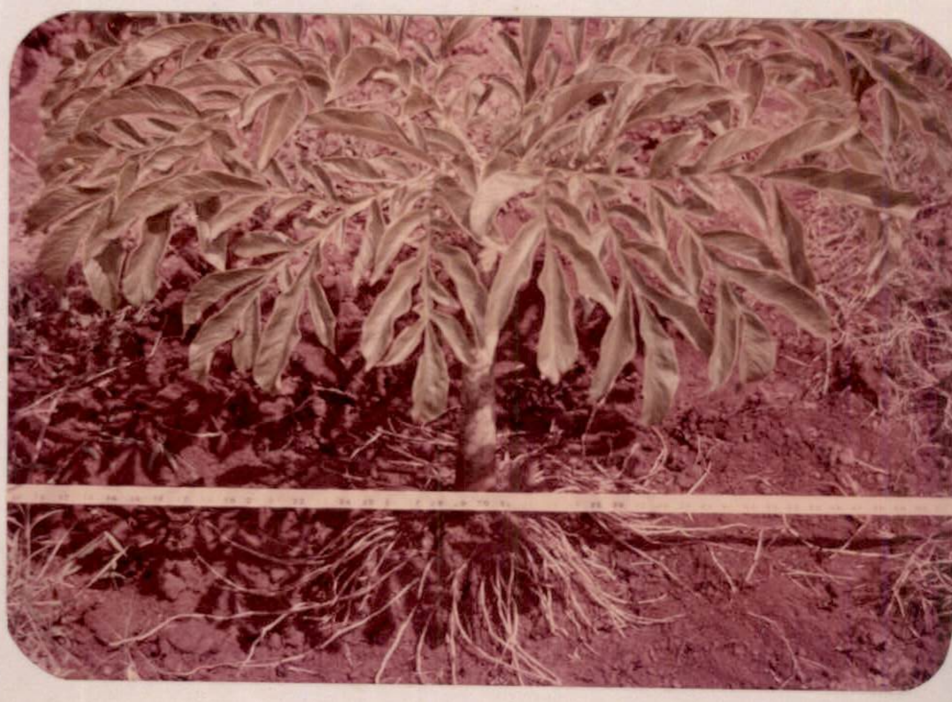
Appendix.V Economics of intercropping cassava (C)in paired row with cowpea (CP), groundnut (GN) and GN + red gram (RG)

Cropping systems	Ferti- lizer levels	1983-84						Benefit cost ratio
		Gross return			Cost of cultivation		Net return	
		Cassava	Inter- crops	Total	Inter- crops	Total		
				(Rupees)				
C+CP-CP	MO	9722	3200	12922	1804	8944	4152	1.4
	M1	11879	2995	14874	1886	9026	6002	1.7
	M2	13889	3365	17254	1966	9106	8281	1.9
C+CP-GN	MO	11416	2610	14026	1804	8944	5256	1.6
	M1	13583	3730	17313	1886	9026	8441	1.9
	M2	14194	3585	17779	1966	9106	8806	2.0
C+GN-CP	MO	10953	2638	13591	1380	8520	4726	1.6
	M1	13889	3763	17652	1562	8702	8551	1.9
	M2	14509	3343	17752	1745	8885	8531	1.9
C+GN-GN	MO	10805	2700	13505	1380	8520	4640	1.5
	M1	10953	3215	14168	1562	8702	5075	1.6
	M2	14194	2958	17152	1745	8885	7831	1.8
C(N)+CP	M2	13583	3170	16753	1966	9106	6780	1.8
C(N)+GN	M2	13889	2765	16429	1745	8885	7108	1.8
C		13009	-	13009	-	7140	5869	1.8
C(N)		12657	-	12657	-	7140	5517	1.8
				(1984-85)				
C+CP-CP	MO	12564	3120	15684	1630	8944	6914	1.8
	M1	15110	3440	18550	1732	9026	9678	2.1
	M2	15221	3200	18421	1833	9106	9448	2.0
C+CP-GN	MO	14185	2740	16925	1630	8944	8155	1.9
	M1	13212	3390	16602	1732	9026	7730	1.8
	M2	13657	3160	16817	1833	9106	7844	1.9
C+GN-CP	MO	14712	2893	17605	1725	8865	8740	2.0
	M1	12907	3280	16187	1953	9093	7094	1.8
	M2	16972	2893	19865	2181	9321	10544	2.1
C+GN-GN	MO	13092	2315	15407	1725	8865	6542	1.7
	M1	13064	2990	16054	1953	9093	6961	1.8
	M2	14814	2765	17579	2181	9321	8258	1.9
C(N)+CP	M2	14814	3020	16834	1833	9106	8861	2.0
C(N)+GN	M2	14712	2893	17605	2181	9321	8284	1.9
C+GN+RG	M2	14629	3085	17714	2527	9667	8047	1.8
C		15147	-	15147	-	7140	8007	2.1
C(N)		15379	-	15379	-	7140	8239	2.1

C-cassava CP-cowpea GN-groundnut RG-red gram MO, M1 and M2 are fertilizer doses for intercrops and represent 0, 50 and 100 % of the sole crop recommendation respectively.

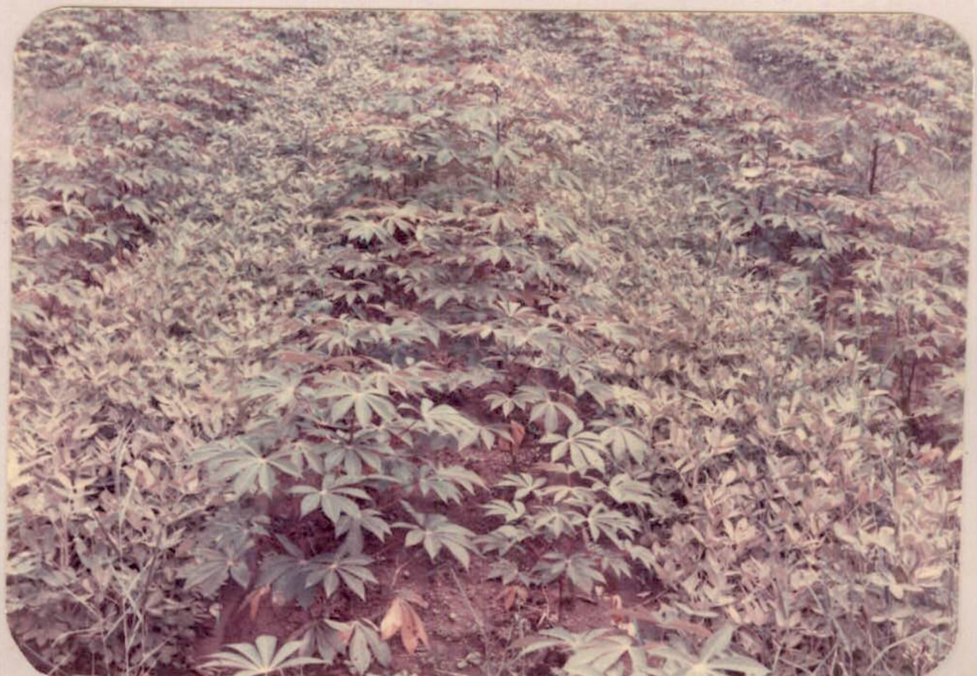
Price of produce per tonne- Rs.750 for C, Rs.2500 for GN and Rs.5000 for CP and RG

Plates




T+CP


TP-EY



PRODUCTION POTENTIAL OF CASSAVA-BASED CROPPING SYSTEMS

By

ASHOKAN, P. K.

ABSTRACT OF A THESIS

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Department of Agronomy
COLLEGE OF HORTICULTURE
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Kerala - India

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ABSTRACT

A series of field experiments were conducted during the years 1983-84 and 1984-85 at College of Horticulture, Kerala Agricultural University, Trichur, to evaluate some of the cassava based intercropping systems and to investigate the interspecific interactions. There were three field trials and two micro plot trials. In the first field trial, the treatments were factorial combinations of two planting geometries of cassava viz., paired row and square cluster planting and four intercropping practices viz., intercropping with colocasia, elephant foot yam, banana and no intercropping. In the second field trial, there were 12 treatments derived from the factorial combinations of three geometries of planting (paired row, square cluster and triangular cluster) and four intercropping practices (growing a floor crop of cowpea, groundnut, elephant foot yam and not growing any floor crop) in a cassava + banana intercropping system. In the third field trial, the possibility of growing two crops of cowpea and/or groundnut in sequence (Kharif and Rabi) and the fertilizer requirements of intercrops were studied. All the three field trials were laid out in Randomised Block Design and replicated thrice.

In one of the micro-plot trials, 32P absorption by the component species in a cassava + banana + elephant foot yam polyculture with cassava planted in square cluster was studied. In the other micro plot trial 32P absorption by cassava and

groundnut under the situations of cassava planted in paired row-ridge, mound and flat bed methods were studied. These two micro-plot trials were laid out in Completely Randomised Design with three replications.

Paired row and square clustered planting of cassava gave similar yields as that of normal method when the plant population was the same. Intercropping cassava in square cluster with elephant foot yam resulted in maximum yield of cassava (20.1 t/ha) and elephant foot yam (10.6 t/ha). Banana and colocasia were also found to be successful as intercrops in cassava planted in paired row or square cluster. Intercropping with elephant foot yam and banana resulted in higher yield of cassava.

The intercrops colocasia and elephant foot yam recorded lesser yields than the sole crops whereas in intercrop banana such difference was not observed. The maximum LER of 1.81 was obtained in cassava + banana cropping system. The cassava + elephant foot yam intercropping removed 133, 11, 107, 46, 12 and 18 kg/ha of N, P, K, Ca, Mg and S respectively whereas in the cassava + banana combination the corresponding figures were 227, 14, 236, 70, 16 and 11 kg/ha.

From the two year trials, the cassava + banana + elephant foot yam cropping system with cassava planted in square cluster (9070 plants/ha) / triangular cluster (6800 plants/ha) was found to be the most productive and economical cropping system. Elephant foot yam was found to be shade tolerant and the yield reduction in intercropped situation was only marginal. The floor crops of cowpea and groundnut were successful in the first year. The land equivalent ratio in cassava + banana + elephant foot yam intercropping was 1.7 and this cropping system gave a net profit of Rs. 13300 per hectare. The N, P, K, Ca, Mg and S removal in a cassava + banana + elephant foot yam cropping system was found to be 198, 24, 200, 166, 34 and 19 kg/ha respectively.

Sequential intercropping in paired row planted cassava was not successful, but growing groundnut and red gram simultaneously in the interspace was found to be successful; groundnut was harvested after four months, red gram after eight months and cassava after nine months. The fertilizer requirements of intercrop cowpea and groundnut were found to be only about 60-90 per cent of the sole crop recommendation and the optimum doses of N, P and K worked out were 6, 18 and 18 kg/ha for cowpea and 4, 30 and 30 kg/ha for groundnut. The main crop of cassava also was benefited by the application of fertilizers to the intercrops.

The organic carbon and total nitrogen content of soil were reduced in two or three component intercropping systems by the two year cropping practices. The exchangeable P, K, Ca, Mg and SO_4 increased in situations where legumes alone were intercropped and decreased when banana and a floor crop of cowpea, groundnut or elephant foot yam were intercropped. The micronutrient status of the soil was not remarkably changed by the two season cropping. The intercrop and sole crop systems were not different in their influence on the post crop nutrient status of the soil.

The radiophosphorus applied to the root zone of any of the components in the mixed cropping system cassava + banana + elephant foot yam with cassava in square cluster planting was absorbed not only by the treated plants but also by the surrounding species. Banana was the most dominant component in this polyculture.

In a cassava + groundnut cropping system, cassava was the most dominant component, accumulating about 90 to 98 per cent of the 32P applied to cassava on mounds/ridges and about 50 percent of that applied to the groundnut root zone in the interspaces. Groundnut root system was small and less active and was able to derive only about 2 to 5 per cent of the 32P applied to cassava mounds. It was also deduced that the root interactions were stronger when all the components of the intercropping systems were of longer duration and it would be mild with legume intercrops of short duration.