NUTRIENT - MOISTURE - LIGHT INTERACTIONS IN A COCONUT BASED HOMESTEAD CROPPING SYSTEM

By

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DECLARATION

I hereby declare that this thesis entitled **"Nutrient - Moisture - Light interactions in a coconut based homestead cropping system"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Nutrient - Moisture - Light interactions in a coconut based homestead cropping system"** is a record of research work done independently by **Sri. C. S. Ravindran** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

%	-	per cent
CD (0.05)	-	Critical Difference at 5%
CGR	-	Crop Growth Rate
cm	-	centimetre
CO_2	-	Carbon-di-Oxide
cpm	-	counts per minute
CPCRI	-	Central Plantation Crops Research Institute
CTCRI	-	Central Tuber Crops Research Institute
d	-	days
DAP	-	Days after planting
g	-	gram
h	-	hours
ha^{-1}	-	Per hectare
HCN	-	Hydro cyanic acid
IAEA	-	International Atomic Energy Agency
kg	-	kilogram
K lux	-	Kilo lux
LAI	-	Leaf Area Index
LAR	-	Leaf Area Ratio
LEC	-	Land Equivalent Co-efficient
LER	-	Land Equivalent Ratio
M-4	-	Malayan-4
MBq	-	Mega Becquerel
mCi	-	milli Curie
mm	-	millimetre
NAR	-	Net Assimilation Rate
^{32}P	-	Radio Isotope of Phosphorus
PAR	-	Photosynthetically Active Radiation
PVC	-	Poly vinyl chloride
SLW	-	Specific Leaf Weight
t	-	tonne
$\mu E\ m^2 s^{-1}$	-	micro Einsteins per square metre per second
WUE	-	Water use efficiency

INTRODUCTION

INTRODUCTION

Coconut is the main crop of Kerala and it occupies an area of 8.17 lakh hectares. Since the pressure on land is very high in the state, the availability of open space is limited and the farmers are compelled to grow different crops in the coconut garden itself. Major portion of the roots of the adult coconut palm is concentrated laterally within a radius of 2m from the base and vertically within 30-120cm depth. Coconut palms are generally grown with a spacing of 7.5m x 7.5m ($56.25m^2$) which provide 77.7 per cent of the total available land area for other intercrops and enough light for other crops to be grown in the interspaces.

There is no systematic and scientific principle and arrangement of crops grown in a cropping system at present. The selection of intercrops mainly depends upon the requirement of the farmer such as food, fodder and fuel.

At present a series of crops like cassava, banana, elephant foot yam, vegetables and forage crops are grown in the system. Cassava, the important subsidiary food crop of Kerala, is suitable for growing under partially shaded situations. Cassava var. *Sree Vishakam* is recommended as an intercrop in coconut gardens (KAU, 1989).

Banana is another important intercrop mostly grown in these situations under rainfed conditions. Banana var. *Njalipoovan* is particularly suitable for planting in coconut gardens (KAU, 1989).

There is an acute shortage of vegetables in Kerala and elephant foot yam and cowpea are being cultivated as intercrops under the partial shade of coconut.

The above crop combinations are most important and are mostly followed by majority of farmers in Kerala.

In a cropping system the intercrops have varying rooting patterns and their absorbing zones and requirements of nutrients are also different. There may be competition among the component crops for a set of nutrients. The absorption of nutrients in relation to the sum total of the situation available in a coconut garden has not been investigated in detail. Instead of assessing the crop performance individually the system can be taken as a whole whereby a substantial savings in the costly inputs are possible. The ideal crop mix must be one which results in minimum competition for nutrients. Hence a thorough investigation of the interplay of different nutrients in the system is required.

In a cropping system there is a likelihood of competition for moisture by roots of component crops especially in a rainfed situation prevailing in Kerala. The moisture available in the soil profile must be utilized by the different crops grown in an unit land. The rooting pattern and moisture depletion rate may be different with different crops in the system. Farmers are apprehensive that when more crops are grown there will be more competition for moisture. The influence of crop canopy on evaporation and residual soil moisture in the system is also to be established. So a detailed investigation is imperative on moisture regime under a set of crops grown with different rooting pattern.

In a coconut garden a substantial quantity of sunlight is infiltered through the crop canopy. The studies conducted at the Central Plantation Crops Research Institute, Kasaragod, Kerala have shown that while the young bearing palms permit only less than 20 per cent incident radiation, the middle aged palms allow about 30 per cent and pre bearing and old palms up to 80 per cent. Light is not fully utilized in sole coconut gardens and there is a possibility of maximum utilization by raising intercrops in the interspaces of coconut palms. Detailed studies are not available on the performance of these crops under partially shaded conditions in a cropping system.

Eventhough the extent of nutrient interaction is understood to a certain level the quantification of the nutrient absorbed and the intensity factor are yet to be established. Isotope studies are the best methodology for getting information on this aspect. Such investigations will throw more light on the extent of competition for a particular nutrient in the rhizosphere of all the component crops grown in a system. This information is very vital for planning nutrient management for the system as a whole.

A coconut garden of 40 years old was selected for this investigation. The intercrops are chosen in such a way that there is minimum competition for nutrients, moisture and light. The intention is to give the farmer a suitable crop cafetaria which will generate sufficient income through out the year without any detrimental effect on the productivity of the soil as well. The available information on this aspect is meagre and they did not give much details on the interaction of the intercrops in relation to the main crop. Hence the present investigation is initiated with the following objectives :

1. To identify the most productive crop combination in a coconut based homestead cropping system,
2. To assess the interaction between coconut and intercrops in the absorption of nutrients,
3. To determine the soil moisture regime as affected by intercrops,
4. To evaluate the utilization pattern of light intercepted by crop canopy,
5. To economise the level of nutrients for intercrops in different cropping systems and
6. To identify the most economic crop combination.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Coconut enjoys a distinct place in the economy of Kerala. Several useful annuals, bienniels and perennials can be successfully raised in association with coconut (CPCRI, 1977). A proper combination of inputs viz. nutrients, moisture and light influence the productivity of an ideal cropping system.

The production in a coconut based cropping system can be improved considerably by scientific management. In this review, information available mainly on the effect of nutrients, moisture and light on coconut based cropping system involving cassava, banana, elephant foot yam and vegetable cowpea are considered. The experiments with these factors on coconut intercropping system are rare. However, available literature has been collected.

2.1. Combined effect of nutrients on growth and production of intercrops

2.1.1. Cassava

The availability of adequate quantity of nutrients in the soil in a balanced ratio is essential for higher tuber yield in cassava. Vijayan and Aiyer (1969) concluded that a N : P_2O_5 ratio of 3:2 (150 kg N + 100 kg P_2O_5) was best for increasing tuber yields in cassava. The same ratio also resulted in the highest contents of dry matter, protein and starch in tubers. They also observed that HCN content in tubers increased with increase in N rates and decreased as P_2O_5 rates increased.

The nitrogen - potassium balance is especially significant in cassava nutrition. The N:K interaction was studied by Rajendran *et al.* (1976) and found that application of N and K_2O in the ratio 1:1 (ie. 100 kg each ha^{-1}) was optimum in all the cassava varieties tested for maximum tuber productivity in acid laterite soil. According to Nair and Aiyer (1985), for cassava grown in red loam soils, N:K_2O ratio of 1:1.28 was optimum. Nair (1982) while studying the N:K interaction in red loam soils also reported similar results. Sarkar *et al.* (1986) obtained highest yield of cassava when N and K were applied in 2:3 ratio.

For cassava, intercropped in coconut garden, an N:K_2O ratio of 1:2 was found to be beneficial (Nayar and Sadanandan, 1992).

It shows that for optimum tuber production in cassava, a proper balance between nutrient elements both in soil and plant is important.

Fertilizer recommendations for cassava

Chew (1970) observed that cassava required 180 kg N, 22 kg P and 92-133 kg K ha^{-1} in the peat soils of Malaysia. Takyi (1972) recommended application of 60 kg N, 20 kg P and 209 kg K ha^{-1} for the forest soils of

Ghana. Ahmed (1973) reported that cassava responded to 124 kg N, 29kg P and 98 kg K ha^{-1} in the Serdang region of Malaysia. However, in Kuala Lumpur, Cheing (1973) got response up to 150 kg N, 30 kg P and 150 kg K ha^{-1}.

Tarazona *et al.* (1973) found that the best rate of fertilizer application for cassava was 50 - 60 kg N, 131 kg P and 42 - 50 kg K ha^{-1} in the inceptisols of Colombia. The recommendation from CIAT was 100 kg N, 87-175 kg P and 133 kg K ha^{-1} for the Oxisols of Colombia (CIAT, 1974 & 1975).

Hadi and Gozallie (1975) in Indonesia got response upto 90 kg N, 13 kg P and 42 kg K ha^{-1}. While higher rate of N (150 kg ha^{-1}) reduced the tuber quality as measured by tuber DM, starch, protein and HCN contents and higher rate of P (100kg ha^{-1}) improved these characters (Prema *et al.*, 1975).

Pillai and George (1978) recommended 100 kg N, 50 kg P_2O_5 and 150 kg K_2O ha^{-1} for maximum tuber yield of cassava cv. Malayan-4. They also obtained higher tuber DM and starch content with increased doses of N, P and K. Lorenzi *et al.* (1983) reported that application of 40 kg N, 80 kg P and 60 kg K ha^{-1} had a positive linear effect on root dry matter content of cassava in Brazil.

Muthuswamy and Rao (1981) observed that application of N increased the crude fibre and HCN content of tubers, whereas application of K decreased the HCN content and had no effect on crude fibre content. Trials conducted at CTCRI and elsewhere indicated that most of the local cultivars and M-4 responded to a lower dose of NPK (50:50:50), whereas some of the earlier released hybrids like H-97 and H-226 responded to an NPK dose of 75:75:75 kg ha^{-1} (Thampan, 1979; KAU, 1989). For high yielding cassava hybrids viz. H-165, Sree Visakham and Sree Sahya, an NPK dose of of 100:100:100 kg ha^{-1} is recommended (CTCRI, 1983 a; KAU, 1989). In Thailand, the recommended rate of fertilizer application to cassava was 50 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} (Sarobol *et al.*, 1984).

The review reveals that there is wide variation in fertilizer application for cassava ranging from 40-180 kg ha^{-1} for N, 13-175 kg ha^{-1} for P and 42-209 kg ha^{-1} for K.

The productivity of cassava evaluated under rainfed and irrigated conditions revealed that the crop responded to NPK application at 150:100:150 kg ha^{-1}, when supplementary irrigation was provided during the dry months (Nayar *et al.*, 1985).

In an intercropping system involving cassava + groundnut on the effect of different levels of nitrogen, phosphorus and potash, it was observed that application of 75 kg nitrogen, 75 kg phosphorus and 100 kg potash was sufficient to realise optimum yield from cassava and groundnut (CTCRI, 1983 b). However, under irrigation, cassava + groundnut responded to an additional dose of 20 kg K_2O ha^{-1}.

In a study on the fertilizer requirement of cassava based intercropping system conducted at the College of Agriculture, Vellayani, Sheela and Kunju (1990) observed that for getting maximum net returns, groundnut can be raised as an intercrop with a fertilizer dose of 50: 62.5: 62.5 kg N, P_2O_5 and K_2O ha^{-1}. According to Nayar (1986) for cassava intercropped in coconut garden NPK dose of 50:50:100 kg ha^{-1} was found to be optimum.

The above review clearly indicate that the fertilizer requirement of cassava is less when raised along with other crops.

Asher *et al.* (1980) reported that the nutrient uptake by 30 t of tubers was 164 kg N, 31 kg P and 200 kg K ha^{-1}.

According to Howeler (1981), cassava extracts about 2.30 kg N, 0.5 kg P and 4.10 kg K per tonne of tuber. If the whole plant is removed for forage and planting materials, these amounts would increase to 4.91 kg N, 1.08 kg P and 5.83 kg K ha^{-1}.

Cassava removed 180 -200 kg N, 15 - 22 kg P and 140 - 160 kg K ha^{-1} to produce an yield of 30 t ha^{-1} fresh tubers (CTCRI, 1983 a).

Portieles *et al.* (1986) recorded uptake values of 4.9 kg N, 2.9 kg P_2O_5 and 5.1 kg K_2O t^{-1} of fresh tuber yield.

Wide variations are thus observed in the uptake of nutrients by cassava in different locations.

2.1.2 Banana

Nambiar *et al.* (1979) observed highest bunch weight with an application of N and P_2O_5 each at 225 g $plant^{-1}$ and K_2O at 450 g $plant^{-1}$ with two split doses in banana.

In banana cv. Campierganj Local (Musa-ABB) Ram and Prasad (1988) obtained maximum TSS (21.21%) with N:P_2O_5 : K_2O at 200:80:200 g $plant^{-1}$ and highest total sugar with 300:120:100 g plant $^{-1}$. Ram and Prasad (1989) also recorded maximum bunch weight and yield with 300 g N+ 40 g P_2O_5 + 100 g K_2O $plant^{-1}$ in the same variety.

In an irrigated crop of banana N as ammonium sulphate at 0.09 or 0.18 kg $plant^{-1}$, P as super phosphate at 0.13 or 0.26 kg $plant^{-1}$ and K as muriate of potash at 0.26 or 0.52 kg $plant^{-1}$ were applied. The highest bunch yield was obtained at the highest rate of N and P whereas the fruit quality was best with the lowest rate of N, P and K (Upadhay, 1988).

In South Gujrat, application of 180:180:180 g of N, P_2O_5 and K_2O $plant^{-1}$ is recommended for banana (Dave *et al.*, 1990)

In rice fallows, application of N, P_2O_5 and K_2O at 400 g, 100 g and 600 g $plant^{-1}$ respectively gave the highest yield in banana variety, Nendran (Nair, *et al.*, 1990).

Lot of variations are thus observed in the fertilizer recommendation of banana in different locations.

The nutrient requirement of a crop producing 6.5 t $acre^{-1}$ of fruit are 34 lb - N, 7 lb P and 255 lb K (Joseph, 1971).

In rainfed banana, var. Palayancodan, N uptake was highest in plants receiving the highest rate of N, P and to a lesser extent K uptake were enhanced by N nutrition (Mathew and Aravindakshan, 1981).

Sheela and Aravindakshan (1990) observed that in rainfed banana, Palayancodan, the total N uptake increased between the early vegetative phase and the shoot development phase and then declined. K rate had no effect on N uptake whereas P and K uptake increased with rising K rate.

The review shows that the K requirement of banana is high and there is an increase in the uptake of N and K with an increase in N and K rates.

2.1.3 Elephant foot yam

Mandal and Saraswat (1968) suggested a manurial dose of 25 t of farm yard manure and a fertilizer dose of 80:80:120 and 40:40:80 kg N, P_2O_5 and K_2O ha^{-1} for maximum and economic yield respectively. Muthuswamy (1983) observed that 80 kg N, 60 kg P_2O_5 and 100 kg K_2O ha^{-1} registered the highest yield of 78 per cent over no fertilizer treatment. A fertilizer dose of 80:60:100 kg N, P_2O_5 and K_2O ha^{-1} has been recommended for elephant foot yam in Kerala (KAU, 1986).

Mukhopadhyay and Sen (1986) proposed a fertilizer dose of 150:60:50 kg N, P_2O_5 and K_2O ha^{-1} for maximising the corm yield in elephant foot yam in West Bengal. According to them starch and protein content of the corms at harvest were influenced with the increasing levels of both nitrogen and potassium and the maximum was observed at 150 kg of each nutrient. Nair *et al.* (1991) suggested a fertilizer dose of 100:50:150 kg N, P_2O_5 and K_2O ha^{-1} for an upland rainfed crop in the ultisols of Kerala.

According to Pushpakumari and Sasidhar (1992), the fertilizer dose for elephant foot yam when grown as an intercrop in coconut garden can be reduced to 50 per cent of the recommended dose ie. 40:30:50 kg N, P_2O_5 and K_2O ha^{-1}. Under the partial shade of coconut, application of 12.5 t ha^{-1} of FYM and 27:20:33 kg N, P_2O_5 and K_2O ha^{-1} was found to be adequate for optimum tuber production in elephant foot yam (Ravindran and Kabeerathumma, 1990). Fertilizer recommendations ranging from 80 to 150 kg N, 50 to 60 kg P_2O_5 and 50 to 150 kg K_2O have been reported from different parts of India. Under partially shaded condition, a reduced dose of fertilizer is recommended for elephant foot yam.

Under rainfed upland conditions, in acid ultisol the nutrient uptake of elephant foot yam was found to be 124.8 kg N, 26.1 kg P and 222.4 kg K ha^{-1} (Nair *et al.*, 1991).

2.1.4 Cowpea

Malik *et al.* (1972) obtained highest yields of 1.35 t ha^{-1} of cowpea by the application of 20 kg of N and 60 kg P_2O_5 ha^{-1}. Kurdikeri *et al.*

(1973) observed that in cowpea (*Vigna catjang*) highest yield was 1.58 t ha^{-1} with 11 kg N and 44 kg P_2O_5 ha^{-1}. Optimum application of nutrients for grain yield was calculated as 31.67 kg N and 37.37 kg P_2O_5 ha^{-1} for cowpea cv. Kanakamani, whereas the economic dose was 23.13 kg N and 23.55 kg P_2O_5 ha^{-1} (Viswanathan *et al.*, 1978). They also observed that response to applied K was not significant. The highest grain yield of 706 kg ha^{-1} was obtained with 20 kg N and 40 kg P_2O_5 ha^{-1} in cowpea variety P-118 (Kumar and Pillai, 1979). Angne *et al.* (1993) observed that application of N and P increased grain yield in cowpea and the highest yield of 1.69 t ha^{-1} was obtained at 15 kg N and 30 kg P_2O_5 ha^{-1}.

Fertilizer rates ranging from 11-30 kg N and 23-60 kg P_2O_5 ha^{-1} have been recommended for grain cowpea in different locations of India.

Reddy and Saxena (1983) observed that rates of N,P and K uptake were maximum between 45 and 60 days. Concentration of these nutrients was higher in the spring whereas their uptake was higher in the Kharif (monsoon) season in all the plant parts at harvest.

2.2 Performance of different intercrops to moisture regimes

2.2.1 Cassava

Oliveira *et al.* (1980) concluded that 30-150 days after planting was the critical period for irrigation of cassava which coincides with the time of root and tuber production. Water stress reduced root yield by 58 per cent during root formation and 62 per cent during tuber formation. They also observed that water stress after 6 months of growth did not result in significant yield reduction. The adverse effects of low moisture content were accentuated when root development was initiated under high soil bulk density or low total porosity (Lai, 1983).

Cassava hybrids, Sree Sahya and Sree Visakham responded positively to supplementary irrigation during drought spells with significant increase in dry matter production, crop growth rate, utilization index, mean tuber weight and tuber yield (Nayar *et al.*, 1985).

When the soil water content was maintained at 80 per cent of field capacity during the first 70 days, the highest yields were obtained in cassava clones 'Senorita' in Cuba. (Portuondo *et al.*, 1989). They also estimated that the water requirement during the growth period of 9 months ranged from 6955.2 to 8397.0 m^3 ha^{-1}.

Baker, *et al.* (1989) concluded that reduction in cassava yield to water stress was caused by a reduction in total biomass and that stress occuring late in the season was most detrimental to yield. Ramanujam (1990) observed that there were reductions in LAI (18-40 per cent), light interception (42-70 per cent), net photosynthesis (24-56 per cent), total biomass (25-36 per cent) and tuber yield (28-42 per cent) due to moisture stress in cassava.

Nayar (1992) observed that the varieties Sree Prakash and Sree Visakham were the best for cultivation in low lands with higher soil moisture regimes.

Yao and Gove (1992) observed that for cassava WUE was about 1 g kg^{-1} water under drought conditions and as high as 8-10 g kg^{-1} under favourable soil water conditions.

According to Sasidhar and Sadanandan (1974) the water requirement of cassava - cowpea rotation was the lowest among five rotations studied.

Studies on cassava based intercropping system in Salem district revealed that cassava intercropped with black gram resulted in maximum plant height, number of tubers $plant^{-1}$, tuber yield and higher benefit-cost ratio (Balakrishnan and Thamburaj, 1993).

In cassava cv. Malavella, HCN content of the tuber, rind, stem, bark and leaf decreased with decreasing soil moisture (Kailasam *et al.*, 1977. Nayar (1992) observed that a shallow water table resulted in higher HCN content of cassava.

The review reveals that deficiency of soil moisture during the critical stages of growth (30-150 days) adversely affect the tuber yield.

2.2.2 Banana

Chen (1971) observed that for banana the most congenial soil moisture content was 50-60 per cent of field capacity, whereas water logging for more than 24 hours was particularly harmful.

Yields of banana grown in lysimeters increased from 5650 to 37800 kg ha^{-1} by lowering the water table to 36 cm after which they tended to decline (Irizarry *et al.*, 1980). They also observed that root development in the upper 15 cm soil layer was little affected by changes in the water table, but at lower soil depths (15-30 and 30-45 cm) root development was successively greater with each lowering of the water table.

Lateral and vertical spread also increased with decreasing available soil moisture, maximum vertical spread at harvest for the three respective treatments (20, 40 and 60 per cent moisture depletion) being 69, 69 and 74 cm and the corresponding lateral spread being 288, 306 and 324 cm (Krishnan and Shanmugavelu, 1980 a).

Krishnan and Shanmugavelu, (1980b) observed that in banana cv. Robusta the daily water consumption ranged from 4.81 to 6.11mm. They also found that the yields were highest (89.38 t ha^{-1}) at 20 per cent depletion of available soil moisture.

In a study on intercropping of tuber crops with banana, Joseph (1992) observed that among the intercropped plots, the reduction in the bunch yield was lowest in the combination of banana and elephant foot yam. Banana intercropped with tannia gave the highest net returns followed by the combination of banana and elephant foot yam.

In banana the fruit fresh weight, dry weight, length and circumfrence were reduced by water stress. Water stress increased total soluble solids slightly and decreased the pulp : peel ratio (Hegde and Sreenivas, 1989).

The review shows that soil moisture status has a definite role on the biomass production, bunch yield and bunch characters and root distribution pattern in banana.

2.2.3. Cowpea

The three soil moisture regimes (15, 35 and 55 per cent soil moisture depletion) gave grain yields of 932,932, and 958 kg ha^{-1} in the summer season and 1.16, 1.16 and 1.19 t ha^{-1} in the monsoon season respectively (Singh and Lamba, 1971).

Higher soil moisture gave highest number of pods and seed weight (1.51 - 2.86 g $plant^{-1}$) at all the stages except at the vegetative stage. However, pod number and seed weight (0.39 g $plant^{-1}$) were lowest with deficient moisture levels at the podding stage (Kamara, 1976). Ogunremi *et al.* (1981) observed that the growth of cowpea was better at 40 cm water table depth than at 0 or 15 cm depth. They also found that the grain yield and consumptive water use increased with deeper water tables.

From the review, it is clear that experiments on inter cropped situations are rare.

2.3. Response of different intercrops to intensities of light

2.3.1. Height

Ramanujam *et al.* (1984) reported that plant height continued to increase in all the cultivars of cassava grown under shade. He also observed that the stem girth of the dwarf type Ci-590 was almost double under shade.

Okoli and Wilson (1986) observed that the plant height of cassava increased as percentage of shade increased. Sreekumari *et al.* (1988) found an increase in plant height of cassava genotypes grown in a coconut garden.

There was significant difference in plant height due to shade at the initial growth stages of elephant foot yam up to 130 DAP, the height of the plant recorded an appreciable increase under intense shade and a decrease with increase in light intensity (Pushpakumari, 1989). Ashokan (1986) recorded increased plant height in elephant foot yam under intercropped situation.

In cowpea, Tarila *et al.* (1977) observed reduced plant height at higher light intensity of 27 K lux.

The review reveals that the crop plants grown under shade invariably record an increase in height compared to those raised in the open.

2.3.2. Leaf area

Fukai *et al.* (1984) examined the effects of solar radiation on crop growth by growing cassava cultivar, M Aus-7 and observed that specific leaf area under full sun decreased as the plant aged. Low radiation led to leaves with high specific leaf area particularly in young plants.

Significant differences between cultivars for LAI and specific leaf weight were observed when six cassava cultivars were raised as intercrop in 30 year old coconut plantation (Ramanujam *et al.*, 1984).

Ramanujam and Jos (1984) concluded that leaves of cassava plants grown under shade were thinner and dark green in colour when compared to plants grown under normal light.

According to Okoli and Wilson (1986) the LAI of cassava decreased as percentage of shade increased in trials conducted in S.W. Nigeria.

In an evaluation with 50 lines of cassava grown as intercrop in coconut garden, Sreekumari *et al.* (1988) observed larger, but less number of leaves and increase in leaf longivity under shade.

2.3.2.2. Elephant foot yam

Lee (1992) indicated increase in leaf area of elephant foot yam with decreased shade.

In elephant foot yam, the LAI was increased upto 25 per cent shade level and thereafter it decreased considerably (Pushpakumari, 1989).

Tarila *et al.* (1977) reported an increase in leaf area and plant size of cowpea at a higher light intensity.

The review shows that there is an increase in specific leaf area and a decrease in LAI with increase in shade.

2.3.3. Photosynthesis

Tsuno *et al.* (1983) reported that the photosynthetic rate of cassava was similar in the morning and afternoon at light intensities more than 30 K lux and showed a peak at 28^0 C having light intensity of 25- 40 K lux.

Kasela *et al.*(1984) observed reduced diversion of dry matter to tuberous roots under shaded conditions. They also found that dry weight of tuberous roots $plant^{-1}$ after six months ranged from 7.0 to 66.5 g and 2.5 to 24.0g in unshaded and shaded plants respectively.

Ramanujam *et al.* (1984) suggested that the dry matter accumulations in the shoots of sun and shade grown cassave plants were similar while marked differences were observed for dry matter accumulated in tuber.

Ramanujam and Jos (1984) stated that the photosynthetic apparatus per unit leaf area was curtailed under low light intensity.

In a study on the effect of shading on cassava, Okoli and Wilson (1986) observed that stem and leaf dry weights increased with decreasing degree of shade.

Miura and Osada (1981) observed that light saturation point of photosynthesis increased from 20 to 740 K lux during the 30 days when all leaflets unfolded irrespective of shading, then decreased 2 months later, the decrease being sharper in shaded plants. Under full light and 25 per cent shade, photosynthetic rate reached a maximum of 10 mg $CO_2 dm^{-2} h^{-1}$ at 20 days after leaf unfolding, then decreased rapidly. Under weak light the rate was high upto 30 days after unfolding, then decreased gradually.

Shading decreased the photosynthetic capacity of *Amorphophallus konjac* (Lee, 1992).

The higher light intensity (27 K lux) reduced plant height, but improved plant growth, in terms of increased branching and plant size under controlled environment (Tarila *et al.*, 1977).

The review shows that an increase in shade decreases the photosynthetic activity and dry matter production of majority of crops and in tuber crops, there is a reduction in dry matter accumulation in tuber.

2.3.4 Growth analysis

Ramanujam *et al.* (1984) compared the growth characters of 12 cultivars of cassava under shade with those obtained under open and observed that LAI, SLW and CGR were 2.19, 5.6 mg cm^{-2} and 5.3 gm^{-2} day $^{-1}$ respectively in the open and 2.40, 3 mg cm^{-2} and 1.8 gm^{-2} day $^{-1}$ respectively in shade. They also stated that due to longer leaf life, the number of leaves retained at any stage of the crop in all the cultivars under shade were significantly higher, resulting in higher LAI. Ramanujam and Jos (1984) reported that under low light though the leaf blades were slightly broader, the LAR was very high.

Fukai *et al.* (1984)reported that in cassava, reducing solar input to 32 per cent decreased the CGR to about half that of the control regardless of plant age. Ramanujam *et al.*(1984) observed that the CGR and NAR of cassava grown under shade were reduced significantly when compared to those plants grown under normal light. Under low light intensities, the SLW was reduced significantly by 57 to 62 per cent (Ramanujam and Jos, 1984).

Pushpakumari (1989) reported that there was a decrease in NAR with increase in shade intensity in many minor tuber crops. But significant variation was observed in elephant foot yam which recorded higher CGR values by medium and low shade during the first and second phases of growth respectively.

According to the review, there are contradicting reports on the response of shade on growth of crop plants.

2.3.5. Yield attributes and yield

Ramanujam *et al.* (1984) observed a considerable delay in tuber initiation under shade when compared to the open condition. It was reported that the yield reduction of the varieties due to shade effect ranged from 65 to 94 per cent. They observed less number of tubers plant^{-1} in cassava grown under established coconut garden.

In an inter institute trial on intercropping conducted at Kasaragod, cassava gave a tuber yield of 4.3 t ha^{-1} in an established coconut plantation of 25 years old compared to 35.6 t ha^{-1} in the open (CTCRI, 1985).

Ramanujam, *et al.* (1984) reported a reduction in tuber yield due to shading caused by intercropping in 30 year old coconut plantation.

It was observed that 20, 40, 50, 60, and 70 per cent shade levels reduced cassava yield by 43, 56, 59, 69, and 80 per cent respectively, as compared to control (Okoli and Wilson, 1986).

Sreekumari *et al.* (1988) found that the tuber yield was significantly reduced under shade in coconut garden.

Ghosh *et al.* (1990) observed that growth and tuber yield of cassava were greater when grown with banana compared to the sole stand.

According to Nayar and Sadanandan (1991) Sree Visakham was found to be the best under shaded condition recording superior yield attributes.

Sreekumari and Abraham (1991) observed that shading in general adversely affected tuber development rather than shoot and leaf formation.

Girth of stem and tuber showed significant positive correlations with tuber yield under shade.

Suma *et al.* (1989) assessed the performance of 16 cultivars of banana as intercrop with coconut in non-irrigated, partially shaded conditions in which Booditha Bontha Bathusa and Kanchikela gave the highest yields (8925 and 8890 kg ha^{-1}) respectively. Poovan, Chenkadali and Palayankodan were found to be shade tolerant and have been recommended for the homesteads of Kerala. Miura and Osada (1981) observed that under full light and 25 per cent shade photosynthetic activity reached the maximum of 10 mg CO_2 dm^{-2} h^{-1} at 20 days after leaf unfolding and then decreased rapidly. Under weak light, the rate was high up to 30 days after leaf unfolding and then decreased gradually. They also observed that corm dry weight was increased by shading.

In a study on the intercropping of tuber crops in irrigated Nendran banana, the reduction in the bunch yield of banana was the least in the combinations involving Nendran banana and elephant foot yam (Joseph, 1992). Nayar and Nair (1992) observed no adverse effect on the growth and yield of banana due to intercropping with *Amorphophallus paeoniifolius, Dioscorea alata and Xanthosoma sagittifolium.*

Pushpakumari and Sasidhar (1992) found that yield decreased with increasing level of shade and the lowest value was recorded with 75 per cent shading.

In a field trial to test the feasibility of growing *Vigna unguiculata* with coconut, c v. Kanakamani was artificially shaded by 25, 50 and 75 per cent (George and Nair, 1987). Yields for 0,25, 50 and 75 per cent shading were 1.58, 0.66, 0.40 and 0.15 t ha^{-1} respectively. It was concluded that under shaded condition yield was less.

The review shows that the effect of intercrop varied with the type of crop.

Expt -II

Radiotracer techniques for studying plant root systems

Radioisotopic methods to study the plant root systems in the field using ^{32}P were initiated by Lott *et al.* (1950) and Hall *et al.* (1953). Since then ^{32}P and many other radioisotopes were utilised for studying the root activity and root distribution patterns of many crops.

Based on the absorption of applied ^{32}P, highest root activity of banana was found to be near the soil surface at a distance of 40 cm from the plant (IAEA, 1975). Mohan and Rao (1987) observed highest root activity in banana at a distance of 30 cm from the plants. Under rainfed conditions, approximately 85% of the active roots reside within 40 cm from the banana plant. Active roots tended to be concentrated at a depth of 15-30 cm (Sobhana *et al.*, 1989).

The root activity pattern of rainfed cassava cv. M-4 planted on mounds was studied in the field using a ^{32}P soil injection technique (Ashokan *et al.*, 1989). Highest uptake of ^{32}P was observed from the soil at 20 cm lateral distance and 20 cm depth during 90-150 d of growth.

Anilkumar and Wahid (1988) investigated the root activity pattern of a 9 year old coconut palm using ^{32}P soil injection technique. They observed that over 80 per cent of the active roots were confined to an area of 2m radius around the plam. The vertical spread of the majority of the roots was limited to a depth of 60 cm below which root activity declined sharply.

In coconut palms, isotope studies on the efficiency of fertilizer utilization revealed that uptake was most efficient at 10 cm depth and 0.5 m distance from the palm (Balakrishnamurthi, 1971).

The root competition for the radiophosphorus by species grown in intercropping systems including corn-field bean, corn-sesame, corn-casterbean, caster bean-sesame were studied by Lai and Lawton (1962). They 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).

Absorption of applied ^{32}P in 2-and-8-crop intercropping systems involving cassava, banana, elephant foot yam and groundnut was studied in field trials by Ashokan *et al.* (1988). They observed that ^{32}P applied to the root zone of one species was absorbed not only by the treated plant but also by the neighbouring plants. Banana was the dominant species in the cassava / banana / elephant foot yam intercropping system and accumulated the major portion of the radioactivity recovered in the system. Cassava planted on raised mounds absorbed ^{32}P from the root zones of elephant foot yam and banana growing in the interspaces.

Absorption of ^{32}P from cassava mounds by elephant foot yam was negligible. In cassava groundnut intercropping systems cassava accumulated 96-99% of the ^{32}P recovered when the radiolabel was applied to cassava and 48-88% when it was applied to the intercrops. Groundnut absorbed only negligible quantities of ^{32}P from the cassava root zone.

The literature available showed that most of the root studies using ^{32}p were in monocrop situations. Investigations on the absorption of radiophosphorus by component crops in cropping systems are rare.

The review of literature revealed that under rainfed conditions many crops could be raised successfully as intercrop in the partial shade of coconut with a reduced dose of fertilizer. There was a decline in the yield of intercrops with an increase in shade under coconut garden. The root activity and root distribution pattern of crops in the cropping systems could be studied precisely by using radio isotopes.

MATERIALS AND METHODS

MATERIALS AND METHODS

The productivity of intercrops was evaluated in a coconut based cropping system by conducting two field experiments at the College of Agriculture, Vellayani, for two consecutive cropping seasons of 1992-93 and 1993-94.

The expt.I. was intended to evaluate the cropping system generally followed in a coconut garden. The expt.II. was conducted as a follow up study in the second year. In this experiment some of the most important crop combinations excluding vegetable cowpea were chosen and included for the isotopic studies with ^{32}P, so as to get a clear idea about the root activity and rooting pattern, which will have dominant influence on the performance of the crops in the system.

3.1 Experimental site

The field trials were conducted at the Instructional Farm, College of Agriculture, Vellayani. The Instructional Farm is located at 8° 30′ north latitude and 70° 54′ east longitude at an altitude of 29 metres above sea level. The second experiment was conducted in a protected area with hazard warning boards as it was a radiotracer study. Vellayani experiences a typical tropical climate and the weather data during the experimental period are presented in Fig. 1a and 1b and in Appendix 1a and 1b. The soil of the experimental site is red loam. The mechanical and chemical characteristics of the soil are given in Appendix II.

3.2 Cropping history

The experimental area was lying fallow during the previous year. Prior to that, the land used for experiment I was under guinea grass and that used for experiment II was under vegetable crops.

3.3 Technical Programme

3.3.1 Experiment I

The treatments included five different crop combinations involving coconut as the main crop and two levels of fertilizers for intercrops in a factorial combination. Sole crops of coconut and inter crops were maintained in the open area for comparison. The following are the treatments (Plates 1-9).

3.3.2 Treatments

a) Crop combinations

C_0 - Coconut alone

C_1 - Coconut + cassava

C_2 - Coconut + cassava + vegetable cowpea

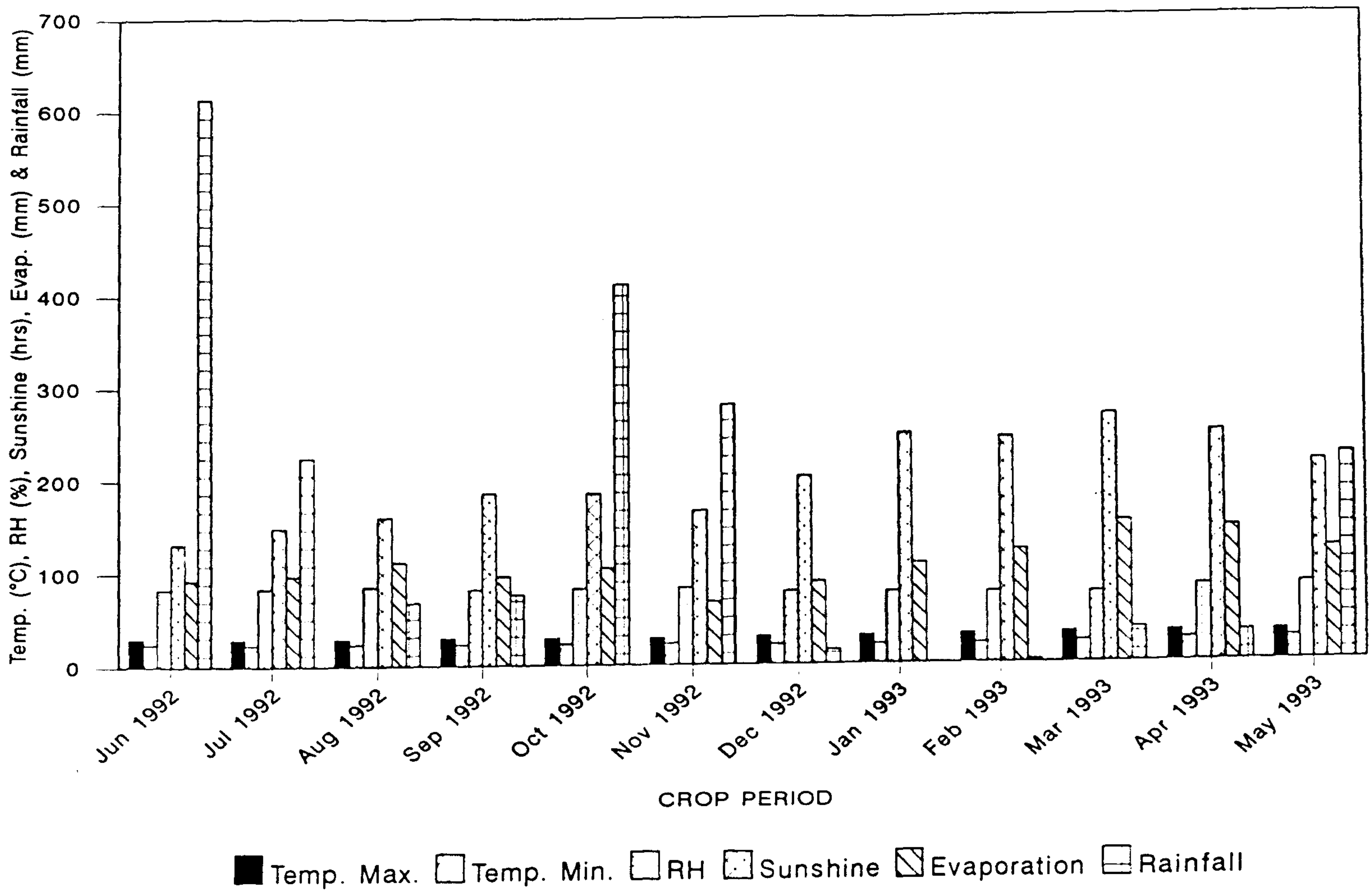


Fig. 1a. Weather parameters during the first season (1992-93)

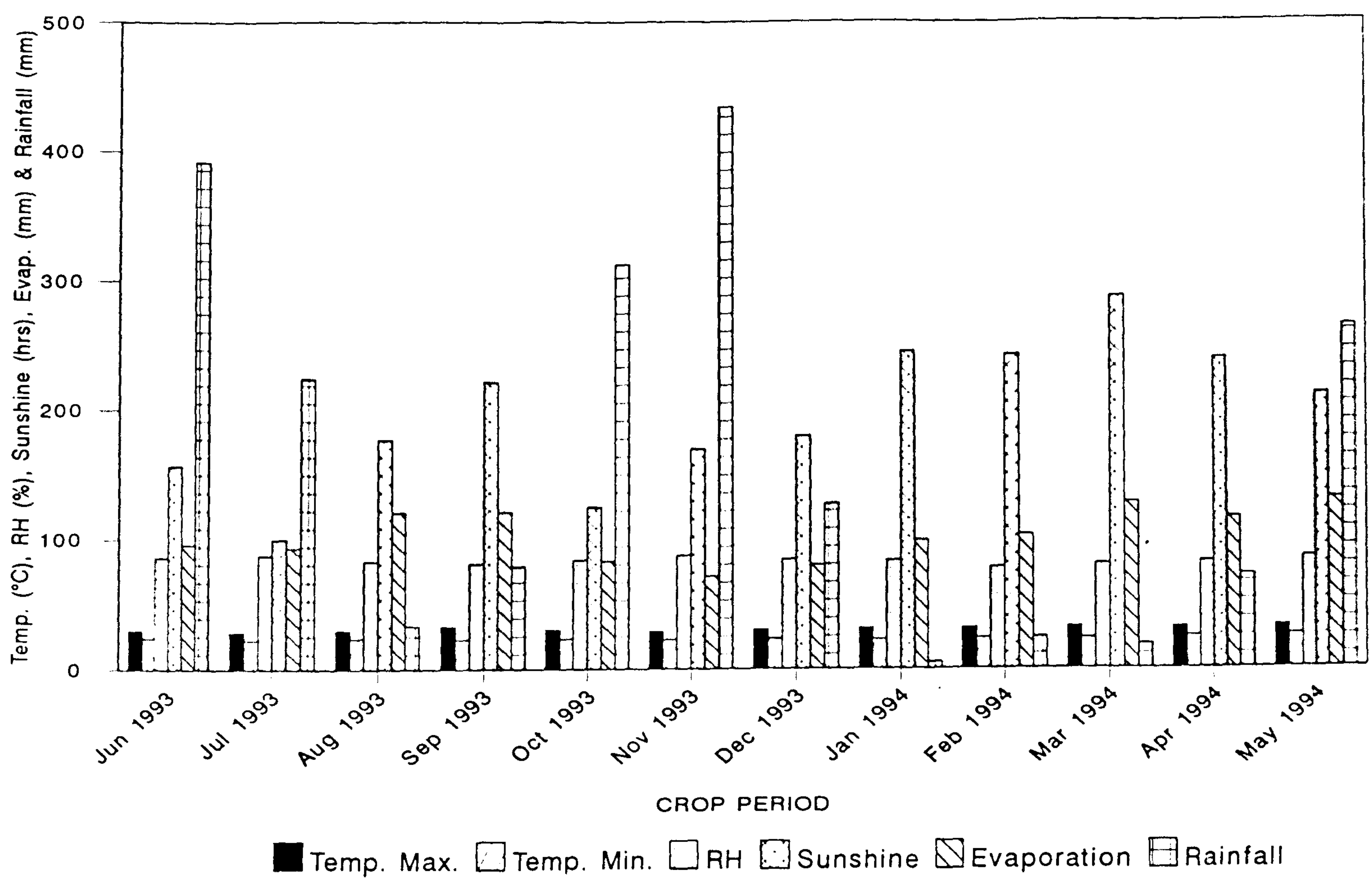


Fig. 1b. Weather parameters during the second season (1993-94)

C_3 - Coconut + cassava + elephant foot yam

C_4 - Coconut + cassava + banana

C_5 - Coconut + cassava + banana + elephant foot yam + vegetable cowpea

b) Fertilizer levels for intercrops

F_1 - Full recommended dose of N, P and K

F_2 - Half the recommended dose of N and P and full K.

Treatment combinations - 11

T_1 - C_0

T_2 - C_1F_1

T_3 - C_1F_2

T_4 - C_2F_1

T_5 - C_2F_2

T_6 - C_3F_1

T_7 - C_3F_2

T_8 - C_4F_1

T_9 - C_4F_2

T_{10} - C_5F_1

T_{11} - C_5F_2

Plate 1. General view of the experimental plot

Plate 2. Cropping system - Coconut + cassava

Plate 3. Cropping system - Coconut + cassava + vegetable cowpea

Plate 4. Cropping system - Coconut + cassava + elephant foot yam

Plate 5. Cropping system - Coconut + cassava + banana

Plate 6. Cropping system - Coconut + cassava + elephant foot yam + vegetable cowpea + banana

Plate 7. Sole crops in the open

Plate 8. Cassava F1 (open)

Plate 9. Cassava F2 (open)

3.3.3 Layout of the experiment I

The experiment was laid out in a randomised block design with three replications (Fig. 3). The gross plot size was 7.5 x 7.5m.

The population of coconut and intercrops in different treatments is given in Table 1.

3.4 Details of crops

The coconut palms were about 40 years old and of medium yielders and were spaced at 7.5 x 7.5 m. There was uniform shade of 25 per cent compared to open situation.

Single or double rows of cassava were planted around the basins of coconut palms at a spacing of 90 x 90cm. There were 28 cassava plants in the outer row and 20 plants in the inner row (Fig. 2).

Banana plants occupied the four remote corners of the plot with the coconut plam at the centre. Thus there were four banana plants in a plot (Fig. 2).

Elephant foot yam was planted in the inner row around the basins of coconut palms at a spacing of 90 cm between plants. There were 20 plants of elephant foot yam around each coconut palm (Fig. 2).

Table 1. Population of coconut and intercrops in different treatments (ha^{-1})

Treatments	(Gross area basis)				
	Coconut	Cassava	EFY	Banana	Vegetable cowpea (hills)
T_1	175	—	—	—	—
T_2	175	8400	—	—	—
T_3	175	8400	—	—	—
T_4	175	8400	—	—	12600
T_5	175	8400	—	—	12600
T_6	175	4900	3500	—	—
T_7	175	4900	3500	—	—
T_8	175	7700	—	700	—
T_9	175	7700	—	700	—
T_{10}	175	4200	3500	700	12600
T_{11}	175	4200	3500	700	12600
Sole crop	175	12345	12345	2500	111110

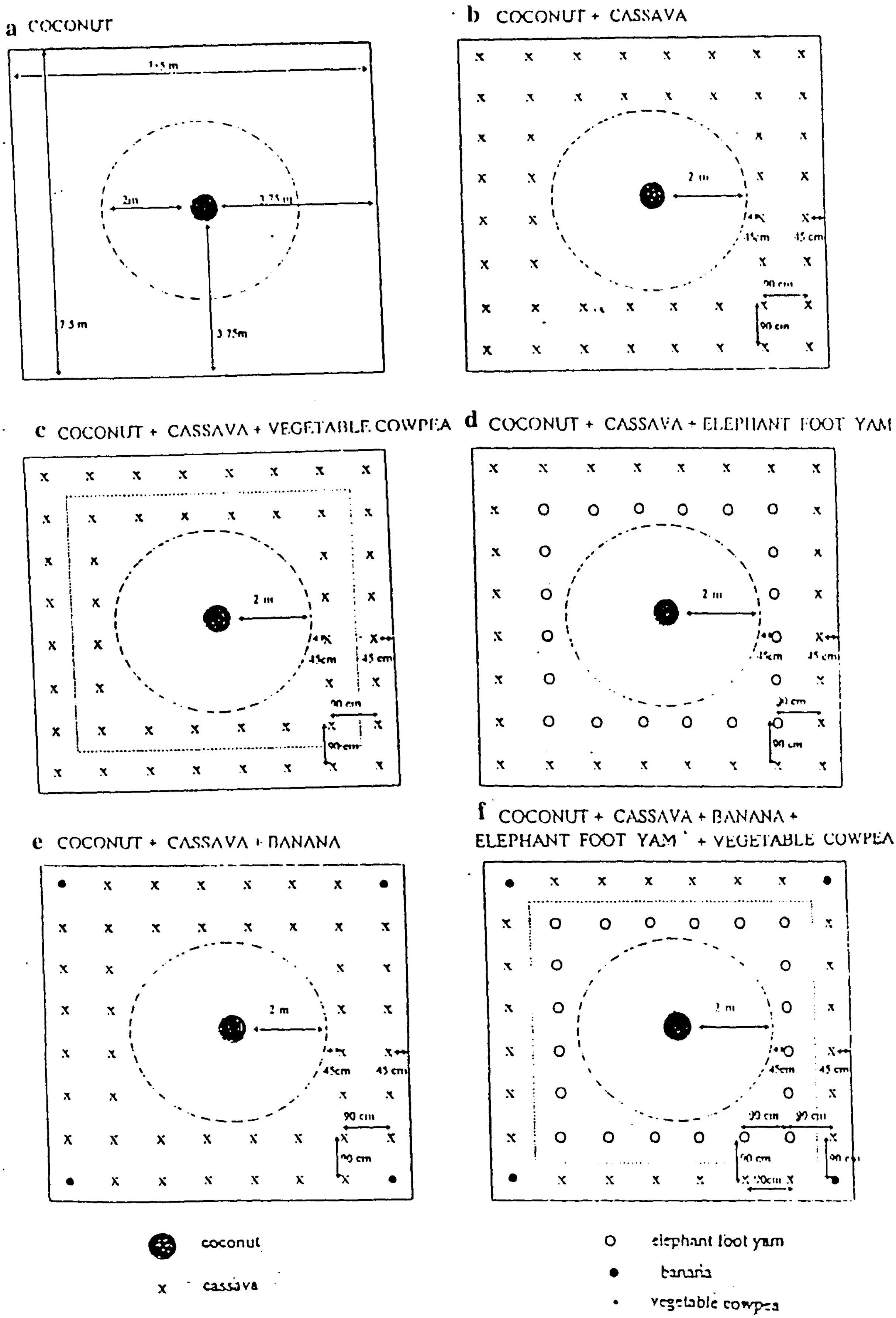


Fig. 2 Planting pattern of component crops in coconut based cropping systems

Fig. 3a. Layout of the Expt I. In coconut garden

Replication - I		Replication - II		Replication - III	
C_4F_2	C_2F_2	C_5F_2	C_3F_1	C_3F_2	C_1F_2
C_5F_1	C_1F_1	C_2F_2	C_1F_2	C_5F_2	C_1F_1
C_3F_1	C_5F_2	C_3F_2	C_4F_1	C_5F_1	C_4F_2
C_4F_1	C_3F_2	C_5F_1	C_1F_1	C_2F_1	C_3F_1
C_0	C_2F_1	C_4F_2	C_0	C_4F_1	C_0
	C_1F_2		C_2F_1		C_2F_2

Treatments

a. Crop combinations

C_0 - Coconut alone
C_1 - Coconut + cassava
C_2 - Coconut + cassava + vegetable cowpea
C_3 - Coconut + cassava + elephant foot yam
C_4 - Coconut + cassava + banana
C_5 - Coconut + cassava + banana + elephant foot yam + vegetable cowpea

b. Fertilizer levels for intercrops

F_1 - Full recommended dose of N, P and K
F_2 - Half the recommended dose of N and P and full K

Fig. 3b. Open area

CpF_1	CaF_2	CaF_1
CpF_2	$EFYF_1$	$EFYF_2$
	BaF_1	BaF_2

Sole crops

Ca - Cassava
Ba - Banana
EFY - Elephant foot yam
Cp - Vegetable cowpea

Vegetable cowpea was raised in a row in between rows of cassava and elephant foot yam or in between two rows of cassava with a plant to plant spacing of 30 cm. A total of 72 hills (2 plants per hill) were accommodated in a plot. (Fig. 2).

3.5 Details of varieties

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

Crop	Variety	Description
Coconut	West Coast Tall	40 year old palms, medium yielders
Cassava	Sree Visakham	Hybrid, Semi branching 10 months duration
Banana	Njalipoovan	Thrives even under rainfed conditions, a good table variety
Elephant foot yam	Local	9 to 10 months duration
Vegetable cowpea	Arka Garima	Bushy plants with long pods. 70-75 days duration

3.6 Planting materials

The planting materials of cassava and elephant foot yam were collected from Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Vegetable cowpea seeds were obtained from Mithranikethan, Vellanad, Thiruvananthapuram and banana suckers from Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram. Care was taken to collect disease free banana suckers of uniform age.

3.7 Manures and fertilizers

The farm yard manure used for the trial was found to contain 0.45 per cent nitrogen, 0.33 per cent phosphorus and 0.25 per cent potassium. Fertilizers with the following grades were used for the experiment.

Urea - 46 per cent nitrogen (expressed as N)

Mussoorie phosphate - 20 per cent P_2O_5 expressed as P

Muriate of potash - 60 per cent potassium (expressed as K)

Quick lime (CaO) - Neutralising value - 162

3.7.1 Methods of manuring

3.7.1a Coconut

Opened a circular basin of radius 1.80 m around the plam to depth of 25 cm during May. Applied farm yard manure @ 25 kg per palm during June and inorganic fertilizers @ 0.50 kg N, 0.32 kg P and 1.20 kg K per palm per year. One third dose of inorganic fertilizers was given during June - July and two third dose was given during September - October.

3.7.1b Cassava

Well decomposed farm yard manure @ 12.5 t ha^{-1} was mixed with soil at the time of preparation of mounds. N,P and K were applied @ 100: 100: 100 kg ha^{-1} for F1 and 50:50:100 kg ha^{-1} for F2 treatment. One third of N and K and full dose of P were applied before planting cassava. The remaining quantity of N and K were applied in two equal splits at 30 days and 60 days after planting followed by earthing up. In vegetable cowpea-intercropped plots, half of N and K and full dose of P were applied as basal and the remaining quantity was applied after the harvest of vegetable cowpea.

3.7.1c Banana

Farm yard manure was incorporated at the rate of 10 kg per pit at the time of planting. A fertilizer dose of 200:200:400 g $plant^{-1}$ of N, P and K for F_1 and a reduced dose of 100:100:400g $plant^{-1}$ for F_2 were given to banana. Half of N and P and full dose of K were applied at a radius of 30 cm from the base of the plant to a depth of 20 cm at 60 days after planting. The balance amount of N and K were applied two months later.

3.7.1d Elephant foot yam

Farm yard manure was applied at the rate of 2 kg per pit and mixed with top soil before planting the corms. A fertilizer dose of 80: 60: 100 kg

ha^{-1} and a reduced dose of 40:30:100 kg ha^{-1} of N,P and K were applied to treatments F_1 and F_2 respectively. Half of N, full dose of P and half dose of K were incorporated to the soil around the plant at a distance of 30 cm and to a depth of 20 cm, one month after sprouting. The remaining dose of N and K were applied one month later with a light raking of the soil.

3.7.1c Vegetable cowpea

A fertilizer dose of 10:20:20: and 5:10:20 kg ha^{-1} of N,P and K were applied to treatments F_1 and F_2 respectively. Half of N and K and full dose of P were applied as basal and the remaining dose was applied one month after sowing.

Lime was applied to vegetable cowpea as basal @ 250 kg ha^{-1}. The cowpea seeds were inoculated with Rhizobium culture prior to sowing.

The cultural and plant protection operations were followed as per the package of practices recommendations of KAU, 1989.

3.8 Observations

Three plants each of cassava and elephant foot yam, three hills of vegetable cowpea and one plant of banana were selected at random for recording the following observations.

3.8.1 Height

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

3.8.2 Girth

In elephant foot yam and banana, the girth of the pseudostem was measured at a height of 5cm and 15cm respectively from the base.

3.8.3 Leaf area

The leaf area of different component crops was measured with the help of a leaf area meter. The leaf area index was worked out by the formula suggested by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area of the plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.8.4 Canopy spread

In elephant foot yam, the canopy spread was measured across the diameter of the leaf.

3.8.5 Root distribution

The vertical and later al spread of the roots of the intercrops were studied by carefully excavating the soil.

3.8.6 Number of tubers per plant

In cassava, the total number of tubers from the observation plants was recorded at the time of harvest and the mean values were used for statistical analysis.

3.8.7 Tuber yield/corm yield

After the harvest of crops, the tuber/corm yields were recorded.

3.8.8 Bunch emergence

In banana, the time taken for bunch emergence from the date of planting was recorded.

3.8.9 Bunch yield

The banana bunches were harvested when they attained full maturity and the bunch weight was recorded. The number of hands per bunch and the number of fingers per hand were also recorded.

3.8.10 Pod yield

The fresh weight of pods from vegetable cowpea was recorded immediately after picking.

3.8.11 Coconut yield

The number of nuts harvested from coconut palms was recorded at an interval of 45 days.

3.8.12 Haulm yield

The fresh haulm yield of vegetable cowpea was recorded immediately after harvest. The vegetative portion of banana and elephant foot yam were also recorded at the time of harvesting.

3.8.13 Dry matter production

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

3.8.14 Harvest index

Harvest index was worked out from the dry weight of the whole plants and that of the economic produce.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.8.15 Total dry matter production

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

3.9 Competitive parameters

3.9.1 Land equivalent ratio (LER)

It was worked out from the data on the yield of intercrops both in mixture and pure culture by using the formula suggested by Mead and Willey (1980).

$$LER = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} + \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Y_{ab} and Y_{ba} are the component crop yield in intercropping system and Y_{aa} and Y_{bb} are their yields as sole crop. Z_{ab} and Z_{ba} are proportion of land area occupied in intercropping when compared to crop for species (a) and (b) respectively.

3.10. Soil moisture depletion

Soil moisture was measured at depths of 30, 60 and 90 cm using a non-nuclear moisture probe, sentry 200 AP moisture monitor (Plate 10). The instrument can measure the moisture content of soil at different depths quickly and precisely. It consists of a control unit, one calibrated probe, one access tube extender and cable stops. The measurement is taken by lowering the probe to the desired depth in a standard two inch PVC access tube. The moisture content is determined by measuring the changes in the dielectric constant of a soil sample.

The measurements were made at fortnightly intervals on volume basis during the second year from the experiment I (Plate II).

3.11 Light infiltration

Light measurements from different plots were made using a Line Quantom Sensor at monthly intervals. The instrument measured the photosynthetically active radiation available at the crop canopies in micro einsteins per square metre per second (μ E m^{-2} s^{-1}).

3.12 Quality attributes

3.12.1 Starch content

Starch content of the tubers of cassava, and corms of elephant foot yam was estimated by the potassium ferricyanide method (Aminoff *et al*, 1970). The values were expressed as percentage on fresh weight basis.

3.12.2 HCN content

HCN content of the tubers of cassava was estimated by Picrate method (Indira and Sinha, 1969).

Plate 10. Non nuclear soil moisture probe

Plate 11. Access tube for measuring soil moisture

3.13 Plant analysis

Nitrogen, phosphorus and potassium content of the plant parts of main crop and intercrops were analysed.

3.13.1 Nitrogen

Total nitrogen content of the plant parts was estimated by the modified micro Kjeldahl method (Jackson, 1967).

3.13.2 Phosphorus

The phosphorus content in plant parts was estimated by the colorimeter method (Jackson, 1967).

3.13.3 Potassium

Potassium content in plant parts was determined photometrically using a Systronics flame photometer.

3.14 Nutrient uptake studies

Uptake of nitrogen, phosphorus and potassium at different stages of growth was estimated in Experiment I. The content of these elements in each plant part viz. leaf, stem, tuber/corm, pod and bunches was estimated and the total nutrient uptake was worked out.

3.15 Soil analysis

Soil samples were taken before the commencement of experiment and after the harvest of crops in both seasons in Experiment I. The data on initial analysis showing the physical and chemical composition of the soil is presented in Appendix 2. The soil collected after the harvest of each crop was analysed for organic carbon, available nitrogen, phosphorus and potassium.

The methods followed for the analysis of physical and chemical properties of soil are given below.

3.15.1 Mechanical analysis

The international Pipette method (Piper, 1950) was used for the mechanical analysis of the soil

3.15.2 Soil pH

The pH was determined with the Elico pH meter (Jackson, 1967) in 1:2.5 soil water suspension.

3.15.3 Organic carbon

Walkely and Black's net oxidation method as described by Jackson (1967) was used for the estimation of organic carbon.

3.15.4 Available nitrogen

Available nitrogen was estimated by the alkaline permanganate method of Subbiah and Asija (1956).

3.15.5 Available phosphorus

Available phosphorus was estimated by Bray's No.1 extract method (Jackson, 1967).

3.15.6 Available potassium

Available potassium was extracted by neutral normal ammonium acetate solution and determined by a Systronics flame photometer (Jackson, 1967).

3.16 Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for randomised block design (Cochran and Cox, 1965). While analysing the data statistically CD were provided only when the F values were significant. Statistical analysis was performed using IBM-PC AT/486 computer installed in the department of Social sciences, CTCRI Sreekariyam, Thiruvananthapuram.

3.17 Economics

The gross income, gross expenditure and net profit for each cropping system was worked out.

3.18 Experiment II

Competition for applied ^{32}P in coconut + cassava + banana + elephant foot yam intercropping system

The following crop combinations as well as sole crops were selected for ^{32}P treatment (Fig. 4).

a. Coconut + cassava
b. Coconut + banana
c. Cassava + banana
d. Cassava + elephant foot yam
e. Banana + elephant foot yam
f. Coconut
g. Cassava
h. Banana
i. Elephant foot yam

The treatments compared in this experiment were different combinations of sole and mixed crops and two sampling periods (Plates 12-20). Following were the treatments adopted for ^{32}P application and the layout plan is given in Fig. 5.

3.18.1 Treatments

a) i. To cassava sole crop inner row
ii. To cassava sole crop outer row
iii. To cassava inner row in coconut + cassava

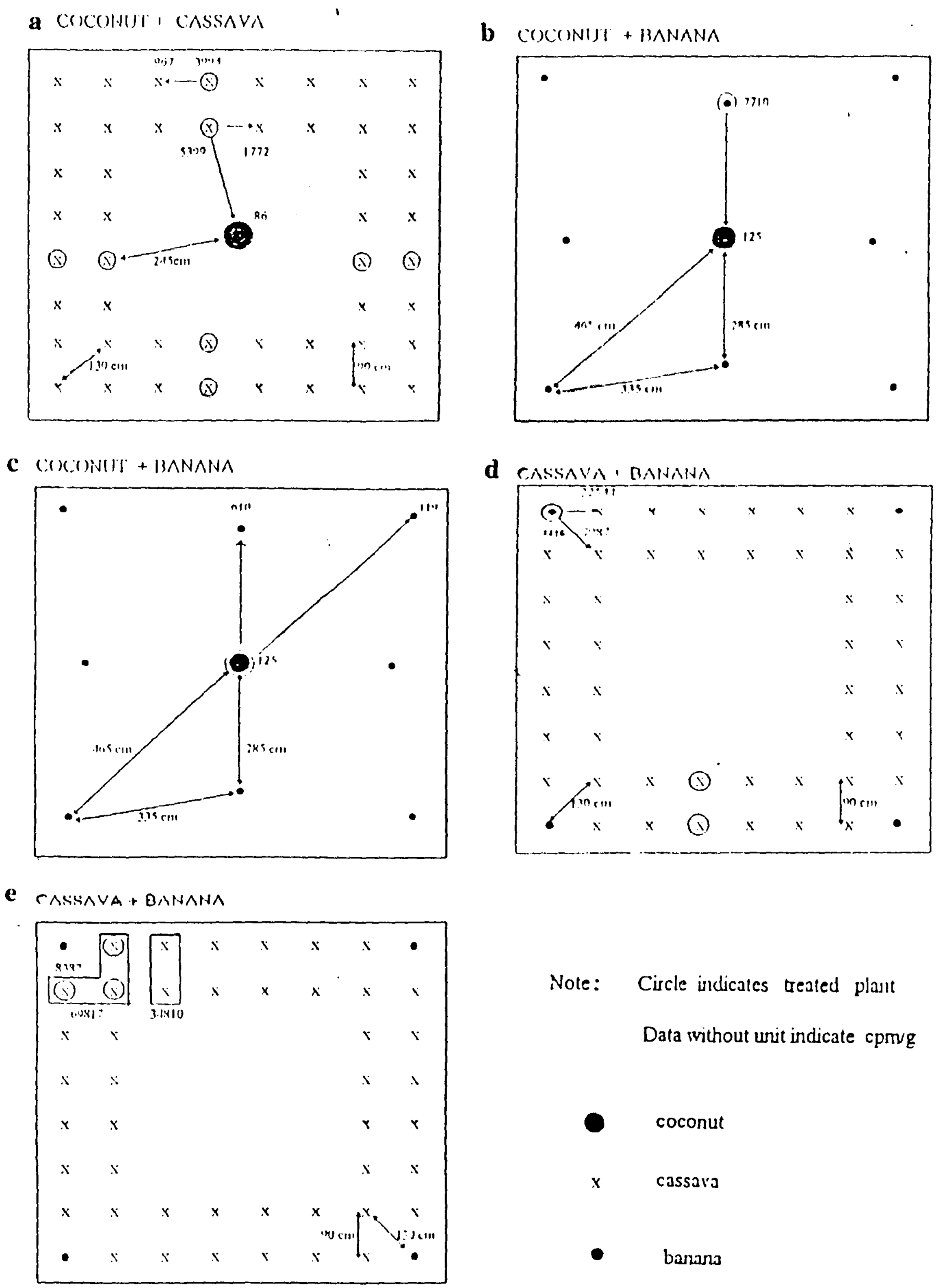
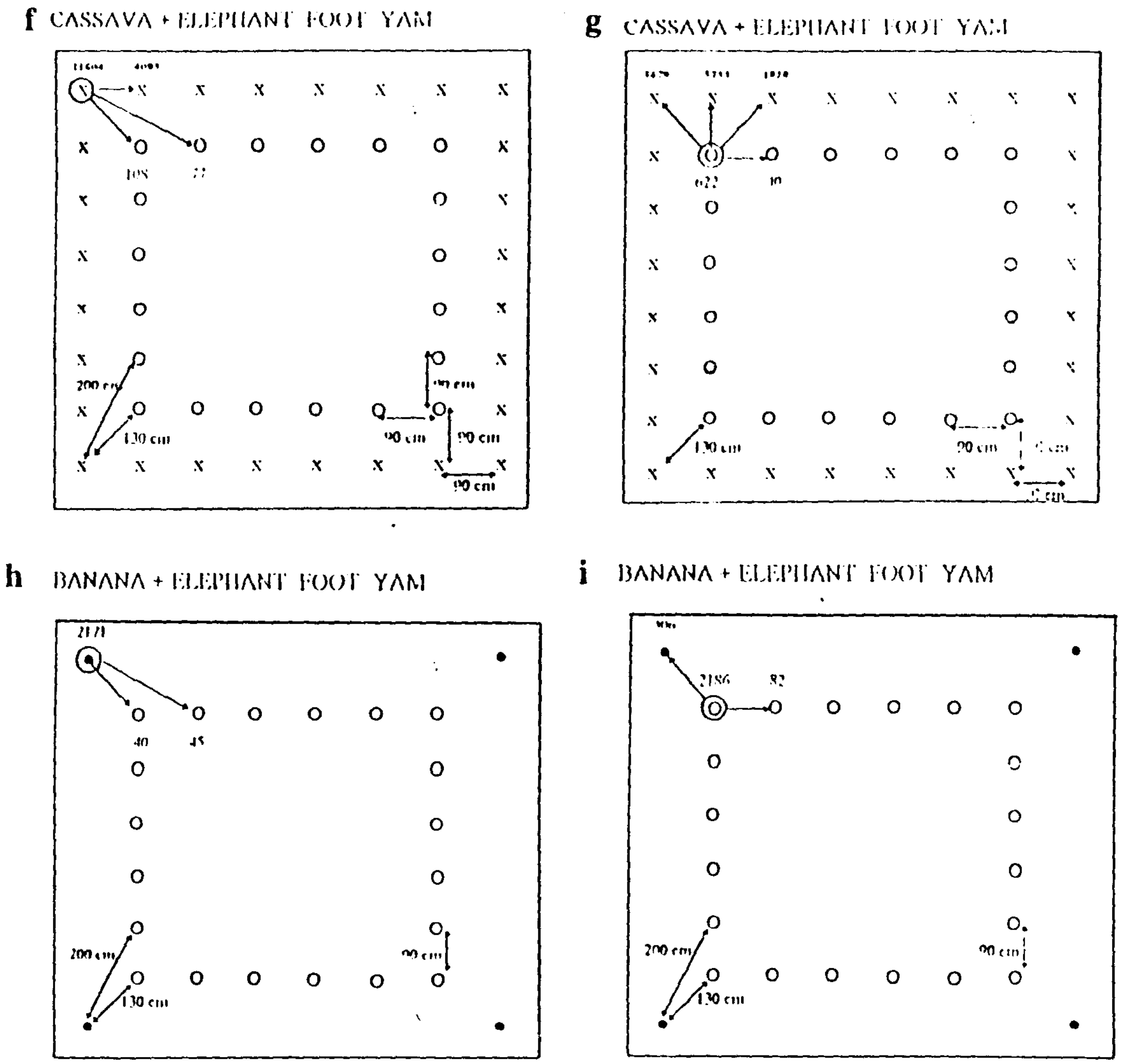


Fig. 4a-e. Absorption of ^{32}P by coconut, cassava and banana



Note: Circle indicates treated plant

Data without unit indicate cpm/g

x cassava

● banana.

o elephant foot yam

Fig. 4f-i. Absorption of ^{32}P by cassava, banana and elephant foot yam

Fig. 5. Layout of Experiment - II

Fig. 5a. Treated cassava in mono and mixed systems

RI	Ca_{ti} (+Ba)	Ca_{ti} (S)	Ca_{ti} (+Co)	Ca_{to} (+Ba)	Ca_{to} (S)	Ca_{to} (+Ca)	Ca_{to} (+EFY)
RII	Ca_{ti} (+Co)	Ca_{to} (+EFY)	Ca_{to} (S)	Ca_{to} (+Co)	Ca_{to} (+Ba)	Ca_{ti} (+Ba)	Ca_{ti} (S)
RIII	Ca_{ti} (S)	Ca_{to} (+Ba)	Ca_{to} (+Co)	Ca_{ti} (+Ba)	Ca_{ti} (+Co)	Ca_{to} (+EFY)	Ca_{to} (S)

Fig. 5b. Treated banana in mono and mixed systems

RI	Ba_t (S)	Ba_t (+Ca)	Ba_t (+EFY)	Ba_t (+Co)
RII	Ba_t (+Ca)	Ba_t (+Co)	Ba_t (+EFY)	Ba_t (S)
RIII	Ba_t (S)	Ba_t (+EFY)	Ba_t (+Ca)	Ba_t (+Co)

Fig. 5c. Treated elephant foot yam in mono and mixed systems

RI	EFY_t (S)	EFY_t (+Ba)	EFY_t (+Ca)
RII	EFY_t (+Ba)	EFY_t (S)	EFY_t (+Ca)
RIII	EFY_t (+Ca)	EFY_t (+Ba)	EFY_t (S)

Fig. 5d. Treated coconut in mono and mixed systems

Co_t (S)	Co_t (+Ba)

Ba - Banana
Ca - Cassava
Co - Coconut
EFY - Elephant foot yam
i - inner row
o - outer row
S - Sole crop
t - treated

iv. To cassava outer row in coconut + cassava

v. To cassava inner row in banana + cassava

vi. To cassava outer row in banana + cassava

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

b) i. To banana sole crop

ii. To banana in coconut + banana

iii. To banana in cassava + banana

iv. To banana in elephant foot yam + banana

c) i. To elephant foot yam sole crop

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

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

d) i. To coconut sole crop

ii. To coconut in banana + coconut

The details of cultural operations adopted for different crops are same as in Expt. I and hence not repeated here.

3.18.2 Application of ^{32}P

The radioactive ^{32}P solution was applied along the fertilizer application zone in the rhizosphere. The following specifications were fixed for application, based on the root data collected.

Plate 12. Access tubes installed for application of ^{32}P to coconut

Plate 13. Access tubes installed for application of ^{32}P to cassava

Plate 14. Access tubes installed for application of ^{32}P to banana

Plate 15. Access tubes installed for application of ^{32}P to elephant foot yam

Plate 16. ^{32}P treated plants in coconut + cassava cropping system

Plate 17. ^{32}P treated plants in coconut + banana cropping system

Plate 18. ^{32}P treated plants in cassava + banana cropping system

Plate 19. ^{32}P treated plants in cassava + elephant foot yam cropping system

Plate 20. ^{32}P treated plants in banana + elephant foot yam cropping system

Coconut - 100 cm radius and 30 cm depth

Cassava - 20 cm radius and 30 cm depth

Banana - 20 cm radius and 30 cm depth

Elephant foot yam - 30 cm radius and 15 cm depth

The ^{32}P solution was injected to the desired soil depth through PVC access tubes of 2 cm diameter. The soil injection of ^{32}P solution was done using a device designed for the purpose (Wahid *et al.*, 1988)

The stock ^{32}P solution in the vial was transferred to the reservoir bottle. The required volume of the 1000 ppm carrier solution ($KH_2 PO_4$) was added to the bottle to give 30µ Ci of ^{32}P per ml. A Lumac Dispensette was then fitted to the reservoir bottle. The calibrated dispenser was set to deliver one ml with every stroke of the plunger.

Equally spaced holes at the required depth were made along the periphery of the fertilizer application zone around the plant. The number of holes made for coconut, banana, cassava and elephant foot yam were 16, 8, 4 and 4 respectively.

The holes were dug a day in advance of the application of ^{32}P using a soil auger of 2 cm diameter. The PVC access tubes were inserted into the hole and the opening at the top of the tube was covered with polythene paper and secured firmly with rubber bands to prevent the entry of water.

The delivery tube of the dispenser was introduced into the access tube during application of ^{32}P solution and one ml of the radioactive solution was dispensed at each hole. The total activity applied per plant was as follows.

Coconut - 0.96 m Ci (3.55 MBq)

Banana - 0.24 m Ci (0.89 MBq)

Cassava - 0.12 m Ci (0.44 MBq)

Elephant foot yam - 0.12 m Ci (0.44 MBq)

3.18.3 Plant sampling for radioassay

The leaves were sampled at 15 and 30 days after application of ^{32}P. The treated and surrounding plants were sampled separately. In coconut, leaf samples were collected from the middle portion of the sixth leaf from the first fully opened leaf for radioassay (IAEA, 1975). In cassava, the fifth leaf from the terminal bud, which was giving stable values of ^{32}P count was taken for radioassay (Ashokan *et al.* 1988). In banana, the third leaf from the top was considered as the reflect for nutrient analysis (Hewitt, 1955) and the same was taken for radioassay (IAEA, 1975 and Sobhana *et al.* 1989). Since there is only one compound leaf in elephant foot yam, leaflets were collected at random from the leaf (Ashokan *et al.*, 1988). Leaf samples were taken from not only the ^{32}P treated plant, but also from those surrounding it inorder to examine whether the plants absorbed from the root zones of neighboring plants.

3.18.4 Radioassay of plant samples

The oven dried plant samples were cut into small pieces and one gram was digested with 15 ml 1:1HNO_3 : $HClO_4$ diacid mixture, until the digest was 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 distilled water and the washings were also transferred to the vial and made up to 20 ml in comparison with the 20 ml mark of water kept in another scintillation vial. The vial was kept undisturbed for four hours and the radioactivity was determined by Cerenkov technique in a liquid scintillation counter (Wahid *et al.*, 1985).

3.18.5 Statistical analysis

The data recorded were statistically analysed (Gomez and Gomez 1984). The data were corrected for background and decay and the analysis of variance was done after log transformation.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results of the experiments conducted to study the effect of nutrient-moisture, light interactions in a coconut based homestead cropping system are presented in this chapter.

The individual crops are taken in the beginning for consideration and the system as a whole is described afterwards.

The first experiment consists of cropping systems and fertilizer doses and the second experiment deals with radiotracer studies.

Particular emphasis is given to the production of these crops as influenced by nutrients, moisture and light.

Only the important growth and yield attributes which influence the system as a whole is taken into consideration as it is different from a normal experiment under monoculture situation.

4A. Expt.1. Nutrient-Moisture-Light interactions

4A.1. Cassava

4A.1.1 Growth characters

4A.1.1.1 Height

Different cropping systems involving coconut did not influence the height of cassava significantly in both the years (Table 2).

Cassava plant height was not influenced by the doses of fertilizers applied to intercrops in both years.

The height of cassava was very high under coconut garden, when raised as intercrop, compared to the plants in the open at all the stages of growth.

The PAR received under the partial shade of coconut was only 75 per cent of that obtained in the open. The taller plants observed in shaded condition is probably due to lesser PAR obtained in the intercropped situation. The cassava plants raised in the open were much shorter because of the availability of full sunlight in both fertility conditions. Ramanujam *et al.* (1984), Okoli and Wilson (1986) and Sreekumari *et al.* (1988) also observed higher plant height for cassava under shaded situations.

4A.1.1.2 Leaf area

The influence of cropping systems on leaf area of cassava was not conspicuous (Table 3). However the leaf area was higher under shaded condition, compared to open situation.

Increased leaf area was observed in plants in the open with full dose fertilizer compared to the reduced dose especially in the early stages.

Table 2. Effect of cropping systems and fertilizer doses for intercrops on the height of cassava at different stages of growth (cm)

Cropping systems	1992-93				1993-94			
	Days after planting				Days after planting			
	75	150	225	300	75	150	225	300
C1 - Co + Ca	107	175	355	369	81	187	306	368
C2 - Co + Ca + VCP	119	151	323	335	80	174	314	365
C3 - Co + Ca + EFY	81	157	301	310	80	166	294	347
C4 - Co + Ca + Ba	97	145	324	334	85	181	293	361
C5 - Co + Ca + VCP + EYF + Ba	82	131	306	318	75	159	287	370
CD (0.05)	13.02	-	-	-	-	-	-	-
SEM ±	4.38	9.60	13.12	16.06	3.23	7.00	11.24	15.26
Fertilizer doses								
F1 - FD	95	163	330	341	77	176	303	357
F2 - RD	99	140	314	326	83	170	295	367
CD (0.05)	-	18.03	-	-	-	-	-	-
SEM ±	2.77	6.07	8.30	10.16	2.04	4.43	7.11	9.65
Sole cassava (open)								
F1 - FD	88	119	191	203	89	140	231	241
F2 - RD	66	102	158	178	75	135	207	210

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam,
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 3. Effect of cropping systems and fertilizer doses for intercrops on the leaf area of cassava at different stages of growth (m^2 $plant^{-1}$)

Cropping systems	1992-93				1993-94			
	Days after planting				Days after planting			
	75	150	225	300	75	150	225	300
C1 - Co + Ca	1.854	2.567	3.018	1.042	1.322	2.569	2.718	2.656
C2 - Co + Ca + VCP	2.122	2.296	2.748	1.177	1.026	1.687	2.199	2.598
C3 - Co + Ca + EFY	1.730	2.829	3.122	1.084	1.136	1.713	2.520	2.435
C4 - Co + Ca + Ba	1.967	2.225	3.408	0.844	1.038	1.886	2.229	2.259
C5 - Co + Ca + VCP + EYF + Ba	1.464	2.257	3.480	1.297	1.004	1.737	2.560	2.955
CD (0.05)	0.301	-	-	-	-	-	-	-
SEM ±	0.101	0.220	0.273	0.160	0.040	0.168	0.298	0.356
Fertilizer doses								
F1 - FD	1.968	2.723	3.513	1.088	1.101	1.954	2.243	2.199
F2 - RD	1.687	2.147	2.797	1.090	1.110	1.883	2.647	2.962
CD (0.05)	0.190	0.414	0.514	-	-	-	-	0.699
SEM ±	0.064	0.139	0.173	0.101	0.025	0.106	0.188	0.225
Sole cassava (open)								
F1 - FD	1.242	2.087	3.269	0.131	1.478	4.072	1.281	0.532
F2 - RD	1.171	2.411	1.780	0.403	1.340	2.927	0.616	0.894

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam,
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

The tendency of plants to increase the LAI due to moderate shading may perhaps be a plant adaptation to expose larger photosynthetic surface under limited illumination (Pushpakumari, 1989). Increase in leaf area of cassava consequent to shading was reported by Ramanujam *et al.* (1984).

Increased leaf area with full dose of fertilizer is due to higher vegetative growth at early stages.

The results reveal that fertilizer dose has clear effect on the leaf area of cassava.

4A.1.2 Yield attributes

4A.1.2.1 Tuber length

The length of tuber was not influenced by cropping systems in both years (Table 4). This shows that tuber length is not influenced by sunlight.

4A.1.2.2 Girth of tuber

Girth of tuber was more in the cropping system involving vegetable cowpea and elephant foot yam.

Cassava in the presence of vegetable cowpea or elephant foot yam showed an increase in girth of tuber, while the increase in tuber girth was tremendous in the presence of both vegetable cowpea and elephant foot yam.

Table 4. Effect of cropping systems and fertilizer doses for intercrops on the length, girth, number of tubers and mean tuber weight of cassava at the time of final harvest.

Cropping systems	1992-93				1993-94			
	Length (cm)	Girth (cm)	No of tubers plant^{-1}	Mean tuber weight (g)	Length (cm)	Girth (cm)	No of tubers plant^{-1}	Mean tuber weight (g)
C1 - Co + Ca	26.0	14.8	8.3	244	24.1	16.2	6.3	270
C2 - Co + Ca + VCP	26.4	15.2	8.5	189	24.7	17.1	6.8	264
C3 - Co + Ca + EFY	26.2	15.3	9.2	268	21.8	16.4	5.7	460
C4 - Co + Ca + Ba	25.2	14.1	10.2	227	25.5	16.3	8.2	228
C5 - Co + Ca + VCP + EYF + Ba	28.6	17.2	7.7	325	24.4	18.6	5.8	433
CD (0.05)	–	1.784	–	–	–	–	–	168.018
SEM ±	1.560	0.600	0.747	30.102	1.528	0.698	0.902	56.550
Fertilizer doses								
F1 - FD	26.6	15.1	9.6	257	22.6	15.9	7.2	335
F2 - RD	26.4	15.5	7.9	244	25.6	17.9	5.9	326
CD (0.05)	–	–	1.403	–	2.872	1.311	–	–
SEM ±	0.987	0.380	0.472	19.038	0.967	0.441	0.570	35.765
Sole cassava (open)								
F1 - FD	27.1	14.2	12.0	356	27.1	18.0	9.0	451
F2 - RD	27.1	13.8	7.3	263	29.5	16.2	7.7	216

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam

FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Cassava might have derived additional plant nutrients from the rhizosphere of vegetable cowpea and elephant foot yam. An increase in tuber girth of cassava due to intercropping was also reported by Bhat (1978), Anilkumar (1984) and Ashokan (1986).

4A.1.2.3 Tuber number per plant

The number of tubers per plant was not influenced by different cropping systems. However with full dose of fertilizer, higher number of tubers was observed both under shaded and open condition (Table 4).

In cassava, tuber initiation generally starts by about 30 days after planting and tuber formation will be over with in two three months there after (Keating *et al.* 1982). According to Enyi (1972) carbohydrate supply in the early growth stages influences storage root number. Higher dose of fertilizer along with full sunlight results in efficient photosynthesis leading to higher number of tubers per plant. The reaction in the number of tubers under shaded condition may be due to the subsidence in light compared to open situation.

4A.1.2.4 Mean tuber weight

Cropping systems influenced the mean tuber weight significantly in the second year especially when intercropped with elephant foot yam.

Mean tuber weight was not influenced by fertilizer doses for intercrops.

In the open, higher mean weight was observed, compared to shaded condition (Table 4).

The superior mean tuber weight obtained for cassava in cropping systems involving elephant foot yam implies that a portion of the nutrient applied to elephant foot yam was absorbed and utilized by cassava for its growth and tuber production.

Radiotracer studies also indicated that when ^{32}P was applied to elephant foot yam, a substantial quantity was absorbed by the neighbouring cassava plants (Table 35).

In the open, photosynthesis took place at an enhanced rate resulting in higher mean tuber weight, where as under shade, the shortage of light leads to reduced photosynthesis with a lesser mean tuber weight.

4A.1.2.5 Tuber yield

Tuber yield was not influenced by cropping systems and interactions during both years (Table 5).

Eventhough different doses of fertilizers had effect on tuber yield in the first year, there was no effect during the second year. Full dose of fertilizers produced significantly higher tuber yield in the first year compared to reduced dose.

Table 5. Effect of cropping systems and fertilizer doses for intercrops on the tuber yield of cassava (t ha^{-1}) (Net area basis)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	27.542	22.468	25.005	21.785	17.078	19.432
C2 - Co + Ca + VCP	22.283	17.221	19.752	20.345	19.867	20.106
C3 - Co + Ca + EFY	31.743	27.838	29.791	31.731	31.394	31.563
C4 - Co + Ca + Ba	30.854	23.777	27.316	26.209	18.308	22.259
C5 - Co + Ca + VCP + EFY + Ba	34.965	25.431	30.198	36.907	21.509	29.208
Mean	29.477	23.347		27.395	21.631	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	3.740		–	4.592	
Cropping systems	–	2.642		–	3.247	
Fertilizer doses	4.463	1.667		–	2.062	
Interaction		3.740			4.592	
Sole cassava (open)						
F1 - FD	38.405			41.170		
F2 - RD	32.343			19.295		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Tuber yield was inferior under shaded condition compared to open.

It was seen from the results that cropping system either alone or in interaction with fertilizer dose did not influence the tuber yield (Plates 21-23). There was no decrease in yield of cassava under intercropping system with vegetable cowpea, elephant foot yam and banana when compared to cassava alone under partial shade of coconut. The competition from component crops was less and so the tuber yield of cassava was not affected adversely.

Vegetable cowpea was in the field as an intercrop in cassava only for the first three months. Elephant foot yam remained in the field for eight months after planting and its canopy once established did not vary much. The banana plant occupied the four remote corners of the plot and hence its competition was also minimum which resulted in the smooth growth and tuber production in cassava.

Radiotracer studies using ^{32}P also revealed that cassava can be raised along with coconut, banana and elephant foot yam without any drastic effect on cassava nutrition (Table 35).

The results reveal that under the partial shade of coconut, cassava needs only a reduced dose of fertilizer, especially N and P in the presence of other component crops viz. vegetable cowpea, elephant foot yam and banana (Table 5).

Plate 21. Tubers of cassava at harvest (T2, T3, T4 and T5)

Plate 22. Tubers of cassava at harvest (T6, T7, T8 and T9)

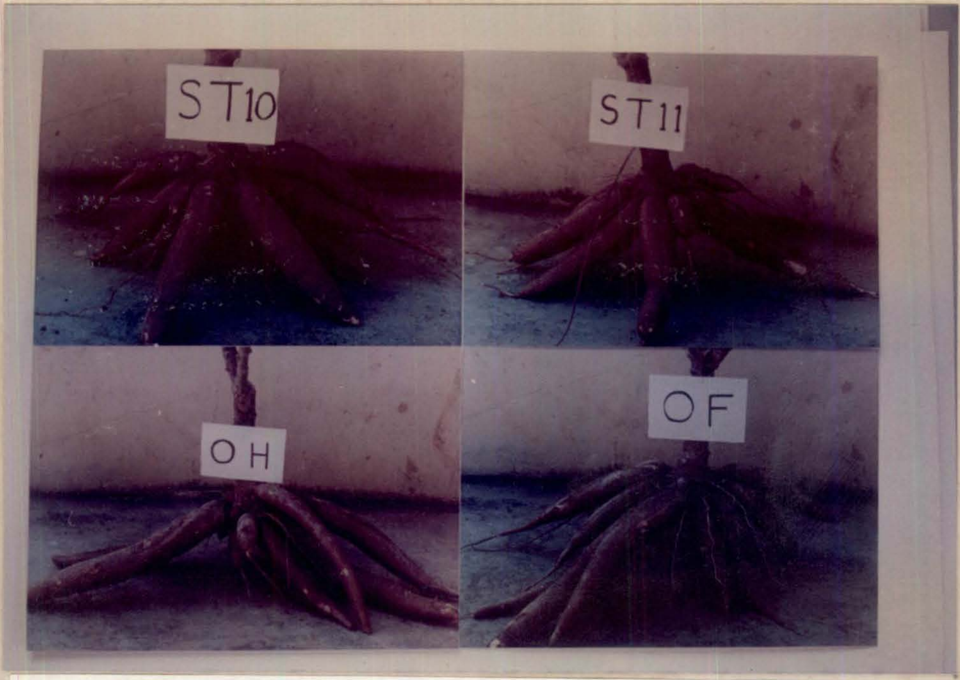


Plate 23. Tubers of cassava at harvest (T10, T11, F1 (open), F2 (open)

A reduced dose of fertilizer resulted in drastic reduction in the tuber yield of cassava in the open during second year, whereas the reduction was negligible in the case of cassava under shaded condition, indicating that for cassava grown in the cropping system a reduced dose is sufficient (Table 5).

In this connection, it may be mentioned that the earlier recommendation in the package is to apply the full recommended dose for cassava either as a sole crop or when grown as an intercrop so as to avoid competition for nutrients.

In fact one of the main objectives of the study was to assess whether such a practice was necessary or not. The results clearly reveal that in an intercropping situation where multiple crops are grown, half the fertilizer dose especially N and P is sufficient for cassava.

One of the probable reasons is that PAR is just 75 per cent when compared to open sole crop situation (Fig. 15). This drastically reduces the uptake and utilization of nutrients as shown in Fig. 7. Naturally it is to be surmised that the full dose of fertilizer applied in the system was not being utilised by the crop and resulted in the wastage as evidenced by uptake data which shows that almost the same uptake is recorded in full dose especially in the case of N and K in the second year (Fig. 7).

The presence of component crops especially vegetable cowpea, elephant foot yam and banana might have helped in retaining the moisture content of the field by reducing evaporation loss because of their canopy. The intercrops also might have suppressed the weeds in the plot by smothering them. Thus increased moisture retention in summer as revealed in Fig. 12, 13 & 14 and lesser weed population might have resulted in satisfactory growth of cassava in coconut based cropping system involving other component crops. There was no competition for moisture and hence there was no drastic reduction in the yield of cassava under shaded condition.

One peculiar view among cultivators is that when more crops are grown in unit area more quantity of moisture has to be given. In fact, this is one of the main factors for not adopting a cropping system approach in the rainfed coconut gardens of the state. This fear of the cultivator is unfounded as revealed in the experiment. In a cropping system, the evaporative demand of the moisture is reduced considerably and the moisture retention in the soil is favoured by the canopy cover of the component crops as revealed in the Fig. 12, 13 & 14 especially in summer months.

Significantly higher tuber yield was observed in the first year with full dose of fertilizers compared to the reduced dose eventhough no effect was observed in the second year. This shows that it takes some time for stabilising the effect of treatments. In the second year, the reduced dose of fertilizer produced equivalent yield as that of full dose. The uptake of NPK by intercrop cassava also shows that there is not much variation between full dose and reduced dose. This indicates that a reduced dose is sufficient for cassava under the partial shade of coconut.

The main reason for the inferior tuber yield recorded under shaded condition compared to open might be due to the reduction in the availability of PAR as there was no shortage of moisture and nutrients under shaded condition. Only 75 per cent of PAR was received under shaded condition compared to open sole crop. Due to shortage of light, the nutrients and moisture available in the soil were not effectively absorbed and utilized by cassava grown in the shade. Kasala *et al.* (1984) observed reduced drymatter of tuberous roots under shaded condition. Ramanujam *et al.* (1984) suggested that the drymatter accumulation in the shoots of sun and shade grown cassava plants were similar while marked differences were observed for drymatter accumulated in tuber.

4A.1.2.6 Shoot yield

The different treatment combinations as well as cropping systems had no effect on shoot yield of cassava (on net area basis) in both years (Table 6).

The reduced dose of fertilizer for intercrops had no effect on shoot yield during the first year whereas in the second year, the reduced dose recorded a lower yield.

The interaction effect was also not significant in both years.

Compared to open, the shoot yield of cassava in cropping system expressed tremendous increase in yield.

Table 6. Effect of cropping systems and fertilizer doses for intercrops on the shoot yield of cassava ($t\ ha^{-1}$) (Net area basis)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	37.566	29.060	33.313	28.838	26.813	27.826
C2 - Co + Ca + VCP	28.233	21.233	24.733	32.443	20.024	26.234
C3 - Co + Ca + EFY	36.665	33.097	34.881	34.085	22.900	28.493
C4 - Co + Ca + Ba	33.739	39.097	36.418	31.961	19.678	25.820
C5 - Co + Ca + VCP + EFY + Ba	40.331	32.838	36.585	42.245	31.616	36.931
Mean	35.307	31.065		33.914	24.206	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	4.753		–	5.210	
Cropping systems	–	3.358		–	3.691	
Fertilizer doses	–	2.123		6.926	2.333	
Interaction	–	4.753		–	5.210	
Sole cassava (open)						
F1 - FD	21.715			44.035		
F2 - RD	17.283			27.986		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

In the second year, yield in the open was higher than that of shaded condition whereas there was not much difference between open and shade at reduced level of fertilizers.

4A.1.2.7 Drymatter production

The effects of cropping systems and fertilizer doses for intercrops on drymatter production of cassava is presented in Table 7.

The different treatment combinations had no marked effects on dry matter production in both years.

Cropping systems had influence on dry matter production in the first year only. Cassava in coconut + cassava + vegetable cowpea + elephant foot yam + banana (C5) recorded the maximum dry matter production.

Full dose of fertilizers to intercrops resulted in higher drymatter production in first year.

There was not much variation in the dry matter production of cassava between shaded and open condition in both years.

The results show that in coconut based cropping system other intercrops with different doses of fertilizers did not affect the dry matter production of cassava. It reveals that cassava is an ideal crop component in

Table 7. Effect of cropping systems and fertilizer doses for intercrops on the dry matter production (tuber + shoot) of cassava (t ha^{-1}) (Net area basis)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	19.76	15.68	17.72	15.45	13.24	14.35
C2 - Co + Ca + VCP	15.39	11.72	13.56	15.97	12.33	14.15
C3 - Co + Ca + EFY	20.98	18.62	19.80	20.37	17.06	18.72
C4 - Co + Ca + Ba	19.77	18.89	19.33	17.77	11.67	14.72
C5 - Co + Ca + VCP + EFY + Ba	23.02	17.73	20.38	22.23	19.21	20.72
Mean	19.78	16.53		18.36	14.70	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	2.122		–	2.941	
Cropping systems	4.438	1.493		–	2.079	
Fertilizer doses	2.807	0.945		–	1.315	
Interaction	–	2.112		–	2.941	
Sole cassava (open)						
F1 - FD	20.70			28.78		
F2 - RD	15.80			14.73		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

coconut based cropping system and there is no unfavourable competition from other component crops for nutrients, moisture and light.

The dry matter production of cassava under the partial shade of coconut is comparable with that of open. The nutrients, moisture and light available in the partial shade of coconut was sufficient to produce dry matter equal to that of the open, eventhough there were variations in tuber and shoot yield compared to open (Table 5 and 6).

4.A.1.2.8 Harvest index

The harvest index of cassava was not influenced by any of the treatment combinations or treatments in both years (Table 8).

4.A.1.2.9 Percentage of starch

Cropping system had no influence on the percentage of starch of cassava tuber in both years (Table 9).

Fertilizer doses for intercrops had significant influence on percentage of starch of cassava tubers in first year, while in the second year there was no effect.

In general, there was an increase in percentage of starch in the second year compared to first year under shaded condition.

Table 8. Effect of cropping systems and fertilizer doses of intercrops on the harvest index of cassava (%)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	49.21	49.06	49.14	47.66	45.80	46.73
C2 - Co + Ca + VCP	50.49	51.27	50.88	43.47	55.38	49.43
C3 - Co + Ca + EFY	51.00	50.85	50.93	52.11	61.68	56.90
C4 - Co + Ca + Ba	53.69	43.49	48.59	49.19	54.28	51.74
C5 - Co + Ca + VCP + EFY + Ba	52.14	49.79	50.97	51.42	45.45	48.44
Mean	51.31	48.89		48.77	52.52	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	4.672		–	4.133	
Cropping systems	–	3.303		–	2.922	
Fertilizer doses	–	2.089		–	1.848	
Interaction	–	4.672		–	4.133	
Sole cassava (open)						
F1 - FD	63.88			48.32		
F2 - RD	65.17			40.81		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

In treatments with full dose of fertilizers for intercrops, the increased dose of N and P might have helped in better absorption and utilization of K resulting in higher starch percentage of cassava tubers.

Cassava might not have utilized the entire quantity of K applied during the first year. Thus the increased level of K in the soil in the second year might have resulted in the higher starch percentage.

In the open, as a result of better exhaustion of soil K, there must be a reduction in K which might have resulted in reduced K content of soil in the second year, causing a subsidence in starch percentage.

4.A.1.2.10 HCN content

The HCN content of tuber was not influenced by cropping systems and fertilizer doses for intercrops (Table 9).

There was not much variation in the HCN content between shaded and open conditions. Full dose of K (100 kg ha^{-1}) was applied to cassava in all the treatments where cassava was included. Besides there was a reduction of 25 per cent in the quantum of PAR received in the shaded area compared to open. These may be the reasons for the low HCN content of tuber under shaded and open conditions. Muthuswamy and Rao (1981) has also reported that application of K decreased the HCN content of cassava tubers.

Table 9. Effect of cropping systems and fertilizer doses for intercrops on the starch (%) and HCN content ($\mu g\ g^{-1}$) of cassava tuber at the time of harvest

Cropping systems	Starch (%) (Fresh weight basis)		HCN ($\mu g\ g^{-1}$)	
	1992-93	1993-94	1992-93	1993-94
C1 - Co + Ca	22.0	25.4	47.5	37.5
C2 - Co + Ca + VCP	22.7	25.6	24.3	59.0
C3 - Co + Ca + EFY	24.7	26.9	32.8	42.0
C4 - Co + Ca + Ba	22.8	25.3	34.8	47.8
C5 - Co + Ca + VCP + EFY + Ba	24.8	24.8	28.7	75.5
CD (0.05)	–	–	–	–
SEM ±	1.145	1.290	6.245	11.603
Fertilizer doses				
F1 - FD	24.8	26.7	32.4	56.1
F2 - RD	22.0	24.5	34.9	48.7
CD (0.05)	2.151	–	–	–
SEM ±	0.724	0.816	3.950	7.338
Sole cassava (open)				
F1 - FD	27.2	22.7	43.0	82.0
F2 - RD	23.7	21.2	34.0	51.3

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

4A.2 Banana

4A.2.1 Growth characters

4A.2.1.1 Height

The height of banana at different stages of growth was not influenced by cropping systems (Table 10).

Fertilizer doses for intercrops had not much effect on the height of banana.

Under shaded condition, the height was more compared to open situation. This was true in plants applied with full dose and reduced doses of fertilizers.

Almost the same height was recorded in both the cropping systems involving banana, probably because banana was planted on the remote corners of the plot and hence the chances of competition from other component crops were less.

The superior height recorded under shaded condition, compared to open, might be due to etiolation as result of reduced light received.

4A.2.1.2 Leaf area

The leaf area was not influenced by cropping system and fertilizer doses for intercrops (Table 10).

Table 10. Effect of cropping systems and fertilizer doses for intercrops on the height of banana (cm) and leaf area (m^2 $plant^{-1}$) at different stages of growth

Cropping systems	1992-1994 Days after planting				1992-1994 Days after planting			
	90	180	240	360	90	180	270	300
	Height (cm)				Leaf area (m^2 $plant^{-1}$)			
C4 - Co + Ca + Ba	66.17	144.83	146.83	196.67	0.719	2.433	2.026	2.078
C5 - Co + Ca + VCP + EFY + Ba	63.17	148.17	153.67	212.67	0.611	2.345	2.025	3.331
CD (0.05)	-	-	-	-	-	-	-	-
SEM ±	3.682	10.238	9.446	14.135	0.068	0.292	0.286	0.753
Fertilizer doses								
F1 - FD	67.67	163.67	170.50	225.00	0.766	2.748	2.572	2.946
F2 - RD	61.67	129.33	130.00	158.50	0.566	2.030	1.478	2.463
CD (0.05)	-	-	32.687	-	-	-	1.401	-
SEM ±	3.682	10.238	9.446	14.135	0.068	0.292	0.286	0.753
Sole banana (open)								
F1 - FD	66.67	101.67	114.67	166.33	0.333	1.444	2.060	1.382
F2 - RD	55.33	100.33	109.67	148.33	0.300	1.239	0.967	1.168

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Under shaded condition, leaf area was more compared to open both under full dose and reduced dose of fertilizer.

The higher leaf area observed under shaded condition might be due to lesser availability of light as given in Fig 16. The increased moisture availability also is possible on account of the reduced transpiration loss in a crop canopy comprising several component crops as clearly brought about in Fig.12, 13 & 14.

4A.2.1.3 Number of days taken for bunch emergence

Significant difference was observed in the number of days taken for bunch emergence due to cropping systems as well as fertilizer doses for intercrops (Table 11). Banana in association with cassava, vegetable cowpea and elephant foot yam produced bunches earlier compared to banana when raised along with cassava alone under shaded situation.

Number of days taken for bunch emergence was significantly less with full dose of fertilizers for banana compared to the reduced dose.

More delay was observed in bunch emergence in the open in comparison to shaded area.

In coconut + cassava + banana + elephant foot yam + vegetable cowpea cropping system (C5) the competition from cassava was less as only less

Table 11. Effect of cropping systems and fertilizer doses for intercrops on the number of days taken for bunch emergence, number of hands bunch^{-1} and number of fingers bunch^{-1} in intercrop-banana

Cropping systems	1992-1994 No. of days taken for bunch emergence	1992-1994 No. of hands bunch^{-1}	1992-1994 No. of fingers bunch^{-1}
C4 - Co + Ca + Ba	445	8.000	92.17
C5 - Co + Ca + VCP + EFY + Ba	396	7.000	78.50
CD (0.05)	47.715	–	–
SEM ±	13.789	0.366	4.384
Fertilizer doses			
F1 - FD	379	7.333	85.00
F2 - RD	463	7.667	84.00
CD (0.05)	47.715	–	–
SEM ±	13.789	0.366	4.384
Sole banana (open)			
F1 - FD	475	7.00	79.33
F2 - RD	481	6.14	67.71

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

number of cassava plants were present. The competition from vegetable cowpea and elephant foot yam was less as they were short statured as well as short duration crops compared to banana.

When banana was raised along with cassava (C4) there might have been competition from cassava in the first year due to mutual shading ultimately resulting in the tardy growth of banana and delayed bunch emergence.

Full dose of fertilizers, especially N and P might have helped in the faster growth of banana resulting in early bunch emergence compared to the plants which received a reduced dose under shaded situation.

Lack of moisture due to excessive evaporation during summer months might be the reason for the slow growth and delayed bunch emergence in crops of banana raised in the open. It is also probable that more nutrients are made available to banana in a cropping system rather than banana grown alone in the open. Radiotracer studies also revealed that the uptake was more in banana when raised in association with other crops compared to the sole crop (Table 36).

4A.2.2 Yield attributing characters

The yield attributing characters such as number of hands per bunch and number of fingers per bunch were not affected by different cropping systems as well as fertilizer doses for intercrops (Table 11) and hence not discussed.

4A.2.2.1 Bunch yield

The bunch yield was not affected by any of the treatments (Table 12). It is also particular to note that there is no difference between fertilizer treatments.

In the open, the bunch yield was less, compared to partially shaded condition.

Cassava had a height of more than 3 m at 300 days after planting (Table 2) while that of banana was around 2 m at 360 days after planting (Table 10). As there was no late branching in cassava under shaded condition, the competition from cassava under shading was negligible.

Vegetable cowpea and elephant foot yam are short duration crops with short stature compared to banana. Banana because of its tall canopy was in an advantageous position as far as light utilization in the cropping systems was concerned.

Under shaded condition, the moisture availability was more as a result of reduction in evaporation loss of moisture by crop canopies of other component crops. The shade in the coconut garden has not reduced the yield of banana.

Table 12. Effect of cropping systems and fertilizer doses for intercrops on the bunch yield (t ha^{-1}), dry matter production (t ha^{-1}) and harvest index (%) of intercrop – banana

Cropping systems	(Bunch yield (t ha^{-1})			Dry matter (t ha^{-1})		Harvest index
	1992-1994			1992-1994		(%)
	FD	RD	Mean			1992-1994
C4 - Co + Ca + Ba	4.050	4.847	4.449	Co + Ca + Ba	2.225	23.02
C5 - Co + Ca + VCP + EFY + Ba	4.340	3.685	4.013	Co + Ca + VCP + EFY + Ba	1.955	33.94
Mean	4.195	4.266	–	CD (0.05)	–	-
		CD (0.05)	SEM ±	SEM ±	0.188	2.401
Fertilizer doses						
Treatments		–	0.287	FD	2.215	30.84
Cropping systems		–	0.203	HD	1.965	36.12
Fertilizer doses		–	0.203	CD (0.05)	-	-
Interaction		–	0.287	SEM ±	0.188	2.401
Sole banana (Open)						
F1 - FD			3.465	FD	1.748	39.05
F2 - RD			2.543	RD	1.266	32.43

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

As far as nutrition is concerned, banana is in an advantageous position under cropping system than the sole crop of banana. Eventhough there is some competition for light this is more than compensated by nutrients as indicated in radiotracer studies (Table 36). The duration of banana is also less under cropping system compared to open because of favourable growth conditions available under shaded condition. Thus growing banana in cropping system is no way detrimental to banana.

Because of the factors already mentioned, the plants which received half of the dose are probably benefited by the manures applied for component crops in the system, thus giving almost same yield as that of the full dose of fertilizer. This opens yet another advantage of the cropping system ie., for realising optimum production, fertilizer dose can even be reduced.

The reasons given above are applicable to banana raised in the open also.

4A.2.2.2 Dry matter production

As in the case of bunch yield, there was no significant reduction in the dry matter production by cropping systems or fertilizer doses (Table 12). The same reasons as given to bunch yield is applicable in this case also.

4A.2.2.3 Harvest index

The value is same as far as the cropping systems and fertilizer doses are concerned (Table 12). However, there is difference in the performance in the characters in open and shaded situation. Half dose of fertilizers have given a higher harvest index under cropping system situation. This is attributed to superior levels of yield under this treatment as already reported.

4A.3 Elephant foot yam

4A.3.1 Growth characters

4A.3.1.1 Height

The height of elephant foot yam under shade was not influenced by different cropping systems and fertilizer dozes for intercrops in both the years in all the stages (Table 13).

The height was more in the shaded condition, compared to sole crop in the open.

The increase in height observed for intercrop elephant foot yam may be due to etiolation caused by reduced light under shaded condition. There was only 70 per cent PAR under shaded condition compared to open situation.

4A.3.1.2 Leaf area

A decreasing trend was observed in the leaf area of intercrop - elephant foot yam in the cropping system involving coconut + cassava + vegetable cowpea + banana (C5) compared to coconut + cassava + elephant foot yam (Table 14).

Table 13. Effect of cropping systems and fertilizer doses for intercrops on the height of intercrop - elephant foot yam (cm)

Cropping systems	1992-1993			1993-1994		
	Days after planting			Days after planting		
	75	150	225	75	150	225
	Height (cm)			Height (cm)		
C3 - Co + Ca + EFY	40.50	44.28	45.72	37.72	42.17	45.89
C5 - Co + Ca + VCP + EFY + Ba	43.33	43.89	45.95	36.39	39.61	41.50
CD (0.05)	–	–	–	–	–	–
SEM ±	1.504	1.279	1.372	1.658	2.130	1.977
Fertilizer doses						
F1 - FD	42.83	45.11	47.61	37.95	40.78	44.67
F2 - RD	41.00	43.06	44.06	36.17	41.00	42.72
CD (0.05)	–	–	–	–	–	–
SEM ±	1.504	1.279	1.372	1.658	2.130	1.977
Sole elephant foot yam (open)						
F1 - FD	38.67	41.33	43.00	33.00	39.67	42.67
F2 - RD	36.33	39.67	39.00	31.00	35.00	41.67

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 14. Effect of cropping systems and fertilizer doses for intercrops on the leaf area of intercrop - elephant foot yam (m^2 $plant^{-1}$)

Cropping systems	1992-1993			1993-1994		
	Days after planting			Days after planting		
	60	120	180	60	120	180
	Leaf area $plant^{-1}$ (m^2)			Leaf area $plant^{-1}$ (m^2)		
C3 - Co + Ca + EFY	0.856	0.908	0.821	0.912	0.573	0.407
C5 - Co + Ca + VCP EFY + Ba	0.708	0.650	0.825	0.834	0.691	0.528
CD (0.05)	0.118	0.092	-	-	0.102	0.091
SEM +	0.034	0.026	0.069	0.032	0.029	0.026
Fertilizer doses						
F1 - FD	0.921	0.877	0.798	0.844	0.647	0.445
F2 - RD	0.643	0.681	0.848	0.902	0.617	0.490
CD (0.05)	0.118	0.092	-	-	-	-
SEM +	0.034	0.026	0.069	0.032	0.029	0.037
Sole elephant foot yam (open)						
F1 - FD	0.942	0.788	0.732	0.635	1.301	0.925
F2 - RD	0.853	0.772	0.703	0.535	0.504	0.686

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Fertilizer doses had no clear influence on the leaf area of intercrop elephant foot yam.

In the sole crop, leaf area was more with full dose of fertilizer compared to the reduced dose.

The reduction in leaf area of elephant foot yam in the presence of cassava, vegetable cowpea and banana might be due to competition for nutrient as discussed earlier.

The higher leaf area observed for sole crop in the open might be due to better utilization of the full dose of applied nutrients in the presence of full sunlight.

4A.3.1.3 Canopy spread

It is already seen from leaf area that this character was more under full dose of fertilizer in open and also in most of the observations under shaded condition (Table 15).

4A.3.2 Yield attributes

4A.3.2.1 Tuber yield

Cropping systems and fertilizer doses for intercrops had no effect on the tuber yield of elephant foot yam in both years (Table 16).

Table 15. Effect of cropping systems and fertilizer doses for intercrops on the canopy spread of intercrop - elephant foot yam (cm)

Cropping systems	1992-1993			1993-1994		
	Days after planting			Days after planting		
	60	120	180	60	120	180
C3 - Co + Ca + EFY	116.3	119.8	124.1	103.8	110.6	111.5
C5 - Co + Ca + VCP EFY + Ba	121.2	117.8	123.9	102.9	108.9	107.2
CD (0.05)	-	-	-	-	-	-
SEM ±	6.082	3.800	3.949	4.104	1.739	1.960
Fertilizer doses						
F1 - FD	122.0	121.3	127.5	102.7	113.1	113.3
F2 - RD	115.4	116.3	120.6	103.9	106.4	105.3
CD (0.05)	-	-	-	-	6.019	6.784
SEM ±	6.082	3.800	3.949	4.104	1.739	1.960
Sole elephant foot yam (open)						
F1 - FD	100.0	113.0	108.0	94.0	109.3	110.7
F2 - RD	89.3	103.3	104.0	94.0	100.0	108.7

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 16. Effect of cropping systems and fertilizer doses for intercrops on the total biomass production of intercrop - elephant foot yam (t ha^{-1})

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C3 - Co + Ca + EFY	6.693	5.006	5.849	4.245	3.567	3.911
C5 - Co + Ca + VCP + EFY + Ba	5.336	5.161	5.248	3.590	3.480	3.535
Mean	6.014	5.084		3.922	3.524	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	-	0.579		-	0.379	
Cropping systems	-	0.409		-	0.268	
Fertilizer doses	-	0.409		-	0.268	
Interaction	-	0.579		-	0.379	
Sole elephant foot yam (open)						
F1 - FD	4.572			3.026		
F2 - RD	3.722			2.643		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

The tuber yield was less in the sole crop in the open compared to shaded condition.

There was no marked difference in the quantum of PAR incident on canopy of elephant foot yam in both the cropping systems (Fig. 17). Similarly not much variation was observed in soil moisture content between the two cropping systems (Fig. 12, 13 & 14). Thus the crop produced more or less equal yields under both fertilizer levels.

In the open sole crop, eventhough the quantum of PAR received was more, the moisture content of the soil was less compared to shaded condition, especially in summer months. Higher rates of evaporation (Fig. 1a and 1b) along with moisture shortage might be the reason for lower yield in the open compared to shaded condition.

Thus from the results it can be concluded that elephant foot yam is a crop best suited for the shaded condition in the cropping system situation. The shade tolerance of the crop is one of the most beneficiary factors. There is an added advantage by growing the crop in the system combination. This crop requires only 50 per cent of N and P and it had given almost the same yield as full recommended dose. Thus elephant foot yam can be grown with advantage in both the cropping systems.

4A.3.2.2 Dry matter production

Cropping systems and fertilizer doses had no influence on dry matter production of intercrop elephant foot yam in both years (Table 17). The same trend was observed in sole crop in the open with the two doses of fertilizers.

Table 17. Effect of cropping systems and fertilizer doses for intercrops on drymatter production (t ha^{-1}) and harvest index (%) of intercrop - elephant foot yam

Cropping systems	Drymatter production (t gross ha^{-1}) of coconut plantation		Harvest index (%)	
	1992-93	1993-94	1992-93	1993-94
C3 - Co + Ca + EFY	1.387	0.937	76.97	76.55
C5 - Co + Ca + VCP + EFY + Ba	1.281	0.903	75.22	71.72
CD (0.05)	–	–	–	–
SEM ±	0.075	0.049	1.392	1.462
Fertilizer doses				
F1 - FD	1.426	0.951	77.32	75.62
F2 - RD	1.242	0.889	74.87	72.65
CD (0.05)	–	–	–	–
SEM ±	0.075	0.049	1.392	1.462
Sole elephant foot yam (open)				
F1 - FD	1.296	1.289	79.11	66.55
F2 - RD	1.055	1.036	81.89	72.29

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam,
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

4A.3.2.3 Harvest index

No marked difference was observed in harvest index due to cropping systems and fertilizer dose to intercrops under shaded situation (Table 17).

In the open also harvest index was not affected much due to differences in fertilizer doses.

Since the harvest index was not markedly different in intercrop and sole crop of elephant foot yam it, may be concluded that the partitioning and translocation of photosynthates in elephant foot yam was not influenced by shade of coconuts. The harvest index of about 75 per cent observed in elephant foot yam was very high considering other intercrops studied.

Elephant foot yam is peculiar in its morphological behaviour that the canopy is having only a single layer of leaf and the canopy does not expand much once it is fully formed and hence there is no chance of mutual shading. The full formation of the canopy takes only about 30 days from planting. After this for the remaining period of about 7 months, the assimilates is used for the corm formation and development only. According to Loomis and Williams (1963) a single horizontal canopy can utilize only about 25 per cent of the total photosynthetically active radiation received and the rest go unutilized. Hence solar energy may be under utilized in places where this crop is grown in sole stand.

4A.4 Vegetable cowpea

4A.4.1 Growth characters

4A.4.1.1 Height

There was no effect on the height of intercrop - vegetable cowpea by cropping systems as well as by fertilizer doses for intercrops at different stages of growth (Table 18).

An increase in height was observed in vegetable cowpea raised under shade, compared to open area.

A reduction in PAR received by intercrop vegetable cowpea (Fig.18) compared to open area might be the reason for the etiolation and higher height observed under shaded condition.

4A.4.1.2 Leaf area

Cropping systems and fertilizer doses had influence on leaf area of vegetable cowpea under shaded situation (Table 19).

There was a reduction in leaf area of vegetable cowpea in the cropping system involving elephant foot yam.

Leaf area was higher with full dose of fertilizer in all stages of growth in the open as well as under shade.

Table 18. Effect of cropping systems and fertilizer doses for intercrops on the height of intercrop - vegetable cowpea (cm)

Cropping systems	1992-93			1993-94		
	Days after sowing			Days after sowing		
	25	50	75	25	50	75
C2 - Co + Ca + VCP	45.83	56.47	57.37	45.40	55.17	57.72
C5 - Co + Ca + VCP + EFY + Ba	42.00	53.87	54.50	42.45	46.03	61.17
CD (0.05)	-	-	-	-	3.352	-
SEM ±	2.798	0.925	1.552	1.439	0.969	2.467
Fertilizer doses						
F1 - FD	44.50	56.43	56.97	45.28	50.20	61.33
F2 - RD	43.33	53.90	54.90	42.57	51.00	57.56
CD (0.05)	-	-	-	-	-	-
SEM ±	2.798	0.925	1.552	1.439	0.969	2.467
Sole vegetable cowpea (open)						
F1 - FD	35.00	45.00	49.00	26.00	40.00	42.00
F2 - RD	26.00	37.00	44.00	19.67	32.00	34.30

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 19. Effect of cropping systems and fertilizer doses for intercrops on the leaf area of intercrop - vegetable cowpea (m^2 $hill^{-1}$)

Cropping systems	1992-93			1993-94		
	Days after sowing			Days after sowing		
	25	50	75	25	50	75
C2 - Co + Ca + VCP	0.266	0.470	0.295	0.215	0.400	0.046
C5 - Co + Ca + VCP + EFY + Ba	0.264	0.434	0.282	0.195	0.236	0.136
CD (0.05)	–	0.035	–	–	0.036	0.019
SEM ±	0.022	0.010	0.019	0.007	0.011	0.005
Fertilizer doses						
F1 - FD	0.276	0.455	0.358	0.223	0.329	0.116
F2 - RD	0.254	0.448	0.218	0.187	0.306	0.065
CD (0.05)	–	–	0.066	0.025	–	0.019
SEM ±	0.022	0.010	0.019	0.007	0.011	0.005
Sole vegetable cowpea (open)						
F1 - FD	0.225	0.254	0.132	0.227	0.158	0.033
F2 - RD	0.102	0.211	0.038	0.129	0.147	0.026

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

The reduction in leaf area of vegetable cowpea in the presence of elephant foot yam might be due to higher canopy spread of elephant foot yam (Table 15).

Full dose of fertilizers helped in the better absorption of nutrients and moisture resulting in increased vegetative growth, especially leaf area under cropping system as well as open.

4A.4.2 Yield attributes

4A.4.2.1 Fresh pod yield

Cropping systems and fertilizer doses for intercrops had no effect on fresh pod yield of vegetable cowpea in both years (Table 20).

Fresh pod yield was less in the open compared to that in cropping system.

Growing vegetable cowpea in the cropping system with coconut + cassava + elephant foot yam + banana did not decrease the yield inspite of more crops grown due to the following reasons.

Light infiltration on the crop canopy of vegetable cowpea is more in the latter cropping system (C5). This is probably because in the former system (C2) cowpea is grown in between two rows of cassava which continues to

Table 20. Effect of cropping systems and fertilizer doses for intercrops on the fresh pod yield of intercrop - vegetable cowpea (t gross ha^{-1} of coconut plantation)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C2 - Co + Ca + VCP	0.854	1.391	1.123	0.953	1.462	1.208
C5 - Co + Ca + VCP + EFY + Ba	1.743	1.272	1.508	1.353	1.114	1.234
Mean	1.299	1.332		1.153	1.288	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	0.309		–	0.286	
Cropping systems	–	0.219		–	0.203	
Fertilizer doses	–	0.219		–	0.203	
Interaction	–	0.309		–	0.286	
Sole vegetable cowpea (open)						
F1 - FD	0.736			0.434		
F2 - RD	0.431			0.424		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

shade cowpea canopy till the harvest of cowpea whereas in the other system, one row of cassava is replaced by elephant foot yam and there is not much competition for light on one side.

With reference to moisture it can be said that there is not much difference in the moisture content between the two cropping systems as revealed in Fig. 12. Hence it is presumed that moisture is not a constraint for cowpea production in cropping system.

It is also possible that the soil is more enriched by growing vegetable cowpea in the C5 system of intercropping than C2 as evidenced by the soil analysis data in Table 29. There is also not much difference between the uptake of cowpea grown in both situation (Fig. 10) thereby suggesting that there is absolutely no competition for nutrients on account of more crops grown in C5. It is also probable that vegetable cowpea might have received some nutrients from the neighboring cassava mounds (Plate 24) and also from the pits where elephant foot yam was raised.

Fertilizer doses also have not shown any variation in the pod yield. In fact a trend is shown to give more production at the reduced levels of N and P. This is probably attributed to the main effect of nitrogen where in addition of nitrogen more than 50 per cent dose is not required in a cropping system involving banana and elephant foot yam probably because of the reasons already cited. It may be further noted that there is a tremendous difference between the pod yield of vegetable cowpea grown in the open and

Plate 24. Root spread of vegetable cowpea

in cropping systems where in, the latter has recorded an appreciable increase in pod yield. This is inspite of the fact that cowpea is a sun loving crop. This is probable because primarily in the cropping system vegetable cowpea was not shaded to a detrimental level. Secondly the nutritional factor would have definitely played a dominant role.

4A.4.2.2 Haulm yield and dry matter production

Haulm yield and dry matter production are presented in Table 21 and 22 respectively. Since the trend for these observations are same as that of pod yield a separate discussion is not given.

4A.4.2.3 Harvest index

Harvest index is significant in first year where in higher values were recorded in the C5 combination where as such a result was not obtained in second year (Table 22). A perusal of the rainfall data (Fig. 1a & 1b) show that during the period of the cowpea there was more rainfall in the first year than the second year. The pod yield data presented in Table 20, during the first year cropping system (C5) has recorded a higher pod yield where as in the second year the increase is very very marginal. The haulm yield data did not show much variation in both the years. The difference in the rainfall would have contributed to the variation in harvest index.

There is no difference in harvest index between the two fertilizer levels.

Table 21. Effect of cropping systems and fertilizer dose for intercrops on the haulm yield of intercrop - vegetable cowpea (t gross ha^{-1} of coconut plantation)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C2 - Co + Ca + VCP	1.126	1.612	1.369	1.040	1.683	1.362
C5 - Co + Ca + VCP + EFY + Ba	1.280	1.221	1.250	1.357	1.200	1.279
Mean	1.203	1.416		1.199	1.442	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	-	0.296		-	0.211	
Cropping systems	-	0.209		-	0.149	
Fertilizer doses	-	0.209		-	0.149	
Interaction	-	0.296		-	0.211	
Sole vegetable cowpea (open)						
F1 - FD	0.572			0.228		
F2 - RD	0.187			0.178		

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 22. Effect of cropping systems and fertilizer doses for intercrops on dry matter production and harvest index of intercrop - vegetable cowpea (cm)

Cropping systems	Dry matter ($t\ ha^{-1}$)		Harvest index (%)	
	1992-93	1993-94	1992-93	1993-94
C2 - Co + Ca + VCP	0.522	0.528	19.82	21.56
C5 - Co + Ca + VCP + EFY + Ba	0.521	0.505	27.46	22.34
CD (0.05)	-	-	3.680	-
SEM±	0.083	0.063	1.063	1.340
Fertilizer doses				
F1 - FD	0.488	0.473	24.43	22.51
F2 - RD	0.555	0.560	22.85	21.38
CD (0.05)	-	-	-	-
SEM ±	0.083	0.063	1.063	1.340
Sole vegetable cowpea (open)				
F1 - FD	0.568	0.298	30.22	39.13
F2 - RD	0.288	0.284	43.65	44.54

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

4A.5 Yield of intercrops

The intercrop yields obtained during 1992-93 and 1993-94 are given in Table 23. Tuber yield of cassava from different treatments varied due to differences in their population. Cropping systems and fertilizer doses for intercrops had not much influence on the yield of other intercrops such as banana, elephant foot yam and vegetable cowpea. Only one crop was harvested from banana during 1993-94 as there was a delay in bunch emergence under shaded situation.

4A.5.1. Total dry matter production of economic produce by intercrops

The total dry matter production of economic produce of intercrops during 1992-93 and 1993-94 cropping seasons are given in Table 24.

In coconut based cropping system the total dry matter production of economic produce was not influenced by cropping system. Eventhough there was significantly higher total dry matter production of economic produce due to full dose of fertilizer, compared to the reduced dose in the first year, no such difference was observed in the second year.

In coconut based cropping systems, involving different intercrops such as cassava, elephant foot yam and vegetable cowpea, the inputs such as space, nutrients, moisture and light are utilised efficiently compared to monocrop situation. The component crops are having different crop canopies, root system and duration which enable them to utilise the inputs efficiently and produce

Table 23. Yield of intercrops (t gross ha^{-1} of coconut plantation)

Treatments	1992-93				1993-94			
	Cassava (tuber)	Banana (bunch)	EFY (corm)	Veg. cowpea (fresh pods)	Cassava (tuber)	Banana (bunch)	EFY (corm)	Veg. cowpea (fresh pods)
C1F1	18.74				14.82			
C1F2	15.29				11.62			
C2F1	15.16			0.85	13.84			0.953
C2F2	11.72			1.39	13.52			1.462
C3F1	12.60		6.69		12.60		4.25	
C3F2	11.05		5.01		12.56		3.57	
C4F1	19.24				16.35	2.84		
C4F2	14.83				11.42	3.39		
C5F1	11.90		5.34	1.74	12.56	3.03	3.59	1.353
C5F2	8.65		5.16	1.27	7.32	2.58	3.48	1.114
Sole crop F1	38.41		19.66	6.49	41.17	8.66	16.44	3.83
(Open) F2	32.34		16.56	3.80	19.30	6.36	14.37	3.74

C1 - coconut + cassava, C2 - coconut + cassava + vegetable cowpea, C3 - coconut+ cassava + elephant foot yam, C4 - coconut + cassava + banana, C5 - coconut + cassava + banana + elephant footyam + vegetable cowpea, F1 - full dose of N, P and K, F2 - half dose of N and P and full dose of K.

Table 24. Effect of cropping systems and fertilizer doses for intercrops on total dry matter production of economic produce of intercrops (t gross ha^{-1} of coconut plantation)

Cropping systems	1992-93			1993-94		
	Fertilizer doses			Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	6.37	5.20	5.79	5.04	3.95	4.50
C2 - Co + Ca + VCP	5.24	4.12	4.68	4.80	4.73	4.77
C3 - Co + Ca + EFY	5.52	4.68	5.10	5.07	4.89	4.98
C4 - Co + Ca + Ba	6.54	5.04	5.79	6.18	4.64	5.41
C4 - Co + Ca + VCP + EFY + Ba	5.19	4.01	4.60	5.72	3.81	4.77
Mean	5.77	4.61		5.36	4.40	
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	-	0.651		-	0.759	
Cropping systems	-	0.461		-	0.537	
Fertilizer doses	0.866	0.291		-	0.340	
Interaction	-	0.651		-	0.759	

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, Ba - banana more dry matter per unit area per unit time. In this system, the PAR infiltered through the crop canopies of taller crops are utilised by crop canopies at a lower strata. Similarly nutrients and moisture not absorbed by the shallow roots of some crops are utilised by the crops having deeper root system. Fallen leaves of short duration crops decay and form a mulch in the early stages and a manure at later to the neighbouring long duration crops. Evaporation loss is also reduced from such a system and soil moisture status is better compared to open condition. Reduction in weed infestation is also observed in such system. All these factors contribute to higher productivity from unit area resulting in higher dry matter production of intercrops. Thus it may be concluded that in coconut garden, we can rise crops such as cassava, banana, elephant foot yam and vegetable cowpea in different combinations without much variation in total dry matter production of economic produce of intercrops.

Application of different doses of fertilizers had no effect on total dry matter production of economic produce of intercrop in the second year. In the second year, the dry matter production of all the intercrops including banana are taken into consideration and hence this period gives a clear picture of the impact of fertilizer doses on dry matter production. Under cropping system situation there is sharing of nutrients by component crops. There is no difference in fresh pod yield of vegetable cowpea, bunch yield of banana, tuber yield of elephant foot yam and cassava in the second year. Similarly there is not much variation in the total uptake of NPK by intercrops (Fig 11). Thus the results reveal that only a reduced dose of fertilizer is required for intercrops in coconut based cropping system.

4A.5.2 Rooting pattern of Intercrops

The mean spread, depth, fresh weight and number of roots of intercrops at different stages of growth in the cropping system and open are given in Table 25 and Fig. 6.

The data show that there is not much variation between the depth of roots of crops in the cropping system and open. However, there is an increase in the spread, fresh weight and number of roots of crop in the open compared to those in the cropping system. In general, it is observed that the crops in the open have a better root system compared to those in the shade especially in the case of cassava and banana.

Lesser tuber yield recorded by cassava in the shade (Table 5) might be the result of an inferior root system under such system compared to that in the open. The reduced light intensity received under shaded condition might be influencing the growth of crops grown under such situation adversely, including the root system. In a similar study conducted with colocasia plants, Suja *et al.* (1995) observed more roots in plants grown in the open than those grown in shade as intercrop with coconut.

In the case of elephant foot yam, grown under shade, there was no restriction in the root growth at later stages of growth compared to open situation. This might be due to the higher availability of moisture in shaded condition (Fig. 12) compared to open resulting in higher corm yield under shaded condition.

Table 25. Rooting pattern of intercrops

Cassava	Shade	Open	Shade	Open	Shade	Open
	100 DAP		200 DAP		300 DAP	
Spread (cm)	41	45	45	45	35	44
Depth (cm)	22	19	32	27	34	28
Fresh weight (g)	8	14	13	23	8	9
Number	18	24	23	18	10	9
Banana	**Shade**	**Open**	**Shade**	**Open**	**Shade**	**Open**
	90 DAP		180 DAP		360 DAP	
Spread (cm)	67	113	41	51	161	101
Depth (cm)	30	30	18	17	32	27
Fresh weight (g)	285	352	58	113	311	530
Number	195	277	73	86	178	291
Elephat foot yam	**Shade**	**Open**	**Shade**	**Open**	**Shade**	**Open**
	60 DAP		120 DAP		180 DAP	
Spread (cm)	53	63	53	58	47	53
Depth (cm)	20	21	22	25	21	23
Fresh weight (g)	190	197	119	243	253	179
Number	240	206	335	282	156	93

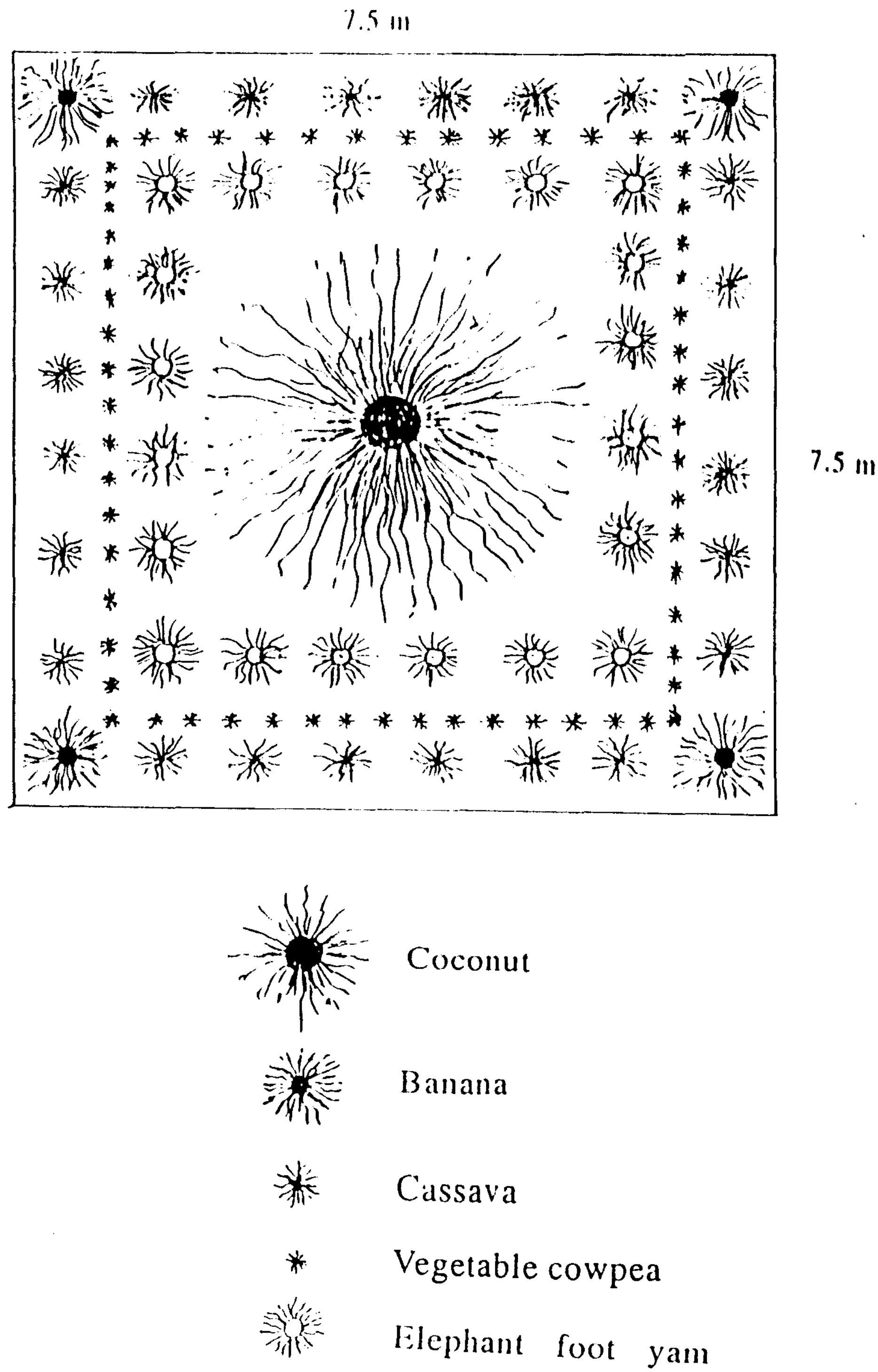


Fig. 6. Rooting pattern of component crops in coconut based cropping system

The rooting pattern of crops grown under the partial shade of coconut (Fig. 6) shows that there is no competition for nutrients and moisture among the component crops. Scientific selection and arrangement of intercrops can result in successful models of intercropping systems.

4A.6 Yield of coconut

The yield of coconut is not included as the duration of the investigation is for two years only. Normally, it takes at least three years to reflect any impact of intercrops on the yield of coconut.

4A.7 Uptake of NPK by intercrops

4A.7.1 Cassava

The NPK content of cassava leaves, stem, tuber and roots were estimated at the time of harvest and were found to be not significantly different in various cropping systems. The uptake of NPK by intercrop cassava for 1992-93 and 1993-94 are presented in Fig. 7.

The uptake of NPK by cassava was higher in cropping system involving coconut + cassava (C1), coconut + cassava + vegetable cowpea (C2) and coconut + cassava + banana (C4) whereas the uptake was low in coconut + cassava + elephant foot yam (C3) and coconut + cassava + vegetable cowpea + elephant foot yam + banana (C5) in both the years.

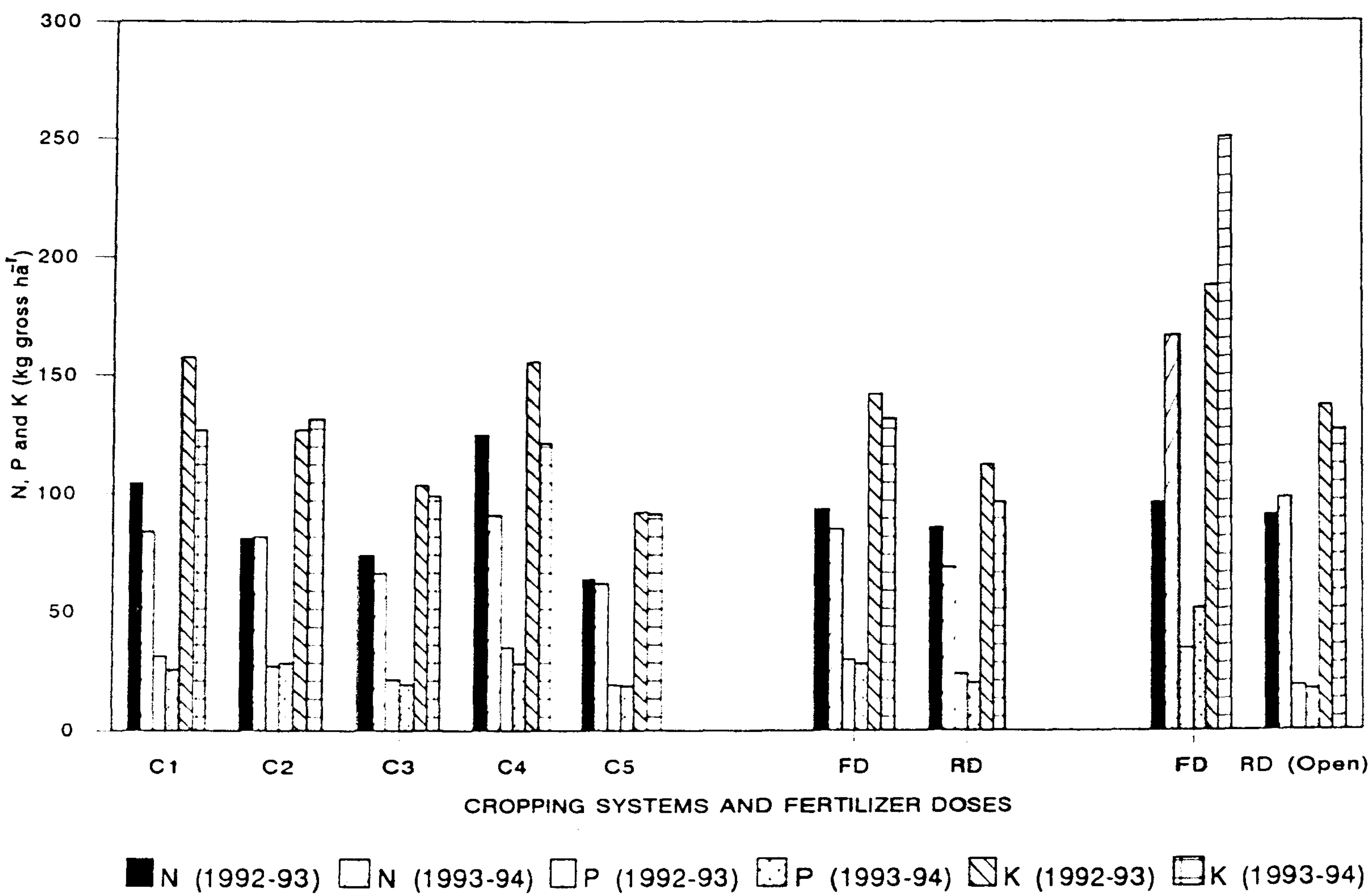


Fig. 7. Uptake of N, P and K by intercrop - Cassava

Full dose of fertilizers resulted in higher uptake of NPK by cassava in both the years.

The NPK uptake by sole crop cassava was more compared to the intercrop.

The higher plant population of intercrop cassava (62-68 per cent of sole crop) in cropping system coconut + cassava (C1) coconut + cassava + vegetable cowpea (C2) and coconut + cassava + banana (C4) was the reason for the increased uptake of NPK in those cropping systems. In coconut + cassava + elephant foot yam (C3) and coconut + cassava + vegetable cowpea + elephant foot yam + banana (C5) cropping system, the plant population ranged from 34 to 40 per cent of sole crop resulting in reduced uptake of NPK compared to the sole crop.

Nutrient removal by cassava was 92.78, 29.30 and 142.38 kg NPK ha^{-1} during the first year with a tuber yield of 22.38 t ha^{-1} as intercrop having a population of 8400 plants ha^{-1}. In the second year, the values were 82.94, 27.26 and 129.19 kg NPK ha^{-1} with tuber yield of 19.77 t ha^{-1}. Irizarry and Rivera (1983) reported nutrient removal to the extent of 204, 12 and 222 kg ha^{-1} respectively for a cassava crop of 10 months duration in an intercropping system. The comparatively higher nutrient removal might be due to the higher tuber yield they had obtained (37.5 t ha^{-1}) compared to the present study. In the shade there is not much variation in the uptake of NPK by cassava compared to open suggesting that cassava is suited to shaded condition also.

In the open, 8400 plants removed 96.28, 34.70 and 188.03 kg NPK with a tuber yield of 25.73 t in the first year while in the second year the same number of plants removed 166.86, 51.73 and 250.49 kg NPK with a tuber yield of 27.58 t. The values were less with reduced dose of fertilizer.

4A.7.2 Banana

The nutrient status of the different plant parts were almost similar in intercrop and sole crop banana.

The mean nutrient uptake by intercrop banana with a plant population of 700 ha^{-1} was 5.85, 0.298 and 19.81 kg NPK ha^{-1} during the first year and 15.39, 1.25 and 60.55 kg NPK ha^{-1} during the second year. In the open, the same population of banana removed 7.048, 0.365 and 25.95 kg NPK ha^{-1} during the first year and 12.72, 0.66 and 29.15 kg NPK ha^{-1} during the second year with full dose of fertilizers and the values were less with reduced dose of fertilizer (Fig 8). Thus it shows that in the system along with other crops there is no reduction in yield and uptake of banana.

4A.7.3 Elephant foot yam

Under shaded condition, different doses of fertilizers had no effect on the uptake of NPK by elephant foot yam.

The elephant foot yam crop on an average removed 28.41, 30.08 and 31.19 kg NPK ha^{-1} as intercrop with a population of 3500 plants ha^{-1} in the

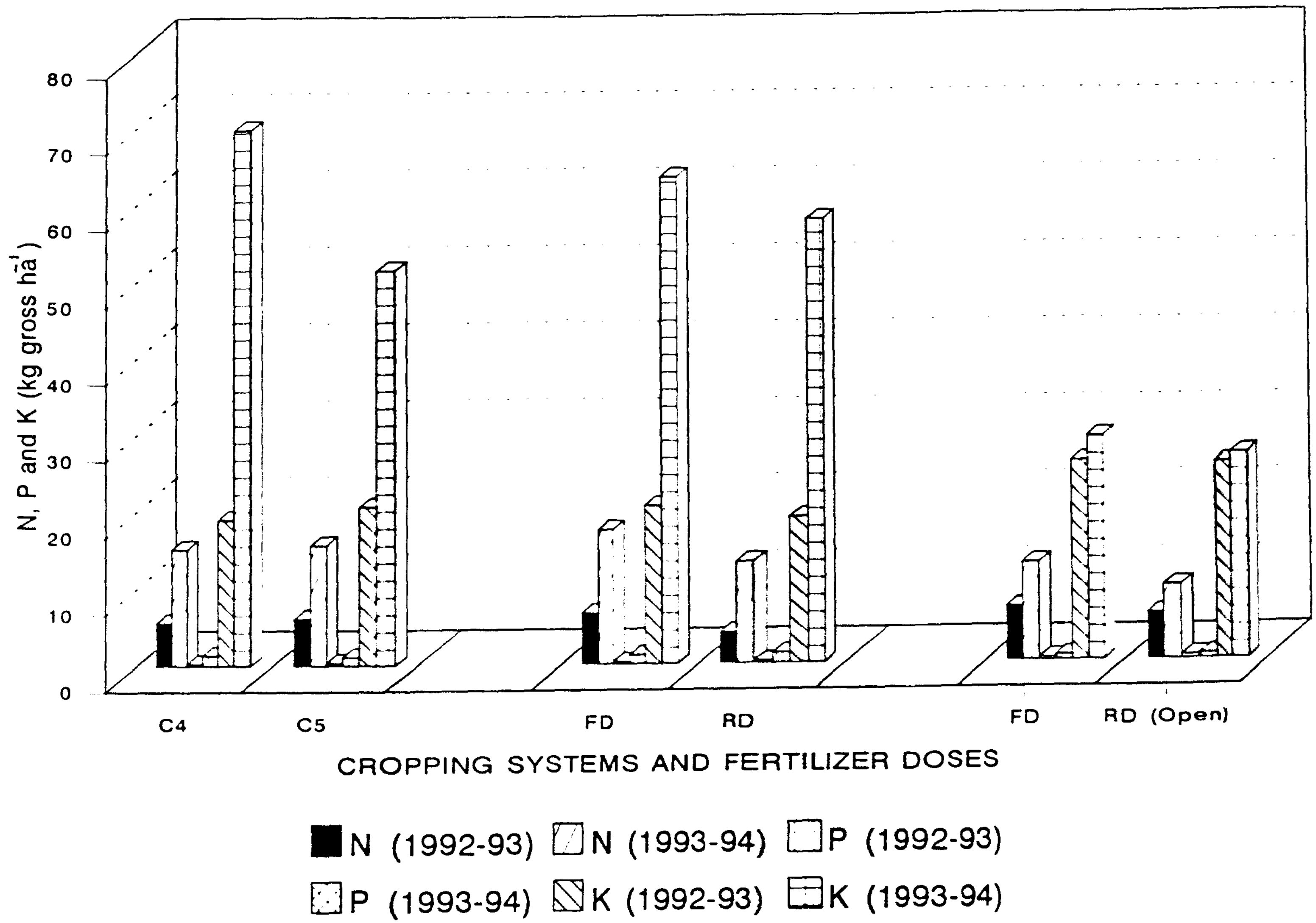


Fig. 8. Uptake of N, P and K by intercrop - Banana

first year whereas in the second year the uptake was 19.61, 2.08 and 22.11 kg NPK ha^{-1}. (Fig. 9). The uptake was not influenced by higher levels of fertilizers under shaded condition which shows that in the cropping system a reduced dose of fertilizer is sufficient for elephant foot yam.

4A.7.4 Vegetable cowpea

The mean uptake of nutrients by intercrop vegetable cowpea was 8.04, 0.96 and 9.57 kg NPK ha^{-1} during the first year and 7.73, 0.91 and 9.38 kg NPK ha^{-1} during the second year (Fig. 10).

The nutrient uptake by intercrop vegetable cowpea was similar with different doses of fertilizers in both the years.

In vegetable cowpea, the NPK uptake as well as fresh pod yield were not reduced even in the second year. It suggests that there was no severe competition from other component crops and vegetable cowpea can be successfully raised as an intercrop in coconut based cropping system.

As there is no difference in the nutrient uptake by intercrop vegetable cowpea with different doses of fertilizers, it implies that the crop requires only a reduced dose of fertilizer under shaded condition.

4A.7.5 Intercrops

The total nutrient removal by intercrops was higher in cropping system involving coconut + cassava + banana (C4), coconut + cassava + vegetable

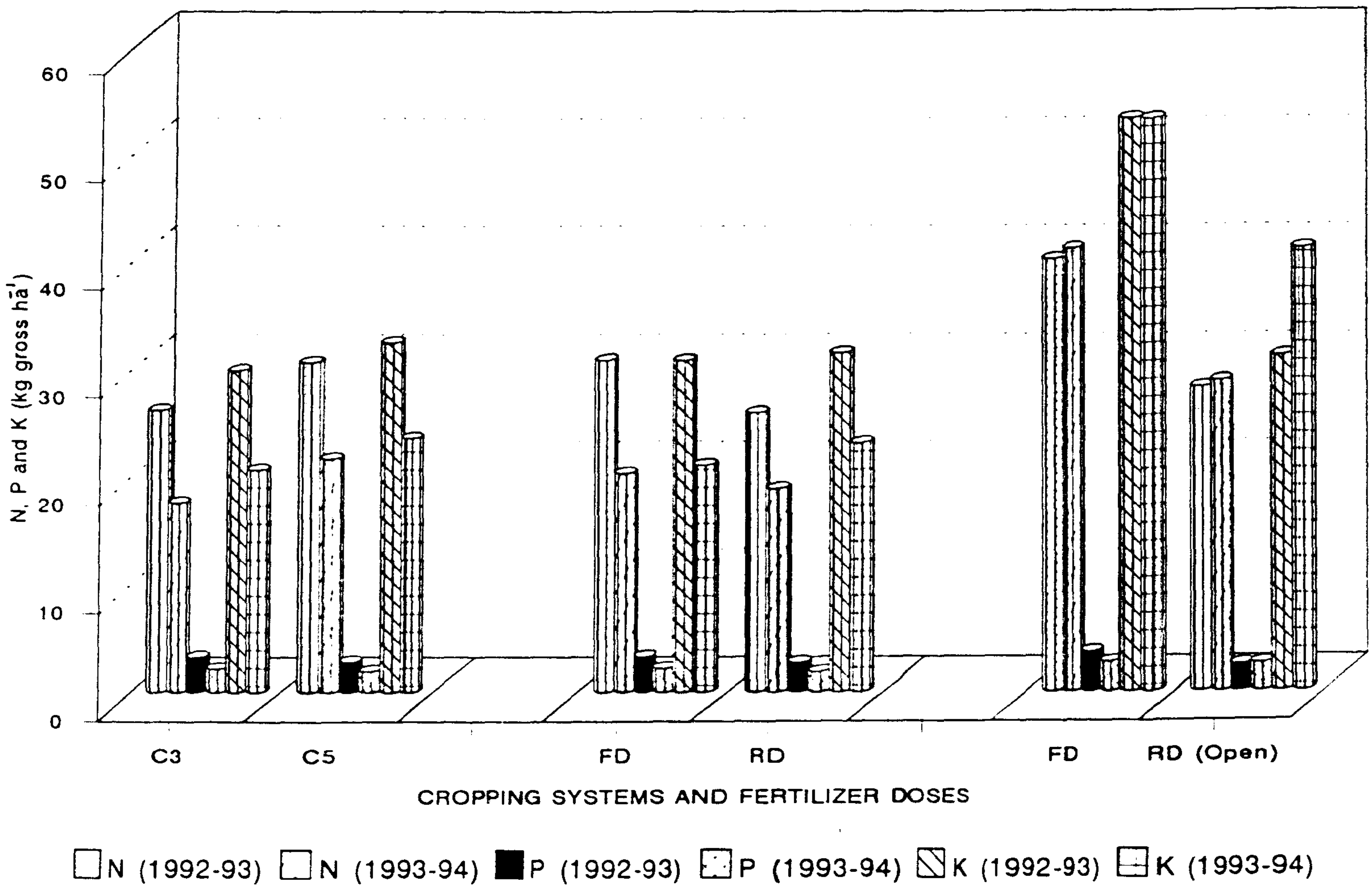


Fig. 9. Uptake of N, P and K by intercrop - Elephant foot yam

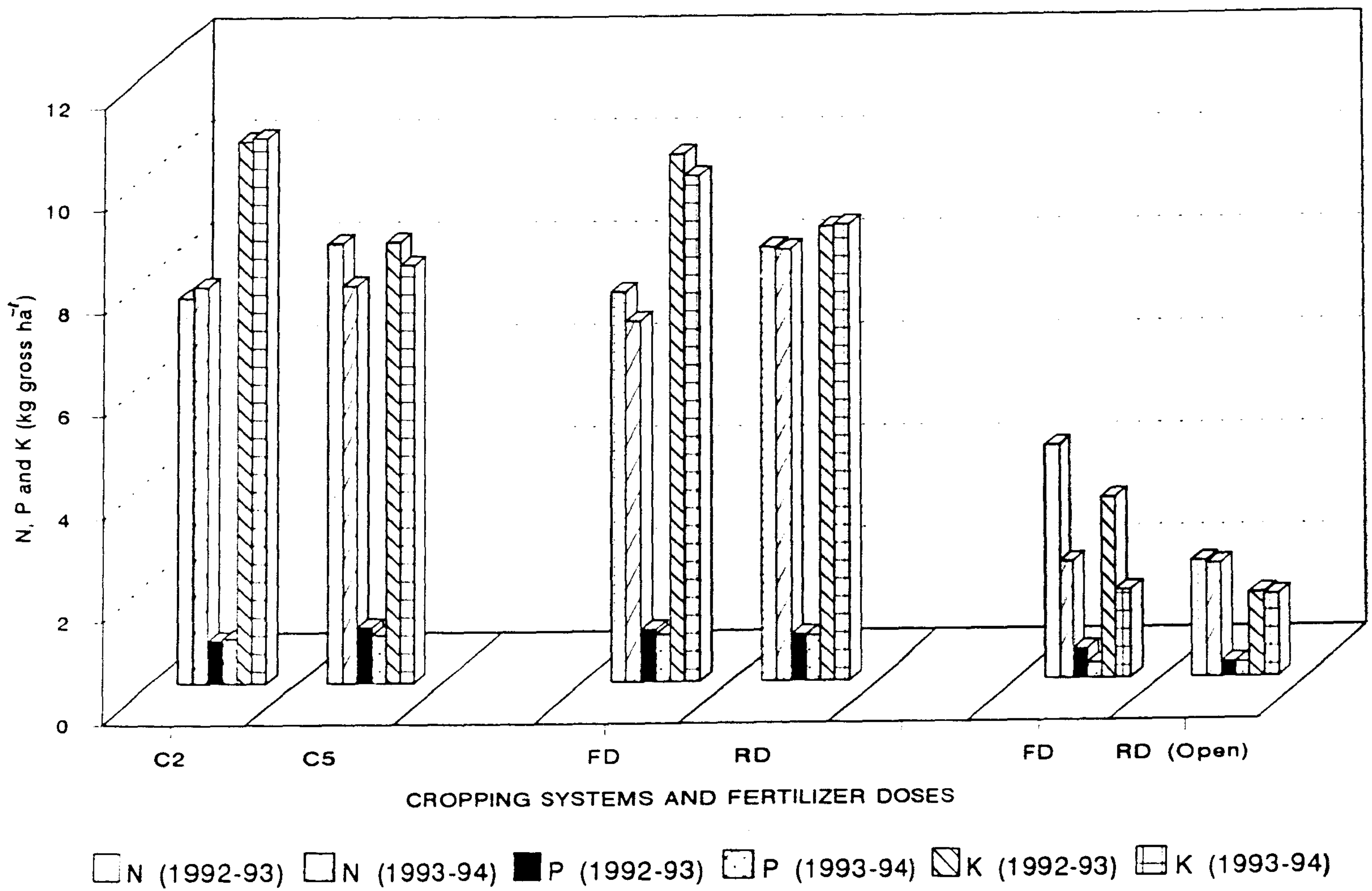


Fig. 10. Uptake of N, P and K by intercrop - Vegetable cowpea

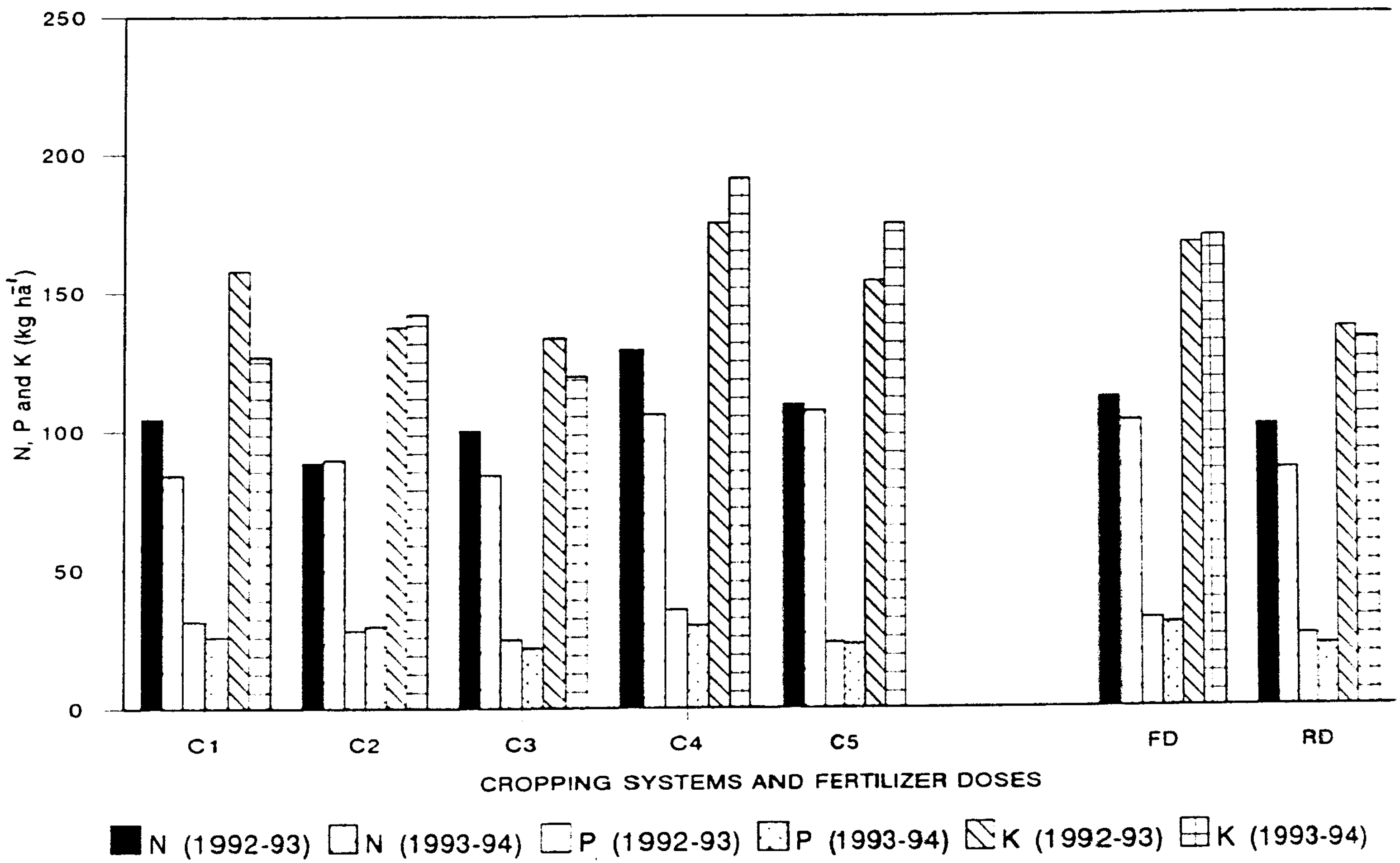


Fig. 11. Uptake of N, P and K by intercrops - Cassava + Banana + Elephant foot yam + Vegetable cowpea

cowpea + elephant foot yam + banana (C5) and coconut + cassava (C1) during the first year (Fig. 11). Cassava and banana were mainly responsible for the higher uptake of nutrients. In the second year, the cropping system coconut + cassava + banana (C4) and coconut + cassava + vegetable cowpea + elephant foot yam + banana (C5) recorded higher uptake. Higher uptake of K observed in the second year might be due to the increased absorption of K by banana in the second year, when the banana bunches were produced.

The full dose of fertilizers for intercrops resulted in the increased uptake of nutrients by intercrops compared to the reduced dose in both the years. However no difference in fresh pod yield of vegetable cowpea, bunch yield banana, tuber yield of elephant foot yam and tuber yield of cassava was observed in the second year. Thus it clearly shows that excess nutrients removed by crops are utilized for the increased vegetative development of crops and the production of economic parts are not affected much.

4A.8.1 Post experiment soil nutrient status

The initial and post experiment data on soil organic carbon, total N, available P and K in the rhizosphere of cassava, banana, elephant foot yam, vegetable cowpea and coconut are presented in Tables 26, 27, 28, 29 and 30a & 30b respectively.

The results showed that the post experiment organic carbon, total N and available P and K status of the soil were not significantly different after two years. The different cropping systems and fertilizer doses for intercrops had no effect on the post experiment soil nutrient status.

Table 26. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil organic carbon, N,P and K in the rhizosphere of cassava

Cropping systems	Soil organic carbon (%) 1993-94	Soil N (kg ha^{-1}) 1993-94	Soil P (kg ha^{-1}) 1993-94	Soil K (kg ha^{-1}) 1993-94
Initial value	0.520	163.07	54.32	51.52
C1 - Co + Ca	0.811	159.00	33.53	102.67
C2 - Co + Ca + VCP	0.664	156.15	41.16	101.92
C3 - Co + Ca + EFY	0.710	170.35	27.09	103.04
C4 - Co + Ca + Ba	0.698	144.80	31.73	82.88
C5 - Co + Ca + VCP + EFY + Ba	0.748	147.65	28.56	94.45
CD (0.05)	–	–	–	–
SEM ±	0.048	11.676	4.033	16.458
Fertilizer doses				
F1 - FD	0.765	160.15	32.52	103.04
F2 - RD	0.688	151.05	32.71	90.95
CD (0.05)	–	–	–	–
SEM ±	0.030	7.385	2.550	10.409

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam

FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 27. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil organic carbon, N, P and K in the rhizosphere of banana

Cropping systems	Soil organic carbon (%) 1993-94	Soil N ($kg\ ha^{-1}$) 1993-94	Soil P ($kg\ ha^{-1}$) 1993-94	Soil K ($kg\ ha^{-1}$) 1993-94
Initial value	0.520	163.07	54.32	51.52
C4 - Co + Ca + Ba	0.679	153.32	27.03	82.88
C5 - Co + Ca + VCP + EFY + Ba	0.625	144.80	23.33	86.61
CD (0.05)	–	–	–	–
SEM ±	0.046	7.332	2.881	13.045
Fertilizer doses				
F1 - FD	0.645	144.8	27.62	73.55
F2 - RD	0.660	153.32	22.74	95.95
CD (0.05)	–	–	–	–
SEM ±	0.046	7.332	2.881	13.045

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 28. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil organic carbon (%) N, P and K (kg ha^{-1}) content of the rhizosphere of elephant foot yam

Cropping systems	Soil organic carbon (%) 1993-94	Soil N (kg ha^{-1}) 1993-94	Soil P (kg ha^{-1}) 1993-94	Soil K (kg ha^{-1}) 1993-94
Initial value	0.520	163.07	54.32	51.52
C3 - Co + Ca + EFY	0.99	207.26	65.52	106.77
C5 - Co + Ca + VCP + EFY + Ba	1.01	224.3	59.17	116.85
CD (0.05)	–	–	–	–
SEM ±	0.069	12.321	6.169	7.953
Fertilizer doses				
F1 - FD	0.925	221.46	60.57	114.24
F2 - RD	1.075	210.10	64.12	109.39
CD (0.05)	–	–	–	–
SEM ±	0.069	12.321	6.169	7.953

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY- elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 29. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil organic carbon N, P and K content of the rhizosphere of vegetable cowpea

Cropping systems	Soil organic carbon (%) 1993-94	Soil N (kg ha^{-1}) 1993-94	Soil P (kg ha^{-1}) 1993-94	Soil K (kg ha^{-1}) 1993-94
Initial value	0.520	163.07	54.32	51.52
C2 - Co + Ca + VCP	0.617	147.65	40.41	75.79
C5 - Co + Ca + VCP + EFY + Ba	0.657	136.30	25.29	54.88
CD (0.05)	–	–	12.388	–
SEM ±	0.026	6.454	3.580	9.141
Fertilizer doses				
F1 - FD	0.578	133.45	32.48	62.35
F2 - RD	0.696	150.50	33.23	68.32
CD (0.05)	0.089	–	–	–
SEM ±	0.026	6.454	3.580	9.141

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY- elephant foot yam

FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 30a. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil organic carbon (%) and N content (kg ha^{-1}) of the rhizophere of coconut

Cropping systems	Soil organic carbon (%) 1993-94 Fertilizer doses			Soil nitrogen (kg ha^{-1}) 1993-94 Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
Initial value	-	-	0.520	-	-	163.07
C1 - Co + Ca	0.957	1.047	1.002	243.37	261.18	252.28
C2 - Co + Ca + VCP	1.098	0.887	0.993	270.05	219.63	244.84
C3 - Co + Ca + EFY	0.766	0.827	0.797	261.18	243.37	252.28
C4 - Co + Ca + Ba	0.887	0.868	0.878	267.12	237.44	252.28
C5 - Co + Ca + VCP + EFY + Ba	0.867	0.968	0.918	249.31	243.37	246.34
Mean	0.915	0.919	-	258.21	241.00	-
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	-	0.097		-	19.802	
Cropping systems	-	0.069		-	14.002	
Fertilizer doses	-	0.043		-	8.856	
Cropping system x Fertilizer	-	0.097		-	19.802	
Treatment vs Control	-	0.102		-	20.750	

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam
FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

Table 30b. Effect of cropping systems and fertilizer doses for intercrops on the post experiment soil P and K content (kg ha^{-1}) of the rhizophere of coconut

Cropping systems	Soil phosphorus (kg ha^{-1})			Soil potassium (kg ha^{-1})		
	1993-94 Fertilizer doses			1993-94 Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean
Initial value	-	-	54.32	-	-	51.52
C1 - Co + Ca	84.19	83.25	83.72	189.65	138.88	164.27
C2 - Co + Ca + VCP	70.75	81.76	76.26	170.24	207.57	188.91
C3 - Co + Ca + EFY	70.37	62.72	66.55	166.51	157.55	162.03
C4 - Co + Ca + Ba	71.12	77.65	74.39	142.61	156.80	149.71
C5 - Co + Ca + VCP + EFY + Ba	73.20	59.38	66.29	215.79	167.25	191.52
Mean	73.935	72.95	–	176.96	165.61	–
	CD (0.05)	SEM ±		CD (0.05)	SEM ±	
Treatments	–	10.383		–	21.749	
Cropping systems	–	7.342		–	15.379	
Fertilizer doses	–	4.644		–	9.726	
Cropping system x Fertilizer	–	10.383		–	21.749	
Treatment vs Control	–	10.895		–	22.821	

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam

FD - full dose of N, P & K, RD - half dose of N and P and full dose of K.

From the results it is clear that inspite of intensive cropping practices, the nutrient status of the soil was not affected. This is evident from the lack of significant differences among cropping systems viz. coconut + cassava, coconut + cassava + vegetable cowpea and other cropping systems involving coconut and cassava. This could be due to the fact that the component crops in the cropping system were adequately and separately manured. In addition to fertilizers, farm yard manure was applied to intercrops and there might be recycling of nutrients by the leaf fall of cassava, banana and vegetable cowpea.

The initial and post experiment soil analysis of the rhizosphere of coconut (Tables 30a & 30b) show that there is an improvement in the soil nutrient status after two years of experiment. An increase in soil organic carbon, N, P and K were observed.

There was no difference in the post experiment soil nutrient status between the control plot and the treatment combinations and also among the treatment combinations. The cropping systems and fertilizer doses for intercrops had no influence on the soil nutrient status of coconut rhizosphere. It clearly shows that intercropping in coconut with one or more crops is not adversely affecting the soil nutrient status of coconut. The intercrops were planted outside the root zone of coconut in a planned manner. Fertilizers were also applied to the intercrops and main crop separately. Different doses of fertilizers were also applied to intercrops independently. Thus there was not much competition between the main crop and intercrop as far as nutrition was concerned.

4A.8.2 Post experiment leaf nutrient concentration of coconut

The leaf nutrient concentration of coconut collected 1½ years after the completion of the experiment is presented in Table 31.

A similar trend as in the case of soil nutrient status of coconut, was observed in leaf nutrient content also. The N, P and K content of the leaves showed no significant difference between the treatments. The nutrient status of the leaves of palms under various treatment combinations were also on par with that of control. The critical nutrient levels worked out by the IRHO (Institute De Researches Pour Les Huiles Et Oleagiveux, Paris) for West African Palms using the 14th leaf as the reference leaf in % dry matter are N - 1.800 to 2.000, P - 0.120 and K - 0.800 to 1.000 The nutrient concentration of leaves of coconut in the intercropped plots were higher than that of the critical nutrient levels. The results reveal that the nutrition of coconut palms were not adversely affected by raising intercrops in betweem them. Thus it can be concluded that intercrops can be grown safely in between coconut palms without adversely affecting the nutrition of coconut.

4A.9 Soil moisture content

Influence of cropping systems on soil moisture content is presented in Fig. 12, 13 & 14.

It shows that under shaded condition, there is not much variation in soil moisture content, between control plot (coconut alone) and intercropped plots.

Table 31. Post experiment leaf nutrient concentration of coconut (%)

Cropping systems	Nitrogen (%) Fertilizer doses			Phosphorus (%) Fertilizer doses			Potassium (%) Fertilizer doses		
	FD	RD	Mean	FD	RD	Mean	FD	RD	Mean
C1 - Co + Ca	2.097	1.904	2.000	0.232	0.245	0.239	1.450	1.350	1.400
C2 - Co + Ca + VCP	2.006	1.974	1.990	0.228	0.231	0.221	1.117	1.017	1.067
C3 - Co + Ca + EFY	1.935	1.912	1.924	0.243	0.183	0.213	1.200	1.083	1.142
C4 - Co + Ca + Ba	1.971	1.918	1.945	0.210	0.237	0.224	0.983	0.950	0.967
C5 - Co + Ca + VCP + EFY + Ba	2.092	1.885	1.989	0.217	0.217	0.217	1.483	0.967	1.225
Mean	2.020	1.919	-	0.226	0.219	-	1.247	1.073	-
Control (coconut alone)	1.810			0.198			1.233		
	CD 5 (%)	SEM ±		CD 5 (%)	SEM ±		CD 5(%)	SEM ±	
Treatments	-	0.091		-	0.014		-	0.232	
Cropping systems	-	0.064		-	0.010		-	0.164	
Fertilizer doses	-	0.041		-	0.006		-	0.104	
Cropping system x Fertilizer	-	0.091		-	0.014		-	0.232	
Treatment vs Control	-	0.095		-	0.015		-	0.243	

Co - coconut, Ca - cassava, VCP - vegetable cowpea, EFY - elephant foot yam, FD - full dose of N, P & K,
RD - half dose of N and P and full dose of K.

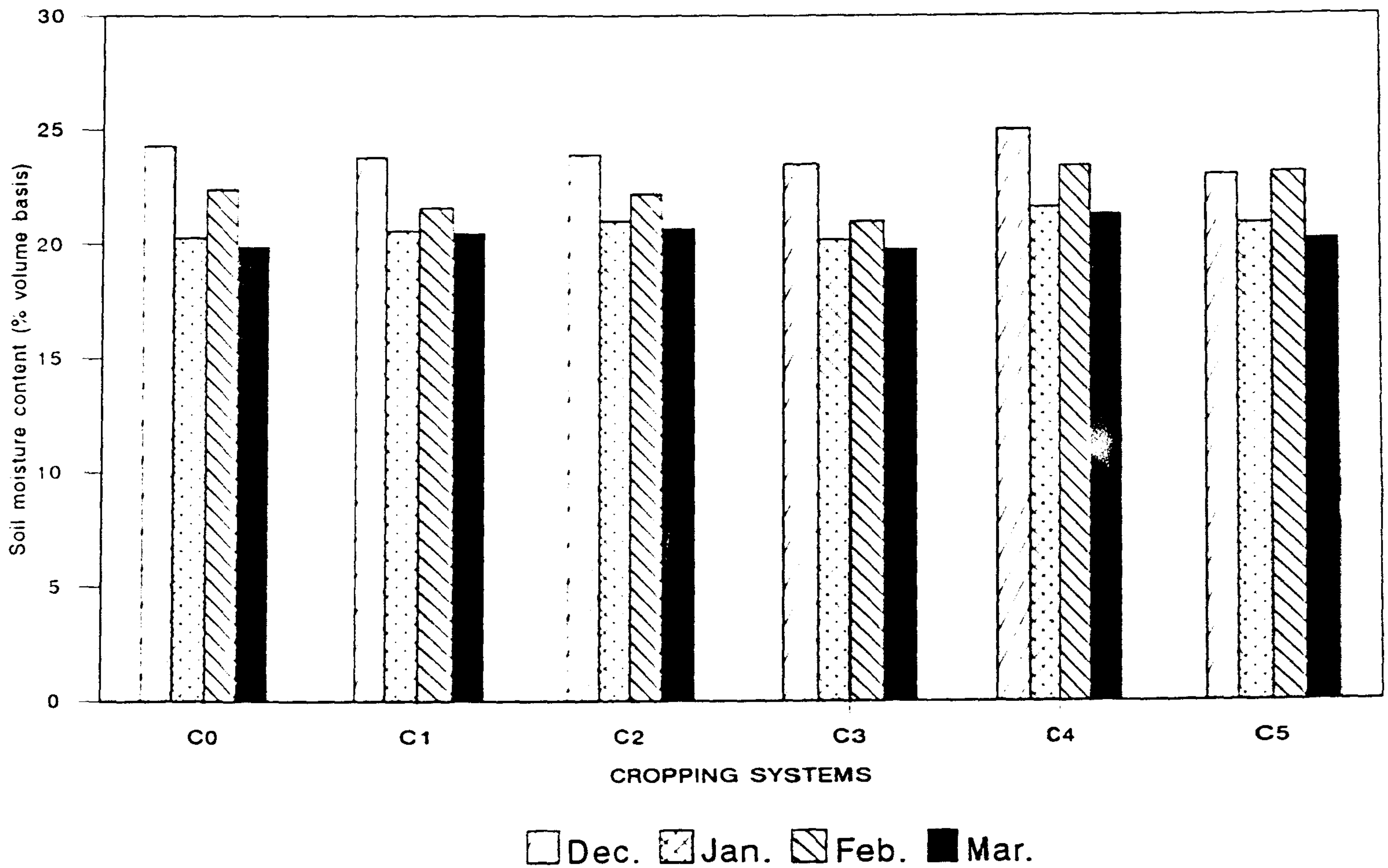


Fig. 12. Influence of cropping systems on soil moisture content at 30 cm depth (1993-1994)

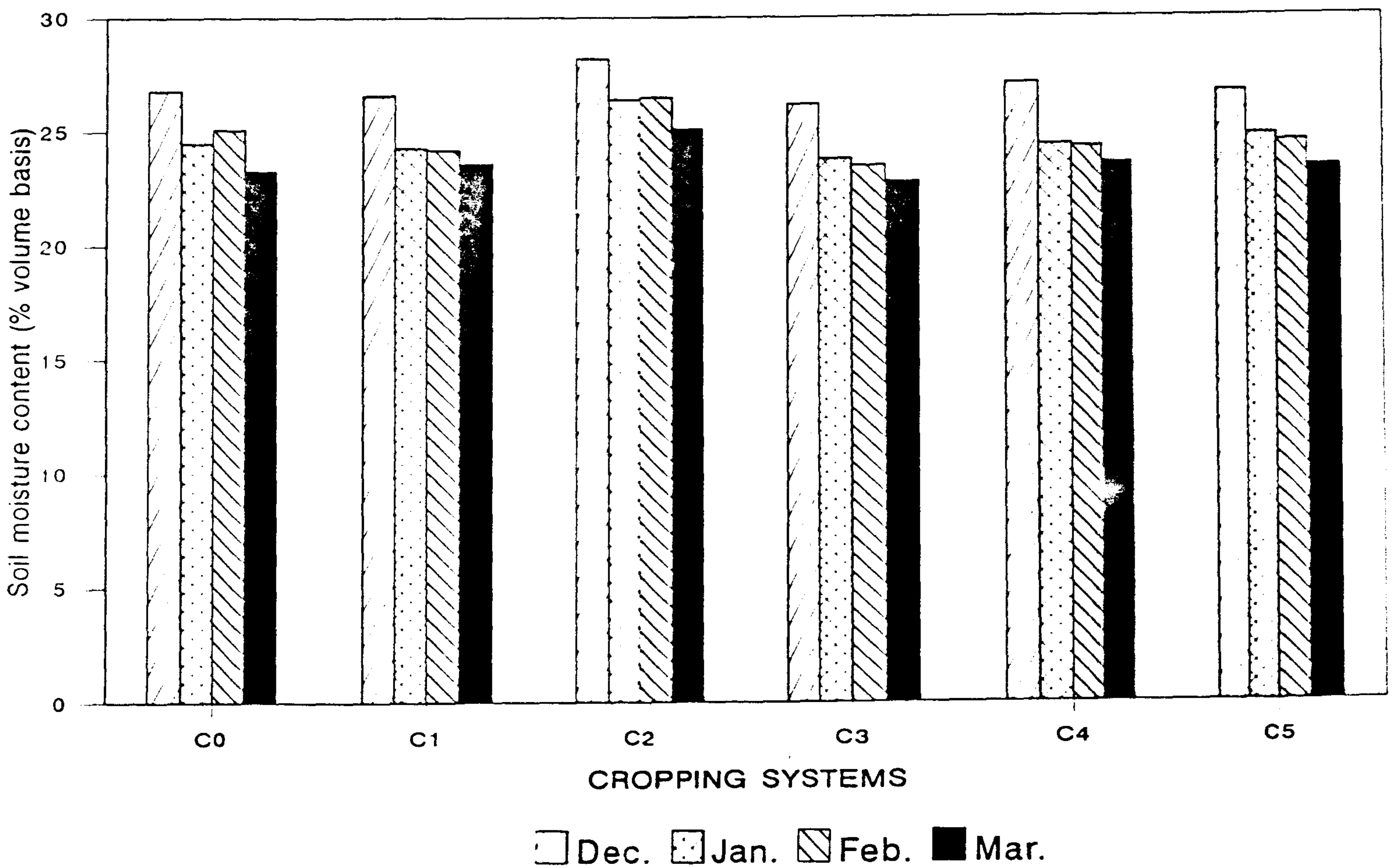


Fig. 13. Influence of cropping systems on soil moisture content at 60 cm depth (1993-1994)

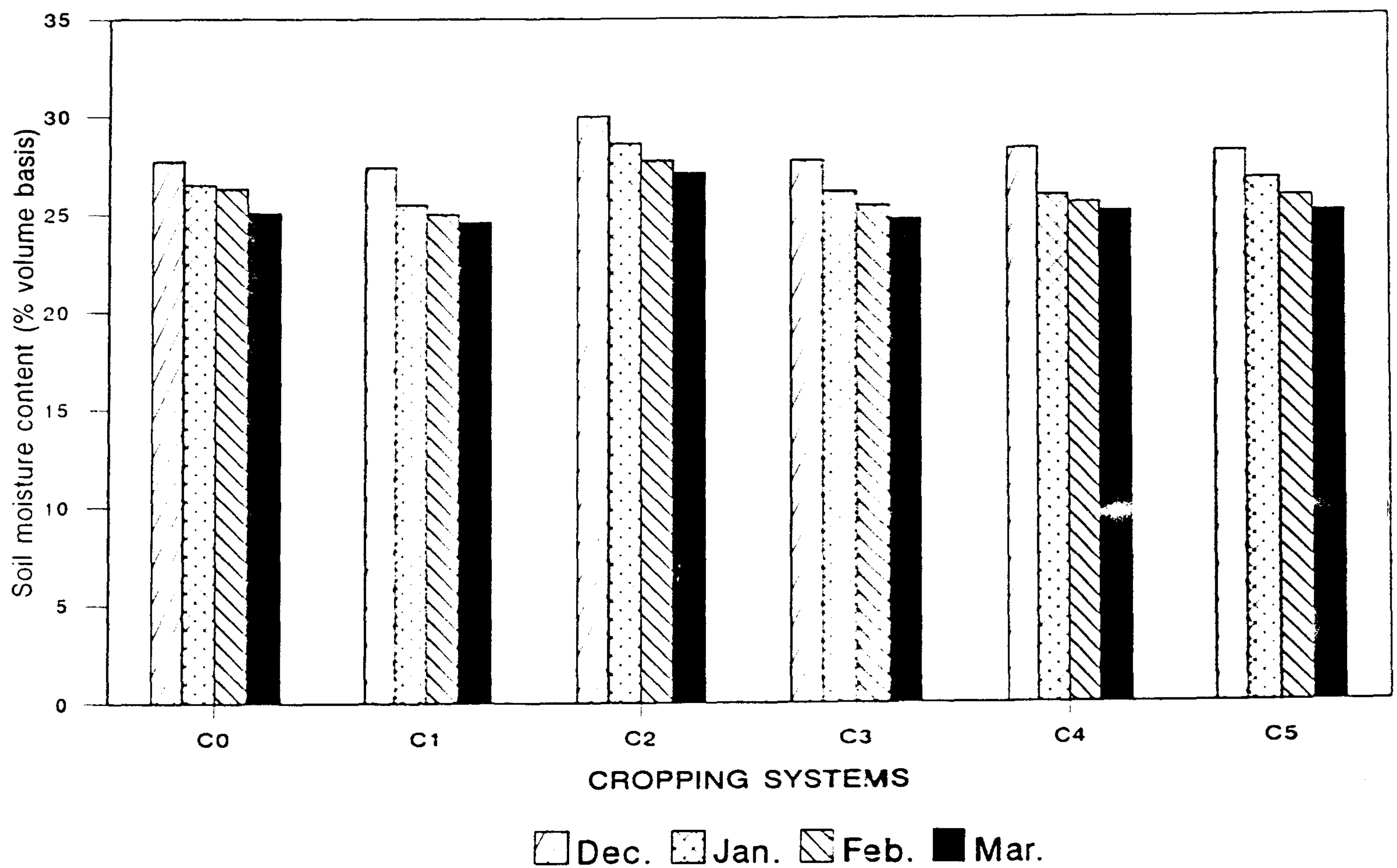


Fig. 14. Influence of cropping systems on soil moisture content at 90 cm depth (1993-1994)

The results reveal that by raising different intercrops together in coconut garden the soil moisture content is not depleted and in certain cropping systems especially in C2 (Fig. 13 & 14) and C4 (Fig. 13) there is a slight increase in soil moisture content.

Eventhough there is absorption of moisture by intercrops in coconut based cropping system, it was compensated by low evaporation loss and run off under such system. Besides the fallen dry leaves also add to the organic matter content of the soil and increase the water holding capacity. Thus it can be concluded that under partial shade of coconut, intercrops of different types can be raised without any depletion in soil moisture content.

4A.10 Light infiltration

4A.10.1 Cassava

The quantum of PAR incident on the crop canopy of cassava during 1993-94 crop period is depicted in Fig. 15. There was no difference in the quantum of PAR received by cassava canopy in different treatments under partial shade of coconut (Fig. 8) and the mean value recorded was 1301/μEm $^{-2}$s^{-1} which works out to approximately 75 per cent compared to open situation. During rainy months PAR received between shaded and open condition was similar where as in summer months higher PAR was recorded in open situation. Under the partial shade of coconut, as the quantum of PAR received was less, it resulted in reduced tuber yield of cassava compared to open area (Table 5).

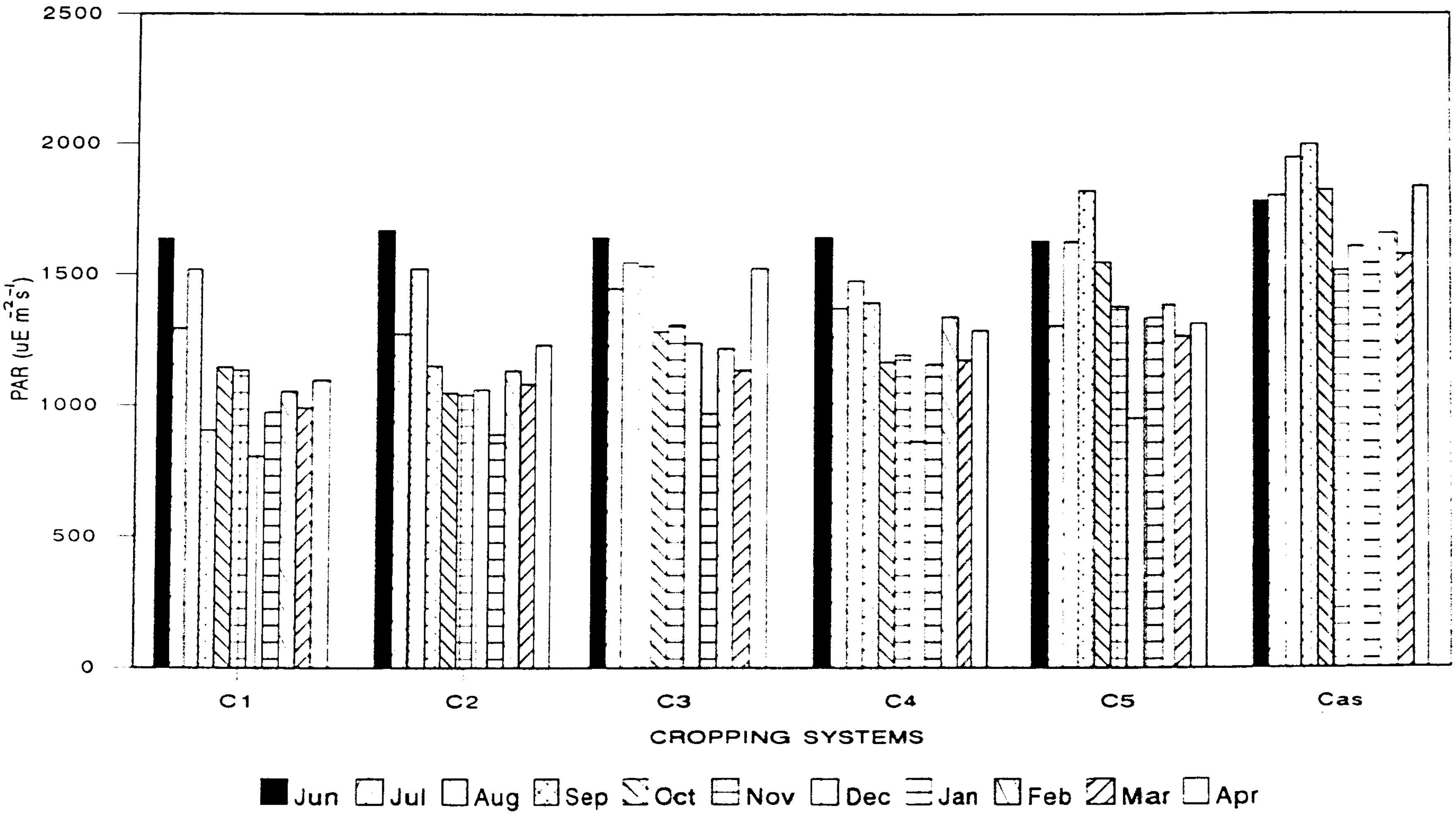


Fig. 15. PAR incident on the crop canopy of intercrop - cassava (1993-1994)

Cassava being taller, it is the dominant crop in the different cropping systems and so other intercrops may not be exerting any influence on the light incidence on cassava canopy.

Adequate solar radiation is essential for the normal growth and yield of cassava. A reduction in PAR resulted in etiolation of plants under shaded condition and its photosynthetic efficiency was also affected adversely. In the open, due to the availability of full sunlight, photosynthesis might have taken place at the normal rate resulting in higher mean tuber weight and mean number of tubers per plant with enhanced tuber yield. Kasela *et al.* (1984) observed reduced dry matter of tuberous roots under shaded condition. According to Ramanujam *et al.* (1984) the dry matter accumulation in the shoots of sun and shade grown cassava plants were similar, while marked differences were observed for dry matter accumulated in tuber.

4A.10.2 Banana

PAR incident on the canopy of intercrop banana during 1993-94 is presented in Fig. 16. There was no difference between the pattern of light intercepted by intercrop banana involved in the two cropping systems viz. C4 and C5. PAR received by intercrop banana was 78 per cent of that of open as the position of the banana plants was away from the base of the coconut palm. Nair and Balakrishnan (1976) reported similar pattern of light interception by canopies in a coconut + cacoa crop combination. The growth and yield characters of banana involving the two cropping systems under

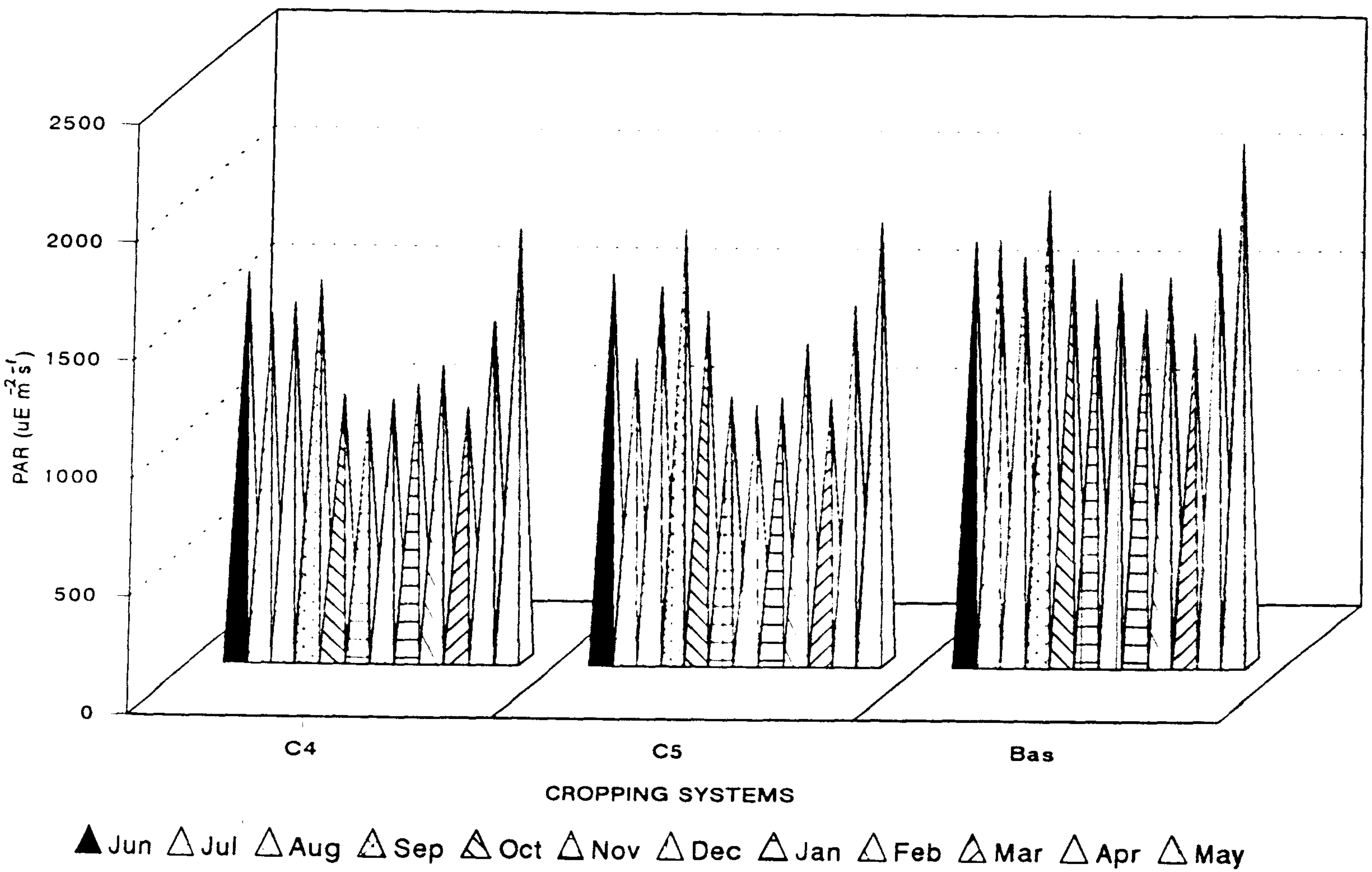


Fig. 16. PAR incident on the crop canopy of intercrop - banana (1993-1994)

the partial shade of coconut were similar. There was no influence from other component crops on the incidence of PAR on banana crop especially cassava.

As there was no late branching in cassava under shaded condition, unlike in the case of open, the competition from cassava by shading was negligible. So non-branching varieties of cassava should be grown along with banana under coconut based cropping system. Cowpea and elephant foot yam are short duration crops with short stature compared to banana. Banana because of its tall canopy was in an advantageous position as far as light utilization in the cropping system was concerned.

Bunch yield was more in the shade compared to open because under shade, the soil moisture content was more (Fig. 12, 13 & 14) and evaporation loss was less.

4A.10.3 Elephant foot yam

PAR incident on the canopy of intercrop elephant foot yam during 1993-94 crop season is given in Fig. 17.

There was not much difference between PAR incident on intercrop elephant foot yam involved in the two cropping systems. Mean PAR incident on intercrop elephant foot yam was 1207μ E m^{-2} s^{-1} which comes to 71 per cent compared to open.

Under the partial shade of coconut, the height of intercrop elephant foot yam was more as compared to open (Table 13), where as leaf area was

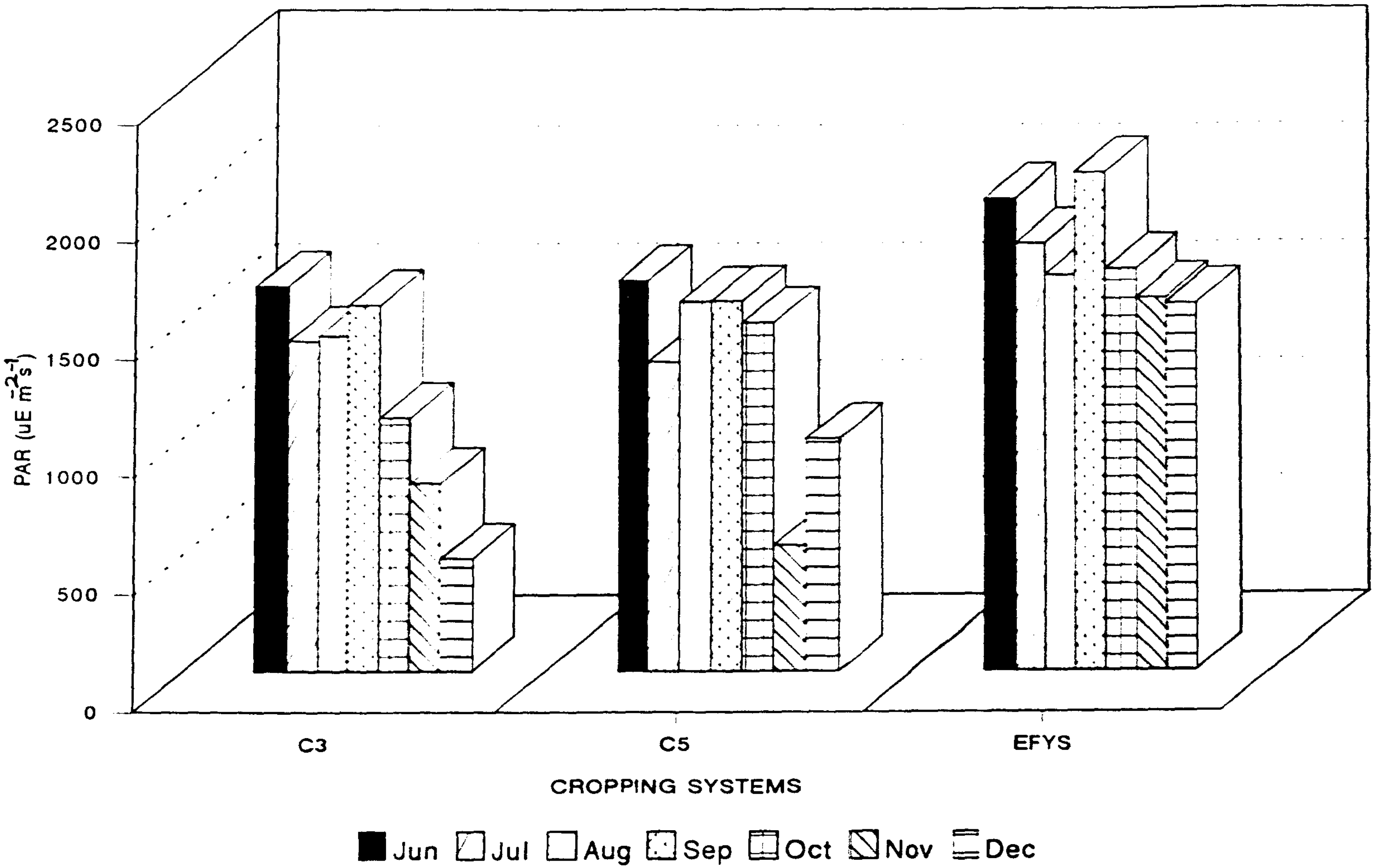


Fig. 17. PAR incident on the crop canopy of intercrop - Elephant foot yam (1993-1994)

less compared to open sole crop (Table 14). An increase in corm yield was recorded in intercrop elephant foot yam compared to open (Table 16).

The increase in height observed for intercrop elephant foot yam might be due to etiolation caused by reduced light under shaded condition. The reduction in leaf area of elephant foot yam in the presence of cassava, banana and vegetable cowpea might be due to competition for light from component crops especially vegetable cowpea in the early stages of banana. In the early stages vegetable cowpea has quick growth and elephant foot yam takes about 1½ months for attaining full canopy. Eventhough there was a reduction in leaf area under shaded condition it was not reflected in corm yield. This is because elephant foot yam is mainly a shade tolerant crop. Besides, higher soil moisture content and lower rates of evaporation also might have contributed towards corm yield.

4A.10.4 Vegetable cowpea

PAR incident on the crop canopy of vegetable cowpea during 1993 is given in Fig. 18. There was no appreciable difference between the quantum of PAR intercepted by vegetable cowpea involved in the two cropping systems. Mean value of PAR received by intercrop vegetable cowpea was 1464μ E $m^{-2}s^{-1}$ and it works out to 82 per cent compared to the sole crop in the open. An increase in height was observed in vegetable cowpea raised under shade compared to open.

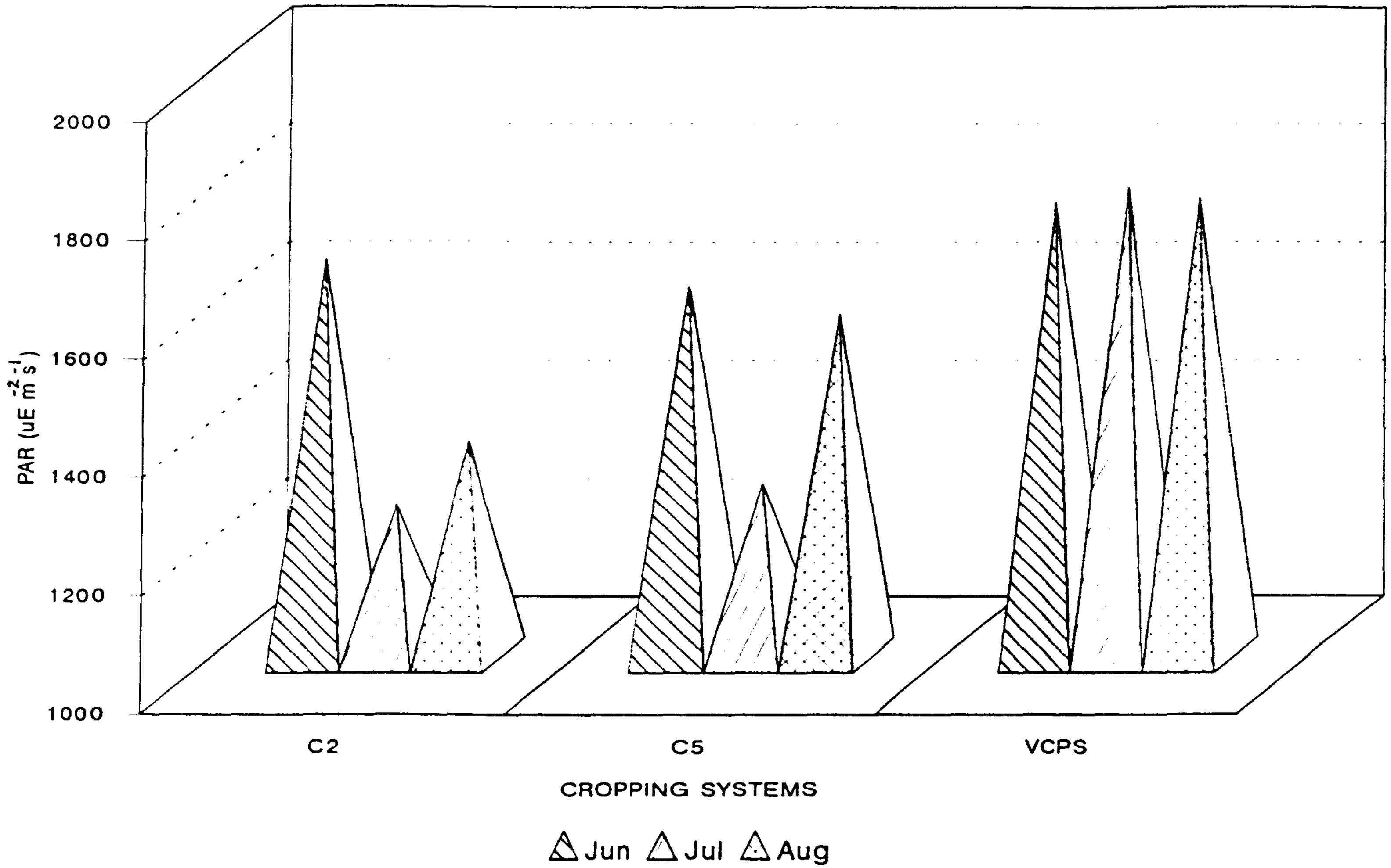


Fig. 18. PAR incident on the crop canopy of intercrop - Vegetable cowpea (1993-1994)

Vegetable cowpea could utilize 82 per cent of PAR compared to open because the other component crops especially cassava and elephant foot yam were in young stage and they did not shade vegetable cowpea. Reduced PAR received by intercrop vegetable cowpea compared to open, might be the reason for etiolation and higher plant height observed under shaded condition. Eventhough the vegetable cowpea chosen is a sun loving crop, the pod yield was not affected by the reduction in light. The crop has given more pod yield and bhusa yield under shaded condition. So shade tolerant varieties are to be preferred in a cropping system.

Among the intercrops, the PAR incident in the crop canopy of vegetable cowpea was maximum (82 per cent of open) and that of elephant foot yam was minimum (71 per cent compared to open). In these cropping systems, cassava is the most dominating intercrop because of its tall character and probably exerting its influence on other component crops (Fig. 2b-2f). However, its influence on other crops on light incidence especially elephant foot yam and vegetable cowpea is less because of the absence of late branching observed under shaded condition. Next to cassava, banana is less and the plants are located away from the base of coconut palm and so banana also does not exert much influence on the receipt of light by other intercrops. Elephant foot yam was raised in the inner rows around the coconut palm (Fig. 2d & 2f). Eventhough there was some competition for light from vegetable cowpea, banana and cassava it was not reflected in the yield suggesting that elephant foot yam can perform satisfactorily in such a cropping system under reduced light condition.

Vegetable cowpea occupied the field only for 2 1/2 months in the early growth stages of other intercrops and hence there was not much competition for light from other intercrops. Thus it can be concluded that the light filtered through the crop canopy of coconut is utilized in a most efficient manner by the intercrops in these cropping systems. In a cropping system in Kerala, the floor crop can be vegetable cowpea or some other short duration, short satured vegetable crop which can with stand shade.

4A.11 Economics

Economics of intercropping in coconut based cropping system is presented in Table 32. Highest net income was obtained from treatment C5 (Rs. 26, 726 ha^{-1}) followed by C4 (Rs. 25, 760 ha^{-1}) and C3 (Rs. 22, 251 ha^{-1}) by C4 (Rs, 25, 760 ha^{-1}) and C3 (Rs, 22, 251 ha^{-1}) the lowest net income was recorded from C1 (Rs. 17, 411 ha^{-1}) and it was comparable with that of C2 (Rs, 17, 653 ha^{-1})

Benefit : cost ratio was highest in C4 (2.64) followed by C1 (2.36) and C2 (2.25), the lowest value was recorded by C5 (1.96) and C3 recorded a value of 2.03.

The results show that raising more number of intercrops in coconut garden can generate more income than raising a single intercrop. The highest net income was received from C5 which included the highest number of intercrops. Cassava alone as intercrop gave the lowest net income. With

Table 32. Economics of intercropping in coconut gardens (Rs gross ha^{-1})

Treatment	Intercrop	Expenditure	Produce ($t\ ha^{-1}$)	Value of individual crop	Gross income	Gross expenditure	Net income	Benefit cost ratio
C1	Cassava	12825	15.118	30236	30236	12825	17411	2.36
C2	Cassava	12825	13.560	27120	31776	14123	17653	2.25
	Veg. cowpea	1298	1.164	4656				
C3	Cassava	7485	12.203	24406	43926	21675	22251	2.03
	Elephant foot yam	14190	4.880	19520				
C4	Cassava	11760	16.460	30920	43384	17624	25760	2.46
	Banana	5864	1.558	12464				
C5	Cassava	6419	10.108	20216	54488	27762	26726	1.96
	Banana	5864	1.403	11224				
	Elephant foot yam	14190	4.393	17572				
	Veg. cowpea	1298	1.369	5476				

C1 - coconut + cassava, C2 - coconut + cassava + vegetable cowpea, C3 - coconut + cassava, + elephant foot yam, C4 - coconut + cassava + banana, C5 - coconut + cassava + elephant footyam + vegetablecowpea. tapioca - Rs. 2/kg, banana - Rs 8/kg, elephant foot yam - Rs. 4/kg, vegetable cowpea - Rs. 4/kg.

additional crops, the net income also increased. It is not only yield from intercrop, but the value of individual crop also count for higher net income.

It may be concluded that higher net income could be obtained from coconut garden by growing cassava, banana, elephant foot yam and vegetable cowpea together as intercrops followed by cassava + banana and cassava + elephant foot yam.

4A.12 LER

The LER values averaged for the years 1992-93 and 1993-94 for different cropping systems are given in Table 33. Cropping system C5 has given the highest value (4.840) followed by C2 (3.176) C3 (1.621) and C4 (1.485). The lowest value was given by C1 (0.708).

The values show that it is advantageous to grow more that one crop as intercrop in coconut garden.

The results reveal that cropping systems involving vegetable cowpea have given higher values of LER. So it is beneficial to include vegetable cowpea as one of the components of coconut based cropping system.

Table 33. LER in coconut based cropping system

Cropping system	LER
C1	0.708
C2	3.176
C3	1.621
C4	1.485
C5	4.840

C1 - coconut + cassava, C2 - coconut + cassava + vegetable cowpea, C3 - coconut + cassava + elephant foot yam, C4 - coconut + cassava + banana, C5 - coconut + cassava + banana + elephant foot yam + vegetable cowpea

4A.13 Income distribution

The distribution of income from coconut based cropping systems is presented in Table 34. It shows that in such a system, income is generated throughout the year. Income from coconut is obtained once in 45 days; from cassava in March; from elephant foot yam in January and from vegetable cowpea in August. The income from banana is distributed from November to April.

The intercrops are having different durations and hence the harvesting of these intercrops is distributed to different months of the year. Thus eventhough the planting of intercrops is done during May-June, the yield and income is obtained in different months of the year.

Thus it may be concluded that, in a coconut based cropping system income can be generated throughout the year by raising suitable intercrops.

4B. Expt. 2. Radiotracer studies

Interspecific competition for applied ^{32}P in cropping system involving coconut, banana, cassava and elephant foot yam.

Interspecific root competitions in cassava + coconut, cassava + banana, cassava + elephant foot yam, banana + coconut and banana + elephant foot yam systems were studied by comparing the absorption of applied ^{32}P in their sole and mixed systems. Absorption of ^{32}P in two crop cropping system was

Table 34. Income distribution

Treatment	Crops		Months
C0	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
C1	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
	Cassava	-	March
C2	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
	Cassava	-	March
	Vegetable cowpea	-	August
C3	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
	Cassava	-	March
	Elephant foot yam	-	January
C4	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
	Cassava	-	March
	Banana	-	Nov, Dec, Jan, Feb, Mar, and Apr
C5	Coconut	-	Jul 15, Aug 30, Oct 15, Nov 30, Jan 15, Feb 28, Apr 15, May 30
	Cassava	-	March
	Banana	-	Nov, Dec, Jan, Feb, Mar and Apr
	Elephant foot yam	-	January
	Vegetable cowpea	-	August

C0 - coconut alone, C1, - coconut + cassava, C2, - coconut + cassava + vegetable cowpea, C3 - coconut + cassava + elephant foot yam, C4 - coconut + cassava + banana, C5 - coconut + cassava + banana + elephant foot yam + vegetable cowpea.

Time of planting of intercrops : May - June.

evaluated by quantifying the radioactivity absorbed during 15 days and 30 days after application by the crop to which the radiophosphorus was applied as well as by the neighbouring non-treated component crop.

4B.1 Relative absorption of ^{32}P by treated plant in mono and mixed cropping systems

Data on the relative absorption of ^{32}P by treated cassava in mono and mixed cropping systems are presented in Table 35. Significant differences were observed in the absorption of ^{32}P among the treated cassava plants in mono and mixed cropping systems during 15 and 30 days after application of radiophosphorus.

During 15 days after application, maximum absorption was recorded by treated cassava of inner rows in the presence of banana (30974 cpm/g) whereas the lowest values were recorded by treated cassava of inner rows in the presence of coconut (1542 cpm/g).

No significant difference was observed in the absorption of ^{32}P between inner and outer rows of treated cassava under monoculture situation. Higher cpm values were recorded by the inner rows of treated cassava (26546).

In the presence of coconut, there was a reduction of 27.9 per cent in the absorption of ^{32}P by treated cassava in the inner rows and the reduction was 23.9 per cent in treated cassava in the outer rows, when compared to treated

Table 35. Relative absorption of ^{32}P (log transformed values) by treated cassava in mono and mixed systems

Cropping system	Days after ^{32}P application	
	15	30
Ca_{ti}(Sole)	4.242 (26546)	4.452 (28314)
Ca_{to}(Sole)	4.221 (16634)	4.302 (20045)
Ca_{ti}(+Co)	3.188 (1542)	3.657 (4539)
Ca_{to}(+Co)	3.212 (1629)	3.526 (3357)
Ca_{ti}(+Ba)	4.491 (30974)	4.612 (40926)
Ca_{to}(+Ba)	4.431 (21928)	4.691 (49091)
Ca_{to}(+EFY)	3.853 (7129)	4.051 (11246)
CD (0.05)	0.647	0.592
SEM ±	0.210	0.192

Figures in parentheses are retransformed values in cpm/g.

Ba - banana   Ca - cassava   Co - coconut   EFY - elephant foot yam

i - inner row   o - outer row   t - treated

cassava sole crop. There was no significant difference in the absorption of ^{32}P by treated cassava between the inner and outer rows in the presence of coconut. In the outer row, the absorption by cassava was slightly higher (1629 cpm/g) when compared to the inner row (1542 cpm/g).

When banana was raised along with cassava, no significant difference was observed in the absorption of ^{32}P by treated cassava in the inner and outer rows, compared to the monocrop situation.

In the presence of elephant foot yam no significant reduction was observed in the absorption of ^{32}P by outer row of treated cassava. The reduction was only 12.9 per cent when compared to the absorption of ^{32}P by treated cassava in the outer row under monoculture situation.

During 30 days after application, maximum absorption of ^{32}P was observed in treated cassava of outer row in the presence of banana (49091 cpm/g) and the lowest value was recorded by treated cassava of outer row in the presence of coconut (3357 cpm/g).

Between inner and outer rows of treated cassava, under monoculture situation, no significant difference was observed in the absorption of ^{32}P. Significant reducation was observed in the absorption of ^{32}P by treated cassava in the presence of coconut. Compared to the sole crop of cassava, the reducation was 17.9 per cent for treated inner row cassava and 18.0 per cent for treated outer row cassava. There was no significant difference in the absorption of ^{32}P by treated cassava between the inner and outer rows in the presence of coconut. In the inner row, the absorption by cassava was 4539 cpm/g and in the outer row, 3357 cpm/g.

When banana was raised along with cassava, no significant difference was observed in the absorption of ^{32}P by treated cassava between the inner and outer rows, compared to monocrop situation.

Absorption of ^{32}P by outer row of treated cassava in the presence of elephant foot yam was 11246 cpm/g and it did not differ significantly compared to the sole crop of cassava (20045 cpm/g).

An increase in the uptake of ^{32}P was observed in all the treatments during 30 days after application compared to 15 days. The increment ranged from 0.6 per cent in inner row of treated cassava under monoculture situation to 14.7 per cent in inner row of treated cassava in the presence of coconut.

In the two-crop system involving coconut and cassava, the application of ^{32}P to cassava in the inner row resulted in higher accumulation of radioactivity (5399 cpm/g) in the inner row cassava itself (Fig. 1a). The two cassava plants on either side of the treated plants accumulated 1772 cpm/g each while in the neighbouring coconut palm, the radioactivity was 86 cpm/g.

When the cassava plant in the outer row was treated with ^{32}P, the radioactivity accumulated in the treated plant was to the tune of 3994 cpm/g and that in the two neighbouring cassava plants was 967 cpm/g each.

When ^{32}P was applied to cassava in cassava + banana cropping system (Fig. 4e), the radioactivity accumulated in the three treated cassava plants was 69817 cpm/g each, in the two neighbouring untreated cassava plants was 34810 cpm/g while in the banana plant was only 8387 cpm/g.

In cassava + elephant foot yam cropping system, the absorption of ^{32}P was studied when it was applied to either of the crops in the system. Application of ^{32}P to cassava resulted in higher cpm values (11604) in the applied plant itself, 4095 each in the two cassava plants on either side of the treated plant and 108 in the neighbouring elephant foot yam plant (Fig. 4f).

The relative uptake of ^{32}P by treated cassava under sole crop situation both in the inner and outer rows was high as there was no competition from roots of other species. The lower cpm values recorded by treated cassava in the presence of coconut showed that there was stiff competition for nutrients from coconut roots. Ashokan *et al.* (1989) observed that in cassava highest uptake of ^{32}P was from the soil zone at lateral distance of 20 cm and at a depth of 20 cm during 90-150 days of growth of the rainfed crop. According to Anilkumar and Wahid (1988) over 80 per cent of the active roots of coconut palm were confined to an area of 2 m radius around the palm and the vertical spread of majority of the roots was limited to a depth of 60 cm below which root activity declined. It was observed that ^{32}P applied to inner row cassava was absorbed by the coconut at the centre of the system (Fig. 4a). Based on this it may be concluded that although most of the coconut roots were within 2 m radius, the roots growing beyond 2 m radius from the base of the palm might have competed with cassava for applied ^{32}P.

In cassava - banana cropping system, absorption of ^{32}P by treated cassava was not influenced by the presence of banana. The uptake was almost similar with inner and outer rows of cassava. Avilan *et al.* (1981) observed that in banana more than 80 per cent of root weight was within the top 30 cm of soil and at lateral distance of 0 - 45 cm from the main stem. In rainfed banana, maximum percentage of active roots (82%) was observed in a soil zone of 40 cm radius and 30 cm depth (Sobhana, 1985). It was observed that a major portion of the applied ^{32}P was absorbed by the treated cassava plant and neighbouring non treated cassava plants and only a small quantity was absorbed by neighbouring non-treated banana plants (Fig. 4e). Ashokan (1986) obtained similar results in a cassava - banana cropping system when cassava was treated with ^{32}P. The data on root characters of banana (Fig. 19a) showed that under rainfed condition, banana roots did not spread extensively and this might be the reason for the lack of root competition of banana with that of cassava.

In cassava - elephant foot yam cropping system, the uptake of ^{32}P by treated cassava was not affected adversely as compared to the sole crop of cassava, indicating thereby that the roots of elephant foot yam did not compete with the cassava roots for ^{32}P.

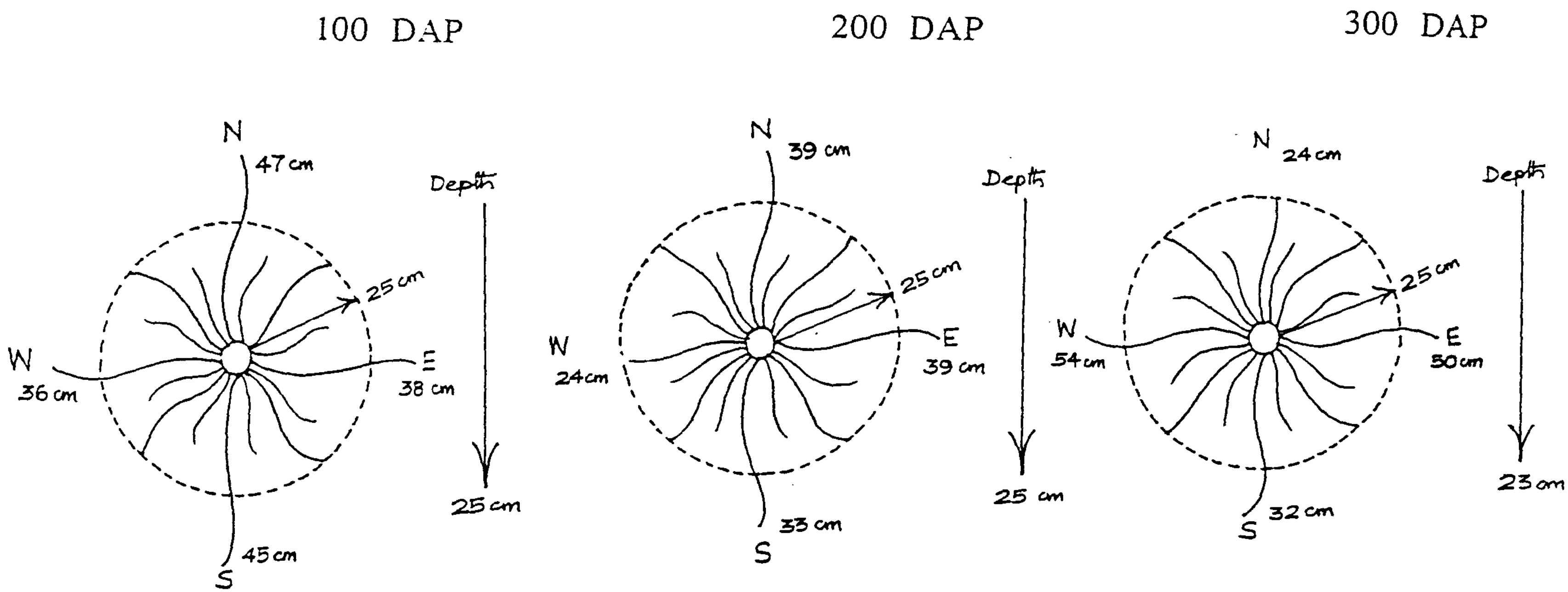


Fig. 19a. Root spread of cassava (cm)

Ashokan *et al.* (1988) observed that absorption of ^{32}P from cassava mounds by *Amorphophallus paeniifolius* was negligible. The result of the present study confirms this (Fig. 4f).

The results suggest that it is advantageous to grow cassava along with banana or elephant foot yam than with coconut as far as competition for nutrient is concerned.

4B.2 Relative absorption of ^{32}P in treated banana in mono and mixed cropping systems

Data pertaining to the relative absorption of ^{32}P in treated banana in mono and mixed cropping systems are presented in Table 36.

No significant differences were observed in the absorption of ^{32}P among the different treatments during 15 and 30 days after application. Highest cpm values of 3184 and 6442 were observed in treated banana plants in the presence of coconut during 15 days and 30 days after application respectively. The lowest cpm value was recorded by the sole crop of treated banana (177 cpm/g) during 15 days after application and the least value was observed in treated banana (2138 cpm/g) in the presence of elephant foot yam.

There was an increase in the absorption of ^{32}P at 30 days after application, compared to 15 days. The increase ranged from 8.7 per cent in treated banana in the presence of coconut to 48.6 per cent in treated sole crop of banana.

Table 36. Relative absorption of ^{32}P (log transformed values) by treated banana in mono and mixed systems

Cropping system	Days after ^{32}P application	
	15	30
Ba_t(Sole)	2.247 (177)	3.339 (2183)
Ba_t(+Co)	3.503 (3184)	3.809 (6442)
Ba_t(+Ca)	2.600 (398)	3.628 (4246)
Ba_t(+EFY)	2.322 (210)	3.330 (2138)
CD (0.05)	NS	NS
SEM ±	0.367	0.187

Figures in parentheses are retransformed values in cpm/g.

Ba - banana   Ca - cassava   Co - coconut   EFY - elephant foot yam

i - inner row   o - outer row   t - treated

In coconut + banana intercropping system (Fig. 4b) application of ^{32}P to banana in the inner row resulted in higher cpm values in banana (7710) and that accumulated in the coconut palm was 125.

In cassava + banana cropping system (Fig. 4d), application of ^{32}P to banana resulted in low accumulation of ^{32}P in banana (4416 cpm/g). The radioactivity observed in the two neighbouring untreated cassava plants was 22544 cpm/g each and that accumulated in the untreated cassava plant at the corner was 7987 cpm/g.

In banana + elephant foot yam cropping system, the treated banana plant accumulated radioactivity of 2171 cpm/g while the elephant foot yam plant close to the banana plant absorbed only a negligible quantity (Fig. 4h).

Relative absorption of ^{32}P in treated banana was not influenced when grown in association with coconut compared to the sole crop. In banana, it was observed that the majority of the active roots were confined to a radius of 30 cm and to a depth of about 20 cm (Fig. 19b). Maximum percentage of active roots (85 per cent) was observed in a soil zone of 40cm radius and 30cm depth in rainfed banana (Sobhana *et al.* 1989). In coconut palm, lateral spread of majority of active roots was confined to a radius of 2m around the palm and the vertical spread was limited to a depth of 60cm (Anil kumar and Wahid, 1989). In coconut + banana cropping system (Fig. 4b) when ^{32}P was applied to banana plant, the radioactivity absorbed in the treated plant was 7710 cpm/g and that absorbed by the neighbouring non - treated coconut palm

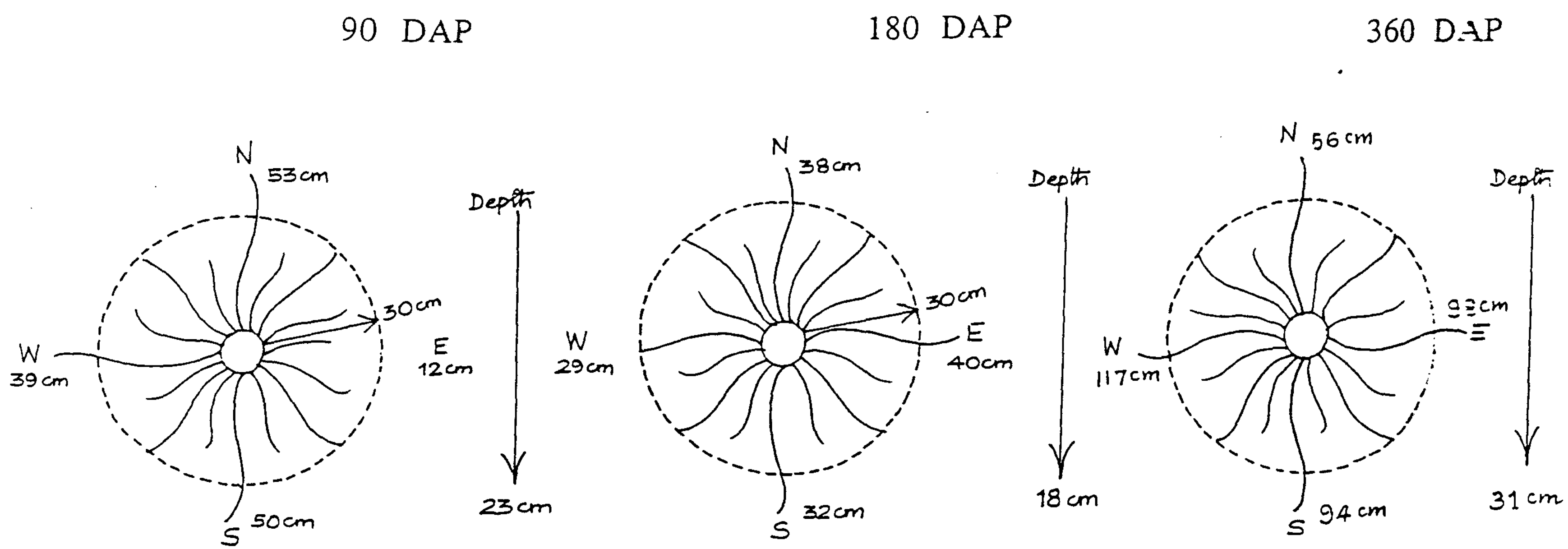


Fig. 19b. Root spread of banana (cm)

was 125 cpm/g. The results suggested that banana can be grown as an intercrop with coconut, as the roots of coconut do not compete with those of banana for nutrients.

In the presence of cassava and elephant foot yam, the absorption of ^{32}P by treated banana was not affected. 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 (Ashokan, 1986). He also observed from root excavation that distribution of roots of elephant foot yam was mainly confined to a radial distance of 25 cm from the plant and to a depth of 20 cm. In banana + cassava cropping system, (Fig. 4d) even though higher quantity of ^{32}P (22544 cpm/g) was absorbed by the neighbouring non - treated cassava plant compared to the treated banana (4416 cpm/g) the competition from cassava was negligible. In banana + elephant foot yam cropping system (Fig. 4h) it was observed that the treated banana itself had absorbed the major portion of the ^{32}P applied (2171 cpm/g) and only a negligible portion (40-45 cpm/g) was absorbed by the neighbouring untreated elephant foot yam and cassava roots were not competing with those of banana for nutrients.

Increase in absorption of ^{32}P observed in treated banana under mono and mixed cropping at 30 days after application implies that even in the presence of other crops absorption of the applied ^{32}P by radiotreated banana was unaffected. The increase was highest (177 to 2183) in treated sole crop of banana followed by treated banana in the presence of elephant foot yam

(210 to 2138) and treated banana in the presence of cassava (398 to 4296). In the case of treated banana along with coconut there was no marked change in the absorption of ^{32}P at 30 days after application as compared to 15 days after application. This indicates that coconut roots also are not competing with banana for the uptake of ^{32}P.

The results suggest that banana can be raised along with coconut, cassava or elephant foot yam without any adverse effect on banana nutrition.

4B.3 Relative absorption ^{32}P by treated elephant foot yam in mono and mixed systems

Data on the relative absorption of ^{32}P by treated elephant foot yam in mono and mixed systems are presented in Table 37. No significant differences were observed in the absorption of ^{32}P by various treatments during 15 days and 30 days after application. During 15 days after application, highest absorption of ^{32}P was observed in treated sole crop of elephant foot yam (272 cpm/g) while the lowest value was recorded by treated elephant foot yam in the presence of cassava (76 cpm/g). Similar trend was observed during 30 days after application for the same treatments and the cpm values were 2361 and 462 respectively.

During 30 days after application of ^{32}P there was an increase in the absorption for all the treatments, compared to 15 days after application. The increase ranged from 38.6 per cent for sole crop of treated elephant foot yam to 52.0 per cent for treated elephant foot yam in the presence of banana.

Table 37. Relative absorption of ^{32}P (log transformed values) in treated elephant foot yam in mono and mixed systems

Cropping system	Days after ^{32}P application	
	15	30
EFY_t(sole)	2.434 (272)	3.373 (2361)
EFY_t(+Ca)	1.882 (76)	2.665 (462)
EFY_t(+Ba)	2.095 (125)	3.184 (1528)
CD (0.05)	NS	NS
SEM $\pm$	0.257	0.201

Figures in parentheses are retransformed values in cpm/g.

Ba - banana   Ca - cassava   Co - coconut   EFY - elephant foot yam

i - inner row   o - outer row   t - treated

When ^{32}P was applied to elephant foot yam, the radioactivity accumulated was 622 cpm/g in the treated plant where as only a negligible quantity (40 cpm/g) was present in the neighbouring untreated elephant foot yam plant. 5753 cpm/g was observed in the untreated cassava plant on one side, 3479 in the untreated cassava in the corner and 1828 in the untreated cassava at the extreme (Fig. 4g).

When elephant foot yam was treated with ^{32}P in banana + elephant foot yam cropping system (Fig. 4i), the radioactivity accumulated in the treated elephant foot yam plant was 2186 cpm/g; 82 in the neighbouring elephant foot yam and 306 in the banana plant located at the corner.

There was no drastic reduction in the uptake of ^{32}P by treated elephant foot yam in the presence of cassava indicating lack of stiff competition from cassava. Cassava was raised on mounds and their root system was mainly confined to a radius of 25 cm and to a depth of 25 cm (Fig. 19a). As such the root system of cassava might not be reaching the root zone of elephant foot yam raised in pits.

The uptake of ^{32}P by treated elephant foot yam in the presence of banana was not affected because in that system the roots of banana were located outside the root zone of elephant foot yam and hence there was no seious competition from banana for nutrients. The absorption of ^{32}P by treated elephant foot yam was very high (2186 cpm/g) and only a small portion (306 cpm/g) was absorbed by the neighbouring untreated banana (Fig. 4i). The uptake of ^{32}P by treated elephant foot yam under monocorop was similar to that of the one in the presence of banana.

It can be concluded that elephant foot yam may be grown with advantage in association with banana followed by cassava.

4B.4 Relative absorption of ^{32}P by treated coconut in mono and mixed systems

The relative absorption of ^{32}P by treated coconut in mono and mixed systems is presented in Table 38. ^{32}P absorbed by treated coconut palm in sole crop was high (214 cpm/g) compared to palms in the presence of banana (125 cpm/g). In both the cases there were increases in the uptake of ^{32}P during 30 days after application compared to 15 days after application.

In coconut + banana intercropping system (Fig. 4c) when ^{32}P was applied to coconut, uptake was more by neighbouring banana plants (610 cpm/g) while that of treated coconut was 125 cpm/g. Uptake of ^{32}P by banana in inner row was higher (610 cpm/g) compared to outer row (119 cpm/g).

There was a subsidence in the uptake of ^{32}P by treated coconut in the presence of banana compared to the sole crop (Table 38). The uptake was more by banana in the inner row compared to those in the outer row (Fig. 4c).

The rooting pattern of banana and coconut suggested that majority of their active roots are confined to a radius of 30 cm and 2 m respectively (Fig.

Table 38. Relative absorption of ^{32}P (log transformed values) by treated coconut in mono and mixed systems

Cropping system	Days after ^{32}P application	
	15	30
Co_t(sole)	1.580 (38)	2.330 (214)
Co^*_t(+Ba)	1.491 (31)	2.097 (125)

Figures in parenthesis are retransformed values of cpm/g

Ba - banana Co - Coconut

*Only one replication was present and statistical analysis was not done.

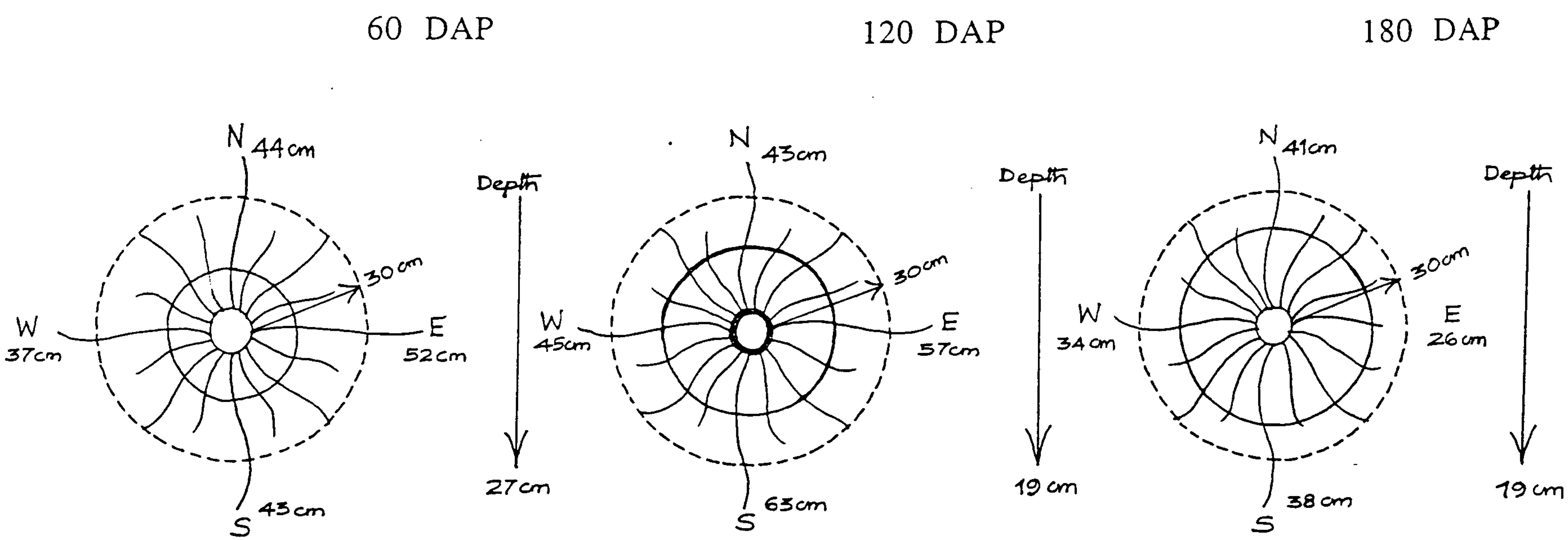


Fig. 19c. Root spread of elephant foot yam (cm)

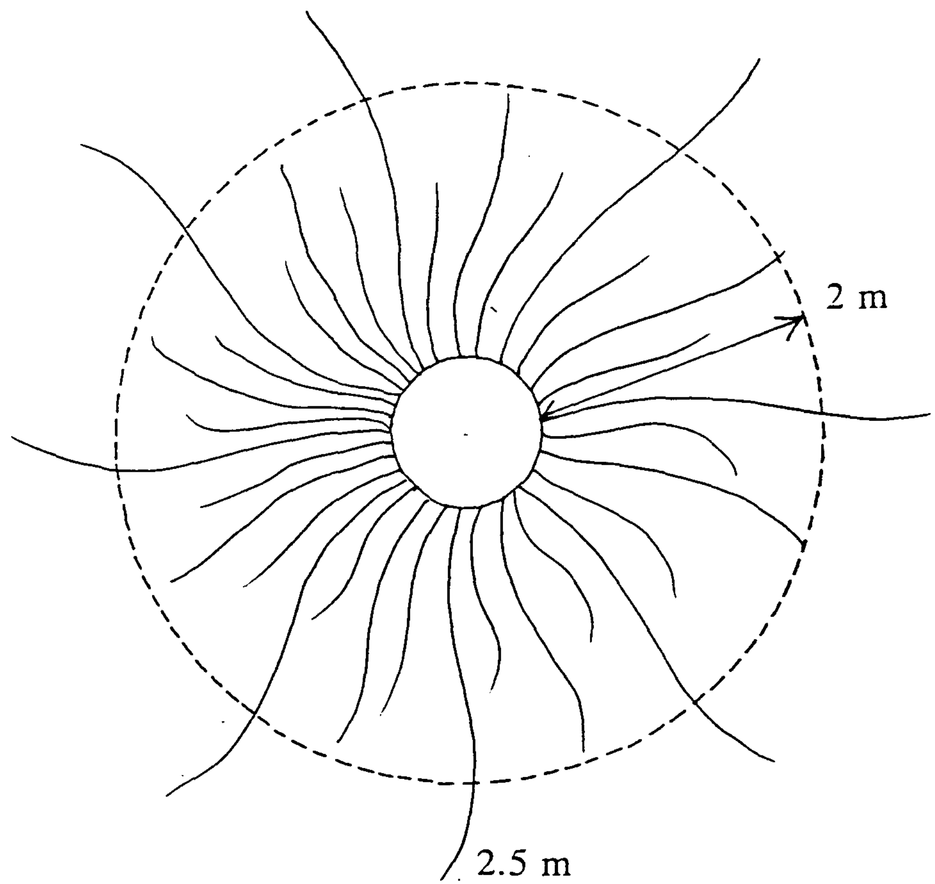


Fig. 19d. Root spread of coconut (m)

19c and 19d). Sobhana (1985) observed maximum percentage of active roots (82%) in a soil zone of 40 cm radius and 30 cm depth in rainfed banana. In coconut palm, over 80 per cent of the active roots were confined to an area of 2m radius around the palm and the vertical spread of majority of the roots extended upto 60cm (Anilkumar and Wahid, 1989). The above findings revel the fact that the competition from banana roots was negligible and as such did not affect the ^{32}P uptake by coconut significantly.

The following conclusions can be drawn from the results obtained from the present study. Cassava can be raised as an intercrop in coconut without much competition for nutrients. Cassava is planted in two rows around the coconut palm at a spacing of 90 x 90 cm leaving a distance of 2 m radius from the base of the palm.

Banana can be raised in association with coconut without any adverse effect on banana nutrition. Banana is planted in two rows around the coconut palm. 4 plants are planted in the outer row at a distance of 4.65 m away from the base of the coconut palm and four others are planted alternate to the first row at a distance of 2.85m away from the base of the coconut palm.

Cassava and banana can be raised together as intercrops in coconut garden without any competition for nutrients. Cassava is planted in two rows around the coconut palm at a spacing of 90 x 90 cm. The banana plants occupy the four remote corners at a distance of 4.65 m away from the base of the palm.

Elephant foot yam and banana constitute ideal companion crops and thrive well as intercrops in coconut garden. Elephant foot yam is raised in a row around the coconut palm at a distance of 2.45 m away from the base of the palm. The banana plants occupy the four remote corners at a distance of 4.65 m away from the base of the palm.

Cassava and elephant foot yam is an ideal combination of intercrops in coconut garden. Cassava is raised in the outer row around the coconut palm at a distance of 3.35 m away from the base of the palm while elephant foot yam occupies the inner row at a distance of at least 2.45 m away from the base of the palm.

Future line of work

1. Further experiments with different types of cropping systems in different age groups of coconut palms have to be studied.

2. In a cropping system in Kerala, the floor crop can be vegetable cowpea or vegetables other than cowpea, subjected to investigation in a coconut garden situation.

3. Different shade tolerant varieties of intercrops should be tried under the partial shade of coconut.

4. Performance of cassava stems obtained from intercropped situation should be assessed in shaded as well as open situations.

5. Productivity of coconut as influenced by intercrop should be studied.

6. Further trials with lower doses of P for intercrops may be tested under the partial shade of coconut.

7. Influence of microclimatic factors such as soil temperature, RH and evaporation on the intercrops as well as the main crop in cropping system should be studied.

8. Detailed investigation in moisture extraction pattern, residual moisture and soil moisture regime should be executed with different intercrops.

SUMMARY

SUMMARY

Two field experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani from 1992-1994 to study the performance of intercrops in an adult coconut garden. In the first experiment, the effects of nutrients, moisture and light on the productivity of intercrops, uptake of nutrients, quality of produce, soil properties and economics were studied. The effect of five cropping systems with two doses of fertilizers along with a control were tried in Randomised Block Design with three replications. In the second experiment, the interspecfic root competition was studied using the radio tracer technique. The absorption of ^{32}P by component crops in mono and mixed crop situations were investigated.

The salient results of the study are summarised below.

Different cropping systems and fertilizer doses had no marked effects on the height of intercrops under the partial shade of coconut. However intercrops were taller under shaded conditions compared to open situation.

The leaf area of intercrops was not affected much by cropping systems and fertilizer doses.

The yield attributing characters of intercrops such as cassava, banana, elephant foot yam and vegetable cowpea were not affected by different cropping systems and doses of fertilizers.

Tuber yield of cassava was not affected by other crops grown in the system.

Cropping systems and fertilizer doses for intercrops had not affected the bunch yield of banana, corm yield of elephant foot yam and fresh pod yield of vegetable cowpea and there was no yield reduction for these intercrops under the partial shade of coconut compared to open.

The results show that, cassava can be raised along with banana, elephant foot yam and vegetable cowpea successfully under the partial shade of coconut.

Half the recommended dose of N and P and full dose of K was found sufficient for the intercrops grown in a coconut garden of 40 years old.

The uptake of NPK by cassava, banana, elephant foot yam and vegetable cowpea was not influenced by different cropping systems and fertilizer doses.

Highest uptake of NPK by intercrops was recorded in cropping system, coconut + cassava + banana followed by coconut + cassava + banana + elephant foot yam + vegetable cowpea.

The post experiment soil analysis data showed that there was no depletion in soil nutrient status even after two years of intercropping.

The post experiment leaf nutrient concentration of coconut was higher in cropping system compared to that of the control plot, indicating that the nutrition of coconut palms was not adversely affected by raising intercrops in between them.

By raising different intercrops together in coconut garden, the soil moisture content at 30cm, 60cm and 90cm depth was not depleted.

PAR incident on the crop canopy was 75 per cent in cassava, 78 per cent in banana, 71 per cent in elephant foot yam and 82 per cent in vegetable cowpea compared to open situation. Yield reduction due to lack of PAR was observed only in the case of cassava to the extent of 25 per cent compared to open.

Highest net income obtained by intercropping in coconut garden was from the cropping system, coconut + cassava + banana + elephant foot yam + vegetable cowpea (Rs 26726 ha^{-1}) followed by coconut + cassava + banana (Rs 25760 ha^{-1}) and coconut + cassava + elephant foot yam (Rs 22251 ha^{-1}).

Cropping systems, coconut + cassava + vegetable cowpea and coconut + cassava + banana + elephant foot yam + vegetable cowpea recorded higher LER.

In coconut, based cropping system, income could be generated throughout the year by raising suitable intercrops.

Following are the conclusions from radiotracer studies using ^{32}P.

Cassava can be raised as an intercrop in coconut without competition for nutrients eventhough there was a reduction in the absorption of ^{32}P by treated cassava in the presence of coconut, compared to the sole crop.

Banana could be raised in association with coconut without any adverse effect on banana nutrition.

Both cassava and banana can be raised together as intercrops in coconut garden without any competition for nutrients.

Elephant foot yam was found to be an ideal companion crop with banana and cassava as intercrops in a coconut garden situation.

From the results, it can be concluded that cassava, banana, elephant foot yam and vegetable cowpea can be raised successfully and economically as intercrops in an adult coconut garden applying half the recommended dose of N and P and full dose of K without much competition for nutrients, moisture and light.

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* Original not seen

APPENDICES

Appendix Ia. Weather parameters during the first season (1992-93)

Months	Temperature (°C)		Mean relative humidity (%)	Total sunshine (hours)	Total evaporation (mm)	Total rainfall (mm)
	Max.	Min.				
Jun. 1992	29.8	24.2	83.1	131.7	92.3	613.3
Jul. 1992	28.9	23.0	84.0	149.1	97.2	224.7
Aug. 1992	28.9	23.3	85.2	160.3	111.7	67.8
Sep. 1992	29.3	23.2	81.7	186.0	96.2	76.3
Oct. 1992	28.9	22.7	52.5	184.9	104.8	412.0
Nov. 1992	29.2	23.0	82.9	166.6	68.0	281.0
Dec. 1992	30.3	21.5	78.6	203.1	88.9	15.1
Jan. 1993	30.3	20.6	77.2	247.9	108.0	Nil
Feb. 1993	31.2	21.3	76.5	243.7	121.8	2.8
Mar. 1993	32.4	23.1	75.7	268.2	152.3	36.3
Apr. 1993	32.5	24.6	82.2	249.0	145.0	31.6
May. 1993	32.1	25.0	83.3	215.6	121.8	223.2

Appendix Ib. Weather parameters during the second season (1993-94)

Months	Temperature (°C)		Mean relative humidity (%)	Total sunshine (hours)	Total evaporation (mm)	Total rainfall (mm)
	Max.	Min.				
Jun. 1993	30.0	24.1	85.9	156.7	95.9	391.3
Jul. 1993	28.3	22.5	87.6	100.1	93.3	224.2
Aug. 1993	29.7	23.7	83.0	177.1	120.9	33.2
Sep. 1993	32.7	22.9	81.0	221.5	121.4	78.8
Oct. 1993	29.9	23.4	83.8	124.6	82.9	312.2
Nov. 1993	28.8	22.4	87.2	169.6	71.4	434.3
Dec. 1993	30.2	23.0	84.2	179.7	80.0	127.3
Jan. 1994	30.9	22.4	83.1	244.7	98.7	5.0
Feb. 1994	31.0	23.2	77.7	241.9	102.8	24.0
Mar. 1994	32.0	23.1	80.1	287.2	128.0	18.2
Apr. 1994	31.3	24.6	81.9	239.2	116.0	71.8
May. 1994	32.1	25.4	85.1	211.2	130.5	264.2

Appendix II. Soil characteristics of the experimental site

A. Mechanical composition

1.	Coarse sand	14.00 %
2.	Fine sand	34.00 %
3.	Silt	12.00 %
4.	Clay	40.00 %

B. Chemical composition

1.	Available nitrogen	163.07 kg ha^{-1}
2.	Available phosohprus	54.32 kg ha^{-1}
3.	Available potassium	51.52kg ha^{-1}
4.	Organic carbon	0.52 %
5.	pH	5.95

NUTRIENT - MOISTURE - LIGHT INTERACTIONS IN A COCONUT BASED HOMESTEAD CROPPING SYSTEM

By

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ABSTRACT OF A THESIS
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THE REQUIREMENT FOR THE DEGREE OF
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VELLAYANI, THIRUVANANTHAPURAM

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ABSTRACT

Two field experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, to study the performance of intercrops in a mature coconut garden. The study was conducted for two years from June 1992 to May 1994. In the first experiment, the effect of nutrients, moisture and light on the productivity of intercrops, uptake of nutrients, quality of produce, soil properties and economics were studied. The effect of five cropping systems with two doses of fertilizers along with a control were tried in Randomised Block Design with three replications. In the second experiment, the interspecific root competition was studied using the radiotracer technique. The absorption of ^{32}P by component crops in mono and mixed crop situation were investigated.

Plant characters such as height and leaf area of intercrops were not influenced by cropping systems and different doses of fertilizers applied to intercrops.

The results show that cassava can be raised along with banana, elephant foot yam and vegetable cowpea successfully under the partial shade of coconut.

Half the recommended dose of N and P and full dose of K was found sufficient to the intercrops grown in coconut garden.

The total dry matter production of economic produce of intercrops was not varying much by cropping systems and fertilizer doses probably because of the substitution effect.

The highest uptake of NPK by intercrops was recorded in cropping system, coconut + cassava + banana (C4) followed by coconut + cassava + banana + elephant foot yam + vegetable cowpea (C5).

The soil moisture status was not altered by raising different intercrops in coconut garden.

Cassava received only 75% of PAR in the cropping system compared to open and there was a corresponding decrease in tuber yield also.

Highest net income was obtained from coconut + cassava + banana + elephant foot yam + vegetable cowpea cropping system.

Radiotracer studies using ^{32}P showed that, cassava can be raised as an intercrop in coconut, without much competition for nutrients. Banana can be grown in association with coconut without any adverse effect on banana nutrition. Cassava + banana, elephant foot yam + banana and cassava + elephant foot yam are ideal combinations of intercrops which can be raised in coconut garden without any competition for nutrients.

From the results, it can be concluded that cassava, banana, elephant foot yam and vegetable cowpea can be raised successfully and economically as intercrops in mature coconut garden applying half the recommended dose of N and P and full dose of K without much competition for nutrients, moisture and light.